INTRODUCTION: ARCHITECTURE FOR SCIENCE
by Payette

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The rapid change in science and its methodologies are exciting, invigorating challenges for architects. We are fascinated by the multi-layered aspects of contemporary human inquiry. We become part of the commitment to make places that support and enable scientific advancement and learning to improve the human condition. We strive for our creative process to result in a place of creative discovery.

Designers who work on successful buildings for science approach this building type from several points of view. As architects, we believe beautiful and humanistic surroundings inspire creativity and intellectual achievement. As laboratory planners, we strive for ideas that define new and innovative ways for people to work collaboratively, efficiently, and safely in a highly technical environment. As campus planners, we are thoughtful in how we place a new building on a campus because we respect the character of its past and its future.

The High Cost of Research

Buildings for science today are more sophisticated than yesterday's utilitarian and functional "research laboratories." This is prompted by several trends. First, scientific investigation has produced remarkable advances in all areas of science and has resulted in increased funding. Second, new instruments, utilities, chemicals, and gases require specialized environments and infrastructure. Third, there is an expanding need for shared core facilities such as analytical instrumentation and animals. Finally, research programs have become multidisciplinary to benefit from the combined knowledge of a broad range of specialists.

A consequence of these trends is high cost. Science buildings are a major financial commitment and owners need to realize a return on investment. Academic institutions try to ensure continuous grant funding and donor contributions by recruiting top-notch scientists for their faculty, while enticing the brightest students who can pay increased tuition. In turn, the top-notch scientists and the brightest students have their own expectations for pleasant work and living environments. Academic administrations need to balance costs versus benefits because they are accountable to regents or trustees who have become guardians in terms of financial viability, campus planning, and building design.

Corporations have similar goals to recruit top-notch scientists and the brightest employees. These are often the same people being recruited by academia, so there is intense competition. Corporate administrations need to balance costs versus benefits because they are accountable to directors, shareholders, municipalities, and government agencies. Governmental agencies are accountable to elected officials and ultimately to their constituents.

A new phenomenon is gaining momentum – the research park – where universities, corporations, and governments become partners on a variety of research projects by bringing together talent and resources. This partnering redefines the line between "open and free" and "applied" research in terms of intellectual property, copyrights, and profitability.

The Role of the Client

Today, science buildings are the symbols of scientific achievement much like high-rise office buildings are symbols of business and commerce. The notion of a laboratory achieving architectural significance was first realized in 1965 with Louis Kahn's Salk Institute in La Jolla, California. This building is well conceived in meeting the needs of function and utility, but goes further, transcending to a poetic spirit and a sense of place.

But why is the Salk Institute able to make this transition to architecture: what makes a successful building for science? Kahn was able to achieve his remarkable design because Jonas Salk was able to clearly articulate his vision for the Institute. There is no substitute for an engaged, well-informed client. The better the communication between the owner and the design team, the better the result. That said, the nature of the client has become more complicated. Who is the owner? In addition to the "visionary" (*a la* Salk), the client can comprise several committees with representatives who are designated advocates for researchers, administration, building operations and maintenance, engineering, security, and Environmental Health and Safety (EH&S). These representatives need to be able to communicate the issues to their constituencies and be empowered to make decisions on their behalf. It has been our experience that achieving consensus is more realistic than obtaining 100 percent agreement.

The Nature of Research

To answer the question about what makes a successful science building, one needs to understand the basic categories of a program for research spaces. These are laboratories, laboratory support (instruments and equipment), offices, core facilities (glasswashing, imaging, and animals), and meeting spaces. For teaching, this also includes classrooms, and common space. The size and relative proportion of these categories varies with the type of science. For example, the needs for biological sciences are different from those of physical sciences. Regardless, each science building has these essential categories. Key to a successful building is the designer's knowledge of how the components of each category are designed and how they are assembled to best meet the needs of owner and users.

As science has become more interdisciplinary, with teams of specialists brought together to solve a common problem, space needs have changed. This has had implications for the lab planner and designer from several aspects. Teams can vary in size, and are rarely the same size over time. The nature of specialists can vary from less intensive needs (such as biology) to more intensive needs (such as organic chemistry). One measure of success is how a building can adapt to changes in use, occupants, and technology over time and within reasonable initial budget constraints.

Another measure of success is whether or not a new building is able to enhance or redefine the culture of the user through spatial arrangement. How do people want to work together? How does a series of interconnected spaces promote interaction that can lead to good science? Is there a perfect design that can be copied? (The answer to the last question is no – every building has its unique requirements in terms of program, people, and context.) However, it has been our experience there is one decision that consistently has the greatest impact on redefining culture: the relationship between Principal Investigator offices and their laboratories.

There are many different ways Principal Investigator (PI) offices can be situated. For example, they can be clustered together to promote communication among the team leaders, which is beneficial when specialists want to collaborate and integrate their collective expertise. It promotes "open" environments where laboratories are interconnected to accommodate large teams and a sharing of resources. While issues of security between assigned spaces and possible contamination between different types of research are often cited as disadvantages of this approach, it has been our experience that administrators and users prefer this model.

