Demand for Biomedical Facilities

by Oakleigh J. Thorne, CRE

Prior to discussing the overall market demand for biomedical buildings or laboratories, it is important to understand construction and design attributes relating to various facilities and the safety features presently required to work with bio-toxins. Building design and handling practices and policies have been evolving since 1941. Although modest improvements in interior barrier designs and handling practices were evident since that time, significant and formal building design and practice changes occurred after 1980 with the discovery of the HIV. Even prior to this discovery, there was growing concern over the treatment of medical waste and its disposal. Since 1980, formalized approaches to facility design and the construction of primary and secondary barriers which impede the transmission of harmful pathogens have become national standards.

Present facility design and construction has evolved into four design types known as Bio-Safety Levels (BSL), and building classification depends on the biological agents present in the facility. Understanding the building type enhances the appraiser's knowledge regarding marketability, demand, and probable target industry issues. *Table 1* outlines the current four biosafety levels.

Each of the BSLs listed in *Table 1* have different design complexities and related costs. Although labor and wage rates vary nationally, material and equipment prices remain fairly constant. At the risk of using a generality, construction costs to produce buildings that are BSL 4 compliant can range in excess of $700 per square foot and even higher.

A review of the biomedical and microbiological industry provides a brief insight into the demand potential for obtaining tenants to fill proposed or existing laboratory buildings.

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Table 1

RECOMMENDED BIOSAFETY LEVELS (BSL)
AND BARRIER DESIGN STANDARDS

		Barriers	
		Primary	Secondary
BSL	Bio-Agents	Equipment	Facility
1	Not known to cause disease in healthy adults	None Required	Open bench counters with top sink required
2	Associated with human disease	Containment devices including: lab coats, gloves, and face protection	Autoclave devices should be available as required
3	Indigenous or exotic agents with the potential for lethal consequences	BSL Two plus respiratory protection as needed	BSL Two plus physical separation, negative airflow, and no air recirculation
4	Dangerous/exotic agents which pose high risk of life-threatening disease	Full-body, air-supplied, positive pressure personnel suit	BSL Three plus totally isolated zones, dedicated air supply exhaust, and decon systems

Source: National Institutes of Health

GLOBAL DEMAND ISSUES

According to the U.S. Department of Commerce, International Trade Administration's Chemicals, Pharmaceuticals, and Biotechnology Division, in its publication, *U.S. Industry and Trade Outlook 1998: Chemicals and Allied Products*, the United States leads the worldwide pharmaceutical industry in market share, research and development (R&D) spending, and the development of new therapeutic products. American firms accounted for 30 percent of the total worldwide market in 1994, followed by Europe (27 percent); Japan (22 percent); Latin America (7 percent); Southeast Asia (6 percent); and other areas (8 percent). In terms of R&D spending, U.S. companies account for about one-third of all pharmaceutical R&D work worldwide. U.S. firms spend heavily on new drug R&D, and enjoy a high degree of productivity from those investments. Of the 265 major new drugs developed between 1970 and 1992, almost half originated from U.S. firms, based on data from the Pharmaceutical Research and Manufacturers of America (PhRMA).

U.S. companies have found eager markets abroad, especially in developing and emerging economics. Based on PhRMA data, U.S. pharmaceutical companies expanded their drug sales from $10.5 billion in 1980 to an indicated $33.4 billion in 1996. Readily available and relatively low in cost, prescription drugs are typically the first line of medical therapy throughout the world. With leading U.S. drug manufacturers generating, on average, close to two-fifths of their sales abroad, U.S. firms are affected by overseas demand, the tempo of foreign business, international regulatory conditions, and fluctuations in the dollar compared with other world currencies.

The European Community's Economic Union, formed in 1993, has made marketing in Europe more efficient and has streamlined the process for new drug approvals there. The union's new Committee for Proprietary Medicinal Products is a universal regulatory agency; drugs approved by this organization are automatically cleared for marketing in all 15-member states. In the past, regulatory clearance had to be obtained in each country where a drug was to be sold. Foreign sales have benefited recently from the formation of the economic union, the passage of NAFTA in 1994, and the revision of the General Agreement on Tariffs and Trade in 1995.

