Journal of The Washington Academy of Sciences,
Volume 74, Number 3, Pages 61–66, September 1984

High Technology, Can Higher Education Meet the Challenge[1]

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In order to better understand the interrelationships of high technology and education, it is important to understand the requirements for high technology and the state of America's colleges and universities in the 1980s.

Technological development is based primarily on individuals with basic backgrounds in science, engineering and related fields. Peter Drucker[2] in a discussion on applied science and technology, suggests "Technology is not then the application of science to products and processes as is often asserted—at best, this is a gross oversimplification. In some areas for example, Polymer chemistry, pharmaceuticals, atomic energy, space exploration and computers, he line between scientific inquiry and echnology is a blurred one. The scientists who find new basic knowledge and the technologist who developed specific products and processes are one and the same man. In other areas, however, highly productive efforts are still primarily concerned with technological problems and have little onnection to science as such.

"In the design of mechanical equipment, machine tools, textile machinery, printing resses, scientific discoveries as a rule play very small part and scientists are not ommonly found in the research laboratory. More important is the fact that science, even where most relevant, provides only the starting point for technological effort. The greatest amount of work on new products and processes comes well after the scientific contribution has been made. Know-how in the technological contribution takes a good deal more time and effort in most cases than the scientists know what. But science is not a substitute for today's technology, it is the base and starting point."

Peter Drucker[2] points out technological research has not only a different methodology for invention, it leads to a different approach known as innovation or the purposeful and deliberate attempt to bring about through technological means a distinct change in the way man lives. Innovation may begin by defining a need or an opportunity, which then leads to organizing technological efforts to find a way to meet the need or to exploit the opportunity. To reach the moon, for example, required a great deal of new technology. Once the need had been defined, the technological work was organized systematically to produce the technology.

Innovation can proceed from new scientific knowledge in the analysis of the opportunities it might be capable of creating.

Innovation is not a product of the twentieth century. Edison was an innovator as well as an inventor. It is only, however, in the twentieth century and largely through the research laboratory and its approach to research that innovation has become central to technological effort. Innovation technology is used as a means to bring about change in education and in the economy. Thus, modern technology influences traditional society and culture, but innovation means that technological work is done not only for technological reasons, but also for non-technological reasons.

High technology requires not only the inventor or innovator or the entrepeneur, but development requires the finances or the venture capitalist. No cash means trouble in any industry. The new company is not yet producing or selling a product so the marketplace cannot pass judgment on the company's activities or products.[3]

A company and the venture capitalist hope the product makes a splash in the marketplace and sizeable profits will be realized.

In a Wall Street Journal article[4] in August of this year Ed Zschau and Don Ritter, the Chairman and Vice-Chairman of the Republican Task Force on high technology initiatives in the House of Representatives indicated that they believe the government needs to foster an environment in which innovation, new ideas and new companies can flourish. They suggested four conditions are needed for an environment that promotes innovation.

- "A strong commitment to basic research. Deepening and broadening our understanding of fundamental processes will form the basis for industries, processes, and products in the future.
- Incentives for investors, entrepreneurs, and innovators provide the capital and take the personal risks associated with making technological advances, developing new products, establishing new companies and rejuvenating mature industries.
- A strong educational capability, particularly in the sciences that ensures an ample quantity of trained technical and managerial personnel and a broa
educated and well-trained citizens
meet the challenges of a rapidly
world.
- Expanding market opportun
mestic as well as foreign, require he
mestic economic environment an
sive trade policy."

How do the universities fit into
for developing entrepreneurs and h
nology. Obviously, there is the
role of training scientists and engi
a modern fashion. It is important
nize, however, that the number
rates in the physical sciences and
tics have been dropping. For ex
1950 there were 200 mathemati
tists completing their Ph.D.s whic
its peak in 1969–70 of 1300; it ha
back to about 800 with only 61
Ph.D.s going to U.S. citizens in m
ics. The same pattern holds true i
try and physics[5].

The pipeline of scientists and en
also against us. Betty Vetter[6] re
the number of 22 year-olds will
between 1983 and 1999. This yea
year's graduating classes will be t
in history and 25% larger than th
1998. The estimate is that curre
seventh grade through college, 4.
men and 1.9% of the women earn
tative bachelor's degree. One in
men who earn a quantitative bac
gree will go on to a Ph.D. and one
of the women will go that far.

