The Role of Small Business in Research, Development, 
Technological Change and Innovation in Region I 
by 
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Introduction 
Historically, the development of many large-scale businesses and industries in New England have sprung from intense entrepreneurial activity in small high-technology businesses. Recent examples of this are the electronics and instrumentation businesses established along Massachusetts' Route 128 in the 1950s and 1960s and the mini-computer industry developed in the region in the late 1960s and 1970s. Smaller technology-based companies are generally acknowledged to generate a disproportionate number of innovative ideas and products (U.S. Department of Commerce, 1967). Further, the nurturing and growth of the smaller (less than 500 employees) high-technology companies in New England is essential to make up the jobs lost from the decline of the region's older and more mature industries. For example, from 1970-1977, Massachusetts had an increase of 29,000 jobs in its high-technology manufacturing. In the same period, Massachusetts employment in non-
high-technology manufacturing decreased by 58,000 jobs (Massachusetts High Technology Council, 1978). In Massachusetts one manufacturing job in three is now in a high-technology industry. On a national level, studies (Brinner, 1978) have shown that high-technology industries surpassed low-technology industries in real growth and productivity by a factor of two. The increased productivity without loss of employment, characteristic of high-technology industries, is essential to a healthy U.S. economy and a competitive position in world markets.

The driving force behind the growth of these high-technology industries has been the birth and expansion of small businesses by technical entrepreneurs. "In the new, small, technically-based enterprise, innovation is a way of life that results in the creation of new products, processes and services and increased employment" (U.S. Department of Commerce, 1976). In contrast, innovation in mature companies is often directed at cost reduction and increased productivity, which can lead to reduced employment.

In areas of New England, innovation and technical change have been advanced greatly by "spin-offs" and technology transfer to small new high-technology firms. For example, one research and development laboratory at MIT has given birth to 50 new high-technology companies. Because such a phenomenon fuels innovation and small company development, it is important to understand the factors that lead to successful high-technology spin-offs and why they occur in one area and not another.
The balance of this paper will thus be devoted to examining and discussing in more detail, the relative role of small and large businesses in developing new technologies and new products. Measures of innovation such as the number and quality of new products and processes, productivity, and the costs of innovation will be discussed for both large and small firms. The relative role of a representative group of small and large technology businesses in generating net new jobs in New England will be examined.

The computerized business data files and retrieval systems developed by David L. Birch of MIT's Joint Center for Urban Studies (Birch, 1975, 1979) have been used for this purpose. From these data files it is possible to follow the progress of establishments by categories over time and to aggregate data to determine how change takes place. The ways in which technology is transferred from large to small companies is discussed and suggestions will be made for improving the efficiency of this process. Institutional and environmental factors that encourage or restrain the development of small technology businesses are identified and discussed. Finally, recommendations will be made for policy changes that should favorably affect the ability of small business to continue to contribute importantly to innovation and new product development.
Effects of Technological Change, Innovation and R&D

While it is difficult, if not impossible, to measure directly the effects of technical research and development and production of new products and services on our national well-being, certain economic facts and figures are offered as substantive evidence. Foremost amongst these are the following:

- A positive relationship between innovation and real growth in the Gross National Products.
- An increase in the competitive strength of U.S. industry that results in a positive balance of trade in R&D intensive industries. For example, in 1976, the balance of trade in R&D-intensive industries was +$29 billion while in non-R&D-intensive industries, the trade balance was -$16.5 billion.
- A reduction of inflationary pressures through increases in productivity due to technological innovation.
- Net new job creation. Although technological change produces fear that machines will cause increased human unemployment, the net outcome has generally been the opposite: innovation and technological change have resulted in net new job creation.

A recent analysis (Brinner, 1978) on a national level has demonstrated that high-technology industries positively affected four meaningful economic indicators from 1950-1974. The high-technology industries were selected as those having a higher-than-average ratio of R&D expenditures to gross product and
included industrial chemicals (SIC Group 28), electrical equipment (SIC 36) and professional and scientific instruments (SIC 38). The results of Brinner's analysis are shown below.

Table 1
Comparative Performance of
High Technology Industries
1950-1974

Compound Annual Growth Rates (% Shown

<table>
<thead>
<tr>
<th>Industry</th>
<th>Employment</th>
<th>Labor Productivity</th>
<th>Real Output</th>
<th>Price Inflation</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Technology</td>
<td>2.6%</td>
<td>4.0%</td>
<td>6.7%</td>
<td>0.5%</td>
</tr>
<tr>
<td>All Manufacturing</td>
<td>1.2%</td>
<td>2.3%</td>
<td>3.5%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Low Technology</td>
<td>0.3%</td>
<td>2.0%</td>
<td>2.3%</td>
<td>3.0%</td>
</tr>
</tbody>
</table>

The table's data show that the employment and productivity (real output per employee) growth rates of the high-technology industries were substantially better than that for all manufacturing and the low technology group. The combined effect of increases in employment and productivity led to the greater growth in real output of the high-technology group. Note also that the growth in employment in the high-technology industries was achieved with the lowest price inflation among the industry groups. Although we have presented data for 1950-1974 and for two-digit SIC groupings, Brinner also presents data for shorter
time periods within 1950-1974 and for high-technology sub-industries that confirm the results presented above.

Clearly, on a national basis, high-technology industries surpass low-technology industries and all of manufacturing on four important economic indicators, and contribute substantially to the economic health and development of the U.S.

However, the full impact of innovation and technological change are not captured by such economic outcomes (National Science Foundation; 1977). For example, technical innovation may result in products or services that satisfy wants and needs of society previously not met, e.g. the improved medical care that has resulted from biomedical innovation.

If the importance to our economy of R&D, innovation and technological evolution is accepted, and if we have established that high-technology industries are prime agents of these changes, we can then ask whether high-technology businesses vary in this respect by virtue of size or other characteristics and what the experience is in New England. Quantitative data to answer this question are scant, but published material as well as some analyses especially conducted for this discussion indicate that small businesses contribute disproportionately in comparison with large businesses, as agents of change.
Performance of Small vs. Large Business in Innovation and Technical Change

Although data specific to the New England area are virtually nonexistent, some national studies exist that compare the contribution to innovation of small and large, and young and old firms. Although we pride ourselves on individualism in New England, we will abnegate to the extent of assuming that what can be demonstrated nationally regarding small businesses probably applies to our area as well. In addition, we have made a study of the comparative generation of jobs (a primary goal of innovation) by large and small high-technology companies in New England, the results of which will be described in the next section.