DIAGNOSTIC SUBSTANCES

The diagnostic substances subsector (SIC 2835) includes companies that make chemical, biological, or radioactive substances for testing blood or other bodily fluids and tissues. These substances may be

used for in vitro (test tube) or in vivo (administered in the body) testing.

In vitro diagnostic substances are used for diagnostic tests that are performed in containers or instruments and are used for identifying and measuring normal or abnormal constituents of body fluids or tissues. In vivo diagnostic substances are taken internally to enhance the images of targeted body organs or functions during a diagnostic imaging procedure such as magnetic resonance imaging or computed tomography. Diagnostic substances are used for the early detection of disease, to distinguish between diseases, or to monitor a present condition or level of therapy.

Domestic Trends

According to the above-mentioned *U.S. Industry and Trade Outlook 1998*, the diagnostic substances industry is considered a mature industry in developed economies and one dependent on an increase in the patient population and the introduction of innovative products to spur growth. Health care cost-containment, consolidation among producers and users, and advances in molecular biology are among the forces reshaping the diagnostics industry into the next decade. Since the early 1990s, cost-containment programs to reduce health care expenditures in the U.S. and major foreign markets have placed diagnostic tests under greater scrutiny as an area for potential savings. The spread of managed care organizations and consolidation within the ranks of hospitals and clinical laboratories, by far the largest end-users of diagnostic substances, have pressured suppliers to reduce prices. In this cost-cutting environment, there is a trend toward increasing the automation of testing equipment to handle more tests with faster turnaround times.

Nonetheless, an increase in demand for diagnostic tests and U.S. producers' international competitiveness have resulted in healthy gains for the industry over the last several years. The U.S. supplier industry is diverse, comprising more than 500 companies involved in developing new diagnostic tests, although only a handful dominate the U.S. market. Likewise, about 15 companies, mainly U.S. and European, account for 75 percent of the worldwide sales of diagnostic substances. Most of the top foreign companies operate in the United States and have invested in or acquired U.S. firms.

BIOTECHNOLOGY

Biotechnology is defined by various U.S. government publications as a set of enabling technologies that use organisms or their cellular, subcellular, or molecular components to make products or to modify plants, animals, and microorganisms to carry desired traits. Advances in molecular biology in the last 25 years have led to the development of recombinant DNA or genetic engineering, monoclonal antibodies, gene therapy, DNA amplification, genomics, and other technologies that have become workaday tools in life sciences research. These techniques provide scientists with the means to uncover the genetic codes of organisms, find new substances of potential industrial value, and modify the genetic makeup of organisms with far greater precision and speed than previously possible.

Domestic Trends

More than 1,300 enterprises in the United States, ranging from start-ups to multinationals, are involved in industrial biotechnology, employing well over 100,000 people. Sales of products made through biotechnological means by U.S.-based firms, virtually nonexistent in 1982, were estimated at $9.7 billion in 1996 and $10.8 billion in 1997, an 11 percent increase over 1996, according to Consulting Resources of Lexington, Massachusetts. Governments usually gather data concerning industries based on the product or service produced, not on the method of manufacturing. Consequently, sales of products made through biotechnology have not been collected as a separate industry, but have been encompassed within traditional industry categories.

The greatest commercial impact of biotechnology is in the discovery and production of new pharmaceuticals, safer vaccines, and faster and more reliable diagnostic tests. By 1996, 16 different drugs, one vaccine, several in vivo diagnostic imaging agents, and hundreds of in vivo diagnostic tests had reached the market, generating about $8.9 billion in 1996. Estimates of the exact number of biotech-derived medicines under development vary, but the upward trend is unmistakable. A 1996 survey by PhRMA found that 284 biotech medicines were in development, an 11 percent increase over 1995, with the largest increases occurring in gene therapy and vaccines.

Table 2 lists the seven major applications of biotechnology.

