Chapter 6

New Roles for Universities in Information Technology R&D

Contents

Tables

Figures

Chapter 6

New Roles for Universities in Information Technology R&D

Introduction

Throughout history, new institutional arrangements have been created to satisfy changing needs. As one of society's major institutions, the university, too, has evolved. Particularly in the case of information technology R&D, new roles for universities are developing. Other major players–industry, State and local governments and the Federal Government–are involved along with the university in the formation of new institutional relationships.

The new institutional arrangements between university and industry, as well as those among university, industry and government, are driven by many factors. These include the need for new knowledge and the application of advancing technologies in new products and processes; the efficient use of high-technology manpower and ensuring a renewable supply of manpower resources; economic survival and future industrial growth; and maintenance of national security and defense.

Since these efforts are essentially in their formative stages, it is difficult to draw conclusions now about their long-term impacts. In establishing a framework for analysis and policy options, OTA developed a series of seven case studies (described later in this chapter) that were selected as examples of the range of new institutional relationships. Taken together, they illustrate several of the key issues in today's debate.

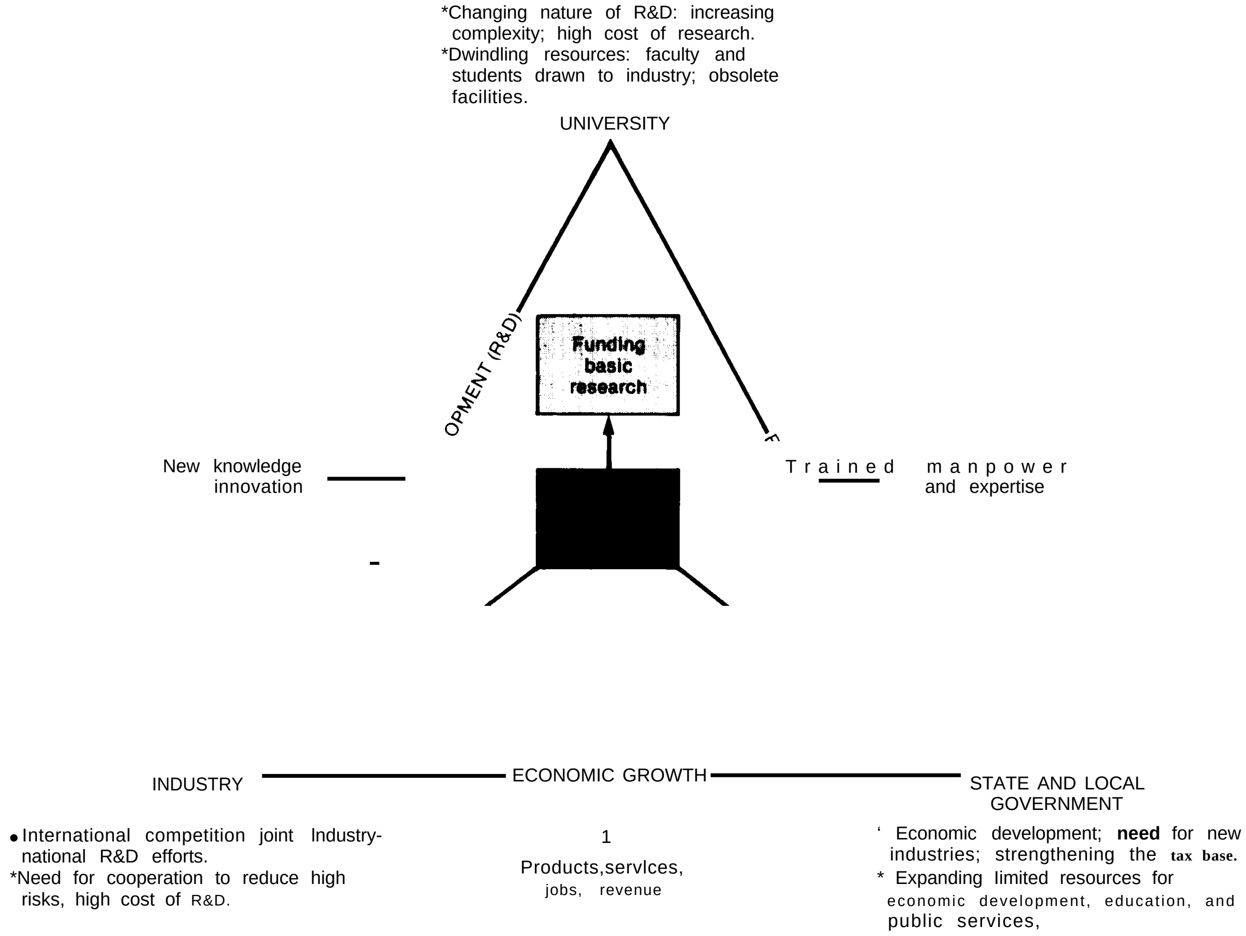
A Conceptual Framework

OTA created a conceptual framework to analyze the changing institutional R&D relationships being played by the Nation's academic institutions–one that emphasizes the pivotal role being played by them. Figure 30 outlines this framework and focuses on the connections among university, industry, and government in terms of education, research, and economic development. At the same time there are forces converging on these institutions that, while creating new opportunities and strengthening connections among university, industry and government, also are creating strains and producing tensions.

While education, research and development, and economic development are separate functions, they, like the institutions that foster them, are becoming increasingly interrelated. For example, concepts in advanced computer architecture taught in a university program or course are directly dependent upon the rapid advances in research and development at both the university and in the industry. Similarly, the development of new industries and subsequent economic growth are directly tied to the products coming from the university—highly trained technical graduates and new knowledge, new processes, and new applications—as well as to the advances and offshoots coming directly from industry.

In examining the institutional players in terms of their relationship to education, research, and economic development, we see that both universities and industry are directly involved in the creation of new knowledge through research, that both universities and State and local governments are directly concerned with the educational process and the provision of a renewable supply of trained graduates, and that both State and local governments and industry are directly concerned with economic health and growth.

Figure 30.–A Conceptual Framework: New Roles for Universities in Information Technology R&D



* Forces driving new Institutional relationships

SOURCE Off Ice of Technology Assessment

There are also important indirect relationships. The educational program and knowledge resources of the university can have an impact on the economic well-being of the region. Industry is involved in education indirectly through the training and resources it has to offer to the other players. Industry is also a consumer of talent and new ideas, the products of the university. States and localities are finding that they need to be concerned with research not only because the creation of new knowledge can lead to the development of new processes and products by industry, but because the quality and scope of university research efforts can strengthen the educational program and in turn provide the region with a renewable supply of highly trained manpower.

There is also a national dimension to this triad. These relationships and interactions are affected by and in turn affect national issues and the Federal role. The strength and effectiveness of the educational system, the quality of research, and the level of economic growth and industrial innovation and productivity determine, in part, the Nation's national security and economic well-being. The role of the Federal Government has also been both direct and indirect. For example, the passage of the Merrill Act in 1862 fundamentally affected the nature of research and education in the universities, as did the direct collaboration among government, industry and academic researchers during World War 11.[1] Recently, the Federal Government's role has become more indirect, increasing authority to State and local government for various discretionary education programs, providing a positive climate for industrial joint ventures, and encouraging joint sponsorship of R&D through tax incentives.[2]

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[1] See ch. 6, "The Provision of Education in the United States," in *Information Technology and Its Impact on American Education,* **OTA, 1982.**

[2] *See* ch. *2,* **"The Environment for Research and Development in Information Technology in the United States. "**

Forces Driving New Relationships

One can argue that the institutional framework has been in place a long time, even though the interconnections may not have been sharply defined. Why, then, are the relationships among the university, industry, and State and local government increasing in strength and activity today? Although there are many factors that could be considered, several forces appear to be critical.

One of the principal factors has been the change in the direct and indirect roles played by the four participants shown in figure 30. The changing Federal role in education, research, and economic growth has shifted certain areas of responsibility to State and local governments, academia, and the private sector. While Federal R&D funding has stayed roughly constant in real dollars over the past decade, recent increases have been targeted to specific areas, such as defense. The consolidation of federally funded discretionary programs in education has increased local and State decisionmaking and control.

Universities have been constrained by the resources available for support of research, faculty, students, and facilities.[3] The rapid obsolescence of laboratory and research tools, coupled with the highly complex and sophisticated nature of the equipment now needed for advanced information technology research, results in capital costs beyond the reach of most academic institutions.[4] The retention and attraction of top-quality faculty and the recruitment of advanced-level students, many of whom are being drawn to industry, are critical problems.[5] Further, as information technology R&D advances, multidisciplinary efforts are required to achieve new breakthroughs.[6] Not unexpectedly, universities have had to seek new ways to operate educational and research programs.

Given the resources for R&D within the major information technology corporations,[7] it is logical to ask why industries would initiate or be responsive to new institutional research relationships. The change in the scope of the information technology industry from a national to a global arena has been a critical factor. Competition within the industry has expanded from the U.S. to a new situation where the competition derives from nationally coordinated industry-government efforts worldwide.[8]

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[3] W. R. Lynn and F. A. Long, "University-Industrial Collaboration in Research, " Technology in Society, vol. 4, 1982, p. 199.

[4] For example, in 1970 a need for $200 million in new instrumentation in the Nation's university research laboratories was identified: a decade later the accumulated need is estimated to **be more than $1 billion. National Research Council,** *Revitalizing Laboratory Instrumentation* **(Washington, DC, National Academy Press, 1982).**

[5] **Louis Branscomb, former Chairman of the National Science Board, points to needs for advanced degree training in computer science, electrical engineering, polymer science and materials engineering-a problem which requires both fellowship support and the strengthening of university instructional and research facilities, At the same time, he points out that incentives must be provided to make university research careers as attractive as offers from industry-principally through the provision of research and equipment support. See: L. Branscomb, "The Computer's Debt to Science,"** *Perspectives in Computing,* **vol.** *3, No. 3,* **October** 1983, p. 18.

[6] 1 bid, **pp. 13-15. See also** ch. **3,** *Case Studies on Advanced Computer Architecture, Fiber Optics, Software Engineering, and Artificial Intelligence.*

[7] *See* table *23,* **R&D Intensities of Selected Major U.S. Telecommunications Firms, 1982,** ch. **4,** *Divestiture.*

[8] See ch. 7. *Information Technology R&Din the United Kingdom, France, and Japan,* for examples of such efforts.

Based on the perception that industrial growth, productivity and competitiveness are dependent on new knowledge and innovation, and a renewable supply of highly trained manpower, industries have turned increasingly to the universities. The increased cost of R&D makes cooperative efforts highly desirable among the industries themselves, and among cosponsored efforts with universities. Such cooperation goes beyond cooperation among large companies. It includes cooperation between large and small companies, and among business, academia, and government.[9] In sum, given the rapid advances in technology, the escalating costs of R&D, and the global intensity of competition, *intranational cooperation* is seen as a means of *maintaining international competitiveness*,[10] and universities are seen as cornerstones of the cooperative effort.