Universities have an added pr
sides not attracting the students
and engineering in large numbers
not teaching the students with
technology. Some reports have
that engineering and science stud
are being trained on equipme
about four generations away fro
being used in the new industries
tional Science Foundation, the
Education and other groups have
surveys which suggest that prob
lion dollars would be required
modern up-to-date equipment

leges and universities in the basic sciences and engineering. A 1984 survey of university chemistry departments suggests $500 million is needed for Chemistry instrumentation alone[7]. Universities, neither public nor private, have that amount of money to invest. New modern instrumentation for research is very expensive.

Spectrometers of all types, infra-red, ultra-violet, visible, mass are all electronically run with their computers built in. The "simple IRs" that cost $2–3,000 twenty years ago now cost $40–50,000; which is significantly greater than the inflation factor. The whole cost of the instrumentation has escalated dramatically. A simple nuclear magnetic resonance spectrometer to do proton NMR that is designed for routine work, nothing fancy, cost $30,000 four years ago. The company no longer makes the instrument because it would only do routine work and was used only for teaching purposes. A 90 megahertz instrument cost $100,000 about six years ago. The state of the art 500 megahertz instrument is about a half-million dollars without considering the aspects of the money and personnel required to maintain it or the auxiliary computers required to process the data.

However, NMR is only one of four or five spectral techniques which most organic and biochemists would employ to do studies on molecular structure. A mass spectrometer (simple version $100,000), IR, UV-Visible, possibly X-ray, atomic absorption, etc., are also required by the organic chemist. The equipment required by the biologist, in modern DNA studies, gene splitting, etc., of course, is even more expensive.

Engineering schools have always been equipment based and have problems greater than the sciences. However, the problems for science and engineering departments of universities go beyond the equipment; personnel is a very key aspect of the whole process. The figures for the Fall of 1984 on the unfilled vacancies in engineering and computer science are not yet available but there is no reason to expect that things will have improved substantially. In 1983 engineering schools across the country had about 10% of their positions unfilled.[8] Computer science faculty in most universities have degrees from either engineering or sciences. Ph.D.s in computer science were not generally offered 20 years ago, but there are special problems with the scientists and engineers who go into computer science because they quickly find life is more lucrative outside academia; academic salaries are simply not competitive with industry. They never have been, but the gap has been widening in recent years. In some state universities while the salaries for faculty may be higher overall than they are in private institutions, many state universities preclude paying differential salaries for marketplace conditions so that added salary cannot be provided to the engineering faculty. Private universities whose salaries are often lower are more likely to pay the added salary for the engineer or scientist but they still simply are not competitive.

Unfortunately, the salary differential has an additional impact on the high school science and math teachers who are well trained and who can find an even greater salary differential. The number of trained science and math teachers leaving secondary education for the industrial marketplace is growing and is a problem that the nation must face and recognize.[9]

The Panel on Technical Manpower Resources[9] reports:

> "Today's shortage in engineering faculty comes at a time when the demand for an engineering education is skyrocketing. The Engineering faculty Shortage Project notes that many deans—more than 80% surveyed—report that the quality of instruction has declined: class sizes are reaching unmanageable levels; existing faculty already overloaded have become more so; and the overall system is showing signs of fatigue if not outright collapse. Although engineering graduates may be turned out in appreciable quantities, the quality of their education is being progressively degraded."

The cooperation needed between universities and high tech industries is, of course, best exemplified by Silicon Valley and Stanford University. It is important to recognize, however, that there are certain special characteristics that led to the success of Silicon Valley. First of all, Stanford owned 8,800 acres of land which they could not sell. Stanford administrators were faced with the problem of converting the University land into money.[10]

Stanford, prior to Silicon Valley, was not the great university it is today. The whole concept of Silicon Valley as a high technology industrial park was really the idea of Frederick Terman who was then Vice President of Stanford. Terman said the idea of an industrial park near a university was completely foreign, both to Stanford and to the firms that would become leasees. The first leasee for the Stanford industrial park was Varian Associates who had some rented buildings in San Carlos. In 1951 they signed the first lease for four acres prepaying $4,000 an acre for a 99 year lease. There is no inflation clause in that original agreement and it has been suggested that Varian Associates probably has one of the sweetest land deals in Silicon Valley. Hewlett Packard took a lease in 1954 and became really the lease nucleus for Silicon Valley. Terman would use Packard or Hewlett to talk about the advantages of being close to a university; today there are 90 tenant firms employing 25,000 workers in the Stanford research park.[10]

