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

October 1984

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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.

OPPORTUNITY:

The College of Engineering of the University of Michigan 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 necessary for major long-term economic impact. The present status of the College is impressive:

Reputation: 5th in the nation
Capacity: 6,000 students, 320 faculty (3rd in the nation)
Productivity: 1,000 BS/y, 550 MS/y, 100 PhD/y
Research: $20 million/y (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
Operating Fund: Seriously deficient

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 new business and build new industry.

THE PLAN:

To achieve maximum economic impact, the UM College of Engineering must be provided with the capacity to achieve national leadership in areas of key importance to this State. To compete with institutions such as MIT, UC-Berkeley, Stanford, and Illinois, the College will require the following special initiatives by the State of Michigan:

Annual Base Budget Growth Requirements: $15 million, per year, building up over 3 years

- $7 M faculty and technical support staff
- $4 M sustained laboratory equipment support
- $4 M sustained computing environment support

Equipment Support Requirements: $40 million over 3 years

- $15 M Restoration of laboratory equipment inventory
- $8 M Solid State Electronics Laboratory
- $7 M Materials Research Laboratory
- $5 M Startup Equipment for new Faculty
- $3 M Center for Applied Optics
- $2 M UM Engineering Television Network

New Physical Facilities Requirements: $20 million

- $20 M Experimental Research Project Laboratory
- ($20 M Incubation Center for spinoff companies) (privately financed)

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

$30 million/y	federal and industrial research contracts
$25 million/y	tuition and fees
$15 million/y	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. (A more detailed analysis of the proposed resource distribution among State, federal, and private sources is provided in the Table.)

THE IMPACT:

The required investment ($15 million added to the annual operating fund, and $60 million in capital outlay over a four-year period) is modest compared to the economic impact that would result from the presence of a MIT-Stanford-Caltech class engineering school in Michigan. Graduates, faculty, and staff of the UM College of Engineering would be key factors strengthening the competitiveness of existing Michigan industry. But of even more importance, research activities of the College would spawn and attract new industry to diversify Michigan's economic base.

Roughly 70 years ago, the automotive industry took roots 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 occurred in Silicon Valley and along Route 128 suggest that future industrial growth will be stimulated less by physical capital than by intellectual capital -- by technological innovation and the talented engineers capable of understanding and applying new technology.

It is from this perspective that the University of Michigan's College of Engineering must be viewed as the most important investment Michigan can make for its long-term economic prosperity.

TABLE

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	10	25*	15
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Total	$57 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	$15.4	$20
Equipment	1.0	
Federal		
Buildings	1.5	10
Equipment	3.6	
State		
Buildings	39.9	20
Equipment	8.8	40
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	$70.2 M	$90 M

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

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

Rationale and Plan

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.

Background:

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 intel- lectual 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.

Experience has shown that a primary source of new jobs is the creation of new companies and industries. Hence 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.

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 economic bases of California and New England are 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.

OPPORTUNITY:

The College of Engineering of the University of Michigan 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 necessary for major long-term economic impact:

Background:

As one of the leading engineering schools in the nation, the College of Engineering of the University of Michigan has long been distinguished for its ability to integrate outstanding undergraduate and graduate educational activity with research programs to achieve extraordinary breadth and depth across the full spectrum of engineering disciplines.

Status of the College:

The College today is clearly recognized both within and outside our State as one of the few institutions in the world capable of making major impact on economic development. More specifically, the present status of the College can be summarized as follows:

Reputation: 5th in the nation
Capacity: 6,000 students, 320 faculty (3rd in the nation)
Productivity: 1,000 BS/y, 550 MS/y, 100 PhD/y
Research: $20 million/y (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

Unique Opportunities of the Moment:

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 will be a major competitor for a NSF-sponsored Engineering Research Center for Integrated Manufacturing and Productivity. If successful, this $5 million/y Center would almost certainly provide Michigan with the nation's leading program in manufacturing sciences. Success on this initiative will require the strong support both of State government and Michigan industry.

- 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 will provide Michigan almost instantly with world-wide recognition for its programs in electrical engineering, computer science, and telecommunications technology -- areas of critical importance to Michigan industry.

- 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 <u>microelectronics factory of the future</u>. 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 one of the leading materials scientists in the nation to head a major effort 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 major grant from the National Science Foundation to establish a major <u>Materials Research Laboratory</u> 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 <u>Center for Applied Optics</u>. 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-Arsinide" Valley) phenomenon in the southeastern Michigan area.

- The College has recently spearheaded an effort to attract a major federally-sponsored <u>supercomputer center</u> to Michigan. Several such Class VII computer centers will be funded over the next several years in an effort to stimulate both scientific and industrial uses of these "fifth generation" computers. 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. This past year seven new companies were started by College faculty. We expect this number to double in 1984.

- 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 with the most potential for our State's future.

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.

Indeed, the experience of the College of Engineering over the past decade vividly demonstrates the inadequacy of traditional funding mechanisms. Despite its central importance to economic development in Michigan as one of the leading engineering schools in the nation, the level of public support to the College declined. The level of funding dropped to not only the lowest of any of its peer institutions, but the lowest level of State funding of any academic institution in Michigan. As one illustration of the magnitude of this deficit, one can compare the difference in the tuition revenue ($10,000 per student) available to private institutions such as MIT, Stanford, and Caltech to public institutions such as Michigan ($2,000 per student). Based on the College's present enrollment of 6,000 students, this differential amounts to a funding disadvantage of roughly $40 million per year relative to these institutions.

The leading public institutions such as UC-Berkeley, UCLA, Illinois, and Texas have benefited from sufficient state support to offset this tuition differential. In sharp contrast, State support of the UM College of Engineering has dwindled to the point at which the College must now support essentially its entire operating budget from tuition revenue, research grants and contracts, and private gifts. The absence of adequate State funding resulted in a seriously overloaded faculty, deteriorating physical facilities, and obsolete laboratories. Even more seriously, it forced the College to place strict limits on its enrollments, despite the enormous demand for engineering graduates and the surging numbers and outstanding quality of students seeking admission to the College these days. (Freshmen entering the College rank in the 98th percentile of their high school graduating class. Over 25% are straight 4.0 students.) Even more serious is the very real possibility that the College will be forced to cut enrollments by as much as 50% and dismantle critical programs over the next several years if this chronic degree of underfunding cannot be reversed.

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.

And 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 must in the strengthening and diversification of Michigan's future.

THE PLAN:

To achieve maximum economic impact, the UM College of Engineering must be provided with the capacity to achieve national leadership in areas of key importance to this State. To compete with institutions such as MIT, UC-Berkeley, Stanford, and Illinois, the College will require the following special initiatives by the State of Michigan:

Specific Components of the Plan:

Base General Fund Support Increments:

An increase in the College's General Fund support to bring this to a level comparable to leading public and private engineering colleges (e.g., UC-Berkeley, Illinois, MIT, Stanford, and Caltech):

$7 million	faculty and technical support staff
$4 million	sustained laboratory equipment support
$4 million	sustained computing environment support

Capital Outlay Support:

Equipment: A one-time investment to restore the College's laboratory equipment inventory (decimated during the erosion in State support of the 1970s) and respond to specific federal and industrial initiatives:

$15 million	Restoration of laboratory equipment inventory
$ 8 million	Microelectronics facility
$ 7 million	Materials Research Laboratory
$ 5 million	Startup equipment for new faculty
$ 3 million	Center for Applied Optics
$ 2 million	UM Engineering Television Network
$40 million	Total equipment support (over 3 years)

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 million	Flexible experimental laboratory facility

Technology Transfer:

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

$20 million	Incubation center for spinoff companies (privately financed)
$ 2 million	UM Engineering TV Network (+ $200 K/y operating costs for satellite link)

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/y	federal and industrial research contracts
$25 million/y	tuition and fees
$15 million/y	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. (A more detailed analysis of the proposed resource distribution among State, federal, and private sources is provided in the Table included in the Executive Summary).

THE IMPACT:

There is ample evidence across this nation (including Michigan) to demonstrate the impact that world-class engineering schools have on economic development. In particular, experience has shown the following:

- Most of the significant technology behind industrial growth originates in world-class engineering schools and their associated research laboratories.

- Such innovations are typically exploited by new firms established by faculty, staff, and graduates of these schools.

- Companies with origins in leading engineering schools have frequently formed the basis for entirely new industries (e.g., aerospace, microelectronics, computer, biotechnology)

- The graduates of such institutions provide industry with the ability to sustain their competitiveness.

- Such institutions attract the federal R&D support which provides the "risk capital" for major industrial development.

A major investment by the State of Michigan in the UM College of Engineering can be expected to have a similar impact on our State's long-term economic development. Furthermore, since the most talented of Michigan's high school graduates now enroll in the College, such action is also an investment in Michigan's most precious and valuable resource, its youth. These extraordinarily talented students will become the leaders of Michigan industry. Not only will they sustain the competitiveness of existing Michigan companies, but they will spawn the new companies 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. Furthermore, it alone possesses the reputation to leverage this investment of State support several-fold through federal and industrial grants and contracts.

CONCLUDING REMARKS:

The required incremental investment ($15 million in sustained annual funding and $60 million in capital outlay over a four-year period) is modest compared to the economic impact that would result from the presence of a MIT-Stanford-Caltech class engineering school in Michigan. Graduates, faculty, and staff of the UM College of Engineering would be key factors strengthening the competitiveness of existing Michigan industry. But of even more importance, research activities of the College would spawn and attract new industry to diversify Michigan's economic base.

Roughly 70 years ago, the automotive industry took roots 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 <u>intellectual capital</u> -- by technological innovation and the talented engineers capable of understanding and applying this technology.

It is from this perspective that the University of Michigan's College of Engineering must be viewed as the most important investment Michigan can make for its long-term economic prosperity.

SCHEDULE

SUSTAINED (BUDGET-BASE) GROWTH (in millions)

	Year 1	Year 2	Year 3
Staffing	$5	$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 Res Lab	$3	$2	$2
New Faculty Programs	$1	$2	-
Applied Optics Lab	$1	$2	-
Inst TV Network	$2	-	-

RESEARCH FACILITIES (Building) (in millions)

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

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

THE ASSUMPTIONS:

- Future economic growth in Michigan will be stimulated primarily by investments in intellectual capital. The UM College of Engineering, as the State's primary source of technological innovation, talented engineering graduates, and seasoned entrepreneurs, must be viewed as the most important investment Michigan can make for its long-term economic prosperity.

- Furthermore, since the most talented of Michigan's high school graduates now enroll in the College, such action is also an investment in Michigan's most precious and valuable resource, its youth.

- The UM College of Engineering is unique in this State in its ability to attract outstanding faculty and students. Further, it alone possesses the reputation to leverage the investment of State funds many times over through federal and industrial grants and contracts.

- Experiences elsewhere in our nation have firmly established the economic impact of world-class engineering colleges:

  i) Most of the significant technology behind industrial growth originates in such colleges and their associated research laboratories.

  ii) Such innovations are typically exploited by new firms established by faculty, staff, and graduates of these schools.

  iii) Companies with origins in leading engineering schools have frequently formed the basis for entirely new industries (e.g., aerospace, microelectronics, computer, biotechnology).

  iv) The graduates of such institutions provide industry with the ability to sustain their competitiveness.

THE INVESTMENT:

An additional base budget allocation of $15 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 enigneering, materials research, and biotechnology.

Capital outlay of $20 million for an Experimental Research Projects Laboratory.

THE PAYOFF: NEAR TERM

- 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 keep pace with the efforts made by other states to build world-class engineerings 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.

- The College would have the resources to proceed at once with several important initiatives:

  NSF Engineering Research Centers
  NSF-DOD Materials Research Laboratory
  SRC Center of Excellence in Manufacturing Sciences
  DOD Software Engineering Institute
  National Supercomputer Center
  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

THE PAYOFF: LONG TERM

- 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 graduates 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 be a key to the survival of hundres 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:
  Flexible automation
  Optoelectronics ("Gallium Arsinide Valley"?)
  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
BASE SUPPORT NEEDS

- Restoration of Instructional Staffing: $7 M per year
- Sustained Support of Laboratory Equipment: $4 M per year
- Sustained Support of Computing Environment: $4 M per year

-STATE BUDGET REQUEST-

RESTORATION OF INSTRUCTIONAL STAFFING

THE UM COLLEGE OF ENGINEERING

(Base Funding Level: $7 million per year)

REQUEST FOR ADDITIONAL BUDGET ALLOCATION

College/Unit: College of Engineering

Request Title: Instructional and Support Staff Increases in Engineering

REQUEST PURPOSE:

To meet a growing industrial demand for engineers in the State of Michigan, as well as to respond to a dramatic increase in the number of Michigan high school students seeking to enter its engineering programs, the enrollment of the College of Engineering has increased by 45% over the past several years. Yet during this same period, a serious erosion in General Fund support of the College led to a drcrease in instructional staff of 54 FTE positions (roughly 20%). It has become apparent that unless this instructional staffing can be restored, the College will be forced to drastically cut enrollments in order to maintain the quality of its academic programs -- despite the critical needs of Michigan industry for talented engineers and the demand on the part of the most outstanding of Michigan's high school graduates to pursue engineering studies in the College.

The proposed additional budget allocation of $7 million would restore the instructional staff loss of the past several years. More specifically, it would add 90 FTE instructional staff (40 FTE faculty and 50 FTE flexible staff), along with associated support staff. This would allow the College to maintain the levels of its present enrollment and research activities, thereby allowing it to provide the intellectual creativity so fundamental to technological innovation in Michigan industry, the talented, broadly-educated engineers who can understand and implement this technology, and the entrepreneurs capable of exploiting these resources to stimulate economic development in Michigan.

SUPPORTING RATIONALE:

The State of Michigan faces a serious engineering manpower crisis. Talented engineers are desperately needed to revitalize the productivity of existing Michigan industry and to attract new industry into the State. The heavy manufacturing industry of southeastern Michigan anticipates intense needs for computer, electrical, industrial, and mechanical engineers as they rapidly introducer high technology automation (including robotics) into their plants. Furthermore, these graduates will become the entrepreneurs capable of transferring technology to the private sector and rebuilding Michigan's economy. There is every indication that this intense demand for engineering graduates will persist throughout the next decade because of industrial needs and the inability of engineering schools to expand capacity to meet these needs.

For over a century the College of Engineering at the University of Michigan has ranked among the leading engineering institutions in the world, with claims to unusual strength across the full spectrum of technical interest. The College represents an important resource to the State, a resource that can play a major role in revitalizing and diversifying its industry through its engineering graduates and the research activities of its faculty. Furthermore the College has placed a very high priority on strengthening its direct relationships with Michigan industry through a variety of mechanisms such as joint research programs, co-operative education, and faculty/staff exchange programs and by acting as the catalyst for attracting new industry to the State.

Over the past decade, enrollment in the College has grown some 45% to its present level of 5,600 students. In spite of this growth, student demand for admission into engineering continues to increase at a rate of 10% to 15% per year (with over 3,400 applicants for 750 available positions in the freshman class of 1984), while industrial demand for the graduates of the College has increased even more rapidly. Yet the serious erosion in State support of the College of Engineering over this same period of time has placed it in a position today where it has neither the faculty resources nor physical facilities to adequately handle even its present enrollment, much less to expand this enrollment to address the needs of the State.

There is also a widely recognized crisis in the supply of graduate engineers at the M.S. and Ph.D. levels. These engineers represent not only the manpower essential for the development and implementation of high technology in Michigan industry, but they also represent the engineering faculty of tomorrow. Unless the crisis in engineering education is addressed by leading programs such as those at the University of Michigan, the engineering faculty shortages in other Michigan engineering schools will almost certainly worsen. The College of Engineering has received world-wide acclaim for the quality of its graduate and research programs and could respond in a major way to meet these needs if the proposed increase in instructional staff were funded.

The College of Engineering of the University of Michigan is at a critical point in its history. The budget decline experienced by the College over the past decade (ironically accompanied by an intensified demand for engineering graduates, technical innovation, and entrepreneurs by Michigan industry) has come periously close to dismanteling one of the State's most important assets. It has become increasingly difficult for the College to compete for outstanding faculty and externally-sponsored research with peer engineering institutions in other states which have benefited from direct and strong public funding. Unless the State of Michigan acts rapidly, it could well lose one of its most valuable resources, a resource that can and should play a critical role in strengthening and rebuilding existing industry in the State while attracting the new industry necessary to diversify the State's economy. To address the serious engineering manpower and technology needs of the State of Michigan and retain its national reputation for excellence, the College of Engineering requires the increase in State support outlined in this request for additional budget allocation.

STAFFING RESTORATION PLAN

	FTE	Cost
Professorial Staff	50	$2,800,000
Flexible Instructional Staff	70	1,750,000
Technical Support Staff	30	900,000
Office Staff	30	600,000
P&A Staff	10	250,000
Non-Salary		700,000
Total		$7,000,000

MAJOR STAFFING AREAS (Faculty)	FTE
Flexible manufacturing Mechanical Eng - 5 Industrial Eng - 2 Electrical Eng - 3	10
Computer science and engineering Software engineering - 4 Artificial intelligence - 4 Other areas - 4	12
Microelectronics Silicon Devices - 3 Advanced Devices - 3 Electronic materials - 4	10
Applied Optics Optoelectronics - 3 Nonlinear optics - 2 Laser diagnostics and machining - 3	8
Materials Polymer engineering - 2 Ceramics - 2 Metallurgy - 2 Composites - 2 Materials characterization - 2	10
Total	50

DOCUMENTATION OF THE NEED

FACT SUMMARY:

History (during the 1970s):

Instructional staff (FTEs) declined by 15% (-45 FTEs)
Enrollment (FYES) increased by 46% (+1150 FYES)
Annual growth rate in General Fund support (GF$/SCH or GF$/student) was the lowest in the University (less than 0.5% compared to a University average of 7% and a CPI of 8% for this period).

Recent History (1981 - 1984):

Instructional staff (FTEs) has continued to decline (-9 FTE)
Enrollments have continued to increase (+420).
Real budget growth (aside from salary or University-wide programs) has been less than $1.6 million ($2,000,000 - $530,000 = $1,470,000).
The College has been forced to support an increasing fraction of its salary program, flexible instructional staff, and administrative staff from private gift receipts -- resources which more properly should be directed toward student financial aid, equipment support, and research initiatives.

Present Status:

The instructional loads of the College are now among the highest in the University:

FYES/FTE = 18.1
SHC/FHC = 22.1
SCH/FTE = 244

General Fund budgeted instructional staff (216) is less than half that estimated by the Owens-Huffman Needs formula (435) and the National Accreditation Board for Engineering and Technology (441) for the present College enrollment (5,607 headcount or 4,070 FYES).

REQUESTED ACTION:

General Action:

Special State action to restore an adequate level of General Fund support to the College of Engineering.

Alternative:

Phased enrollment reductions of 30% or greater.

Consequences of Enrollment Reduction:

Admission denial to large numbers of Michigan's most outstanding high school graduates.

Public and political reaction to enrollment cuts in engineering during a period of peak demand on the part of both students and industry.

Tuition loss of $9 million per year (compared to the General Fund growth of $7 million needed to sustain present enrollments).

Comment:

The rest of this decade will see a continuation of the unprecedented demand on the part of Michigan's most outstanding high school graduates for engineering educations, coupled with the urgent need of our State and nation for talented, broadly-educated engineers. We believe a decision to reduce engineering enrollments at Michigan, in the face of such intense societal demand and need, would be irresponsible. We could not endorse such action.

BACKGROUND:

The serious erosion in Michigan's support of higher education in general and engineering education in particular has been well documented. Over the past decade public support of higher education in Michigan dropped to the point where the State today ranks 43rd in the nation in its level of State support per student. Even states such as Mississippi are now investing twice as much in higher education as Michigan. Indeed, Michigan ranks 50th in the change in public support provided to higher education over the past decade.

More specifically, over the past several years, the University of Michigan, the flagship of public higher education in this nation, has reeled from $45 million in permanent cuts in the state component of its base budget (roughly 20% of its state funding). It has been forced to close programs, lay off faculty and staff, and deny admission to large numbers of Michigan students. It has been forced to the brink -- to the shock and dismay of colleagues across the State and the nation -- to those who depend on the University's graduates and research.

This decline in State funding has fallen with particular harshness on the UM College of Engineering. During a period in which enrollment in the College grew by 45%, the level of State funding for its programs effectively vanished. This loss of State support resulted in seriously overloaded faculty, overcrowded classes, and a dramatic increase in the use of teaching assistants. Technical support staff and equipment funds were cannibalized to offset the deterioration in State support, resulting in obsolete and inadequate laboratories.

As a consequence of this loss of State support, the College has been forced to place strict limits on its enrollments, despite the enormous demand for engineering graduates and the surging numbers and outstanding quality of students seeking admission to the College these days. (Freshmen entering the College rank in the 98th percentile of their high school graduating class. Over 25% are straight 4.0 students). Even more serious is the very real possibility that the College will be forced to cut enrollments by as much as 50% and dismantle critical programs over the next several years if this chronic degree of underfunding cannot be reversed.

Comparisons with Peer Institutions:

A decade of deteriorating public support has left the UM College of Engineering with not only the lowest level of funding of any of its peer institutions, but as well the lowest level of

State funding of any academic institution in Michigan. As one illustration of the magnitude of this deficit, one can compare the difference in the tuition revenue ($9,000 per student) available to private institutions such as MIT, Stanford, and Caltech to public institutions such as Michigan ($2,000 per student). Based on the College's present enrollment of 6,000 students, this differential amounts to a funding advantage of roughly $40 million per year for these institutions.

The leading public institutions such as UC-Berkeley, UCLA, and Illinois have benefited from sufficient state support to offset this tuition differential. In sharp contrast, State support of the UM College of Engineering has dwindled to the point at which the College must now support essentially its entire operating budget from tuition revenue, research grants and contracts, and private gifts.

Actions Taken by Other States:

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.

A Call for Special Action:

Unfortunately, Michigan stands apart in its failure to act to restore an adequate level of support to its premier engineering shcool at the University of Michigan. Despite the obvious importance of world-class programs in science and engineering for economic development, over the past decade Michigan has pursued a course precisely opposite to those taken by other states. It has 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 the UM College of Engineering.

Beyond this fact, our State's traditional manner of allocating resources seems to have developed, as Dr. William Hubbard, President of UpJohn put it, "an extraordinary intolerance of extreme excellence." In sharp contrast to other states which seek to focus resources to achieve excellence, Michigan has approached higher education as if it had a social responsibility to level out peaks of excellence -- to eliminate those world-class programs which have been developed in our research universities over the years in favor of the support of mediocrity.

The lesson is clear. Only programs at the cutting edge of technology which are capable of ranking among the nation's leaders are going to have a major impact on economic development in this State. Only such world-class programs are capable of attracting the outstanding faculty, students, and resources necessary to stimulate the growth of new industry. Michigan must acknowledge this fact and develop the capability not just to tolerate excellence, but to focus its resources to achieve it in selected programs of critical importance to this State.

Michigan's traditional methods of funding higher education are simply not adequate to focus resources to achieve the necessary level of excellence in programs of critical importance to the future of this State. Extraordinary measures are required.

And its 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 must in the development of Michigan's future.

CONSEQUENCES OF AN INADEQUATE RESPONSE

The consequences of an inadequate response to the urgent funding needs of the College have been quite serious. The "Engineering Gap" in funding relative to peer institutions continues to seriously hinder our efforts to provide the quality of instruction and research expected of one of the leading engineering schools in the nation. Furthermore it has seriously jeopardized our ability to respond to the needs of this State and its citizens:

- The College presently enrolls the most outstanding students in this State -- by any measure. Indeed, the 5607 students in the College represent an extraordinary resource of this State. The talents of these students demand an engineering education of exceptional quality. Yet the College continues to suffer from one of the lowest levels of General Fund support per enrolled student (FYES) of any unit in the University.

- Over the past three years the critical degree of underfunding of the College has compelled us to target the limited General Fund budget growth provided by the University to meet only our most urgent needs -- namely, those for competitive faculty salary programs and sponsored research support -- because of their importance in maintaining the quality of our faculty and attracting the external resources on which we have become so heavily dependent. Other critical needs such as equipment, instructional staff, and support staff have gone unmet.

- To meet the shortfall in our budget needs, the College has funded an increasing fraction of its administrative and instructional activities from discretionary resources (primarily income derived from our annual giving program -- gifts which should instead be preserved for student financial aid and other special needs).

- Despite continued growth in engineering enrollments, our instructional staffing has continued to decline. For example, during 1983-84 the College's instructional staff dropped to an all-time low of 213 FTEs. Models developed both by the State of Michigan and by the National Accreditation Board for Engineering and Technology suggest we are presently understaffed by roughly a factor of two. (These models suggest an instructional staffing requirement of 435 FTEs for our present enrollment of 5,607 (4003 FYEs).

- While it is true that over the past two years the faculty of the College of Engineering has become "smaller but better", it is also true that our enrollments have continued to increase -- particularly at the graduate level. Our students are plagued by overcrowded and closed-out classes, while the faculty is burdened with staggering instructional overloads. It is now clear that both the University and the State must soon come to grips with the staggering degree of understaffing and equipment shortages which cripple our instructional programs.

- There seems general agreement at the local, State, and national level that the College must play a critical role in Michigan's industrial and economic development. In the face of such an instructional overload (which is roughly twice that of peer institutions), faculty of the College simply do not have the time to participate in external activities aimed at economic development (not to mention the development of major new research initiatives).

- Our attempts to rebuild the intensity, momentum, and quality of the faculty, instructional programs, and research activities have been seriously damaged by an inadequate level of General Fund support.

The College of Engineering has been crippled in its efforts to respond to the intense demand of Michigan's most outstanding students for engineering educations, to meet its responsibilities to participate in rebuilding the economy of this State and nation, by inadequate support form this University. Indeed, it is extraordinary that a more aggressive effort has not been made to deal with the crippling degree of underfunding of the College in the face of these responsibilities, as have most other peer institutions.

CONCLUDING REMARKS

The $7 million in base support requested for the restoration of instructional staffing is believed to be the minimum General Fund restoration program necessary to enable the UM College of Engineering to remain among the leading engineering schools in the nation and respond to the major opportunities and responsibilities that lie before it in the decade ahead. Without such a prompt and substantial increase in General Fund support, it is almost certain that the College will be unable to maintain its national reputation and meet its serious obligations to provide the engineering graduates, the technological innovation, and the entrepreneurs so desperately needed by this State and the nation. It furthermore would be forced to deny the opportunity for engineering careers to the most outstanding of Michigan's high school graduates.

Failure to respond now to restore an adequate and equitable measure of General Fund support for the UM College of Engineering would be a tragedy of major proportions for the State of Michigan and for our nation.

SUPPORTING STATISTICS

Enrollments

ENROLLMENTS

FIGURES:

- 30-Year Enrollment History of College
- Recent Enrollment Trends of College
- Graduate Enrollments
- Absolute Enrollment Changes (University Comparison)
- Enrollment Comparisons of Departments and Colleges

COMMENTS:

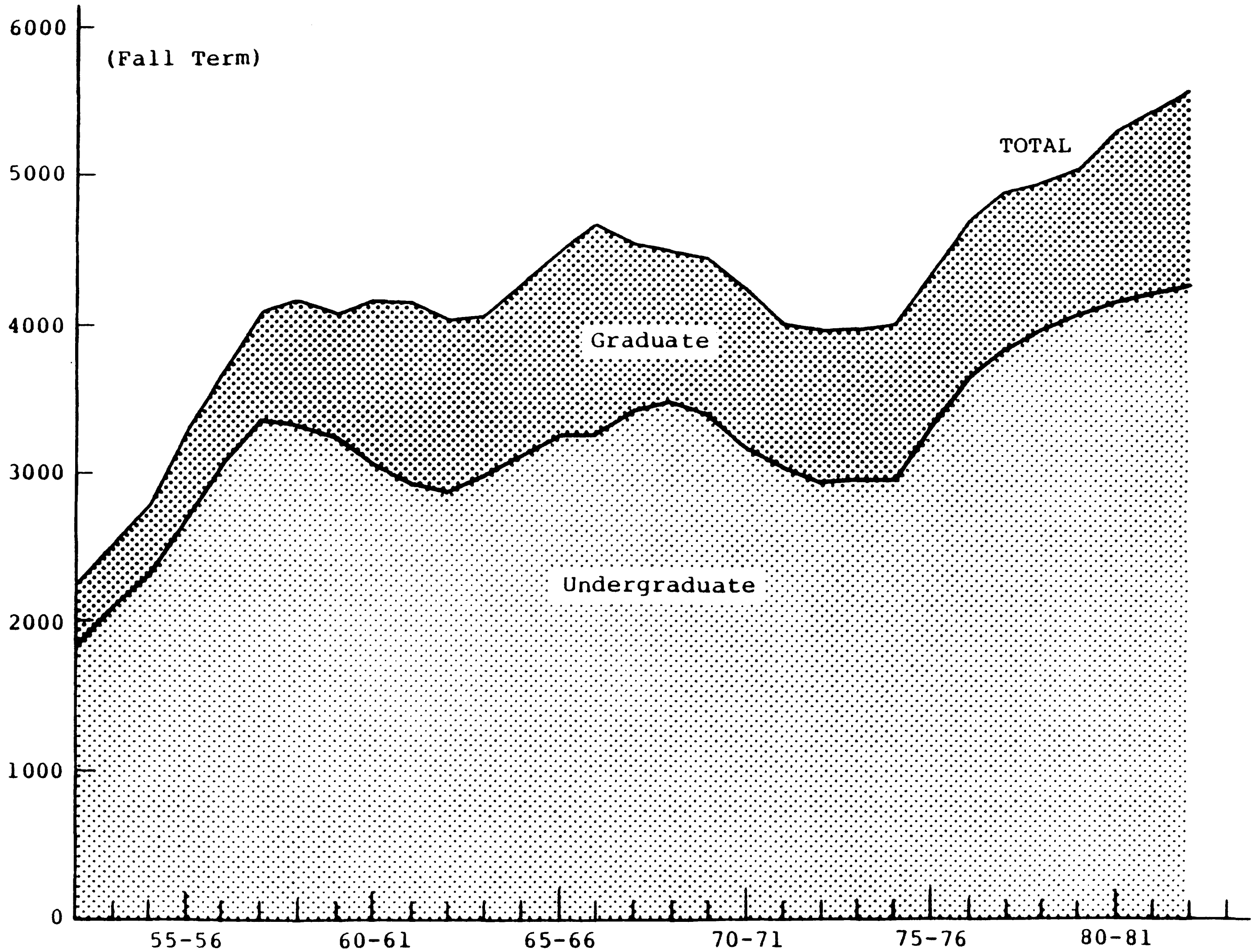
1. The College continues to experience enrollment growth, although this mix is changing to heavier graduate enrollments.

2. While undergraduate enrollments appear to have stabilized at 4,200 students, graduate enrollments have increased by 20% in past three years (due to the College's response to the critical national need for engineering doctorates).

3. The present College enrollment is 5,607. With the addition of Computer Science students (whether enrolled in LS&A or Rackham), the College will be responsible for the degree programs of <u>over 6,000 students</u> by Fall of 1984 -- slightly over one-sixth of the enrollment of the entire University.

4. Enrollment growth (2,000 students) in the College of Engineering over the past decade has exceeded that of <u>all other schools and colleges combined</u>. (However this enrollment growth does not completely compensate for the major enrollment losses in units such as Education, Natural Resources, Social Work, Library Science, Nursing, and Pharmacy so that the University has still undergone a net loss of roughly 1,500 students.)

5. The College has two departments with enrollments larger than most schools and Colleges. Indeed, one of these departments, Electrical Engineering and Computer Science with 1,800 students, is larger than all schools and colleges except LS&A, Engineering, and Business Administration.

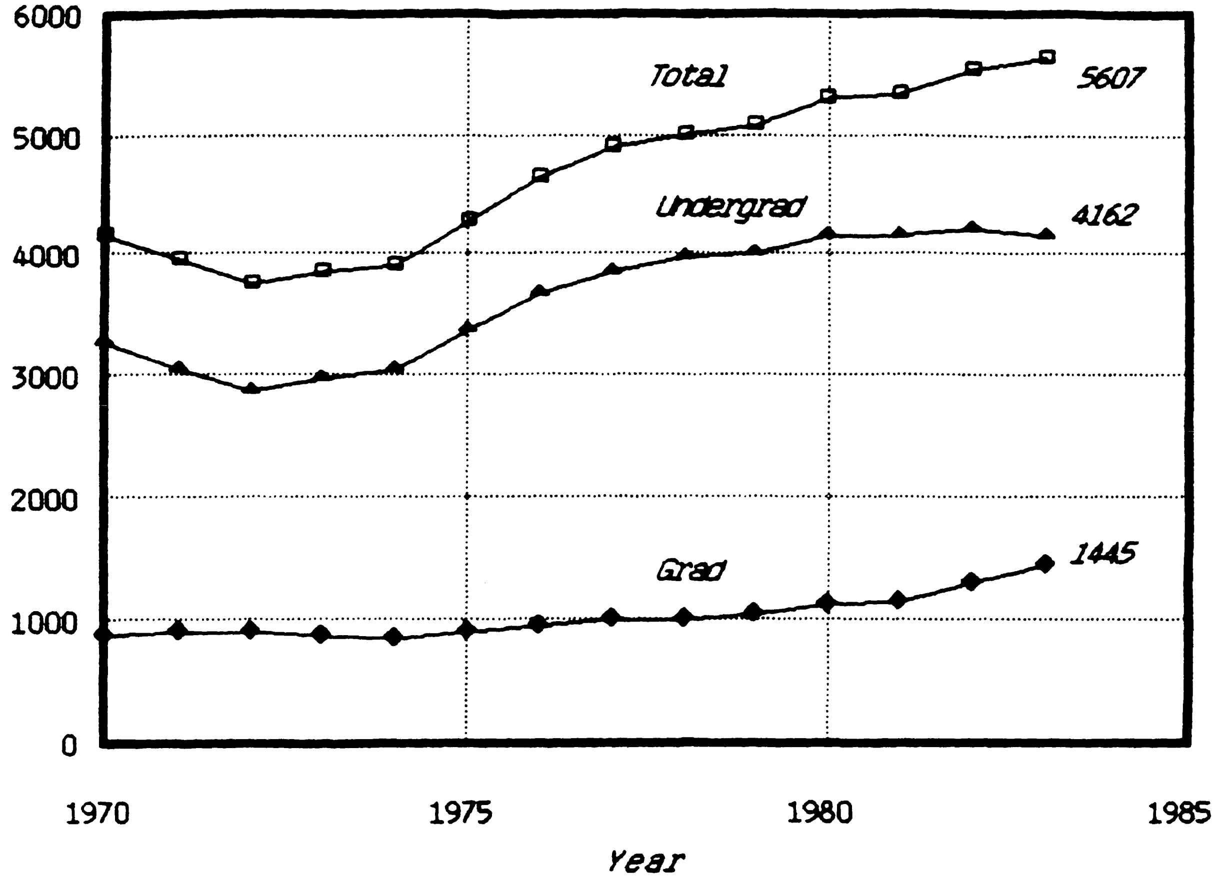


ON-CAMPUS HEADCOUNT ENROLLMENT

Aside from a 10% drop during the late 1960s, Engineering enrollments have been monotonically increasing since the end of WWII.

Enrollments

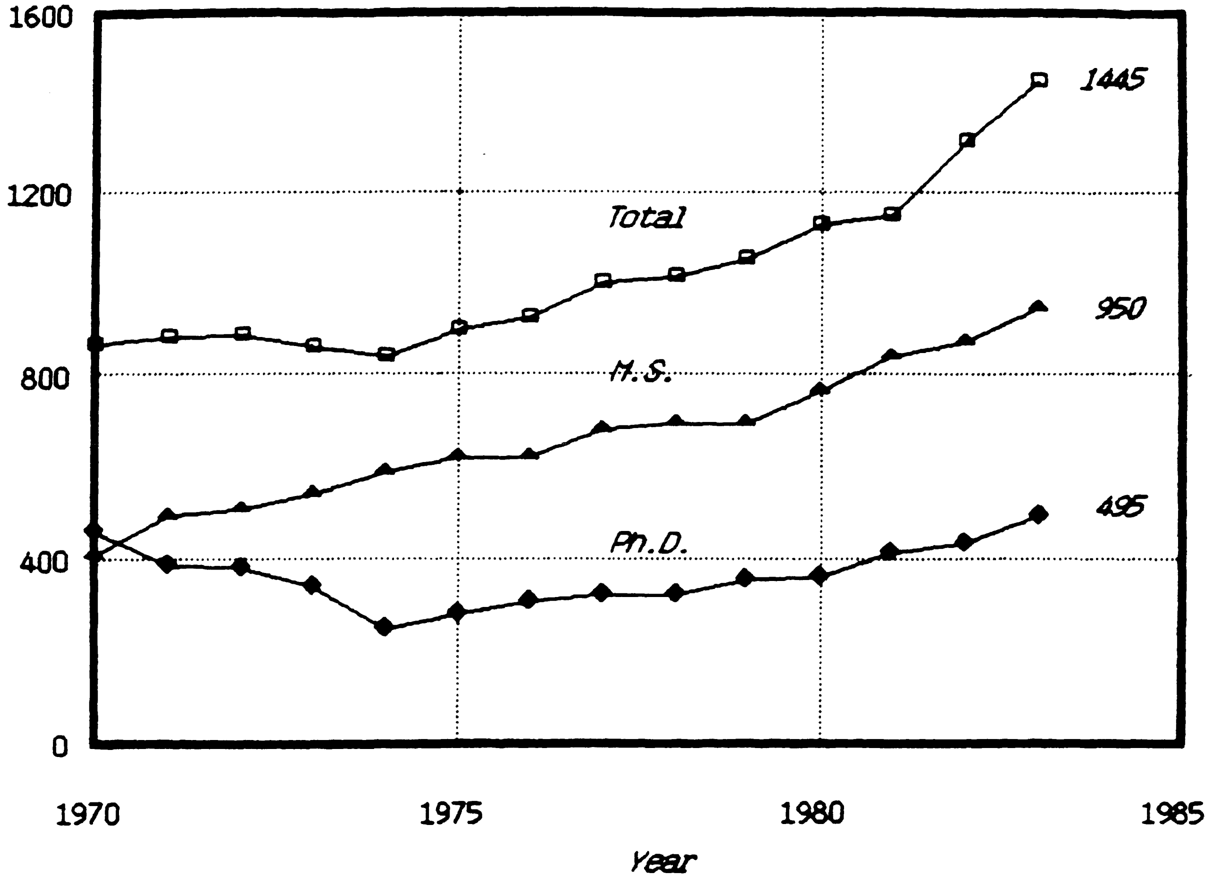
College of Engineering



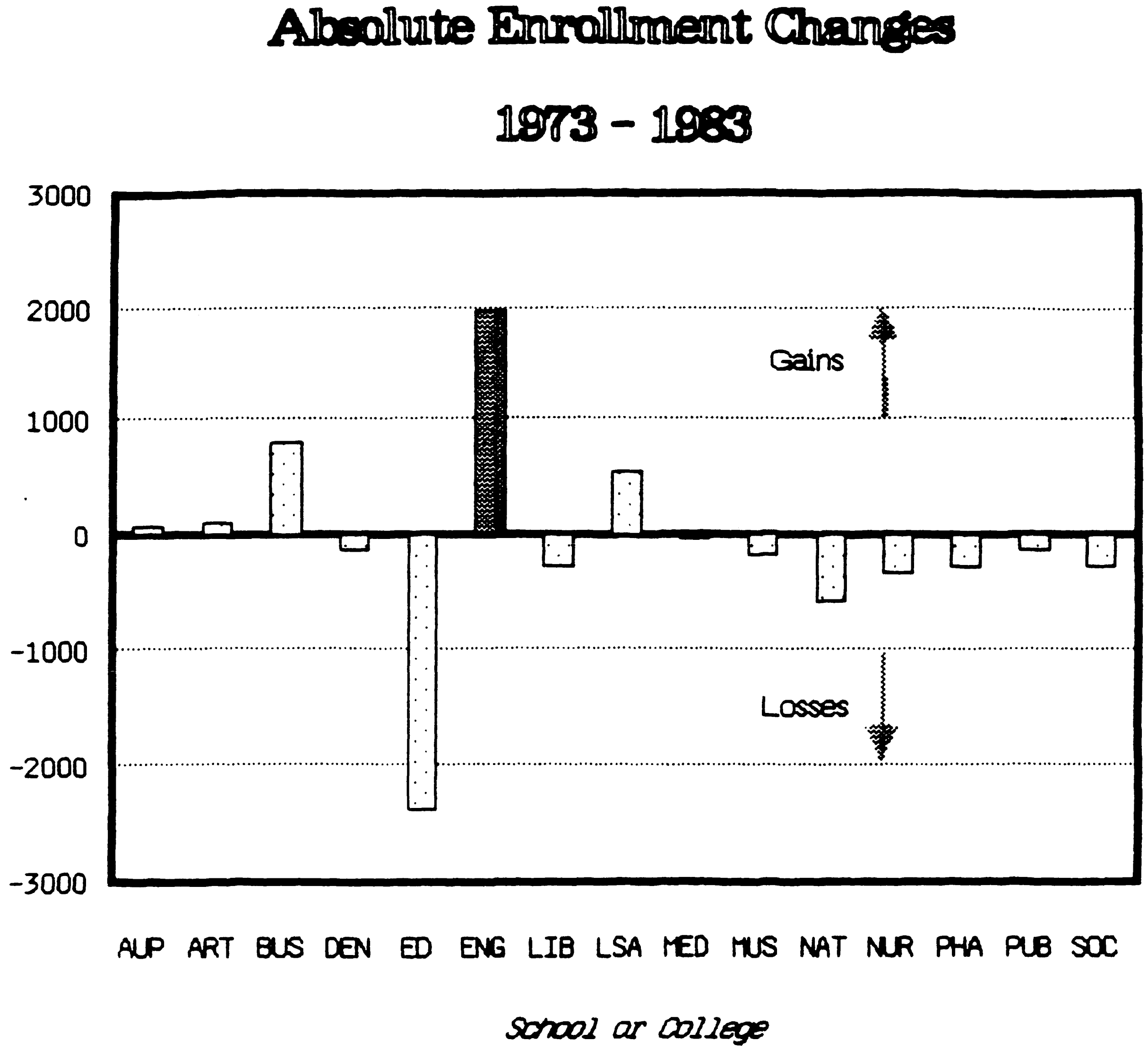
Total College enrollment is at an all time peak. Undergraduate enrollment has stabilized. (However transfer of CCS to Engineering will cause a major jump in effective undergraduate enrollments.)