Over the past two decades, several regions of the United States have developed strong local economies based on high-growth, technology-based firms that are engaged in systematic development and commercialization of new products, processes, and services. These firms, and the industries they represent, have provided a major source of new jobs in the manufacturing sector.[11] [12] Thus States, as well as local communities have become active competitors in seeking to attract high-technology firms. Just as U.S. industries have had to acknowledge the international change in the competitive forces for their products, so too have State and local governments had to recognize that the competition for high-technology industry is interregional. The intensive State bidding for location of the Microelectronics and Computer Corporation (MCC) is such an example, with some 60 mayors and 27 governors involved. Notes Arizona Governor Bruce Babbitt,

> The great MCC bidding war marks a special chapter in American industrial history. State and local governments across the country have discovered scientific research and technological innovation as the prime force for economic growth and job creation. And local officials have also uncovered a broad base of public interest that can be translated into support for aggressive action programs. With the exception, perhaps, of the post-Sputnik era, such grassroots enthusiasm for science and technology has not been seen since the Gilded Age of the 19th century, when communities vied to finance the transcontinental railroads. *

To attract such industry, incentives such as tax breaks, donations of real estate, venture capital for industry and funding for educational programs have been provided.[13] Not all State and local high-technology initiatives have focused on education, nor does every State or locality have equal resources on which to draw. However, a strong educational base is seen as a way of becoming more competitive. In a survey of 691 high-technology firms, completed for the congressional Joint Economic Committee, “the importance of skilled labor points up the necessity of linking State and local development efforts with a region’s universities in order to attract high-technology

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[9] See for example, testimony by Erich Bloch, Vice President, IBM, and Chairman, Semiconductor Research Corp. “In order to cope with increasing competition in the world market, the semiconductor industry must increase its efforts in research and development. At the same time the research tasks are becoming more complex and more capital-intensive; lead time is increasing and the shortages of sufficiently trained manpower make the staffing of needed projects difficult. For all these reasons, some research efforts are beyond the affordability of individual companies. ” Hearings Before the Subcommittee on Investigations and Oversight and the Subcommittee on Science, Research and Technology, House of Representatives, 98th Cong., 1st sess., June 29-30, 1983, *Japanese Technological Advances and Possible United States Responses Using Research Joint Ventures*, p. 46.

[10] W. B. Norris, “How to Expand R&D Cooperation. ” *Business Week*, Apr. 11, 1983, p. 21. Keynote Address “Cooperation for Improving Productivity, ” San Diego, July 20, 1983, IEEE Task Force on Productivity and Innovation.

[11] U.S. Congress, Office of Technology Assessment, *Technology, Innovation, and Regional Economic Development, Census of State Government Initiatives for High Technology Industrial Development—Background Paper* OTA-BP-STI, May 1983; *Encouraging High-Technology Development—Background Paper*, OTA-BP-ST1-25. February 1984.

[12] Total employment in the information technology industry experienced considerable growth in the decade between 1972 and 1982, despite economic recessions. See ch. 9.

* B. Babbitt, “The States and the Reindustrialization Of America,” *Issues in Science and Technology*, fall 1984, p. 85.

[13] For examples of such efforts, see the report by the National Governor’s Association, *Technology and Growth: State Initiatives in Technological Innovation* (Washington, DC: National Governors’ Association, 1983), pp. 23-45.

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Impacts of New University Arrangements

While we can find examples of State and local high-technology initiatives and numerous examples of long-standing university-industry interactions including industry's support for research through gifts of funds or equipment; cooperative research grants and contracts; the use of university consultants, exchange of personnel between universities and industries and other arrangements,[15] *the university today is in a special position. Universities are being courted by all of the principal actors and many are initiating programs of their own. Most im-*

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[15] National Science **Foundation,** *University-Industry Research Relationships* (Washington, DC: National Science Foundation, 1982).

portantly, they are the linking element in multi-institutional R&D relationships.

The new institutional relationships take many forms; some efforts represent new and largely experimental ways of working together; many efforts that are being developed are not really new, but are evolving from previous efforts and relationships. However, all of the efforts that OTA examined involve a set of agreements whose principal characteristics are multidisciplinary arrangements and commitments to research with long-term objectives. While several of the ventures have been initiated by one or few individuals, the negotiated agreements themselves are made at the institutional level. It is the level of commitment and the extent of the involvement that differs from previous university-industry efforts.

It is too early to know with any certainty the benefits and costs of the new university-centered activities. However, in breaking new ground, the university arrangements, cosponsored efforts, and high-technology State and local initiatives have generated high expectations amid questions of appropriateness.[16] The number of meetings, conferences, hearings, and publications on this subject has been significant.[17] The debates over these relationships have involved university leaders and academicians, governors, congressmen, and corporate executives.

Expected Benefits

The increased interactions among the university-industry-government triad depicted in figure 30 underlie potentially successful approaches to several critical problem areas:

- *Research and new knowledge:* The coupling between university and industry may match needs of both. Industry gets access to the research and knowledge that resides in the university. Similarly, university researchers can benefit from the pool of industry expertise. The academic community obtains R&D laboratory facilities and research tools, as well as funding to undertake research. With increased interaction, the university has an opportunity for better understanding of the industry's practical concerns, and, conversely, industry may get a closer look at the university's research findings, speeding technology transfer.
- *Education and manpower:* With the increased opportunities for research, and a strengthening of the academic research program, the educational program can also be affected positively. Incentives that would attract and retain top-level faculty and advanced graduate students are derived from higher levels of support of new facilities and research. Moreover, as a result of interacting with industry personnel, students can make more informed decisions about their future employment. The combination of top-level personnel, adequate facilities, and a vigorous research agenda can strengthen the educational program, as new courses are developed and learning opportunities increase. The university products can then feed back into both industry and the community.
- *Economic growth: New* institutional efforts are aimed at a strengthened research base and a renewable source of highly trained manpower, which are needed by industry for its economic growth. This, in turn, can strengthen the regional econom-

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[16] This concern has been most focused on biotechnology, where several university-industry agreements have involved large sums of funding, over multiyear periods, and where a major research unit of the university is involved with a single company with varying agreements for industry participation on campus, and on some agreement to delay publication or provide exclusive licensing to processes and products developed during the duration of the research agreement.

[17] "Academe and Industry Debate Partnership," *Science,* vol. 219, No. 4481, January 1983, pp. 150-151; T. W. Langfitt, S. Hackney, A. P. Fishman, et al., Partners in the Research Enterprise, University-Corporate Relations in Science and Technology (Philadelphia: University of Pennsylvania Press, 1983). U.S. House of Representatives, University/Industry Cooperation in Biotechnology. Joint hearings of the Subcommittee on Investigations and Oversight and the Subcommittee on Science, Research, and Technology, June 16-17, 1982.

ic base through new jobs, new spin-off industries, and the continued development of entrepreneurial efforts to fill new niches.[18]

Potential Costs

The increased interactions among academia-industry-government also raise questions of long-term impact:

- *Research and new knowledge:* Closer interaction may lead to subtle changes in the setting of research goals both in terms of the selection of topics to be studied and in the shortening of time horizons for results. Breakthroughs in fundamental research often require decades of study. Thus some problems may be overlooked if the institutional time frames for research are 3, 5, or even 10 years. How will topics *not* of direct interest to industry be covered in such institutional arrangements?

  In addition, industry's traditional emphasis on secrecy is in direct conflict with academic practices. The new arrangements have involved extensive negotiation regarding patent and licensing agreements.[19] Thus far, most universities have resisted industry pressure to limit access to research results, maintaining their traditional role "to protect and to foster an environment conducive to free inquiry, the advancement of knowledge and the free exchange of ideas. "2° The conflict between openness and control is of continuing concern,[21] and will require solutions on a case by case basis.
- *Education and manpower:* It is possible that these new, highly visible, exciting ventures will cause competition between research and education, drawing faculty away from teaching, and recruiting students from other areas. There is the danger that these new efforts will skew the balance among programs and capture unequal attention and support from university administration.
- *Economic growth and development:* While there are many other joint industry-university activities involving small and large businesses, a variety of academic institutions, and individual faculty members, the industry sponsors and major participants in both the multidisciplinary university centers and the industry cooperative ventures have mainly been the large information technology corporations. Fewer numbers of smaller companies have joined projects as "associate' (in contrast to fully participating) members. Full membership includes access to research as well as personnel exchanges, and active participation in planning research, selecting proposals for funding and evaluating ongoing programs. Thus, cooperative joint-industry ventures among the information technology giants may put the smallest, entrepreneurial companies at a disadvantage.

The costs of increased interaction come from two directions. First, in coming together, each of the institutions may lose some measure of autonomy and relinquish aspects of their traditional roles. Conflict is inevitable, for example, between the university's need for openness and industry's need for protection of proprietary interests. Another conflict may develop if the traditional distinctions that have separated the use of public funds from private interest and gain are blurred.[22]

Second, there is the "cost" of nonparticipation. Most of the debate has focused solely on

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[18] For example, in a recent study of the Route 128 High Technology Industrial Corridor, Massachusetts' advantage in attracting and supporting industries has resulted from the rich university environment. "Entrepreneurs in the electronics fields come mainly from the staffs of universities and their research labs, and from other high tech firms (already established)." N. S. Dorfman, "Route 128: The Development of a Regional High Technology Economy," *Research Policy,* 12:6, December 1983, p. 309; see also table 1, p. 301, ibid.

[19] Fowler, "University-Industry Research Relationships: The Research Agreement, " *Journal of College and University Law,* 9:4, *1982-83.*

[20] A.B. Giarnetti, "The University, Industry and Cooperative Research, " *Science, vol. 218,* December 1982, pp. 1278-1280.

[21] D. Nelkin, "Intellectual Property: The Control of Scientific Information, " *Science* 216:14, May 1982, pp. 704-708.

[22] " Weighing the Social Costs of Innovation, " *Science,* vol. *223,* March 1984, p. 1368. A suit involving the University of California and its research, raises the question of the legality of spending public funds for research that allegedly benefits large agribusiness more than small farmers and laborers.

the generic institution without recognition of the differences within each of the institutional communities. Thus, it has not looked very much at how the establishment of university industry relationships may affect a smaller or less prestigious research institution, nor how joint-industry ventures may affect smaller businesses, nor how local and State initiatives place some other regions or other institutions within the region in an inequitable position.

There is concern that the already existing differences between the Nation's top-tier and second-tier universities may grow even greater as the competition for industrial resources and partnerships accelerates. Thus, there is concern for the needs of the range of the Nation's universities. Even though programs may be less ambitious in scope and scale, the needs for sophisticated equipment, advanced research facilities, highly trained and knowledgeable faculty, and advanced-level students remain critical. Therefore, a diversity of efforts and approaches needs to be explored and supported.

