An Environment For Entrepreneurs*

Edward B. Roberts

June, 1991 WP# 3300-91-BPS

This paper is edited and reprinted with permission from Edward B. Roberts, *Entrepreneurs in High Technology: Lessons from MIT and Beyond* (New York: Oxford University Press, 1991). It is to be published in K. R. Manning et al. (Editors), *MIT: Shaping the Future* (Cambridge: MIT Press, forthcoming 1992).

AN ENVIRONMENT FOR ENTREPRENEURS*

by

Edward B. Roberts
David Sarnoff Professor of Management of Technology
M.I.T. Sloan School of Management

Global pursuit of technology-based industrial development has mushroomed in the past decade. Greater Boston's Route 128 and California's Silicon Valley have become prototypes for other regions' and other nations' visions of their own futures. Research and writing about the Technopolis (Dorfman, 1983; Miller, 1985; Rogers and Larsen, 1984; Segal Quince Wickstead, 1985; Smilor, Gibson and Kozmetsky, 1989; Tatsuno, 1986) have accompanied actions by cities and states throughout the United States and Europe to launch entrepreneurial centers, often based on newly established university incubators and venture capital firms. In Asia, Japan has committed major funding to create a network of "science cities" (going beyond its own Tsukuba), the Republic of China has coupled tax incentives and subsidies to help grow its technology park, and Singapore has linked sophisticated local industrial development planning with government-funded venture capital investments in overseas start-ups to attract high-tech opportunities. Even the Soviet Union has established joint ventures with U.S. and Japanese corporations to generate centers for new technology-based industry.

None of these kinds of governmental programs contributed to the growth of high-technology industry in the Greater Boston area. But what did cause this original American Technopolis to develop? What forces continue today to encourage young local scientists and engineers to follow entrepreneurial paths? In his review of entrepreneurial decision-making, Cooper (1986) argues for six different potential environmental influences: economic conditions, access to venture capital, examples of entrepreneurial action, opportunities for interim consulting, availability of support personnel and services, and access to customers. This chapter traces the evolution of Boston's high-technology community, providing support for all of Cooper's

---

* This chapter is edited and reprinted with permission from Edward B. Roberts, *Entrepreneurs in High Technology: Lessons from MIT and Beyond* (New York: Oxford University Press, 1991).

variables. But I also identify even more critical aspects of culture and attitude that have built a local environment that fosters entrepreneurship .

Early Influences: The Heritage of World War II Science and Technology

The atomic bomb, inertially guided missiles and submarines, computer-based defense of North America, the race to the moon, and the complex of high-technology companies lining Route 128 outside of Boston are phenomena that became prominent in the postwar years. This was a time marked by a plethora of scientific and technological advances. World War II had defined technology as the critical element upon which the survival of the nation rested. That war brought scientists from the shelter of their labs into the confidence of those in the highest levels of government. And in the postwar years their power and their products and by-products began to shape society, the economy, and the industrial landscape.

How had this started? The sudden need for war research in the early 1940s transformed universities like MIT into elite research and development centers where the best scientific and technological talent was mobilized for the development of specific practical devices for winning the war. Virtually whole universities redirected their efforts from pure scientific inquiry to the solving of critical problems. While many scientists had to neglect their previous research in favor of war-related innovations, the scientists themselves were not neglected. Science and its offspring technology had become the property of the whole nation with an immediate relevance for all the people.

In addition to the urgent expansion and redirection of university research, the war made necessary the reorganization of research groups, the formation of new working coalitions among scientists and engineers, between these technologists and government officials, and between the universities and industry. These changes were especially noteworthy at MIT, which during the war had become the home of major technological efforts. For example, the Radiation Laboratory, source of many of the major developments in wartime radar, evolved into the postwar Research Laboratory for Electronics. The Servomechanisms Lab, which contributed many advances in automatic control systems, started the research and development project that led to the Whirlwind Computer near the end of the war, created numerically controlled milling machines, and provided the intellectual base for undertaking, in 1951, the MIT Lincoln Laboratory. After the war the Servo Lab first changed its name to the Electronic Systems Lab and continues today as the Laboratory for

Information and Decision Systems. Lincoln Lab focused initially on creating a computer-based air defense system (SAGE) to cope with the perceived Soviet threat. To avoid continuing involvement in production and operations once the SAGE system was ready for implementation, MIT spun off a major group from Lincoln Lab to form the nonprofit MITRE Corporation, chartered to aid in the later stages of SAGE and undertake systems analysis for the government. Lincoln then reaffirmed its R&D thrust on computers, communications, radar and related technologies primarily for the U.S. Department of Defense. The Instrumentation Lab, growing out of the wartime gunsight work of Dr. Charles Stark Draper, its founder and director throughout his long career at MIT, continued its efforts on the R&D needed to create inertial guidance systems for aircraft, submarines, and missiles. It followed up with significant achievements in the race to the moon with developments of the guidance and stellar navigation systems for the Apollo program. The former Instrumentation Lab now bears Draper's name in its spunoff-from-MIT nonprofit status. Draper testified as to the scope of these endeavors: "Personal satisfaction ... was greatest when projects included all essential phases ranging from imaginative conception, through theoretical analysis and engineering to documentation for manufacture, supervision of small-lot production, and finally monitoring of applications to operational situations" (Draper, 1970, 9). All these MIT labs, major "source organizations" for the new high-technology enterprises that were studied in my entrepreneurship research program (Roberts, 1991), were spawned during a period in which little debate existed about a university's appropriate response to national urgency. These labs have been successful in fulfilling their defined missions, while also providing a base of advanced technology programs and people for other societal roles.