Graduate Enrollments

College of Engineering

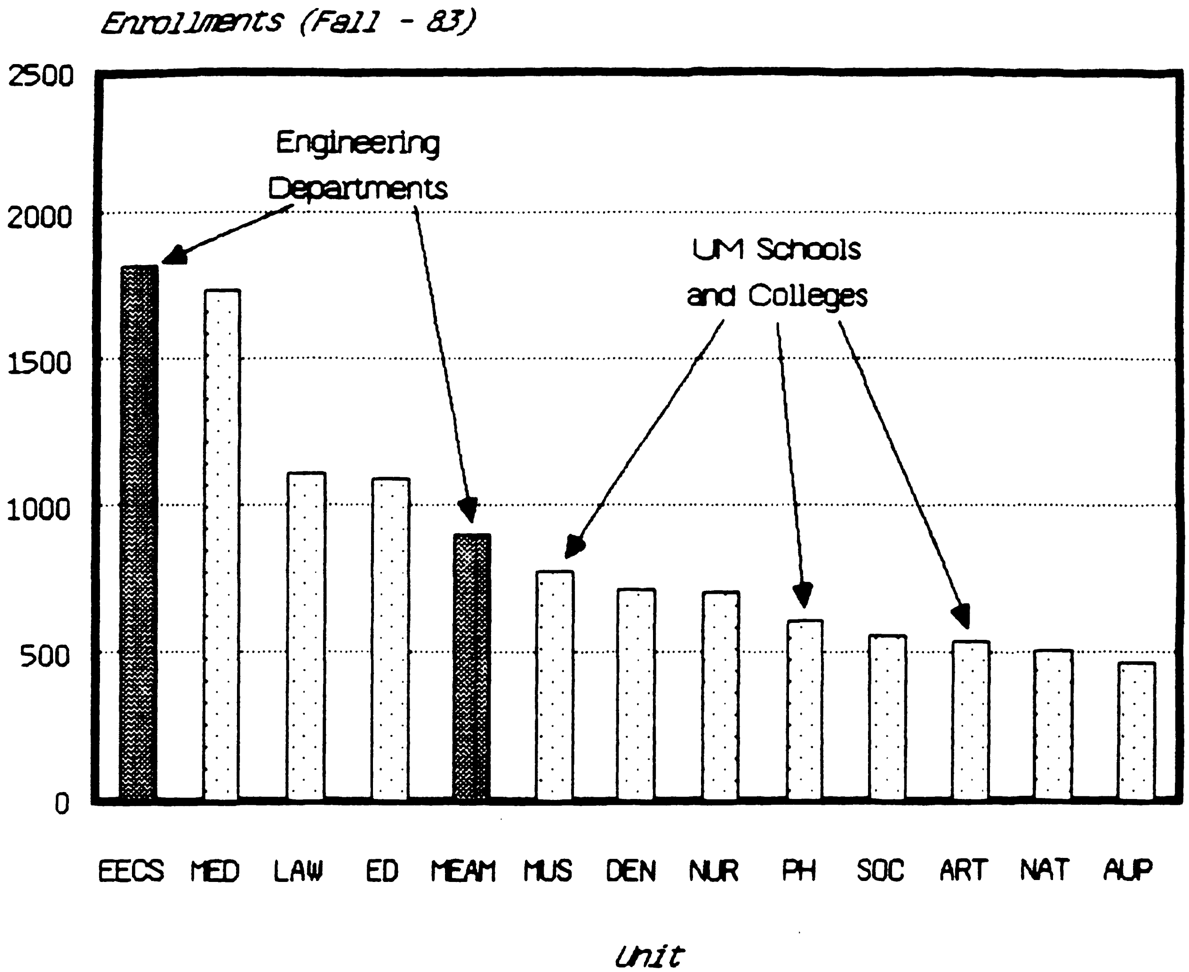


Graduate enrollment is increasing, particularly at the PhD level, to achieve a better balance between undergraduate and graduate enrollments and to respond to serious national needs for engineering doctorates.



College enrollment growth over the past decade (> 2,000) exceeds growth in all other UM schools and colleges combined.

Some Enrollment Comparisons



Engineering now has several departments larger than most schools and colleges in the University (albeit with only a fraction of the General Fund budget allocated these smaller schools).

Degree Production

DEGREE PRODUCTION

FIGURES:

- Degree Production (All Levels)
- Graduate Degree Production

COMMENTS:

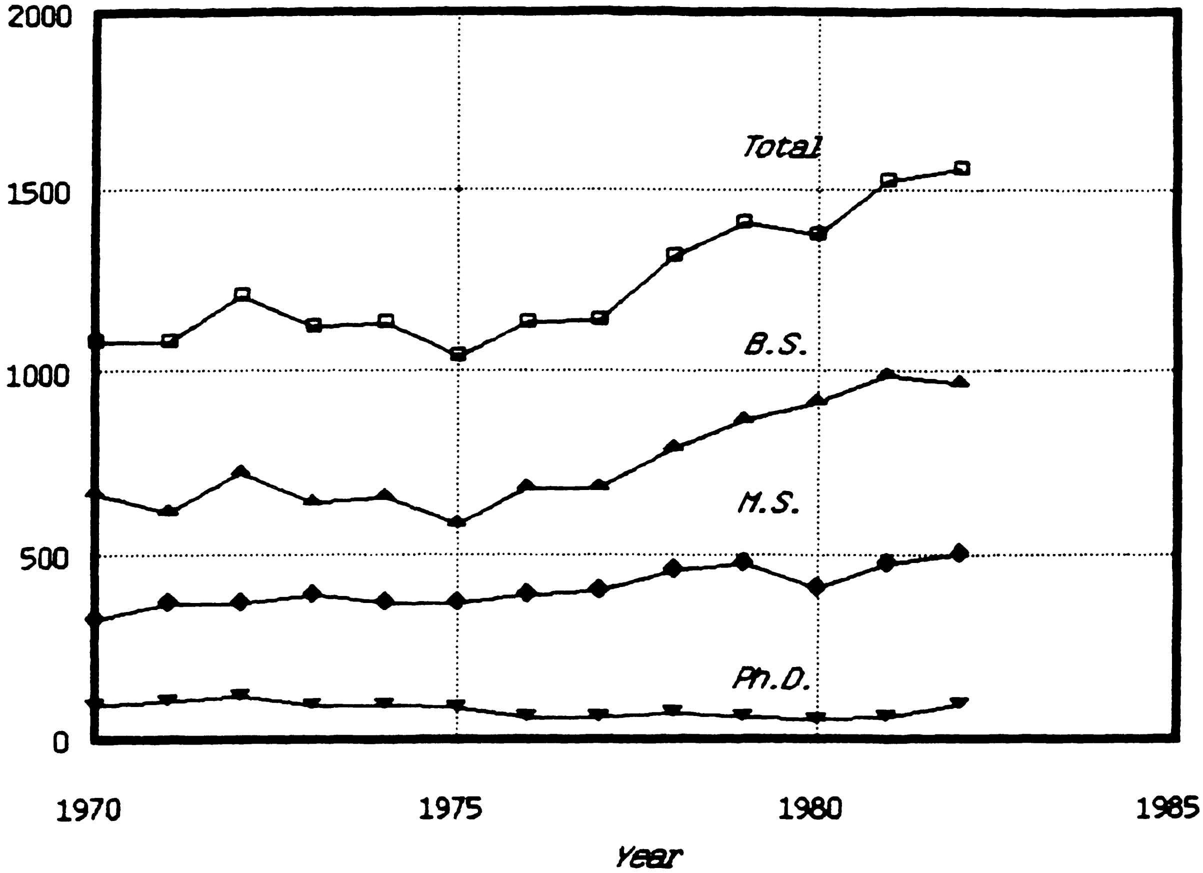
1. Undergraduate degree production appears to be stabilizing at roughly 1,000 B.S. degrees per year.

2. M.S. degree production is continue to grow, consistent with the growth in graduate enrollments.

3. After almost a decade of decline, PhD degree production has taken a sharp upturn, due in large part to efforts to respond to critical national needs for engineering doctorates.

Degree Production

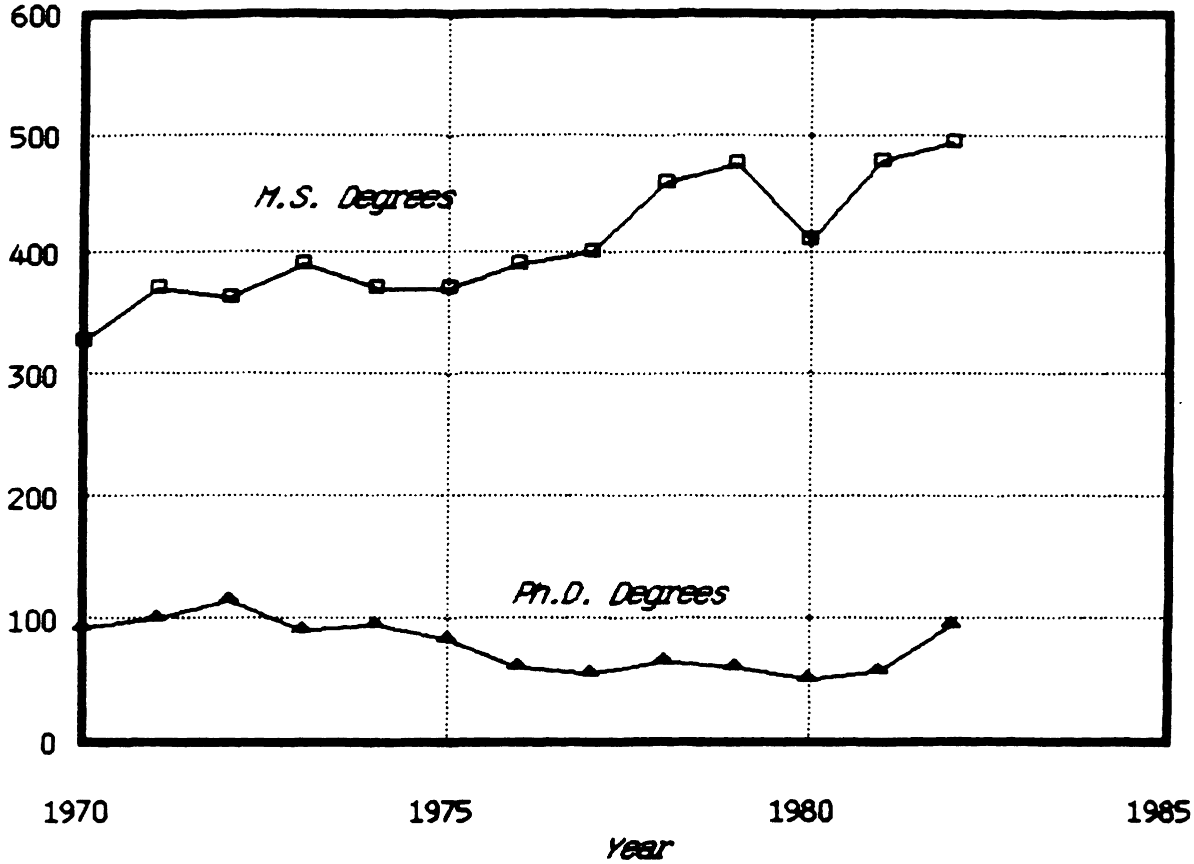
College of Engineering



Engineering degree production has reached 1600 per year: roughly 1,000 BS, 500 MS, and 100 PhD (ranking UM 5th nationally in each category).

Graduate Degree Production

College of Engineering



After a decade of decline, PhD production has increased sharply due to strong efforts to stress the College's doctorate programs.

Student Quality

STUDENT QUALITY

FIGURES:

- Applications for Admission
- Trends in SAT Scores of Entering Freshmen
- Trends in Class Ranking of Entering Freshmen
- Rackham Quality Factor of Selected Graduate Programs

COMMENTS:

1. Applications for admission to all degree levels of the College continue to be very strong.

2. By any quantitative measure, the most outstanding students in this University are choosing to enroll in the College of Engineering.

3. SAT Scores of entering engineering freshmen are now over 100 points higher than those entering any other unit on campus.

4. Over 25% of entering engineering rank in the 99th percentile of their high school graduating class (compared to 12% of students choosing to enroll in LS&A).

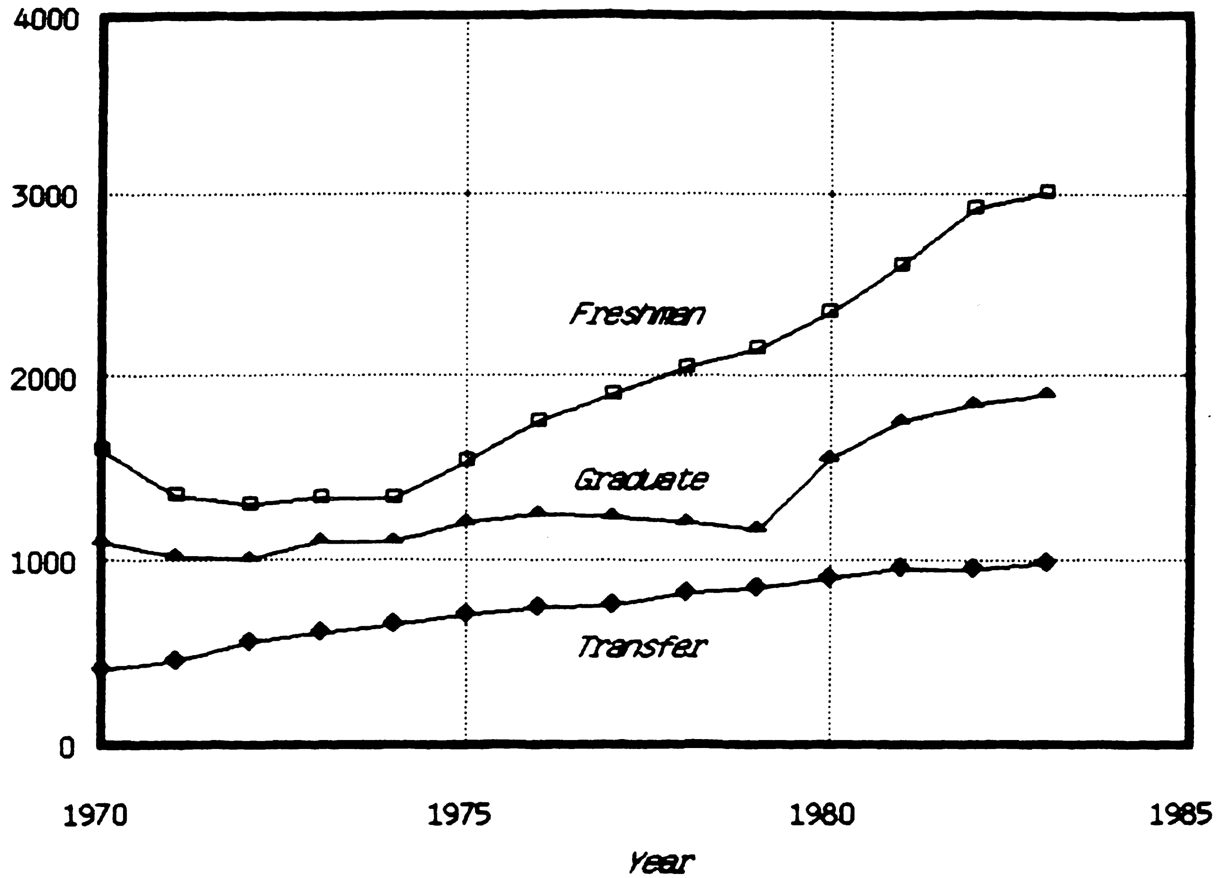
5. It is probable that the College enrolls the largest groups of truly outstanding engineering students in the United States. As such, it represents a unique resource for both this State and the nation.

6. Quantitative quality indices such as entering GPA or GRE scores indicate that graduate students enrolling in the College are comparable to those enrolling in other Division II programs (e.g., Mathematics, Physics, Astronomy).

7. The extraordinary abilities and commitment of the students enrolled in the College demands the <u>best</u> from this University and this State -- and certainly not the lowest level of General Fund support of any of Michigan's schools and colleges.

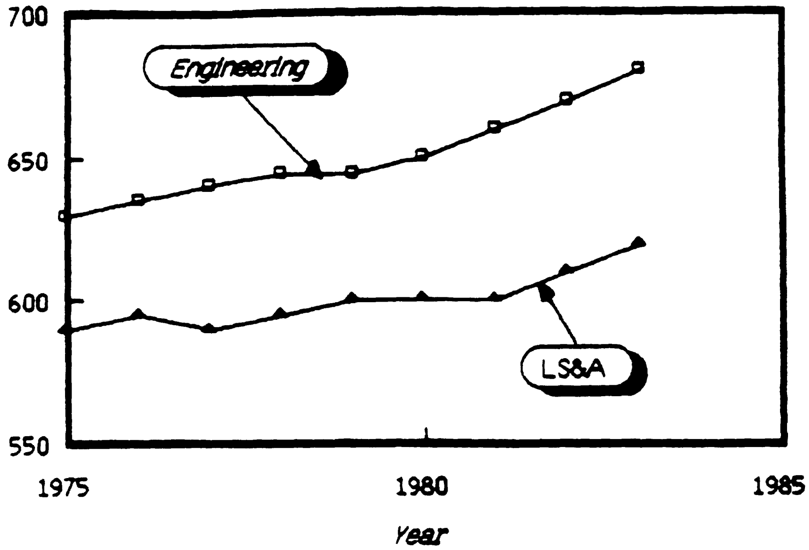
Applications for Admission

College of Engineering

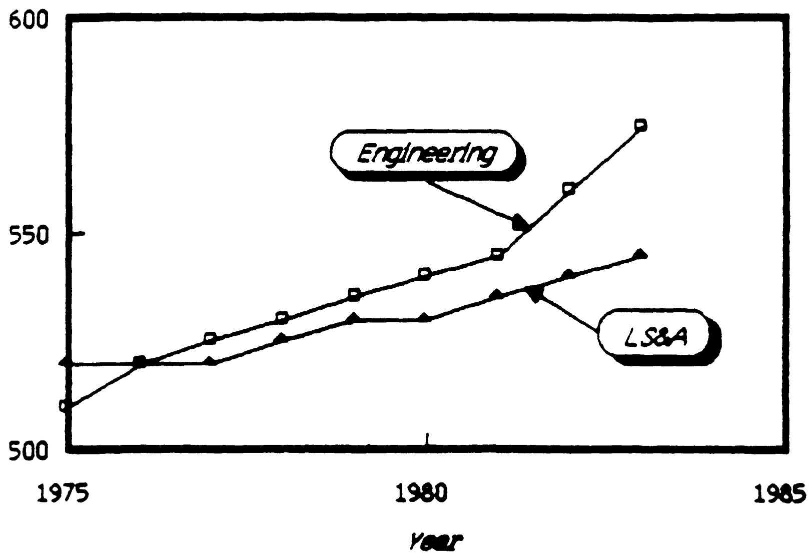


The number of applications for admission to the College continues to increase at all levels (freshman, transfer, and graduate).

SAT Math Scores for Entering Freshmen College of Engineering

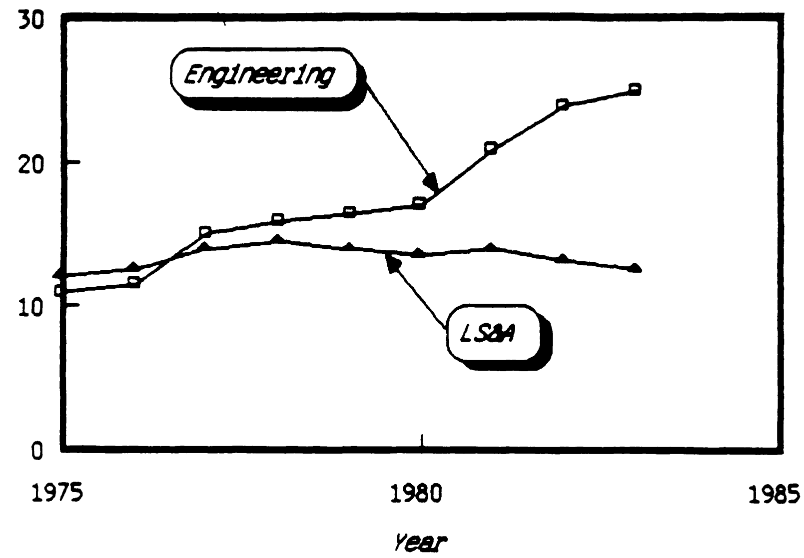


SAT Verbal Scores of Entering Freshmen College of Engineering

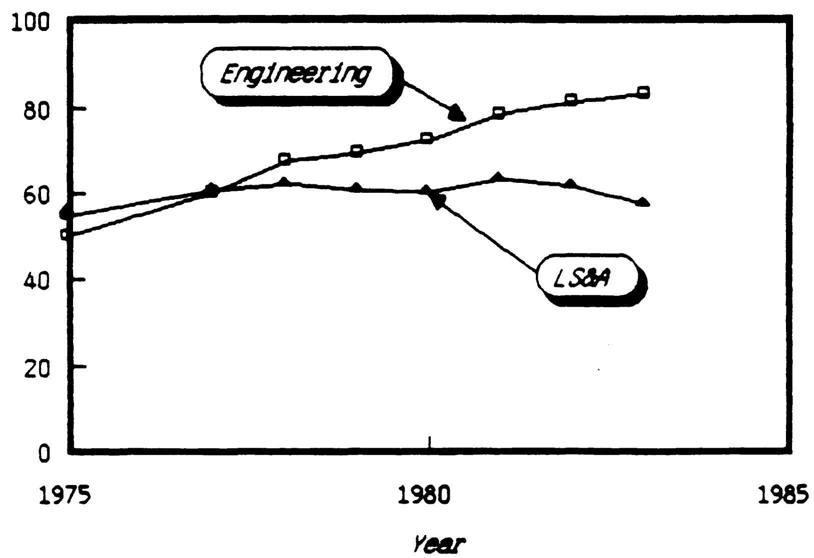


The SAT scores of freshmen entering the College are now over 100 points higher than those characterizing any other UM unit (and comparable to Ivy League standards).

Percent of Entering Freshman in 99th Percentile
College of Engineering



Percent of Entering Freshmen in 90th Percentile
College of Engineering



The most outstanding high school graduates in Michigan are now seeking admission to the College.

Instructional Loads

INSTRUCTIONAL LOAD

FIGURES:

- Student Credit Hour Production
- Fiscal Year Equated Students (FYES)
- Instructional FTEs (Faculty + GTAs)
- FYES/FTE Trends

COMMENTS:

1. Student credit hour and FYES production continue to increase at all levels.

2. General Fund budgeted instructional staff (FTE) continues to drop at an alarming rate due to seriously inadequate funding (-32 FTE over the past decade). Both national accreditation models and the State Formula Funding model (Owen-Huffman) suggest the College has less than <u>one-half</u> the level of FTE instructional staffing required to meet its present enrollments.

3. The combination of rising FYES levels and declining instructional FTEs in recent years has led to an all-time high in FYES/FTE of 18.1 -- once again roughly twice the national goal of 8 proposed both by the Accreditation Board of Engineering and Technology and the National Academy of Engineering.

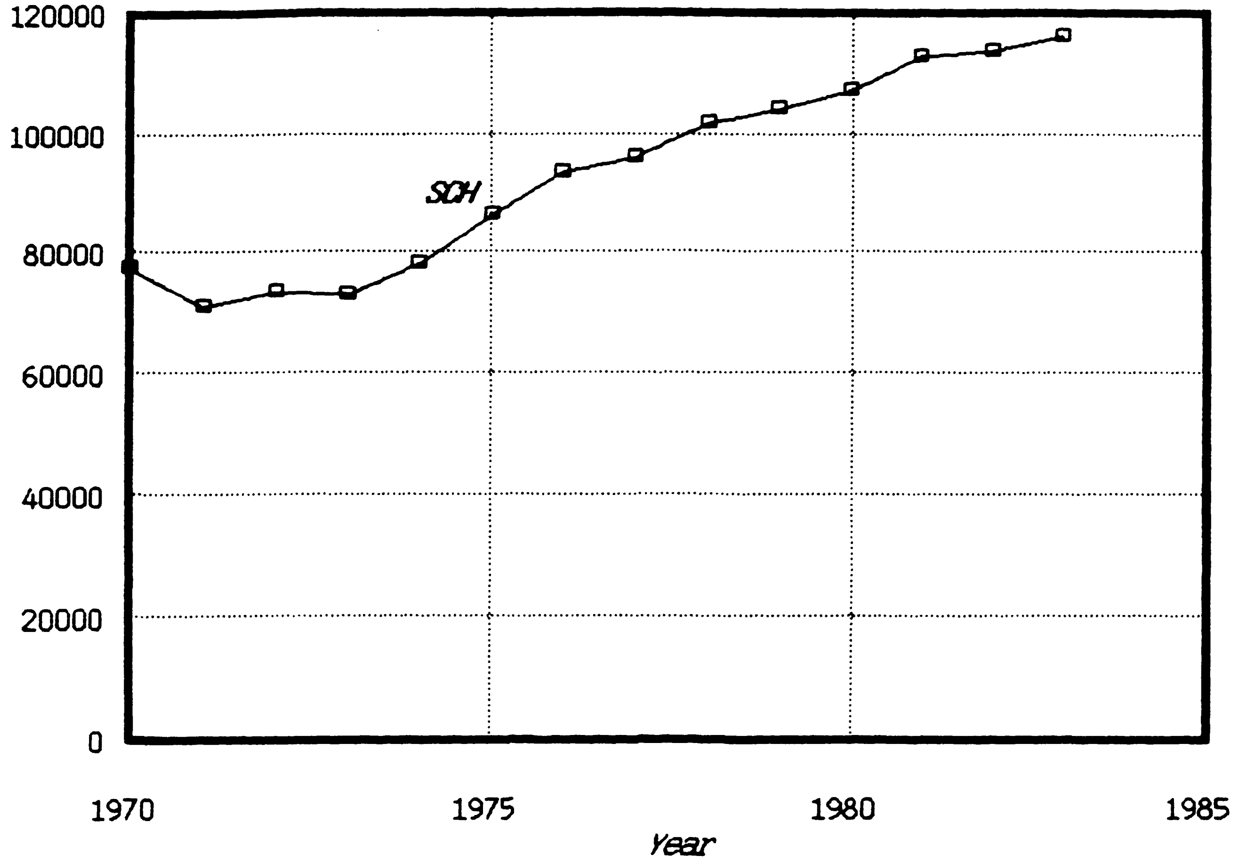
5. The College's instructional load is now higher than even LS&A -- despite the fact that most of the College's instruction occurs at the upper class and graduate levels and involves extensive laboratory and design coursework and the use of GTAs is at a minimum (due to inadequate flexible staff funding).

6. Due to inadequate General Fund support, the College is now being forced to fund a substantial component of its flexible instructional staff from discretionary funds (private support, research offset) -- at a level far below its actual needs.

7. The inability of the University to provide an adequate level of General Fund support for the College's instructional programs continues to be one of the most serious problems faced by the College.

8. Such a persistent, unacknowledged degree of understaffing is both unique and unprecedented among the schools and colleges of this University.

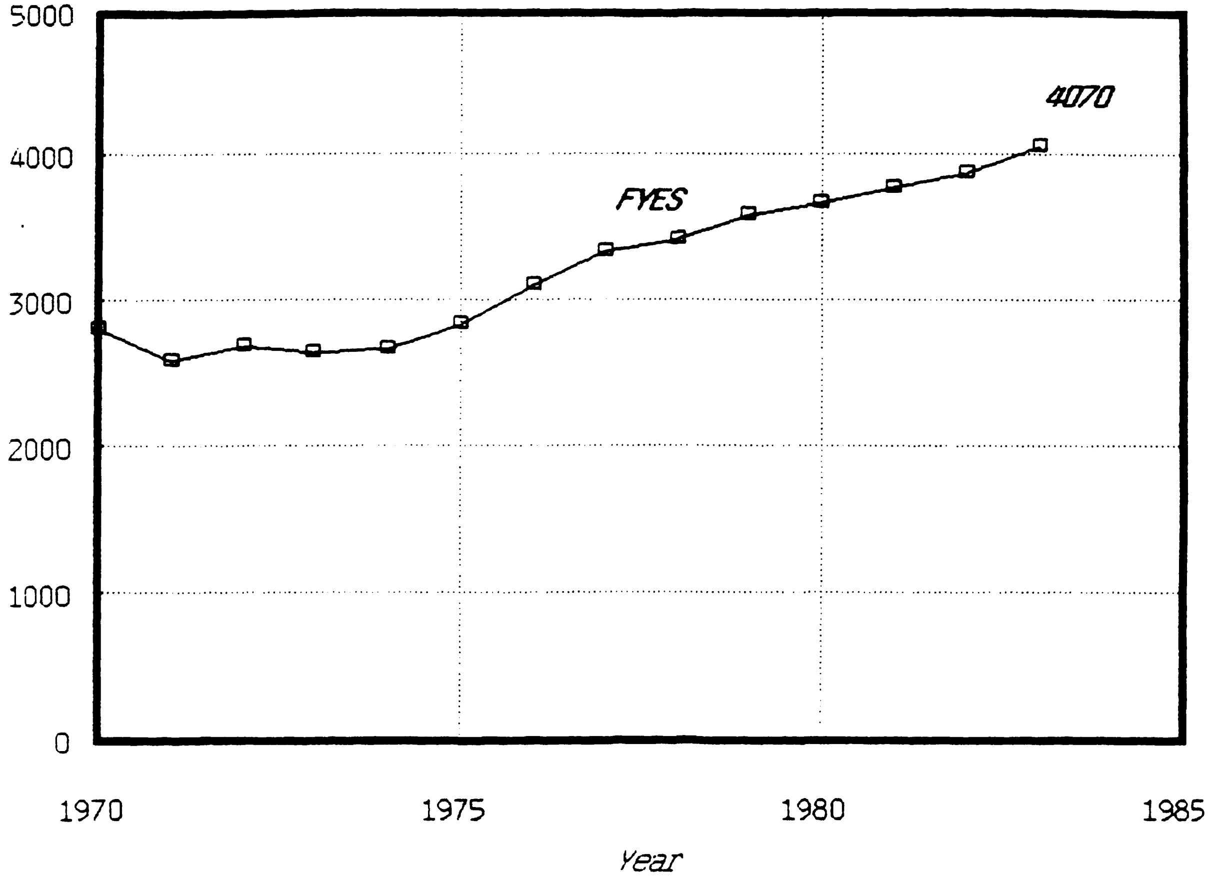
Student Credit Hour Production
College of Engineering



Student credit hour production in the College continues to increase (with primary growth at the upperclass and graduate level).

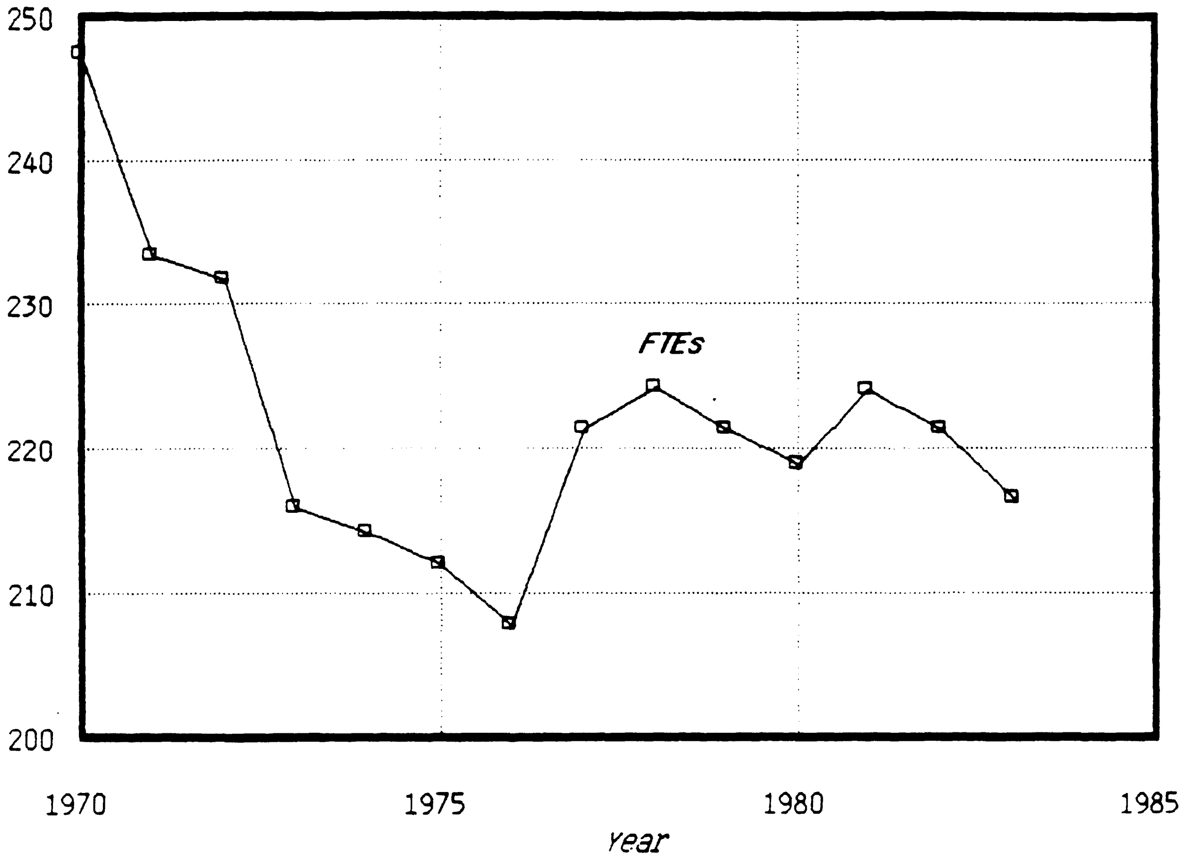
Fiscal Year Equated Students (FYES)

College of Engineering



College FYES levels have reached an all-time high

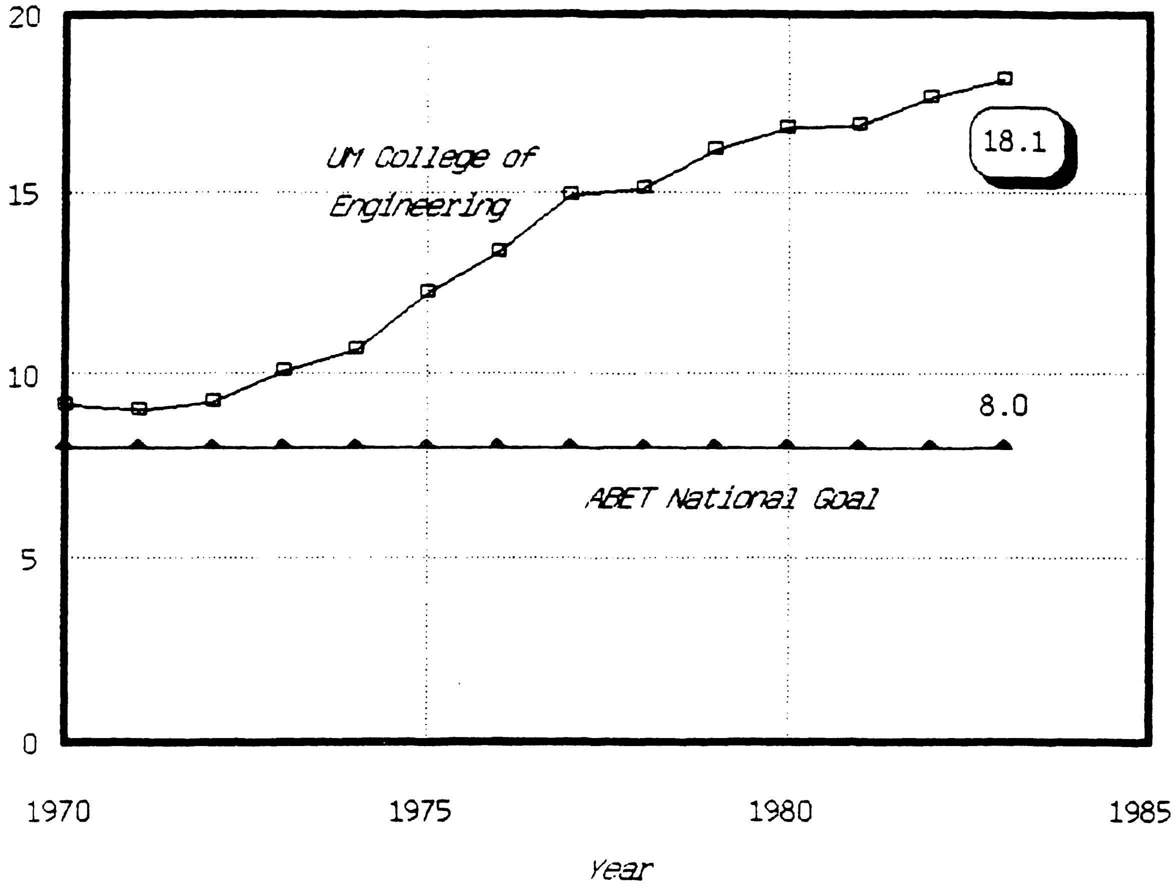
FTE Instructional Staff (Faculty + TAs)
College of Engineering



Inadequate General Fund support has led to a steady decline in College instructional FTEs over the past several years, despite staggering instructional overloads and steady enrollment growth.

FYES/FTE

College of Engineering



College instructional load (FYES/FTE) is now roughly twice that recommended by State and national guidelines.

A Decade of Neglect

A DECADE OF NEGLECT

FIGURES:

- Deterioration of General Fund Support of the College
- Decrease in CPI Adjusted General Fund Support per Student
- Cumulative Base Budget Cuts Sustained by the College

COMMENTS:

1. The decade of the 1970s saw a series of base budget cuts of the College's General Fund support at the same time its enrollments were increasing dramatically.

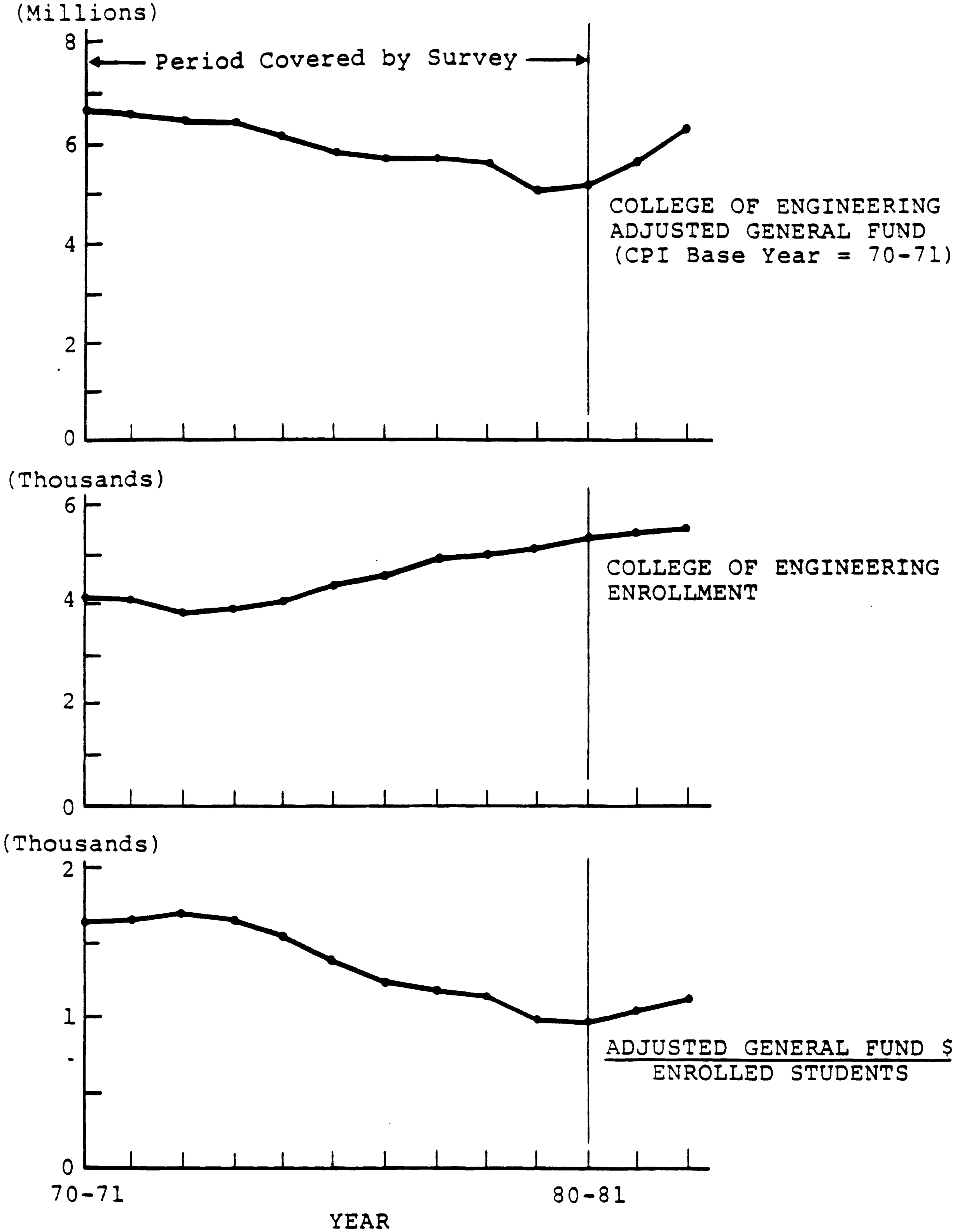
2. During the 1970s, the effective General Fund support per engineering student was methodically cut in half!

3. Despite recent efforts, the University has been able to provide only modest restoration of the budget cuts experienced by the College during the 1970s (in part because it insists on cutting the College's budget still further even as it attempts to restore it...)