At the State and regional level, the ability to compete for new industry, for research centers of excellence, and for expert manpower may also become equity issues. As noted earlier, while the number of high-technology centers has increased in recent years, the competition among State and regional localities is becoming fierce. The ability of States to assure significant support for new facilities, additional faculty and graduate students, the availability of venture capital, and the cooperative efforts of business and academic leaders are critical factors in attracting new institutional research ventures. Moreover, as a result of successful bids, regions expect to attract other high-technology companies while the universities hope to attract senior faculty and the top graduate students.

New Roles for Universities: Selected Case Studies

University-industry-government information technology R&D efforts demonstrate a variety of approaches which have been only recently implemented. Because these efforts are essentially in formative stages, an assessment of their effectiveness and impact on R&D is premature. Yet it is clear that the efforts examined in this chapter provide important examples of new directions and major commitments. The case studies provide examples of how problems or barriers raised by these new relationships are being addressed, as well as those issues which are not yet resolved. The case studies also provide an understanding of the motives and factors stimulating change, how the institutional players are responding, and the role played by incentives and directions from the Federal Government. Thus, they provide a framework for analysis and the development of policy options.

While each of the case studies is unique, several themes emerge:

- Institutional arrangements involve long-term, multiyear commitments with agreements that include facilities, equipment, and human resources.
- These arrangements bring together multi-disciplines, multi-institutions, and multi-funding resources to support wide-ranging research, educational, and development efforts.
- These arrangements involve leadership and support of individuals at the highest levels of the university, corporations, and government.
- While Federal funds continue to support a significant portion of the research at the university centers, the Federal Government had a limited role in development of the institutional arrangements, influencing them by providing limited funds for startup activities, by creating tax credit incentives, and by its supportive policy towards joint ventures.

Massachusetts Institute of Technology Microsystems Industrial Group

MIT's experience with joint industry arrangements is extensive and reaches virtually every program area in the Institute. More than 300 joint programs are currently sponsored at MIT by industrial firms. Federal sources nonetheless provide the bulk of funding for research. In 1983, only 10 percent of MIT's sponsored research was funded by industry.[23] It is estimated that support from industry will not grow beyond 15 or 20 percent. However, MIT faculty point out that industry involvement is important because it provides exposure to and understanding of industrial concerns, motivations, and needs. This interaction is seen as critical for the future of most students who graduate from the university to work in the information technology field. Equally important, it provides necessary expansion of academic research concerns that would otherwise be guided primarily by the interests of particular Federal funding agencies.[24]

While there have been long and well established industry-university research ties at MIT, the formation of the Microsystems Industrial Group breaks new ground. Increased industrial involvement in the MIT Microsystems program was stimulated by the program's need for advanced state-of-the-art equipment and laboratory facilities. A proposal to reach out to industry for help in developing these facilities was made by members of the faculty, who argued that the amount needed (originally estimated at $10 million) could not be supported by any Federal program or by the university itself. The advanced research Very Large Scale Integration (VLSI) laboratory and facilities are supported by industry sponsors; contributions are estimated to be $10 million (half of the actual cost of renovation and operation). The rest of the cost is being recovered through overhead charges on current contract research. In agreements negotiated with industry, full member companies contribute $250,000 annually for 3 years, and associate member companies contribute $50,000 annually for 5 years.

Thus far, 18 companies have joined the group.[25] Full member companies can send one technical staff member to MIT to work in the Microsystems research program annually for 3 years. Each visiting professional submits a plan of proposed research topics, and these are matched with an appropriate faculty member or research group. More than a dozen industry people have participated in the program. The opportunity to work in a new area of interest, "get caught up in the MIT atmosphere" and interact daily with students and faculty members is viewed very positively .2'

Research projects under way have been developed by faculty and reflect their traditional roles as principal investigators. The director and faculty meet with the industry member advisory group, who provide information and advice. Even more directly, the technical people from industry have contributed to the research efforts, and have broadened the view of faculty and students. The director of the Microsystems Industrial Group explains: "These are smart people with different backgrounds than my University colleagues. It is very important for those of us who do research to have the industrial viewpoint in front of us.' '[27]

Understanding grows both generally through interaction with the Council of member companies, who offer advice and guidance, and in the process of working out specific visiting relationships. This understanding helps faculty, students, and the academic program. But it is also clear to faculty and administra-

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"Kenneth A. Smith, "Industry-University Research Programs,"' *Physics Today,* vol. *37, No. 2,* February 1984, p. 24.

"Ibid., p. 24.

[25] Full member companies included AT&T Bell labs, Digital Equipment, General Electric, General Motors, GTE, Harris, IBM, Raytheon, and United Technologies. Associate member companies are Analog Devices, GCA, Genrad, NCR, Polaroid, Sanders Associates and Teradyne.

*'Personal communication, March 1984. According to Paul Penfield, Director, MIG, these experiences provide industry associates unique opportunities for professional growth and development, and appear to be a way for a company to retain highly valued employees.

"Personal communication. Paul Penfield, Director, Microsystems Industry Group.

tors who have responsibility for university-industry research that, even though time and competitive pressures are high, the academic integrity of both the research and educational program must not be compromised. Thus, in some cases, decisions are made not to undertake certain projects, for example, when the proprietary stakes are too high, or the time-frames are inappropriate or if scientific exchange is jeopardized.[28] From industry's point of view, the Microsystems Industrial Group, as well as other similar efforts such as the Center for Integrated Systems at Stanford, are working because the research effort is focused.[29]

New institutional relationships can benefit both university and industry if the agreements meet the needs of the partners. In analyzing the aspects of such negotiations at MIT, the Associate Provost and Vice President for Research identifies the fundamental issues to be addressed:

1. *the relevance of a proposed line of inquiry to the essential missions of the university and the industry—maintaining* a balance between the pursuit of research as an integral part of the educational process and industry's need for useful knowledge to be applied in the development of products, processes and services;
2. *the organization of a program that meets the different time constraints of industry and the* university—accommodating the multiyear efforts of graduate students with the shorter time pressures of the marketplace;
3. *the issue of proprietary rights versus* openness—achieving openness and free exchange of research results while protecting the industrial partners' proprietary rights;
4. *the issue of patents and copyrights*—determining licensing agreements that advance scientific and technological discoveries in ways that are most likely to benefit the public and the research participants and institutions; and
5. *the issue of conflict of commitment*—assuring that faculty are primarily committed to the university: its research and its educational programs.[30]

Microelectronics and Information Sciences Center (MEIS)

University of Minnesota

The Microelectronics and Information Sciences Center (ME IS) is a joint endeavor between the University of Minnesota's Institute of Technology and Minnesota industry. It was created to establish a center of excellence in these sciences as well as to meet local industry's technical manpower needs. Such joint efforts are not new to Minnesota.[31] The impetus for the Microelectronics and Information Sciences Center came from Minnesota industries—Control Data, Honeywell, 3-M, and Sperry Corp.—who committed $6 million to launch the effort. The Minnesota State legislature allocated an additional $1.2 million. Current operation is at $2.5 million a year matched by $4.0 million in external grants and contracts.

Faculty members, university officials, corporate executives and center administrators have worked together to define the directions for research and educational programs, the center's operation, and the university-industry interface mechanisms. This negotiation took time to work out, and programs were phased in gradually over a several-year period.[32] The

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[28] Personal communication, George Dummer, MIT, March 1984.

[29] Personal communication, Bill Nelson, GTE, April 1984.

[30] K. A. Smith, "Industry-University Research Programs, " op. cit., p. 25.

[31] For example, in the early 1970s such a joint effort initiated the development of the Minnesota Educational Computing Consortium to provide instructional time-sharing capability to the State's colleges and universities, as well as the elementary and secondary schools. See: a case study of "Minnesota Schools and the Minnesota Educational Computing Consortium, *Informational Technology and Its Impact on American Education*, (Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-CIT-187, 1982) pp. 214- 221.

[32] The Center's slow start has been criticized by some. However, the benefits of taking the time to work out an arrangement that suited the needs of both the university and the sponsoring industries outweighed the costs of delay. Personal communication, Dr. Martha Russell, March 1984,

results of the negotiations are embodied in the ME IS Center goals:

1. to sponsor and conduct research at the frontiers of microelectronic and information sciences;
2. to strengthen the course offerings of the University of Minnesota in these sciences; and
3. to provide active interplay between university researchers who seek discovery and industrial firms that apply those research results to the development and marketing of innovative products and services.

Research

Through the sponsorship of interdisciplinary research projects, the center links faculty, students, and industry. Proposals for research are submitted by faculty members. ME IS-sponsored research is reviewed annually by technical experts at the university and supporting companies. In 1983, projects in 3-D Integrated-Circuits, Processor Array Concepts for Engineering, Design Automation and Software Engineering, and Ultrasmall Electronic Research received ME IS seed funding, totaling $625,000; additional research funds of $4,312,000, principally from Federal grants, was obtained. In 1984, MEIS has awarded both seed and matching funding to three integrated team efforts in Intelligent Systems Research, II I-V Semiconductor Materials and High Speed Devices, and High-Performance Integrated Circuits. Another planned effort will include a project on Artificially Structured Materials.

Renovation and development of laboratory facilities has been directly tied to the research efforts. The University is planning a new Computer Science and Engineering building which will house both offices and laboratories. ME IS co-owns, with Argonne National Laboratory, a Synchrotrons X-Ray Beamline Facility, located in Stoughton, WI. In addition, MEIS and the University share the newly remodeled microelectronics laboratory and the VLSI engineering design laboratory.

Education

Strengthening the educational program has focused on increasing the number of faculty members, starting new courses, and attracting top-quality graduate students. Eighteen new graduate and undergraduate courses have been added in computer science, electrical engineering, materials science and chemical engineering; seven new faculty members have already been recruited through a 3-year cost-sharing program with the university, and plans call for hiring an additional four members in Computer Science as well as a director; 54 graduate students and four post-doctoral assistants were supported by MEIS funds in the five departments receiving ME IS research sponsorship; 16 fellowships will be available for 1984-1985.[33]

Technology Transfer

The exchange of knowledge and technology between MEIS member companies and the university community has been a major goal of the Center. Through direct scientist-to-scientist interaction, it is anticipated that the time between discovery and application will be shortened. Faculty, students, and industry technical staff have worked jointly on projects, in some cases using industry's state-of-the-art facilities for design, special fabrication or testing. A major assumption is that graduate students serve a key role in the transfer of technology between industry and university. After the first year of graduate study in the doctoral program, students work in the research laboratories of the industry sponsors, learning what drives industrial use of innovation in science and technology, and bringing their recently acquired knowledge and skills to the task. Research projects developing from these experiences expand the involvement of faculty, students, and the industrial scientists.

Like other joint efforts, the center has fostered the exchange of ideas through confer-

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[33] Microelectronics and Information Sciences Center, 1983 Annual Report, February 1984.

ences and seminars. ME IS technical reports and newsletters have also been widely disseminated. Center participants from both academia and industry point out that this open exchange has been facilitated by concentrating on long-term research areas conducted over a 5 to 7 year period. The Center has thus far avoided the issues regarding exclusive research and proprietary information.