Building on a Tradition

The war efforts and the immediate postwar involvements of MIT with major national problems built upon a much older tradition at MIT, enunciated by its founder William Barton Rogers, in 1861, when he created an institution to "respect the dignity of useful work". Its slogan is "Mens et Manus", the Latin for mind and hand, and its logo shows the scholar and the craftman in parallel positions. MIT "for a long time ... stood virtually alone as a university that embraced rather than shunned industry" (*The Economist*, 1987, 7). From its start MIT developed close ties with technology-based industrialists, like Thomas Alva Edison and Alexander Graham Bell, then later with its illustrious alumnus Alfred P. Sloan during his pioneering years at General Motors, and

also with close ties to the growing petroleum industry. In the 1930s, MIT generated The Technology Plan, to link industry with MIT in what became the first and is still the largest university-industry collaborative, the MIT Industrial Liaison Program.

These precedents were accelerated by the wartime leadership of its distinguished president, Karl Taylor Compton, who brought MIT into intimacy with the war effort just as he himself headed up all national R&D coordination in Washington. In the immediate postwar years Compton pioneered efforts toward commercial use of military developments, among other things helping to create the first institutionalized venture capital fund, American Research and Development (ARD). "ARD was, in part, the brain-child of Compton, then head of MIT. In discussions with Merrill Griswold, Chairman of Massachusetts Investors Trust, and Senator Ralph Flanders of Vermont, then President of the Federal Reserve Bank of Boston, Compton pointed out that some of the A-bomb technology which had been bottled up for four years had important industrial applications. At the same time, it was apparent to Griswold and Flanders that much of New England's wealth was in the hands of insurance companies and trusts with no outlet to creative enterprises. Griswold and Flanders organized ARD in June 1946 to supply new enterprise capital to New England entrepreneurs. [Compton became a board member, MIT became an initial investor, and a scientific advisory board was established that included three MIT department heads. General Georges] Doriot, who was Professor of Industrial Management at Harvard, was later asked to become president" (Ziegler, 1982, 152). ARD's first several investments were in MIT developments, and some of the emerging companies, such as Ionics and High Voltage Engineering, were housed initially in MIT facilities, an arrangement that even today would be seen as a source of controversy and potential conflict at most universities. Compton's successor as president of MIT, James R. Killian, furthered the encouragement of entrepreneurial efforts by MIT faculty and staff, as well as close ties with both industry and government. At various times Killian served on the boards of both General Motors and IBM, and as President Eisenhower's Science Advisor.

The traditions at MIT of involvement with industry had long since made legitimate the active consulting by faculty of about one day per week, and more impressive for its time had approved faculty part-time efforts in forming and building their own companies, a practice still questioned at many universities. Faculty entrepreneurship, carried out over the years with continuing and occasionally heightened reservations about potential conflict of interest, was generally extended to the research staff as well, who were thereby enabled to "moonlight" while being "full-time" employees of MIT labs

and departments. The result is that approximately half of all MIT spin-off enterprises, including essentially all faculty-initiated companies and many staff-founded firms, are started on a part-time basis, smoothing the way for many entrepreneurs to "test the waters" of high-tech entrepreneurship before making a full plunge. These companies are obvious candidates for most direct movement of laboratory technology into the broader markets not otherwise served by MIT. Incidentally, few of the faculty founders ever resign their MIT positions, preferring to remain at MIT like Amar Bose, founder of Bose Corporation, or Harold Edgerton, co-founder of EG&G, while turning over the full-time reins to their former graduate students and lab colleagues. George Hatsopoulos, founder of Thermo Electron Corporation, Jay Barger, co-founder with another faculty colleague of Dynatech, and Alan Michaels, founder of Amicon, are among the few faculty who left to pursue their entrepreneurial endeavors on a full-time basis, with great success achieved in all three cases.

Although today regional and national governments on a worldwide basis seek to emulate the Boston-area pattern of technological entrepreneurship, in the early years the MIT traditions spread to other institutions very slowly. The principal early disciple was Frederick Terman, who took his Cambridge experiences as an MIT Ph.D. student back to Stanford University, forsaking a faculty offer by MIT to eventually lead Stanford into technological excellence. Terman had gained first-hand exposure to the close ties between MIT and industry, made more important to him by his being mentored by Professor Vannevar Bush, later dean of engineering and then vice president at MIT, who participated in founding the predecessor of the Raytheon Corporation. The attitudes he developed at MIT led Terman to encourage and guide his former students, such as William Hewlett and David Packard and the Varian brothers, to start their high-technology firms and eventually to locate them next to the university in Stanford Research Park (Rogers and Larsen, 1984, 31). While Terman's efforts obviously produced what has evolved into "Silicon Valley", the resulting proliferation of firms there came from multiple spin-offs of other companies, and did not follow the dominant Greater Boston pattern of direct fostering of new firms from MIT labs and departments. One early study found only 8 out of 243 new technical firms in the Palo Alto area had their origins in Stanford University (Cooper, 1971), probably due in part to Stanford's lack of major government-sponsored laboratories. Indeed, despite the distance from their alma mater, MIT alumni are surprisingly the founders of over 175 companies in northern California, accounting for 21 percent of the manufacturing employment in Silicon Valley (Chase Manhattan, 1990).

Our MIT study of major technology-based regions in North America and

Europe (Sirbu et al., 1976) determined that Research Triangle Park in North Carolina has little evidence of local entrepreneurial activity and few ties between entrepreneurship and the three major universities in that area. And in 1989, only 23 firms in total are documented as "spin-outs" of University of Texas-Austin, including faculty, staff, students, and technology transferred out to other entrepreneurs (Smilor, Dietrich and Gibson, 1989). Feeser and Willard (1989) find far fewer university spin-offs, just one, in their national sample of 108 computer-related founders. Cambridge University, England is seen as heavily responsible for the development of the several hundred high-technology firms in its region, and yet only "17% of new company formation has been by individuals coming straight from the University (or still remaining in it)" (Segal Quince Wickstead, 1985, 32). Thus, the MIT-Route 128 model still today remains unusual in its degree of regional entrepreneurial dependence upon one major academic institution. Perhaps other regions need other "models" if they are to achieve technology-based industrial growth (Cooper, 1985).