One of the first government-sponsored studies of technological innovation (U.S. Department of Commerce, 1967) noted that "small technologically-based companies are responsible for a remarkable percentage of the important inventions and innovations of this century - a much larger percentage than their relative investments in these activities would suggest." The study cited research showing that over two-thirds of the major inventions made from 1946-55 resulted from the work of independent inventors and small companies (Hamberg, 1963). Exhibit 1 provides a list reproduced from that report of twentieth-century inventions made by small companies and independent inventors.
<table>
<thead>
<tr>
<th>EXHIBIT 1</th>
<th>SOME IMPORTANT INVENTIVE CONTRIBUTIONS OF INDEPENDENT INVENTORS AND SMALL ORGANIZATIONS IN THE TWENTIETH CENTURY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xerography</td>
<td>Shrink-proof Knitted Wear</td>
</tr>
<tr>
<td>DDT</td>
<td>Dacron Polyester Fiber &quot;Terylene&quot;</td>
</tr>
<tr>
<td>Insulin</td>
<td>Catalytic Cracking of Petroleum</td>
</tr>
<tr>
<td>Vacuum Tube</td>
<td>Zipper</td>
</tr>
<tr>
<td>Rockets</td>
<td>Automatic Transmissions</td>
</tr>
<tr>
<td>Streptomycin</td>
<td>Gyrocompass</td>
</tr>
<tr>
<td>Penicillin</td>
<td>Jet Engine</td>
</tr>
<tr>
<td>Titanium</td>
<td>Frequency Modulation Radio</td>
</tr>
<tr>
<td>Shell Molding</td>
<td>Self-Winding Wristwatch</td>
</tr>
<tr>
<td>Cyclotron</td>
<td>Continuous Hot-Strip Rolling of Steel</td>
</tr>
<tr>
<td>Cotton Picker</td>
<td>Helicopter</td>
</tr>
</tbody>
</table>


Subsequent studies confirm the important role of small companies and independent inventors in producing innovation, all such studies showing that approximately half or more of American innovations were produced by small companies or individuals. A study (Gellman, 1976) of 310 major U.S. innovations developed
between 1953 and 1973 reported the following relationship between those innovations and the size of the originating business.

TABLE 2

MAJOR U.S. INNOVATIONS BY SIZE OF ORIGINATING FORM

<table>
<thead>
<tr>
<th>Percent of Innovations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firms with less than 100 employees</td>
</tr>
<tr>
<td>Firms with 100 to 999 employees</td>
</tr>
<tr>
<td>Firms with over 1,000 employees</td>
</tr>
</tbody>
</table>

These data show that firms with less than 100 employees produced about one-quarter of the major innovations in the period. If firms with less than 1,000 employees are considered "small," then small firms produced about one-half of the major innovations of the period. (The SBA definition of small is a firm with less than 500 employees.)

The costs of major innovations and the relative efficiency of producing them in larger and smaller firms have been looked at from several different angles. One estimation of the relative costs (National Science Foundation, 1977) in different-sized firms is shown in Table 3 following.
For the whole 1953-73 period, it was estimated that the smaller firms produced innovation at about 1/25 the cost of the largest firms and 1/4 the cost of the middle-sized firms.

The relative efficiency of small and large high-technology firms in innovating was analyzed (Scheirer, 1977) in connection with the Rabinow panel's examination of the role of small business in fulfilling Government contractual requirements for research and development (Committee on Small Business, House of Representatives, 1978). On the basis of empirical evidence, Scheirer drew the following conclusions regarding the performance of firms with less than 1,000 employees when compared with those having more than 1,000 employees:

- The ratio of innovation to sales was about one-third greater in forms with less than 1,000 employees;
- The ratio of innovations to R&D employment was four times greater in firms with less than 1,000 employees.

### Table 3

<table>
<thead>
<tr>
<th>Firm Employee Size</th>
<th>Relative Innovation Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1000</td>
<td>4.2</td>
</tr>
<tr>
<td>1,000-10,000</td>
<td>16</td>
</tr>
<tr>
<td>10,000+</td>
<td>100</td>
</tr>
</tbody>
</table>
The cost to maintain an R&D scientist or engineer was one-half as expensive in firms with 1,000 or less employees.

These empirical conclusions reinforce the NSF estimates that show small firms to be more efficient innovators than large firms.

The contribution of small, young technology businesses to job generation was recently examined through a broad-based study conducted by the American Electronics Association (AEA) (Zschau, 1978). The AEA results are based on a survey of its 675 member companies and an additional 56 non-member electronics companies. All member companies are manufacturers of electronic components or suppliers of information-processing services and equipment. Among the 325 companies (40%) responding to the survey the following results pertaining to job generation were obtained:
These data show that the employment growth rates in 1976 for the developing and startup companies were substantially greater than those of the mature companies. Especially interesting is the result that although the mature companies had 221 times the average employment per company of the start-up companies, the mature companies created only about twice as many jobs per company as the start-ups. And the developing companies (5-10 years old), with an average employment per company only 2.2% that of the mature companies, created more jobs per company than the mature firms. Zachau presents other data that show the revenues of companies less than 10 years old to be growing 5 or more times faster than that of older companies. These data confirm earlier results (U.S. Department of Commerce, 1976) that concluded, through specific examples, that young high-technology companies...
from 1960-74 had growth rates in revenue and employment substantially greater than mature companies and greater even than older technically innovative firms.

In summary, the conclusion is inescapable from all of the available studies and evidence that smaller businesses are a substantial source of innovation and technical change and that they make their contribution more efficiently and at a lower cost than larger businesses. After evaluating 75 reports and studies of innovation, a recent Office of Management and Budget study (Scheirer, 1977) concluded aptly: "Small business has produced a striking record of innovation, particularly in view of their limited share of economic resources."

Why is small business better at producing technological change and innovation than larger businesses? No one has pat answers to this question, but several speculations are possible. In the small technically-based firm, innovation and new product creation tends to be more a way of life and survival than in the large firm which seeks more to maintain its product market positions. The managers of a small technology company (in which they often own a share) may also have greater incentive to innovate. On the other hand, many large firms prefer, for marketing reasons, to hold their technical improvements to a minimum. Rabinow (Committee on Small Business, House of Representatives, 1978) believes that researchers and innovators in large firms overspecialize while innovators in small firms tend more to be technical generalists. He concludes that over-
specialization limits innovation and that the more an innovator can draw on related as well as unrelated arts and technology, the more original the resulting innovations tend to be.

Employment Growth: Small vs. Large High-Technology Companies in New England

One of the important outcomes of innovative, high-technology companies is the generation of new jobs. In the preceding section we noted that, on a national basis, the employment growth rates for small and young technology companies seem to be substantially greater than for older and larger companies. In this section we will compare the job-generating performance of small vs. large firms, and independents (single-plant) vs. branches and subsidiaries in some of New England's primary high-technology industries for the period 1969-76.

Our analyses are based largely on the computerized business data file developed by David Birch of MIT's Joing Center for Urban Studies (Birch, 1975 and 1979). This file contains data recorded by the Dun and Bradstreet Corporation. For each business establishment in the file, data are provided at different points in time regarding employment, location, sales, corporate affiliation (branch, subsidiary, independent firm), and principal industry (identified by 4-digit 1972 SIC number). A computerized data retrieval system allows changes in the status of individual establishments to be determined and aggregated by industry, establishment size and/or type, etc. Thus, one can follow the progress of individual establishments over time and

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then combine data to determine how change takes place. For example, the employment changes from 1969-76 of establishments that had zero to twenty employees in 1969 can be traced. (For more information on this data, see Birch's paper on The Role of Small Business in New England.)

The New England file used for our analysis contains data on about 330,000 businesses, estimated to represent about 80% of the private sector employment in the area. Five high-technology industries that we believed to be important to the New England economy were selected for analysis. The net employment change in these industries was derived by totaling the jobs created by expansions, births of new firms and in-migrations and subtracting from this total the number of jobs lost through death of firms, contractions and out-migration.