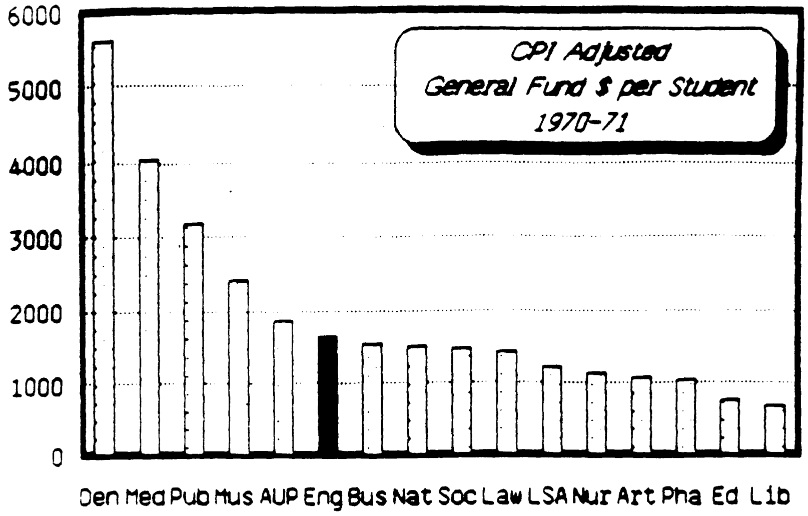
4. The College of Engineering remains the most seriously underfunded unit on this campus -- and, almost certainly, in any public institution in this State.

5. Despite best efforts, the University has been unable to find the College's State support. It remains, in effect, a privately-funded institution, forced to support its programs entirely from tuition revenue, sponsored research support, and private gifts.

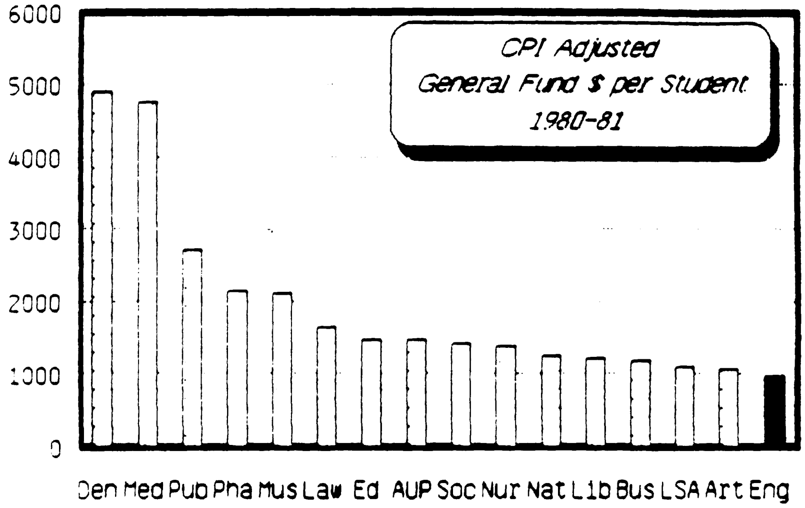
6. The impact of this neglect -- and the inability to deal with it on a timely basis -- has been devastating -- to the University, the State, and the nation. The College today continues to find itself struggling to meet the intense demand from the best of Michigan's high school graduates -- and the employers seeking talented, broadly-educated engineers -- in the face of inadequate funding, decaying physical facilities, obsolete equipment, and a badly overloaded faculty.



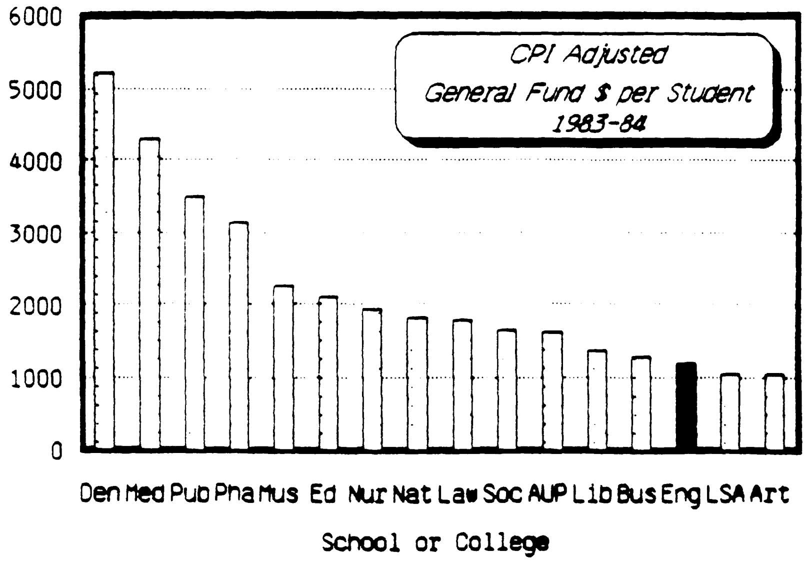
During the 1970s, the effective (CPI-adjusted) General Fund support per engineering student was cut in half!



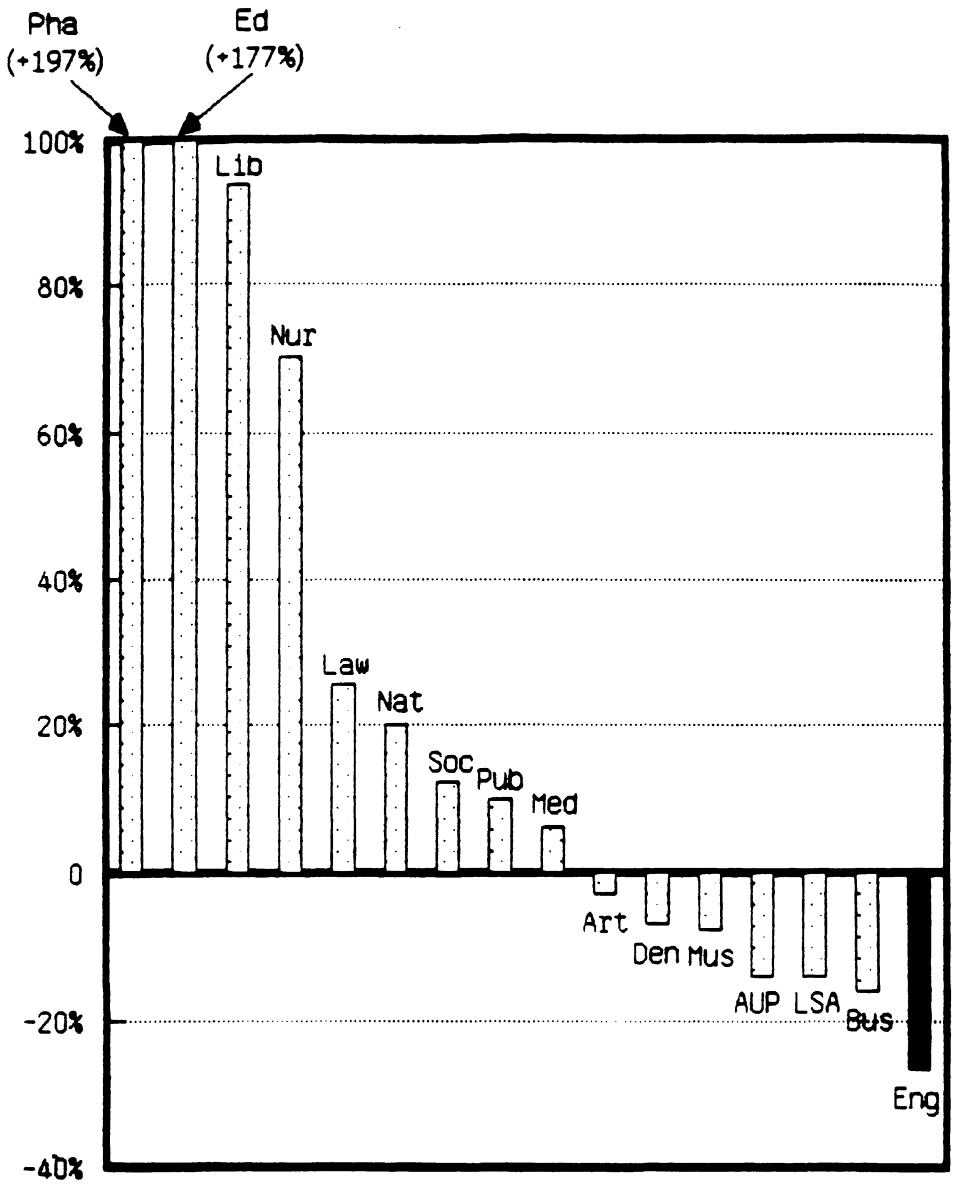
During the 1970s, the General Fund support of Engineering students was methodically reduced to the lowest level of any UM school or college.



Despite recent efforts to deal with this problem, the University has been unable to restore an adequate level of General Fund support for the College.



Change in CPI-Adjusted General Fund $ per Student 1970 - 1983



Comparative data clearly indicate that the College of Engineering has borne the brunt of the University's loss of State support over the past 14 years.

This discrimination in the support of Engineering students is particularly disturbing since, by any measure, they are most outstanding students enrolled at this University.

-STATE BUDGET REQUEST-

SUSTAINED FUNDING FOR ENGINEERING LABORATORY EQUIPMENT

THE UM COLLEGE OF ENGINEERING

(Base Funding Level: $4 million per year)

REQUEST FOR ADDITIONAL BUDGET ALLOCATION

College/Unit: College of Engineering

Request Title: Engineering Laboratory Equipment

REQUEST PURPOSE:

In recent years it has become apparent that Michigan will become increasingly dependent upon technology, and therefore upon engineers, to rebuild the competitiveness and diversify its industrial base. It is distressing to note that this increased dependence on technology is occurring in the aftermath of a decade of deteriorating State support for the College of Engineering of the University of Michigan.

Of particular concern is the appalling state of the College's laboratory equipment inventory. A decade of neglect has left the laboratories sadly obsolete. This crisis in the state of its laboratories has seriously impeded the College's efforts to provide the intellectual creativity and engineering graduates so desperately needed by Michigan industry.

The proposed additional budget allocation of $4.0 million in base support would restore an adequate level of funding to rebuild and sustain the laboratory equipment needs of the College. This request is consistent with the estimate of the College's backlog of equipment needs made by the Michigan Society of Professional Engineers ($44 million) and the level required to sustain this inventory estimated by the national Accreditation Board for Engineering and Technology ($2,000 per degree recipient), i.e., $3.5 million for the College of Engineering.

SUPPORTING RATIONALE

Both our nation and our State are becoming increasingly dependent upon science and technology. Government and industry are turning to institutions of engineering education to provide the intellectual creativity so fundamental to technological innovation and the talented, broadly-educated engineers who can understand and implement this technology. It is disturbing to note that most engineering schools have been crippled by sadly obsolete laboratories and equipment inventories in their efforts to respond.

Nowhere has this crisis become more serious than in the State of Michigan. Although our State is heavily dependent upon technology, a decade of deteriorating public support has left the laboratories of its engineering schools in a shambles. While industry in this State cries out for engineering graduates with knowledge of the sophisticated equipment so critical to productivity, the laboratories of our engineering colleges have deteriorated to a crisis level. A recent report of the Michigan

Society of Professional Engineers notes:

> "Continuing obsolescence of laboratory equipment and instruments has placed many schools in the position of not being representative of modern professional practice. New technologies, apparatus and methodologies are evolving more rapidly in industry, and lack of up-to-date equipment and instruments within the university exacerbates the situation. Rapid evolution of such fields as robotics, microelectronics, computer aided design, optics, spectrographics, electron microscopy, computer graphics, ...etc. has left the universities in a teaching mode far behind current professional practice.
>
> A decade-long decline in the flow of resourcers to laboratory equipment for higher education has taken its toll. The university no longer at the "cutting edge", and current graduates will not be the contributers that their predecessors were. Some have said engineering education is destressed, but a more apt description is a "crisis state."

In particular, the equipment inventory of the College of Engineering of the University of Michigan has deteriorated to a level that can no longer sustain high quality education or research--thereby crippling the College's efforts to respond to the needs of Michigan industry. National studies of engineering education suggest that an amount equivalent to $2,000 per engineering graduate should be budgeted each year just to sustain an adequate equipment inventory. For the College, with 1,750 graduates each year, this translates into an annual investment of $3.5 million just to support instructional equipment. Furthermore, detailed studies performed by the Michigan Society of Professional Engineers now place the investment necessary to restore the College's instructional equipment needs at $44 million.

BACKGROUND STATEMENT

THE ENGINEERING LABORATORY EQUIPMENT CRISIS

THE ENGINEERING LABORATORY EQUIPMENT CRISIS

As America becomes increasingly dependent upon science and technology, government and industry are turning to institutions of engineering education to provide the intellectual creativity fundamental to technological innovation and the talented, broadly-educated engineers capable of understanding and implementing this technology. It is therefore particularly disturbing to note the degree to which most engineering schools have been crippled by obsolete laboratories and equipment inventories in their efforts to respond to national needs.

UNDERLYING CAUSES OF THE LABORATORY EQUIPMENT CRISIS

The deterioration in the laboratory equipment inventories of our nation's engineering schools over the past decade can be attributed to several factors:

- To respond to a retrenchment in the support of higher education in general and engineering education in particular, many universities chose to cannibalize equipment budgets rather than reduce staffing. This may have been explicitly or implicitly caused in part by a strong, albeit temporary, presence of anti-technology sentiment in American society.

- Coincident with this retrenchment, a groundswell in the demand for engineering graduates was building which resulted in sharp increases in engineering enrollments (50% or greater in most cases). Few institutions responded to the staggering increases in engineering enrollments of the 1970s with corresponding increases in equipment support.

- Few academic administrators comprehend or acknowledge the major differences between the funding requirements of programs in science and engineering and those in other areas such as humanities and social sciences. In sharp contrast to the humanities and social sciences in which staffing dominates resource needs (90% or greater), in the sciences a very significant component of resources (30%$ - 40%) must be dedicated to equipment and technical support staff.

- The federal government methodically cancelled or decreased most of its support for instructional laboratory equipment during the 1970s.

- The sophistication of modern instructional and research laboratory equipmenmt has sharply increased acquisition costs. Furthermore, maintenance costs of such sophisticated equipment typically runs 10% - 15% of purchase costs per year.

- The explosion in the use of computers in all phases of engineering education, research, and practice has effectively doubled the equipment needs of most institutions.

MAGNITUDE OF THE PROBLEM

Surveys conducted by the National Society of Professional Engineers, the National Academy of Engineering, and other organizations during the early 1980s identified a shorfall in engineering laboratory equipment expenditures from 1971 to 1981 in excess of $1 billion, just to maintain laboratories in 1971 conditions. Restoration to 1971 status plus additions to accommodate enrollment growth to 1981 would have cost over $2 billion. Converting these numbers to unit costs results in required expenditures of <u>$2,000 per engineering degree student recipient per year</u>.

As one specific example of the staggering magnitude of the laboratory equipment crisis, a very detailed inventory of present equipment needs of one major engineering college identified a backlog of urgent laboratory equipment needs (primarily for instructional laboratories) of $30 million. In addition, the implementation of a modern computing environment necessary to support this engineering program will entail an additional investment of $40 million over the next five years.

It should be stressed that these estimates cover primarily instructional needs. They do not include the major additional needs for research laboratory equipment (which is usually funded from grants and contracts).

CONSEQUENCES OF THE LABORATORY EQUIPMENT CRISIS:

Most engineering schools are now forced to conduct their instructional and research activities with obsolete and inadequate equipment. Much of this equipment is 20 to 30 years old -- ever older than the students who are using it. (Indeed, in a recent visit, representatives from the People's Republic of China remarked during a visit to a leading university laboratory that it was the first place they felt like home in their U.S. tour).

Continuing obsolescence of laboratory equipment and instruments has placed many engineering schools far behind modern professional practice in industry or government. New technologies, apparatus, and methodologies are evolving more rapidly in industry, and the lack of up-to-date equipment within the university exacerbates the situation. Rapid evolution of such fields as robotics, microelectronics, computer aided design (CAD/CAM), optics, electron microscopy,...etc. has left the universities in a teaching mode far behind current professional practice. Automated equipment of the kind used in industry is largely nonexistent in university teaching laboratories.

consequently many engineering students graduate without ever having worked with modern, state-of-the-art equipment.

A decade-long decline in the flow of resources to laboratory equipment for higher education has taken its toll. Universities are no longer at the "cutting edge", and current graduates will not be the contributors to our nation's technological leadership that their predecessors were. Our nation's engineering schools have lost the capacity to produce graduates experienced with the technology needed to strengthen and maintain this nation's productivity and security. Industry can no longer depend on today's engineering graduates to provide the technological innovation that this nation has depended upon throughout its history.

This situation stands in sharp contrast to that found in other industrialized nations (particularly West Germany, France, Sweden, and Japan) where university laboratories are given top priority.

Inadequate laboratory experience has caused a major shift in the character of engineering education, away from experiment toward analysis. Engineering, like other sciences, is a highly experience-oriented discipline. Students must gain first-hand knowledge and experience with physical phenomena and technology. Most of today's students graduate with educations that are far more theoretical than laboratory (experience) -based. Indeed, we run the risk of producing graduates and research based almost entirely on computer simulation and analysis rather than experiment and synthesis. Although this trend is not without positive features, it would be a tragedy for both industry and the research establishment of this nation if carried to the extreme.

WHAT CAN BE DONE

The engineering laboratory equipment crisis is a consequence of a classical "pass-the-buck" syndrome. Few universities have been willing to recognize the urgency or priorities of the equipment needs of their programs in science and engineering. The federal government has eliminated most of its direct support for instructional laboratory equipment, arguing that industry should carry the load, since it is the principal beneficiary of the graduates and research produced by engineering schools. And while industry has increased its equipment contributions somewhat, its support falls orders of magnitude short of needs. Furthermore, industry has always depended on government to provide the dominant support for education ("after all, what do we pay taxes for if not to support engineering education...").

Our national experience emphasizes that technological development and education cannot be turned on and off as the winds of public sentiment shift. Unless these are supported on a continuing basis, enormous "catch up" costs are required each time public sentiment shifts back to stress science and engineering.

A variety of apporaches have been taken to address the crisis. Legislation has been enacted to provide tax incentives for equipment contributions. Debt-financing schemes have been developed for large equipment purchases. The Department of Defense has implemented a modest program to respond to equipment needs of programs conducting research of direct relevance to national defense. (It should be noted, however, that the most logical federal agency for this role, the National Science Foundation, has not mounted a major laboratory equipment initiative for over 15 years).

Perhaps the most encouraging and effective action in recent years has been taken at the state level. Acting in response to appeals from universities, industry, and the engineering profession, a number of states have enacted legislation to provide direct funds for re-equipping engineering laboratories. Most such initiatives are based on establishing "Engineering Excellence Funds", which provide roughly $2,000 per engineering graduate to institutions on a matching grant basis. Such programs of sustained public support have been the most successful action to address the engineering laboratory equipment crisis.

DOCUMENTATION OF NEED

1. Letter of September 12, 1984 to Dr. John Hanieski

2. Detailed UM Engineering Equipment Needs

Office of the Dean

Chrysler Center
Ann Arbor, Michigan 48109-2092
313 764-8470

College of Engineering
The University of Michigan

September 12, 1984

Dr. John Hanieski
Commission on the Future
of Higher Learning
North Ottawa Street Building
Fourth Floor
P.O. Box 30026
Lansing, MI 48909

Dear John:

This is in response to your request for further information and analysis regarding our estimates of the magnitude of the equipment needs of the College of Engineering of The University of Michigan. I would now like to share with you both our raw data and my analysis of it.

Please find attached the collated responses of each of our academic departments to our request for a list of equipment needed to upgrade their instructional laboratories and those research laboratories which have direct involvement in education of doctoral students. As you are aware, in a university such as ours the line between research and instruction is quite fuzzy because a primary goal of our research program is the education of doctoral students. Nonetheless, some effort must be made to draw some financial distinction between the two, and you will see how I have addressed this below.

The list for each department was drawn up by the faculty members responsible for maintaining the major instructional and research laboratories. They were asked to assign priorities ranging from 5 (maximum) to 1 (minimum) to each item requested, and they were asked to estimate the balance between instructional use (i.e. direct use in formal courses) and research use (i.e. use in sponsored research and training of research students). As in any such endeavor, the accuracy and care with which these were prepared may vary a bit from department to department. Nonetheless, I believe that the estimates are quite accurate. This is a second iteration with the departments, and they know that our need for information is serious. In any event, I am confident that in the aggregate they present a good analysis of our real needs.

It is my belief that a distinction should be drawn between general equipment needs and the need to develop major facilities or laboratories. The prime example of such a facility is the

Solid-State Electronics Laboratory. Such facilities are characterized by a need for major, one-time, capital needs. These large capital needs must be met in order for the facility to reach a level of quality from which it can serve the industry, research and educational institutions of the State and become self-supporting on the basis of industrial and governmental research and development contracts.

The total needs identified by our academic departments are $44,608,000. I have separated from this $14,200,000 which represent equipment for "facilities" from the total leaving a net of $30,408,000. Please note that these figures do not include the costs of our Computer-Aided Engineering Network (CAEN). An analysis of the estimates indicates that approximately 50% of the use of the equipment is for instruction in formal courses and 50% is for research and training of graduate students. I have assumed that the "instructional" equipment should be depreciated over 8 years and subject to an annual maintenance expenditure of 10% of its original cost. These costs would be expected to be carried by the State. The equivalent annual maintenance and depreciation costs for the "research" equipment would be charged as direct and indirect costs associated with externally-sponsored research contracts and grants.

The above analysis of our needs results in a request for a capital expenditure of $30,408,000 and an annual recurring cost of $3,415,000. In addition, we show four facility requests totalling $14,200,000, of which the $8,000,000 Solid State Electronics Laboratory is the most critical to both the College and the State.

Interestingly, this model indicates that the recurring cost annual cost is $1,891 per degree granted, which is quite compatible with the generic estimate of $2,000 per degree granted used by the National Society of Professional Engineers.

These computations are summarized for you on an accompanying sheet. It is interesting that the needs per degree are rather uniform among the departments. The major exceptions on the high side are Materials and Metallurgical Engineering, which is a completely experimentally-oriented field, and Nuclear Engineering, which is dominated by its doctoral program. On the low side is Industrial and Operations Engineering, which is primarily an analytically and computationally oriented discipline.

In addition to the raw data and my summary analysis, I have also appended the detailed analysis of the equipment needs for the Solid State Electronics Laboratory. This need, as you know, is critical.

As mentioned above, this analysis has excluded the cost of creating and maintaining a state-of-the-art computer environment in the College - a step that is essential in today's world. A thorough breakdown of the costs of the Computer-Aided Engineering Network are also appended. It requires annual operating expenditures of the order of $5,500,000.

I believe that the analysis of the problem contained herein is a rational one. Obviously, details such as priorities, depreciation schedule, relative role in instruction and research can be debated and refined. I will be very happy to work with you to further refine and analyze this statement of need.

Sincerely yours,

Chuck

Charles M. Vest
Associate Dean for
Academic Affairs

Attachments

cc: J.J. Duderstadt
D. E. Atkins

ANALYSIS OF EQUIPMENT NEEDS OF THE COLLEGE OF ENGINEERING

SEPTEMBER 11, 1984

DEPT.	EQUIPMENT	(FACILITIES) *	NET	DEGREES	$/DEG.
AERO	6948687	- 2500000	4448687	117	38023
AOS	392325		392325	31	12656
CHEM	5181150	- 1600000	3581150	174	20581
CIVIL	3205200		3205200	205	15635
EECS	14794993	- 8000000	6794993	538	12630
IOE	90150		90150	171	527
MME	4554280	- 2100000	2454280	45	54540
MEAM	4103950		4103950	384	10687
NAME	735726		735726	85	8656
NUCL	4602075		4602075	55	83674
COLLEGE	44608536	- 14200000	30408536	1805	16847

SPECIAL FACILITIES

AERO	WINDTUNNEL:	$2,500,50
CHEM	SURFACE ANALYSIS:	1,600,00
EECS	SOLID-STATE ELECTRONICS:	7,000,00
MME	ELECTRON MICROSCOPY:	2,100,00

50% of the equipment is to be used for classroom/laboratory instruction; It should be subject to 10% annual maintenance and depreciation over 8 years.

50% of the equipment is for research/doctoral education. Its maintenanc and depreciation should be addressed through external research support.

Hence: CAPITAL INVESTMENT = $30,400,000

****

ANNUAL MAINTENANCE =	$ 1,515,000	=	$ 839
ANNUAL DEPRECIATION =	$ 1,900,000	=	$1052

ANNUAL COST PER DEGREE = $1891

****

CAEN 3-5 YEAR PLAN

ITEMS	UNIT $	FAC	STF	STU	TOTAL	TOTAL $
Workstations						
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-total						$27,345,000.00
File servers						
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						$ 9,180,625.00
Print servers						
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						$ 2,975,000.00
Backbone						
Interface	2,000.00				15	30,000.00
Cable	500,000.00				1	500,000.00
Sub-total						$ 530,000.00
Software						
Core Site	100,000.00				1	100,000.00
Application	800,000.00				1	800,000.00
Sub-total						$ 900,000.00
Grand Total						$40,930,625.00

THE UNIVERSITY OF MICHIGAN
COLLEGE OF ENGINEERING

DEPARTMENTAL LABORATORY EQUIPMENT NEEDS SUMMARY

November 1983

DEPARTMENT	LABORATORY	NEED
AEROSPACE		$1,530,000
	Computer, Information and Control	
	Gas Dynamics	
	High Altitude Engineering	
	Structural Dynamics	
ATMOSPHERIC and OCEANIC SCIENCE		$1,100,000
	Air Pollution and Instrumentation	
	Atmospheric Chemistry	
	Data Processing and Synoptic	
	High Altitude Engineering	
	Marine Chemical	
	Marine Geological	
	Michigan AirGlow Observatory	
	Physical Oceanography	
	Space Physics	
CHEMICAL ENGINEERING		$4,050,000
	Applied Polymer	
	Biochemical Engineering	
	Bioengineering	
	Catalysis and Spectroscopy	
	Chemical Engineering	
	Coal Slurry and Energy Logistics	
	Ecosystem Simulation	
	Electrochemical	
	Heat Transfer	
	Laser Light Scattering	
	Oil Shale Research	
	Petroleum Research	
	Process Dynamics	
	Sonochemical Engineering	
	Thermal Properties of Fluids	

CIVIL ENGINEERING		$2,400,000
	C.E. Materials	
	Concrete Research	
	Construction Engineering	
	Geotechnical Engineering	
	Hydraulic Transients	
	Coastal Hydraulics	
	Sanitary Engineering	
	Solid Wastes	
	Structural Dynamics	
	Structures	
	Water Resources Engineering	
ELECTRICAL and COMPUTER ENGINEERING		$7,700,000
	Bioelectrical Sciences	
	Cooley Electronics	
	Electro-Optics	
	Electron Physics	
	Power Systems	
	Technology Assessment	
	Radiation	
	Robotics	
	Space Physics	
	Systems Engineering	
	Ultrasonic Imaging	
	Vehicular Electronics	
INDUSTRIAL and OPERATIONS ENGINEERING		$1,500,000
	Center for Ergonomics	
	Information Systems Design and Optimization Systems	
	Manufacturing Systems	
MATERIALS and METALLURGICAL ENGINEERING		$3,100,000
	Carbon	
	Cast Metals	
	Chemical Metallurgy	
	Electron Microscopy	
	Heat Treating	
	High Temperature Metallurgy	
	Metallography	
	Physical Ceramics	
	Physical Testing	
	Polymers	
	Scanning Electron Microscope, Microprobe and Mass Spectroscopy	
	X-Ray Diffraction	

MECHANICAL ENGINEERING and APPLIED MECHANICS		$6,100,000
	Acoustic Emissions and Fatigue	
	Automatic Control	
	W.E. Lay Automotive Engineering	
	Cavitation and Multophase Flow	
	Computer-Aided Design	
	Emission Research	
	Failure Analysis and Composite Materials	
	Fluid Dynamics	
	Fluid Mechanics	
	Heat Transfer	
	Interferometry	
	Machine Tool	
	Material Processing	
	Mechanical Analysis	
	Mechanical Design	
	Non-destructive Testing	
	Numerical Control	
	Plastic Deformation of Materials	
	Power and Fluids	
	Rehabilitation Engineering	
	Solid Mechanics	
	Thermodynamics	
	Tribology	
	Welding	
NAVAL ARCHITECTURE and MARINE ENGINEERING		$970,000
	Ship Hydrodynamics	
NUCLEAR ENGINEERING		$1,580,000
	Laser-Plasma	
	Mossbauer Measurements	
	Neutron Experimental Bay	
	Neutron Spectroscopy	
	Plasma Experimental Bay	
	Radiation Measurement	
	Diffusion	
	Material Preparation	
	Photoneutron	
	TOTAL:	$30,030,000

A STATEWIDE RESPONSE TO THE CRISIS:

THE ENGINEERING EXCELLENCE FUND

STATEMENT OF REQUESTED ACTION:

The State of Michigan will establish an Engineering Excellence fund to support the acquisition and maintenance of laboratory equipment for the engineering schools of Michigan's public universities. Annual appropriations to the fund would be at a level of $2,000 per engineering degree recipient in these institutions in the previous fiscal year. Disbursement of funds from the Engineering Excellence Fund would require matching grants of equipment support for each institution. The maximum matching grants appropriated from the Fund to any eligible institution would be limited to $2,000 per engineering graduate per year.

The annual cost of this program is estimated to be $8,500,000 based on 4,250 graduates per year (and 100% success in raising matching support).

NOTES:

Similar Engineering Excellence Funds or related legislative actions for the purpose of rebuilding engineering college laboratories have been implemented in most states (including actions last year taken in Illinois, Ohio, Pennsylvania, Texas, Arizona, New Mexico, Iowa, Oklahoma, Colorado, Minnesota, Tennessee, Washington, and Wyoming).

These initiatives have been encouraged by the National Society of Professional Engineers and its affiliated societies.

The NSPE, along with other national groups including the National Academies, have recommended the base support level of $2,000 per engineering degree recipient as the amount necessary to sustain engineering college laboratories. (Obviously, the restoration of the equipment inventories after the past decade of neglect requires an even larger commitment).

-STATE BUDGET REQUEST-

SUSTAINED FUNDING FOR COMPUTING ENVIRONMENT

THE UM COLLEGE OF ENGINEERING

(Base Funding Level: $4 million per year)

REQUEST FOR ADDITIONAL BUDGET ALLOCATION

COLLEGE/UNIT: College of Engineering

Request Title: Computing Equipment

REQUEST PURPOSE:

The emerging generation of computing systems, stimulated by dramatic advances in integrated circuit and communication technology, is now focusing on enhancing the productivity of people rather than merely the productivity of operations. Engineering and computer science teaching, research, and practice will increasingly depend upon routine access to networks of individual computer workstations with powerful local processing, interactive high-resolution graphics, and rapid access to enormous technical databases.

The College of Engineering has accepted the challenge to build the next generation distributed computing environment which will be necessary to maintain leadership in research and instruction. This environment is known as the Computer Aided Engineering Network (CAEN). Through the CAEN the College is committed both to enhancing the productivity of the educational process and to educating students who will use, develop, and propagate computer-aided engineering tools. This environment is also prototypical of the distributed computing environment which is at the core of the "factory or business of the future."

The proposed additional budget allocation of $4.0 million in base support would provide the necessary level of sustained resources to support the ongoing maintenance costs of the $41 million Computer Aided Engineering Network. The initial equipment acquisition for the Network is being financed through private gifts and research contracts.

SUPPORTING RATIONALE:

There is growing evidence that over the long term computer technology (both hardware and software) will play a major role in economic development in the Great Lakes area. Signs of this increasing importance include:

- The transformation of traditional manufacturing firms into computer and microelectronics companies.

- The presence of the nation's leading software laboratory, Bell Laboratories in Naperville, Illinois, and its impact on the attraction of large numbers of software engineers into the Great Lakes area.

- The growing dependence of the heavy manufacturing industry on computers (e.g., automation) and therefore on computer engineers and scientists.

- The increasing number of software companies being spun off by faculty of the College of Engineering (e.g., the recent spinoff of the $2 million data base development firm ISDOS, Inc.).

We propose that the State of Michigan, industry, and the College of Engineering commit themselves to building the nation's leading computer science and engineering program in an effort to provide the nucleus of major new computer industry in Michigan. Factors in support of such a commitment include:

- The University of Michigan already conducts programs in computer science and computer engineering that are within striking distance of national leadership (presently these programs rank within the top ten in the nation).

- 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 Michigan one of only a handful of institutions in the nation able to coordinate research and instructional programs in computer technology, thereby giving it instant visibility and credibility in attracting new faculty.

- These programs presently attract perhaps the largest concentration of high quality students in the country. This year the degree programs offered by this Department enroll over 1800 students drawn from the 99th percentile of high school graduates.

- The recent State commitment of $30 million for the College's Electrical Engineering and Computer Science Laboratory (so-called Engineering Building I) which will house this new department provides an excellent opportunity to draw national attention to Michigan. Every effort should be made to take maximum advantage of the ground-breaking ceremony for this facility to be held in early spring.

- Recent modifications to the Internal Revenue Code (initial legislation in 1981 and pending legislation to cover software) have made it very attractive for companies to provide major equipment gifts to leading academic institutions. There is also an unusual opportunity to use such mechanisms to attract matching funding from industry in these areas.

- The College has recently announced the development of its Computer Aided Engineering Network which leapfrog the efforts at peer institutions such as MIT and Carnegie-Mellon to provide the most sophisticated environment in the nation for instruction and research in computer science and engineering.

- In October of 1984, the College submitted a proposal to the National Science Foundation for a $37 million grant to establish a national supercomputer center. Such a center would have a major impact on industrial development in our State.

- The College will be submitting a $5 million proposal to the National Science Foundation in fall of 1985 as part of a national competition for support of coordinated experimental research in computer science and engineering. A major State commitment to this area would have a significant impact on the chances for success of this proposal.

- The College and University are now exploring with federal officials the possibility of locating a major new supercomputer facility on campus.

- The College has recently negotiated new mechanisms for the transfer of intellectual properties into the private sector. As a result, we are beginning to see an increasing number of faculty spinoff software research activities into private companies. We are making every effort to encourage this activity.

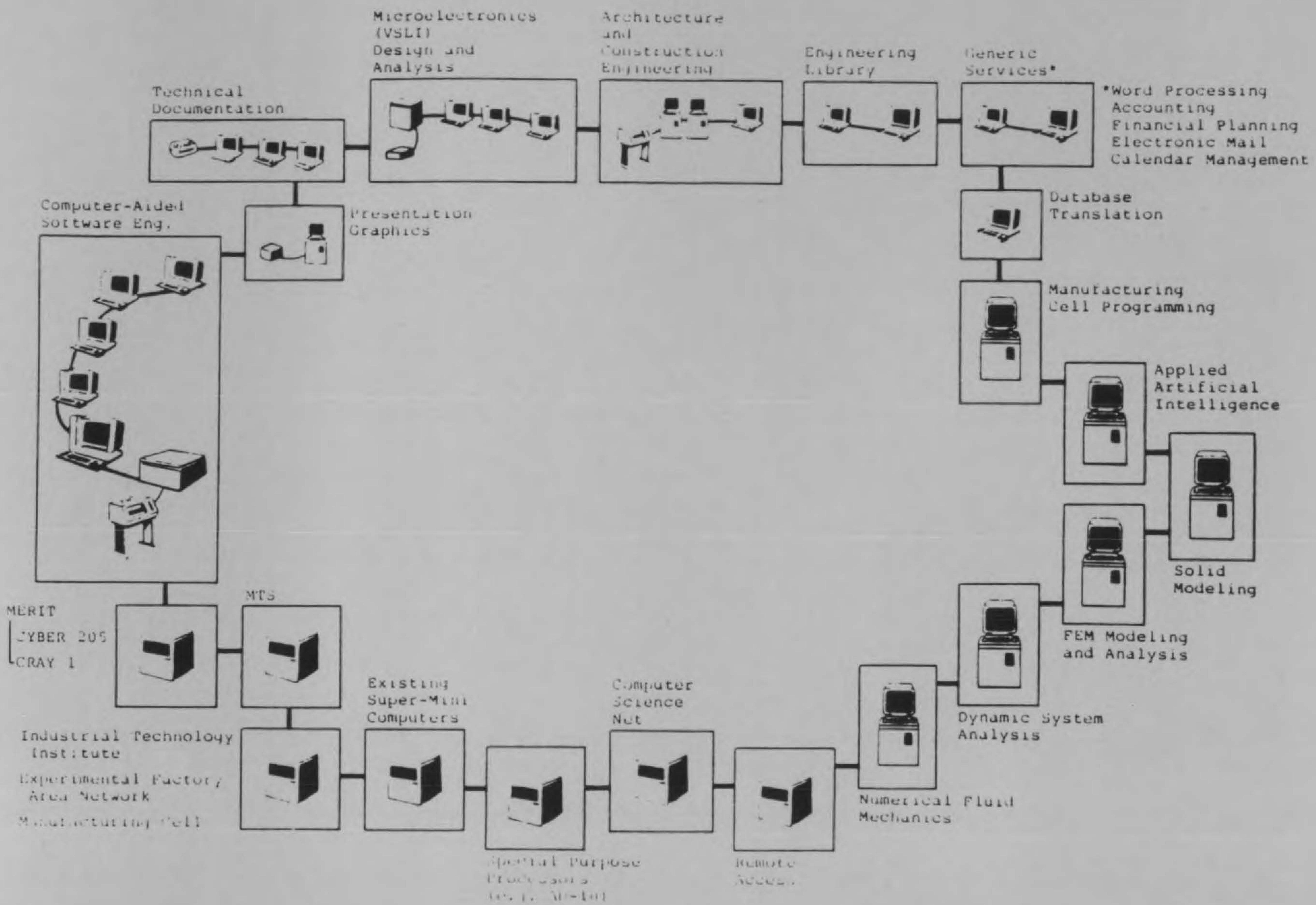
- The presence of roughly 6,000 engineering students and 600 faculty and staff in the College provides an extraordinary resource for major new developments in computer software. The College is now exploring the formation of incubation mechanisms to transfer these developments outside the University into the private sector.

DOCUMENTATION OF NEED

Based upon prices of "engineering workstations" such as the Hewlett-Packard 9000, the Sun Microsystems stations, and the Apollo Domain family, we have developed a detailed plan for the building of the CAEN over the next 3-5 years. We are quoting list prices but based upon past experience, would expect significant discounts from the vendors. An adequate number of workstations for faculty, staff, and students is estimated to cost $27.3 million. Storage and printing servers for the network are $12 million, and network interfaces and software licenses are $1.6 million. The total is $40.9M. More detail is shown on the next page. The maintenance of such a facility requires about 10% of equipment cost per year, i.e. about $4M.

ITEMS	UNIT	FAC	STF	STU	TOTAL	TOTAL &
Workstations						
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						$27,345,000.00
File servers						
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						$ 9,180,625.00
Print servers						
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						$ 2,975,000.00
Backbone						
Interface	2,000.00				15	30,000.00
Cable	500,000.00				1	500,000.00
Sub-total						$ 530,000.00
Software						
Core Site	100,000.00				1	100,000.00
Application	800,000.00				1	800,000.00
Sub-total						$ 900,000.00
Grand Total						$40,930,625.00

TECHNICAL DESCRIPTION OF
THE COMPUTER-AIDED ENGINEERING NETWORK
THE UM COLLEGE OF ENGINEERING



THE COMPUTER AIDED ENGINEERING NETWORK:

AN EXPERIMENT IN COMPUTER-ENHANCED PRODUCTIVITY

THE COMPUTER AIDED ENGINEERING NETWORK

1. BACKGROUND

Engineering practice is entering an era of unprecedented change. Developments in computer and communications technology already have had major impact through applications such as computer-aided design (CAD), computer-integrated manufacturing (CIM), and distributed intelligence computer and communication networks. The disciplines of computer science and engineering are now focusing on enhancing the productivity of people rather than simply the productivity of operations.

In an attempt to keep pace with this technology, an increasing number of universities are requiring all entering students to purchase a personal computer, typically costing $1,000 - $2,000, for use during their studies. However, while this approach may indeed address the need for "computer literacy" among general college students, we do not believe it is appropriate to meet the needs of most engineering students who require more powerful computer workstations (costing in the $5,000 to $20,000 range) capable of supporting sophisticated languages and operating systems (e.g., FORTRAN, Pascal, C, and UNIX), powerful graphics, and communications with mainframe hosts. Furthermore, the rapid evolution of personal computer technology will almost certainly make those machines typically selected for student purchase obsolete during the several years of their studies.

Hence the College of Engineering believes a more effective way to approach the challenge of providing "personal computing" resources to its students is for the educational institution itself to assume the primary responsibility for acquiring, installing, maintaining, and upgrading such computer - communications technology. We intend to respond to this challenge through the development and implementation of a distributed-intelligence, hierarchical computing system linking together personal computer workstations, superminicomputers, mainframe computers, function-specific machines, and gateway machines to supercomputer installations and external networks. The system is being designed to support not only traditional computer-aided instruction, and administrative activities (wordprocessing, electronic mail and conferencing, calendar and schedule management, and database management).

It is common to refer to the application of computer technology to improve the efficiency, productivity, and quality of engineering activities as computer-aided engineering (CAE). Hence we have chosen to refer to this ambitious project in the application of computing and telecommunications technology to engineering education as the Computer Aided Engineering Network.

Both the design and implementation of the Computer Aided Engineering Network are well underway. Physically the Network is being built from a collection of mainframe and superminicomputer class general purpose machines together with local area networks of the emerging generation of personal computer workstations.