The Neighboring Infrastructure

Yet MIT has not been alone over the past several decades in nurturing the technology-based community of Boston, now sprawling outward beyond Route 128 to the newer Route 495. Northeastern University, a large urban institution with heavy engineering enrollment and an active cooperative education program, has educated many aspiring engineers who provide both support staff and entrepreneurs to the growing area. Wentworth Institute educates many of the technicians needed to support the development efforts at both the university labs as well as the spin-off companies. Boston University and Tufts University, both with strong science and engineering faculties, also play important roles. Even small liberal arts Brandeis University has participated, with Professor Orrie Friedman in 1961 starting Collaborative Research, Inc., forerunner of the much later biotechnology boom in the Greater Boston area.

Possibly surprising to readers from outside of the Boston area, Harvard University has not had a substantial role in entrepreneurial endeavors until the recent biotechnology revolution. In many ways Harvard, over the years, has looked down its "classics" nose with disdain at the "crass commercialism" of its technological neighbor a few miles down the Charles River. An Wang, who had worked at the Harvard Computation Laboratory, is the most prominent exception to this rule. Change in regard to encouraging entrepreneurship is in the wind, even at Harvard. The outpouring of excellent

research and discovery from Harvard's Chemistry and Biology Departments, as well as from the Harvard Medical School across the river in Boston, has caused Harvard faculty and staff recently to become much more active and successful participants in entrepreneurial start-ups, although not without voiced reluctance and controversy at the university. In fact, in a dramatic revolution of its policies Harvard asked Professor of Biochemistry Mark Ptashne to start Genetics Institute in 1979, a company in which Harvard would hold 15 to 20 percent equity. But protest by critics as to possible influence of such ownership caused Harvard to pull out. Ptashne went ahead and formed the company, while still remaining on the Harvard University faculty (*Boston Business Journal*, March 23, 1987). In 1989, the Harvard Medical School took the far reaching step of organizing a venture capital fund to invest in new companies whose founders relate in some manner to Harvard Medical, in some ways mimicking MIT's much earlier activities in regard to AR&D, but nevertheless a pioneering step among academic institutions. Indeed, a recent survey of life sciences faculty (Louis et al., 1989) places Harvard tenth in the nation, with 26 percent, in percentage of "faculty members holding equity in a company whose products or services are based on their own research". MIT life sciences faculty place first in that same survey with 44 percent, such as Professors Alex Rich and Paul Schimmel who co-founded Repligen Corporation. Some of these biotech ventures involve faculty from both Harvard and MIT, such as Biogen, co-founded by Harvard's Walter Gilbert and MIT's Phillip Sharp.

Encouraged no doubt by the exemplary venture capitalist role of Professor Doriot, and separated by a river from main campus influence, many Harvard Business School graduates, joined after its 1951 founding by MIT Sloan School of Management alumni, found welcome homes even in the early company developments. These business school graduates got involved in start-up teams initially as administrators and sales people, and in more recent years participating frequently as primary founders. Thus, Aaron Kleiner, from the MIT School of Management, shares the founding of three high-technology companies with his MIT computer science undergraduate roommate Raymond Kurzweil. And Robert Metcalfe combined MIT educational programs in both engineering and management prior to his launch of 3Com. The Greater Boston environment has become so tuned to entrepreneurship that even student projects with local companies, a part of routine course work in every local management school, have ended up helping to create numerous entrepreneurial launches. Several firms are claimed to have been generated from feasibility studies done as part of Doriot's famed *Manufacturing* course at the Harvard Business School. And *INC.* magazine founder Bernard Goldhirsch

credits a Sloan School marketing course with confirming for him the huge market potential for a magazine targeted toward entrepreneurs and small business managers (*INC.*, 1990, 39-40).

Boston entrepreneurs also have benefited from understanding bankers and private investors, each group setting examples to be emulated later in other parts of the country. The First National Bank of Boston (now Bank of Boston) had begun in the 1950s to lend money to early stage firms based on receivables from government R&D contracts, a move seen as extremely risky at the time. Arthur Snyder, then vice president of commercial lending of the New England Merchants Bank (now the Bank of New England division of Fleet National Bank), regularly took out full page ads in the *Boston Globe* showing himself with an aircraft or missile model in his hands, calling upon high-technology enterprises to see him about their financial needs. Snyder even set up a venture capital unit at the bank to make small equity investments in high-tech companies to which he loaned money. Several scions of old Boston Brahmin families became personally involved in venture investments even in the earliest time period. For example, in 1946, William Coolidge helped arrange the financing for Tracerlab, MIT's first nuclear-oriented spin-off company, eventually introducing William Barbour of Tracerlab to ARD which carried out the needed investment (Ziegler, 1982, 151). Coolidge also invested in National Research Corporation (NRC), a company founded by MIT alumnus Richard Morse to exploit advances in low-temperature physics. NRC later created several companies from its labs, retaining partial ownership in each as they spunoff, the most important being Minute Maid orange juice. NRC's former headquarters building, constructed adjacent to MIT on Memorial Drive, now houses the classrooms of the MIT School of Management. Incidentally, long before the construction of Route 128, Memorial Drive in Cambridge used to be called "Multi-Million Dollar Research Row" because of the several early high-technology firms next to MIT, including NRC, Arthur D. Little Inc. and Electronics Corporation of America. The comfortable and growing ties between Boston's worlds of academia and finance helped create bridges to the large Eastern family fortunes --the Rockefellers, Whitneys, and Mellons, among others-- who also invested in early Boston start-ups.