The five high-technology areas analyzed and the four-digit SIC codes they include are summarized in Exhibit 2. It is worth noting that the industry groups shown in the exhibit belong to industries that were classified as high-technology, based on the level of their R&D expenses, in a 1978 study by Data Resources (Brunner, 1978).
**EXHIBIT 2**

**HIGH TECHNOLOGY INDUSTRIES FOR NEW ENGLAND JOB GENERATION STUDIES**

<table>
<thead>
<tr>
<th>High-Technology Industry</th>
<th>Four-Digit SIC Codes Included in High-Technology Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group I</strong></td>
<td></td>
</tr>
<tr>
<td>Engineering &amp; Scientific Instruments</td>
<td></td>
</tr>
<tr>
<td>SIC Code</td>
<td>Name</td>
</tr>
<tr>
<td>3811 Engineering, Laboratory, Scientific and Research Instruments</td>
<td></td>
</tr>
<tr>
<td>3823 Industrial Instruments for Process Control</td>
<td></td>
</tr>
<tr>
<td>3824 Fluid Meters &amp; Counting Devices</td>
<td></td>
</tr>
<tr>
<td>3825 Instruments for Electricity &amp; Electrical Signals</td>
<td></td>
</tr>
<tr>
<td>3829 Measuring &amp; Controlling Devices</td>
<td></td>
</tr>
<tr>
<td>3832 Optical Instruments</td>
<td></td>
</tr>
<tr>
<td>3861 Photographic Equipment</td>
<td></td>
</tr>
<tr>
<td><strong>Group II</strong></td>
<td></td>
</tr>
<tr>
<td>Computers</td>
<td></td>
</tr>
<tr>
<td>SIC Code</td>
<td>Name</td>
</tr>
<tr>
<td>3573 Electronic Computing Equipment</td>
<td></td>
</tr>
<tr>
<td><strong>Group III</strong></td>
<td></td>
</tr>
<tr>
<td>Communication, Radio &amp; TV Equipment</td>
<td></td>
</tr>
<tr>
<td>SIC Code</td>
<td>Name</td>
</tr>
<tr>
<td>3661 Telephone &amp; Telegraph Apparatus</td>
<td></td>
</tr>
<tr>
<td>3662 Radio &amp; TV Transmission and Detection Equipment</td>
<td></td>
</tr>
<tr>
<td>3671 Radio &amp; TV Receiving Tubes</td>
<td></td>
</tr>
<tr>
<td>3672 Cathode Ray TV Tubes</td>
<td></td>
</tr>
<tr>
<td>3673 Special Purpose Electron Tubes</td>
<td></td>
</tr>
<tr>
<td><strong>Group IV</strong></td>
<td></td>
</tr>
<tr>
<td>Electronic Components</td>
<td></td>
</tr>
<tr>
<td>SIC Code</td>
<td>Name</td>
</tr>
<tr>
<td>3674 Semiconductor &amp; related devices</td>
<td></td>
</tr>
<tr>
<td>3675 Capacitors</td>
<td></td>
</tr>
<tr>
<td>3676 Resistors</td>
<td></td>
</tr>
<tr>
<td>3677 Coil Transformers &amp; Inductors</td>
<td></td>
</tr>
<tr>
<td>3678 Electronic Connectors</td>
<td></td>
</tr>
<tr>
<td>3679 Other Electronic Components</td>
<td></td>
</tr>
<tr>
<td>3693 X-Ray Tubes &amp; Apparatus</td>
<td></td>
</tr>
</tbody>
</table>
Group V

Chemicals & Drugs
2821 Plastic Materials
2822 Synthetic Rubber
2823 Cellulosic Man-Made Fibers
2824 Synthetic Organic Fibers
2831 Biological Products
2833 Medicinal Chemicals
2834 Pharmaceuticals
2879 Pesticides
2891 Adhesives & Sealants

Results: Job Generation by Independent (Single-Plant) Firms vs. Branch Plants and Subsidiaries

The results of our analysis of the comparative job-generation of independent vs. branch plants and subsidiaries are summarized in Tables 5 and 6. Table 5 shows that only the independent firms had a net increase in jobs in every one of the five high-technology industry areas. Moreover, for the five high-technology areas taken together, only the independent firms show a net job gain - and this gain was sufficient to make up for about 50% of the total jobs lost by subsidiaries and branch plants. The contributions of independent firms of different sizes to this job growth is described in more detail below. However, it is also worth noting that all of this 1969-76 net job gain was within the group of independent firms either founded between 1969 and 1976 or having less than 100 employees at the beginning of that period.

Subsidiaries achieved employment growth only in the computer industry, and branch plants showed job growth in 3 of 5 technology groups. However, as Table 6 shows, the rate of job growth
for the independent firms exceeded that of the subsidiaries and branch plants for all technology areas except chemicals and drugs.

The data summarized above strikingly show the importance of independent firms to the 1969-76 job generation process in New England. Although some of the "so-called" growth industries were undergoing contractions from 1969-76, independent firms still produced job growth. The most notable contracting high-technology area was that of electronic components where the large decline in jobs is likely associated with the decline of defense-related business in New England and the emergence of Palo Alto as the semiconductor manufacturing of the U.S.

Results: Job Generation as a Function of Firm Size

The second question that concerned us was: What were the relative contributions of larger and smaller firms to the net employment change in the five high-technology industries defined in Exhibit 2.

The data file available to us could not provide a direct answer because it contained data for establishments in New England. Establishments can be independent firms, or branches or subsidiaries of a much larger parent firm. To analyze job generation by size of firm, we needed to associate the job changes of branches and subsidiaries with the size of their larger parent firms, for it is usually the parent firm that governs expansions and contractions of its branches and
### TABLE 5

**NET JOBS GENERATED 1969-1976 BY DIFFERENT TYPES OF ESTABLISHMENTS IN HIGH-TECHNOLOGY MANUFACTURING INDUSTRIES IN NEW ENGLAND**

(Net Actual Job Change Shown)

<table>
<thead>
<tr>
<th>Type of Establishment</th>
<th>Eng. &amp; Sci. Instruments</th>
<th>Computers</th>
<th>Communication</th>
<th>Radio &amp; TV Equip.</th>
<th>Electronic Components</th>
<th>Chemicals</th>
<th>Total Technology Groups</th>
<th>Manufacturing (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent</td>
<td>389</td>
<td>3934</td>
<td>1820</td>
<td>2039</td>
<td>202</td>
<td>8384</td>
<td>-21019</td>
<td></td>
</tr>
<tr>
<td>Subsidiary</td>
<td>-381</td>
<td>2435</td>
<td>-102</td>
<td>-624</td>
<td>-2112</td>
<td>-784</td>
<td>-38944</td>
<td></td>
</tr>
<tr>
<td>Branch Plant</td>
<td>-3393</td>
<td>4150</td>
<td>1489</td>
<td>-19638</td>
<td>1657</td>
<td>15735</td>
<td>-101913</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>-3385</td>
<td>+10519</td>
<td>+3207</td>
<td>-18233</td>
<td>-253</td>
<td>-8135</td>
<td>-161,876</td>
<td></td>
</tr>
</tbody>
</table>

(1) Manufacturing includes SIC codes from 2000 to 3999.