Continued ability to recruit high-quality graduate students, as well as recruiting and retaining excellent faculty, is critical to the long-term stability and growth of the program. Stable funding and full implementation of programs are anticipated by 1985. In addition, the Center expects to attract additional State and private support.

Rensselaer Polytechnic Institute Center for Industrial Innovation

The RPI Center for Industrial Innovation is the result of a focused University initiative that has involved key participants from academia, industry, and New York State government—including the governor. This initiative was based on the experiences of RPI's three established Centers for Interactive Graphics, for Manufacturing Productivity, and for Microelectronics. With a $30 million interest-free loan from the State and an additional $30 million commitment by RPI, construction of a facility to house these Centers is under way. These Centers involve more than 100 arrangements and agreements with industry, including support for ongoing research through industry affiliates, specific research and problem-solving agreements, continuing education and training, adjunct industry-faculty arrangements, faculty-industry consulting, industry fee payments, and gifts or loans of equipment and software. However, it was not the quest for industrial partnerships, but rather the desire to improve the undergraduate engineering education program, that served as the initial catalyst for these activities.[34]

The effort to improve RPI's educational program was begun in 1975-76 and resulted in several new interrelated directions: expansion of the graduate program (from approximately 500 to a goal of 2,400 graduate students by the year 2000); an institutional commitment to research through the expansion of faculty and facilities as well as of the number of students, and a revision of the undergraduate curriculum to overcome the lack of hands-on engineering experiences.

Center for Interactive Graphics

The first step was the creation of an interactive computer graphics laboratory designed as a service facility for undergraduates. This was based on the belief that an important emerging tool for engineering was the interactive computer graphics terminal. The facility and the applications have grown beyond the original classroom to a Center for Interactive Graphics. The growth was due not only to the increased use in almost all engineering courses, but also to the decision to combine research with practice as the means for keeping up to date with the advancing technology.

The Center for Interactive Graphics was created in 1978, with initial funding from the National Science Foundation. From its inception, it was intended to involve industry, and to share research results with industry. A measure of its success is that the Center has grown from 20 supporting companies with $20,000 annual fees to 35 companies with $40,000 annual fees. An early concern that it would not be possible to keep up with the continually advancing hardware and software has been reduced: companies have been willing to donate their latest equipment. Just recently, for example, the Center received a $3 million equipment grant from IBM.[35]

Center for Manufacturing Productivity

The Center for Manufacturing Productivity and Technology Transfer was the result of a deliberate decision to train students in areas

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[34] G. M. Low, "The Organization of Industrial Relationships in Universities," *Partners in the Research Enterprise*, T. W. Langfitt et al. (eds.), (Philadelphia: University of Pennsylvania Press, 1983), p. 71.

[35] Personal communication, Dr. Christopher LeMaistre, Director Center for Industrial Innovation and Assistant Dean, School of Engineering, March 1984.

Graduate student and faculty member using a CAD/CAM workstation, in the Center for Interactive Computer Graphics, RPI

that would be needed in the decade of the 1980s and at the same time to meet industry's research needs so that industrial funding would be available. Support from Federal sources was not available. Thus, the Dean of the School of Engineering made initial contacts with executives from General Electric. He and two GE executives traveled to Europe to see how industry and universities were working together. RPI's Center was modeled after one at the University of Aachen in West Germany.

With a commitment from GE, the Center started in May 1979. Presently there are eight founding companies and five affiliate companies who support the operation of the Center and its research.[36] In addition, the Center engages in contract work and involves undergraduates and graduates in "real life, real time" industrial problem solving, all under the direction of faculty and a project manager. The intent is to create experiences that are directly relevant for students' entry into the industrial world. The Center reports to and receives guidance from a board of advisers comprised of founding member company representatives.

Center for Integrated Electronics

The Center for Integrated Electronics also has industrial sponsors, who support research efforts which are fully open with no restrictions on disclosure.[37] The Center is equipped with $8 million in hardware, much of it donated, from companies such as IBM, Calma, and Computervision. RPI also provides "incubator space" for small fledgling companies on campus and provides administrative support to help companies while they find venture capital, develop management capability, and begin to grow.

In addition, RPI has created an industrial park, located 10 miles south of the institute, on a 1,200-acre parcel of land owned by RPI. With strong leadership from then RPI President George Low the Institute committed $3 million for initial preparation of the site in 1982. National Semiconductor was the first company to move in, with several others following. RPI is currently constructing its own building in the park to provide startup space for companies that are not yet large enough to be on their own.

Center for Industrial Innovation

All of these activities led to the Center for Industrial Innovation. The RPI President and the Chief Executive Officers of GE and Kodak, along with other corporate executives, met with the Governor to push for a State Technology Initiative to be funded through the State legislature. The arguments, as in other industrial States, were that the smokestack industries were dying, new technology industries were locating elsewhere, and that to overcome this, new catalysts were needed. RPI argued that it had the necessary infrastruc-

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[36] Member companies include General Electric, General Motors, Boeing, Norton, IBM, Alcoa, Digital Equipment Corp., and United Technologies. Affiliate companies include Kodak, Cincinnati Milacron, Fairchild Republic, Fairchild Schlumberger, Altech, and Timex.

[37] Founding members include Harris Corp., Computervision, Digital Equipment Corp., Eastman Kodak, General Electric, Raytheon, Polaroid, GTE, IBM, Phoenix Data Systems, Eaton Corp., and AIR Products. Affiliate members include Sperry, Xerox, Hewlett-Packard, Perkin-Elmer, Fairchild Semiconductor, BTU Corp., Matheson, I'IT, and the PEW Memorial Trust.

ture in place and that what was needed was a $30 million interest-free loan.

The ground has been broken for the Center at RPI and the university expects completion of the facility in September 1986. RPI expects to put an additional $30 million into the facilities. In return for the State loan, RPI will provide an outreach program to 2-year colleges and to industry to upgrade the level of technological expertise.

While there has been strong support for these activities and agreement that they have helped the Institute, their industrial orientation does cause concern to some faculty. The Center argument is, however, that there is a healthy balance between uncommitted research support and both focused engineering and applied projects. There is evidence that the program brings together a blend of research and application for students, and that the quality of the instructional program has been significantly improved.[38]

Stanford University Center for Integrated Systems

Like the MIT, RPI, and University of Minnesota efforts, the institutional relationship developed between Stanford University and industry breaks new ground. In May 1983, more than the construction of a $15 million facility to house the Center for Integrated Systems (CIS) was being celebrated. According to participants from the faculty, university administration, and industry, this project and others like it are part of a new willingness by industry and the academic community to become "allies in basic research."[39] According to William Hewlett, "CIS is a clear and distinct answer to three major problems that face the United States–the failure of our national programs of basic research to keep pace with the needs of our universities and industries, the need to strengthen our system of education, and the challenge to U.S. trade and technology posed by foreign countries."[40]

Planning Activities

As early as 1977, Stanford engineering faculty discussed the idea of a center for integrated systems research, a multidisciplinary endeavor involving the interaction of people knowledgeable about integrated circuits with another group knowledgeable about computer and information systems. "From the outset it was clear that a collaboration, more intense than had ever before occurred, between IC types and systems engineers needed to evolve."[41] Furthermore, such a center could vertically integrate the research process, with a state-of-the-art facility for design, fabrication and testing of VLSI chips. This fast-turnaround facility would allow a systems designer, in collaboration with an IC designer, to create experimental devices in a shorter time than ever before.

The faculty took their idea to the Dean of the School of Engineering, and subsequently a formal proposal was submitted to the university. By January 1980, the Center for Integrated Systems was under way with approval from the Board of Trustees. Executives of Hewlett-Packard, TRW, Xerox, and Intel formed a development committee to raise funds. By March 1981, 10 corporations agreed to contribute $750,000 each, spread over a 3-year period. By 1983-84, an additional 10 sponsors brought the total to 20, with each also agreeing to provide $100,000 annually for education, research, and administration of the facility.[42]

Formulating New Policies

Not unexpectedly, the most controversial aspect of the plan was not the facility, but the intention to involve industrial companies as sponsors of the Center and offer them "facilitated access" to the research program. Of con-

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[38] Low, op. cit.

[39] F. H. Gardner, "Special Report: The Center for Integrated Systems," *Hewlett-Packard Journal,* November 1983, p. 23.

[40] Ibid.

[41] John G. Linvill, Director Industrial Programs, Center for Integrated Systems, Stanford University. Personal communication, April 1984.

[42] Corporate sponsors are General Electric, Hewlett-Packard, TRW, Northrop, Xerox, Texas Instruments, Fairchild, Honeywell, IBM, Tektronix, Digital Equipment Corp., Intel, ITT, GTE, Motorola, United Technologies, Monsanto, Gould/American Microsystems, Inc., North American Philips/Signetics Corp., and Rockwell International.

cern to faculty members and corporate sponsors was how patent ownership, licensing, and intellectual property rights would be determined. The companies' initial posture was insistent on exclusive proprietary rights to inventions which involved their own people. The university, on the other hand, argued that research in the Center was funded principally with Federal support and that the University's legal obligation was to make sure that any resulting patents would be brought into the stream of commerce as quickly as possible, with any company capable of commercialization having the right to bid and obtain a license.

The successful resolution of the issue centered on categorizing the patent in terms of the inventor (see fig. 31, CIS Patent Policy). In addition, if a corporate visiting scholar develops a patentable product jointly with a Stanford faculty member or student, the company may request a 90-day delay of publication to get the patent filed; it also gets free but nonexclusive rights to exploit the product. CIS sponsor companies have also agreed to a cross-licensing plan, sharing any inventions developed at CIS. While intellectual property rights have generated much discussion and have taken time to work out, it appears unlikely that highly commercial applications will result, given the basic nature of the research under way at CIS. Moreover, both sponsors and faculty point out that it is in their interest that the Center produce new basic knowledge as well as students trained as broadly as possible.

Another area of concern focused on the question of research direction: would the nature and direction of basic research be distorted by industrial sponsorship? The answer appears to be that this is unlikely, given the tradition of independent research teams led by principal investigators. At the same time, the investment of industrial sponsors is not insignificant, and there is the sense that faculty will be receptive to good problems posed by industry. There is also the sense that research questions can be shaped to examine fundamental issues likely to be of interest to all.[43] There is additional concern that there will be pressures to keep research secret. Such pressures are likely to be strongly resisted; the number of seminars, publications, and open meetings have demonstrated the University's and the Center's intent to maintain openness.