Biotechnology plays a vital role in the development of tests to diagnose elusive food pathogens. A 1996 federal regulation designed to reduce the incidence of food poisoning in meat and poultry

Table 2

THE SEVEN MAJOR APPLICATIONS OF BIOTECHNOLOGY

Health Care
- Pharmaceutical
  - Therapeutic drugs
  - Vaccines
- Diagnostics
  - Monoclonal antibody-based tests
  - Genetic probes and DNA amplification
  - Agents to improve in vivo diagnostic imaging
- Gene therapy
- Tissue replacement
- Veterinary disease diagnostics, therapeutics, and vaccines
- Animal and plant "factories" to produce pharmaceuticals and chemicals

Agriculture
- New plant varieties for new or improved foods
- Safer pest control
- Plant disease diagnostics
- Improved livestock for food production
- Veterinary disease diagnostics, therapeutics, and vaccines
- Animal and plant "factories" to produce pharmaceuticals and chemicals

Food Processing
- Microbial starter cultures, enzymes, and vitamins
- Food contamination test kits

Marine Biotechnology
- Novel pharmaceuticals, chemicals, and biomaterials

Industrial Processes
- Organic chemicals
- Mineral recovery
- Bioelectronics
- Waste stream reduction
- Environmental clean-up (bioremediation)
- Energy production

New Understanding of Biological Systems
- Understanding human disease
- Deciphering the human genome
- Sequencing genomes of microorganisms and plants

Laboratory Instrumentation and Techniques to Support Life Sciences Research, Development, and Manufacturing
- Nucleic acid amplification technology
- Combinatorial chemistry

Source: Adapted from Biotechnology, *May 1995, California Trade and Commerce Agency*

products caused by E-coli and Salmonella bacteria will spur growth of this segment. Biotech-derived diagnostics are also being used to detect pesticide residues in crops, drug residues in food animals, and environmental pollutants.

Biotechnological techniques also are revitalizing the enzyme industry by providing more economical methods of changing chemical structures to enhance performance. Before genetic engineering, enzymes added to laundry detergents to remove stains and brighten colors could not be produced economically. According to some industry observers, most industrial enzymes will be produced by genetic engineering within the next decade.

Industrial biotechnology activity focuses, to a large extent, on research and the discovery of biological information useful to the development of new products. According to *U.S. Industry and Trade Outlook 1998*, most biotech companies are unprofitable and rely instead on income from equity investments, public offerings, and research and development contracts. The U.S. biotechnology enterprise is research-intensive, spending roughly 10 times more on research than other U.S. industries. New information about the genetic origin and pathway of diseases is being uncovered at a remarkable rate, and drug companies, both U.S. and foreign, have increased acquisitions and alliances with U.S. biotech companies to gain a foothold in the latest generation of technologies and to access genetic information to develop new products. Many of the strategic alliances occurring in the 1995-1996 period between biotechnology companies and established firms were in the emerging areas of genomics and gene therapy.

U.S. INDUSTRY GROWTH PROJECTIONS FOR THE NEXT FIVE YEARS

Although trade data on biotech-derived products are unavailable, the U.S.-based biotechnology industry contributes to a positive trade balance. Most top-selling biotech products on the market are developed by U.S. companies and are being produced domestically for export or licensed for production abroad. Biotech companies also receive patent royalties and contract research and development payments. The major foreign markets for U.S. biotech products closely parallel those of the pharmaceutical industry, e.g., the European Union, Japan, and Canada. The positive export earnings trend should continue at least for the next five years as the U.S. private and public sectors still account for the preponderant share of worldwide research dollars and numbers of biotech products in development. However, export growth of genetically modified crops will hinge on timely approval by foreign regulatory authorities and acceptance by consumers.

Future growth rates will depend on the level of research and development, regulatory approval of new products, demonstration of price/performance advantages, and consumer acceptance. Medical biotechnology revenues are expected to increase by at least 10 percent annually over the next five years.

Future growth rates will depend on the level of research and development, regulatory approval of new products, demonstration of price/performance advantages, and consumer acceptance. According to *U.S. Industry and Trade Outlook 1998*, medical biotechnology revenues are expected to increase by at least 10 percent annually over the next five years, given an increase in the number of biotech-derived medicines in advanced stages of development and because of progress in FDA regulatory reform which is leading to quicker approval of new medicines. Sales are expected to climb at nearly 20 percent annually over the next five years. Overall sales for the biotech sector are expected to reach $12 billion by 1998 and $18 billion by 2002.