### TABLE 6

**NET PERCENTAGE CHANGE 1969-76 IN JOBS FOR DIFFERENT TYPES OF ESTABLISHMENTS IN HIGH-TECHNOLOGY MANUFACTURING INDUSTRIES IN NEW ENGLAND**

<table>
<thead>
<tr>
<th>Type of Establishment</th>
<th>Eng. &amp; Sci.</th>
<th>Communication</th>
<th>Radio &amp; TV Equip.</th>
<th>Electronic Components</th>
<th>Chemicals</th>
<th>Total Technology</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent</td>
<td>+ 6.9%</td>
<td>+315%</td>
<td>+29.0%</td>
<td>+18.4%</td>
<td>+6.1%</td>
<td>+30.4%</td>
<td></td>
</tr>
<tr>
<td>Subsidiary</td>
<td>-24.7%</td>
<td>+115%</td>
<td>-4.9%</td>
<td>-14.9%</td>
<td>-43.8%</td>
<td>- 5.3%</td>
<td></td>
</tr>
<tr>
<td>Branch Plant</td>
<td>-10.7%</td>
<td>+ 35.4%</td>
<td>+ 3.7%</td>
<td>-39.0%</td>
<td>+14.8%</td>
<td>-10.8%</td>
<td></td>
</tr>
</tbody>
</table>
subsidiaries. Although Birch has developed a more advanced data file (Birch, 1979) that ascribes all changes in branches and subsidiaries to the parent corporation, the file is currently accessible to MIT staff only. We adopted, therefore, an approximation for relating the net employment changes of branches and subsidiaries to the size of their parent firm: From the 1972 Enterprise Statistics of the Department of Commerce (U.S. Department of Commerce, 1977), we obtained, at a 3-digit SIC level, the number of companies and establishments by fourteen size classes of companies. The difference between the number of establishments and the number of companies represented the number of branches and subsidiaries in a given company size class. With these data, we were able to determine the percentage of total branches and subsidiaries in an industry category that fell in a given size class of company. These data are shown in Appendix A for the high-technology industry categories that most closely match those in Exhibit 2.

We considered three size categories, 0-20, 21-100, and more than 100 employees, and allocated the net employment change of branches and subsidiaries to parent companies according to the 1972 percentages of subsidiaries and branches in each size class. Although this procedure may seem to approximate, consider the following:

(1) Companies with 20 or less employees have almost no branches or subsidiaries. In the industry categories of interest, the number of branches and/or subsidiaries for
companies with 20 or fewer employees ranged from 2 to 7, and in no case were more than 0.7% of the total number of branches and subsidiaries.

(2) Companies with 100 or more employees accounted for from 96% to 99.6% of all branches and subsidiaries. Thus, the impact of branches or subsidiaries on any conclusions reached about the job-generating performance of firms with less than 20 employees should be small. The impact of branches and subsidiaries in job generation occurs principally in firms with more than 100 employees. If anything, our approximation procedures most likely underestimate the employment created by businesses with less than 20 employees in 1969. This is because firms with less than 20 employees in 1969 who expanded through branches and subsidiaries would be attributed to a larger size category by our approximation. In any case, the errors introduced by our approximation are considered to be small, will not affect our conclusions about the role of independent single-plant firms in job generation at all, and should have very small influence on our conclusions concerning the size of firms that generate jobs.

The percentage distribution of net employment change by size of firm that results from our analyses and assumptions is shown in Table 7 for each of the five high-technology industries as well as for the five technology groups taken together. The results show that:

For the technology groups taken together, independent firms having less than 20 employees in 1969, or founded between 1969
and 1976, were the largest contributors of new jobs. The jobs they generated made up for 65% of all jobs lost. Without the contribution of these firms, the net total job loss would have been 2.3 times as large as it was. Independent firms with 100 or less employees generated enough jobs to compensate for about 75% of the total of all jobs lost.

Independent firms born between 1969-76 or having 20 or less employees in 1969 were significant creators of jobs in each high-technology group. Their contributions ranged from +19% of the net job change for the Computer Industry to +240% of the net job change for the Chemical and Drug Industry. The births of new firms were the predominant factor in this job generation.

In the important Computer Industry, firms founded between 1969 and 1976, or with fewer than 100 employees in 1969 generated 40% of the net positive employment change in that industry.

In the Communication, Radio and TV equipment group, firms with 100 or less employees in 1969 or that came into being from 1969 to 1976, produced 84% of the net positive job change in that industry.

Only in the Computer, and the Communications, Radio and TV Equipment industries, did firms with more than 100 employees and branch plants and subsidiaries make positive contributions to employment.

Although our data is limited, the results shown in Table 7 indicate that independent firms with 20 or less employees in 1969, or that were born from 1969 to 1976, were an important
### TABLE 7

**PERCENTAGES OF NET EMPLOYMENT CHANGE 1969-76**

**FOR NEW ENGLAND HIGH-TECHNOLOGY MANUFACTURING BY SIZE**

OF FIRM IN 1969

<table>
<thead>
<tr>
<th>High-Technology Industry</th>
<th>Type of Establishment</th>
<th>Employment Size, 1969</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Birth 1969-76, Up to 20 Employees</td>
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<tr>
<td></td>
<td>Employees</td>
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<td>Engineering &amp; Scientific Instruments</td>
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<td>+38.8%</td>
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<td></td>
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Technology Transfer, Spin-offs and Small High Technology Businesses

Spin-offs and technology transfer from corporate and university-affiliated research and development organizations played a key role in the growth of Boston's high-technology industry along Route 128 in the 1950's and 1960's. In the late 1960's and the 1970's, technological enterprises resulting from new as well as second-generation spin-offs extended further from Boston and into the southern counties of New Hampshire—resulting in substantial economic development of those counties. Similar development of high-technology, small-company complexes have also occurred in Palo Alto and Minneapolis and, on a much smaller scale, near Hanover, New Hampshire.

Boston's "Route-128" high-technology complex has become a model that other regions strive to replicate. According to a Stanford Research Institute Report (Draheim, et al., 1966), this sort of founding and growth of small-to-medium-sized high-technology companies is the most effective way to develop a research and development complex. What can be learned from the Boston experience to help in establishing similar centers of high technology and innovation?
Edward B. Roberts and his graduate students (Roberts, 1968, 1970; Wainer, 1965 and Cohen, 1970) at MIT's Sloan School of Management conducted extensive research in the mid to late 1960's on the factors that influenced the birth and growth of new high-technology companies. Roberts' studies focused on the formation and development of 216 high-technology companies founded by ex-employees of several of MIT's labs as well as other R&D organizations in the Boston area. The results of their study dramatically show the very substantial impact that technological spin-offs had on the economy of the Greater Boston area.

Of the 216 companies studied by Roberts:
- 105 came out of four MIT laboratories: Lincoln Laboratory (50); Instrumentation Laboratory (30); Electronic Systems Laboratory (11); and Research Laboratory for Electronics (14). By 1964, the sales of only 83 of these spin-offs exceeded $160 million and their employment was over 10,000.
- 51 came out of MIT's engineering departments: Electrical (15); Mechanical (10); Metallurgy (8); Aeronautics and Astronautics (18).
- 39 spun out of an industrial electronics system contractor. In 1966, the 32 survivors of this group had sales of $70 million, which was double the revenues of their erstwhile parent company.
- 5 came from the Mitre Corporation.
- 16 came from the Air Force Cambridge Research Laboratory
  - a government laboratory.

Most of the companies studies by Roberts et al. were from 4
to 5 years old, with a few over 20 years old. Their average
sales revenues were about $1.5 million, and the failure rate of
the spin-offs was only about 20% - considerable less than the
national failure rate of 80% of all new businesses.

Factors Affecting Successful Spin-Offs and Technology Transfer

Discussed below are some of the principal findings (Roberts
1968, 1970) concerning the factors affecting the success of high-
technology spin-off ventures and technology transfer in the
Boston area. An understanding of these should help us later to
define policies which will encourage such activities in other
areas.