Finally, there is the question concerning the advantage corporate sponsors have over nonparticipating companies. The questions here

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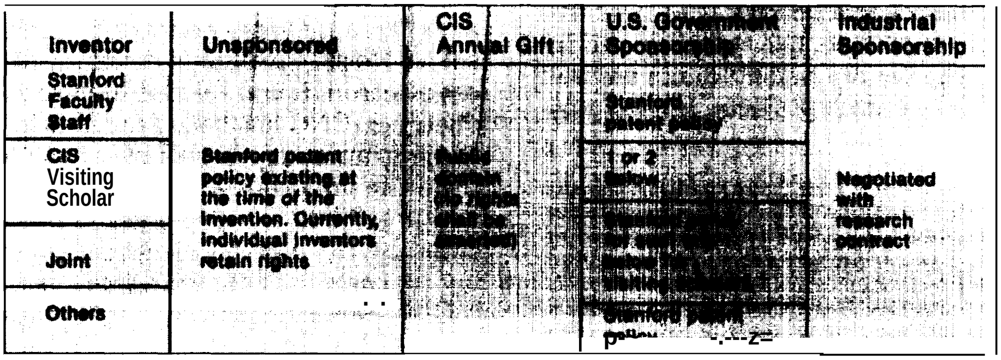
[43] John Linvill, Director, CIS, notes, "We gain much more through access with each other. The watchword is not isolation, but interaction. " Personal communication, March 1983.

Figure 31.—Stanford University, Center for Integrated Systems Patent Policy

CIS Patent Policy
Disposition of Rights



Inventor	Unsponsored	CIS Annual Gift	U.S. Government Sponsorship	Industrial Sponsorship
Stanford Faculty Staff	Stanford patent policy existing at the time of the invention. Currently, individual inventors retain rights	[illegible]	Stanford patent policy	Negotiated with research contract
CIS Visiting Scholar			1 or 2 below	
Joint			[illegible]	
Others			Stanford patent policy	

1. Stanford takes title and Inventor receives nonexclusive, fullv paid license Including right to sublicense
2. Upon request of inventors, Stanford will authorize a petltlon by Inventor's employees to U.S. Government for greater r!ghts than 1

SOURCE: HewlettPackard Journal, November 19S3.

relate not just to this project but to other projects as well. Proponents of the Center argue that the fundamental nature of the university has not been changed, that everything the university does is open to dissemination-a way of life that undergirds every relationship—no matter “whom we get money from. ”[44] While sponsoring companies have access to graduate students, and may seem to have an advantage in recruiting them, the networks between Stanford faculty and their contacts in hundreds of companies in the Silcon Valley remain strong. In addition, if a CIS research team wishes to include a nonparticipating company on a research project, they can do so. Reaching this agreement, noted several participants, was a hard fight to win.

Nonetheless, the controversy persists, and questions are likely to remain.[45] The negotiated agreements concerning patents, and the disposition of licenses are seen as experiments which may or may not work out and which may need to be revised as research and work progresses. The experimental nature of the center is not limited to intellectual property arrangements, note participants, but includes as well the social and organizational arrangements built around cooperation—both among the various departments and among the corporations.

Center Operation

While the Center itself is still evolving in terms of the agreements for intellectual property rights, the working relationships between corporate sponsors and faculty, and the facilities under construction, the research and involvement of the faculty and students are well under way. CIS research projects, funded principally by the Federal Government, total $12 million a year. (see table 26: CIS Research Topics). Seventy-one faculty members, representing seven departments, are affiliated with the center, and 30 Ph.D. and 100 MS degree candidate students a year are being trained. It is the people who are the most important output of the Center for Integrated Systems: “To the extent that we educate people with the right background, have them do interesting research of significance to the Nation’s problems but at a fundamental level, and do this in close collaboration with the industries which need such people, we will significantly modify the nation’s productivity and competitiveness. “[46]

Microelectronics Center of North Carolina (MCNC)

Universities play a critical role in the Microelectronics Center of North Carolina (MCNC). As a multi-institutional R&D effort, MCNC combines the resources of Duke University, North Carolina A&T State University, North Carolina State University, University of North Carolina at Chapel Hill, and University of North Carolina at Charlotte, as well as the Research Triangle Institute. These institutions, along with the MCNC core organization, the new MCNC research facility, and the communications system linking all the facilities provide a concentration of resources for education, research, technology transfer, and industrial development.

Established in July 1980, MCNC is organized as a private, nonprofit corporation to assist North Carolina’s development of modern electronics and related high-technology industry. MCNC has been funded primarily with State grants, as a result of strong leadership from the governor and support from the legislature. Thus far, $43 million has been allocated by the North Carolina General Assembly for constructing, equipping, and operating MCNC. An additional $34 million for new capital facilities at the participating institutions has also been provided.

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[44] 1 bid.

[45] A recent article in the New York Times highlights the continuing questions and controversy. While the Vice Provost notes that CIS is an “innovative setup for Stanford, ” a professor of history argues, “It’s potentially very dangerous for a university to give privileged space and privileged access to information to particular companies. There is a danger that researchers will create relationships that are likely to influence what they study and what they do not study. It is a threat to the autonomy of the university. '' See: R. Reinhold, “Stanford and Industry Forge New Research Link, ” New *York Times,* Feb. 10, 1984.

[46] John Linvill, personal communication, April 1984.

Table 26.—Stanford University, Center for Integrated Systems Research Topics

Although its building won't be completed until early 1985, the Center for Integrated Systems is already coordinating a $12-million-a-year basic research program at Stanford, funded largely by the Federal government. Here's a sampler of recent and current topics investigated by CIS affiliated faculty in various existing labs.

Computers

- Research on streamlined-instruction -set microprocessor (featuring partnership of computer and IC engineers)
- Research in VLSI systems
- Knowledge-based VLSI project
- Image understanding
- Intelligent task automation
- Network graphics
- Partitionable computer systems
- Analysis and verification of high-order language programs
- Study of very high-speed integrated circuits (VHSIC-Phase 3)
- Real-time communications systems: design, analysis, and implementation
- Structured design methodology for VLSI systems
- Logical methods for program analysis
- Ultra-concurrent computer systems
- Silicon compilation
- Data base theory
- Computer languages for VLSI fabrication

Information Systems

- Multiple user channels and information theory
- Computational complexity, efficiency, and accountability in large-scale teleprocessing systems
- Multiplexed holographic reconstruction methods for 3D structures
- Information theory and data compression
- Signal processing and compression
- Statistical data processing, system modeling, and reliability
- Algorithms for locating and identifying multiple sources by a distributed sensor network
- Fast algorithms for improved speech coding and recognition
- Dual-energy digital subtraction radiography for noninvasive arteriography

Integrated Circuits

- Computer modeling of complete IC fabrication process
- Integrated electromechanical and optical sensor arrays for Optacon II (a reading aid for the blind)
- BME Center for Integrated Electronics in Medicine (to produce implantable telemetry systems for biomedical research)
- Computer-aided design of IC fabrication processes for VLSI devices
- Submicron device physics and technology
- Development of multichannel electrodes for an auditory prosthesis
- Study of transdermal electronics for an auditory prosthesis
- Multilevel-metal interconnection technology
- Biomedical silicon sensors
- Fast turnaround laboratory for VLSI

Solid State

- Ion implantation and laser annealing in semiconductors and related materials
- Laser and electron beam processing of semiconductors
- Characterization of high-speed semiconductor device materials using advanced analytical techniques
- Ion implantation and laser processing of 3-5 compound conductors
- Defects at electrode-oxide and electrode-silicon interfaces in submicron device structures
- Microstructure fabrication using electron beams of conventional and very low energies
- Advanced concepts in VLSI metallization
- Advanced packaging concepts for VLSI
- Studies of surfaces and interfaces of 3-5 compounds and Si:silicides
- Silicon photocells in thermophotovoltaic energy conversion
- Investigation of metallic impurities introduced into SiO_2 and Si by various candidate VLSI metallization systems
- Modeling of emitters
- Structural and bonding studies of practical semiconductor layers

Space Telecommunications and Radioscience

- Establishment of a Center for Aeronautics and Space Information Sciences at Stanford University (Funded by the U.S. National Aeronautics and Space Administration. The focus will be on applying VLSI techniques to develop new hardware and firmware for space instrumentation and command and control.)
- Communication satellite planning center

Material Science and Engineering

- Atomic-level physics modeling of the thermal oxidation process
- Fabrication and properties of multilayer structures
- Computer simulation of surface and film processes
- Photoelectronic properties of 2-4 heterojunctions
- Photoelectronic properties of zinc phosphide crystals, films, and heterojunctions
- Photovoltaic heterodiodes based on indium phosphide
- Preparation and properties of CdTe evaporated films compared with single-crystal CdTe

Ginzton Laboratory

- Superconducting thin films, composites, and junctions
- Acoustical scanning of optical images
- Research on nondestructive evaluation
- Evaluation of machining damage in brittle materials
- Optical and acoustic wave research
- High-frequency transducers
- Research on acoustic microscopy with superior resolution
- Study of properties of material by channeling radiation
- Surface acoustic wave MOSFET signal processor

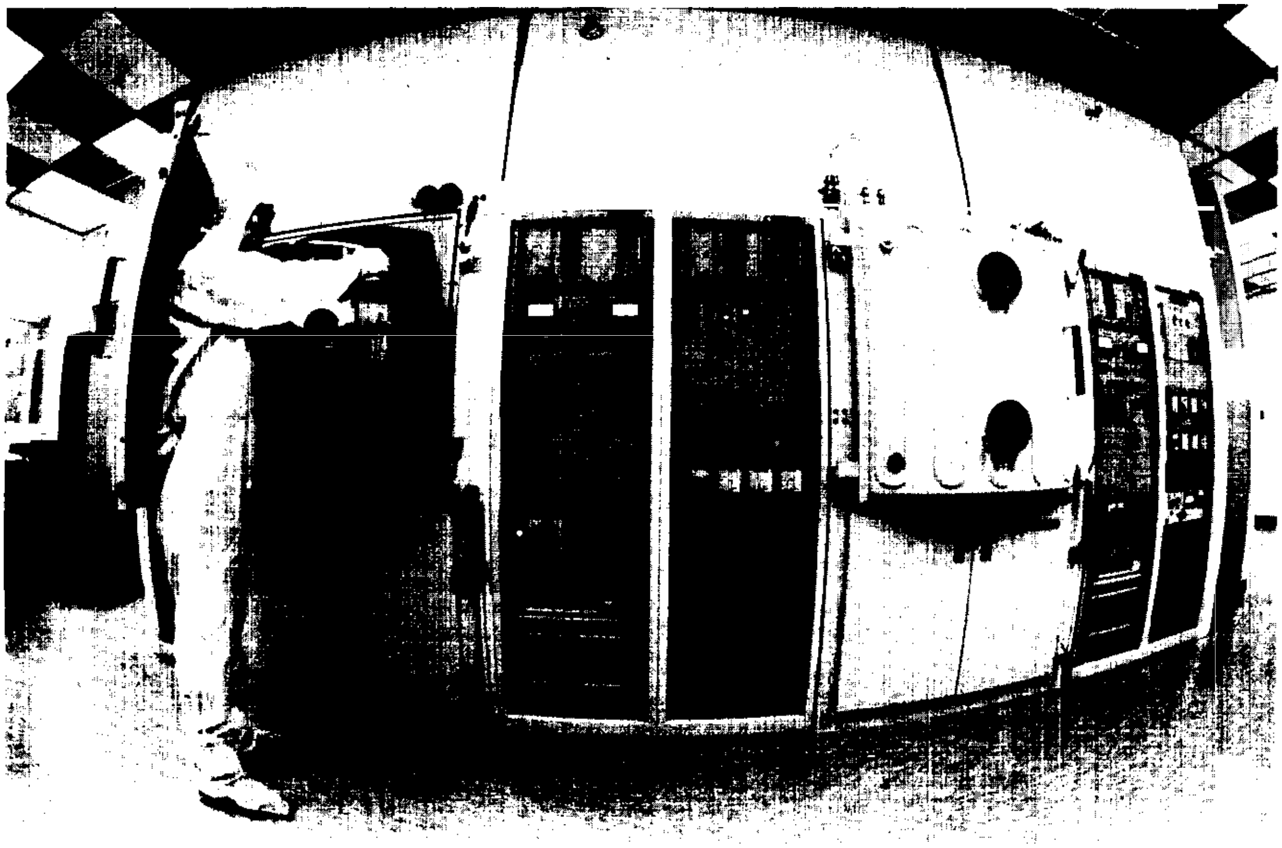
SOURCE Hewlett Packard Journal, November 1983