INDUSTRY LINKAGES WITH MEDICAL SCHOOLS

The relationships between Colleges of Medicine and the need for nearby laboratories is evident from prior historical relationships. Most campus land areas have very limited available sites to provide the space for new lab buildings. Funding and delivery systems necessary to satisfy growth opportunities in the biomedical testing industry is better suited to the private sector as opposed to the inexperienced constructing staffing in the college environment. A college usually links its research effort to contract research grants from several domestic pharmaceutical companies with testing activities occurring not only on campus, but on the critical mass (available sites) to expand the connection between academia and private industry. Below are

a few examples where universities have engaged in joint-ventures with the private sector for mutual advancement.

University of Connecticut at Storrs - Pfizer Pharmaceutical Company recently executed an agreement with the University of Connecticut at Storrs to build and lease back a 52,000-square-foot biomedical building costing about $19 million or $365 per foot. Pfizer, currently located in Groton, Connecticut, outgrew its space and had no expansion room. UCONN offered to lease the land to the drug company and enter into a sale-leaseback on the building in exchange for the right to occupy about 20 percent of the total building's space. Pfizer was expected to link its needs for biomedical testing with UCONN's science and medical schools to advance its drug manufacturing business. In this situation, Pfizer is forced to separate its divisions from its primary headquarters in Groton.

Unfortunately, the local community recently rejected the proposal. Pfizer is now back in the market looking for another expansion site near a major university.

Massachusetts Institute of Technology - In 1983, the Massachusetts Institute of Technology selected Forest City Enterprises, a national publicly-traded real estate company headquartered in Cleveland, Ohio, to develop its 27-acre parcel directly adjacent to the MIT campus in East Cambridge, Massachusetts. University Park at MIT, Boston's only corporate park affiliated with a major university, is a three-building campus of retro-fitted, turn-of-the-century, multi-story manufacturing lofts totaling 350,000 square feet of space. The first building opened in December 1987, contains just over 100,000 square feet of rentable floor area in five stories, and is leased by ARIAD Pharmaceutical, NEMAPharm, PFN, Inc., and SensAble Technologies. The second five-story building opened in March 1989 and contains over 121,600 square feet; its major tenants include OraVax, ProScript, Genszyme Tissue Repair, Acusphere, Etex Corp, and OnLine Environs. The third five-story building of 126,100 square feet was finished in 1990 and is occupied by Alkermes, Genzyeme Tissue Repair, Ascent Technology, and others. A fourth multi-story building of 75,000 square feet opened in the fall of 1998.

The MIT Park offers state-of-the-art, flexible, and first-class space accommodating firms of all sizes from start-ups to major corporations. Special features include fiber optic telephone cabling, clean rooms, redundant electrical service, and upgraded HVAC and floor loading capacities. The mission statement for the Park is to link its related departments to national pharmaceutical and molecular bioscience firms for the advancement of both MIT and the national firms who seek access to the MIT's academic pool of skilled researchers. The Park also has surplus land on which a 212-room independent hotel and conference center opened in late 1998. Although the Park and campus are close, an auto or shuttle bus is required between the two locations.

George Mason University - Prince William County, located in the Northern Virginia portion of Washington's metropolitan region, recently entered into a public-private development program with nearby George Mason University. The county, long known as a bedroom community, recently set aside a 1,200-acre campus to entice the private sector and academia to a joint-venture in achieving common goals. As a result of this effort, the first of three buildings opened in Spring 1997. Building One consists of 100,000 square feet of classrooms, administrative space, and state-of-the-art wet labs. The building, as well as 45,000 square feet of laboratory and office space at George Mason University, is occupied by American Type Culture Collection (ATCC), the world's largest and most diverse archive of biological materials. Building One's base costs were $180 per foot, and ATCC added another $200 per foot in special fit-up. In addition to its bio-archives, it also is a patent repository of microbiological products and processes.