The Entrepreneur

The key to the development of a successful enterprise is
generally agreed to be a capable entrepreneur. The entrepreneur
recognizes which ideas and/or technologies have sufficient
commercial potential to be the basis of a business, and then
marshals sufficient human, financial and technical resources to
develop such a business. Research and examples show that it is
the entrepreneur who makes the bridge from laboratory to market
place.

Among the behavioral characteristics (Timmons, et al., 1977)
that typify most successful entrepreneurs are: Unwavering
commitment to the business; ability to persist with problems;
ability to learn from failure and criticism, moderate risk
taking, and ability to set and meet realistic, yet challenging,
goals.

In addition to these general characteristics, Roberts found
that the high-technology entrepreneurs were, generally, in their
early 30's and had prior experience in converting advanced
technical ideas into hardware, as opposed to experience only in
research. The technical entrepreneurs had a Master's degree in
engineering or science rather than a Ph.D. or only a B.S., but
were not the "technical geniuses" of their business. Their
technical knowledge was used primarily to understand and guide
the work of others and to market their products. The successful
technical entrepreneurs had a concern for the personnel in their
organization and a balanced managerial point of view although
initially they may have been lacking certain management skills.

A Management Team

Substantiating a view held by most venture capitalists,
Roberts and his co-workers found that high-technology companies
started by a "team" had a better chance of success and performed
better (in terms of sales and profits) than ventures started by a
single individual. The single-founder ventures tended to be more
research-oriented and "one-man" shows. Successful multi-founder
companies included people with complementary skills in such areas
as engineering, marketing, finance and production. The
successful ventures included someone with marketing skills and
had an organized approach to marketing and sales; they did not wait for customers to come to them.

**Technology Transfer**

The more successful technical ventures were characterized by rapid, direct, and effective transfer of a substantial amount of technology from the entrepreneur's former organization to the new venture. To the extent that some entrepreneurs delayed in exploiting a technology, their chances of success were impaired. Success for the new technology ventures was directly related to the rapidity with which products and services based on new technology spin-offs about 5-6 years to achieve substantial growth in sales. Converting laboratory research and development into successful venture products is not a simple or easy process. In the authors' experience, one key to converting laboratory R&D into successful venture products is to have the inventor/innovator actively participate with an entrepreneur in the development of a venture based on the transfer of technology. Attempts to transfer technology via written descriptions of technology and prototypes are frequently not successful. The greater-Boston high-technology ventures studies by Roberts appear to have achieved successful entrepreneur-innovator interaction.
Federal R&D Support

Most of the high-technology ventures studied by Roberts started their lives with government contracts or as subcontractors to other companies engaged in developing equipment for the defense and space markets. As these technology ventures developed, they became less dependent on such government R&D support, and at 4-5 years old, obtained only about half of their revenues from government contracts. However, (Roberts, 1968) the defense and space requirements provided a customer for high-price advanced technology products before the commercial market was willing or able to do so. As technical products were refined and costs and prices reduced, the technology ventures were better able to penetrate commercial markets.

This important support for the young high-technology venture has declined substantially in this decade. Section 6 discusses the trend of federal contract funds for small high-technology ventures in more detail.

Size of Parent Organization

In addition to the foregoing factors identified by Roberts as important to the success of spin-offs, there is some evidence (Forseth, 1966, Cooper, 1971) that the spin-off rates are higher in smaller laboratories and small firms. The primary reasons for this probably lie in the working environment typical of small firms, i.e. the greater responsibility and range of tasks given
to professional employees that help to familiarize them with small business management.

The Boston experience strikingly demonstrates the very substantial impact that entrepreneurial activity coupled with technology transfer can have on innovation as well as on the economic development of a geographical area. But why does this happen in one area and not another? Numerous factors have been presented by a number of investigators as bearing significant influence on whether technical entrepreneurial activity takes place in an area or not. These are discussed below.

**Institutional Factors That Contribute To Or Restrain The Development of Small Technology Businesses**

Although a number of institutional factors are considered to affect American innovation, it is not the impact of each alone that is considered important, but rather their interaction to produce a climate that either encourages or restrains the formation of new technology businesses.

We shall consider some of the primary institutional factors that impact small businesses and will note those factors that are amenable to change to provide a positive climate for the birth and growth of small high-technology companies.

Several of these factors, specifically the types and numbers of small technology businesses in the area, the availability of credit and venture capital, the Federal regulatory impact and the state tax environment are the central concerns of other papers, and will be recognized only briefly here.
The number of universities with strong technological departments in an area, the participation of faculty in industrial activities

A good university with strong technology departments is generally considered conducive to the creation of technical firms in an area. In New England, MIT's faculty and research staff have played a major role in the development of technology ventures in the Boston area and in southern New Hampshire. However, the mere presence of a university does not insure that it will serve to stimulate entrepreneurial activity in the area. This was concluded in a study sponsored some years ago by the Federal Reserve Bank of Philadelphia (Deutermann, 1966). In this study, founders of research-oriented firms in Philadelphia and in Boston were interviewed regarding the problems of seeding science-based industry. Asked if local universities "play any role in stimulating new science-based firms," all of the Boston entrepreneurs replied that the universities play an important role. The Philadelphia entrepreneurs unanimously replied that universities played a small role. Reviewing this study, the Charpie panel (U.S. Department of Commerce, 1967) commented judiciously that the differences in the role assumed by the university in each of the cities probably had some bearing on the propensity of each city to generate new technological enterprises, Philadelphia having a low rate and Boston a high rate of such new businesses.

Certainly MIT's policy of encouraging its faculty to interact with industry and to do consulting work has fostered their
involvement with technological innovation and high-technology companies. As noted in Section 5, some 156 new technical enterprises have been traced to MIT laboratories and academic departments (Roberts, 1968). Additionally, MIT faculty are active on numerous company boards of directors and are engaged in widespread consulting activities.

It is apparent that the presence of a strong technology university can have a substantial impact on the generation of new high-technology businesses. Further, in all areas there is the indirect role of technical universities in attracting students to the area, where they often settle to live, and sometimes decide to found a new high-technology firm.

The size and activity of an area's scientific and engineering community

Technical entrepreneurs tend to start firms where they already are living and working. It follows that the larger the size of an area's scientific and engineering community, the larger the pool of potential entrepreneurs, and other things being equal, the greater the chance of new venture formation. Researchers have found, however, that it is the nature of the organizations employing these engineers and scientists that is critical in determining whether new entrepreneurial activity occurs (Cooper, 1971).

Two conditions tend to discourage new enterprise even in the presence of a large scientific and engineering community: the requirement for a sizeable capital investment for entry into an
industry; and a need to amass a large organization in order to compete with existing businesses. If the engineers and scientists in the area are relatively complacent, are narrowly-trained rather than broad-based in their abilities, and if the existing firms are well-run and create little frustration for their employees, then the chances of new business generation are further weakened (Cooper, 1971).

In summary, a sizeable and active technology community appears to be a necessary, but not a sufficient prerequisite for new enterprise formation.

Federal support for research and development: the ability of the small business to obtain and perform profitably on such contracts

The spate of innovative development in the Boston area following World War II and throughout the 1950s and 1960s has been related by many researchers to the availability of government research and development (R&D) funds, and particularly to their greater distribution in former times to smaller companies. The Federal Government has, in fact, sponsored the greatest amount of research and development, and has been recognized as a prime energizing force for the expansion of the nation's research and innovation efforts.