And by the end of the 1940s, when space constraints in the inner cities of Boston and Cambridge might have begun to be burdensome for continuing growth of an emerging high-technology industrial base, the state highway department launched the building of Route 128, a circumferential highway (Europeans would call it a "ring road") around Boston through pig farms and small communities. Route 128 made suburban living more readily accessible

and land available in large quantities and at low prices. MIT Lincoln Lab's establishment in 1951 in the town of Concord, previously known only as the site of the initial 1776 Lexington-Concord Revolutionary War battle with the British, "the shot heard round the world", or to some as the home of Thoreau's Walden Pond, helped bring advanced technology to the suburbs. Today Route 128, proudly labeled by Massachusetts first as "America's Technology Highway" and now as "America's Technology Region", reflects the cumulative evidence of forty years of industrial growth of electronics and computer companies. Development planners in some foreign countries have occasionally been confused by consultants and/or state officials into believing that the once convenient, now traffic-clogged, Route 128 highway system actually caused the technological growth of the Greater Boston area. At best Route 128 itself has been a moderate facilitator of the development of this high-technology region. More likely the so-called "Route 128 phenomenon" is a result and a beneficiary of the growth caused by the other influences identified earlier.

Accelerating Upward From the Base: Positive Feedback

A critical influence on entrepreneurship in Greater Boston is the effect of "positive feedback" arising from the early role models and successes. Entrepreneurship, especially when successful, begets more entrepreneurship. Schumpeter observed: "The greater the number of people who have already successfully founded new businesses, the less difficult it becomes to act as an entrepreneur. It is a matter of experience that successes in this sphere, as in all others, draw an ever-increasing number of people in their wake" (Schumpeter, 1936, 198). This certainly has to be true at MIT. The earliest faculty founders, Edgerton and his colleagues (the co-founders of EG&G), Bolt and Beranek of the MIT Acoustics Lab and then of the company bearing their names (now BBN, Inc.), and John Trump of High Voltage Engineering, were senior faculty of high academic repute at the times they started their firms. Their initiatives as entrepreneurs were evidences for others at MIT and nearby that technical entrepreneurship was a legitimate activity to be undertaken by strong technologists and leaders. Karl Compton's unique role in founding ARD furthered this image, as did the MIT faculty's efforts in bringing early-stage developments to ARD's attention. Obviously, "if they can do it, then so can I" might well have been a rallying cry for junior faculty and staff, as well as for engineers in local large firms. Our comparative study of Swedish and Massachusetts technological entrepreneurs finds that on average the U.S. entrepreneurs could name about ten other new companies, three or

four of which were in the same general area of high-technology business. Few of the Swedish entrepreneurs could name even one or two others like them (Utterback et al., 1988). A prospective entrepreneur gains comfort from having visibility of others like himself, this evidence more likely if local entrepreneurship has a critical mass, making the individual's break from conventional employment less threatening.

The growing early developments also encouraged their brave investors, and brought other wealthy individuals forward to participate. As example of the spiraling growth of new firms, even in the early days, Ziegler (1982) shows the proliferation of thirteen nuclear-related companies "fissioning" within fifteen years from Tracerlab's 1946 founding, including Industrial Nucleonics (now Accuray), Tech Ops, and New England Nuclear (now a division of DuPont). With forty years of activity, a positive feedback loop of new company formation can generate significant outcomes, even if the initial rate of growth is slow. In the mid-1960s, through dramatic proliferation of spin-off companies, Fairchild Semiconductor (founded by MIT alumnus Robert Noyce) gave birth to similar and rapid positive feedback launching of the semiconductor industry in Silicon Valley (Rogers and Larsen, 1984). And Tracor, Inc. seems to be providing a comparable impetus to new company formation in Austin, Texas, leading to 16 new firms already (Smilor, Gibson and Kozmetsky, 1989). Exponential growth starting in the early-middle 1970s has generated the several hundred firm Cambridge, England high-tech community (Segal Quince Wickstead, 1985, 24).

A side benefit of this growth, also feeding back to help it along, is the development of supporting infrastructure in the region -- technical, legal, accounting, banking, real estate, all better understanding how to serve the needs of young technological firms. In Nancy Dorfman's (1983) assessment of the economic impact of the Boston-area developments she observes "a network of job shoppers that supply made-to-order circuit boards, precision machinery, metal parts and sub-assemblies, as well as electronic components, all particularly critical to new start-ups that are developing prototypes and to manufacturers of customized equipment for small markets. In addition, dozens if not hundreds of consulting firms, specializing in hardware and software populate the region to serve new firms and old." Of course, this massive network is itself made up of many of the entrepreneurial firms I have been investigating over the years. Within this infrastructure in the Boston area are new "networking" organizations, like the MIT Enterprise Forum (to be discussed later) and the 128 Venture Group, which serve to bring together on a monthly basis entrepreneurs, investors, and other participants in the entrepreneurial community, contributing further positive loop gain

(Nohria, 1990).

This positive feedback phenomenon certainly occurred in the Greater Boston region as a whole and, as illustrated by the Tracerlab example, also was effective at the single organizational level. As one individual or group departs a given lab or company to form a new enterprise, the event may mushroom and tend to perpetuate itself among others who learn about the spinoff and also get the idea of leaving. Sometimes one group of potential entrepreneurs feels it is better suited than its predecessors to exploit a particular idea or technology, stimulating the second group to follow quickly. Perhaps as a result, four companies were formed from Instrumentation Laboratory employees to produce "welded module" circuits, a technique developed as part of the Instrumentation Lab's Polaris guidance system project. Ken Olsen, co-founder and builder of Digital Equipment Corporation, recalls that being approached by others to start a company was his first thought about entrepreneurship as a career. The "outside environment" can help this process by becoming more conducive to additional new enterprise formation. In some circumstances, venture capitalists, learning more about a source organization from its earlier spin-offs, may actively seek to encourage further spin-offs from the same source. This certainly played an important role in the 1980s proliferation of biotechnology spin-offs from MIT and Harvard academic departments.