Building Two opened in mid-1998 with about 100,000 square feet of laboratories and classrooms, housing ATCC's research and education programs. GMU's new Molecular Biosciences and Technology Institute (MBTI). MBTI has created a joint-venture with ATCC to further advance two new technologies: 1). high-throughput signal conditioning and base-calling in real time, and 2). pattern recognition software to analyze data from gel-based automated DNA sequencing instrumentation. The University has established 10 new teaching positions to work with ATCC in the fields of cellular and molecular biosciences and bioinformatics. The campus is 20 minutes drive time from GMU. George Mason researchers are helping a group of companies led

by BDM International, Inc., in McLean to perfect a method for transmitting huge flows of data between computer microprocessors more rapidly by using light signals instead of wires.

Rensselaer Polytechnic Institute - Located just outside Albany, New York, in East Greenbush Township is a project with more than 825,000 square feet in place owned by the Rensselaer Polytechnic Institute and is a university-related park for technology joint-ventures between industry and education. The primary objective of the venture is to develop interactions between tenant companies and the University in order to enrich the educational environment of the University and assist the companies in staying on the leading edge of their technologies. The Park has over 50 tenants (and in excess of 2,000 employees) with a diversity of research technologies including electronics, physics, biomedicine, and software. Of the 20 buildings in the Park, 12 are University-owned, multi-tenant facilities and eight are single-purpose, tenant-owned facilities. It is the policy of the University that land sites are available only for lease. The Park is located roughly five miles south of the University campus.

The list continues with such examples as the Princeton Forestall Center in Princeton, New Jersey, and Research Triangle Park in Raleigh-Durham, North Carolina. Additional industry/academic relationships include MetaMorphix, Inc., of Baltimore, which is developing protein-based products created though genetics research at Johns Hopkins University. The products can be used to repair human tissue, combat neuromuscular disorders, and dramatically increase muscle mass in livestock. Hughes Network Systems, a Montgomery County company, is collaborating with researchers at the University of Maryland to develop complex voice and data transmission technologies that draw simultaneously on satellite, fiber-optic and cable systems. Throughout the Midwest and western U.S., there are about 20 additional examples of ventures between industry and academia. Proximity to the schools and laboratories does not appear to be a significant issue.

New England is second to the San Francisco Bay area with regard to concentration of biotechnology companies. Most of the New England firms are found along I-95 in Connecticut and in the Boston/Cambridge area of Massachusetts. *Table 3* compares the concentrations of biotechnology companies by location in the United States.

The biotech and pharmaceutical companies seeking relationships with universities place a high priority on local labor skills and availability, labor costs, transportation systems, reputation of the academic institution, and costs of living. Biotech and pharmaceutical companies rank competing universities according to number of degree programs for its employees, number of faculty consultants in its field of endeavor, access to laboratories, and faculty research activity. Other intangible goals for the private sector include the academic linkage for the transfer of technology. The mechanisms for

Table 3

BIOTECHNOLOGY INDUSTRY CONCENTRATIONS

Region	Number of Companies	Percent
San Fransicso Bay Area	192	28.8
New England	172	25.8
Mid-Atlantic	114	17.1
San Diego	102	15.3
New York	86	12.9
National Firm Total	666	100.0

Source: U.S. Department of Commerce's U.S. Industry and Trade Outlook 1998 *and Thorne Consultants, Inc.*

transferring new ideas emanating from basic research housed in a university to the corporate world provide a vital link in the sequence of events leading to innovation and eventual patents.

THE DEMAND FOR NEW LABORATORY FACILITIES

The National Science Foundation (NSF) is the largest source of grants for the exploration of science, medicine, physics, engineering, and agriculture. As a consequence of its major funding role, NSF conducts biennial surveys in which it collects data on issues related to science and engineering (S&E) research facilities in the nation's colleges and universities. One objective of the surveys is to insure that NSF grants provide the highest returns for its stated mission of advancing science and technology. An equally important objective is to determine the adequacy of presently configured laboratory space (age, condition, and quality of labs) and the additional space needed to accommodate science's changing technologies. The latest (1996) NSF "Survey of Scientific and Engineering Research Facilities at Colleges and Universities" was mailed to a sample of 314 institutions representing 560 research-performing colleges and universities. The survey found that:

- At least half of the surveyed institutions indicated inadequate amounts of science and engineering (S&E) research space in the biological sciences outside of medical schools, the physical sciences, engineering, the agricultural sciences, and the medical sciences, both within and outside medical schools.