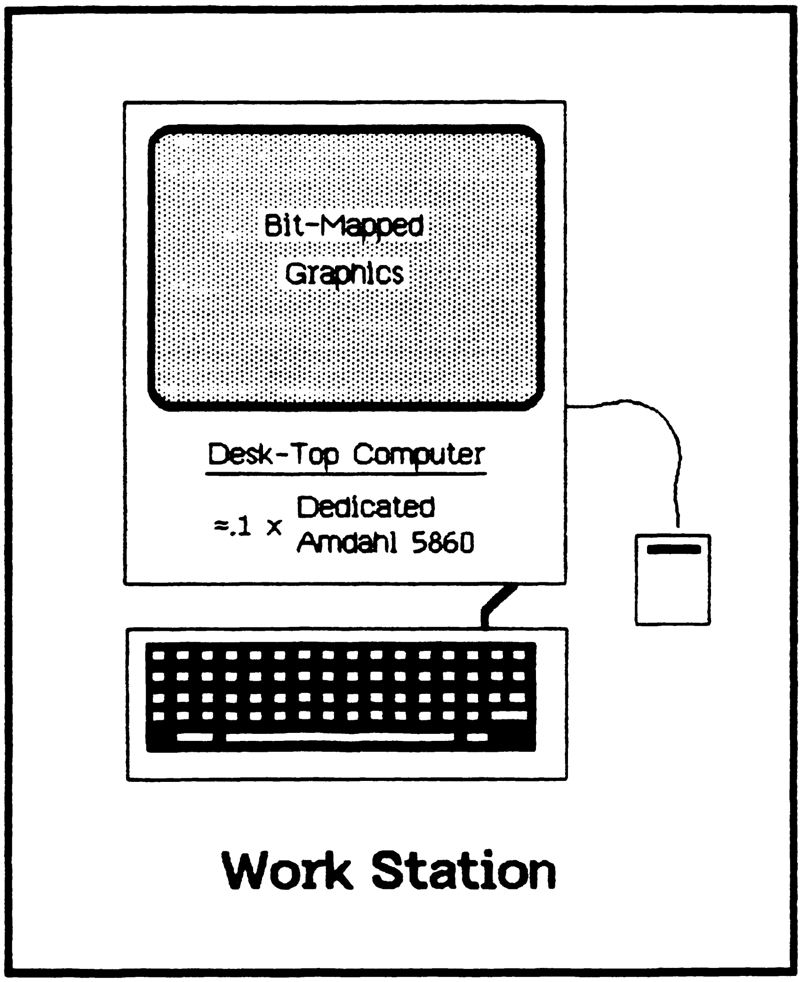
2. COMPUTER WORKSTATIONS

The personal or individual computer is evolving rapidly in its ability to meet a broad range of computing needs for the professional. Machines with the capability for meeting most computing needs on a stand-alone basis working as nodes in a network are referred to as computer "workstations". Eventually the predominant workstations in the College -- and in most technology-based organizations -- will be those of the "5M" type, having:

- One million (or greater) instructions per second.
- Several megabytes of real memory with demand paging for large virtual memory and thus capacity to run "mainframe" programs with little modification.
- One million pixel (or greater) bit-mapped graphics display.
- Multi-tasking, multi-window display manager with mouse or other pointer devices.
- Multiple megabyte/second (or greater), peer-to-peer communication channels.

We have approached the task of designing the Computer Aided Engineering Network upon three basic premises. First, we believe that such workstations will become the primary interface with the human user and will be the access point to a broad spectrum of resources including large database archives and supercomputers. Graphics, supporting a highly interactive pull-down menu environment will be the norm for all applications -- alpha-numeric text is but a special case. Although samples of software development tools and application packages designed explicitly for such hardware are just beginning to appear (for example, the Apple Lisa-Macintosh and Xerox Star systems), they show promise for major advances in man-machine interaction and professional productivity.

A second important premise is that a single workstation in a user's workplace should provide access to all computing - information management needs. It must be part of a robust information sharing network. A faculty member, for example, should be able to run analysis programs, embed results in a technical paper and print it on a multi-font printer, design a


Bit-Mapped
Graphics
Desk-Top Computer
≈.1 x Dedicated
Amdahl 5860
Work Station

VLSI chip or mechanical part, communicate with students and colleagues (on or off campus) via electronic mail, schedule a meeting of the committee, and check the status of research accounts, all from a single workstation. Students should be able to do the same, save, for example, replacing access to research accounts with access to interview scheduling systems at the placement office. "Electronic communities" will abound and likely produce fundamental changes in daily work habits.

A third premise is that the environment cannot be constructed totally from a single "compatible" family. Most companies already have a large installed, multi-vendor base. They must be able to continue to deploy and service equipment from a variety of vendors.

The personal computer and its derivatives pose interesting new approaches to providing high-access computing for other reasons. The availability of an enormous number of third-party hardware and software packages and the economy of scale of the "computer store" product line opens the possibility for the evolution of a powerful and cost-effective computing environment. This environment cannot, however, consist only of isolated personal computers. It must include the capability for sophisticated engineering applications in areas such as CAD, scientific computation and simulation, and software development. The environment must also include provisions for host-to-host communication and the shared access to large databases. This is the intent of the Computer Aided Engineering Network.

Given this technology-driven evolution, the College has embarked on an experiment to integrate collections of different but cooperating machines, software, databases, and interactive users and to expand the environment around "5M" workstations. Initially for experimental and cost reasons, not all of the stations will have all of the 5M properties. We will, however, build with product lines from vendors which we see evolving to at least "5M" status.

It appears that "personal computers" are evolving upward in function (e.g., the Apple Lisa and Macintosh) while maintaining fixed cost. High-end "engineering workstations" (e.g., Apollo and Sun) are decreasing in cost while maintaining function. We are pursuing both tracks in this project, since it is virtually certain that the two will intersect in cost/performance within a shot time. Our strategy is to build rapidly something of immediate usefulness and then bootstrap it to pursue evolutionary enhancements. Under a technical partnership with several vendors, we are building upon what is commercially available.

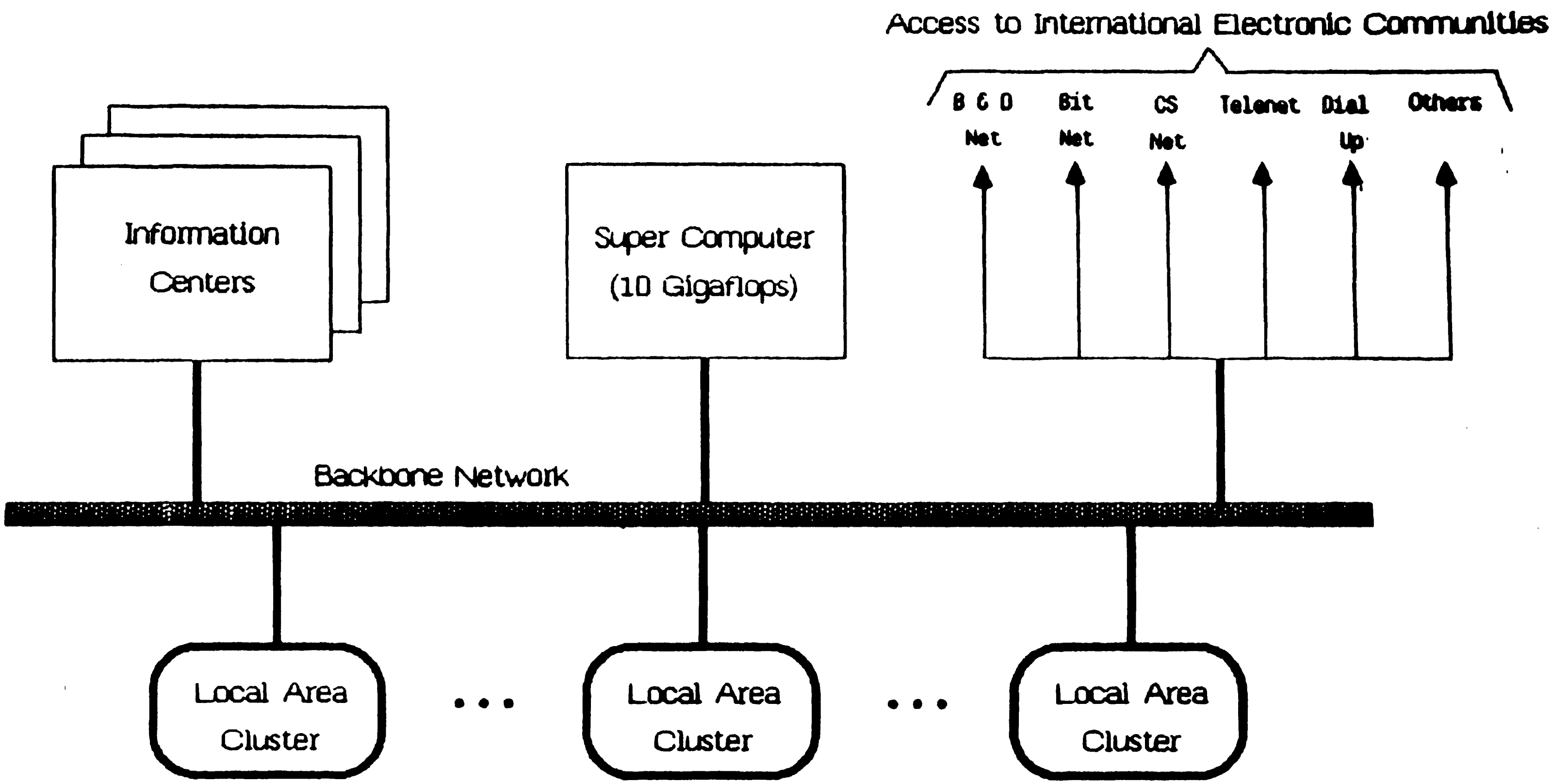
3. PRESENT NETWORK STATUS

The schedule for the installation and evolution of the Computer Aided Engineering Network is ambitious. During the 1983-84 academic year, facilities containing large numbers (roughly 500) of such personal computers and engineering workstations have been installed on both the Central and North Campus of the University for the exclusive use of engineering students. Already seven such student computer clusters have been opened containing 120 Apple Lisas, 120 IBM PC/XT computers, 180 Macintosh computers, and 30 powerful Apollo engineering workstations. Resident software and peripherals (printers, graphics plotters, file servers) are supporting a variety of activities including instructional work, wordprocessing, database management, and communication with larger host systems. Unlimited use of these facilities are being provided to all enrolled engineering students on an "open computing" basis (e.g., students present an identification card upon entering the cluster and are then allowed complete freedom in the use of the computers and associated networks).

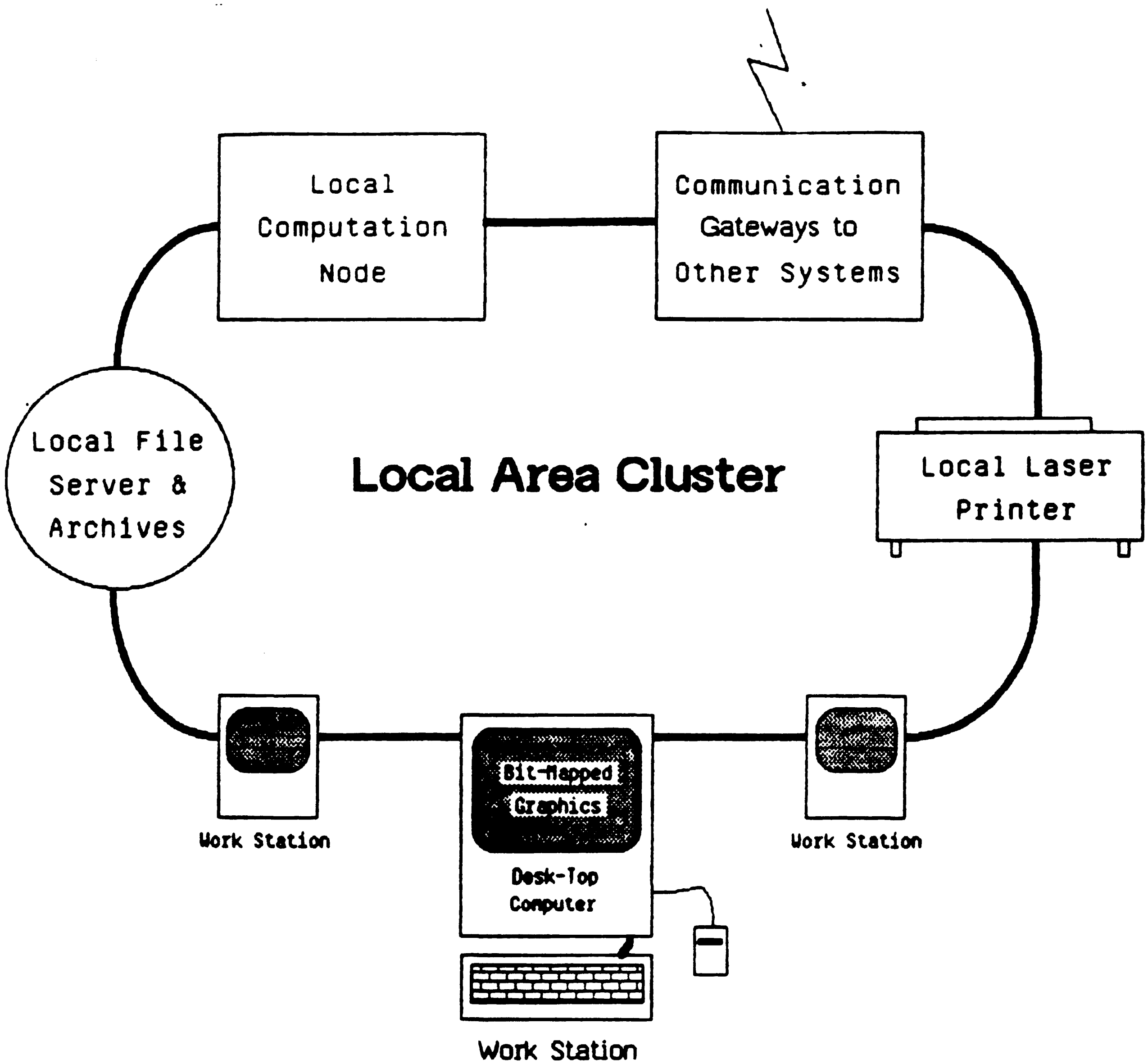
Concurrent with the development of the student computer clusters, the College has provided each faculty member with a personal computer workstation (IBM XT, Apple Lisa, or Apollo Domain) amounting to an additional 400 workstations. Additional clusters of workstations are also being installed in graduate student work areas to support research activities. Included in these clusters will be more powerful 32-bit computers (so-called "desktop mainframes") capable of supporting sophisticated color graphics and very fast floating-point calculations. The present inventory of workstations in the Network in both the student and faculty environment now exceeds 1,000 units.

In addition, the College has embarked on a major experiment in computer-enhanced productivity by installing a turnkey network based on roughly 100 Apollo DN320, DN460, and DN660 workstations connecting together faculty, students, and staff from wide ranging disciplines. This prototype network will give us immediate experience with the impact of such state-of-the-art technology on a wide range of activities in research, instruction, and administration.

The acquisition and maintenance of the equipment associated with the student component of the Computer Aided Engineering Network is being supported through private gifts and a differential tuition assessment. The faculty component of the Network is supported from research grants and discretionary funds.



Access to International Electronic Communities
B & D Net
Bit Net
CS Net
Telenet
Dial Up
Others
Information Centers
Super Computer (10 Gigaflops)
Backbone Network
Local Area Cluster
Local Area Cluster
Local Area Cluster


Local
Computation
Node
Communication
Gateways to
Other Systems
Local File
Server &
Archives
Local Area Cluster
Local Laser
Printer
Bit-Mapped
Graphics
Work Station
Desk-Top
Computer
Work Station
Work Station

CHRYSLER CENTER COMPUTER CLUSTER

Simultaneously with the acquisition and installation of the computer workstations, the College is moving rapidly to link these workstations together in local area networks within given departments or facilities. Each local area network is being connected to the central University Computing Center which will serve as a central electronic mail handling facility for the near term and as an archival data center over the longer term. In addition, various superminicomputers (VAX/Prime/Harris) are accessible through the networked workstations. Recently a data link has been established to provide students and faculty with access to supercomputer facilities (e.g., the CDC Cyber 205 machine at Colorado State and the Cray computers at NCAR and Los Alamos).

4. NEAR TERM EVOLUTION OF CAEN

Over the next year the University will complete installation of a broadband backbone network, UMNET, in parallel to the College project so that by early 1985, all University buildings (laboratories, classrooms and offices, and residence halls) should be connected by coaxial cables and fiber optics sleeves. Furthermore the College is presently negotiating the installation of a broadband fiber optics communications system on its North Campus site. In addition the College will be installing a satellite link to major national supercomputer centers within the next year.

During 1984 the College of Engineering will make a decision about expanding the Computer Aided Engineering Network to equip <u>all</u> 6,000 engineering students with personal computer workstations (which could be kept in offices or residences and tied into the network). This decision will be determined primarily by two factors:

- The availability of a powerful, portable, and relatively inexpensive personal computer with most of the capabilities of the machines installed in the first phase of the Network (e.g., powerful microprocessor, bit-mapped graphics, mouse).

- Progress in developing the appropriate Local Area Networks necessary to link together offices, laboratories, and residence halls.

If we should decide to take this step, it would be our intent to provide such computers to each student on a lease/buy arrangement In this way we could relieve the student of the costs of software support and hardware maintenance and upgrading.

Although initially confined to the College of Engineering, the Computer Aided Engineering Network has recently assumed a central role in the design of the computing environment for the entire University of Michigan campus. With the recent merger of the Department of Computer and Communications Sciences and the Department of Electrical and Computer Engineering into the new Department of Electrical Engineering and Computer Science, the College has assumed the responsibility for computer instruction in the College of Literature, Science, and Arts, as well as in Engineering. Hence the technology developed and implemented through CAEN for engineering students will be propagated to the much larger University community (32,000 students, 12,000 staff members) over the next several years.

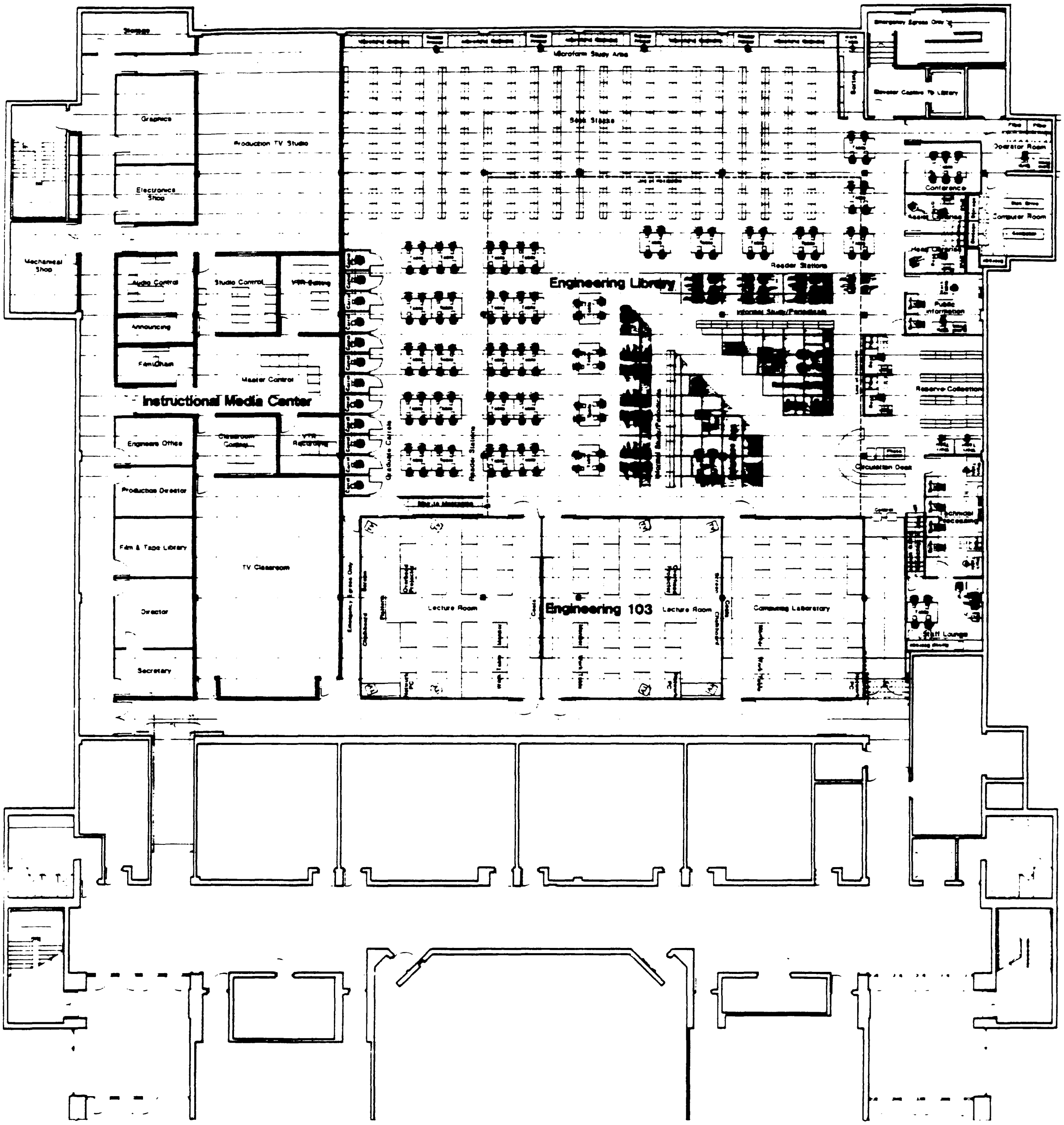
5. THE ENVIRONMENT

The physical environment for the the Computer Aided Engineering Network will be provided by the North Campus Instructional Complex project. Through a joint accession of facilities and equipment based on modern computer/communications, the Complex will enable the College to link its instructional programs with a number of technical information centers, research activities, support services, and administrative functions. The Complex itself will consist of three primary components:

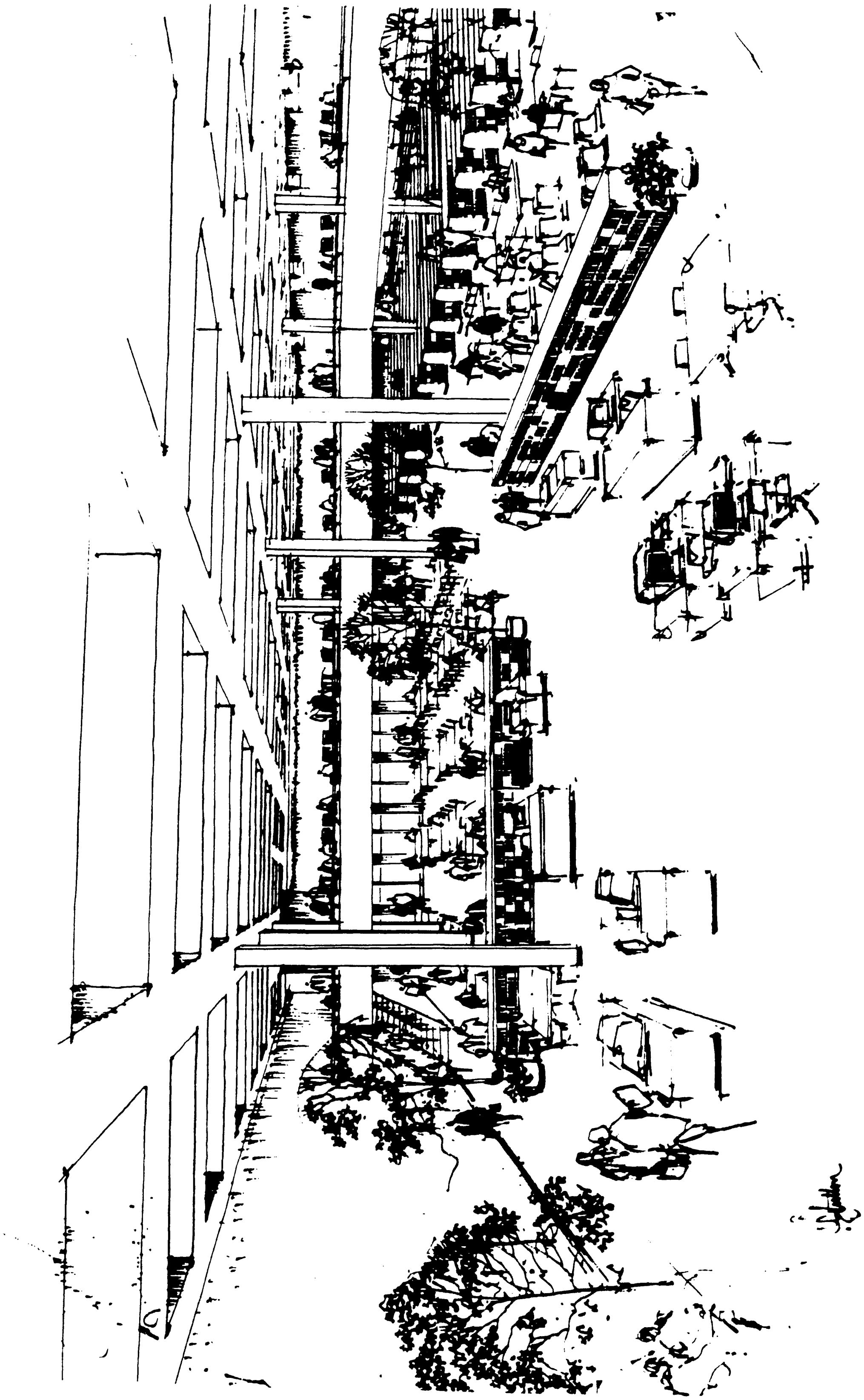
- A versatile instruction center containing classrooms, computer workstation laboratories, and self-paced instructional facilities that are fully integrated with the College's Continuing Engineering Education Programs and Instructional Television System;
- A major new facility containing the College's Engineering Library along with computer database systems for managing technical information and distributing it beyond the University community to business and industry; and
- A sophisticated computer communication network, the Computer Aided Engineering Network, capable of integrating these instructional and information centers with other activities of the College (research laboratories, student dorms, faculty offices, and administrative offices), and with off-campus users as well while providing open access to powerful tools of engineering practice such as CAD/CAM/CIM, scientific computation, database management, and generic services.

The estimated cost of the physical facilities associated with the Complex is $12 million. Additional grants and equipment donations at a level of $5 - 6 million per year are sought to develop and sustain the Computer Aided Engineering Network.

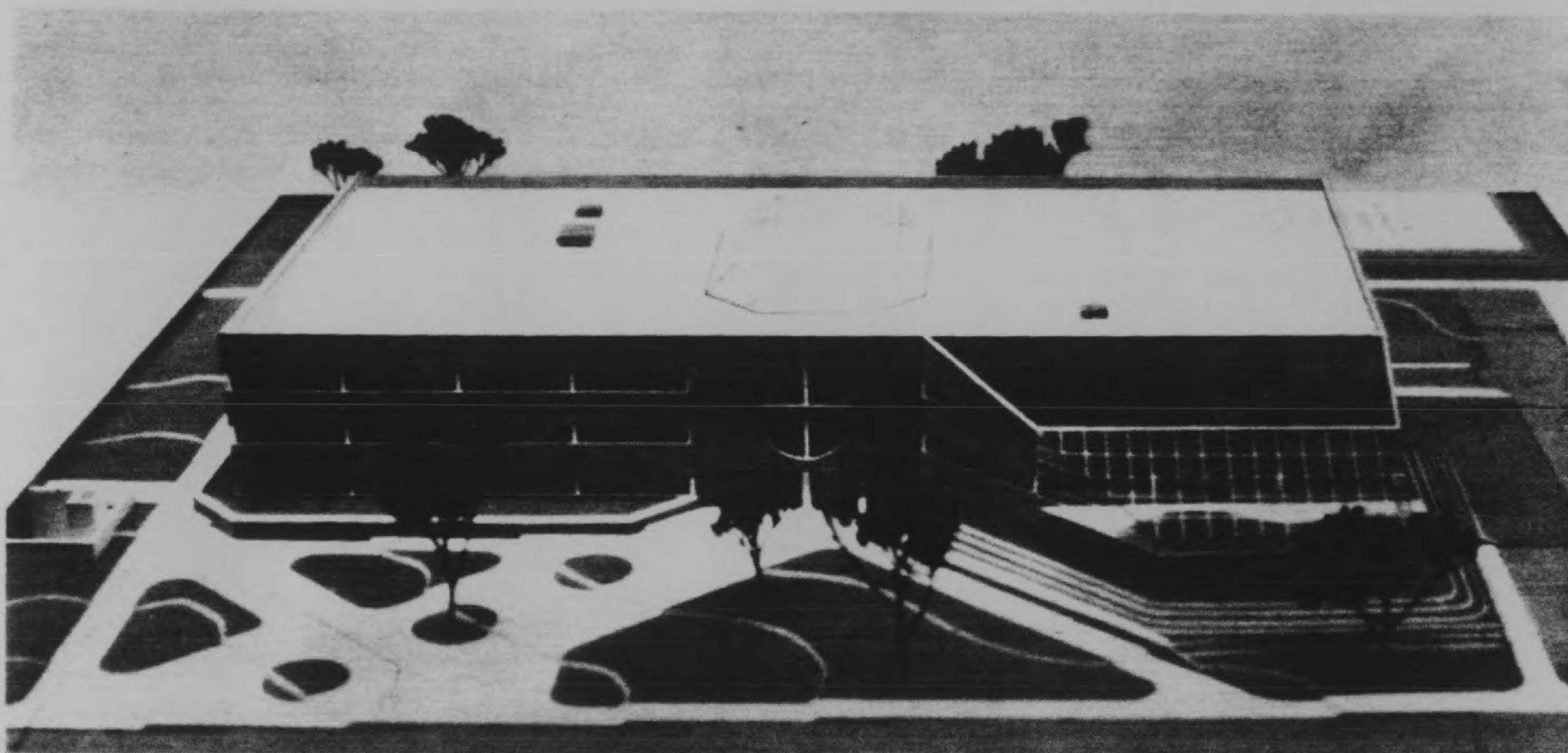
THE NORTH CAMPUS INSTRUCTIONAL CENTER
Lower Level



THE NORTH CAMPUS INSTRUCTIONAL CENTER
Sketch of the Lower Level



THE NORTH CAMPUS ENGINEERING LIBRARY
Model of a Proposed Design



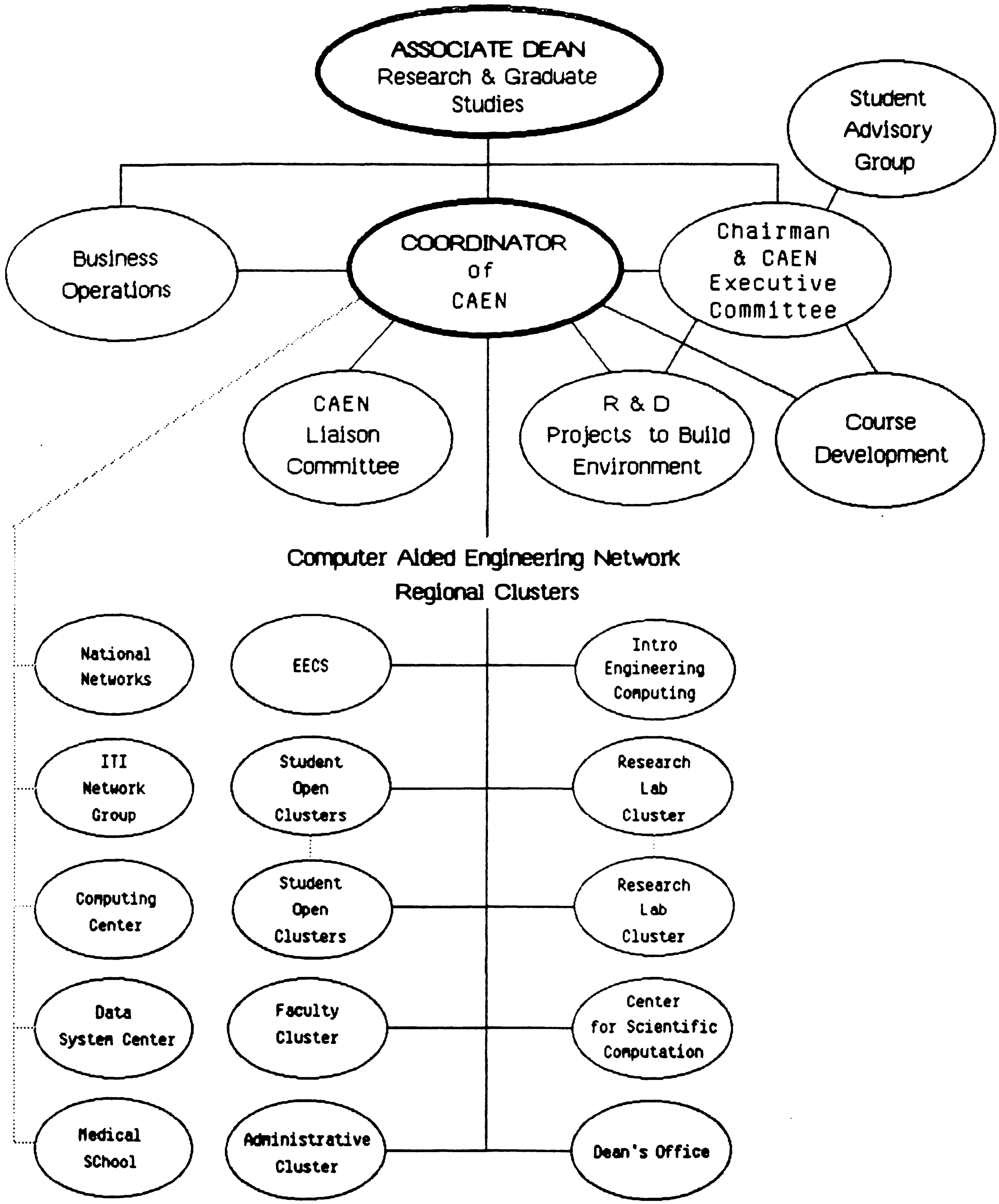
What is being planned amounts not only to an advanced environment for exploiting the latest in computer/communications technology to enhance the productivity of the College. It will also provide a "living laboratory" for further research and development in the related fields. For some years, such component technologies as computer-aided design, computer-assisted instruction, the electronic storage and retrieval of information, database management, electronic mail, and communication networks have been under intensive research and development. Although they have now reached a maturity that allows them to be integrated and utilized on a grand scale, their integration is not yet an established art. What we are undertaking, therefore, is nothing less than a research and development program that, quickly launched, can proceed simultaneously with the construction of the facilities comprising the Complex.

Key to the development of the Complex will be the concept of integration: the use of modern technology to link instructional programs with technical information centers, research activities, support services, and administrative functions. Already such technology is being used in industry to link together various activities ranging from product design to manufacturing to management. The College seeks to accomplish a similar integration of its instructional, research, and administrative functions. By building on strengths already existing in its academic programs while coupling these strengths to its programs in continuing engineering education and instructional television, the College believes that the Complex will become a major resource internally and externally -- for other University units, for other universities, and for organizations of all kinds throughout the nation.

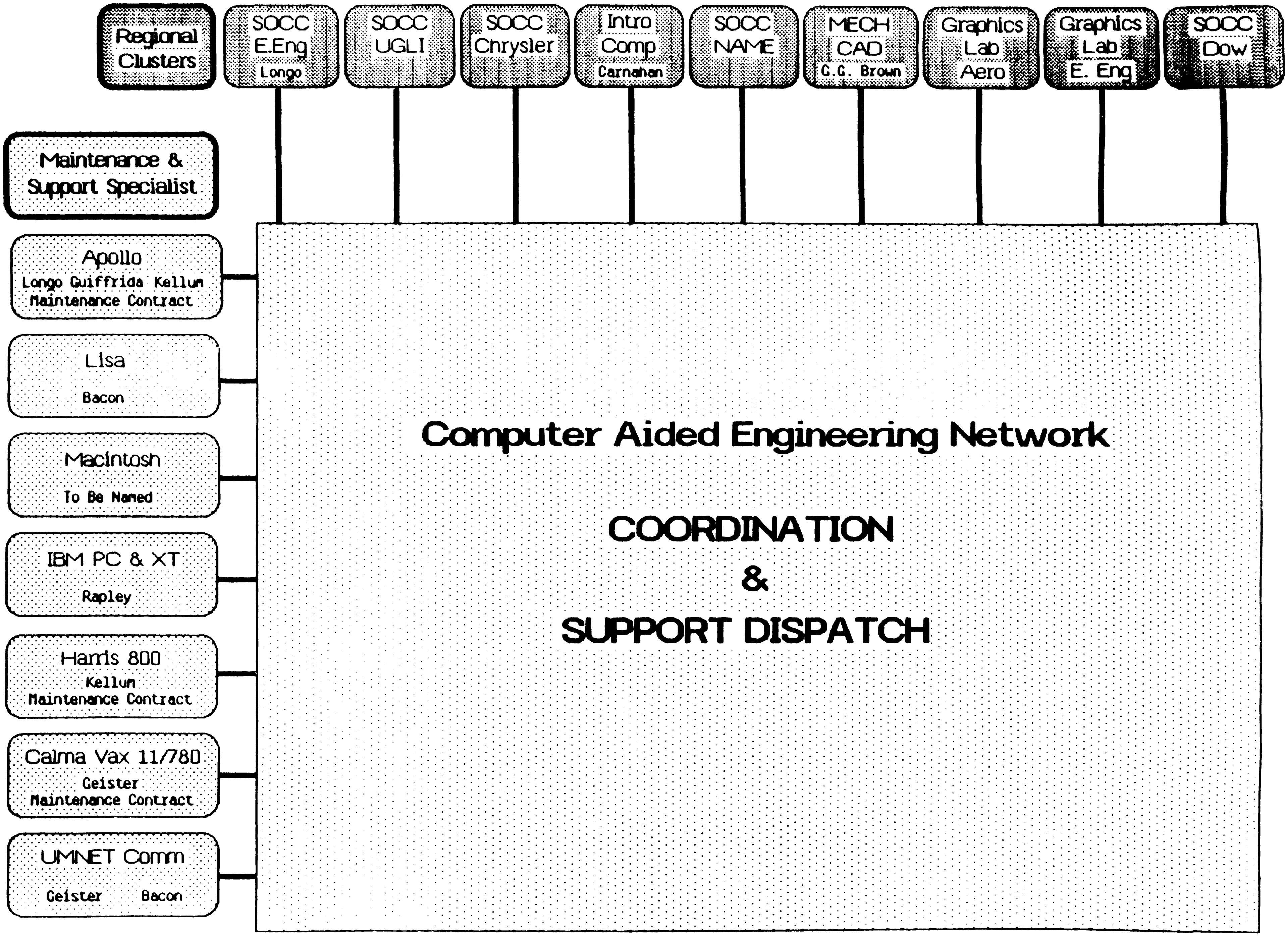
6. CONCLUDING REMARKS

The Computer Aided Engineering Network represents the College of Engineering's firm commitment to build a world-class center of excellence for the use of modern computer methods in engineering education and practice and to develop an environment uniquely supportive of instruction and research in related technologies. This computing environment will provide students and faculty of the College with a unique opportunity to participate in what is sometimes referred to as "the second computer revolution", to integrate this technology into their activities, and to stay with the cutting edge of this technology throughout their studies at Michigan.

The instructional and research programs supported by the Computer Aided Engineering Network will allow the College to respond directly to urgent national needs for talented engineering graduates and creative research in areas of critical importance to industrial productivity and national security.



ASSOCIATE DEAN
Research & Graduate Studies
Student Advisory Group
Business Operations
COORDINATOR of CAEN
Chairman & CAEN Executive Committee
CAEN Liaison Committee
R & D Projects to Build Environment
Course Development
Computer Aided Engineering Network
Regional Clusters
National Networks
EECS
Intro Engineering Computing
ITI Network Group
Student Open Clusters
Research Lab Cluster
Computing Center
Student Open Clusters
Research Lab Cluster
Data System Center
Faculty Cluster
Center for Scientific Computation
Medical School
Administrative Cluster
Dean's Office



Regional Clusters
SOCC E.Eng Longo
SOCC UGLI
SOCC Chrysler
Intro Comp Carnahan
SOCC NAME
MECH CAD G.C. Brown
Graphics Lab Aero
Graphics Lab E. Eng
SOCC Dow
Maintenance & Support Specialist
Apollo Longo Guiffrida Kellum Maintenance Contract
Lisa Bacon
Macintosh To Be Named
IBM PC & XT Rapley
Harris 800 Kellum Maintenance Contract
Calma Vax 11/780 Geister Maintenance Contract
UMNET Comm Geister Bacon
Computer Aided Engineering Network
COORDINATION
&
SUPPORT DISPATCH

A.83

2/23/84

APPENDIX B
ONE-TIME SUPPORT NEEDS

- Restoration of Laboratory Equipment Inventory: $15 M
- Solid State Electronics Laboratory: $8 M
- Materials Research Laboratory: $7 M
- Center for Applied Optics: $3 M
- Engineering Television Network: $2 M

-STATE BUDGET REQUEST-

RESTORATION OF LABORATORY EQUIPMENT INVENTORY

THE UM COLLEGE OF ENGINEERING

(One-Time Funding: $15 M)

REQUEST FOR ADDITIONAL BUDGET ALLOCATION (ONE-TIME)

College/Unit: College of Engineering

Request Title: Engineering Laboratory Equipment

REQUEST PURPOSE:

In recent years it has become apparent that Michigan will become increasingly dependent upon technology -- and therefore upon engineers -- to rebuild the competitiveness and achieve diversification in its industrial base. It is distressing to note that this increased dependence on technology is occurring in the aftermath of a decade of deteriorating State support for the College of Engineering of the University of Michigan.

Of particular concern is the appalling state of the College's laboratory equipment inventory. A decade of neglect have left the laboratories sadly obsolete. This crisis in the state of its laboratories has seriously impeded the College's efforts to provide the intellectual creativity and engineering graduates so desperately needed by Michigan industry.

The proposed additional budget allocation of $15 million is necessary to rebuild the laboratory equipment inventory of the College.

SUPPORTING RATIONALE:

Both our nation and our State are becoming increasingly dependent upon science and technology. Government and industry are turning to institutions of engineering education to provide the intellectual creativity so fundamental to technological innovation and the talented, broadly-educated engineers who can understand and implement this technology. It is disturbing to note that most engineering schools have been crippled by sadly obsolete laboratories and equipment inventories in their efforts to respond.

Nowhere has this crisis become more serious than in the State of Michigan. Although our State is heavily dependent upon technology, a decade of deteriorating public support has left the laboratories of its engineering schools in a shambles. Industry in this State faces unprecedented needs for engineering graduates with knowledge of the sophisticated equipment critical to productivity. Yet the laboratories of our engineering colleges have deteriorated to a crisis level. A recent report of the Michigan Society of Professional Engineers notes:

> "Continuing obsolescence of laboratory equipment and instruments has placed many schools in the position of not being representative of modern professional practice. New

technologies, apparatus and methodologies are evolving more rapidly in industry, and lack of up-to-date equipment and instruments within the university exacerbates the situation. Rapid evolution of such fields as robotics, microelectronics, computer aided design, optics, spectrographics, electron microscopy, computer graphics, ...etc. has left the universities in a teaching mode far behind current professional practice.

A decade-long decline in the flow of resources to laboratory equipment for higher education has taken its toll. The university is no longer at the "cutting edge", and current graduates will not be the contributers that their predecessors were. Some have said engineering education is destressed, but a more apt description is a crisis state".