Other "Pulls" on Potential Entrepreneurs

In addition to the general environmental encouragements on Greater Boston technological entrepreneurship, specific "pulls" are at work on some of the people, making entrepreneurship an attractive goal to attain. Such influences may inhere in the general atmosphere of a particular organization, causing it to be more conducive to the new enterprise spin-off process. For example, until his recent death Stark Draper, visionary leader of the MIT Instrumentation Laboratory (now renamed the Draper Lab), was a key source of encouragement to anyone who came in contact with him. No wonder that the National Academy of Engineering established the Draper Prize to be the equivalent in engineering of the Nobel Prizes in science. With the good fortune to fly coast-to-coast with him one night on a "red eye" from Los Angeles, I learned much about Draper's unique attitudes toward developing young technologists. "I try to assign project managers who are just a bit shy of being ready for the job. That keeps them really hopping when the work gets underway, although the government officials usually want to wring my neck." "I break up successful teams, once they've received their honors. That way

every one remembers them for their success, rather than for some later failure. Also, this causes every young person in the Lab to be sitting within one hundred feet of someone who's had his hand shaken by the President of the United States." "The Lab is a place for young people to learn. Then they can go someplace else to succeed." " When I give speeches I single out those who have already left the Lab -- to become professors elsewhere, VPs of Engineering in industry, or founders of their own companies. Staying behind in the lab is just for a few old beezers like me who have no place else to go!" His environment was one of high achievement, but with negative incentives for remaining too long. Salaries flattened out quickly, causing the income gap between staying and leaving to grow rapidly as an engineer gained experience. Engineers completing a project had a sharp breakpoint, a good time for someone confident from the success of his or her project to spin-off. In retrospect Stark Draper seemed consciously trying to encourage spin-off of all sorts from his laboratory, perhaps the highest attainment achievable by an academic scientist.

"They were looking for excitement. They weren't just looking for a more logical way to make software: they wanted to be part of another major breakthrough. After all, Margaret Hamilton had helped send a man to the moon by the time she was 32. 'Apollo changed my life,' she said. 'It had a profound effect on us. Some people never got over it. And there have been other spinoffs from Draper because of it.' The follow-up for Hamilton, who was in charge of more than 100 software engineers at Draper, was going to have to be something big. She seems to have found it by starting her own business. To Hamilton, 'A growing high-tech company is like a mission.' With theory in hand, Hamilton and [Saydean] Zeldin founded HOS [Higher Order Software, the only company in my entrepreneurship research sample founded by two women] in 1976" (*Boston Business Journal*, August 20-26, 1984, 7).

No questions were asked if Instrumentation Lab employees wanted to borrow equipment to take home over the weekend, and many of them began their new companies "moonlighting" with this kind of undisguised blessing. Draper wanted reasonably high levels of turnover, and constant introduction to the Lab of bright eager young people. Over a fifteen year period during which I traced "I-Lab" performance, the average age of Instrumentation Laboratory employees remained at 33 years, plus or minus six months. This young-age stability, maintaining the lab's vitality and fighting off technological obsolescence, was not true at most of the other MIT labs studied.

Draper apparently produced similar effects in his teaching activities at MIT. Tom Gerrity, founder of Index Systems, which in turn later created Index

Technology and Applied Expert Systems as sponsored spinouts, reports that Draper's undergraduate elective subject showed him the importance of being able to put together lots of different skills and disciplines to produce a result. Gerrity, now dean of the Wharton School of Business at the University of Pennsylvania, adopted this systems point of view in founding Index several years later, after three MIT degrees and a stint as a faculty member in the MIT Sloan School of Management.

Some other MIT laboratory directors followed similar patterns of entrepreneurial "sponsorship" in smaller less well-known labs. For example, the head of the Aeroelastic and Structures Laboratory of the MIT Department of Aeronautics and Astronautics had the attitude that the lab provided an internship type of position and that staff members were more or less expected to move on after a reasonable period. In other labs the environment just seemed to breed entrepreneurism. Douglas Ross, who left the Electronic Systems Lab with George Rodrigues to found SofTech, Inc., comments: "The entrepreneurial culture is absolutely central to MIT. The same mix of interests, drives and activities that make a [Route] 128-type environment is the very life blood of MIT itself. No other place has the same flavor" (Simon, 1985, 20). Ross epitomizes this "life blood" quality. When SofTech was established MIT took the exceptional step for that time of making a direct equity investment in his ground zero company, joining a large number of us who shared great confidence in Doug Ross's vision.

Indeed, the challenging projects underway at most of the labs create a psychological "let-down" for their participants when the projects end. Many of the entrepreneurs indicate that they became so involved with their work on a given project that when these projects were completed they felt that their work too was completed. Several of the entrepreneurs attest that their sense of identification with the source lab began to wane as the project neared completion. As Margaret Hamilton indicates earlier, only through the challenge of starting their own enterprises did they think they could recapture the feelings that they were doing something important.

Beyond the labs other activities at MIT have over the years encouraged entrepreneurship. The MIT Alumni Association, not the central MIT administration, undertook special efforts to encourage entrepreneurship among its members. Beginning in the late 1960s, the Alumni Association initiated a series of Alumni Entrepreneurship Seminars. Intended to serve an expected small group of 40 to 50 Boston-area young alumni, the effort escalated when over 300 alumni signed up for the first weekend. Over a two-year period the Alumni Association then launched a pattern of weekend seminars targeted for MIT alumni all around the country. Over 2,000 attended

the initial national series, and called for more follow-ups. The alumni committee got ambitious and wrote a book on how to start a new enterprise, the only book ever jointly published by the MIT Alumni Association and the MIT Press, and distributed it widely to interested alums (Putt, 1974). Directories were assembled and widely distributed of alumni interested in the possibility of starting a firm, who might be willing to meet with similarly interested alums, thus beginning a rudimentary matching service. Ongoing monthly programs were started in several cities across the country, including The MIT Venture Club of New York City and then the MIT Enterprise Forum in Cambridge. The latter still continues to stimulate and help new enterprises, and to provide the networking needed to build start-up teams and linkages with prospective investors and advisors. And now the MIT Enterprise Forum has expanded to chapters in fourteen major cities across the U.S. and even in other countries where MIT alumni are concentrated. It has recently undertaken operation of the Technology Capital Network, a computer matching service aimed at facilitating linkages between New England entrepreneurs, whether MIT alumni or not, and informal investors (or "angels"). In 1991 the Alumni Association began a new series of MIT Young Alumni Entrepreneurship Seminars, suggesting a renewal of the cycle.