The marked decrease in constant-dollar government R&D support between 1968 and 1974, and its very slight improvement since then, is therefore quite naturally looked upon as an omen of technological decline for the country.
Not only have total Federal R&D dollars (constant) declined on average over the last decade, but small companies have found themselves increasingly cut off from these funds, so that government R&D less often provides a means for small companies to get started. Federal agencies are not inclined to award funds to smaller, high-technology companies because they are considered higher risks, and government funding has become more narrowly mission-oriented, hence not often available to innovative enterprises. Further, small companies are often unknown to agency procurement offices and cannot afford liaison personnel to track government needs and requests for proposals. Federal R&D requirements are often too massive for small company capabilities, so that small companies get only the less desirable sub-contracts given off by prime contractors.

Smaller businesses also cannot afford the "front end" costs of preparing proposals; moreover, reduced acceptance of unsolicited and sole-source proposals in favor of competitive bidding has been a particular hardship for small companies. The unsolicited proposal has been credited (U.S. Department of Commerce, 1976) with "playing a unique role in the development of innovative technologies by providing small amounts of money to bring a new concept or technology to the point where a product might emerge." "Today," Morse in the Department of Commerce report noted, "an unsolicited proposal may provide the basis for a request for additional proposals and competitive bidding. The practice of competitive bidding tends to favor the large corpora-
tion which has the ability to submit and resubmit detailed and costly proposals to fit the requirements of a particular situation."

Although small companies have been shown to be more productive per R&D dollar they obtain (National Science Board, 1977), government regulations for procurement, and time delays involved in economic and risk analyses required by the bureaucracy, have caused many small companies to forego government R&D business altogether.

Of the total Federal R&D funds distributed to industry, small business received approximately 8% in 1977 (Committee on Small Business, House of Representatives, 1978). Among the $7.1 billion R&D funds distributed in that year by the Department of Defense (DOD), the largest supplier of Federal R&D dollars, the small business share was even below the 8% government-wide average. Within the DOD, in fact, awards to small business peaked in 1978 at 5.8% of all R&D awards to industry, and as of the summer of 1978, had not reached that level again. The DOD, acknowledging the low rate of small business participation testified (Committee on Small Business, House of Representatives, 1978) that it has undertaken projects to increase the small business role. These were mainly ways of disseminating information more broadly on methods of successful contracting with the Department, a maneuver that does not address the primary problems.
Several remedial actions were suggested by the Office of Federal Procurement Policy itself: e.g., small high-technology firms with innovative ideas could be earmarked for "up-front" money to prepare proposals; funds could be awarded separately for preliminary feasibility studies, the development awards to follow if the initial studies were successful; and dollar goals could be established for small high-technology firms. Growing pressure resulted in enactment of Public Law 95-507 in 1978, requiring agency heads, after consultation with the Small Business Administration (SBA) to establish goals for the participation by small business in contracts of more than $10,000.

Although it is forecast that industry's share of total Federal R&D funds will be somewhat increased in the next year or two (National Science Foundation, 1977), the 19% decline in industry's share (constant dollar) over the last decade is too deep to recoup with slight increases over a few years. Greater effort to place funds in the high-technology companies, particularly the small high-technology companies, would be one change that could be effective in creating a better climate for innovative development. In New England, which now gets 8.5% of government R&D funds, encouragement of small high-technology businesses by providing them a greater share of government contracts could make a significant difference not only in innovative results, but also in creating jobs to replace those lost in non-technical, and even many technology industries.
The number, type and size of research and development laboratories in the area; their attitude toward "spin-offs" and technology transfer.

It is fair to ask whether non-profit research and development laboratories serve more importantly than industrial firms as generators of new technology enterprises. It is a difficult question to answer quantitatively because studies of this question are not comparable: Spin-off rate based on laboratory population is sometimes used as an indicator of entrepreneurial activity; actual number of spin-offs is used elsewhere; and in any case, different time periods under study confound the comparisons. It can be said, however, that non-profit research and development laboratories affiliated with MIT have been prolific generators of new high-technology businesses, but only one (Lincoln Laboratory) was shown (Roberts, 1968) to generate more spin-offs than an industrial technology firm, also under study, in the Boston area (see Section 5). The Air Force Cambridge Research laboratory ranked 5th in generation of new companies among 11 academic, government and industry laboratories in the Boston area studied by Roberts. On the West coast, neither government nor university laboratories were very active generators of new businesses, serving as a source for less than 3% of new technology businesses founded in the 1960s. There, Cooper showed (1971) that industry was more influential.

The final word is not yet in; additional and more careful studies are needed to identify the conditions that cause one type
of laboratory to generate more new companies than another. It has been suggested, however, that the small direct influence of many non-profit laboratories, government laboratories in particular, on innovation often has to do with the commercial inapplicability of their work. It was also suggested that scientific personnel in government and in some academic labs are, to a greater extent, more research-oriented than entrepreneurial.

On the other hand, these laboratories have an important role to play as either facilitators or obstructors of innovation. As the large governmental "in-house" R&D establishment lacks, in most cases, the ability and experience to commercialize the results of its research, the all-important "coupling to the marketplace" of new inventions and ideas is absent. With so much R&D effort going into these establishments, and with a possible "dead-end" at the point where commercialization could begin, it becomes critical that channels be readily available for the transfer of the technologies developed in establishments not oriented to commercialization.

Some Federal agencies claim to have established such channels. NASA reports, for example, that its Tech Brief Journal briefs 40,000 subscribers on government-created innovations that can be put to private use, and that 10,000 firms annually obtain technical information and expert advice through its network of Industrial Application Centers. The DOD, too, claims that it provides for technology transfer in its Defense Documentation Center, which provides Government contractors with technical
reports of R&D projects. This approach, however, is of a passive, not active, nature, and we suspect that for the effort spent, it is not notably productive.

A basic need for successful transfer of technology has not been addressed: the need for direct contact between technology inventory/developers and the entrepreneurs who will commercialize that technology. Successful commercialization of new technologies does not proceed from descriptions and diagrams mailed to a potential producer. It requires that the inventors or developers transfer their experience, understanding, and enthusiasm along with the documents, so that the producer can absorb the role he is to play and become invested in whatever it is he will commercialize. It requires a purposeful effort to make such contacts possible.

This is another area where changes might be made that could produce a marked effect: in government-supported laboratories, attitudes toward technology transfer, and channels for its accomplishment could be reviewed to see where beneficial improvements can be made.

Entrepreneurial environment -- i.e., the awareness of potential entrepreneurs of prior entrepreneurial activities, sources of capital, and sources of help

An entrepreneurial environment has been defined (Cooper, 1971) as a situation in which prospective founders of new firms have a high awareness of past entrepreneurial action, of sources of venture capital, and of individuals and institutions that
might provide help and advice. In such an environment, the prospective founder may perceive the risks associated with entrepreneurship to be relatively low and the rewards to be relatively high. This entrepreneurial environment has certainly been an important factor in the development of high-technology businesses in and around Boston, southern New Hampshire, and the Palo Alto area of California. Entrepreneurs have indicated that their decision to found a company was made easier by being in an area where entrepreneurship abounded. A comparison (Cooper, 1971) of such entrepreneurs with a group of Midwestern engineers trying to spin off from a large technically-oriented business in a small town suggested the importance of the entrepreneurial environment. The midwestern engineers were not aware of any prior entrepreneurial attempts by employees of their company, were not in touch with other entrepreneurs, did not know of any regional sources of venture capital, etc. They never became entrepreneurs, but "folded their tent" and went to work individually for other employers.