A detailed analysis of the magnitude of the laboratory equipment inventory backlog in the College.

A detailed analysis performed in late 1984 estimated the magnitude of the College of Engineering's laboratory equipment need backlog at $44 million. We are proposing that one-time funding at a level of $15 million be provided to restore roughly one-third of this equipment inventory. The remainder of the inventory needs will be met through matching private gifts. (It should be noted that this request is in addition to the $4 million per year of sustained support necessary to maintain the laboratory equipment inventory once it has been rebuilt).

-STATE BUDGET REQUEST-

THE SOLID STATE ELECTRONICS LABORATORY

THE UM COLLEGE OF ENGINEERING

(One-time Funding: $8 million)

REQUEST FOR ADDITIONAL BUDGET ALLOCATION

College/Unit: College of Engineering

Request Title: Solid-State Fabrication Facility

REQUEST PURPOSE:

The field of microelectronics needs little introduction in terms of its importance and impact on society. From modest beginnings twenty-five years ago, integrated circuits have allowed the cost of electronic functions to decrease by more than ten-thousand times as the number of transistors which can be realized on a single chip has increased nearly a million-fold. Today, sophisticated microcomputers containing hundreds of thousands of devices and executing instructions in millionths of seconds can be implemented on single silicon or gallium arsenide chips less than a centimeter on a side and costing only a few dollars. In terms of any known fundamental limits, we are still orders of magnitude from achievable levels of product performance and sophistication, and even without future advances, it is clear that electronic instrumentation and control will revolutionize many aspects of society.

Michigan industry has not been a leader in the "high-tech" area of solid-state electronics in the past. It has no choice but to be heavily involved in the future. Virtually every machine, instrument, or tool manufactured in the year 2000 will be computer-controlled, either to aid the human operator or as a replacement for him. The design of these electronic control systems will be a vital part of overall product development and is unlikely to be separated from it, geographically or otherwise. Such control systems will be implemented as integrated systems on densely-packed monolithic chips.

The proposed additional budget allocation of $8 million will allow the College of Engineering to equip the new Solid-State Fabrication Facility now under construction at the University of Michigan as a world-class center of excellence for the development of advanced semiconducting devices. The major thrust of this Facility will be the development of the new data acquisition and interface devices which will be an essential part of future activities in biomedicine, transportation, and industrial automation.

SUPPORTING RATIONALE:

It is well known that the State of Michigan is placing major emphasis on establishing itself as a world leader in the area of automated manufacturing. In doing this, it has substantial resources to draw upon. Within the College of Engineering, a major program in manufacturing has recently been put in place, and the nearby Industrial Technology Institute is focusing its efforts in the automated manufacturing area. It is widely accepted that electronics is the foundation on which automation will rest. While the microprocessors and memory to fuel this coming revolution are available and growing in capability, the sensors and interfaces which will be needed to couple this electronics to the non-electronic world are still lacking and must be developed. While the solid-state electronics industry has largely been external to Michigan, the State nonetheless has a base on which to build this necessary component of its manufacturing thrust.

The Solid-State Electronics Laboratory at the University of Michigan has represented one of the top university programs in the nation for many years in its area. Laboratory research has been internationally recognized, including awards at the 1979 International Solid-State Circuits Conference and the 1980 International Electron Devices Meeting. The principal thrust areas of this Laboratory have been in the areas of high-speed interface devices for data processing and microwave power generation and in integrated solid-state sensors for use in health care and robotics. These programs are among the best of their kind worldwide. Thus, the Laboratory is ideally positioned to serve as a center of excellence for the devices which will be needed in future biotechnology, transportation, and automated manufacturing systems. This includes work in high-speed devices, integrated sensors, and optoelectronics. It is intended that the Laboratory serve as a resource to Michigan industry through its research results, process capabilities, and production of trained engineers and that it serve as a catalyst for the formation of new, high-technology, entrepreneurial companies within the State.

The future of the electronics industry itself is strongly dependent on automated manufacturing. Continuing trends in the development of integrated electronics (including larger chip sizes, decreasing feature sizes, and increasing demands for performance) have made it clear that future integrated circuit manufacturing facilities must be automated in order to achieve the required levels of quality control, throughput, and yield. The development of sophisticated production equipment for semiconductor processing is likely to be the most significant single factor pacing the development of the semiconductor electronics industry, which is expected to reach $50 billion in sales by 1988.

Recognizing the need for increased university research in solid-state electronics, leading companies representing the US semiconductor industry recently agreed to use a percentage of their sales to fund such research. The Semiconductor Research Corporation (SRC) was formed to administer the resulting research contracts and presently consists of nearly two dozen companies (including Michigan companies such as Eaton and Burroughs). One of SRC's three thrust areas is embodied in the Manufacturing Sciences Division, formed to address the critical needs outlined above. As the principal focus of this division, SRC has formed a collective center of excellence in manufacturing science and advanced automation, composed of interacting programs at Stanford, the Microelectronics Center of North Carolina, and the University of Michigan. At Michigan, the focus will be on the development of advanced automated sensing systems for the closed-loop control of future semiconductor manufacturing facilities and for the automated evaluation of advanced fabrication processes at the submicron level. It should be stressed that the establishment of this Program at Michigan was not only in recognition of our combined strengths in both manufacturing and solid-state electronics, but also in recognition that the State can serve as a principal focus for automated semiconductor manufacturing. Indeed, this role represents a logical extension of efforts already underway.

The establishment of a world-class Solid-State Fabrication Facility at the University of Michigan offers a unique opportunity for the State to build the high-technology base in interface electronics that will be required for leadership in automated manufacturing; however, a significant investment will be required as well. Stanford is currently completing a $15 million facility for integrated systems and has an established tradition of leadership in silicon valley. The Microelectronics Center of North Carolina was formed by that State in a well-publicized $40 million effort to attract the microelectronics industry there. The effort is succeeding. At the University of Michigan we are fortunately less than a year from the completion of a major fabrication facility for the development of advanced interface devices. The facility features Class 10 and Class 100 work environments to support a broad range of process capability. However, only the cleanroom space is currently funded with the building. In order to make the facility operational, an additional $8 million in processing equipment is needed. With this funding, we expect to fulfill a leadership role for industry nationally and to act as a catalyst for the expansion of high technology in the State. While the required investment is significant, the potential payoffs are enormous and are a necessary part in efforts to establish the State of Michigan as a major center for advanced manufacturing.

BACKGROUND STATEMENT

BACKGROUND STATEMENT

The field of solid-state electronics needs little introduction in terms of its importance and impact on society. From modest beginnings not quite twenty-five years ago, integrated circuits have allowed the cost of electronic functions to decrease by more than ten-thousand times as the number of transistors which can be realized per chip has increased nearly a million-fold. Today, sophisticated microcomputers containing hundreds of thousands of devices and executing instructions in millionths of seconds can be implemented on single silicon chips less than a centimeter on a side and costing only a few dollars. In terms of any known fundamental limits, we are still several orders of magnitude from achievable levels of product performance and sophistication, and even without future advances it is clear that electronic instrumentation and control will revolutionize many aspects of society. As many have said, this is a pervasive technology and one in which every industrialized state will necessarily be involved. Once confined to localized areas near Boston and San Francisco ("silicon valley"), the semiconductor industry is becoming widely distributed geographically. As in other areas of industry, we are currently engaged in a struggle to maintain this nation's leadership in semiconductor electronics. This is a struggle we must not lose.

The State of Michigan has not been a leader in the "high-tech" area of solid-state electronics in the past. It has no choice but to be heavily involved in the future. Virtually every machine, instrument, or tool manufactured in the year 2000 will be computer-controlled, either to aid the human operator or as a replacement for him. The design of these electronic control systems will be a vital part of overall product development and is unlikely to be separated from it, geographically or otherwise. Such control systems will be implemented as silicon integrated systems on a chip.

The Solid-State Electronics Laboratory at the University of Michigan has represented on of the top ten university programs in the nation for many years in the solid-state electronics area. Laboratory research has been internationally recognized, including awards at the 1979 International Solid-State Circuits Conference and the 1980 International Electron Devices Meeting. The Laboratory is now expanding its activities in an effort to act as a catalyst for industrial expansion in the State, much as Stanford and M.I.T. have acted as catalysts in their geographical areas.

An important part of the research focus of the Laboratory is in the area of integrated solid-state sensors. Such devices combine transducers and signal-conditioning circuits on single chips which are capable of interfacing microcomputer-based control with the non-electronic world. This area repesents a critical need in the application of electronics to three areas of particular importance to the State of Michigan: biotechnology, transportation, and automated manufacturing (including robotics). The Laboratory currently has one of the leading international programs in the sensor area and is thus in a position to provide an important leadership role. It should be noted that the automotive industry is currently perhaps the largest producer of integrated circuits and that it depends critically on sensors for automotive control. Similarly, many other industries not formerly involved with electronics are becoming both users and producers of integrated circuits and sensors. Sensors are critically needed in the development of the robotics industry and, more broadly, throughout automated manufacturing.

The further development of the integrated electronics industry itself will depend critically on the development of very sophisticated manufacturing equipment for producing increasingly complex systems on a chip. Such equipment must be compatible with maintaining an ultraclean environment around the silicon wafer being processed. Very high levels of automation and equipment/product monitoring will be required at every stage of the manufacturing process. Thus, the development of sophisticated production equipment for semiconductor processing is likely to be the most significant single factor pacing the development of the semiconductor electronics industry, which is expected to reach $50 billion in sales by 1988. Such equipment development will require skilled labor, and is a possible area in which the State of Michigan could play an important leadership role.

Recognizing the need for increased university research in solid-state electronics, leading companies representing the United States semiconductor industry recently agreed to use a percentage of their sales to fund such research. The Semiconductor Research Corporation (SRC) was formed to administer the resulting research contracts and presently consists of nearly two dozen semiconductor companies (including Michigan companies such as Eaton and Burroughs). One of SRC's three thrust areas is embodied in the Manufacturing Science Division, formed to address the critical needs outlined above. As the principal focus of this division, SRC has just announced the formation of a <u>collective center of excellence in manufacturing science and advanced automation</u>. This Center consists of interacting programs at Stanford, the Microelectronics Center of North Carolina, and the <u>University of Michigan</u>. At Michigan, we will be responsible for the development of advanced automated sensing systems (including machine vision and expert systems) for the closed-loop control of future semiconductor process equipment and for the automated evaluation of advanced fabrication processes at the submicron level. It should be stressed that establishment of this Center at Michigan was not only in recognition of our combined strengths in both manufacturing and in solid-state electronics, but also recognition by the semiconductor industry that the State of Michigan can serve as a principal focus for the development of such equipment for semiconductor manufacturing. Indeed, this role represents a logical extension of efforts already underway in robotics.

We are excited about these activities in automated semiconductor manufacturing but are also aware that a significant investment will be required to fulfill our role as a national center of excellence and catalyst for industry within the State. Stanford is currently completing a $15 million facility for integrated systems and has an established tradition of leadership in silicon valley. The Microelectronics Center of North Carolina was formed by that State in a well-publicized effort to attract this high-technology microelectronics industry there. The effort is succeeding. That Center is part of a $40 million effort by North Carolina and is currently funded at about $6.5 million per year, directly by the State. At the University of Michigan we are fortunately less than three months from ground-breaking on a State-funded Solid-State Fabrication Facility (part of a building to house the Department of Electrical Engineering and Computer Science) which will be the equal of any facility in the nation for research on solid-state devices, integrated sensors, and advanced automation. However, only the fabrication area (clean-room space) is currently being funded with the building. In order to complete the facility, an additional $8 million in semiconductor processing equipment will be needed. With this funding, we expect to be fully capable of fulfilling a leadership role for the semiconductor industry nationally, and of acting as an important catalyst in the expansion of high technology in the State of Michigan. While the required investment is significant, the potential payoffs are enormous, and such investments are viewed as a necessary part in the renewal of the State as a major center for advanced manufacturing.

CENTER FOR AUTOMATION IN SEMICONDUCTOR MANUFACTURING

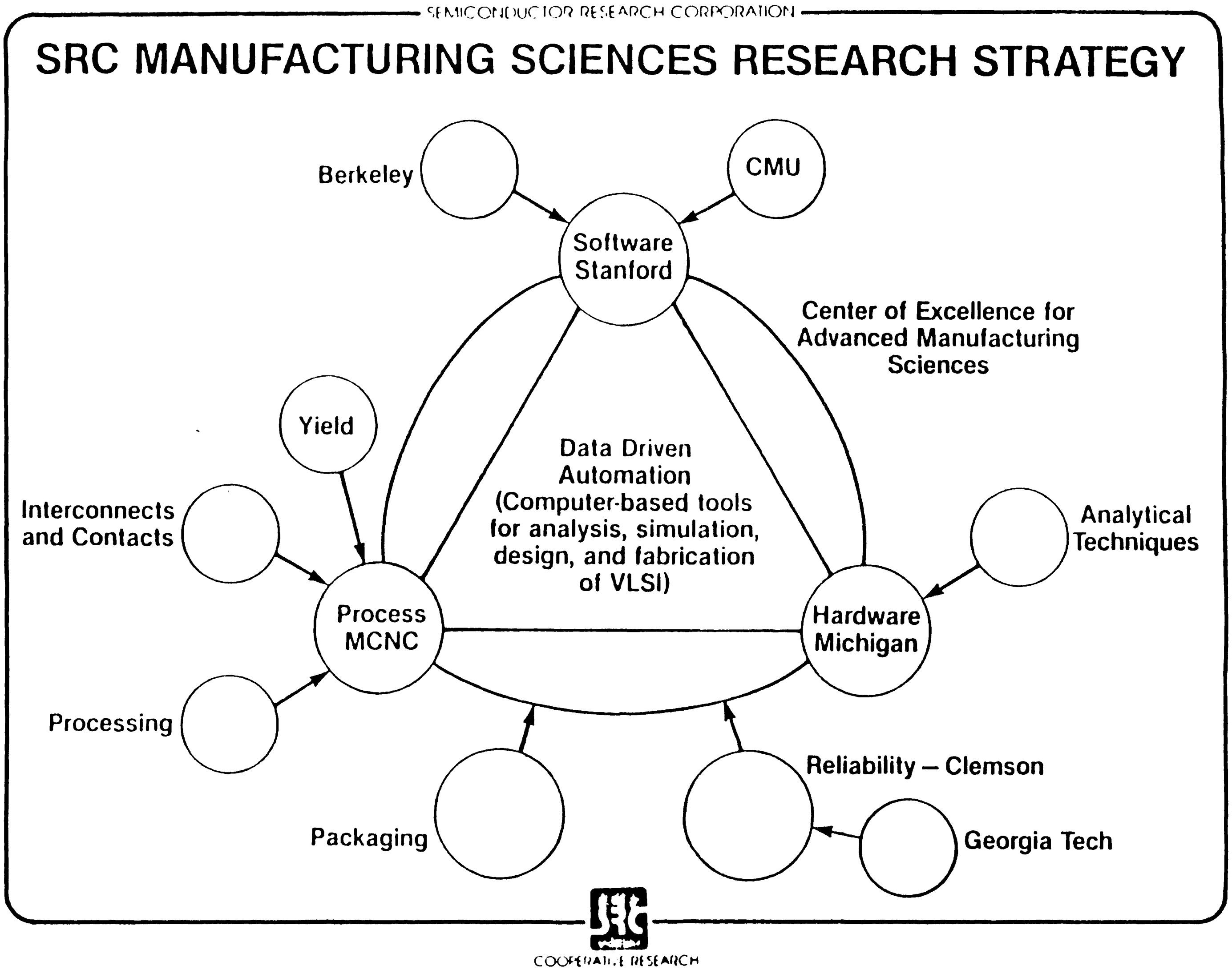
Professor K. D. Wise — University of Michigan

Goal: Total automation of two unit process cells (DSW, RIE).

Background: Maintaining leadership in the electronics industry will require vigorous efforts in manufacturing technology. The VLSI industry is currently only marginally automated. Research is needed to address **where** to automate as well as **how**. Not only is productivity a consideration, but also as geometries shrink, human operators must be removed from the clean environment to achieve reduced defect densities. Reproducibility must also be improved.

Research:

1. Inter unit process cell optimization
2. Sensing systems will be developed to allow reliable evaluation of process cell results
3. Sensor development will include machine vision systems for process evaluation at the submicron level
4. Expert systems concepts will be employed to allow automated closed-loop control and optimization within a process cell


SEMICONDUCTOR RESEARCH CORPORATION
SRC MANUFACTURING SCIENCES RESEARCH STRATEGY
Berkeley
CMU
Software
Stanford
Center of Excellence for
Advanced Manufacturing
Sciences
Yield
Data Driven
Automation
(Computer-based tools
for analysis, simulation,
design, and fabrication
of VLSI)
Interconnects
and Contacts
Analytical
Techniques
Process
MCNC
Hardware
Michigan
Processing
Reliability — Clemson
Packaging
Georgia Tech
COOFERATI.E RESEARCH

DETAILED EQUIPMENT DOCUMENTATION

ANALYSIS OF EQUIPMENT NEEDS FOR SOLID-STATE ELECTRONICS LAB

We have widely quoted the figure of $8 million as the cost of the equipment for the new facility and believe this figure to be accurate. This is the price tag for creating a facility with the sort of equipment which will make the facility a RESOURCE to the State and nation. It is the sort of laboratory to which we can reasonably expect people form industry to come for processes which they do not have available in their own facilities. This is the type of laboratory for which the new facility has been designed. Below this equipment level, there are two intermediate levels at which the lab could be equipped. The lowest level, which I will call BASIC, has a price tag (in current dollars) of $2,228,000 by our best count. This is essentially the price tag to open the doors on the new facility with equipment duplicating our present capabilities. WITHOUT THIS AMOUNT OF EQUIPMENT, WE CANNOT MOVE INTO THE NEW LABORATORY. (Nor do I think it is realistic to think in terms of staying where we are). This may seem an excessive cost in terms of duplicating our present capabilities but remember that we have created a separate teaching laboratory in the new building. About $310,000 of the BASIC price tag is to equip the teacing laboratory. Another complication is that much of our present equipment is worn out and cannot be moved into the new facility no matter what. For example, moving our present Thermco diffusion furnaces into the new facility would be a bad joke, considering the care and cleanliness class of the area. Like it or not, we must have new furnaces for the new laboratory. Likewise, our present mask making facilities are no longer workable. They are causing serious problems for my research and I doubt would be tolerated by anyone else. I have included $400,000 in the BASIC price for new optical mask-making facilities, which at this price would have to be used. A new pattern generator and stepper are about double this amount. These mask making problems must be solved a lot sooner than we will occupy the new building if my research is to remain viable. The BASIC price is the cost of continuing in business and opening the doors of the new facility. Anything less, and it should be turned into a chicken ranch!

Above BASIC and below RESOURCE there is an intermediate level which I will call COMPETITIVE, which has a price tag of about $4,073,000. This facility would add better mask making equipment (another $400K), another mask aligner, an ion implanter, and substantially improved instrumentation/metrology, and would make us competitive with most of the top laboratories in our area of expertise. It would not be a resource, however, and would not contain the uniqueness needed to fulfill such a role. We have a detailed list of equipment for all three of these facilities. The major additions to get from COMPETITIVE to RESOURCE are a DSW aligner, an E-beam lithography system, a second MBE, and a variety of other less-costly process equipment. IT MUST BE

EMPHASIZED, HOWEVER, THAT WHILE basic AND competitive MAY BE POSSIBILITIES FROM A FUNCTIONAL POINT OF VIEW, THEY DO NOT SOLVE THE EQUIPMENT INSTALLATION TIMING PROBLEM AND LEAVE OUR CLASS 10 AREA EMPTY.

From the standpoint of running expenses, rough estimates of these are as follows:

	BASIC		COMPETITIVE		RESOURCE	
STAFF SALARIES (loaded) ($/yr)	GF(3)	$102*	GF(3)	$102*	GF(3)	$102*
	RF(3)	204	RF(4)	288	RF(5)	348
					SB(2)	156
		$306k		$390k		$606k
FACILITIES ($/yr)		$ 54		$ 66		$ 75
SUPPLIES ($/yr)		30		45		75
MAINTENANCE		100		150		500
		$184k/yr		$261K		$650K

*General Fund-Supported Salaries Exclude Indirect Costs

In the above table, we are assuming a constant three staff members supported by the general fund (GF) for all three levels of activity. For the RESOURCE, five people are supported on research (RF) and an additional two people are "subsidized" by other outside sources, presumably the State. It is assumed that most of the new jobs and growth which we all seek for Michigan will come from small start-up ventures, which are unlikely to have the resources to pay the R&D costs associated with research in the new facility. We accordingly ask the State to subsidize these costs. Above some level of corporate size or use, the normal contract relationships would presumably apply. In addition to courting industrial research partnerships, researchers at other Michigan universities should be invited to use the facility so that it truly acts as a State resource. Excluding electric bills, the cost of operating the new facility is substantial at any level, and the maintenance costs (maintenance agreements) may be low. (The third year costs are inflated by the E-beam, which costs about $200,000/yr by itself and includes a full-time person on our premises). In comparison, we presently spend about $250K/yr on staff and about $45K/yr on the rest of the categories. So even BASIC represents substantial growth, and there is no fallback position. There probably shouldn't be.

SOLID-STATE ELECTRONICS LABORATORY

EQUIPMENT NEEDS ($K)

EQUIPMENT	BASIC	COMPETITIVE (Additional)	RESOURCE (Additional)
Diffusion Tubes (12)	400		
Mask Aligners (3)	200	125	
Mask Aligner (DSW)			400
Spinners (1 auto, 2 manual)	12	25	
Wafer Wash Station		20	
Microscopes	60		
Terminals, Computer	20		
Electron-beam writing station			1500
Microbonder, wedge			15
Microbonder, ball	3		
Optical Mask Making equipment	400	400	
MOCVD			350
Scanning Electron Microscope		90	
Vacuum Furnace		80	
Dektak	25		
Leak Detector	18		
Ion Implanter	100	500	
Residual Gas Analyzer			20
Plasma Etch Stations (4)	70		70

Reactive Ion Etcher (2)	100		115
Silicon Epitaxy			100
Ellipsometer		30	
C-V Profilometer			100
Sputter Evaporator			125
Molecular Beam Epitaxy			750
<u>TEACHING LABORATORY</u> ($385K)			
Diffusion Furnaces	180		
Evaporator	70		
Mask Aligner (1)		75	
Wafer Prober (2)	30		
Dicer	20		
Curve Tracer	10		
<u>GENERAL INSTRUMENTATION</u>			
Auger/Sims			250
Oscilloscopes (10)	100		
Pulse Generators	60		120
High Frequency Test Instrumentation	100	200	
CAD (4 stations)	250		
Miscellaneous Material Evaluation		200	
Microprocessor Instrumentation		100	
	$2,228K +	$1,845K +	$3,915K
TOTAL EQUIPMENT	=	$4,073K	$7,988K

-STATE BUDGET REQUEST-

THE MATERIALS RESEARCH LABORATORY

THE UM COLLEGE OF ENGINEERING

(One-time funding: $7 M)

REQUEST FOR ADDITIONAL BUDGET ALLOCATION (ONE-TIME)

College/Unit: College of Engineering

Request Title: Materials Research Laboratory

REQUEST PURPOSE:

The foundation of the manufacturing industry of the Great Lakes area rests upon materials processing technology. While this industry has traditionally been based on metal processing, there are strong indications that a shift is occurring to advanced materials such as polymers, ceramics, and composites. Furthermore, the rapid growth of the use of microelectronics and computer technology in traditional areas such as the automotive industry will place comparable emphasis on electronic materials. Finally, there is strong interest in biological materials for a host of applications.

There is strong need for world-class materials science and processing capability in Michigan universities. To this end, the College of Engineering requests one-time funding of $7 million (over three years) to equip the major laboratory facilities necessary for these programs. Such funding will enable the College to seek sustained support from the federal government for a Materials Research Laboratory while responding to the needs of Michigan industry.

SUPPORTING RATIONALE:

The establishment of a world-class materials science and processing research facility will require substantial commitments from the State, federal, and private sector. A key feature of this facility will be state-of-the art instrumentation for materials characterization including high voltage, high resolution transmission electron microscopes, a dedicated scanning transmission electron microscope, an electrom microprobe analyzer, and Auger spectrometer, an X-ray photoelectron spectrometer, as well as standard instruments such as scanning electron microscopies and 100 kV transmission electron microscopes. Indeed, without such a facility, no university is likely to compete for the major funding available from the federal and private sector.

The Materials Research Laboratory would provide not only a strong source of basic research and graduates for Michigan industry. It would also provide industry with direct access to state-of-the-art analytical facilities to support manufacturing activities in a wide range of areas including metals, ceramics, polymers, composites, electronic materials, and biological materials.

BACKGROUND STATEMENT

MATERIALS PROCESSING RESEARCH CENTER

BACKGROUND

Southeastern Michigan is at the center of the largest industrial base in the world. As in any industrial sector corporations rely heavily on various forms of manufacturing technology to remain competitive. All manufacturing involves materials processing. In fact, the lead in manufacturing often shifts with the lead in processing technology. This technology spans from the more traditional metals forming to plastics and the rapidly expanding field of ceramics. Yet no such processing research center exists in the midwest that has the capability to interact with and lead this massive industrial base. Future advances in processing and future breakthroughs in newly emerging areas (e.g. robotics, microelectronics, computer engineering, applied optics) will crucially depend on first-rate materials research. Improvements in properties of materials are intimately coupled to advances in processing. However, the nationwide materials research community has committed their resources mainly in the areas of microcharacterization and structure of materials. The College of Engineering perceives it as a unique opportunity to fill as the first academic institution in the nation the need for large-scale research linking the structure of materials with processing.

PROPOSAL

The State of Michigan would mount a concerted effort together with industry and the College of Engineering to establish a first-class experimental facility for materials research with emphasis on the link between structue and processing of materials. The facility would be equipped with state-of-the-art instrumentation for characterization of materials. The impact of such a facility on the future development of Michigan's technology would include:

- It would contribute to the rejuvenation and strengthening of existing industries, and tie in with the vast industrial activity in materials processing that is already present in Southeastern Michigan.

- It would act as a nucleus for corporate R and D and provide the necessary climate for diversification of Michigan's industry into new high-technology areas.

- It would fill the need for a materials processing research program in the close proximity to Michigan industry and build on the historical strength of the Materials and Metallurgy Department at this University.

- It would attract outstanding engineers and scientists to southeastern Michigan and serve as "think-tank" for the industry of the state.

- It would enable the College to attract major federal research contracts and grants with potential spin-offs for the local industries.

DETAILED COMPONENTS OF THE PROPOSAL

The establishment of this unique materials research facility would require substantial commitments from the State, the University, and industry.

- Equipment: A key feature of the facility would be state-of-the-art instrumentation for materials characterization including a High Voltage High Resolution Transmission Electron Microscope, a dedicated Scanning Transmission Electron Microscope, an Electron Microprobe Analyzer, an Auger Spectrometer, an X-ray Photoelectron Spectrometer, as well as standard routine instruments such as Scanning Electron Microscopes and 100 kV Transmission Electron Microscopes.

  A new Liquid Metal and Powder Processing facility would be constructed to address growing industrial needs for research in rapid solidification, directional solidification, computer-aided casting, computer-assisted processing, coupling of robotics to casting, powder metallurgy, metal/ceramic interactions, etc.

State:	$5 million for aquisition of core instrumentation (TEM, Auger, XPS) plus $1 million/year for maintenance, upkeep and purchase of new equipment.
Federal Government:	Instrumentation proposals for $5 million and research funding at a level of $5 million/year.
Industry:	A blue-ribbon committee organized by the College would raise industrial funds for the Liquid Metals and Powder Processing facility ($2 million).

- Staff: The State and University would commit funds for additional faculty positions to staff the new facility.

- Technology Transfer: Development of a structure for efficient transfer of technology to industry.

SUPPORTING DOCUMENTATION OF EQUIPMENT NEEDS

MICHIGAN ELECTRON OPTICS AND SURFACE CHARACTERIZATION FACILITY

1. Electron Microscopy Equipment

JEOL Model JEM-4000EX High Resolution Electron Microscope

Equipped with electron energy loss spectrometer, image intensifier and computer system for instrument automation and image analysis.

$1,200,000

JEOL Model JEM-2000EX Analytical Scanning Transmission Electron Microscope

Equipped with energy dispersive x-ray analysis system, electron energy loss spectrometer, computer system for instrument automation and data analysis, and full complement of specimen stages.

$600,000

VG Model 501 Field Emission, High Resolution, Scanning Transmission Microscope

Equipped with energy dispersive x-ray analysis system and electron energy loss spectrometer.

$700,000

JEOL Model JSM-840 MK-II High Resolution Scanning Electron Microscope

Equipped with energy dispersive and wavelength dispersive x-ray spectrometers, full range of sample handling attachments and computer based automation and data analysis system.

$400,000

2. Surface Analysis Equipment

PHI Model 600 Scanning Auger Multiprobe

Equipped with full computer automation, high-pressure reaction system, and multiple sample handling and processing capabilities.

$650,000

JEOL Model JAMP-10SP Secondary Ion Mass Spectrometer

Equipped with fully automated data collection and processing system, energy dispersive x-ray spectrometer, and multiple sample-handling capabilities.

$400,000

KRATOS Model X5AM-800 X-Ray Photoelectron Spectrometer

Equipped with ultraviolet source, automated sample chamber, monochromator and multichannel detector, and microbeam etching.

$530,000

3. X-Ray Diffraction and Analysis Equipment

Philips Model APD 37-20 Computer Automated X-Ray Diffractometer

Equipped with automatic sample changer and accessory camera.

$250,000

Philips Model 1400 X-Ray Fluorescence Analyzer

Equipped with computer automation and automatic sample changer.

$225,000

4. Auxillary Equipment

Optical Metallograph with Image Analysis System

$150,000

Spark Machining and Ion Beam Thinning Units, Diamond Saws, etc. for Specimen Preparation

$100,000

Vacuum Evaporators, Leak Detectors, Residual Gas Analyzers, and Electronic Test Equipment

$100,000

Photographic Processing Equipment, Optical Benches, Optical Microscopes and Related Equipment

$250,000

5. Space Renovations

Renovation of 20,000 square feet of laboratory space to provide the necessary clean environment and special facilities needed to properly house the above equipment.

$1,700,000

5. Personnel

Operator for Transmission EMs	$25,000
Operator for SEMs and EMPA	$25,000
Operator for Surface Analysis Equipment	$25,000
Electronics Engineers (2)	$60,000
Computer Specialist	$35,000
Secretary	$17,000
Faculty Supervisor for EM (1/2 time)	$25,000
Faculty Supervisor for Analytical Microscopy (1/2 time)	$25,000
Graduate Student Assistants (3; part time)	$20,000
General Laboratory Technician	$20,000

6. Micellaneous

Instrument Improvement	$500,000
Service Contracts	$200,000
Supplies	$ 50,000

TOTAL EQUIPMENT COSTS:	$5,330,000
TOTAL LABORATORY COSTS:	$1,700,000
TOTAL RECURRING COSTS:	$1,027,000

-STATE BUDGET REQUEST-

THE CENTER FOR APPLIED OPTICS

THE UM COLLEGE OF ENGINEERING

(One-time funding: $3 million)

REQUEST FOR ADDITIONAL BUDGET ALLOCATION

College/Unit: College of Engineering

Request Title: Center for Applied Optics

REQUEST PURPOSE:

There is little doubt that the next major technological leap in both the manufacturing and electronics industry will involve the area of applied optics. By this term, we refer to the use of lasers, electron beams, and ion beams in sensing, diagnostics, mechanical measurement, manufacturing (non-contact cutting and welding), and optoelectronics and electro-optics. Lasers, electron beams, and ion beams will be the "machine tools" of future manufacturing. Indeed, Michigan industry has led the way in application of lasers to manufacturing processes. Over the next decade such "directed energy beam" devices will largely replace traditional machining with non-contact sensing, diagnostics, cutting, welding, and surface treatment.

The need for increases of several orders of magnitude in information storage capacity, transmission, and processing speeds will demand the transition of the microelectronics industry over the next 20 years to the use of optical methods for processing and storing information. Already there is significant work on "micro-optoelectronics" and "integrated optoelectronics" as the next stage of microelectronics and integrated circuits.

The proposed additional budget allocation of $3 million would assist the College of Engineering in developing the world's leading center for research and instruction in applied optics through sustained support of a **Center for Applied Optics**. This funding would be used as seed funding for the necessary equipment and to attract world-class scientists and engineers to staff the Center. Matching support would be sought from both industry and the federal government.

SUPPORTING RATIONALE:

There is little doubt that the next two decades will see major revolutions in two critical industries: heavy manufacturing and electronics. In both cases, new methods based on applied optics are expected to replace existing technology. In manufacturing, directed energy beams such as lasers, electron and ion beams will replace traditional machine tools with non-contact sensing, diagnostics, cutting, welding, and surface treatment. Moreover, major progress in developing integrated circuit chips containing both optical and electronic microcomponents, e.g., microscopic lasers and optical channels, now threaten to revolutionize the electronics industry in much the same way that the introduction of the solid state transistor did in the 1960s. Without doubt we will again be engaged with other nations in a struggle for technological and industrial leadership.

The College of Engineering and the State of Michigan are ideally positioned to build the world's leading university laboratory for research and instruction these critical areas through the formation of the Center for Applied Optics. The College's world-class reputation in these areas includes its early work on masers and lasers, its developmemt of the technology of holography, its ongoing activities in manufacturing (through organizations such as the Center for Robotics and Integrated Manufacturing and the Industrial Technology Institute of Michigan) and microelectronics (through its Solid State Electronics Laboratory), and its research on directed energy beams (its Laser-Plasma Interaction Laboratory). Furthermore, there is no such applied optics program in any other university in the nation. (Indeed, the only two optics research institutes in this nation, those at the University of Rochester and the University of Arizona, focus largely on basic research in optics). Over the next two decades, optics will change from what is largely an area of physics to being primarily an engineering discipline. We intend to lead the way in this evolutionary process.

The presence of several major research laboratories in the Ann Arbor area with strong reputations in applied optics, including the Environmental Research Institute of Michigan, KMS Fusion, and the Ford Scientific Laboratory, as well as development and production facilities such as Photon Sources, Ray-Con, and Perfect Optics, strengthen this effort. There is already a major industrial infrastructure in applied optics in Southeastern Michigan similar to that which first appeared in Silicon Valley in the microelectronics area. Since there is the strong possibility that optoelectronics will be the successor to microelectronics, the establishment of the Center for Applied Optics could well be the catalyst for stimulating a "Gallium Arsenide Valley" along the Detroit - Ann Arbor corridor.

The requested budget allocation of $3 million would provide the sustained level of support necessary to establish the Center for Applied Optics. Although the major support for the Center (estimated at $10 - $20 million per year) would come from grants and contracts from industry and the federal government, the State allocation would provide the seed funds to leverage major equipment gifts and attract the world-class scientists and engineers necessary to staff the Center. In addition, the College would work with the University and the State to provide mechanisms and encouragement for facilitate spinoff activities (e.g., through aggressive patent development support, close interaction with venture capital groups, and strong internal incentives).

BACKGROUND STATEMENT

THE CENTER FOR APPLIED OPTICS

BACKGROUND

There is little doubt that the next major technological leap in both the manufacturing and electronics industry will involve the area of applied optics. By this term, we refer to the use of lasers, electron and ion beams in sensing and diagnostics, manufacturing (non-contact cutting and welding), and electro-optics.

- Lasers, electron beams, and ion beams will be the "machine tools" of future manufacturing. Over the next decade such "directed energy beam" devices will largely replace traditional machining with non-contact sensing, diagnostics, cutting, welding, and surface treatment.

- The need for increases of several orders of magnitude in information storage capacity and processing speeds will demand the transition of the microelectronics industry over the next 20 years to the use of optical methods for processing and storing information. Already there is significant work on "micro-optics" and "integrated optics" as the next stage of evolution of microelectronics and integrated circuits. Optical storage media such as the laser disk will revolutionize the computer industry.

PROPOSAL

The State of Michigan would assist the College of Engineering and local industry in developing the world's leading center for research and instruction in applied optics through support of the College's newly-formed Center for Applied Optics.

Factors in support of such an effort include:

- The College's world-class reputation in these areas (including its early work on masers and lasers, its development of holography, and its world-class activities in manufacturing engineering and microelectronics).

- The presence of several major research laboratories in the Ann Arbor area with strong reputations in applied optics, including the Environmental Research Institute of Michigan and KMS Fusion.

- The presence of a major infrastructure in applied optics that already exists in southeastern Michigan.

- The absence of such an applied optics program elsewhere in the United States. (Indeed, the only two optics institutes in this nation, those at the University of Rochester and

University of Arizona, focus entirely on basic research in optics).

- The possibility that "micro-optics" will be the successor to microelectronics. (Could Southeastern MIchigan become the next "Gallium Arsenide Valley"?...).

DETAILED COMPONENTS OF THE PROPOSAL

The proposal would involve joint participation by State government, industry, and the federal government in building the Center for Applied Optics. Areas of support include:

- A major commitment for equipment support
- Funding for new faculty/staff positions in applied optics
- Mechanisms for facilitating technology transfer to the private secton

-STATE BUDGET REQUEST-

THE ENGINEERING TELEVISION NETWORK

THE UM COLLEGE OF ENGINEERING

(One-time funding: $2 million)

REQUEST FOR ADDITIONAL BUDGET ALLOCATION (ONE-TIME)

College/Unit: College of Engineering

Request Title: The Engineering Television Network

REQUEST PURPOSE:

To respond to the urgent need of Michigan industry for access to state-of-the-art instruction in engineering, the College of Engineering proposes to expand its current Instructional Television System to a state-wide Michigan Engineering Television Network. The METN project would offer Michigan companies access to a wide range of services, including both formal credit instruction at the undergraduate and graduate level in all areas of engineering, advanced research seminars and conference, and special technical briefings.

While the physical facilities for the studios for METN have been funded from private sources and are presently under construction on the Ann Arbor campus, the major equipment necessary for this project has yet to be acquired. Hence the College of Engineering requests a one-time allocation of $2 million to equip the Michigan Engineering Television Network facilities. Subsequent operating and equipment replacement costs will be supported through subscription fees paid by participating companies.

SUPPORTING RATIONALE:

Michigan industry faces a major challenge in keeping pace with changing technology as it strives to compete in the world marketplace. As Michigan companies become ever more dependent on advanced technologies such as microelectronics, computer science and engineering, and integrated manufacturing, they find it essential to provide their engineering staff and management with ongoing exposure to state-of-the-art engineering and technology management through access to graduate-level instruction. They require in addition a window on the most recent research results across a broad range of fields.

To respond to this growing need, the University of Michigan proposes to embark on a major effort tomake available through television broadcasts the entire range of coursework, research seminars, and internal conferences conducted by its College of Engineering.

Programming would originate from the Ann Arbor campus of the University (although selected off-campus conferences would also be scheduled). It would be related via microwave to transmitters in Detroit and broadcast from there to widely-distributed sites by through direct transmission and satellite links.

BACKGROUND STATEMENT

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Michigan industry faces a major challenge in keeping pace with changing technology as it strives to compete in the world marketplace. As Michigan companies become ever more dependent on advanced technologies such as microelectronics, computer science and engineering, and integrated manufacturing, they find it essential to provide their engineering staff and management with ongoing exposure to state-of-the-art engineering and and technology management through access to graduate-level instruction. They require in addition a window on the most recent research results across a broad range of fields.

To respond to this growing need, the University of Michigan has embarked upon a major effort to make available through television broadcasts to Michigan industry the entire range of graduate coursework, research seminars, and internal conferences conducted by its College of Engineering.

Effective with the 1985-86 academic year, the University of Michigan College of Engineering will begin broadcasting a full schedule of graduate-level courses, seminars, and conferences in engineering and applied science to select Michigan companies. The <u>Michigan Engineering Television Network</u> (METN) will broadcast 60 hours (8 am to 6 pm each weekday) of programming in engineering and related subjects each week consisting of:

Graduate-level courses
Research seminars and lecture series
Workshops and short courses
Special industrial briefings
International conferences

Programming will originate from the Ann Arbor campus of the University of Michigan (although selected off-campus conferences will also be scheduled). It will be relayed via microwave to a transmitter in Detroit and broadcast from there to selected sites throughout southeastern Michigan (and later by satellite throughout the State of Michigan).

Companies wishing to participate in METN will become members of the METN Industrial Consortium. Payment of a single annual fee (based upon company size) will allow company members unrestricted access to METN broadcasts throughout all company sites (although reception and internal distribution will be the responsibility of each Consortium member). In addition, company staff qualifying for admission to the University as degree or non-degree candidates will be allowed to receive credit instruction for courses taken through METN, subject to normal tuition charges.

The University of Michigan believes that the UM Engineering Television Network can be a major resource to Michigan industry. It will provide companies with a cost-effective mechanism for strengthening and sustaining their technological and management capacity. The METN Consortium will provide members with sustained access to world-class faculty, visiting engineers, scientists, and business leaders. In addition, METN will provide them with a window on advanced research and development through the broadcast of programming produced by major research centers such as the Center for Robotics and Integrated Manufacturing, the Industrial Technology Institute of Michigan, and the Computing Research Laboratory.

The UM Engineering Television Network's impact will extend beyond that of individual companies, however. It will provide Michigan companies with a unique environment for technological evolution. And it will provide the State of Michigan with a unique resource in stimulating and attracting new industry.

The University of Michigan Engineering Television Network represents a major commitment to respond to the needs of Michigan, its citizens and its industry.

PROGRAMMING:

The University of Michigan Engineering Television will provide day-long programming in graduate instruction and research in engineering, applied science, and related subjects (e.g., computer science and management methods). Participating members of the METN Consortium will be provided with advance schedules of all programming.

Typical programming will include:

- Both live and video-taped graduate-level courses in engineering (typically 5 to 10 courses per term).
- Regularly scheduled research seminars in engineering and related subjects featuring both University faculty and visiting engineers, scientists, and business executives.
- Major conferences and symposia in engineering and applied science held at the University or adjacent locales (Detroit).
- Special workshops and presentations (e.g., selected summer workshops conducted by the College's Center for Continuing Engineering Education).
- Special workshops and briefings conducted by research centers and institutes (such as the Center for Robotics and Integrated Manufacturing or the Industrial Technology Institute of Michigan).

BROADCAST:

Programming would originate in both live and videotape format from the Ann Arbor campus. It would be conveyed via microwave to central Detroit location (the Renaissance Center) for transmission to the southeastern Michigan region. Participating companies would receive the broadcast at each site and distribute it throughout their organization.