The park contributed financially to the growth of Stanford in that the prepaid leases provided 18 million dollars which was used to retain and recruit star faculty. In 1981 the annual income was about 6 million dollars per year. The advantage of the income from Stanford Research Park is that is is unrestricted and can be put to any good use by the Stanford administrators.[10]

A very important aspect of the development for Stanford and the use of the funds was Terman's plan for Stanford's assent—the strategy "Steeples of Excellence." His view was academic prestige depends upon high, but narrow steeples of academic excellence, rather than upon coverage of more modest height extending solidly over a broad discipline. Exactly what is a steeple? Terman defined it as "A small faculty group of experts in a narrow area of knowledge and what counts is the steeple be high for all to see and that they relate to something important."[10]

Many universities have attempted to follow the Stanford model, route 128 in Boston is one example, the North Carolina Research Park is another. All of the successes relate to the association with a research university. However, the research university also must have policies that facilitate technological transfer through close industry-university relationships. The successful universities also have had programs which are strong in engineering, and the engineering professors took the lead of spinning off new high technological firms. Computer science and biomedical professors are also increasingly engaged in entrepreneurial activities. Engineering, computer science and biomedicine are all highly applied university fields. They do not exist as pure academic disciplines. Commercial firms exploit the advantages and basic knowledge that are made by university scholars.[10]

Everett Rodgers and Judith Larsen[10] point out "It is worth noting that Harvard and Berkeley, universities near MIT and Stanford, respectively, did not play much of a role in Route 128 or in Silicon Valley. They are excellent academic institutions, but both Berkeley and Harvard lack an ethos favorable for technology transfer from university scientists to private firms. Neither Berkeley nor Harvard is particularly strong in engineering; their strength is in more basic science and fields like the social sciences and humanities. There were two important spin-offs from Harvard University to Route 128, Wang Laboratories begun in 1952 by Dr. Wang of Harvard's computer lab and Polaroid launched in 1937 by Ed Land. There were almost no Harvard spin-offs during the 60's and 70's when the MIT engineers were busy getting Route 128 going.

California Institute of Technology in Pasadena is an outstanding engineering school; it has one special kind of spin-off—the jet propulsion laboratory which does high technology work in aeronautics space industry. But other than JPL, Cal Tech did not help create a high tech complex in Pasadena. "It's as if any entrepreneurial spark that might have been generated at Cal Tech suffocated in the smog of the greater Los Angeles basin,"[10] In an information society the university, particularly the research university, where the production of Ph.D.s and the conduct of scientific research is the main activity of the central institution much as the factory was in the previous area of industrial society, it is not an accident that most high technology systems in the United States are centered around a prestigious research university. A nearby source of well trained graduates for work in high technology firms plus a steady flow of research-based technologies are important contributions by the research university in Silicon Valley.

Since the founding of Stanford in 1951, there have been 18 other specifically related research parks which have been created in attempts to attract industrial firms—all were modeled after Stanford's. The University of Miami has been unable to attract any industrial occupants and the university research park in Georgia has been able to attract only one occupant, the University Nursery School for Faculty Children.[10]

Another very important aspect of all of these is the venture capital. One third of the available capital is concentrated in Silicon Valley, most of the rest is in New York and Boston and almost none of it in other parts of the United States. Other important aspects are the climate and quality of life.[10]

People who can work anywhere generally prefer to reside in an area with a sunny climate. However, sunshine is not the only aspect, the quality of life such as the availability of beaches, ski areas, theatres and other culture amenities which can be found in a metropolitan center also seem to be important for success.

However, it has been suggested the most important single factor is entrepreneurial fever. It's doubtful that a university in formal classes can teach entrepreneurship. Entrepreneurship is probably best learned by example. Successful role models who people can actually meet and get to know lead to the "he did it, why can't I" concept. Most communities and states that attempt to establish a scientific complex seek to do it by transplanting growth and appear to ignore the importance of growth from within. Instead of trying to seduce other cities' companies, officials wanting to start a high tech complex should be thinking about their own spin-offs. The conglomeration of spin-offs in the same neighborhood as their parent firms is why high technology complex builds up in a region. The chain reaction of spin-offs from spin-offs is a kind of natural process. Setting off the initial spark is the key.[10]