On the other hand, PI offices can be located adjacent to their laboratories where the investigators have hands-on involvement with their research. This approach is gradually losing favor because it promotes isolation, applies to small team sizes, and reduces flexibility to reassign space.

A key driver in science buildings is the net-to-gross square footage ratio expressed as a percentage and defining the building's efficiency. Owners strive to achieve maximum efficiency because it results in more square footage they can assign to research, thus maximizing their return on investment. The range for a new building may be 55 to 60 percent and for renovations 50 to 55 percent, depending on the building's prior use.

Maximum efficiency has a direct impact on the culture of how the building is used. For example, a layout with a single corridor is more efficient than one with two corridors. A single corridor will tend to have large "open" laboratories whereas smaller laboratories need two corridors for accessibility.

Another important factor that affects efficiency relates to mechanical systems. If the building can "plug into" existing campus-wide or public utility systems, the efficiency will be higher. On the other hand, if the building needs to provide its own boilers for steam, chillers for cooling, and generators for emergency power, the efficiency is significantly reduced.

Related to efficiency, there has been a steady increase in the ratio of support space to laboratory space. In biology-related research, what used to be 1:3 is now 1:1 (this does not apply to chemistry or engineering). Support spaces require more flexibility than laboratories because they accommodate special (and changing) requirements of many researchers. The ideal design is for this area to be as open as possible, unencumbered by shafts, closets, and other obstructions.

A responsibility of the design team is to identify alternatives with their related impact on building use and cost. This information provides the basis of discussions with administration and user committees, and facilitates a clear understanding of priorities as the building design progresses.

Mechanical systems can be up to 50 percent of the construction cost of a science building. It is critical for an owner to be a fully informed, active participant in establishing engineering standards and selecting systems that are compatible with the budget and with their capability to maintain and operate the building.

Laboratories Never At Rest

Why do science buildings need to accommodate change? If the average duration of its research programs is three years, it is conceivable that up to 30 percent of the building can be undergoing some level of intervention at any time. Intervention may be required due to changes in research funding, changes in technology, recruiting, promotions, mergers, acquisitions, legislation, etc. A particular basic science research facility completed within the past two years has experienced changes to 29 percent of the net square feet during construction (before it opened its doors!).

Generally, there are three levels of intervention in terms of the cost of the changes: cosmetic changes within existing rooms (such as repainting, new carpeting); upgrades within existing rooms (such as new utilities, lighting, ceilings, carpeting); and renovation where walls are relocated (all trades are affected). In addition to construction costs related to the intervention, other costs may be incurred for things such as "down time" when the space is not in use, relocation, assuring ongoing operations in adjacent areas, and code upgrades. Owner project management costs are often higher (by 5 percent), as are contingencies (by 5 to 10 percent) and professional fees (by 25 to 50 percent).

A building designed with flexibility to accommodate change will minimize intervention costs but it will also incur higher first costs. A key objective is to incorporate the most amount of flexibility within budget constraints and in the context of other priorities.

Depending on the nature of the project, it has been our experience the following menu of choices can provide cost effective results:

- Select a building layout that accommodates reassignment of space.
- Consolidate uses that require special needs to the infrastructure.
- Broaden application of design criteria to highest appropriate use.
- Selectively build-in a "robust" infrastructure.
- Provide a mechanical distribution that accommodates change.
- Provide a modular distribution of utilities with valves to isolate zones.
- Provide repetitive, modular design.
- Select a cost-effective casework system.
- Consider use of interstitial space.

The emphasis on interdisciplinary research has prompted social environments to be an integral part of a science building. Creative ideas come from discussions that can occur spontaneously during a casual encounter, informally during a break, or formally during a meeting or classroom session. In academic settings, communication among and between faculty, students, staff, and administration is essential to the education and mentoring process. In corporate settings, communication between researchers, administration, and marketing is essential to staying in business.

Highly successful science buildings elevate this to a strategic level. What might appear mundane are actually well-placed, well-conceived spaces that enhance opportunities for people to meet, pause, and talk. For example, prime locations could be at mailboxes, at the end of corridors, next to a cluster of offices, or at lab entrances. These may be “soft spaces,” intimate in scale, with lounge seating, warm colors and natural materials, day lighting, or pleasant views. The spaces may be layered with tools to facilitate productivity, such as computers, marker boards, and audio-visual equipment. This may be “social engineering” but if a stimulating environment leads to scientific achievement, it is vital to maximize use of social space.

Lately, world-renowned architects have received major commissions to design science buildings even if they are not experienced in this field. Why would an owner select a “signature” or “star” architect who is not familiar with the building type to design a very expensive laboratory? The owner may need recognition through the architect’s image and identity. It may be the requirement of a donor. Or the owner may be searching for a new prototype, perhaps because the science is new.

Whatever the reason, the “signature” architect often seeks the advice of a laboratory specialist to collaborate on program and functional aspects of the design. When this collaboration is successful, it advances architecture, technology, education, human interaction, and science. Otherwise, the signature architect is relegated to designing an exterior skin disengaged from the interior’s functional program.