Researchers have not answered the question of how the entrepreneurial environment gets started in an area. Lacking better answers, we would propose that pioneer entrepreneurs are perhaps made of stronger stuff -- greater frustration in their jobs, more willingness to take risks, stronger visions of success, etc., and that with each additional entrepreneur starting a business, the going gets easier for all who follow.
The number, size and kind of high-technology companies in the area

Entrepreneurship in an area has been found to be closely related to the established firms or "incubator" organizations located in that area. Not only are firms typically founded by entrepreneurs who are already employed in the area, but typically, these new entrepreneurs will concentrate on products similar to those they knew in their previous employment. Therefore, the kinds of technologies found in an area determine to a considerable extent the technology base of the area's new firms. In a similar manner, market knowledge acquired during employment in an existing firm is most often the basis for market planning in a new venture. Large firms in an area serve less frequently as incubators of entrepreneurs, but this may depend on their method of internal organization. If a large firm is divided into independent profit centers or product groups, then the opportunities exist for development of entrepreneurial skills. If, on the other hand, each person in the firm has limited responsibility for a small part of a large project, the chances are that skills required to run a business will not be learned and there will be few leaps into self-employment.

Another organizational characteristic that influences the generation of new companies is the extent of frustration within a parent company (Cooper, 1971). Large parent companies often discourage young technical employees by "holding the reigns" on their ventures within the company -- giving them less
independence of judgment than is given more experienced technical employees. It is not surprising, therefore, that those who leave large companies to found their own firms are young technical people who usually see an opportunity for their own company to participate in some part of the same markets as their parent organization.

In brief, to the extent that existing high-technology companies in an area provide skills and knowledge that can be exploited in new ventures, and do not present obstacles to the entry of new companies into their industry, they can be important generators of new innovative companies in the area. An example in the Boston area can be found in 39 new ventures started by former employees of a single industrial electronics systems firm. As established firms have been shown to vary greatly in this capacity, it is apparent that the individual characteristics of the organization, as well as the opportunities in the industry itself, are critical elements.

Availability of venture capital

As the availability of venture capital is discussed in a separate paper (See Metzel's paper), suffice it to note here that the budding entrepreneur must go through several different attempts to amass necessary funds: first to go from idea to start-up; then to finance a respectable "garage" production phase; eventually to expand to an economic size; and finally, if and when propitious, to go public. While it is often assumed that the venture capital organizations enter the picture in the
first or second phases, it is more often than not the entrepreneur's family and faithful friends who put together the capital to start the enterprise off.

Although the decline in innovation is linked frequently to a shortage of venture capital, the argument presents a classical chicken and egg dilemma. In some areas, including Massachusetts, a sympathetic venture capital community has developed on the basis of past successful experience with new technology enterprises, and is readily available to entrepreneurs through a well-known network. Successful technical entrepreneurs of one period often become the sources of venture capital in the next.

Unfortunately, radically new technology or entrepreneurs in the idea stage often do not have the evidence to impress venture capitalists with the promise of their abilities, idea, and inventions. Further, at this critical-decision stage, the new venture probably cannot absorb the amount of investment that most venture capitalists like to make. The supply of initial funds to get an idea off the ground and to determine its feasibility could be explored for possible action to provide a better climate for new enterprise formation.
Personal and business tax environment in states of the region

While the taxation of small business in the region is addressed specifically in another paper (See Toscano-Feeny paper), it can be said generally that differences in personal and business property taxation and in income taxes among both states and regions have created a tense competition for industry and development. Massachusetts high-technology companies have organized to effect changes in the state tax environment. They see high technology jobs drifting away because of regional competition from sunbelt states and concomitant deterioration of the business climate in Massachusetts because of the tax situation, particularly property and income taxes on technical personnel.

Attitudes of bankers regarding loans to new and small high-technology companies

The cost and availability of credit in New England is addressed in depth elsewhere (See Wetzel paper). We will only note the difficulties that new companies have in obtaining commercial loans, particularly if they are not intended for equipment purchases that could be mortgaged. The salient fact regarding the need for loans is that not only has the cost starting a business escalated rapidly over the last decade because of inflation, but the entrepreneur is doubly hit by the high cost of borrowing the increased funds required. The possible need for a business development bank, operating independently of the SBA, but with guaranteed funds, merits review.
The federal and state regulatory environment and its impact on small business innovation

The impact of federal regulations on small business in the region is the central concern of another paper (See Puryear-Wiggins paper.) We will only summarize the main problem -- the difficulties that small businesses encounter in meeting the extensive requirements of government agencies for monitoring, reporting and documentation. Small businesses are particularly vulnerable to the cost burden, as well as the drain on management and employee time, of complying with extensive government requirements. It should also be said, on the other hand, that governmental regulation has also created business opportunities, and in some instance, entire new industries - such as antipollution equipment, automobile and industrial safety equipment, etc.

Policy Recommendations

Within the last two decades, high-technology industries have become a dominant factor in the economic health and growth of the New England area. We have shown the importance of new and small firms in high-technology industries, in terms of innovation and technical change as well as job generation. In view of the contribution that small firms have made to the New England economy, attention to the business environment that produces and nurtures them is warranted and overdue. Our review of the problems attending new and small businesses leads us to believe that the creation and development of small high-technology
businesses in New England might be stimulated by certain actions and policies detailed in the recommendations following. We shall focus on recommendations that are appropriate to our particular studies and not likely to be covered in other papers devoted specifically to taxes, venture capital or the regulatory environment.

In attempting to define the factors that were important to the birth and growth of small high-technology businesses, we quickly learned that the first problem was the paucity of information available on small business and its role in innovation and technical change. If the data at a national level was limited, at the regional level it was virtually non-existent. Lacking such knowledge, it is hard to draw any but broad qualitative conclusions about the contributions of small technology businesses in the region, and it is harder still to make policy decisions as to what types of small technology businesses should be targeted for assistance so as to take maximum advantage of current and projected trends in technology. Therefore, our first recommendation concerns the acquisition of pertinent data.

Development of Adequate Regional Data on Small Technology Businesses

Recommendation 1

Studies should be funded to develop quantitative data on the contribution of small and new businesses in New England to innovation, technological change, employment and economic
growth. These studies should be conducted for segments within the high-technology grouping (e.g., computers) that are or could become important to New England. They should include an examination of the barriers to small technology business development in areas within the region.

The Encouragement and Stimulation of Entrepreneurship

Our next recommendations stem from the fact that while entrepreneurs are recognized as they key factor in the creation and development of technology ventures, little organized effort is made to find good prospects for entrepreneurship and help to nurture their development. For the past eight years, one of the authors has been involved in programs that have systematically identified and evaluated entrepreneurs and helped them to develop new ventures; some two dozen ventures with current sales approaching $67 million resulted from this work in spite of the fact that many of these ventures were located in economically depressed areas with greater obstacles to successful business development. We believe that a similar program could be applied to the development of high-technology ventures in New England. Therefore, the following recommendations are made:
Recommendation 2
Undertake programs to identify good prospects for potential technical entrepreneurship, and to help them systematically to develop high-technology ventures in the region.

Recommendation 3
Develop and offer short courses within the region that are directed to aspiring and existing technical entrepreneurs, and that provide education and training in management skills (e.g. marketing, finance, team development) and entrepreneurial techniques and strategies involved in creating and developing a small business. Consideration should be given to the question of what institutional or other setting would provide the greatest exposure of potential technical entrepreneurs to such training. Potential settings include technology universities, two-year technical training institutes, continuing education curricula, technical high schools, and business schools; and consideration should also be given to the scheduling of such courses to provide maximum accessibility by
working persons interested in entrepreneurship.