- Eighteen percent of all S&E research space was considered to require major renovation or replacement. This portion of space amounts to 24.5 million net assignable square feet (NASF).

- Since 1988, the amount of research space requiring repair/renovation or replacement in many of the S&E fields has increased. In the agricultural sciences, the amount increased from 3.6 million NASF in 1988 to 5.3 million NASF in 1996; in the biological sciences outside of medical schools, the amount increased from 2.4 million NASF in 1988 to 3.4 million in 1996; engineering space in this condition grew from 2.2 million to 4.0 million NASF.

- The construction of S&E research space by research-performing colleges and universities has declined from projects valued at $3.4 billion in 1990-1991 fiscal years; to $3.0 billion in 1992-1993 fiscal years; to $2.8 billion in 1994-1995 fiscal years.

- In 1996, 88 percent of the research-performing institutions had laboratory animal facilities. Most of the 12.2 million NASF of animal research space (93 percent) was contained in doctorate-granting universities. Institutions with animal research space reported that roughly 10.0 million NASF (82 percent) met government regulations designed to ensure the safekeeping and proper use of animals in research. Another 1.2 million NASF (10 percent) needed limited repair/renovation to meet regulations, and 1.1 million NASF (9 percent) required major repair/renovation. Only 6 percent of the research-performing institutions with animal research facilities were scheduled to construct animal facilities in fiscal years 1996-1997.

Information focused solely on the amount of S&E research space and its growth or decline over time is insufficient for understanding whether there is enough space to conduct any form of research, and whether the condition of that space is suitable for conducting particularly sophisticated research. Assessments of both the quantity and quality of existing research space made by respondents to the NSF "1996 Survey of Scientific and Engineering Research Facilities at Colleges and Universities" are examined below. The survey focused on the following questions:

Adequacy - Respondents were asked to rate the adequacy of the amount of research space in each field at their institution ("adequate" indicated the space was sufficient to support all current S&E program commitments in the field; "inadequate" indicated the space was not sufficient or was non-existent, but needed).

Condition - For each field, respondents indicated the condition of research space by reporting the percentage of space falling into one of the following categories: "suitable for use in the most scientifically competitive research in the field"; "effective for most levels of research in the field, but may need limited repair/renovation"; "requires major renovation or replacement to be used effectively"; or "not applicable or no research space in this field."

Responses to the survey were based upon the *subjective* assessments of a variety of different individuals, including the survey coordinator at the

institution, as well as deans and other administrators.

Regarding the adequacy of research space, reports of inadequate research space varied across field and institution type. The percentage of institutions indicating that the amount of available S&E research space was inadequate ranged from 30 percent for mathematics to 66 percent for the medical sciences in medical schools. Over half of all institutions also reported inadequate amounts of space in engineering (57 percent); medical sciences outside of medical schools (57 percent); physical sciences (54 percent); biological sciences outside of medical schools (53 percent); and agricultural sciences (52 percent). Nearly half of the institutions reported inadequate amounts of space in five additional fields: social sciences (47 percent); biological sciences in medical schools (46 percent); earth, atmospheric, and ocean sciences (46 percent); computer sciences (44 percent); and psychology (44 percent).

The top 100 institutions surveyed were most likely to indicate inadequate research space in the biological sciences outside of medical schools, with 61 percent reporting this to be the case. Three other fields were reported to have inadequate research space by over half of the top 100 institutions: physical sciences (56 percent), social sciences (55 percent), and engineering (57 percent).

Medical science space was most likely to be reported as inadequate by the other doctorate-granting universities, both outside medical schools (65 percent) and within (69 percent). In fact, the percentages of those institutions, indicating medical science space to be inadequate, were much higher than for the top-100 institutions.