While the extent of State support is significant, **such a role is not new for North Carolina. The precedents for government-industry-university cooperation span two decades. The development of the Research Triangle Park, the Research Triangle Institute, the establishment of the North Carolina Board of Science and Technology, and now MCNC, are seen as models of government-industry-university cooperation to develop new technology-based industries.**[47]

New Facilities for Education, R&D, and Technology Transfer

The MCNC facility, under construction since May 1982, will house core MCNC staff, visiting engineers and scientists from industry, and visiting faculty and graduate students working on special research projects. The 100,()()()-squar~foot,” $30 million facility has capability for performing advanced manufacturing processes, including high-density integrated circuit fabrication, system design, and design tool research.

The MCNC $6.5 million communications system, scheduled for completion by 1985, will put in place a ISO-mile microwave network linking the educational and research activities at MCNC, the universities, and the Research Triangle Institute (see fig. 32, MCNC Communications System). In the first phase hookup of the system, computer science students at Duke University in Durham and UNC at Chapel Hill take classes (which originate from Durham) together without leaving their own campuses. Similarly, courses on Computer



MCNC dual source electron beam/r.f. metal evaporator for next generation integrated circuit manufacturing research

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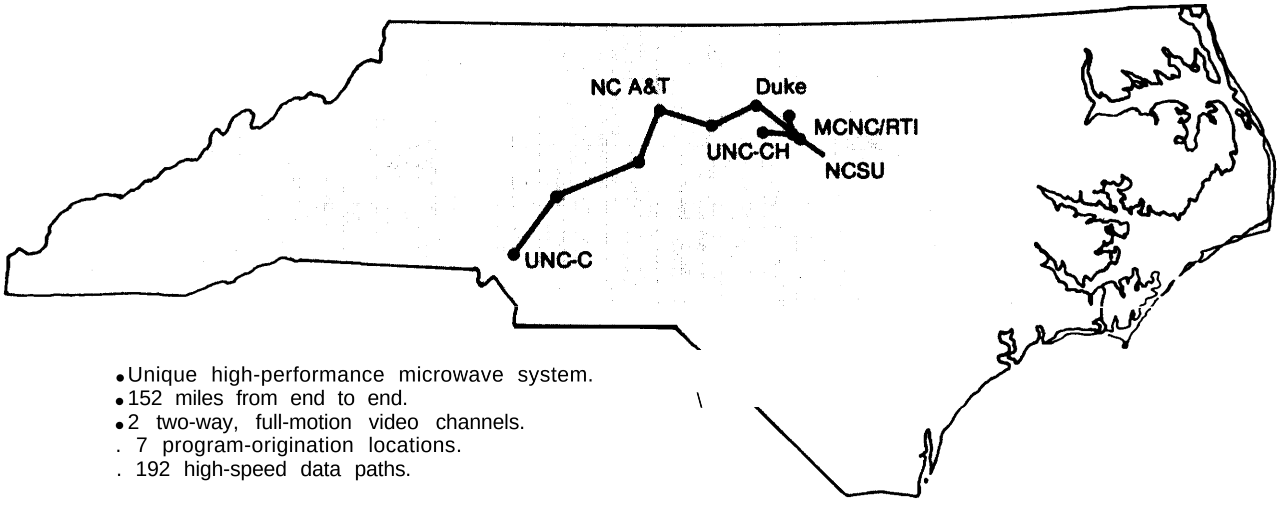
“U.S. Congress, Office of Technology Assessment, *Technology, Innovation, and* ***Regional Economic*** *Development, Census of State Government* ***Initiatives*** *for High Technology Industrial Development–Background Paper, OTA-BP-STI-21,* May 1983, p. 56,

Figure 32.—Communications System Linking MCNC Participating Sites

MCNC Communications System



- Unique high-performance microwave system.
- 152 miles from end to end.
- 2 two-way, full-motion video channels.
- 7 program-origination locations.
- 192 high-speed data paths.

SOURCE Mlcroelectronlcs Center of North Carollna, Research Triangle Park, NC

Graphics and VLSI Design originate from Chapel Hill.

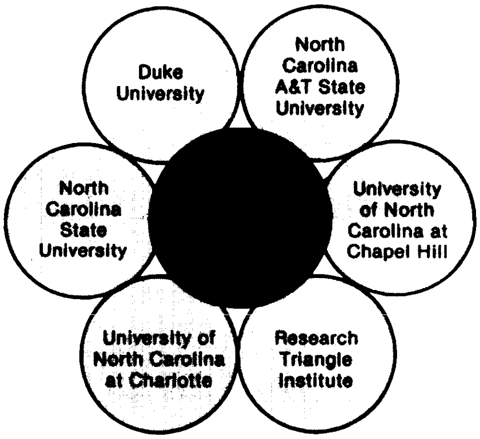
Like the MCNC research facility, the development of the telecommunications system required funding beyond the reach of each of the individual institutions. "Before the center was created, each of our participating universities hoped to develop its own major microelectronics program. But the financial realities and the difficulties of attracting talent from the limited talent pool, soon made it apparent that the only way to develop a first class program was to join forces and work together. "[48]

MCNC Working Relationships

MCNC is more than a consortium of universities sharing resources and interacting with industry. The participating institutions are linked together by MCNC (see fig. 33, The MCNC Community) and MCNC as an organizational entity and actor bridges the interests and functions of the industry and university communities (see fig. 34, Working Relationships). As members of industry work along with university researchers, the applied research and technology projects tie together the commercial technology activities under way in industry and the basic research being conducted at the universities.

Figure 33.—MCNC Participating Institutions

Microelectronics Center of North Carolina
MCNC and the participating institutions



The MCNC community

SOURCE: Microelectronics Center of North Carolina, Research Triangle Park, NC.

Since 1980, more than 30 new faculty members in microelectronics-related disciplines have been recruited. In contrast to the recent trend of faculty leaving universities for em-

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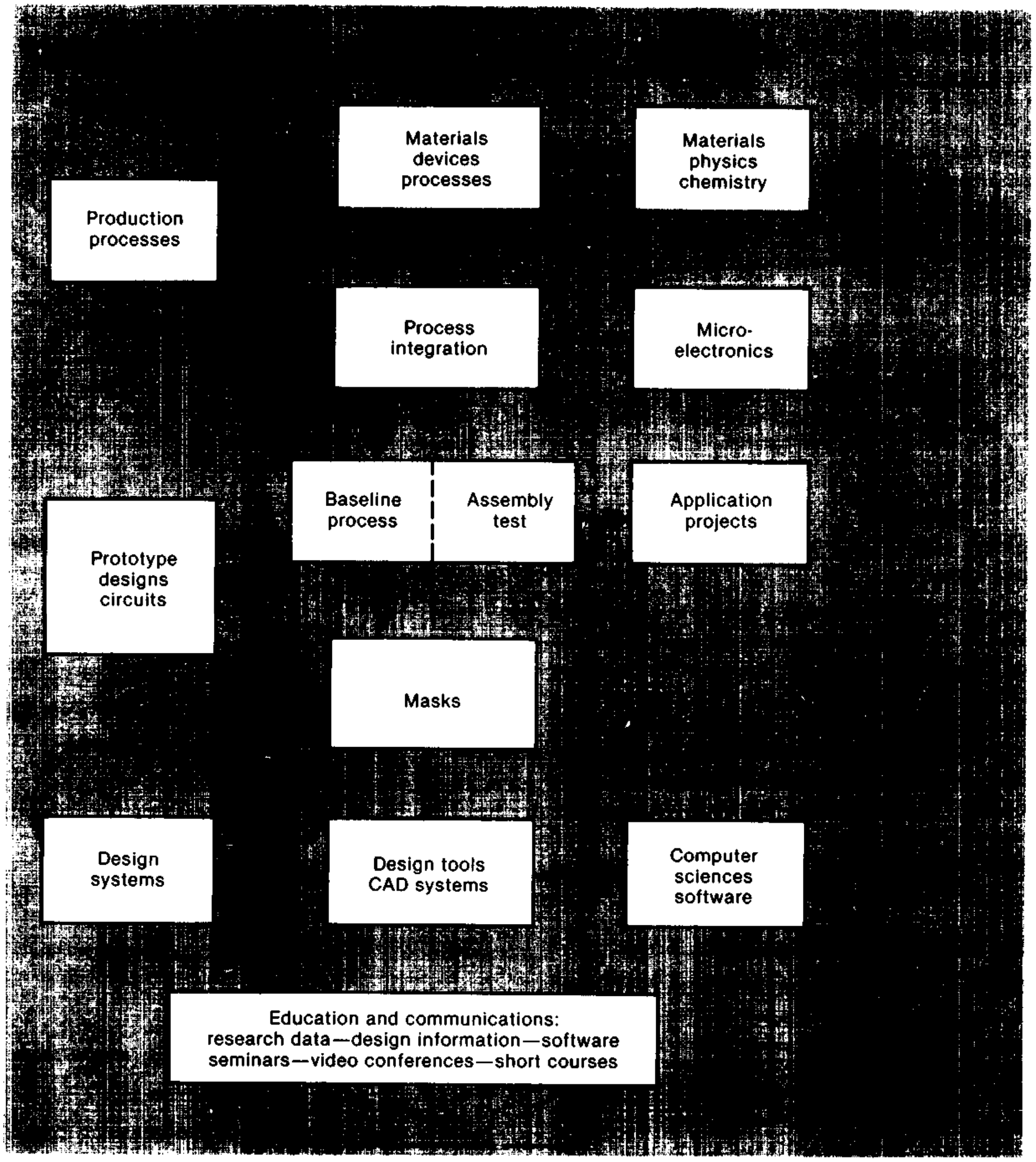
[48] D. S. Beilman, President of MCNC, "New Initiatives in Modem Electronics, " address before the Materials Research Society Annual Meeting, Boston, Nov. 14, 1983.