Research has shown (Cooper, 1971), and Boston's Rt. 128 complex exemplifies the importance of an "entrepreneurial environment" in helping to seed and cultivate small businesses. As it is not known how such an entrepreneurial environment gets started in an area, we believe and recommend that this question merits attention and study.

Recommendation 4
A study should be made of how best to catalyze the development of technology businesses in areas of New England now underdeveloped in this respect.

Increase the Rate of Technology Transfer
Although the development of high-technology ventures in and around Boston was characterized by rapid and effective transfer of technology from MIT and, to a lesser degree, government laboratories, there is, nonetheless, a substantial amount of technology that is not being exploited, and no shortage of good technical ideas. What is lacking is an effective way of linking the ideas and their developers with entrepreneurs who can exploit them. Particularly important in this linkage is the extent to
which an entrepreneur can become psychologically committed to exploiting a new technology that is being transferred.

Recommendation 5
Develop ways to increase the rate at which technology is taken out of university and government research laboratories and converted to commercially viable products. Particular attention should be directed to examining how best to increase the direct involvement of laboratory researchers with technical entrepreneurs in the development of ventures based on the laboratory technology. Attention should also be focused on appropriate rewards for the participation of research personnel — e.g. equity in the venture or royalties on sales. Active cooperation between an inventor/researcher and an entrepreneur should provide a link between the laboratory and the market-place and increase the likelihood of successful technology transfer.

The U.S. government patent policy to date is not to grant exclusive rights to inventions developed with government funds. Largely because of this non-exclusive policy, only about 10% of government-held patents are being exploited. Companies are often unwilling to invest funds to develop and market a product that
can be copied by a competitor. This can be particularly true of small technology companies whose financial and marketing resources are slim and who depend on a unique product to obtain a market position. The non-exclusive government patent policy tends to inhibit technology transfer. The recommendation following expresses the need to find a way of accommodating public interest and small firm survival in a fair policy. We understand that there is some effort in this direction by the Congress at the time of this writing.

Recommendation 6
Examine the feasibility of offering to small firms the exclusive rights to inventions that they developed under government R&D contracts.

Government Support for Research & Development (R&D)
In the 1950s and early 1960s, Federal funding of research and development served to stimulate technical innovation as well as the creation and growth of high-technology companies in New England. Since the late 1960s, the level of Federal funding in constant dollars (adjusted for inflation) has declined. In addition, while the Department of Defense, the largest Federal supplier of R&D funds, has distributed more money each year since 1976, the narrowing of its funding to mission-oriented projects (under the Mansfield Amendment) substantially decreases its support of new innovative technical ideas and basic research.

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These changes have had an adverse effect on the development of new small, high-technology companies that often were able to start up with Federal R&D contracts. Moreover, a change in government contracting practice (Department of Commerce, 1976), that has hurt the development of the small technology firm has been the reduced acceptance of unsolicited proposals and associated sole-source R&D procurements, in favor of competitive bidding for R&D contracts. That bidding favors the large firms. Because of these practices, many small technology companies have opted out of the government contract business rather than have their innovative, unsolicited proposals turned into competitive bidding matches.

**Recommendation 7**

Increase the level of Federal R&D contract awards to small high-technology businesses. Allow increased acceptance of unsolicited R&D proposals from small firms and the placement of sole-source contracts with them when warranted. Reduce the paperwork and unnecessary reporting required of small firms on R&D contracts.

In addition to R&D contracts, government procurement policies can be used to create a demand for new, advanced products from
small firms. The government could pay a premium price for prototypes and early production runs of technically-advanced products, particularly those which can compete with foreign products in the civilian sector. Subsequent government procurement needs could be used to stimulate sufficient production of such products that they could be offered to non-government customers at prices they are willing to pay. Such a procurement policy was used to develop the semiconductor industry, and, more recently, was being considered as a way to accelerate the commercialization of solar heating systems.

Recommendation 8

Evaluate the feasibility of systematically using Federal procurement requirements as a way to increase selectively the demand for new innovative technical products from small firms, with particular attention to increasing high-technology products for use in the civilian sector.

By serving as a source of innovative technical ideas as well as source of engineers and scientists, universities have played an important role in the development of new high-technology firms in New England. However, R&D funds to universities have been increased only minimally over the entire 1968-1978 decade when inflation is taken into account, and Federal student support
reportedly (Wiesner, 1976) has decreased. Our technical universities now perform most of the research cited in patents (Science, March 12, 1976), and strong university research programs are important if we are to maintain or improve our world position in science, technology and innovation. Our next recommendation suggests, therefore, an active effort to use university resources more productively.

**Recommendation 9**

Increase financial support to university-based science and technology research and development programs, particularly those with potential civilian applications. Encourage the sharing and spin-off to small high-technology companies of innovations and new technologies that result from that work.

"Seed Capital" Financing for Technology Start-Ups

Although a substantial amount of money for venture capital has been raised in the last 12-12 months and more capital is becoming available for young companies, there has been and is a shortage of capital for technology start-ups. With some notable exceptions (e.g., Digital Equipment Corp.), seed capital for high-technology start-up generally comes from friends, relatives, and the entrepreneurs themselves. (Professional venture capital investors tend to shun start-up financings because they involve
unproven management, products and markets.) If seed capital is obtained, it is often inadequate and the technical entrepreneur spending a great deal of time seeking additional equity financing and/or bank debt. Technical innovation and product development become secondary to fund-raising and survival.

**Recommendation 10**

Develop ways of increasing the amount of "seed capital" available to finance the start-up of new technology ventures. Among methods that could be considered are: (1) A venture-capital firm with equity capital provided by government as well as private sources (Venture capital firms funded solely by the government have been organized in Sweden); (2) The recently proposed, venture-capital SBIC's (VC-SBICs) (SBA, 1978) that would provide higher-risk financings. The SBA would provide reduced-interest-rate loans and investment guarantees and, in return, would share in the capital gains realized from venture financings; (3) Tax incentives to provide seed capital for high-technology ventures. These might take the form of an immediate tax credit for a portion of an investment in the year it is made, or a further progressive
reduction in the capital gains tax in accordance with the length of time a venture investment is held.
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### APPENDIX A

**DISTRIBUTION OF BRANCHES AND SUBSIDIARIES**

**FOR HIGH TECHNOLOGY FIRMS OF DIFFERENT SIZES**

(Percentages of Branches in Each Size Category Are Shown)

Data Source: 1972 Enterprise Statistics, Part 1

<table>
<thead>
<tr>
<th>Technology Group of This Paper</th>
<th>Enterprise Statistics Industry Codes</th>
<th>Employment Size of Co.</th>
</tr>
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<tr>
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<td>38A Sci. &amp; Measuring Instruments</td>
<td>0-19 20-100 100+ Total</td>
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<tr>
<td>Engineering</td>
<td></td>
<td>0.7% 3.6% 95.7% 100%</td>
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<tr>
<td>Scientific Instruments</td>
<td></td>
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</tr>
<tr>
<td>Computers</td>
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<td>0.02% 0.3% 99.6% 100%</td>
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<tr>
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<td>0.08% 1.1% 98.8% 100%</td>
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<td>36D Electronic Components and</td>
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<td>Accessories</td>
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<tr>
<td>Chemicals &amp; Drugs</td>
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