Two fields, the biological sciences outside of medical schools (52 percent) and the physical sciences (51 percent), were listed by over half of the nondoctorate-granting institutions as having inadequate S&E research space.

Regarding the condition of S&E research space, an overall 37 percent of the S&E research space at the surveyed research-performing institutions was rated as suitable for use in the most scientifically sophisticated research. Forty-four percent of the institutions reported that their S&E space was effective for most levels of research in the field. However, the institutions classified 18 percent of their S&E research space as requiring either major repair/renovation or replacement. There was general consistency among the different types of institutions regarding the amount of S&E research space in this condition, with 19 percent of the S&E research space at the top 100 doctorate-granting institutions, 17 percent of the research space at other doctorate-granting institutions, and 18 percent of the research space at nondoctorate-granting institutions requiring major repair/renovation or replacement.

The pressure on pharmaceutical companies to lower the costs of drugs and the 11-year patent horizon for new drugs are contributing factors which impact the efficient use of capital. More specialized building design is necessary to accommodate more specific procedures, which indirectly effects the pace of obsolescence. However, the present wave of consolidations in the industry should provide the efficiencies needed to advance research and development funding.

Such similarities across institution types mask large differences in actual amounts of space. The 18 percent of space rated as needing major repair/renovation at the top 100 universities, for instance, actually represents 17.6 million NASF, whereas the 18 percent of space rated in the same category at nondoctorate-granting institutions represents only 1.1 million NASF. In total, the nation's research-performing institutions reported that 24.5 million NASF of research space required major repair/renovation or replacement.

In conclusion, the 1996 NSF survey reveals aging facilities that are increasingly inadequate to serve the needs of research across all sciences, resulting in a pent-up demand for additional space to accommodate industry growth. New England is second behind the Bay Area in the concentration of biotech companies. The concentration of medical sciences stretches from Stamford, Connecticut, to Boston, Massachusetts. Demand for lab space can be expected to arise from outside the market area and perhaps even these states. The large cities in the New England and Mid-Atlantic regions of the U.S. are most likely to produce the well-capitalized incubator firms searching for lab facilities throughout

the Boston-Washington corridor. The Bay Area of San Francisco, on the other hand, has such a large critical mass that new and expanding lab and biotech firms can arise from within its market.

CONCLUSIONS

In the last four years, since NSF's survey, little has changed to alter the landscape between user demand and the relationship to the available supply. A more recent survey of 660 research performing institutions in 1998 by NSF (published in mid-November 1999) reported that 64 percent of biological science firms outside of medical schools have inadequate space. A material increase over the 50 percent reported in the 1996 survey. According to this more recent survey, 13 million square feet of newly constructed space is required to fulfill the needs of both the physical and biological science industries. In total, all sectors of the S&F market demands 41 million square feet of space by institutions and private firms to carry out their scientific mandates.

These are very expensive buildings to construct, requiring substantial amounts of venture capital. NSF's more recent survey reports that 61 percent of funding for new construction comes from the private sector, while federal, state, and local funding provide the balance. The pressure on pharmaceutical companies to lower the costs of drugs and the 11-year patent horizon for new drugs are contributing factors which impact the efficient use of capital. More specialized building design is necessary to accommodate more specific procedures, which indirectly effects the pace of obsolescence. However, the present wave of consolidations in the industry should provide the efficiencies needed to advance research and development funding.

Despite the apparent pent-up demand for more modern facilities, the presence of waiting users (tenants and owners) is not a given. Market analysts must have the market knowledge regarding local concentrations (research activities) and related linkages to Universities and native industries that can exploit a relationship with a biomedical firm.

Adaptive reuse of existing facilities for second generation users is generally very poor. Seldom does another bio-firm, even requiring the identical BSL type facility, equate the same dollar value to the facility as the vacating first user. Consequently, interior layout of administration and scientific offices, isolated bio-hazard areas, and research rooms are typically gutted and replaced by a new layout designed by the second or the third generation users. Technological advances in the industry are also contributing factors as to how older space is viewed by subsequent facility users.[REI]