Figure 34.—Working Relationships, Microelectronics Center of North Carolina



SOURCE: Microelectronics Center of North Carolina, Research Triangle Park, NC

ployment in industry, 20 of the 30 new faculty have come directly from industry.[49] Full-time staff of the Center number more than 70, with 12 having joint institutional appointments. Moreover, the combined microelectronics-related manpower resources at the participating institutions consist of over 150 faculty members and 450 graduate students, a significant pool of talent.

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[49] It is felt that MCNC was able to compete with industry because it offered industry-level salaries, access to an advanced state-of-the-art research and manufacturing facility, a strong university R&D environment, and a thriving high-technology industrial center.

MCNC spokesmen argue that MCNC's ability to bridge university/industry concerns is enhanced by its structure as a nonprofit "neutral" facility. The Center's permanent staff, specialists with joint university and Center appointments, resident scientists and engineers representing industrial affiliates, visiting scientists from other national centers, and graduate students involved in special projects physically work together in the MCNC microelectronics manufacturing research complex.

In contrast to MCC (see below), a joint venture owned by its corporate companies, MCNC leaders envision this effort as providing technology functions that are not now provided by either MCC, other planned industry joint development programs, or other joint industry-university collaborative efforts in the microelectronics field. "All of the industrial joint development programs or companies are sponsored by the first tier of large electronic companies. The perceived need for these large-company joint efforts to remain competitive greatly amplifies the need for similar support to the larger number of second-tier and evolving smaller companies in the electronics industry."[50] MCNC expects to involve a broader segment of companies, in part because of lower fee levels, and because of substantial, continuing State support. The industrial affiliate program is just getting under way. By 1985, the Center expects to have 20 industry affiliates."

Affiliates can come and use the MCNC facility to develop products, can participate in research and educational programs (tuition and fees are provided for three staff members at a time for each affiliate), are represented on an advisory council, participate in semiannual reviews, and in the process have increased access to faculty and students. Nonexclusive, nontransferable licenses for intellectual property rights are available to affiliates on a preferred royalty basis. It is expected that the majority of cooperative research will be openly disseminated.

The establishment of MCNC appears to be an example of effective university-industry-government collaboration. Some point out that it is an example of how State leadership and initiative can be the driving force in pulling together traditionally independent public and private academic institutions and forging new relationships to attract significant industry participation in education, research, technology transfer, and industrial development. What has made MCNC work? In reflecting on the experiences thus far, the president of MCNC lists three basic requirements:

1. *the need for a long-term strategic approach to substantial funding.* This includes building upon existing programs and investments, as well as obtaining at least a 3-year commitment from all members of the collaborative effort as a dependable commitment to common goals;
2. *the need to structure in-depth interaction among the limited talent available.* Full participation by personnel from industry, universities, and government is necessary for understanding each other's perspective and for crystallizing and mutually accepting responsibility for important common goals; and
3. *the need to* plan for *and accelerate the transfer of research into technology* and to promote R&D in progressively more scientific endeavors while making use of all basic related investments."

MCNC spokesmen are confident of MCNC'S future. Continued support for two-thirds of its operation are expected to come from the State. Industrial and Federal support are anticipated to cover the remaining third.

Semiconductor Research Corporation (SRC)

Under the aegis of the Semiconductor Industries Association, the Semiconductor Research Corp. (SRC) was formed in 1981, to establish

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[50] D. S. Beilman, personal communication, April 1984.

[51] Each industrial affiliate pays an annual $250,000 fee.

[52] D. S. Beilmen, "New Initiatives in Modern Electronics, " op. cit.

a cooperative organization that would sponsor university research needed by the industry. SRC was incorporated in February 1982. As noted by Robert Noyce, of the Intel Corp., “The semiconductor industry is fiercely competitive and that competition has resulted in the vitality and success of the industry. ”[53] The cooperative institutional arrangement that makes SRC possible represents a change for the semiconductor industry.

In the case of that industry, the forces stimulating cooperation centered around three issues: research, manpower resources, and international competition. There was growing concern that the industry's basic research efforts, the foundation of its future well-being, were increasingly directed towards the solution of near-term problems; that industry research efforts were often duplicative and redundant, as each corporation tried to stay on top of the competition; and that fierce competition and the squeeze for profits, combined with increasing costs of R&D, created disincentives and high risk for long-term industry research efforts.[54]

At the same time, there was growing recognition that the Nation's research universities were underutilized resources that industry could turn to for long-term basic research and creation of new knowledge. There was also concern that the pool of experienced and trained manpower was being “overgrazed” by the industry itself, and that both faculty and advanced graduate students were leaving universities, irresistibly drawn to industry.[55]

In view of the growing competition for semiconductor products, and the increased and coordinated R&D efforts undertaken by its foreign competitors, it was argued that the U.S. semiconductor industry had to increase R&D.[56] Moreover, more complex and more capital-intensive research tasks, coupled with increasing lead time and a perceived shortage of sufficiently trained manpower, created additional difficulties to undertake such research, particularly for a single company.[57] And drawing on the examples of other nations, such as Japan, joint coordinated efforts are seen as ways of assuring long term competitiveness through cooperation.

These factors resulted in four major objectives for SRC:

1. increasing semiconductor research in the United States;
2. sharing research efforts among industry sponsors;
3. strengthening and upgrading research in the universities; and
4. attracting more students to this field of study and improving the quality of education.

Since its formation in 1982, SRC has grown from 10 to 40 companies, of varying size, companies that manufacture or purchase semiconductor devices for manufacturing other products, or companies that manufacture equipment or materials for use by the semiconductor industry.[58] Membership fees are tied to a company's IC sales or purchases worldwide, with annual fees ranging from $60,000 up. All

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[53] R.Noyce, “Competition and Cooperation–A Prescription for the Eighties, ” *Research Management,* March 1982, pp. 13-17.

[54] R. M. Burger, and L. W. Summey, “An Update on the Semiconductor Research Corporation”, *QIE Conference Proceedings, 1983,* pp. 51-59

[55] Robert Noyce uses the analogy of the “Tragedy of the Commons’ where the commonly held resources, in this case, *research* and *manpower* are exploited by industry self-interest, op. cit., p. 15.

[56] E.Bloch, prepared statement, *Hearings, Japanese Technological Advances and Possible United States Responses Using Joint Research Ventures,* Subcommittee on Investigations and Oversight and the Subcommittee on Science, Research, and Technology, U.S. House of Representatives, June 29-30, 1983.

[57] Ibid., p. 46.

[58] SRC membership, as of September 1984, includes: Advanced Micro Devices, Inc., AT&T Technologies, Inc., Burroughs Corp., Control Data Corp., Digital Equipment Corp., E.I. du Pent de Nemours & Co., Eastman Kodak, Eaton Corp., E-Systems, Inc., GCA Corp., General Electric Co., General Instrument Corp., General Motors Corp., Goodyear Aerospace Corp., GTE Laboratories, Inc., Harris Corp., Hewlett-Packard Co., Honeywell, Inc., IBM Corp., Intel Corp., LSI Logic Corp., Monolithic Memories, Inc., Monsanto, Co., Motorola, Inc., National Semiconductor Corp., Perkin-Elmer Corp., RCA, Rockwell International, Silicon Systems, Inc., Sperry Corp., Texas Instruments, Inc., Union Carbide Corp., Varian Associates, Inc., Westinghouse Electric Corp., Xerox Corp, and Zilog, Inc.. In addition, the following companies are in the Semiconductor Equipment and Materials Institute, Inc.: Micro Mask, Inc.; Pacific Western Systems, Inc.; Probe-Rite, Inc.; Pure Aire Corp.

member companies have equal privileges: access to all sponsored research through seminars, annual meetings, and newsletters and reports, access to research data bases and license rights, as well as an expanded recruiting base.

The SRC 1984 budget is over $15 million, up from $6 million in 1982, and $10 million in 1983. Currently, approximately $12 million is available for university research projects, an amount which "substantially increases total available funding for basic research in semiconductor technology."[59] Spokesmen point out that SRC has promoted research in engineering, mathematics, and the physical sciences underlying semiconductor technology. Major areas of focus established by the industrial board members and the technical advisory board are:

- Microstructure Sciences:
    - —Materials, Phenomena, and Device Physics,
    - —Microsciences,
    - —Device Fabrication Technologies.
- Systems and Design:
    - –Design Automation,
    - –System Component Interactions.
- Production and Engineering:
    - –Reliability, Quality Assurance, and Testing,
    - —Packaging,
    - —Manufacturing.

Impacts

In planning the research activities to be undertaken, several different levels of funding and effort were envisioned by board members. SRC has awarded individual university research projects, as well as several contracts for major research "centers of excellence" and major research projects. In its initial solicitation for proposals from the universities, SRC received 166 proposals from 63 universities. In the first. year of operation, eight universities received research contracts. In 1983, more than 30 universities, involving approximately 100 researchers and 125 graduate students, received $10 million for research through 47 contracts with SRC.[60] By May 1984, 34 universities involving 125 faculty and research staff and 202 graduate students were supported by $12.275 million in SRC research funding.

It has been SRC policy to distribute the contracts for centers and individual research projects on a broad geographic basis among leading research centers as well as to universities whose expertise in these areas is not as well established (see table 27, "Regional Distribution of SRC funding"). Thus, SRC efforts may have an impact that goes beyond the specific research projects: in helping to expand a university's research capabilities, it may help it attract high caliber faculty and graduate students. Moreover, in the long run the SRC support may contribute to additional university-industry cooperation, and new high-technology industrial development.

SRC research "centers of excellence" include Cornell University, University of California at Berkeley and Carnegie Mellon University. Major research programs are supported at the North Carolina consortium (MCNC), Massachusetts Institute of Technology, Clemson, Stanford, Rensselaer, and the University of California at Santa Barbara. Over the next few years, there are plans to support 8 to 10 more of these centers and programs, and to to conduct research into design of microstructure, properties of silicon material, computer-aided design and automation of design, lithography, beam processing, fault tolerance, micropackaging and cooling, three-dimensional silicon structures, and manufacturing systems research.

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[59] Erich Bloch, Former Chairman of the Board, SRC, estimates that the semiconductor industry allocates 3 to 5 percent of its R&D budget to basic research–approximately $35 million to $50 million annually. He notes that the R&D tax credit was an important factor in the decision to proceed with the formation of SRC. Moreover, if there were a differentially larger tax incentive for industry-sponsored university research, there could be an even broader expansion of industry funding of university research in the future. Testimony before the Subcommittee on Taxation and Debt Management, Senate Committee on Finance, Feb. 24, 1984.

[60] N. Snyderman, "Industry Observer," *Electronic News*, January 1984.