Eventually the University intends to implement satellite up-link stations so that the broadcast could be made available throughout the State of Michigan.

PARTICIPATION:

Each company participating in the METN Industrial Consortium would be assessed an annual fee based upon its size. Consortium members would be allowed unlimited access to all broadcasts through the Network (although internal distribution would be the responsibility of the company).

Consortium members would be provided with advance schedules of all programming. They would also be provided with opportunities to participate in schedule planning (including mechanisms for requesting the broadcast of specific courses, seminars, conferences, and presentations).

CREDIT INSTRUCTION:

Staff at each Consortium company would be provided with the opportunity for credit instruction, provided they first qualified for admission as either degree or non-degree candidates in graduate programs of the University's College of Engineering. Course enrollment for credit would require the payment of the usual University tuition. Passive (non-credit) audit of courses would be allowed without fee.

REQUEST FOR STATE SUPPORT: $2 million (one-time funding)

The College of Engineering seeks to expand its instructional television network to full-time programming of courses, seminars, conferences, and special technical briefings to industry in the southeastern Michigan area (later extending this service State-wide through satellite transmission). The College seeks one-time funding of $2 million to acquire the equipment necessary to expand its broadcasting facility. Subsequent support will be provided through direct subscriptions from industry.

APPENDIX C
OTHER SPECIAL OPPORTUNITIES

- NSF Engineering Research Center: $1 million per year
- MSE/MBA Program: $2 million per year

UM COLLEGE OF ENGINEERING

ENGINEERING RESEARCH CENTER IN INTEGRATED MANUFACTURING

ABSTRACT

The University of Michigan's response to the Engineering Research Center (ERC) program is focused on computer-integrated manufacturing systems. Since 1981, UM has taken a major initiative in this area by establishing the Center for Robotics and Integrated Manufacturing (CRIM). UM now proposes to establish a major ERC component within CRIM to better address not only the elements of manufacturing systems but especially their integration. The expanded CRIM will address industrial problems in the four interrelated areas of: product design, cell-level production, plant-level production, and strategic management.

A Management Committee, consisting of core faculty with expertise in these four areas, will integrate the ERC activities to address industrial needs for improving productivity, quality, and the worker environment to enhance U.S. industry's international competitiveness.

The proposed ERC is designed to take full advantage of UM's unique strengths: the Computer-Aided Engineering Network (CAEN) (an advanced distributed computing environment in UM's College of Engineering), close links with the Industrial Technology Institute (ITI) (an applied research institute in manufacturing), and established connections with automotive and durable goods companies and with the Semiconductor Research Corporation (SRC) consortium. UM's research ideas will be pursued initially within the automotive and semiconductor industries and later in other transportation and electronics industries, providing a cross-fertilization of manufacturing research germane to both mechanical and electronic systems.

To ensure close interaction with the major automotive and semiconductor companies, this proposal was developed with their assistance and endorsement. Representatives from these companies, including General Motors, Ford, Chrysler, and SRC, are included in the ERC advisory structure.

A significant element of the ERC will be engineering education. To attract, retain, and develop human resources for the next generation of manufacturing systems, UM will take innovative steps in undergraduate, graduate, and continuing education. Providing the structure to engage in University-based cross-disciplinary research and education, with meaningful industrial involvement, presents a considerable challenge, requiring nothing short of a cultural shift in the College of Engineering. The impact on education will be enhanced through a regional network of engineering colleges, including Oakland University, University of Michigan-Dearborn, University of Detroit, and University of Toledo.

Since the expensive equipment necessary for the ERC's empirical research is already available to CRIM through CAEN, ITI, SRC, and a number of companies, a major portion of the ERC funding will provide the leverage to enable CRIM to perform large-system integration, to provide long-term stable infrastructural support, and to create incentives for faculty and student professional involvement in integrated manufacturing.

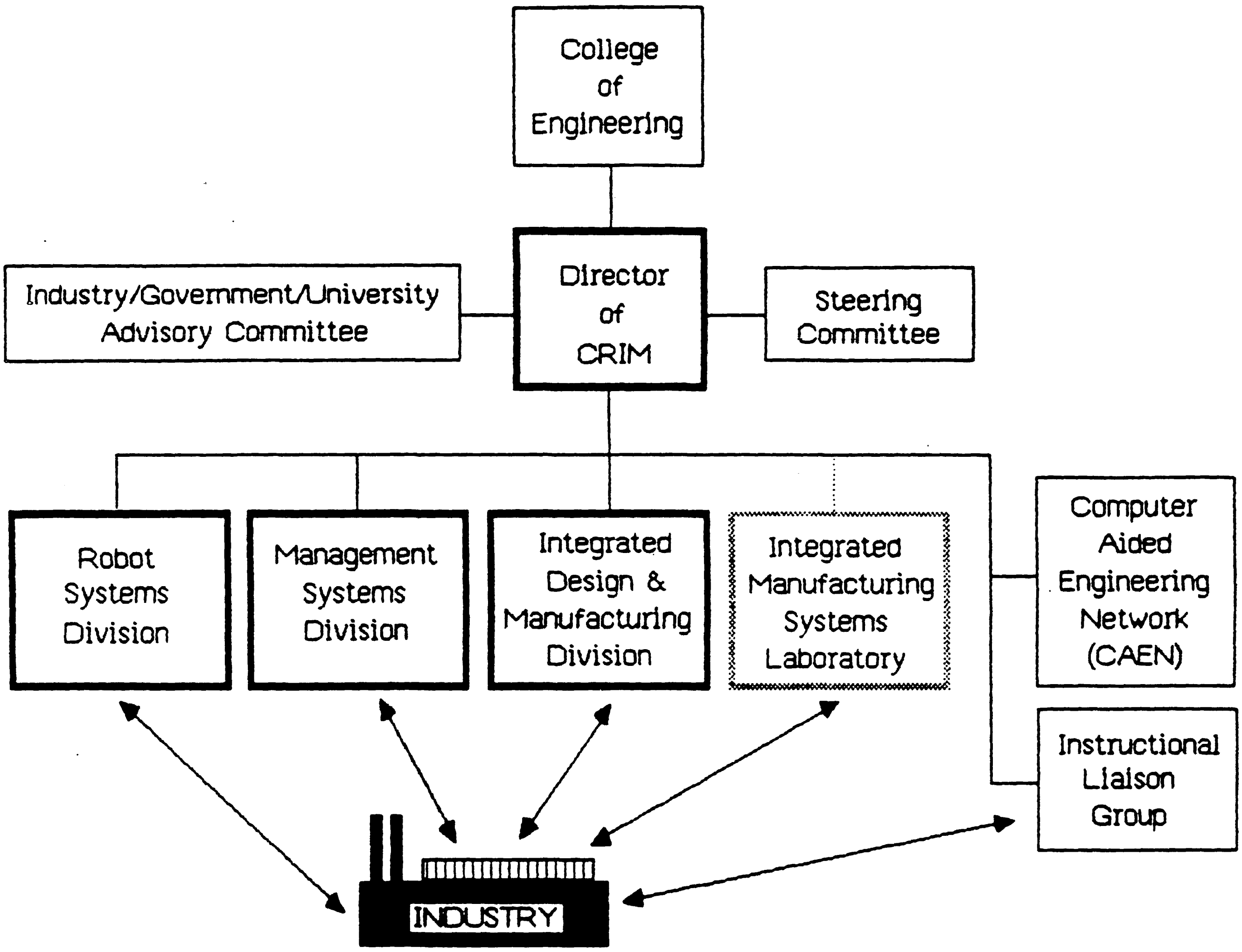

Figure 1.1. Present Organization of the Center for Robotics and Integrated Manufacturing

2. THE PROPOSED ERC COMPONENT OF CRIM

University-based cross-disciplinary research and education on large manufacturing system integration, with in-depth industrial involvement, is a considerable challenge, requiring nothing short of a cultural shift in the College of Engineering. We believe that this shift can be effectively promoted through the ERC.

2.1. MANAGEMENT AND ORGANIZATION

Leadership and management coordination are so critical to cross-disciplinary research centers that how these issues are resolved has largely determined their success or failure (Hetzner and Eveland, 1983). Cross-disciplinary research requires a change in the behavior of normally discipline-oriented university researchers. They must learn each other's language, methodology, and conceptual framework. They must communicate continuously with each other and with industry and adjust to new modes of research management (Saxberg et al., 1981).

While cross-disciplinary research and education in the past have been difficult and not particularly successful in universities, the circumstances surrounding the ERC have elements that augur well for success, and the UM approach to management and organization is designed to stress these positive elements. First, the link between research and education required by the ERC, once firmly established, will increase the stability of the Center within the University. Second, industrial involvement, if managed properly, will provide an added dimension for evaluating faculty accomplishments, jobs and career opportunities for students, and possibilities of stable and leveraged funding — all of which have been difficult for cross-disciplinary centers to achieve. And, finally, engineering faculty members, unlike their colleagues in pure sciences, are problem-oriented and therefore motivated to do cross-disciplinary work.

The UM approach to management and organization began with a deliberate choice of integrated manufacturing as the subject for ERC activities, the subject most central to the College of Engineering's major thrusts and investments (faculty recruitment, facility acquisition, research seed money, etc.) in recent years. The choice of CRIM as the home for the proposed ERC has an organizational significance. Inasmuch as CRIM was established as part of a combined initiative by the State of Michigan, industry, and UM to revitalize and diversify the region's industrial base, CRIM's interest in cross-disciplinary research and education is consistent with that of the College, the UM's central administration, the State of Michigan, and the manufacturing industry. ERC will expand CRIM into an agent to accelerate the fundamental changes desired by the College. The policy statement approved by the College Executive Committee and the Dean of Engineering concerning the operational incentives for faculty to engage in industry-relevant cross-disciplinary research and education (see Appendix E) attests to the College's commitment to these fundamental changes.

Figure 2.1 is an organizational chart of the expanded CRIM, carefully designed to emphasize the three defining characteristics of the ERC program: system integration, educational linkage, and industrial interaction. CRIM's director is Professor Daniel E. Atkins, who for the last three years has also been the Associate Dean for Research and Graduate Studies for the College. With ERC funding, he will commit 75% of his time to the direction of CRIM and ERC activities. As director of CRIM, Professor Atkins will be project director and principal investigator for the ERC component and assume overall technical and financial responsibility. And, as CRIM director, Professor Atkins will remain Associate Dean.

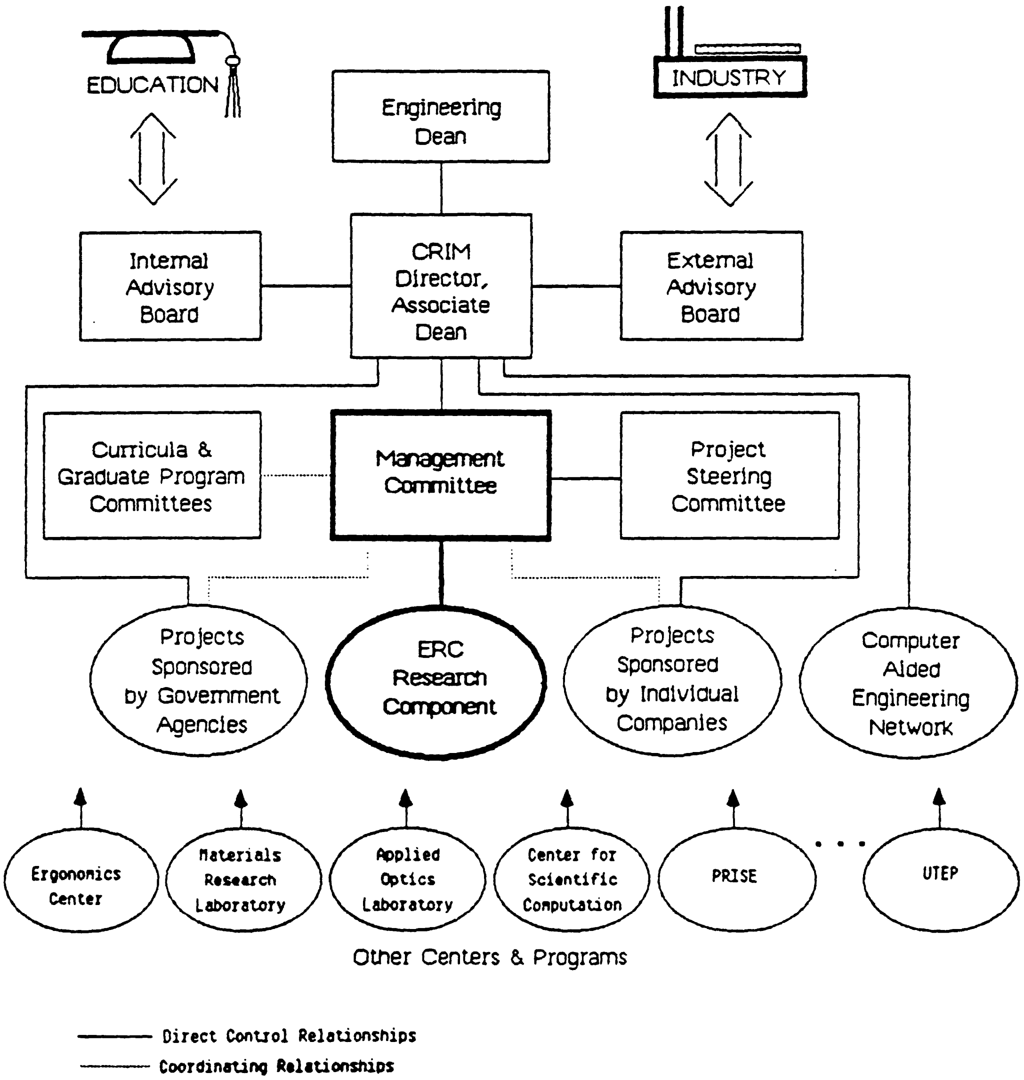

Figure 2.1. Proposed Reorganization of CRIM with ERC

To ensure system integration, the new CRIM will not be divided into divisional subunits. Instead, its leadership will reside in a Management Committee charged with planning, resourcing, and controlling all ERC activities. The same committee will coordinate these activities with the normal educational functions within the College and with other CRIM projects supported by government agencies and individual companies. The Management Committee, chaired by Professor Atkins, consists of a co-principal investigator from each of the four research areas of product design, cell-level production, plant-level production, and strategic management, plus a member to provide leadership for and coordination of educational development. To enrich the intellectual leadership and linkages, an additional four faculty members have also been designated co-principal investigators. They will assist the Management Committee members in leading the four research areas and serve as alternates in the absence of a Management Committee member. To provide a critical mass for success, these ten co-principal investigators will each commit at least 40% of their time in support of ERC goals. The members of the Management Committee are:

Management Committee

Daniel Atkins (EECS, and Associate Dean) (chair)	Center Director
Kan Chen (EECS)	Strategic Management
Joe Eisley (Aero)	Education
Panos Papalambros (MEAM)	Product Design
Stephen Pollock (IOE)	Plant-Level Production
Richard Volz (EECS)	Cell-Level Production

The additional principal investigators and alternates are:

Walton Hancock (IOE)
Harris McClamroch (Aero)
Arch Naylor (EECS)
Galip Ulsoy (MEAM)

The co-principal investigators, under the leadership of the project director, are responsible for building and managing a team of senior and junior investigators to pursue the ERC research and education objectives.

The two blocks on the right side of Figure 2.1 represent an organizational design for industrial interaction. The External Advisory Board will include industrial executives who, from perspectives external to UM, will advise the Center on its policies and directions. They will review CRIM's overall program plans and accomplishments, inform

CRIM's director about industrial trends, and suggest specific opportunities for the Center's industrial involvement in both research and education. The Project Steering Committee will include technical and managerial people from industry to work with CRIM's Management Committee to set specific project goals, to review and steer the research and associated educational linkages.

The initial members are:

External Advisory Board

Robert Burger	Chief Scientist, Semiconductor Research Corp.
Dale Compton	Vice-President, Research, Ford Motor Company
Richard Dauch	Executive Vice-President, Stamping, Assembly, and Diversified Operations, Chrysler Corporation
Robert Eaton	Vice-President, Advanced Product and Manufacturing Engineering Staff, General Motors Corporation
David Nelson	Vice-President, Research and Development, Apollo Computer, Inc.
Jerome Smith	President, Industrial Technology Institute

Project Steering Committee

Billy Crowder	Manager, Advanced Semiconductor Products Technology, International Business Machines
Donald Falkenburg	Director, Flexible Machining Laboratory, Industrial Technology Institute
Phillip Francis	Director, Flexible Inspection and Assembly Laboratory, Industrial Technology Institute
Gregory Kee	University Coordinator, Apollo Computer, Inc.
Norman A. Gjostein	Director, Long Range and Systems Research Laboratory, Ford Motor Company
Richard Lucic	Manager, Microwave Technology Division, Hewlett-Packard
Lothar Rossol	Vice-President, Research and Development, GMF Robotics
Jack Thompson	Manager, Manufacturing Technical Systems, Chrysler Corporation
Gabe Tiberio	Executive Director, Advanced Product and Manufacturing Engineering Staff, General Motors Corporation

The Internal Advisory Board will advise the Center from perspectives internal to UM and will suggest specific disciplines and talents for the Center to draw from. The members of this Board will include the University Vice-President for Graduate Studies and Research, the Engineering Associate Dean for Academic Affairs, chairmen of selected departments (EECS, MEAM, IOE, Aero, MME, etc.), and heads of selected programs and centers (e.g., the Center for Ergonomics). The Center's Management Committee will interact with the curricula and graduate committees in the relevant departments to coordinate course development and revision, Ph.D. qualifying examination requirements, and other educational links in the ERC activities.

The Management Committee will meet at least twice a month and more frequently as needed. The External Advisory Committee will meet twice a year, one of the meetings to overlap with that of the College's National Advisory Committee (see Appendix G.1). The Internal Advisory Committee will meet three times a year, overlapping at least once with the External Advisory Committee meetings. The Project Steering Committee will meet every two months or more frequently if needed.

It is evident from the organization chart that the Management Committee is the focus of a centralized organizational structure. It will serve as the "champion" of the ERC ideas within the University. It will build the infrastructure for the new dimension of engineering education, ranging from facilities, information services (library and computer program documentation), to the recruitment of faculty, research, and support staff. As part of the support staff, CRIM's Director of Corporate Relations will ensure that ERC projects are established with industrial involvement and that commitments made to industry are fulfilled.

A central responsibility of the Management Committee is to initiate, select, fund, interrelate, transfer, and/or phase out research projects. In setting research goals and developing research plans for specific projects involving industry, the Management Committee will work closely with the Project Steering Committee. To stimulate project ideas, the Management Committee will periodically send "requests for proposals" to their colleagues. With concrete project plans that satisfy the three defining criteria of the ERC program, the Management Committee will then select the best combination of proposed projects to fund. These will be reviewed and redirected if necessary by the Management Committee, working in concert with the industry advisors on the Project Steering Committee. The Management Committee will seek additional funds through financial leveraging, maintain a balance of interrelated projects, transfer projects from ERC to alternative funding sources, and phase out those that can no longer be supported.

In managing the ERC budget, the Management Committee will maintain a balance between long-term commitment to key investigators and flexible reallocation of funds to ensure system integration, industrial interaction, and educational linkage. An initial centralized organization is needed to build a critical mass of committed faculty and to nurture the necessary cultural shift in the direction set by the ERC, coinciding with the College's long-term goals. As the ERC becomes established, however, the management structure of the Center may become more decentralized. For objective and professional guidance in this respect, a "formative evaluation" project (see Appendix L) will be conducted by experts external to CRIM and experienced in evaluating industry-relevant cross-disciplinary research centers.

2.2. THE RESEARCH AREAS

Improvement of productivity and quality for the U.S. manufacturing sector today is frequently defined as a set of instrumental goals:

- Shorter lead time for the product development cycle.
- Error-free design and design for manufacturability.
- Flexible manufacturing for a diversity of products.
- Higher yield and less scrap (making it right the first time).
- Reduction of work in process and inventories.
- Safe and desirable workplace.

This set of industrial needs, along with the major technological opportunities on the horizon, helped us define four research areas:

Research Areas	Central Features
(A) Product Design	• Computer-aided integration for creative and optimum design
(B) Cell-Level Production	• Integration of sensors and intelligent control at the cell level

(C) Plant-Level Production	•	Information and physical flow control and planning at the plant level
(D) Strategic Management	•	Strategic technology assessment, planning, and interventions.

These four research areas, presented in detail in Appendices A through D, are closely coupled. Figure 2.2 shows their linkages. Since the use of computers is central to the implementation of integrated manufacturing, a distributed structure of computer control of manufacturing systems, as shown in Figure 2.3, will help explain the linkages. The letters A, B, and C in Figure 2.3 indicate the relevant portions of the diagram corresponding to the first three research areas. (Note that not all the contents of the three research areas, nor those of the fourth area, are included in Figure 2.3). Combining Figures 2.2 and 2.3, we may tabulate the linking features of the four research areas as follows:

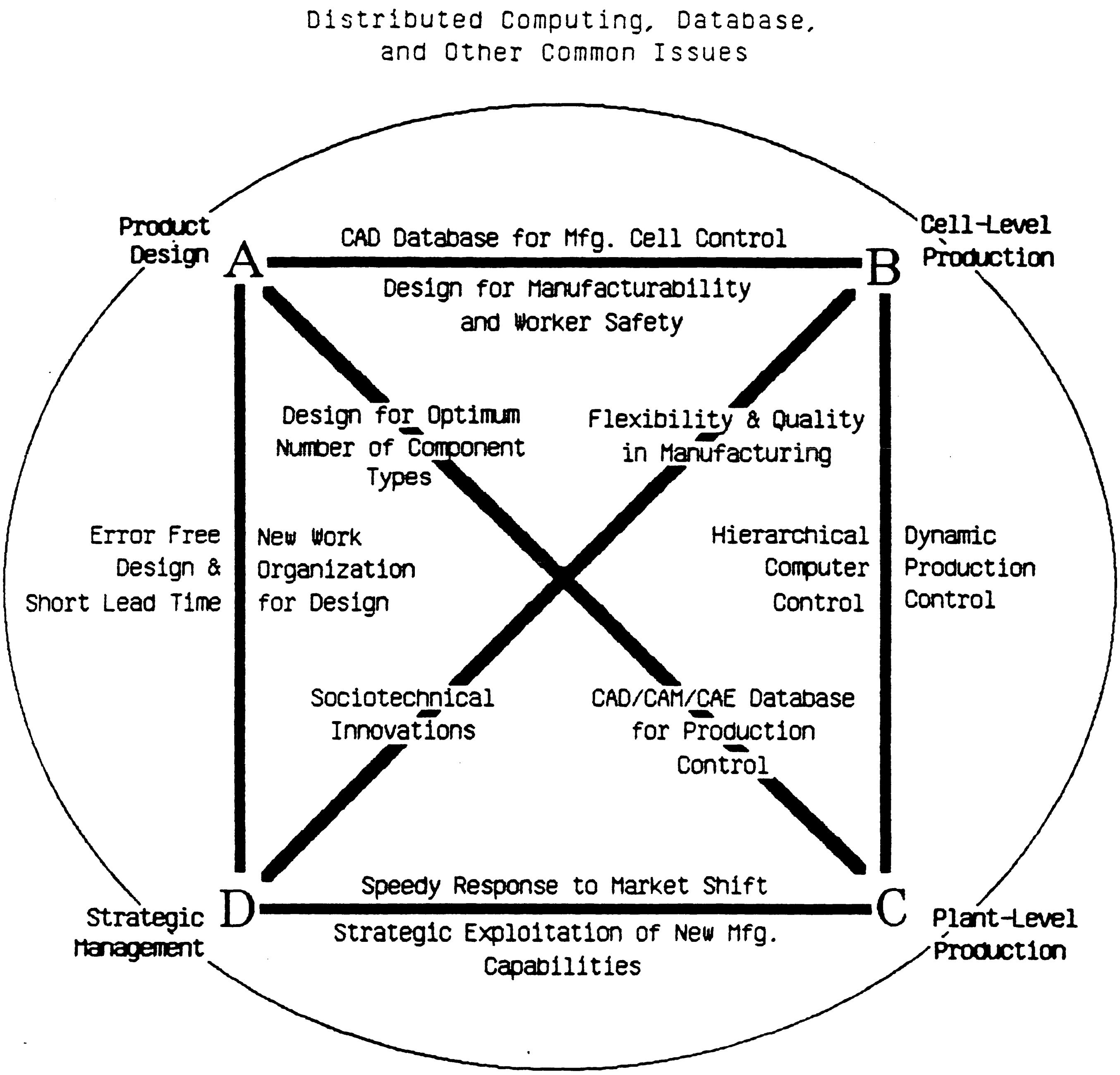

Figure 2.2. Illustrative Interactions Among the Four Research Areas

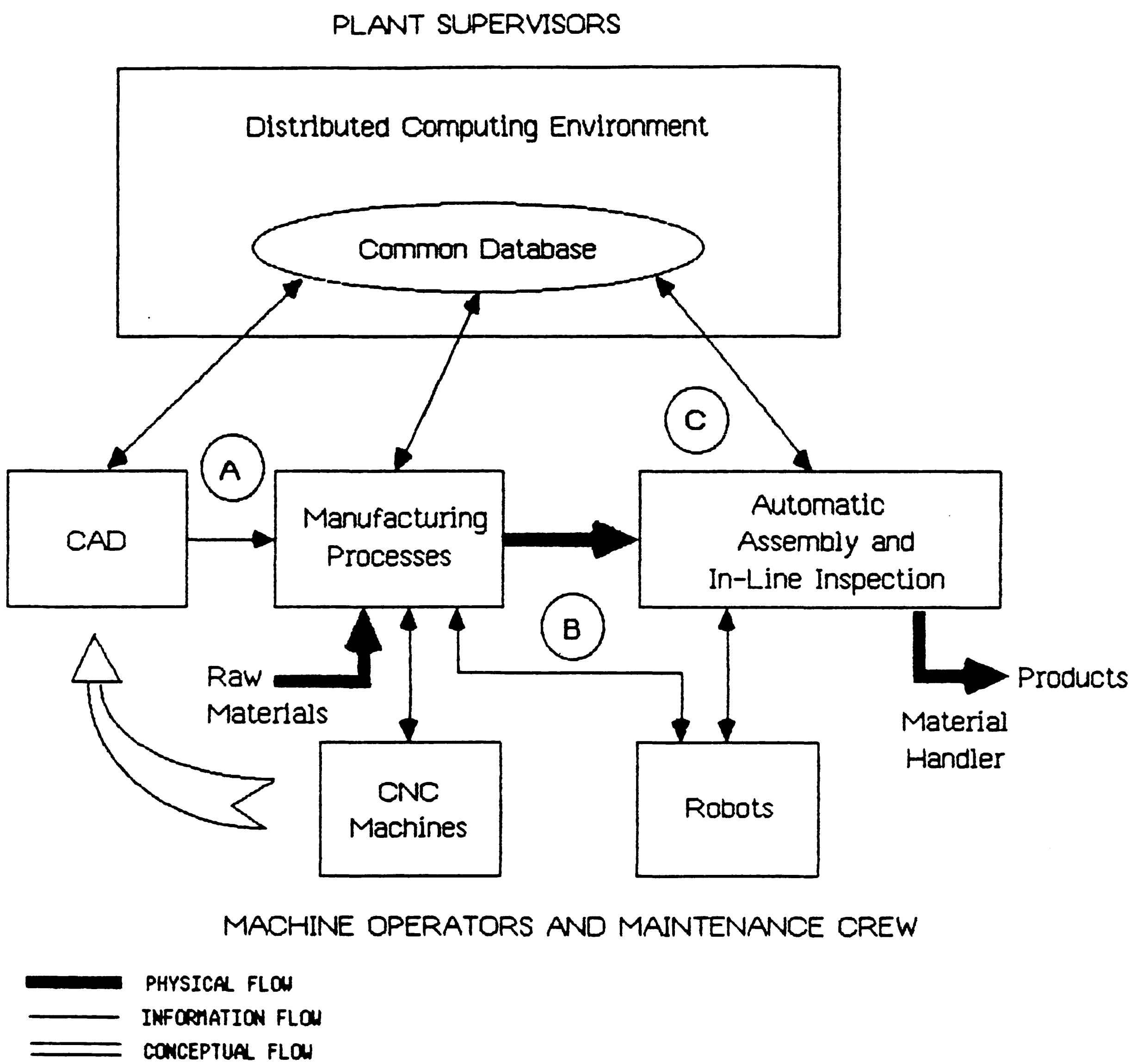

Figure 2.3. Structure of Computer Control of Manufacturing Systems

Pairs of Research Areas	Linking Features
(A & B) Product Design and Cell-Level Production	• Creative and optimum design including manufacturability and worker safety as major design criteria. • Concepts and algorithms for using CAD database for controlling CNC machines, robots, manufacturing cells, and assembly stations.
(A & C) Product Design and Plant-Level Production	• Parts and product design using optimum number of component types. • Concepts and algorithms for using CAD/CAM/CAE data for production control.
(A & D) Product Design and Strategic Management	• Interaction between intellectual process and CAD/CAM data for error-free design and reduced lead time for new product introduction. • New design work organization, including approval procedures, to facilitate the above.
(B & C) Cell-Level Production and Plant-Level Production	• Concepts, algorithms, and equipment implementation of hierarchical computer control. • Dynamic production control, including rescheduling and rerouting in response to changes of status in machines, parts, materials, and tools.
(B & D) Cell-Level Production and Strategic Management	• Economical and effective realization of flexible and high-yield production. • Sociotechnical innovations (including training) for worker/manager acceptance and utilization of integrated manufacturing technology.
(C & D) Plant-Level Production and Strategic Management	• Design and control of production facilities for speedy response to market shifts. • Equipment replacement and capacity expansion. • Strategic exploitation of improved or newly created capabilities of integrated manufacturing.

The large circle surrounding the square in Figure 2.2 is the supporting research required by all four areas. It is essential that there be a commonality and comprehensiveness to the database resources. It will become increasingly important that the large number of distributed computers in factories be operated, at each level of the computing hierarchy, as a distributed computing system rather than a distributed system of computers. ERC will also look for opportunities across all areas to develop and apply artificial intelligence techniques, such as expert systems, to integrated manufacturing.

Our research plans have benefited from significant industrial input, especially from company representatives who have agreed to serve on the Center's External Advisory Board and on the Center's Project Steering Committee. These research plans will be modified and developed into a cluster of projects as greater industrial involvement takes place after the ERC is established. Indeed, we expect some modification of these plans to occur in the course of further industrial interactions before the site visit by the NSF Proposal Review Panel. For this reason, and for the maintenance of program flexibility, the research descriptions in Appendices A through D indicate only preliminary research directions and approaches and the commitment of our core faculty to serve as co-investigators. The plans leave room for adjustments and adaptations stemming from industrial interactions and changes in future research needs.

We intend to test our research ideas on transportation and electronics industries. Initially, the testing will be on two major industries — automotive and semiconductors. The UM's connections with these two industries are exceptionally strong, and the on-campus manufacturing system testbeds are suitable to the generic problems of the two industries. Moreover, the auto industry designs and uses a large number of integrated circuits. The choice has other merits as well. In the auto industry, manufacturing has been driven mainly by design, while in the semiconductor industry, design has been driven mainly by manufacturing. In other words, design for manufacturability has been a cardinal principle in the semiconductor industry: the designer of integrated circuits has to follow a set of rules dictated by the capability of the semiconductor manufacturing process. Similar rules are not nearly as sophisticated in the auto industry. On the other hand, three-dimensional mechanical design in the auto industry has always been sophisticated, and the electronic designer may have something to learn from the mechanical designer as the former gets more involved in three-dimensional problems. In terms of the technoculture, the two industries are quite different in their age, labor relations, capital structure, and organizational characteristics. Thus, an interplay between the two industries in our integrated research can be expected to yield an interesting cross-fertilization of ideas. In addition, we expect to involve the manufacturers of manufacturing systems, including machine tool and robot manufacturers, as well as manufacturing software companies.

2.3. THE INTEGRATION MECHANISMS

Conceptual, physical, and organizational integration mechanisms will be used to ensure integration in the proposed ERC:

- Interrelate all proposed work within an overall system framework.
- Focus proposed work on real industrial problems.
- Demonstrate research results on system-level testbeds.
- Use a next-generation distributed computing environment as the basis for system integration.
- Include researchers from different disciplines in the same project.
- Use management and budgetary control to ensure interrelated projects.
- Encourage dialogue between researchers with different viewpoints.

The linking features of the four research areas, as summarized in Figure 2.2, will provide the overall framework for integration. The framework, to be updated from time to time, will be used to identify and screen proposed projects and interrelate the results of chosen projects.

Focusing on well-defined problems is the general underlying principle for cross-disciplinary research. While this principle has worked well for mission-oriented programs in both industry and government, a creative adaptation is needed in the academic environment where the tradition leans toward solitary endeavors in fundamental research and transmitting knowledge. ERC research, therefore, will be focused on a demonstration of solutions to *generic* problems of integrated manufacturing.

We propose to use several interrelated *testbeds* as an important integration mechanism. Each testbed will be fairly large, incorporating, to various degrees, many facets of an entire manufacturing system. Each will be a prototypical example of a manufacturing system, presenting the generic problems of all such systems. Naturally, there is a limit to how many testbeds an ERC could support, particularly if each had to be developed *de novo*. Fortunately, the UM already has several excellent component-level testbeds on campus, including the equipment and systems in the Robotics Research Laboratory and in the Machine Tool Diagnostic Sensing and Control Laboratory within CRIM.

Moreover, we have access to an automated manufacturing facility in the final stages of completion at the Industrial Technology Institute. A larger facility of the same kind to be developed by ITI in its new quarters adjacent to the Engineering Campus will likely become an important testbed when completed. The two ITI facilities will also provide opportunities to study the coordination of two geographically separated facilities.

Another system-level testbed is an integrated circuit fabrication line currently being developed by UM's Solid-State Electronics Laboratory for the Semiconductor Research Corporation. This facility will be available for experimental research on manufacturing systems for microelectronics.

The previously described Computer-Aided Engineering Network, with powerful graphics capability, distributed database, and access to supercomputing facilities, is another significant testbed for large-system integration, especially for computer-aided design activities and local area network concepts, for both research and pedagogical purposes. The computer network is also an integration mechanism in itself, since any substantive interactions via the network will have to be based on common languages, shared databases, consistent logic, and compatible hardware. CAEN has the potential of further expansion, with optical fiber links to the various testbeds on or near the UM campus, to provide testbeds for large-scale higher-level system integration in ERC activities. All these on-campus testbeds are described in Appendix F.

While we are enthusiastic about the opportunities offered by these testbeds, we are also well aware of the organizational and management problems in mission-oriented research. To this end, the Center will emphasize cross-disciplinary project teams and will have the same people on different projects. Through budgeting control by CRIM's Management Committee, the ERC research will be conducted in a cluster of four interrelated activities rather than in many isolated projects.

While management control implies uniformity of approach, we will also cultivate diversity of ideas by encouraging dialog between researchers with different viewpoints. For example, we recognize two basic origins of engineering research. "Technology push" starts with the definition of the features of the next generation of technology, such as the 3rd generation of industrial robots or the 5th generation of computers (Chen and Chang, 1984). "Societal pull" starts with specific needs for increasing industrial competitiveness, such as shorter lead time for new products and higher yield from production lines. We intend to collaborate with industrial advisors to use both approaches in the identification of generic problems for integrated manufacturing. In looking for solutions to these problems, we will first use the "circular" mode of multidisciplinary research (in which several relevant disciplines are brought together to illuminate a problem), and later use the "directional" mode (in which the necessary interactions among various disciplines are appropriately directed to solve a generic problem by a target date).

2.4. THE EDUCATION COMPONENT

The primary aims of the education component are (1) to bring concepts of large-system integration into the courses and programs of the College and other colleges of engineering and (2) to improve the amount and rate of technology transfer from researchers in manufacturing areas to students and professionals in the field.

It is well known that the emphasis in engineering education in the past several decades has been on basic and engineering sciences. Analysis has dominated over design, theory over experiment, and depth over breadth. Little concern has been paid to manufacturing. This has paralleled a movement toward specialist teams in industry and has resulted in a separation of the design and production processes and a fragmentation of purpose within each.

To improve productivity, quality, and worker environment, a reunification of the design process in itself and a true integration of it with production are needed. The growing availability of computer-aided and integrated engineering and production applications software and computer networks, such as CAEN in the UM College of Engineering, make possible the introduction of large-system integration into the courses and curricula and can greatly shorten the time for technology transfer. In addition, exposure of students to computer-aided engineering and manufacturing and computer network technology expands their understanding of advanced information transfer techniques.

Having recognized these needs some time ago, the College has undertaken several related educational activities. In the past three years, in particular, several new courses were introduced and many others modified to reflect computer-aided engineering and manufacturing, systems integration, and related concepts. A measure of the rich course environment currently available to both the undergraduate and graduate students is given in Appendix I.3. Concurrently, departmental and degree program curricula in Manufacturing Systems Engineering (MSE) were developed. A master's-level option in MSE that was recently approved by three departments is described briefly in Appendix I.4. Perhaps the most significant activity, however, has been the hiring of many new faculty in several departments in manufacturing areas. This more than any other act reflects the degree of commitment of the College to manufacturing research and education.

The ERC will not only accelerate our progress toward the establishment of new courses and curricula and the involvement of more faculty and students in manufacturing but, more importantly, will help us build much stronger ties in three directions: research-education linkages, cross-departmental ties, and industrial involvement in education. To move forward quickly with this transition, it will be necessary to obtain the cooperation of individual faculty members and their departments and degree program committees. A critical mass of cooperating faculty from various departments must be encouraged and supported on a stable long-term basis to carry out educational innovations. We propose, therefore, to use ERC program support to implement the following educational innovations.

(a) Research-education linkages

Faculty researchers supported by ERC funds will be required to make specific and related educational contributions approved by the Management Committee. Such contributions, which will be leveraged by other funds where appropriate, will include developing new courses, revising existing courses, or supervising special student projects. Students supported by ERC funds, in addition to performing the assigned research tasks for which they will be paid, will be required to participate in educational activities, such as electing certain courses, engaging in independent study or projects, gaining manufacturing experience through industrial co-op or internship programs, etc.

(b) Curricula and program planning

One problem commonly associated with course development and revision, as described in (a) above, is that efforts by individual faculty often are not integrated, resulting in significant gaps or unnecessary overlaps of related courses in different departments, or even in the same department. To overcome this difficulty, the Management Committee will interact with curriculum committees within and across the relevant departments (EECS, MEAM, IOE, AE, MME, and others) to plan for manufacturing-related curricula at the baccalaureate, master's, and doctoral levels. Similar planning sessions will be held with the graduate program committees to discuss reasonable and appropriate contents and standards, especially the question of depth versus breadth, for doctoral qualifying examinations related to integrated manufacturing. The recently developed master's option in Manufacturing Systems Engineering will be reviewed, evaluated, and upgraded by the Management Committee.

Structured curricula for manufacturing will also be offered through the Engineering Summer Conference continuing engineering education program. In fact, this program will be extended to offer the option of on-site as well as on-campus instruction. The Instructional Television system of the College will also be used to offer courses in relevant areas, both live and on tape.

(c) Special courses

To meet the special needs of both graduate and undergraduate students who have been conditioned to deal with courses that emphasize depth in narrow disciplinary fields, two new multilevel cross-disciplinary courses in integrated manufacturing will be offered with ERC support. The first course, tentatively entitled Manufacturing Systems Science, will cover a breadth of basic principles that every serious student of integrated manufacturing should know. The second course, tentatively entitled Manufacturing Systems Engineering, will emphasize interdisciplinary group discussion. The purpose of these two courses is to develop a sense of the breadth of knowledge necessary to deal with the problems of system integration in manufacturing areas. More details are given in Appendix I.2.1.

(d) Industrial participation and technology transfer

Industrial involvement in education will take many forms, including guest lecturers and seminar speakers in courses taught by ERC-related faculty, participation in research seminars co-sponsored by CRIM and ITI, participation in research projects with graduate students, teaching in courses both on campus and in continuing education, etc. We will also develop a close coordination between our long-established industrial co-op and internship programs and integrated manufacturing research, including an innovative program in the Placement Office of the College to assist graduate students working on industry-related research find employment with industry after graduation.

While we believe that coupling industrial participation with research and teaching in the various forms described above are among the most effective ways of technology transfer, we will also use ERC support for knowledge diffusion in other forms. This will include the publication of papers, books, manuals, computer programs, etc., and the making of audio and video tapes that can be widely distributed. We also intend to form a regional network of engineering educational institutions, tentatively including Oakland University, UM-Dearborn, University of Detroit, and University of Toledo, to help with knowledge diffusion. More details are given in Appendix I.1.4.

2.5. INDUSTRIAL INTERACTIONS

Industrial interactions will be important for both research and education. They are necessary to ensure that the research performed is relevant to international competitiveness, to increase the usefulness of research results, to provide meaningful testbeds for manufacturing systems, and to develop joint and complementary research between CRIM and industry. They are necessary, likewise, to increase the industrial relevance of manufacturing engineering education, to facilitate technology transfer, and to coordinate the development of engineering human resources in both industry and universities.

To achieve meaningful, continuing, and in-depth industrial interactions, we propose three levels of industrial involvement in the Center:

(1) External Advisory Board (policy level)
(2) Project Steering Committee (project level)
(3) Substantive participation in research and teaching (task level).

The functions and memberships of (1) and (2) are discussed in Section 2.1 on management and organization. Substantive participation by industry people will be at the task level — cooperative research tasks, guest lectures and seminars, and experimenting with ideas on various testbeds on campus or at industrial sites.

We will not name specific industrial participants for research and educational tasks at this time (although several candidates have been identified) because detailed planning for the cluster of ERC-supported projects will take place after the ERC funding is assured. Moreover, industry cannot afford to commit its best people a year or two before projects get underway. However, our Industrial Research Partnership Programs have given us invaluable experience in involving industry in substantive research, teaming industry's engineers and UM faculty on a one-to-one basis, and involving graduate students in the undertakings as well. A list of projects and investigator-pairs under our current Industrial Research Partnership Programs with General Motors, Ford, and IBM is given in Appendix G.2.

While we have been quite successful in industrial interactions at all three levels discussed above, to reach ERC program goals, these interactions need to meet a new two-part challenge: system integration and research-education synergism. The letters of endorsement from the key companies already committed to in-depth involvement in ERC research and education, as shown in Appendix H, indicate their understanding of this challenge and their intention to help us meet it.