All of these efforts spread the word, and lend legitimacy to entrepreneurial activities. And they have produced results. Over the years many entrepreneurs have introduced themselves to me, saying they remember hearing me talk years ago at the MIT Alumni Entrepreneurship Seminars. My first meeting with Neil Pappalardo, with whom I much later participated in founding Medical Information Technology (Meditech), occurred at the first MIT Alumni Entrepreneurship Seminar. Bob Metcalfe, the principal inventor of Ethernet and later the founder of 3Com, a great success in the computer networking market, reports that after attending an MIT alumni luncheon on starting your own business, he resigned from Xerox's Palo Alto Research Center, returned to Boston and established his company with two other engineers (Richman, 1989, 37). Similarly, the founders of Applicon, now the CAD division of Schlumberger, decided to create their firm after listening to a seminar at Lincoln Lab that reported on the characteristics of the previous Lincoln spinoff entrepreneurs.

And most recently new policies instituted by John Preston, head of MIT's Technology Licensing Office, further encourage entrepreneurship, especially by faculty and research staff. In addition to conventional technology licensing to mainly large corporations for fees, still dominating the MIT technology transfer portfolio, Preston now is willing to license MIT-originated technology in exchange for founder stock in a new enterprise

based on that technology. In the first year of this new practice, 1988, six new companies were born based on licensed MIT technology, with sixteen firms started in the second year of policy implementation. Matritech is one example, based on technology developed by Professor Sheldon Penman and researcher Edward Fey to employ antibodies to find proteins within cells, a new approach for detecting certain cancers. Entrepreneur Steve Chubb, Matritech's president, received a license from MIT and raised $3.5 million in early outside venture capital in exchange for giving MIT an equity participation in the new venture (Gupta, 1989).

"Pushes" on Entrepreneurship

Some environmental forces affecting the "would-be" entrepreneur are the "negatives" about his or her present employer, rather than the "positives" of going into business. The uncertainties due to the ups and downs of major projects have often been cited as a source of grief, and sometimes even led to expulsion of individuals into a reluctant entrepreneurial path. The evidence suggests that a stable work environment would probably produce far fewer entrepreneurial spin-offs than one marked by some instability. For example, the entrepreneurs who emerged from one large diversified technological firm that I studied rank most frequently "changes in work assignment" as the circumstance that precipitated formation of their companies, followed by "frustration in job". One fourth of the companies from that firm were founded during the three years that the firm suffered some contract overruns and layed off some technical people, although none of those actually layed off from this firm became entrepreneurs. The "worry about layoff" and seeing the parent firm in a terrible state are cited by many of that period's spin-offs. Even at the Draper Lab staff was cut by about 15 percent through layoff and attrition after the completion of the Apollo program, stimulating a number of new firms. 92% of the spin-offs from the MIT Electronic Systems Lab (ESL) occurred during an eight-year period, when only 28% would have been expected if spin-offs occurred randomly over time as a function only of total employment. The large number of ESL projects completed during that period is one explanation for the "lumpiness" of new company creation.

Frustration with the noncommercial environment at the MIT labs and academic departments bothered some of the potential entrepreneurs. Margaret Hamilton, already mentioned in regard to her formation of HOS, exclaims: "The Draper non-profit charter was frustrating, especially if you wanted to get into something exciting. There was always the sense of living in a no-man's land" (*Boston Business Journal*, August 20-26, 1984, 6). Many

of the entrepreneurs had specific devices or techniques that they wanted to market. Others had no definite products in mind but saw clear prospects for further applications of the technology or skills they had learned at their source organizations. The prospective entrepreneurs usually felt they could not exploit these possibilities at MIT labs, because the labs properly concentrated on developing new technology rather than finding applications for existing technology. Unfortunately for their industrial employers, many of the spinoffs from industrial companies report the same frustration, despite the not unreasonable presumption that their large firm employers should welcome at least some of these new ideas. In another geographic area Cooper (1986) finds that 56 percent of the new company founders had been frustrated in their previous jobs. Yet frustration should manifest itself more reasonably with just job changing, not company creating, behavior. Clearly the overall environment promoting entrepreneurship in Greater Boston makes the new company option an active choice, if other conditions are right.

And the Beat Goes On

What happens now? At the time of this writing in 1991 the U.S. and especially the Massachusetts economy are weakened and many observers are in despair about the future of its high-tech industry. Japan, Singapore, Taiwan, and Korea are rapidly growing as centers of technology-based industry. Europe is experiencing increased political and economic consolidation and strengthening. Does all this mean an end to high-technology entrepreneurship in the U.S. and elsewhere? The evidence suggests the opposite.

At the grass roots students are showing far more interest in recent years in entrepreneurship courses and clubs. For example, MIT Sloan School of Management students have worked with the MIT Technology Licensing Office to set up projects on possible commercialization of MIT technology. The Sloan School's graduate student New Venture Association has raised money in conjunction with the MIT Entrepreneurs Club, consisting mainly of engineering undergraduates, to provide awards for the best new business plans developed by student teams. At the Harvard Business School the several elective courses in entrepreneurial management, finance and marketing muster over 25 percent of the total student body, breaking from the HBS traditional concentration on the large corporation. This growth in student interest and enrollment in entrepreneurship subjects is a national phenomenon, manifested in parallel by the outbreak of national academic society meetings devoted to the same topic. Awards for papers or research on entrepreneurship are

suddenly being provided by business and engineering schools across the country, further nourishing the interests and exposure. To support these student initiatives MIT has just approved a proposal to create a Center for Entrepreneurship based in the Sloan School of Management, following the examples of numerous other universities.