The research triangle in North Carolina began in 1960 with the founding of Research Triangle Park which was a 6,000 acre Research and Development center that now contains 40 private government organizations in such fields as electronics, pharmaceuticals, and air pollution. An early boost was provided by IBM when it decided to locate one of its Research and Development operations there in 1965. With the cooperation of Duke, North Carolina State and the University of North Carolina, along with the support of the state government, the research triangle offered low taxes, freedom from unionization and a pleasant climate. The Research Triangle has also generally concentrated on microelectronics and the North Carolina governor has recently convinced his legislature to put up 24 million dollars for a microelectronic center at North Carolina, a research and training facility. However, the Research Triangle does not yet have venture capital, nor has it yet developed the entrepreneurial spin-offs.[10]

Everett Rodgers[10] suggests that the successful high technology complexes have been planned, have a research university with policies to encourage the involvement of faculty with industry, have venture capital present, have the entrepreneurial spirit demonstrated by spin-offs and have either good climate or quality of life or both. The other aspect is a commitment from the universities, the state governments and a key industry to begin the process. Both Virginia and Maryland, through the state governments and universities, are promoting the concept of developing research parks in the Metropolitan area in Northern Virginia and near the University of Maryland. It is too early to tell whether or not these ventures will be successful. Both have some of the necessary ingredients, but neither has them all. The Virginia General Assemby has approved $11 million for the construction of a center for innovative technology to be built near Dulles International Airport, plus an additional $19 million to improve research facilities at five of the state universities.[11]

The state of Ohio is using fields in which Ohio is already strong to develop its university-high tech center. For example, the Edison Polymer Innovation Corporation received slightly more than five million dollars from the state and will be operated jointly by the University of Akron and Case Western Reserve.[12]

Will higher education meet the challenges of high technology? Higher education can, but only through the cooperation of industry, state and federal government and changing approaches to university policies.

There is probably going to be a need for increasing sponsorship by the government for basic research, more tax incentives for corporate contributions to educational institutions, more flexibility in both universities and corporations in their employment policies and there needs to be strengthening of patent laws. There needs to be establishment of a comprehensive and forward-looking federal policy that recognizes the role of science and technology in the economic health of the country and encourages innovative scientific and technological development facilitating their incorporation into the economy.

As the American Chemical Society communicated recently[13] "We must sustain a strong and long-term federal commitment to the development of a creative scientific personnel in a knowledge base upon which the country can base its economic future."

The universities are the central key in the development of their faculty and their facilities to better train students. It is going to take everyone's effort to ensure success.

References Cited

1 Presented in part of the September meeting of the Washington Academy of Science, American University, Washington, D.C. (1984).

2. **Krangberg, Melvin and Carroll W. Pursell, Jr., eds.** *Technology in Western Civilization, Volume III: Technology in the Twentieth Century,* Oxford University Press, Inc. (1967).

3. **Burked, John G. and Marshall C. Eakin, eds.** *Technology and Change,* Boyd and Frasce Publishing Co., San Francisco (1979).

4. **Zschau, Ed and Don Ritter.** "Encourage Innovation Instead of Industrial Lemons". *Wall Street Journal,* 1 August 1984, p. 24.

5. *Doctoral Recipients from United States Universities,* published by the National Research Council, National Academy Press, Washington, D.C. (1983).

6. "The Science and Engineering Talent Pool," Proceedings of the 1984 Joint Meeting of the Scientific Manpower Commission and Engineering Manpower Commission, Washington, D.C. May, 1984. Available from the Scientific Manpower Commission, Washington, D.C.

7 "Instrumentation Needs of Academic Departments of Chemistry", *Anal. Chem.* **58,** 1225A (1984).

8. *Engineering Manpower Bulletin,* published by Engineering Manpower Commission, New York, New York (1983–84).

9. Technical Excellence in America: Incentives for Investment in Human Capital. Work in Progress, June, 1984. Center for Strategic and International Studies, Georgetown University, Washington, D.C.

10. **Rogers, Everett M. and Judith K. Larsen.** *Silicon Valley Fever,* Basic Books, Inc., New York, New York (1984).

11. "Virginia Tech Center", *Washington Post,* 12 September 1984, p. B14.

12. **Lepkowski, Will,** "States Launches High-Tech Program to Bolster Industrial Economy", *Chem. & Eng. News,* 17 September 1984, p. 9.

13. Letter from Warren Niederhauser, President, American Chemical Society to Honorable Trent Lott, Republican National Committee dated 27 April 1984.