While we are pleased with the industrial interactions we already have at this time, we plan to make continuous efforts to extend and deepen them, especially after ERC funding is assured. Specifically, we will give frequent briefings to selected companies interested in integrated manufacturing (we have given briefings to over 60 companies in the last two years, as shown in Appendix G.3), and we plan to hold annual research conferences that will attract additional companies that may wish to interact with us at any of the three levels. Furthermore, our experience corroborates the findings of NSF's research on industry-university cooperative research (NSF, 1984). Specifically, successful cooperative projects rest on an existing foundation of social and professional exchange between university and industry participants. For the purpose of nurturing such exchanges, the Center will allocate a certain portion of its ERC support to fund selected faculty on a number of "getting-to-know-you" projects, through which they will work informally with their industrial counterparts on critical portions of the system-integrative research agenda determined by the Management Committee.

Recognizing the ITI connection as one of our unique strengths, the Center will seek indirect industrial interactions (especially with small and medium-sized firms) through ITI to complement the Center's direct interactions with major companies. A tangible form of this indirect interaction may be a three-way tie among Center-ITI-industry on those projects that are particularly system-oriented. Furthermore, CRIM has been engaged in a number of projects, and expects to have many more, sponsored by individual companies (IBM, GM, General Dynamics, etc.). We anticipate synergism between the ERC-supported projects on generic problems and the individual-company-supported projects on specific applications. As evidenced by the letters in Appendix H, some of our current project sponsors consider that ERC support will not replace their sponsorship but instead will enhance the benefits they derive from the projects they are now sponsoring, and they are, therefore, likely to support us even more in the future.

Our experience in industrial interactions also confirms another finding of NSF's research on research. A number of initial concerns on the part of industry, such as patents, publications, and antitrust, have little actual importance after the substantive research cooperation gets underway (Tornatzky et al., 1982). The UM will use its extensive experience in working with industry to ensure mutually beneficial arrangements with respect to ERC activities. Appendix G.7 gives the UM's position on general issues of intellectual property.

3. HIGHLIGHTS, MILESTONES, AND IMPACTS

The momentum that the College has achieved in the last three years for integrated manufacturing was described in Section 1. The mechanisms through which the College will use the ERC support to move aggressively toward integrated manufacturing research and education were described in Section 2. The highlights of this dynamic process are tabulated below. The first column lists the momentum, the second the planned expansion with ERC, and the third the intended improvement and impact. The sections or appendices in which the corresponding details are described are indicated in parentheses. The list of highlights is categorized approximately into industrial interaction, research, and education and is presented in that order.

Highlights Of The CRIM Dynamics

Momentum	Expansion with ERC	Improvement/Impact Sought
• 3-year history of CRIM (1.1)	• New CRIM (1.5, 2.1)	• Large-system integration
• National Advisory Committee (G.1)	• External Advisory Board (2.1, 2.5)	• Policy-level industrial interaction focused on integrated manufacturing
• Industrial Partnerships Program - GM, Ford, IBM, Gen. Dyn. (G.2)	• Project Steering Committee working with Management Committee, emphasizing system integration (2.1, 2.2, 2.5)	• Project and system integration; synergism between generic and specific problem-solving relevant to industrial needs
• Industrial briefings and Affiliates Programs (G.3-4)	• Annual Research Conferences and research task participation (2.5)	• In-depth substantive interactions with industry
• Getting-to-know-you projects (2.5)	• Integration with ERC project initiation and selection procedure (2.2)	• Proactive matching of new faculty capabilities with new industrial needs
• U.S.-Japan Auto Study (K.2) and OECD Auto Study (K.6)	• Inclusion of strategic management as one of the four research areas (2.2, D)	• Interaction with strategic decision makers in industry

Momentum	Expansion with ERC	Improvement/Impact Sought
• U.S. Air Force Mfg. Science Ctr. project (1.1)	• Coordination with ERC project cluster (2.1, 2.2)	• Synergism between basic research and generic problem solving
• NSF grants for mfg. research projects on casting, etc. (P.4)	• Coordination with ERC project cluster (2.1, 2.2)	• Synergism between basic research and mfg. system research
• Robotics equipment and CNC lathes/milling machines (F.4-5)	• Access to testbeds in industry and demonstration of cell-level production research (B, F)	• Testing cell-level production ideas in industrial setting
• Major on-campus system-level testbeds at ITI and SRC center (F.1-2)	• Demonstration of ERC project results in plant-level production (C)	• Maximum utilization of expensive mfg. system R & D facilities
• Advanced distributed computing environment (F.6)	• Linkage to design lab at industry for demonstration of design research (A)	• Testing out design process improvements in industrial setting
• SRC Program in automation of semiconductor mfg. automation (M)	• Research in dynamic production control (C)	• Demonstration of production control to improve yield and equipment utilization
• Center for Ergonomics (P.5)	• Inclusion of ergonomics principles in research and education (A,B,C)	• Give appropriate consideration to worker safety and health in integrated manufacturing
• Revised and new courses in manufacturing (I.3.1))	• Two multi-level, cross-listed mfg. system science & engineering courses (2.4, I.2.1)	• Interdisciplinary courses involving undergraduates and research faculty
• Manufacturing Systems Engineering Program for master's students (I.4)	• Modification of curricula and qualifying exams in relevant departments (2.4, I.1.2)	• Attract more undergraduate and Ph.D. students into mfg.

Momentum	Expansion with ERC	Improvement/Impact Sought
• Student team projects (2.4, P.2)	• Master's theses and projects done at industry (I.1.2)	• Education in system integration to meet industrial needs
• Engineering Summer Conferences (I.3.2)	• Structured curriculum for continuing education (I.1.3)	• More systematic retraining of mfg. engineering in industry
• TV course in Robotics to Ford (I.3.2b)	• Use of video tapes and TV broadcast for continuing education (I.1.3)	• Larger-scale retraining of mfg. engineers in industry
• Award-winning textbook by Koren (1.1)	• Additional books, laboratory manuals, computer software for integrated mfg. (I.2)	• Increased knowledge diffusion
• Consolidation of Computer Science and Computer Engineering (1.3)	• Involvement of computer scientists in database and intelligent control issues (2.2)	• Fundamental attack on generic problems underlying computer-integrated mfg.
• A $30M new engineering building and $1.1M renovation of an existing building (1.3)	• Use of the renovated building as new home of the expanded CRIM; access to $10M semi-conductor lab in the new building (1.3)	• Physical integration of mfg. system eng. research and education
• Several million dollars per year of research support (1.1, G.2)	• Substantial, sustained funding for a cluster of interrelated research projects and education (2.2, 2.4, 4)	• Systematic and consistent approach to integrated mfg. and effective dissemination of results to industry

UM's manufacturing activities to the present have emphasized components and subsystems. With ERC support, these activities will move vigorously toward the large-system integration necessary to improve the international competitiveness of the U.S.. Anticipated research results are given in Appendices A through D and will not be repeated here. We anticipate the following milestones at the end of 1st, 3rd, and 5th years:

End of the First Year (1986)

Infrastructural Building:

- Arrangements for in-depth industrial participation at the project level (for the ERC project cluster) completed and starting to work.
- Selection of generic testbeds with detailed specifications for needed equipment.
- Planning process involving faculty in all relevant departments set in motion and educational innovations (special courses, etc.) ready for experimentation.

Substantive Results:

- Preliminary results of several research projects expected. For example:
  - — Understanding of obstacles to design integration and productivity improvement.
  - — Graphical programming methods that include sensor and actuator operation and manufacturing cell simulation.
  - — Assessment of current state of the art of technology-based strategic planning.

End of the Third Year (1988)

Infrastructural Building:

- The Center (new CRIM) located in a building devoted exclusively to its use.
- Regional educational network well established.

Substantive Results:

- Several demonstrations of system integration on related testbeds.
- Significant results of several research projects expected. For example:
  - — Methods for including manufacturability and worker safety in creative and in optimum product design.
  - — Algorithms for integrated sensor-based control of a manufacturing cell.
  - — Integration of path planning with CAD system.
  - — Construction of a model for effective sociotechnical innovation
- Preliminary results of educational innovations, involving at least 10% of the graduate students and a major portion of the undergraduates, ready for assessment.

End of the Fifth Year (1990)

Infrastructural Building:

- Infrastructure for cross-disciplinary research and education in integrated manufacturing well in place at UM.

Substantive Results:

- Significant impact on integrated manufacturing in industry, traceable to ERC activities at UM, leveraged through projects sponsored by individual companies and agencies. For example:

  — Implementation of system integration for optimal design.

  — Integration of NC manufacturing cell with assembly station.

  — Dynamic production control to reschedule and reroute parts in process.

  — Improved rationale and process for strategic exploitation of new integrated manufacturing capabilities.

- New books published on integrated manufacturing.
- Knowledge transferred to industry and a new curriculum for continuing education of integrated manufacturing well established.

In sum, we expect the five-year ERC support to have an enormous impact on the UM College of Engineering's capabilities for system integration in both research and education. The resulting cultural change as well as substantive accomplishments will enable the College to contribute to the U.S. industry's sustained international competitiveness. If replicated by all the ERCs across the nation, the consequence may well be the greatest shift in U.S. engineering education since the Sputnik era.

UM COLLEGE OF ENGINEERING

JOINT MSE-MBA PROGRAM

JOINT MSE/MBA PROGRAM:

Experience has shown that a primary source of new jobs arises from the creation of new companies and industries. Key in the development of such companies is a cadre of aggressive entrepreneurs capable of understanding the key technologies involved as well as the necessary skills for the startup of small businesses.

To assist in expanding Michigan's entrepreneural base, the University of Michigan College of Engineering and School of Business Administration propose to develop a new graduate program aimed at producing graduates with strong skills both in small business startup and technology management. This sixty credit hour program would take BS Engineering graduates and provide them not only with the additional technical education to bring them to the cutting edge of technology in their particular field, but beyond that would provide them with the business and management skills necessary for entrepreneurial and technology management activities. Graduates of this two year program would receive both an MSE degree and an MBA degree from the respective schools.

The University of Michigan is seeking sustained funding from the State of Michigan both to support the additional faculty needed for the conduct of such a program as well as the financial aid necessary to attract most outstanding students into this field. Base funding at a level of $2 million per year is sought for this program.

APPENDIX D
CAPITAL FACILITIES

- Research Projects Laboratory
- Incubation Center

EXPERIMENTAL RESEARCH PROJECTS LABORATORY

The College of Engineering is in desperate need for flexible laboratory space suitable for large interdisciplinary research projects. Research activities in areas such as automated manufacturing, materials science, and chemical processing require facilities which generally cannot be provided by typical classroom/laboratory buildings. In most universities, there has been a major effort to build such flexible space that can then be assigned to research projects for a limited duration. In all such cases, the research projects conducted in these facilities are supported from outside grants and contracts. Hence, the indirect cost recovery generally covers both maintenance and energy costs of such facilities.

The College of Engineering seeks State support at a level of $20 million to build a 200,000 nsf facility to support these activities.

INCUBATION SPACE

To provide companies with immediate access to students, faculty, and facilities of the College of Engineering, the College of Engineering proposes to build an incubation center adjacent to its academic buildings. This incubation center would provide Michigan companies with satellite laboratory and office facilities so that they can interact directly with the College of Engineering staff, employ engineering students, and have access to the College of Engineering research facilities. We believe such an incubation center would not only provide an important resource to Michigan industry and small business development but moreover it would provide an excellent mechanism for technology transfer from the campus into the private sector.

Although we anticipate that rental charges paid by participating companies would cover the operating cost of this facility, there would be some necessity for startup funding from the State to build the facility. We are requesting $10 million in State support as the State's component in a matching fund effort with the private sector to develop such facilities.

APPENDIX E
SUPPORTING DOCUMENTATION

- Fact Sheets on the UM College of Engineering
- Examples of Role in Economic Development
- Efforts in Other States

CHARACTERISTICS OF

THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING

UM COLLEGE OF ENGINEERING

FACT SUMMARY

REPUTATION:

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

TRADITION:

- UM has 7th oldest engineering college.
- It ranks 3rd in total number of degrees awarded (50,000).
- 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:

• Enrollment (1984):	Undergraduates	4,512
	Masters	1,041
	Doctorates	539
	Total	6,092
• Degrees (1984):	B.S.	1,210
	M.S.	584
	Ph.D.	93
	Total	1,887

- Ranks 4th nationally both in enrollment and degrees.

STUDENT QUALITY:

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

FACULTY CHARACTERISTICS:

- 320 faculty members.
- Over 100 new faculty will have been hired in period 1980-85.
- 650 research staff.

RESEARCH ACTIVITY:

- $25 million per year in federally-sponsored research (plus an additional $12 million in affiliated institutes).
- Research in all areas of science and technology.
- 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:

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

UM COLLEGE OF ENGINEERING

A TRADITION OF EXCELLENCE

SOME PARAMETERS:

- UM has 7th oldest engineering college.
- It ranks 3rd in total number of degrees awarded (50,000).
- 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:

• Metallurgical Engineering	1854
• Naval Architecture	1881
• Chemical Engineering	1901
• Aeronautical Engineering	1916
• Nuclear Engineering	1953
• 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:

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

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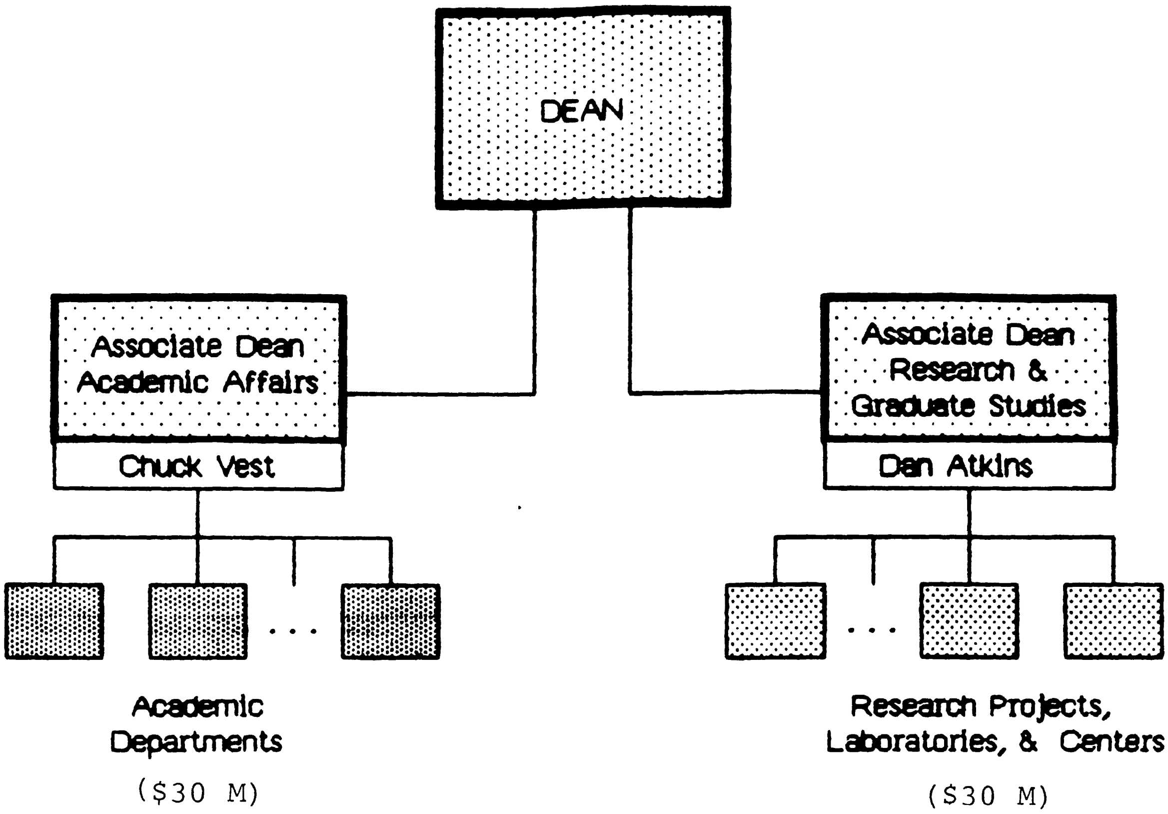
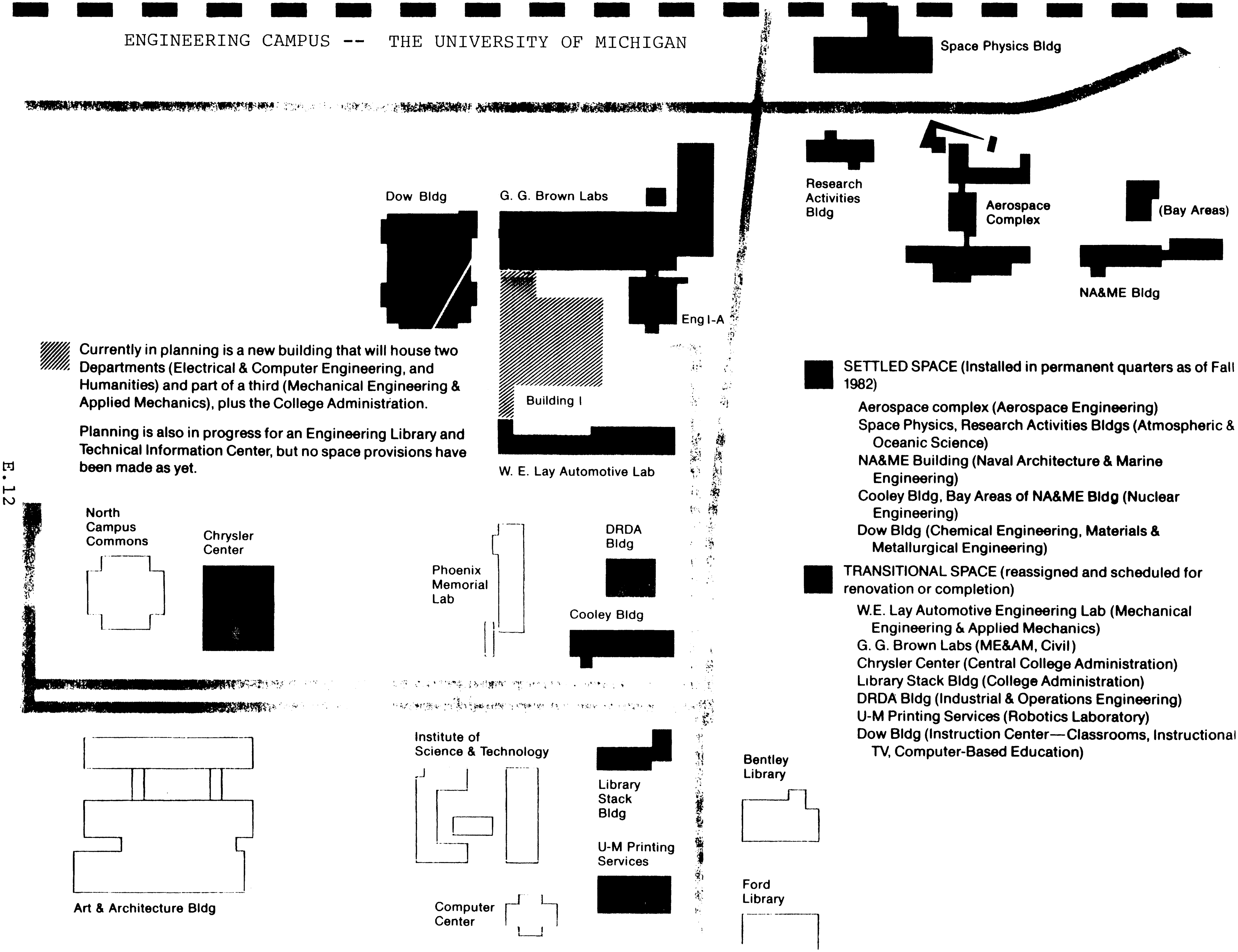
UM COLLEGE OF ENGINEERING

ADMINISTRATIVE STRUCTURE



ENGINEERING CAMPUS -- THE UNIVERSITY OF MICHIGAN



Currently in planning is a new building that will house two Departments (Electrical & Computer Engineering, and Humanities) and part of a third (Mechanical Engineering & Applied Mechanics), plus the College Administration.

Planning is also in progress for an Engineering Library and Technical Information Center, but no space provisions have been made as yet.

SETTLED SPACE (Installed in permanent quarters as of Fall 1982)

- Aerospace complex (Aerospace Engineering)
- Space Physics, Research Activities Bldgs (Atmospheric & Oceanic Science)
- NA&ME Building (Naval Architecture & Marine Engineering)
- Cooley Bldg, Bay Areas of NA&ME Bldg (Nuclear Engineering)
- Dow Bldg (Chemical Engineering, Materials & Metallurgical Engineering)

TRANSITIONAL SPACE (reassigned and scheduled for renovation or completion)

- W.E. Lay Automotive Engineering Lab (Mechanical Engineering & Applied Mechanics)
- G. G. Brown Labs (ME&AM, Civil)
- Chrysler Center (Central College Administration)
- Library Stack Bldg (College Administration)
- DRDA Bldg (Industrial & Operations Engineering)
- U-M Printing Services (Robotics Laboratory)
- Dow Bldg (Instruction Center—Classrooms, Instructional TV, Computer-Based Education)

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

<u>TRADITION</u> 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)

<u>MISSION</u> FOR NATIONAL LEADERSHIP:

- Integrated Manufacturing
- Materials Processing Technology
- Biotechnology
- Computer Science and Engineering

<u>POTENTIAL</u> 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:

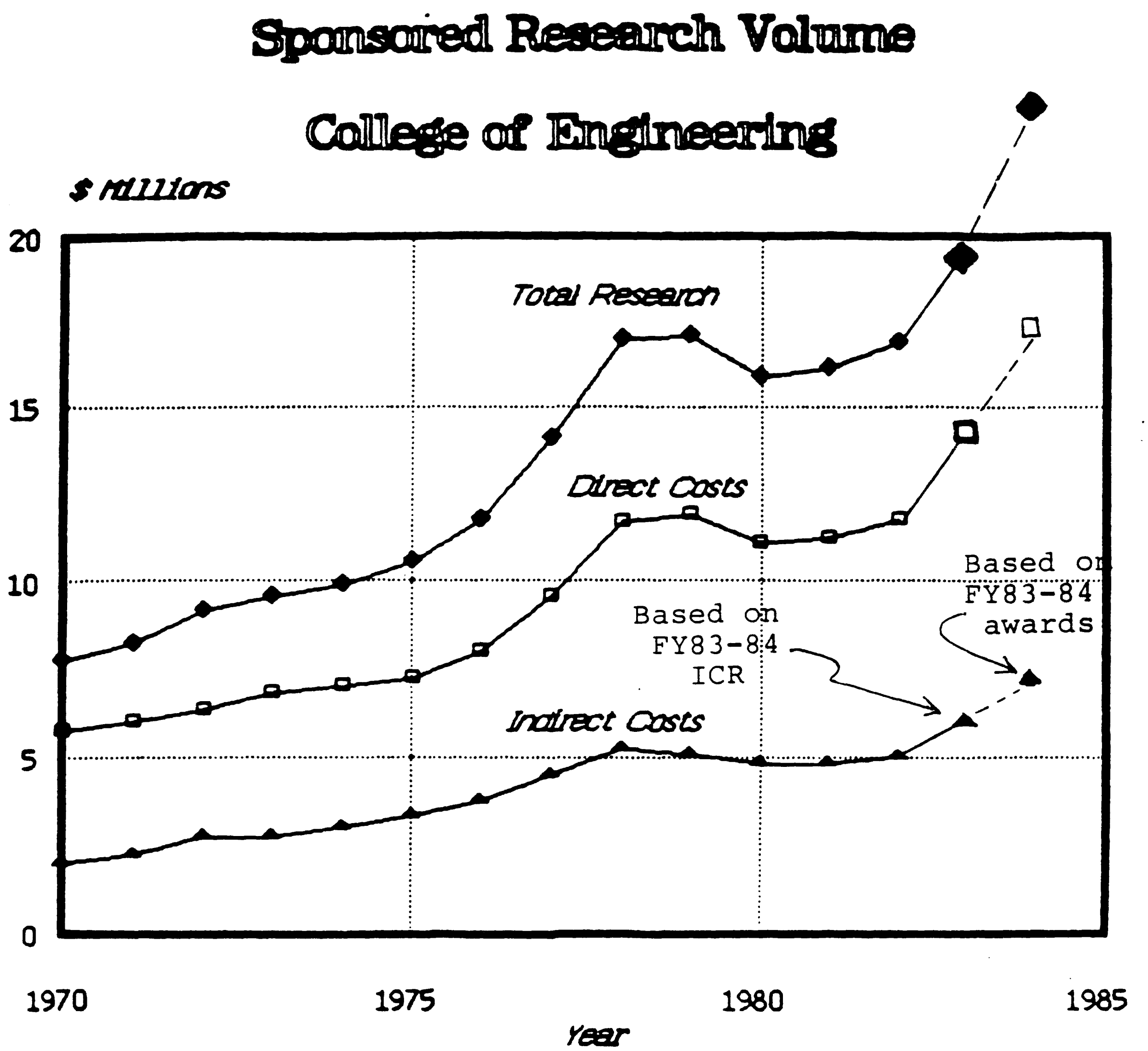
Computer Science and Engineering (CCS + ECE --> EECS)
Applied Physics (Physics, Nuclear, ECE, MME)
Materials Research (Physics, Chemistry, MME, ChE)
Numerical Analysis and Scientific Computation (Eng, Math)
Earth and Planetary Sciences (A&OS, Geo Sci)
Biotechnology (Bio Sci, Chem, ChE, ECE)

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)



Sponsored Research Volume
College of Engineering
$ Millions
20
15
10
5
0
1970
1975
1980
1985
Year
Total Research
Direct Costs
Indirect Costs
Based on FY83-84 ICR
Based on FY83-84 awards

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UM COLLEGE OF ENGINEERING

BASIC STRATEGY

THE MICHIGAN PHILOSOPHY:

- Excellence in education, research, service.
- To stress quality over breadth and capacity.
- To focus resources to achieve national leadership in selected areas.
- Goal: To be the best in what we choose to do!

BA`IC STRATEGY:

- To build peaks of extraordinary excellence!
- To identify those areas in which we have the capacity, the potential, or the mission to become the best, and then to focus resources to build and strengthen these areas.

EXAMPLES OF THE ROLE OF
THE UM COLLEGE OF ENGINEERING
IN ECONOMIC DEVELOPMENT

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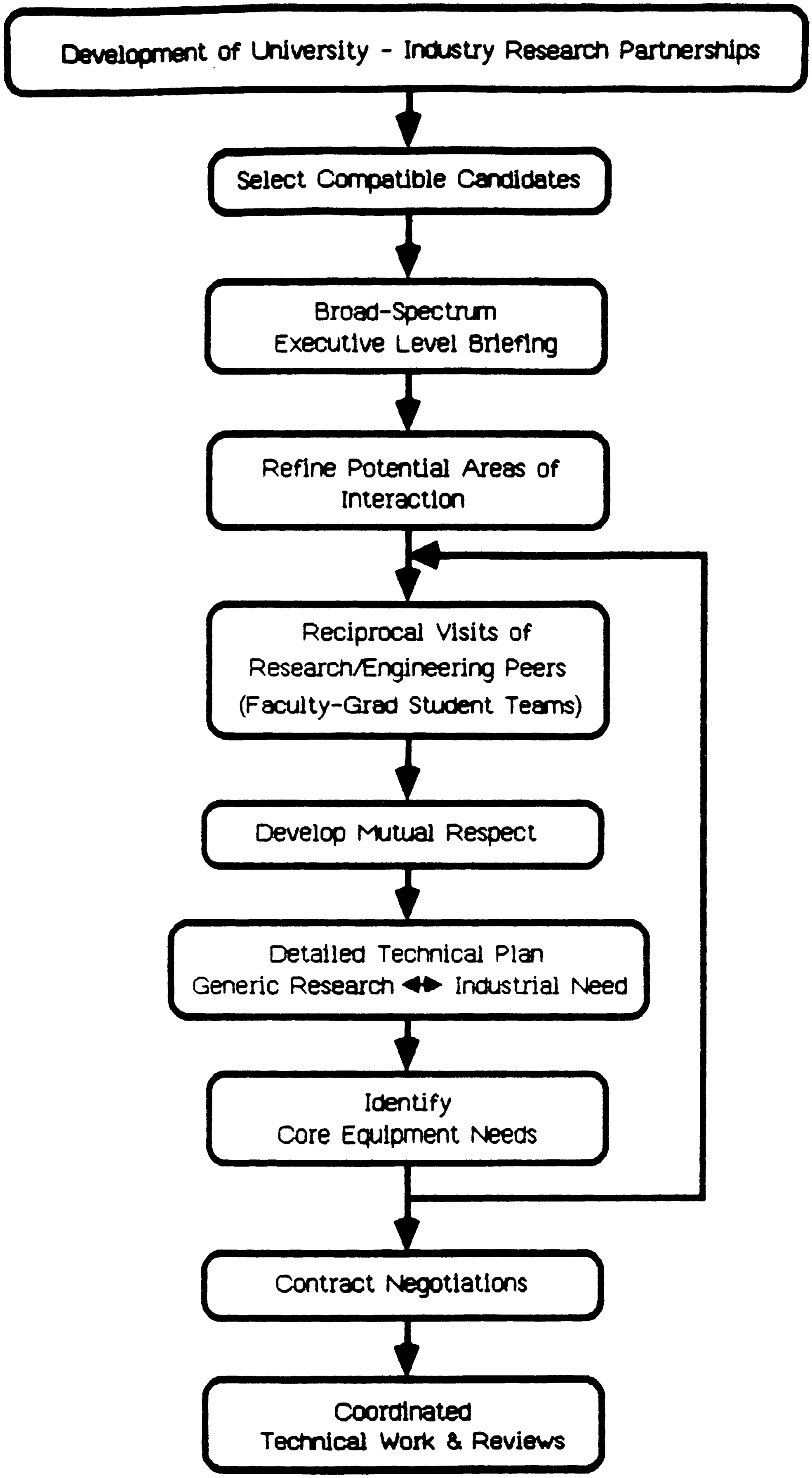
EXAMPLES OF ACTIVITIES OF UM COLLEGE OF ENGINEERING RELATED TO ECONOMIC DEVELOPMENT

1. Center for Research on Integrated Manufacturing
2. Industrial Technology Institute
3. NSF Engineering Research Center
4. Computer-Enhanced Productivity Project
5. Center for Ergonomics
6. Electrical Engineering & Computer Science
7. SRC Center of Excellence in Microelectronics
8. AFOSR Center of Excellence in Robotics
9. Software Engineering Institute
10. Materials Research (MMI, MMPI)
11. National Supercomputer Center
12. Center for Applied Optics
13. Artificial Intelligence Program
14. Industrial Affiliates Programs
15. Research Partnerships
16. Spinoffs. . .
17. Continuing Engineering Education
18. Regional and State Economic Development

INDUSTRIAL AFFILIATE PROGRAMS

- Solid-State Electronics
- Robotics
- Flow Reaction and Porus Media
- Colloidal and Surface Phenomena
- Information Systems Engineering
- Computer-Aided Manufacturing
- Construction Engineering
- Ergonomics


Development of University - Industry Research Partnerships
Select Compatible Candidates
Broad-Spectrum Executive Level Briefing
Refine Potential Areas of Interaction
Reciprocal Visits of Research/Engineering Peers (Faculty-Grad Student Teams)
Develop Mutual Respect
Detailed Technical Plan
Generic Research ◄► Industrial Need
Identify Core Equipment Needs
Contract Negotiations
Coordinated Technical Work & Reviews

1/26/84

EXAMPLES OF INDUSTRIAL - COLLEGE RESEARCH PARTNERSHIPS

- General Motors Tech Center - "Factory of the Future" Project
- IBM (Kingston) - Supercomputer & Robotics
- Ford - Solid-State Electronics, Ergonomics, Optimal Design
- Intel - Object-Based Computing Structures
- Semiconductor Research Corporation - Flexible Automation of IC Fabrication
- General Electric Calma - Computer-Aided Design
- General Dynamics - Distributed Computing Systems for Automation
- Bechtel - Computer Integrated, Large-Scale Construction

UNIVERSITY OF MICHIGAN COLLEGE OF ENGINEERING & GENERAL MOTORS MANUFACTURING ENGINEERING PROJECTS

- Wrinkling Phenomena in Sheet Metal
- Dynamic Simulation of Electrical Resistance Spot Welding
- Mechanism of Surface Formation
- Adaptive and Sensor Based Control of Machine Tools
- Real-Time Adaptive Scheduling
- Distributed Computer Systems
- Manufacturing Cell Modeling

EXAMPLES OF DIRECT PARTICIPATION IN STATE ECONOMIC DEVELOPMENT

- Initial and Continuing Support of the Industrial Technology Institute
- Technical Presentation in Bid for Microelectronics and Computer Corp.
- Affiliations and Research Partnerships with Michigan Companies
- Support of MRC, MTC, Tech Park Initiatives
- Briefings for Potential High-Tech Neighbors
- Consultation with State Government: Computing and Information Systems
- Climate for Entrepreneurial Activities
- Bid for Regional Supercomputer Center
- Expansion and Maintenance of SCRIPT

EXECUTIVE BRIEFINGS
CONDUCTED BY THE COLLEGE OF ENGINEERING

The College of Engineering frequently conducts Executive Briefings for many of the leading corporations in this nation. In these briefings, key officials of the College (deans, faculty, research directors) meet with teams of senior-level executive officers of the corporation for a daylong series of technical presentations, facilities tours, and discussions. A list of the major Executive Briefings conducted during the 1983-84 academic year is provided below, along with the site of the briefing(s):

A.D. Little (campus)
Air Force Office of Scientific Research (campus
AMOCO (Chicago)
Apollo Computer (campus, Boston)
Apple Computer (campus, California)
AT&T (campus, New York)
Bechtel (campus, Ann Arbor, San Francisco)
Bell & Howell (Chicago)
Bell Laboratories (campus, New Jersey)
Bendix (campus, Southfield)
Burroughs (campus)
Calma (campus, California)
Chrysler Corporation (campus, Detroit)
Consumers Power (campus, Jackson)
Department of the Army (campus)
Detroit Edison (campus, Detroit)
DeVilbiss (campus, Ann Arbor)
Dow (campus, Midland)
Downriver Development Corporation (campus)
Eaton (campus, Cleveland)
Ex-Cell-O -- Ray-Con (campus, Ann Arbor)
Ford Motor Company (campus, Dearborn)
General Electric (campus, Connecticut, New York)
General Motors (campus, Warren, Detroit)
Gould, Inc. (campus, Chicago)
Harris Corporation (campus, Florida)
Hewlett-Packard (campus, California)
Hughes (campus)
IBM (campus, Florida, New York)
Intel (campus, California)
International Harvester (Chicago)
Lockheed (campus, California)
MDSI (campus, Ann Arbor)
Michigan Bell Telephone Company - Ameritech (campus)
Michigan Technology Council (campus)
Office of Naval Research (campus)
Schlumberger (campus, New York)
Semiconductor Research Corporation (campus)
Siemens AG (campus)
TRW (campus, California, Cleveland)
United Technologies (campus, Connecticut)
Whirlpool

APPENDIX G. INDUSTRIAL INTERACTIONS

G.1. COLLEGE OF ENGINEERING NATIONAL ADVISORY COMMITTEE

This committee, consisting of leaders from industry, labor, and government agencies, provides policy advice to the UM Dean of Engineering. The current members are:

Dr. Richard E. Balzhiser
Executive Vice-President, Research
Electric Power Research Institute
Palo Alto, CA

Dr. Arden L. Bement
Vice-President, Technical Resources
TRW, Inc.
Cleveland, OH

Dr. Joseph Boyd
Chairman
Harris Corporation
Melbourne, FL

Dr. William Brown
President
ERIM
Ann Arbor, MI

Mr. Dwight D. Carlson
President
Perceptron, Inc.
Farmington Hills, MI

Mr. James M. Chandler
Executive Engineer
V6/V8 Car Engineering
Ford Motor Company
Dearborn, MI

Dr. W. Dale Compton
Vice-President for Research
Ford Motor Company
Dearborn, MI

Ms. Lynn Conway
Computer Research Manager
DARPA/IPTO
Arlington, VA

Mr. Ted Doan
Chairman
Doan Resources
Midland, MI

Mr. Robert J. Eaton
Vice-President
General Motors Corporation
Warren, MI

Dr. Robert A. Frosch
Vice-President
General Motors Corporation
Warren, MI

Mr. Robert A. Fuhrman
Group President
Missiles, Space & Electronics Systems
Lockheed Corporation
Sunnyvale, CA

Mr. L. D. Gschwind
Vice-President
Chrysler Corporation
Detroit, MI

Mr. Charles Heidel
President
Detroit Edison Company
Detroit, MI

Mr. Carl Hirsch
Vice-President
Dana Corporation
Toledo, OH

Mr. Robert D. Hornbeck
Executive Vice-President, Technology
Aluminum Company of America
Pittsburgh, PA

Dr. Robert R. Johnson
Senior Vice-President
Engineering & Information Systems
Energy Conversion Devices, Inc.
Troy, MI

Dr. Mounir M. Kamal
Technical Director
Mechanical and Electrical Engineering
General Motors Research Laboratories
General Motors Technical Center
Warren, MI

Dr. Richard Kashnow
Prod. General Manager
Lighting Business Group
General Electric Company
Cleveland, OH

Dr. William R. Kiessel
Vice-President
Manufacturing Services
Eaton Corporation
Cleveland, OH

Mr. Robert C. Kirkby
Vice-President
Detroit Edison Company
Detroit, MI

Dr. Kaye D. Lathrop
Assoc. Dir. for Engineering Sciences
Los Alamos National Laboratory
Los Alamos, NM

Mr. Dave Nelson
Vice-President
Apollo Computer
Chelmsford, MA

Ms. Thelma Peterson
President
Precision Spring Corporation
Detroit, MI

Dr. Joseph Rowe
Vice-Chairman and Chief Tech. Officer
Gould, Inc.
Rolling Meadows, IL

Mr. William J. Schlageter
Vice-President
Michigan Bell Telephone Company
Detroit, MI

Mr. John D. Selby
Chairman of the Board and President
Consumers Power Company
Jackson, MI

Mr. Raymond J. Smit
Partner
McNamee, Porter & Seeley
Ann Arbor, MI

Dr. Jerome A. Smith
President
Industrial Technology Institute
Ann Arbor, MI

Dr. James R. Street
President
Shell Chemical Company
Houston, TX

Dr. John Ullrich
Vice-President for Manufacturing
Engine and Foundry Division
International Harvester
Chicago, Il

Mr. Howard W. Wahl
Vice-President and Director
Bechtel Power Corporation
Gaithersburg, MD

Mr. John W. Weil
Chairman
Modular Bio Systems
Bloomfield Hills, MI

Mr. John Withrow
Executive Vice-President
Chrysler Corporation
Detroit, MI

Mr. Howard Young
Special Consultant to the President
UAW International Union
Detroit, MI

G.2. INDUSTRIAL RESEARCH PARTNERSHIPS

G.2.1. General Motors Technical Center

Over the past two years, interactions between the College and the General Motors Technical Center Advanced Product Manufacturing and Engineering Staff (APMES) have resulted in a growth in research contracts from a level of just under $500,000 the first year to almost $1,000,000 in the second. The projects have been relevant to manufacturing concerns in the automotive industry today.

These projects have involved at least one faculty member, a corresponding APMES engineer, and doctoral students assigned to each area listed below.

Adaptive and Sensor Based Control of Machine Tools	Chi-Hung Shen (APMES) J. Stein (UM) G. Ulsoy (UM)
Mechanism of Surface Formation	K. Ludema (UM) Chi-Hung Shen (APMES)
Real-Time Adaptive Scheduling	J. Bean (UM) J. Birge (UM) J. Caie, Jr. (APMES)
Distributed Database Analysis and Design	J. Caie, Jr. (APMES) K. Irani UM) T. Teorey (UM) C. Zimmer (Chevrolet)
Wrinkling Phenomena in Sheet Metal	W. Hosford (UM) A. Houchens (APMES)
Optimization of Spot Welding Process	A. Houchens (APMES) W. Yang (UM)
Electrostatic Bell System for Metallic Paints	W. Graebel (UM) H. Lee (APMES)
Commanded Telemetry on an Advanced Machine Tool	S. Birla (APMES) M. Ristenbatt (UM)
Analysis of Surface Waviness Type of Instabilities in Sheet Metal	A. Houchens (APMES) N. Triantafyllidis (UM)
TOTAL PROJECTS	$893,266

G.2.2. Ford Motor Company

Over the past two years, the College's Center for Ergonomics faculty, staff, and students have undertaken several projects to better understand and improve the design of tooling, equipment, and work methods used by workers in Ford Motor Company stamping and assembly operations. Also, ergonomics workshops and briefings provided by the College have trained over 400 Ford engineers and managers, as well as selected vendors in the region. The program has been funded at a level of $1.1 million to date.

The projects are reviewed monthly by at least one of three different ergonomic committees composed of Ford management and engineering staffs and the College of Engineering ergonomics faculty. Some of the current projects and the principal investigators are:

Development of a Computer-Assisted Manual Job Design System	S. Evans D. Chaffin
Evaluation of Operator Reach, Endurance, and Performance in Overhead Operations	S. Wiker G. Langolf D. Chaffin
Development of Visual Display Design Guides for Manufacturing Operations	D. Kochhar D. Pincu
Development of Worker Injury Data Bases and Management Information Systems	G. Herrin L. Fine M. Catterall
Development of Ergonomics Guides for Materials Handling Mechanization	J. Wolstad G. Langolf
Development of Industrial Shoe/Floor Ergonomic Data Base	M. Redfern D. Chaffin
Development of Manual Job Ergonomic Evaluation Procedures	W. M. Keyserling J. Foulke C. Wooley
Development of Powered Hand Tool Ergonomic Guidelines	R. Radwin T. Armstrong

Companies or organizations given special briefings by Ergonomics Faculty in the last year:

Owens Corning Fiberglas	Uniroyal
AMP Inc.	PPG Inc.
Western Electric	Dow Chemical
Firestone Tire and Rubber Company	Zenith
Marathon Oil Corporation	Burroughs
Bundy Corporation	Motor Vehicle Manufacturing Assoc.
United Auto Workers	American Railroad Assoc.
Johnson and Johnson	IBM
Scott Paper Company	Bettcher Industries

G.2.3 IBM Data Systems Division, Kingston, New York

The Kingston, New York, facility of IBM represents one of the company's locations that is engaged in an active research relationship with the College. Kingston is currently supporting five projects totaling almost $500,000.