Increasingly states and regions throughout the United States are championing the cause of high-tech entrepreneurship. While Massachusetts was long ago the first state to establish a venture capital organization to aid new firms, the successful and continuing Massachusetts Technology Development Corporation, many other states have joined its ranks, and with much greater political and economic commitment. Pennsylvania's Ben Franklin Partnership has recruited four venture capital firms to begin efforts in different parts of the state, including Zero Stage Capital of Pennsylvania, located in State College, Pennsylvania and working collaboratively with the main campus of Penn State University to transfer technology, build new companies, and stimulate the region's economy. Efforts underway nationwide include targeting state funds or state pension funds to invest in local-oriented venture capital companies, formation of new company incubator organizations in various cities and on college campuses, developing tax legislation aimed at providing incentives to new or young firms and to their investors. These activities across the United States cross-pollinate and stimulate, not stifle, entrepreneurism in each region.

Indeed high-tech companies are being started at an increasing pace. The Bank of Boston, for example, finds that more new Massachusetts firms were organized by MIT alumni in the past decade than in any prior ten years. (Bank of Boston, 1989) In biotechnology alone they created twenty new companies. A few years back writers like John Kenneth Galbraith came to the wrong conclusion that the age of entrepreneurship in the U.S. is dead. (Galbraith, 1985) He argued that only giant corporations could survive in the present era. Today some writers are equally wrong in arguing that we have too much entrepreneurialism in the United States, which they claim harmful to our competitiveness in world markets. These modern Luddites urge that government policies should be changed so as to discourage our high rate of new company formation, again claiming that only giant corporations can compete effectively. (Ferguson, 1988) This naive argument totally ignores that entrepreneurs have been a unique source of U.S. innovation and economic growth for centuries (Gilder, 1988). High-technology entrepreneurs have rapidly moved ideas from university and corporate research and development laboratories out to the market, where both they and society have benefited. And indeed MIT has been the long-recognized international model of this

achievement. In contrast many large corporations have excelled in generating new technologies but have failed to exploit them commercially. The policy issue that does need attention is not how to stifle independent entrepreneurs, but rather how to stimulate comparable corporate entrepreneurship.

One discouraging development for Massachusetts and for the rest of the U.S. is the apparent peaking in the late 1980s of new venture capital funds. According to Venture Economics, Inc. new monies added to U.S.-based venture capital (VC) funds declined from slightly more than $4 billion in 1987 to about $2.5 billion in 1989, and increasing fractions of these funds are targeted toward later stage companies, rather than seed-stage or early growth stage new enterprises. This shrinkage appears to have continued during 1990 and 1991. To put this into perspective, however, as recently as 1980 new commitments to VC funds were only $0.5 billion. The "overshoot" in funding during the six years from 1983 to 1988 in my judgment caused many inappropriate VC investments to be made, and sometimes at rather irresponsibly high evaluations. Money chased deals, and many companies got funded that would have been overlooked in other time periods. (In sharp contrast, Digital Equipment was funded in 1957 with $70,000 that purchased 78 percent of the new firm.) With the exception of these last few years the new venture capital funds available currently are quite comparable in magnitude with the past. Furthermore, the preference of most venture capitalists has long been for later stage investments, in recent years financing even leveraged buyouts and buybacks of public stock. As a participant in seed funding, I do not notice a dramatically different investment climate at this stage from what has existed during most of the last twenty years, albeit the venture capital squeeze might get even worse. From another perspective the clear institutionalization of the U.S. venture capital industry probably means that it now will go through cycles over time that are comparable to those experienced in the Initial Public Offerings market and in the stock market generally.

Three further aspects of financing deserve comment. (1) Almost all new high-tech enterprises are initially financed by personal savings, family and friends, and informal investors. Later financings still prominently involve the informal investor, alone or in small groups. No evidence suggests that these sources are less available today than in the past. (2) Corporations are today playing a more important role in high-tech financing than in prior years, especially foreign corporations. The increased activity of especially Japanese firms in providing early-round funds for U.S. high-technology companies has the favorable short-term impact of more "smart money" being available, with additional side-benefits to the entrepreneurs of more rapid

growth into foreign markets, if not directly at least on a royalty basis. These vigorous direct foreign investments will in the longer run no doubt further strengthen the foreign companies' technological bases, through learning, licensing, alliances and acquisitions. This foreign-firm strengthening will pose increased downstream competitive problems for larger U.S. corporations that are not actively linking to emerging high-tech enterprises. (3) In terms of other trends, on a worldwide basis more venture capital funds are being developed, financed by the plentiful dollars available abroad, with intended investments partially in their own regions of the world and partially in the United States. In sum, I appraise the overall financing situation for start-up and growth-stage high-tech firms as quite reasonable.

The growth spurt in independent technological entrepreneurship is not limited to the United States. All around the world the symptoms of change are evident. Sticking my neck out a bit I see high-technology entrepreneurship, both in the United States and overseas, as entering a growth mode. From a couple of nodes in the U.S., first Route 128 and then Silicon Valley, U.S. hubs of entrepreneurship have spread to Ann Arbor, Boulder, Minneapolis, Austin, Atlanta, Seattle and myriad others. Each area has had its own initiating forces, not all dependent upon a dominant technological university and its laboratories as forbearers. Each has had to go through its own period of start-up, getting to some successes, generating local visibility of role models for others, gradually building financial and industrial infrastructure, proliferating the positive feedback loops into more active new enterprise formation. This continues to take place throughout the United States, increasingly helped by the role of national media in making the experiences of one part of the country perceived and appreciated by other regions. But high-tech entrepreneurial growth is still primarily a local phenomenon. Only the very beginnings of this pattern are yet underway in Europe and Asia, with a long life ahead. It took over forty years for what has occurred in Greater Boston to reach its present stage. The next forty years should see far more technology-based entrepreneurship, both locally and worldwide.