Table 27.—A Distribution of SRC Funding by Region, January 1985

Region/institution		Funding
New England		$1,377,588
MIT	$ 976,110	
Yale	211,258	
Brown	104,000	
Vermont	86,220	
Middle Atlantic:		$4,441,210
Cornell	$1,776,651	
CMU	1,414,580	
RPI	800,000	
Penn State	126,489	
Rochester	119,000	
Johns Hopkins	114,589	
Columbia	89,901	
North Central		$1,734,900
Illinois	750,607	
Michigan	337,155	
Minnesota	206,755	
Notre Dame	126,000	
Iowa	118,013	
Purdue	102,870	
Wisconsin	93,500	
South Atlantic:		$1,814,927
MCNC	$ 900,000	
Clemson	215,424	
Georgia Tech	190,553	
Auburn	152,342	
North Carolina	149,744	
Mississippi State	135,000	
Florida	71,864	
Mountain:		$ 738,544
Arizona	$ 503,530	
Arizona State	100,914	
Colorado State	84,000	
Texas A&M	50,100	
Pacific:		$3,510,240
Stanford	$1,511,990	
Berkeley (UC)	$1,350,000	
Santa Barbara	450,000	
Southern California	101,943	
UCLA	96.307	
Total		$13,617,409

SOURCE: Semiconductor Reseach Corp. Reasearch Triangle, NC.

In its short span of operation, SRC provides an example of a joint industry approach in the management and coordination of information technology R&D and in the establishment of new relationships between industry and academia for the conduct of research efforts.Thus far, SRC member companies have been able to agree on research priorities. Ongoing research projects have focused onVLSI circuit processes and Computer-Aided Design, aimed at commercially relevant results over a 3-to 5-year period. In developing a list of potential research topics for longer term research (e.g., research needs in GaAs), SRC workshops have involved both university researchers and industry participants. Beginning with abroad array of potential research needs, the groups were able to reach consensus on research topic priorities and areas for future focus.

There is other evidence that SRC's approach has fostered closer links between industry and academia. In addition to the technical advisory board, composed of member company representatives, SRC has established industrial mentors for each contract. With recommendation from the technical advisory board, an industry engineer or scientist in an SRC member company becomes the direct contact point for each of the SRC contracts. The industrial mentor can help identify important problem areas, and may from time to time be able to provide direct technical assistance to the university research community. Through topical research meetings, additional industry-university contacts are strengthened.

Program reviews of SRC Centers of Excellence cover a wide spectrum of technical interest and are designed to attract abroad representation from the industry and research community. Member companies may also participate in SRC activities by assigning an employee to participate in the management of the SRC program at Research Triangle Park. Industry assignees may also become researchers in residence, spending at least 3 months to a year, working in the university laboratory with one or more of the university researchers. This may foster technology transfer in ways that are not accomplished through the dissemination of reports, newsletters, and conference results.

There is no question that SRC has provided additional research opportunities for the university community and that these opportunities have reached a range of institutions. Research results have been freely disseminated. The ownership rights to the patents are held by the universities. So far, only one patent has resulted from SRC-sponsored research. Several researchers have indicated their appreciation of lack of bureaucratic hassle in the SRC contracting process, and find the yearly reports and reviews helpful.

The eventual impacts of SRC will be seen in how well it meets the needs of both universities and the semiconductor industry. For the member companies, the usefulness of research results, in both the short and long term may become factors in their continued support. For the industry as a whole, new knowledge and new manpower are important, as well as the attraction of additional researchers to new fields of study in the future. How effective is the interface between the university and the industry over the long term? A sign of success, at least interim success, note SRC spokesman, is the increase in the number of member companies and the continued support of the initial companies who have signed on each of the three years of operation.

Microelectronics and Computer Technology Corporation (MCC)

The Microelectronics and Computer Technology Corporation (MCC) is an R&D joint-venture owned and operated by 20 U.S. computer and semiconductor companies.[61] The idea for MCC was conceived by William C. Norris, President of Control Data Corp., and in his view "MCC represents a cooperative effort to develop a broad base of fundamental technologies for use by members who will each add their own value and continue to compete with products and services of individual conception and design. "[62] While these companies have traditionally avoided cooperation, "in this period of scarce resources, however, and at a time when this country's leading position in technology is being challenged by foreign competitors, refusal to cooperate is no longer tenable. '[63]

Governed by a Board of Directors composed of representatives of each shareholder company, MCC began formal operations in January 1983, with the selection of its chief executive officer and the development of a plan for R&D. A technology Advisory Board of shareholder representatives provides advice in developing the research strategies, in evaluating new program proposals, and in monitoring existing programs.

With a $50 million to $60 million annual budget, four long-range advanced technology programs are expected to cover a 6- to 10- year time span.[64] In defining the areas of research, the shareholder companies "came to concentrate on areas in which they believed accomplishments were necessary to make quantum jumps in the performance of the next generation of computers. "[65] The programs include:

- Packaging: A 6-year program to advance the state-of-the-art in semiconductor packaging and interconnect technology, with a focus on technologies compatible with automatic assembly at both the circuit and system level.
- Software Technology: A 7- to 8-year program to develop new techniques, procedures and tools that can be used to improve the productivity of the software development process by one or two orders of magnitude.
- Computer-Aided Design and Manufacturing (CAD/CAM): An 8-year program to improve CAD/CAM technology and to develop an integrated set of tools that will have particular application to complex systems and the complex VLSI chips from which they will be built.
- Advanced Computer Architecture: This 10-year effort will focus on artificial intelligence, new techniques for database management, human interface with computers, and parallel processing.

In addition to forming a comprehensive agenda for research, MCC has selected a site for operation and hired staff. While still in tem-

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[61] **Shareholder companies include Advanced Micro Devices, Allied Corp., BMC Industries, Control Data Corp., Digital Equipment Corp., Eastman Kodak, Gould, Harris Corp., Honeywell, Lockheed, Martin Marietta Aerospace, Mostek, Motorola, National Semiconductor, NCR, RCA, Rockwell, Sperry Corp., Boeing, and 3-M.**

[62] W. **C. Norris, "Cooperation for Improving Productivity, " keynote address, Prepatory Meeting for the White House Conference on Productivity, San Diego, CA, July 20, 1983.**

[63] W. **C. Norris, "How to Expand R&D Cooperation, "** *Business Week,* **Apr. 11, 1983, p. 21.**

[64] **B. R, Admiral, President, Microelectronics Computer Corp., personal communication, May 1984.**

[65] **M. A. Fischetti, "MCC: An Industry Response to the Japanese Challenge, "** *IEEE Spectrum,* **November 1983, pp. 55-56.**

porary quarters, more than 173 professionals have been brought into the operation. Originally, the staffing plan was to draw senior and highly trained technical professionals from the participating companies, with only about 25 percent expected to come from the outside. In actuality, 40 percent of the professionals have come to MCC from the shareholder companies. There is some concern that MCC will attract senior faculty members from the universities and put a strain on available manpower resouces, particularly in areas such as artificial intelligence.[66] MCC officials recognize that if they hire away the university faculty, they will compromise the universities' ability to produce highly trained top-quality graduates-the very people they need for the future.[67]

So far, the MCC strategy appears to be working; of the talent on board, the majority are from industry, and the remainder from academia and government. Full operation, expected by late 1985, will bring the total number of professionals to 350. At full strength, MCC will be looking for the "brightest graduates, " and it is expected that many will come from nearby educational institutions–the University of Texas and Texas A&M University.

Not surprisingly it was these universities, and their promised commitment to develop a major, first-class computer science and microelectronics program, as well as strong support from the State officials and the business community, that led to the decision to locate MCC headquarters in Austin, after conducting a search of 57 cities in 27 States. It has been noted that few cities in Texas—or anywhere else—could put together the incentives that were offered. The University of Texas at Austin promised to construct a $20 million office-laboratory facility, to be leased to MCC. Thirty new faculty positions and 75 new graduate fellowships would be supported. In addition, there was a commitment of at least $1 million a year for maintenance and support for researchers, and $5 million for purchase of laboratory equipment at UT-Austin. After MCC selected the Austin site, an anonymous donor made available $8 million, with the proviso that other private sources match that amount. The university then matched that total, using funds from the Permanent University Fund (derived from revenues from oil leases on land owned by the University). The result is 32 new endowed chairs at the University of Texas, 10 of which are in microelectronics and computer sciences.[68]

The developments in the academic community, the development of MCC, and the developments in the fast-growing high-technology corridor between Austin and San Antonio[69] have drawn national attention. The potential for economic growth, quality education and cutting-edge research are cited as the real cause for excitement.[70] Texas leaders point out that these high-technology initiatives (e.g., MCC, the university programs) are just the beginning of the State's commitment to high technology development. It is recognized that not only the universities, but the entire State educational infrastructure have to be strengthened and supported over the long term. The improvement of the State's elementary and secondary schools has been addressed by the Governor as well as MCC's director, Admiral Bobby Inman and other leaders in industry, who are concerned that without improvement Texas public schools represent a deterrent to recruiting engineers and other highly trained specialists. Among the recommendations of a special panel headed by Texas industry leader, H. Ross Perot, are increased teacher salaries,

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[66] See the OTA case study on Artificial Intelligence.

[67] In a recent interview, Admiral Inman discussed this issue. "I have a standard rule that I will not recruit from universities. If I am approached by someone on a faculty, my requirement is that they go up the chain and say they are going to leave to go to industry. I can't have it both ways–to encourage the production of additional top-quality graduate students, and to hire away university talent. " See: J. A. Turner, "Big-Spending U. of Texas Aims for the Top in Computer Science, " *Chronicle of Higher Education,* Apr. 4, 1984.

[68] All 32 chairs are aimed at strengthening the university's science and engineering programs. Eight disciplines are the focus of this effort: chemistry, mathematics, molecular biology, physics, computer engineering, manufacturing, systems engineering, materials science, and microelectronics.

[69] For examples of recent economic development, see J. R. Linebacker, "Letter from Austin: Texas Cash Fuels Electronics Boom. " *Electronics,* June 15, 1983, pp. 95-96.

[70] J. Kraft, "The Japaning of Texas, " *Washington Post,* Apr. 17, 1984.

State aid to equalize school spending among rich and poor districts, and strengthened curriculum requirements—at a cost estimated at nearly $1 billion in new taxes.

The ultimate test for MCC will be its ability to draw sufficient talent to conduct the R&D necessary to keep its member companies internationally competitive. MCC officials and corporate sponsors are confident that this can be accomplished. Some observers are less confident that MCC will be able to transfer its technology to individual corporate efforts. As noted earlier, MCC originally intended to draw its staff principally from the member companies, thereby speeding technology transfer. Since recruitment has drawn more heavily on outside sources, MCC will have to find other approaches if it is to accomplish this goal.

While it is too soon to assess the impacts of the MCC joint venture, and related activities at the University of Texas and Texas A&M, they do provide an example of how academia, business, and government can join forces to create new institutional arrangements.

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