The active projects and their investigators are:

Optimal Design for Automated Assembly Using Manipulators	W. Hollenback (IBM) R. Volz (UM)
An Optimum Scheduling Algorithm for a Multiprogramming Environment	K. Irani (UM) N. Wadia (IBM)
Automatic Solder Joint Inspection	J. Contino (IBM) E. Delp (UM)
Register Spilling for Compiler Optimization	W. Cummings (IBM) V. Rajlich (UM)
A Replacement Methodology Involving Forecasting Uncertainty	J. Lohman (UM) K. Waddell (IBM)
TOTAL PROJECTS	$458,222

Note: In addition, negotiations are presently underway that are expected to result in three additional projects this year that will total another $284,000.

G.2.4. Calma

The College has benefited from a cost-sharing (2:1) relationship with Calma that has resulted in $1 million in workstation hardware and software that is installed and has been operating for instructional and research purposes.

A proposal for software development in computer-aided design has received favorable reaction, and a project director, Tod Sherman of Calma, has been designated. Professors J. Eisley and R. Phillips will be co-investigators representing the College.

Final approval of this $200,000 research project covering a two-year period is expected in the near future.

G.3. INDUSTRIAL BRIEFINGS

In keeping with the commitment by the College of Engineering to expand its involvement with government and the private sector, formal briefings to more than 60 companies have been held over the past two years. Typically, these briefings include presentations by the College administration, principals of various centers and/or directors of technical programs to familiarize representatives of government and industry with current activities in the College. Typically, visiting representatives bear titles such as president, vice-president of research and development (or engineering, manufacturing, etc.), director, and project manager.

The following is a partial list of recipients of these briefings.

3 COM Corporation
Allied/Bendix Corporation
Amax/Climax Molybdenum
Ameritech Development
Ann Arbor Public Schools System
Apollo Computer
Apple Computer
Arktronics
Army Research Office
AT&T Bell Laboratories
AT&T Communications
Bell Northern Research
Borg-Warner
Burroughs Corporation
Calma Company
Chambre de Commerce &
Industrie de Paris (French Engineers)
Chrysler Corporation
Department of Defense, HQ US
Department of the Army
Detroit Edison
Dow Chemical Company
Dupont
Eaton Corporation
Exxon Office Systems
Federal Mogul Corporation
Ford Motor Company
General Electric Company
General Motors Corporation
General Motors Technical Center
Gould Corporation
Gould Laboratories
Harris Corporation
Hewlett Packard Company
Hoover-NSK Bearing Company
Hughes Aircraft Company
Hughes Research
IBM/Academic Information Systems
IBM/Kingston
Informatics General Corporation
Lockheed Missiles & Space Company
Michigan Bell
Michigan Department of Commerce
Michigan High Technology Task Force
Michigan Technology Council
Northern Telecom
Northrup Corporation
Office of Naval Research
Owens-Illinois Corporation
Robot Institute of America
Saab/Scania
Saginaw Steering Gear Division/GM
Semiconductor Research Corporation
Siemens AG
Sperry/Vickers Company
Strategic Defense Initiative Organization
TRW
United Technologies Research Corporation
United Technologies/Electrosystems Division
US Army Intelligence Center
Vlasic Foods
Volvo of America Corporation
Westinghouse R & D Center
Whirlpool Corporation

G.4. INDUSTRIAL AFFILIATES

Industrial Affiliate Programs permit companies, in return for membership fees used to support research and related education programs, to obtain early access to research results, to participate in research seminars and other special functions, to have ready access to faculty consultants and students, and to enjoy other benefits of a close relationship with a research program.

G.4.1. Solid-State

AT&T Bell Laboratories
Ford Motor Company
General Motors Research Laboratories
Kelsey Hayes Research Center
NCR Corporation
Rockwell International Corp.

Hughes Aircraft Company
Intel Corporation
Collins Transmission System Division
Texas Instruments

G.4.2. Robotics

ASEA
Dana Corporation
General Dynamics
  Land Systems Division
General Electric
General Motors Research Labs
Hoover - NSK Bearing Co.
Intel
Lockheed Missiles and Space Co., Inc.
Northern Telecom Inc.
Perceptron
Volvo of America Corp.
Westinghouse Electric Corp.
Whirlpool

G.4.3. Flow And Reaction In Porous Media Program

Chevron Oil Field Research Co.
Conoco Production Research Div.
Halliburton
Marathon Oil Co.
Texaco

G.4.4. Consortium For Diagnostic Sensing And Control For Metal Cutting

Borg Warner
Caterpillar Tractor Co.
John Deere & Co.
Eaton Corporation
Ex-Cell-O Corp.
General Electric
Giddings and Lewis Machine Tool
Kennametal, Inc.
Lodge and Shipley
TRW, Inc.

G.4.5. Center For Construction Engineering And Management

Bechtel Construction
Project Management Associates
Townsend & Bottum

G.5. MICHIGAN RESEARCH CORPORATION

The Michigan Research Corporation (MRC) is a recently formed for-profit technology transfer company located in Ann Arbor and established for the purpose of facilitating technology transfer between researchers and private industry. The University of Michigan helped initiate MRC by developing its organizational and operational concepts and by investing start-up funds, but it retains no direct involvement in the company.

MRC's operating procedure is to:

(1) Identify technologies and concepts that can be licensed, sold, or developed into saleable products or services.

(2) Raise funds for such developments.

(3) Supervise the development of these opportunities and aid in the commercial exploitation through negotiating sales and licensing agreements and by assisting in the development of companies that will produce the products or services directly or through joint ventures.

Because some 50 patent disclosures are handled annually by the University from its faculty and staff members, the MRC is expected to be of substantial assistance in transferring University research, where appropriate, into commercial applications. MRC offers to UM faculty the advantage of on-campus location, a sensitivity to future market needs, and leadership that combines technological and business expertise.

G.6. ISDOS AND PRISE

The ISDOS (Information System Design and Optimization System) Project was started by Professor Daniel Teichroew in the Department of Industrial and Operations Engineering in 1968. The objective of the project was to develop computer-based tools and methods for information system development. Some major characteristics of the Project were (1) The Project was supported by annual grants from companies and government organizations in the USA, Europe, Japan, and South America; (2) Major effort was devoted to getting the technology adopted in practice; and (3) The Project provided graduate and undergraduate students with practical experience in software engineering. The Project has been extremely successful, receiving over six million dollars in grants over the last decade. By 1983, the use base for the technology had reached a level where sufficient support could not be provided by the ISDOS Project in the University. The Regents of the University of Michigan granted an exclusive license to ISDOS, Inc., a company founded by Professor Teichroew to market and support the technology.

The ISDOS Project has been succeeded by PRISE, the Program for Research in Information System Engineering, which is conducting research in advanced software engineering technology, particularly relating to distributed computing environments employing fourth-generation approaches, including artificial intelligence and expert systems.

PRISE/ISDOS SPONSORS

Industrial

Advanced Technology Corp.	General Electric
Aerospace Corp.	Grumman Aerospace
Aquidneck Data Corp.	Hadron
Arabian American Oil Co.	Hughes Aircraft
British Aerospace - Wharton	IBM - Fed. Systems Div.
Boeing Computer Services (Seattle, WA)	IBM (LASC)
	Israel Aircraft Industries Limited
CACI (Arlington, VA)	L.M. Ericsson Telephone Co.
Digital Equipment Corp.	Metropolitan Life Insurance Co.
Dynamics Research Corp.	Southern California Edison Co.
General Dynamics	Standard Oil Co. of California

U.S. Government Sponsors

Air Force Logistics Command	Army MILPERCHEN
Army ALMSA	National Security Agency
Army Computer Systems Command	TRIMIS
Army FESA	U.S. Dept. of Argiculture Graduate school
Army USAFAC	

G.7. INTELLECTUAL PROPERTY

From an extensive experience in arranging grants and contracts with industrial firms, the University has established effective procedures for negotiating intellectual property considerations in accordance with the Regent's Bylaws. Two attorneys in the University's Office of the General Counsel specialize in intellectual property concerns. They counsel faculty members and departmental administrators in developing appropriate agreements with industrial and government sponsors and collaborating institutions.

As is the case with most peer universities, the University of Michigan's Regent's Bylaws state that the ownership of intellectual property developed with the use of the University's equipment, facilities, or in connection with a University research project resides with the University. The normal procedure is to offer to industrial sponsors the option of either an exclusive or non-exclusive license to inventions developed. For an exclusive license, reasonable royalties are negotiated, and the industrial firm is required to commit itself to effectively using its best efforts to make the benefits of the inventions available to the public at a reasonable cost. This option must be exercised by the company within some reasonable period of time agreed upon in advance.

Software developed at the University is normally marketed through proprietary "know how" licenses arranged with interested licensees.

Because ERC will be working on generic problems rather than special applications, it will not likely be involved with the protection of trade secrets. For any subsequent or related work on specific applications, the University would negotiate a separate contract with the company involved, including appropriate provisions concerning potential trade secrets.

In general, the following guidelines are considered in cases where proprietary material is expected to be accepted or generated in connection with a sponsored research contract or grant:

> Unclassified research sponsored by the private sector may involve a sponsor's proprietary interests. The University resists any requirement for "approval of publication" by a sponsor prior to publication. It does, however, accept contracts containing a provision that the sponsor review a manuscript prior to publication, but in such cases it requires that the period for review be specifically limited. Typical review periods range from one to three months. The University very rarely accepts delays of more than six months. Any recommendations for alteration of a manuscript are subject to approval by the investigator.
>
> Subject to contractual agreements, the University also occasionally agrees to protect (i.e., maintain in secrecy) a sponsor's previously-existing proprietary information provided to it in connection with the research. Such agreements must be approved in advance by the President of the University.

1. INTRODUCTION

It is widely acknowledged that the decline of U.S. competitiveness in manufacturing has become a national crisis, not only in mature industries such as transportation and machine tools, but also in new ones such as the fabrication of semiconductor integrated circuits. As a leading university in the heart of the American manufacturing industry, the University of Michigan in 1980 made a commitment to work with industry and government to help revitalize and diversify the manufacturing base of the nation in general and the State of Michigan in particular. Under the leadership of a new president, Harold Shapiro, and a new Dean of Engineering, James Duderstadt, the University of Michigan took two major initiatives: (1) the establishment within the College of Engineering of the *Center for Robotics and Integrated Manufacturing (CRIM)* in October 1981 and (2) collaboration with the State of Michigan and private foundations to launch a not-for-profit *Industrial Technology Institute* (ITI). Both institutions focus on *computer-integrated manufacturing systems,* including design, production, and the effective and safe use of humans, machines, and resources.

This proposal to the NSF Engineering Research Center (ERC) Program is to use the ERC initiative to expand and substantially restructure CRIM to address more fully not only the subsystems of manufacturing but also their overall integration; to expand both the depth and breadth of industrial interaction, especially with the major companies of the automotive and semiconductor industries, including General Motors, Ford, Chrysler, and the Semiconductor Research Corporation; and to accelerate the education of a new breed of engineer. The goals of CRIM, to improve manufacturing productivity, quality, and the worker environment through the integration of machines, people, and organization (see Appendix P.1), are a specific instance of the goals of the ERC program. This program is a unique opportunity to move CRIM into a second phase, considerably increasing its effectiveness.

The Industrial Technology Institute, located on the Engineering Campus and growing cooperatively with CRIM, is a free-standing corporation directing the bulk of its programs to applied research and engineering development. Appendix P.10 is a brochure describing ITI, and Appendix H includes a letter from its president, Jerome A. Smith, discussing its present and future relationship with CRIM and the proposed ERC component.

1.1. HISTORY AND STATUS OF CRIM

The interdisciplinary CRIM has, over the past three years, focused and coordinated the traditional strengths of the College on research to improve manufacturing productivity, quality, and the worker environment. It was understood from the start that research oriented to the "factory of the future" was inherently cross-disciplinary and that, therefore, an organization spanning traditional departmental boundaries was needed. It was also apparent that the College had to make a new commitment to partnerships with industry; to a more timely flow of knowledge between university and industry; and to the coordination of new courses, facilities, and degree options.

As part of the strategic plan for the College, CRIM was begun in October 1981 under the leadership of Associate Dean Daniel E. Atkins (Professor of Electrical Engineering and Computer Science) and three faculty research division directors. Initially $1.9M were invested by the College to encourage its best faculty in relevant areas to begin focusing their research on manufacturing, to recruit new faculty to the area, to initiate research partnerships with industry, and to form a research group that could respond to opportunities for coordinated sponsored research in manufacturing systems and robotics. The initial emphasis on manufacturing components was a deliberate choice based on the realization that a system can be only as strong as its components and that system integration of cross-disciplinary research requires time. A Director of Corporate Relations, reporting to the director of CRIM, was appointed to help develop and coordinate industrial linkages.

CRIM now has 43 faculty associates and about 100 participating graduate students spanning six academic departments. Its sponsored research amounts to about $6M per year (half from industry and half from government).

Figure 1.1 is the present organization chart for CRIM. Appendix P (1-4) includes descriptions of faculty and research projects affiliated with each of the three divisions. Appendix P.5 is a description of the nationally known Center for Ergonomics, which for over 25 years has studied the principles of work. The activities of this Center and its education and training component, Occupational Health and Safety Engineering (Appendix P.6), complement and broaden those of CRIM and provide the relevant experience of a center conducting research related to industry and coordinating a companion educational program. Appendix P.7 provides an overview of a UM special-interest group on the socioeconomic aspects of robotics and integrated manufacturing (SEARIM). Faculty research in both groups will be better integrated through the proposed ERC component of CRIM.

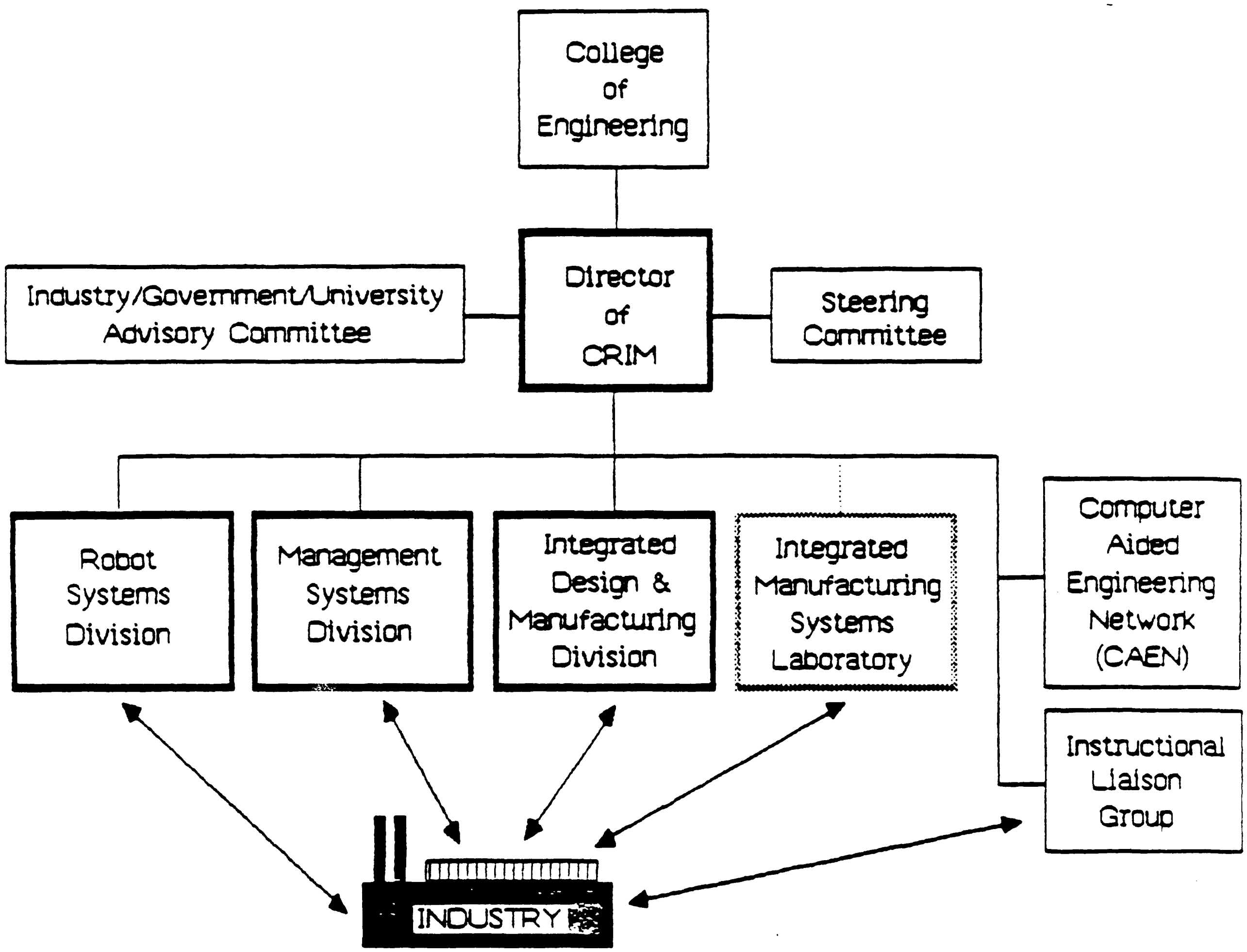


Figure 1.1. Present Organization of the Center for Robotics and Integrated Manufacturing

Appendix P.1-7 defines the research components and infrastructure that are candidates for growth and integration within the proposed ERC component of CRIM. They do not mention faculty members in artificial intelligence, man-machine interaction (cognitive science), and manufacturing cell design that have joined the College within the past academic year. Moreover, the College is committed to hiring a number of additional tenure-track faculty in manufacturing areas over the next several years. Our strategy is to define a set of four linked research areas concerning manufacturing systems, to provide excellent leadership for each area, and to integrate other researchers with the will and the means to contribute to ERC objectives.

A recent review of CRIM, combined with the process of preparing this proposal for the ERC program, has suggested an evolution of the management structure (described in Section 2) and a name change to reflect CRIM's broadening interest. With no intention of diminishing its strong and growing activity in industrial robotics, we will change the name of the Center to *Center for Research on Integrated Manufacturing*. CRIM, the acronym, remains the same.

CRIM was built originally on the foundations of relatively independent projects, such as those sponsored by NSF programs in computer engineering, computer science, productivity research, or mechanical systems. Several new coordinated activities have increased its scope:

- A Center of Excellence in Robotics contract from the Air Force Office of Scientific Research, together with smaller complementary funding from the Army Research Office.

- A multi-investigator research partnership with the General Motors Advanced Product and Manufacturing Engineering Staff, described in a letter from GM Vice-President Robert Eaton in Appendix H.

- Manufacturing research partnerships with IBM-Kingston, General Dynamics, and Ford.

- An award from the Manufacturing Sciences research program of the Semiconductor Research Corporation described in Appendix M.

- A Professional Productivity Program to provide selected research areas with state-of-the-art, networked engineering computer workstations. This program, with strong financial backing from industry, is administered by the Computer-Aided Engineering Network organization. Figure 1.2 illustrates areas being linked during the first phase of this pilot program.

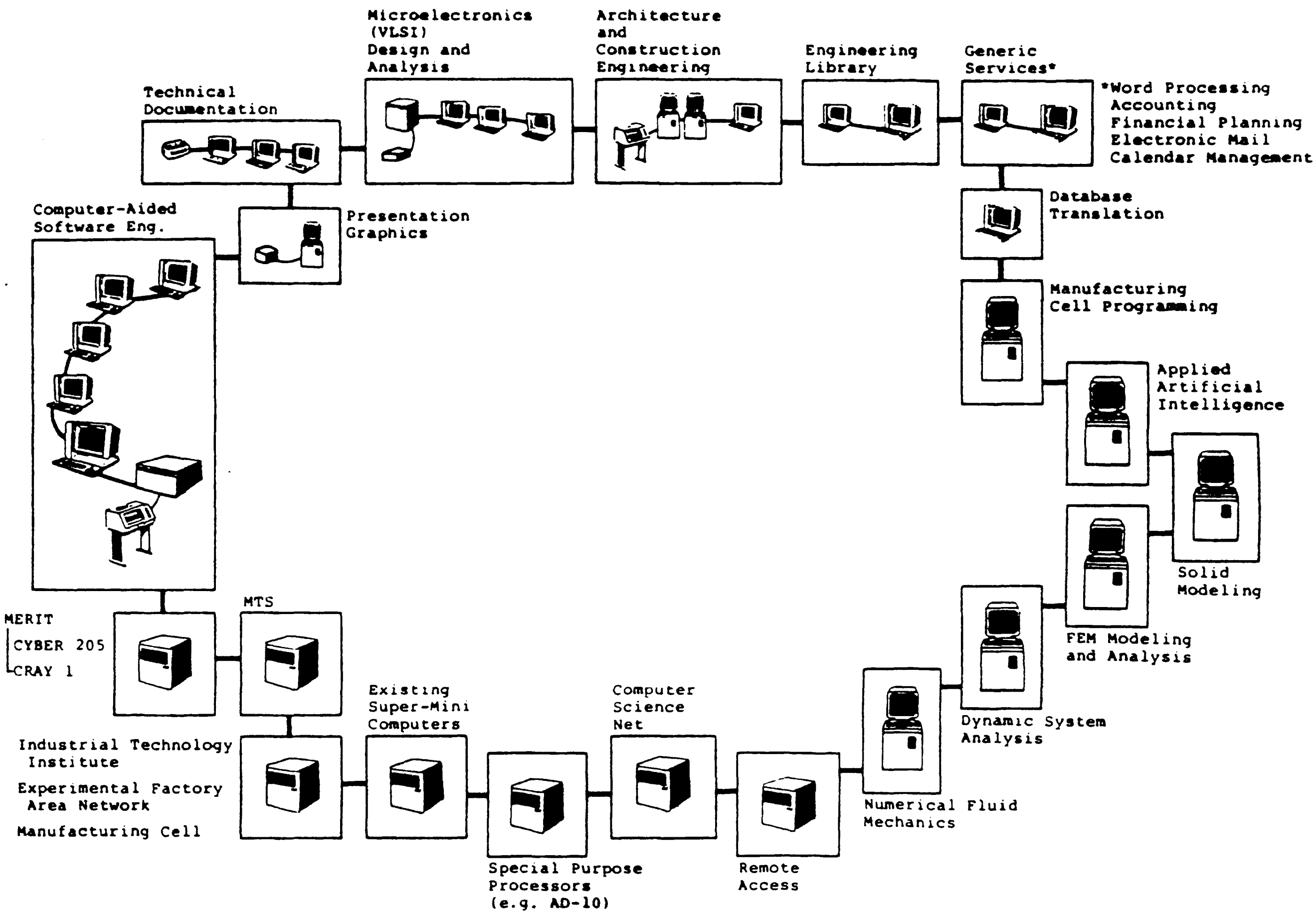


Figure 1.2. The Computer-Aided Engineering Network: An Experiment in Computer-Enhancement

At the same time, CRIM has been instrumental in educational development:

- The Instructional Liaison Committee of CRIM, in the process of developing proposals to several sponsors, produced an inventory of courses in all departments relevant to manufacturing systems and collected proposals from faculty members for augmenting existing courses and creating new ones. It was the basis for creating manufacturing options in several departments as described in Appendix I.4.

- CRIM has sponsored student projects in manufacturing, including the design and fabrication of a spherical coordinate robot shown on page 13 of Appendix P.2.

- CRIM, together with the CAEN, has supported the development of a new mechanical design and analysis course based upon a Calma/Vax mechanical CAD system.

- CRIM has supported the preparation of an award-winning textbook in the area of computer control of manufacturing systems (Koren, 1983).

- Two years ago the College began a high-quality cooperative program with increasing involvement of students interested in manufacturing.

- New industrial research partnerships, most notably with GM, are providing graduate students with in-plant experience to complement their master's and doctoral research in advanced manufacturing.

1.2. THE COMPUTER-AIDED ENGINEERING NETWORK

Central to the "factory of the future" is the evolution of a computing/communication environment to link the various islands of automation, design, and management. In many ways, computer-integrated manufacturing is a natural product of the general computer revolution. Computer-integrated systems are characterized by networks of individual computer workstations, extensive use of "bit-mapped" graphics, and sharing of information via high-speed networks and common file servers. Our own version of this environment is the Computer-Aided Engineering Network (CAEN), a schematic of which is shown in Figure 1.3. The College of Engineering has made a major commitment to building this workstation-based environment for its 6,000 students and 800 staff. CAEN is a large-scale experiment in professional productivity for the College and at the same time an integral part of the supporting infrastructure for CRIM. The brochures in Appendix P include numerous pictures of CAEN facilities now in use. The College's capital campaign to build such a next-generation instructional center is described in Appendix P.8.

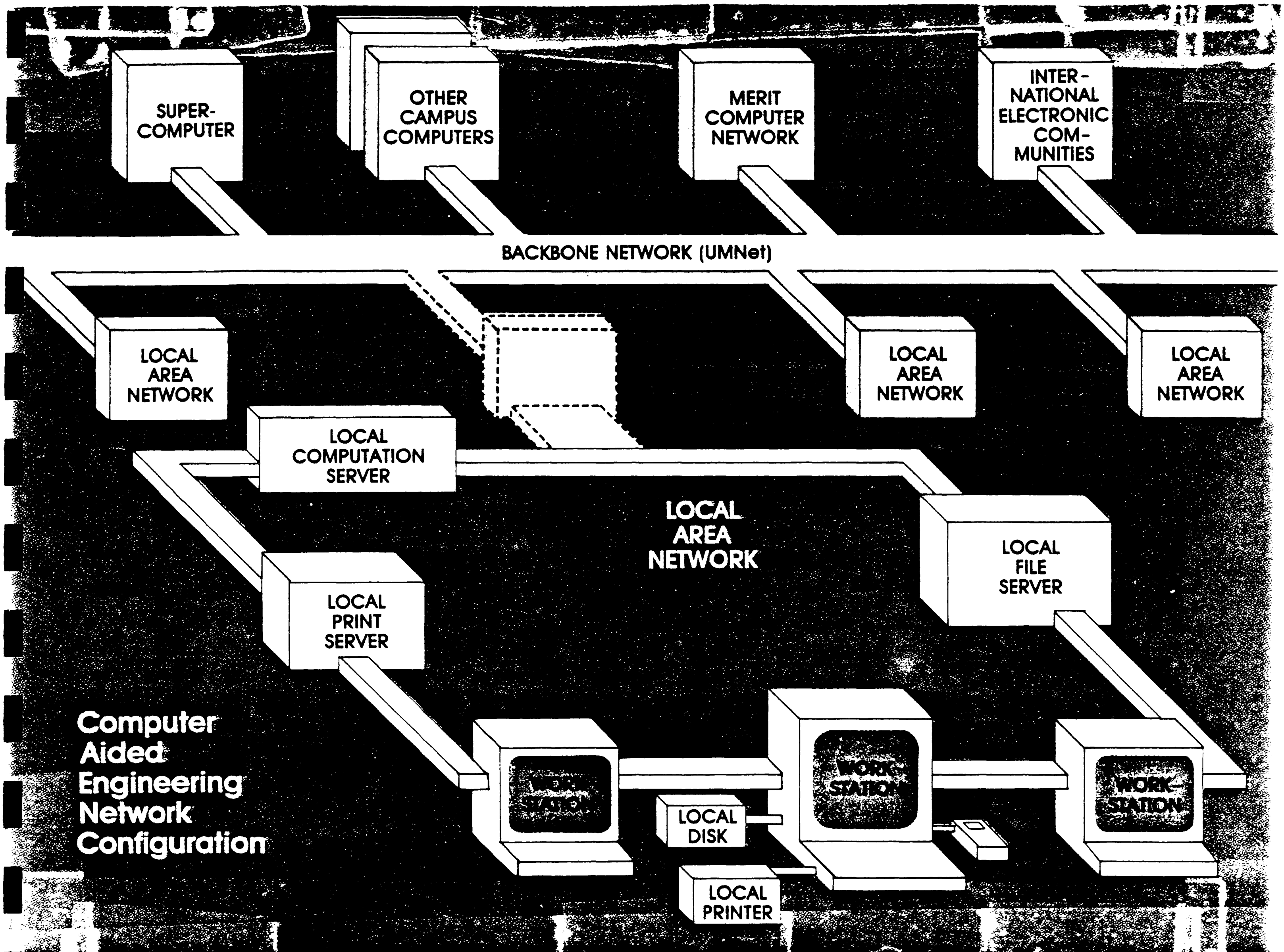


Figure 1.3. Schematic of CAEN

1.3. OTHER DEVELOPMENTS IMPORTANT TO CRIM AND ERC

Other recent developments important to the future of CRIM and ERC are:

- The consolidation of all computer science and computer engineering in a restructured Department of Electrical Engineering and Computer Science (EECS) (see Appendix P.9). Formerly, computer science was distributed across two programs in Engineering and one in the College of Literature, Science, and the Arts. This restructuring brings together into one Engineering department many disciplines, including computer science, communications, artificial intelligence, and microelectronics, central to the technology of manufacturing systems.

- A $30M State-funded building for the EECS Department is under construction. To be completed in about two years, it will include a $10M facility for solid-state electronics research and fabrication and several facilities associated with CRIM, including the testbed for the manufacturing sciences program related to very- and ultra-small integrated circuit fabrication.

- A $1.1M renovation of a 10,000 square-foot building to serve as the temporary (two-year) home for the Industrial Technology Institute and the long-term central facility for CRIM. This building (see Figure 1.4) will include both offices and experimental factory floors. It will become the CRIM building about a year after the initiation of the ERC and will contribute to the physical integration of the proposed research.

- A $1.6M Center Grant from the National Institute for Occupational Safety and Health provided the means to consolidate graduate programs in Occupational Safety Engineering, Industrial Hygiene, and Occupational Medicine in 1982. These combined programs provide a unique resource to ensure that issues of worker health and safety are considered in the strategic management and engineering of future manufacturing facilities.

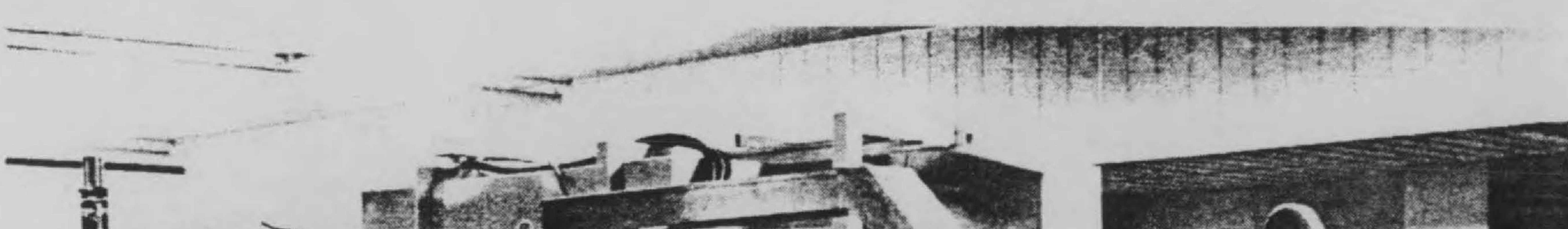


Figure 1.4. Future Home for CRIM

1.4. THEME AND RATIONALE FOR THE ERC - CRIM INITIATIVE

Although CRIM has been fortunate in getting several million dollars of research funding from government and industry, the lack of large, sustained support has hampered its progress toward large-system integration. The potential for such support under the ERC program will enable CRIM to take bold steps toward strategic system integration in manufacturing systems beyond those that universities have customarily been able and willing to take. The theme and rationale for this expansion of CRIM activity is based upon the realization that effective industrial competition requires strategic vision and action (Porter, 1980). A recent University of Michigan study cited four major driving forces in industrial competition: (1) consumer demand for product diversity, (2) flexible manufacturing systems, (3) rapidly evolving technology, and (4) internationalization (Cole and Yakushiji, 1984) (see Appendix K.2 for details). Compared with its major industrial rivals, the U.S. is relatively weak in labor-management cooperation, innovations in mature industries, comparative manufacturing costs, experience in global markets, and workers' general education, especially in mathematics and science (White House, 1984).

It is clear, therefore, from an engineering perspective that we should look at both the unprecedented opportunities offered by technology, yet not lose sight of the socioeconomic contexts within which this technology can make its contributions to international competitiveness (Horton and Compton, 1984; Chen et al./OECD, 1984). ERC will include in its scope not only technological developments in areas such as computer-aided design and manufacturing (CAD/CAM) and flexible manufacturing control but also the human-oriented, non-technical issues, such as the optimal use of equipment and an organizational and behavioral understanding of using new integrated manufacturing technology to increase productivity, quality, and worker safety. We need to make specific suggestions to the strategic decision makers in industry how new manufacturing technology can be used as their competitive weapons (Hayes and Wheelwright, 1984). Inasmuch as academic time and resources are limited, we also need strategic guidance of research and educational activities within engineering colleges in integrated manufacturing.

Based on the above rationale, the main theme for our ERC activities will be *the improvement of manufacturing productivity, quality, and worker environment through a comprehensive and integrated approach to the manufacturing system.*

Although a complete manufacturing cycle that follows the creation of the product from its conceptualization to its shipping includes many steps, the anticipated technological breakthroughs for integrated manufacturing, with profound implications for international competitiveness, center on the integration of product design, cell-level production, and plant-level production (Ofc. of Tech. Assessment, 1984; Kimura, 1984). We propose, therefore, to focus ERC activities on these three technical activities, their interrelationships, and their strategic management, as shown in Figure 1.5 (recognizing that other steps in the manufacturing cycle, such as purchasing, marketing, and servicing are important but not central to the ERC thrust).

The horizontal dimension in Figure 1.5 is time. As a manufacturing company moves through its product planning cycle (from strategy to execution), the emphasis of its technical activities shifts from product design, responding to market demand, to production system planning and control. The purpose of strategic management of these technical activities is to use the capabilities of integrated manufacturing to meet global competition.

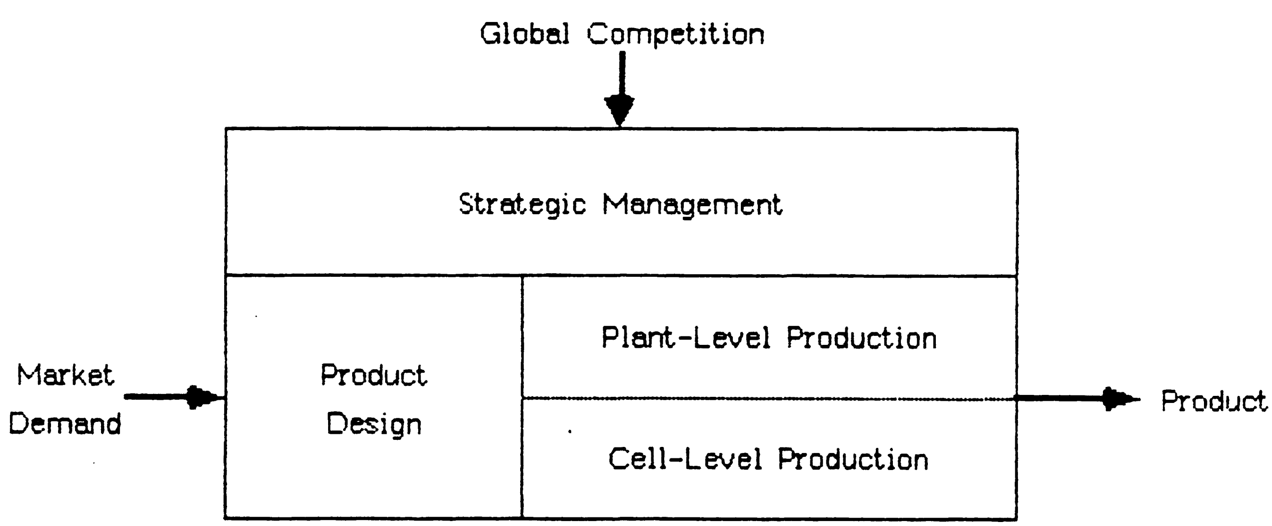


Figure 1.5 Scope of Proposed Research on Integrated Manufacturing

To concentrate on truly significant improvements, the ERC will be guided by the following goals:

- Conduct research to achieve quantum jumps in the next generation of computer-integrated design and manufacturing systems.
- Demonstrate the strategic utility of such systems in industrial settings.
- Educate a new breed of engineer who can contribute to the above.

1.5. THE APPROACH

The ERC approach will be ***cross-disciplinary research and education*** to enhance manufacturing productivity, quality, worker safety, and international competitiveness. *Cross-disciplinarity* will be fostered by concentrating on significant generic problems at the interfaces of the interrelated activities in Figure 1.5 and by using specific manufacturing system testbeds to try out generic solutions. The term "generic" represents the set of problems between basic research problems at one extreme and specific applied problems at the other (Kennedy, 1982).

This approach represents a tremendous challenge for a modern American university, given the long history — and a proud one — of doing largely the opposite: focusing on the separate parts of large systems through research and education in individual disciplines. The UM College of Engineering, however, in concert with the State of Michigan, has clearly begun to meet this challenge.

To build on the current momentum and reach the more ambitious goals noted above, we intend to take the following specific approach:

We will expand CRIM into a major center that can perform large-system integration in manufacturing. The expanded CRIM will be the home for the ERC activities, which will establish new research areas as well as build on existing research on components and subsystems sponsored by a number of private companies (e.g., IBM, GM, and General Dynamics) and public agencies (e.g., NSF, AFOSR, NASA, ARO). ERC research will be aimed at producing demonstrable solutions to generic problems in integrated manufacturing. The demonstrations will be based on experimental research in a number of manufacturing system testbeds, some on or near the UM campus, others in industry. Educational links and industrial involvement in ERC research will permeate all projects.

To achieve large-system integration, the Center will take full advantage of the unique strengths of the UM in integrated manufacturing: the powerful Computer-Aided Engineering Network, close links with the Industrial Technology Institute, and the established connection with the Semiconductor Research Corporation. These strengths include the expensive equipment and manufacturing systems available to the Center through CAEN, ITI, SRC, and local industry. It will also benefit from the availability in the center of the Engineering Campus of a high-quality physical facility uniquely designed and constructed to support research in manufacturing sciences. Consequently, much of the ERC funding will not be needed for the acquisition of expensive equipment (although some upgrading and maintenance of equipment, especially for system interfacing, are requested). Instead, this funding will provide leverage to enable the Center to perform large-system integration, provide long-term stable infrastructural support, and create incentives for professional involvement in research and education in integrated manufacturing. Thus, the requested funding has every chance of being unusually cost-effective in accomplishing ERC goals.

EXAMPLES OF MAJOR INITIATIVES TAKEN BY OTHER STATES TO STRENGTHEN ENGINEERING EDUCATION

A SUMMARY OF STATE INITIATIVES FOR SUPPORTING ENGINEERING SCHOOLS

Essentially every state in the nation has acknowledged the crisis in engineering education by responding with major initiatives. These initiatives can be grouped into several categories: either base budget increments or line item amounts for laboratory equipment, new faculty, faculty salaries, or major new research ventures. Below we have listed several of these initiatives, in most cases corresponding to legislation either approved or in process. (Note these do not include capital outlay projects which have occurred in almost all states over the past three years.)

FLORIDA:

$ 6 million	program support (1982-83)
$12 million	lab equipment (1982-83)
$18 million	lab equipment (1983-84)

ILLINOIS (see attached description):

$18 million (BASE line item increase phased over three years to two U of Illinios Engineering Colleges (Champaign-Urbana and Chicago) (new faculty, faculty salaries, equipment) (1984-86)

Special equipment initiative funded at a level of $1200 per engineering graduate per year

TEXAS:

$20 million lab equipment (1983-84)

$ 6 million (BASE -- Perm Univ Fund) (1983-84) Engineering Schools, U. Texas & Texas A&M

$ 5 million (BASE) + 30 chairs -- computer science and engineering (1983-85) -- U. Texas

ARIZONA:

$32 million electrical and computer (1982-85) Arizona State University

34 new faculty positions

$ 8 million (private sector match)

NEW MEXICO:

$25 million lab equipment (1979-85)

MINNESOTA:

$20 million State + $20 million industry -- (1982-84) special programs (microelectronics and computers)

CALIFORNIA:

Special action to decouple engineering and business faculty salaries
$15 million for microelectronics and biotech programs
$ 3 million (BASE line item) lab equipment (1982-83)

COLORADO:

Differential tuition and salary structure
$25 million lab equipment (1983-86)

MASSACHUSETTS:

American Electronics Association (2% of R&D)
Massachusetts Microelectronics Center

NORTH CAROLINA:

Comprehensive review of engineering education in State
Microelectronics Center ($41 million)

PENNSYLVANNIA:

$40 - $60 million Regional center development

IOWA:

Special lab equipment appropriation (in process)
$16 million (bonded) capital outlay

KANSAS:

Special allocation for engineering faculty salaries

MARYLAND:

Special State efforts ($3.6 million BASE line item) to address lab equipment, capital facilities, and faculty needs at University of Maryland College of Engineering.

MISSOURI:

$3 million (BASE line item) Eng faculty salaries

NEBRASKA:

$434,000 (BASE line item) Eng faculty salaries

OKLAHOMA:

$6 million (BASE) lab equipment

OREGON:

$4.6 million (<u>BASE</u>)	Eng faculty expansion

SOUTH CAROLINA:

$1 million (<u>BASE</u>)	Eng salaries
$2 million (<u>BASE</u>)	lab equipment

TENNESSEE:

$15 million	lab equipment

UTAH:

Major expansion of engineering programs at University of Utah.

WASHINGTON:

$1 million (<u>BASE</u>)	lab equipment (1979)

WYOMING:

$3.5 million	lab equipment

A RECENT EXAMPLE OF SUCH INITIATIVES

THE STATE OF ILLINOIS

This year the State of Illinois approved a line-item base appropriation increase for Illinois' two principal engineering schools (U. of Illinois - Champaign-Urbana and U. of Illinois - Chicago). The appropriation will increase the base budgets of these schools by $18 million over a three year period ($6 million in base increment per year, at a level of $3.7 million to Champaign-Urbana and $2.3 million to Chicago). This base support is being used to provide an adequate level of faculty and equipment support necessary to sustain enrollments at these institutions.

In addition, the State of Illinois approved a matching grants program at a level of $1,200 per engineering graduate per year for engineering laboratory equipment.

Both action items are taking effect in the 1983-84 academic year (1984 Fiscal Year).