SUMMARY

Although quantitative evidence is lacking to support this assertion, an overwhelming amount of anecdotal data argues that the general environment of the Greater Boston area, beginning during the postwar period, and in particular the atmosphere at MIT, have played a strong role in affecting "would-be" local entrepreneurs. The legitimacy of "useful work" from MIT's

founding days was amplified and directed toward entrepreneurial expression by prominent early actions taken by administrative and academic leaders like Compton and Edgerton. Policies and examples that encouraged faculty and staff involvement with industry and, more important, their "moonlighting" participation in spinning off their ideas and developments into new companies, were critical early foundation stones. MIT's tacit approval of entrepreneurism, to some extent even making it the norm, was in my judgment a dramatic contribution to the Greater Boston culture and economy. Key individual and institutional stimulants like Stark Draper and the MIT Enterprise Forum reinforced the potential entrepreneurial spin-off that derived from a wide variety of advanced technology development projects in MIT labs and in the region's industrial firms. These actions fed into a gradually developing positive loop of productive interactions with the investment community that in time created Route 128 and beyond. Despite near term pressures upon local entrepreneurialism, the underlying environment seems strong and grass roots activities are growing. Rest assured -- while the future is never certain and storm clouds loom for some aspects of technological enterprise, high-technology entrepreneurship remains a continuing and ever more important part of the Massachusetts and the American dream and reality, increasingly shared by aspiring young technologists all over the world.

REFERENCES

Bank of Boston. *MIT: Growing Businesses for the Future* (Boston: Economics Department, Bank of Boston, 1989).

Boston Business Journal. August 20-26, 1984.

Boston Business Journal. "Corporate Album: Genetics Institute", March 23, 1987.

Chase Manhattan Corporation. *MIT Entrepreneurship in Silicon Valley* (Privately published, April 1990).

Arnold C. Cooper. "Spin-offs and Technical Entrepreneurship", *IEEE Transactions on Engineering Management*, EM-18, 1 (1971), 2-6.

Arnold C. Cooper. "The Role of Incubator Organizations in the Founding of Growth-Oriented Firms", *Journal of Business Venturing*, 1(1985), 75-86.

Arnold C. Cooper. "Entrepreneurship and High Technology", in D. L. Sexton and R. W. Smilor (editors), *The Art and Science of Entrepreneurship* (Cambridge, MA: Ballinger Publishing, 1986), 153-167.

Nancy S. Dorfman. "Route 128: The Development of a Regional High Technology Economy", *Research Policy*, 12 (1983), 299-316.

Charles Stark Draper. "Remarks on the Instrumentation Laboratory of the Massachusetts Institute of Technology". Unpublished paper (January 12, 1970).

The Economist. "A Survey of New England: A Concentration of Talent", August 8, 1987.

Henry R. Feeser and Gary E. Willard. "Incubators and Performance: A Comparison of High- and Low-Growth High-Tech Firms", *Journal of Business Venturing*, 4, 6 (1989), 429-442.

Charles H. Ferguson. "From the People Who Brought You Voodoo Economics", *Harvard Business Review*, May-June (1988), 55-62.

John Kenneth Galbraith. *The New Industrial State*, 4th edition (Boston: Houghton Mifflin, 1985).

George Gilder. "The Revitalization of Everything: The Law of the Microcosm", *Harvard Business Review*, March-April (1988), 49-61.

Udayan Gupta. " How an Ivory Tower Turns Research Into Start-Ups", *The Wall Street Journal*, September 19, 1989.

INC. "After the Sale", August 1990, 39-50.

Karen Seashore Louis, David Blumenthal, Michael E. Gluck, and Michael A. Stato. "Entrepreneurs in Academe: An Exploration of Behaviors Among Life Scientists", *Administrative Science Quarterly*, 34 (1989), 110-131.

Roger Miller. "Growing the Next Silicon Valley", *Harvard Business Review*, July-August 1985.

Nitin Nohria. "A Quasi-Market in Technology Based Enterprise: The Case of the 128 Venture Group". Unpublished paper (Boston: Harvard Business School, February 1990).

William D. Putt, Editor. *How to Start Your Own Business* (Cambridge, MA: The MIT Press and the MIT Alumni Association, 1974).

Tom Richman. "Who's in Charge Here?", *INC.*, 11 (June 1989), 36-46.

Edward B. Roberts. *Entrepreneurs in High Technology: Lessons from MIT and Beyond* (New York: Oxford University Press, 1991).

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

Joseph A. Schumpeter. *The Theory of Economic Development* (Cambridge, MA: Harvard University Press, 1936).

Segal Quince Wickstead. *The Cambridge Phenomenon*, second printing (Cambridge, England: Segal Quince Wickstead, November 1985).

Jane Simon. "Route 128", *New England Business*, July 1, 1985, 15-20.

M. A. Sirbu, R. Treitel, W. Yorsz, and E. B. Roberts. *The Formation of a Technology Oriented Complex: Lessons from North American and European Experience* (Cambridge, MA: MIT Center for Policy Alternatives, CPA 76-8, December 30, 1976).

R. W. Smilor, D. V. Gibson, and G. B. Dietrich. "University Spin-out Companies: Technology Start-ups from UT-Austin", in *Proceedings of Vancouver Conference* (Vancouver, British Columbia: College on Innovation Management and Entrepreneurship, The Institute of Management Science, May 1989).

R. W. Smilor, D. V. Gibson, and G. Kozmetsky. "Creating the Technopolis: High-Technology Development in Austin, Texas", *Journal of Business Venturing*, 4, 1 (1989), 49-67.

Sheridan Tatsuno. *The Technopolis Strategy* (New York: Prentice Hall, 1986).

J. M. Utterback, M. Meyer, E. Roberts, and G. Reitberger. "Technology and Industrial Innovation in Sweden: A Study of Technology-Based Firms Formed Between 1965 and 1980", *Research Policy*, 17, 1 (February 1988), 15-26.

Charles A. Ziegler. *Looking Glass Houses: A Study of Fissioning in an Innovative Science-Based Firm* . Unpublished Ph.D. dissertation (Waltham, MA: Brandeis University, 1982).