The Role of Security and Safety

Over the years, there has been an increasing concern about security in science buildings. Basic issues relate to personal safety, physical property, intellectual property, and the events of 9/11 have introduced concerns of terrorism. To address these issues, local enforcement agencies or campus police, security consultants, and EH&S have become key participants in the planning process to critique emerging designs and offer recommendations for improvement.

Personal safety is a concern for several reasons. First, some areas of research are controversial and can be the focus of demonstrations by activist groups (stem-cell research and use of animals are good examples). Second, research is a 24-hour activity and it is common for people to be working at off-hours.

For general security, the goal is to limit the number of people in the building during the day and restrict the number of people entering after normal working hours. This can be accomplished by using card readers at entrances, doors, stairways, and elevators. General security involves minimizing places where people can hide, making people feel conspicuous (such as generous amounts of glass), and clear signage to make people aware of their location.

To combat terrorism, common sense suggests restricting unauthorized vehicle access near the building (especially at entrances and loading docks), providing security at the reception area with turnstiles that prevent “piggybacking” and stop someone with malicious intent from slipping through, and locating air intake louvers where they are not easily accessible.

The project team needs to determine the appropriate level of security in the context of the type of research, location, and the type of security already in place. From a designer's point of view, it is preferable to integrate security requirements into the design to minimize their presence while achieving a pleasant, humanistic work environment. For example, safety experts recently cited a new building for science at Yale University as one of the best laboratories they had assessed, thanks to liberal amounts of interior glass for high visibility and transparency between spaces. A spill or accident will be immediately noticed and corrected.

Energy Conservation and Sustainable Design

The movement towards more efficient and environmentally sensitive architecture has grown in recent years. In part, this is ethical and responsible, but it is also prompted by the goal to minimize operating costs by conserving energy.

Clients often ask: what is the cost and the schedule if we pursue sustainable design? The best way to answer this question is to have an interactive work session where goals and objectives can be discussed with possible approaches, initial costs, and life-cycle savings. The U.S. Green Building Council administers a rating system, Leadership in Energy and Environmental Design (LEED), that can be used as a guideline or (with the commitment to document and monitor the process) can result in official LEED certification. Whether certified or not, sustainable design is good design. Energy providers can be partners in the design process and may give rebates when energy efficient systems are selected.

For example, consider alternative fume hoods. Fume hoods have the largest demand for air volume, usually conditioned and fresh air (passing through the building only once). If "low flow" fume hoods can be used, they require less air and, consequently, less energy. If air volumes can be reduced, triple glazing on exterior windows then becomes economically feasible, particularly in cold climates.

Heat recovery systems have the potential to reduce a science building's overall energy consumption significantly, given the high air volumes. In particular, heat wheels have been used effectively on an increasing number of laboratories providing a highly efficient energy transfer mechanism between supply and exhaust streams.

Large exterior windows maximize use of natural light and reduce dependency on artificial light when combined with efficient light controls for perimeter fixtures. Natural light has a positive impact on the quality of interior environments because it is fundamental to our well-being. People feel better when they can look outdoors, relate to the weather, time of day, and time of year. This is especially important in a high-technology lab building where much of the design is based on a clean environment with sensitive instruments and durable finishes.

Coincidentally, large exterior windows are compatible with lab buildings because they have tall floor-to-floor heights and high ceilings to accommodate intensive mechanical and electrical systems. Air conditioning has made buildings wider and to compensate, interior glass in doors and walls brings natural light deeper into the spaces.

Other common sustainable choices include green roofs, use of gray water for restroom fixtures and landscape irrigation, and use of local materials.

Conclusion

In the coming years, the need to accommodate change will remain. The shift from traditional bench-based laboratories to technology-based spaces is likely to continue. For academic institutions, the government, and corporations looking to retrofit older facilities, this will require creative thinking and planning. For example, additions may meet high-technology requirements while the existing structure is downgraded for less intensive uses.

Collaboration will expand to scientists located at remote sites, promoting the further use of computer technologies for data exchange and teleconferencing for team communications. Increased collaboration among academic, corporations, and government will require security to be an integral part of operations and design.

In academic settings, multimodal teaching (talk, watch, write, listen) will expand use of computer technologies, as will programs related to distance learning, continuing education, and virtual teaching programs.

Medical research will further develop translational medicine, where clinical research and application is integral with basic reasearch, reinforcing the collaboration between clinicians, Principal Investigators, and pharmaceutical companies. Inpatients and outpatients will become commonplace in the laboratory setting with a corresponding impact on building use and occupancy.

Due to high cost and the time it takes to deliver a building, new projects will incorporate core facilities to serve the research community beyond the building occupants, thus becoming larger and more expensive.

As we can see, there are many influences on laboratory design. These facilities must be designed for intentional and ad hoc interaction. They must support team-based and individual research in a variety of forms. They must accommodate multiple types of scientific work, including multidisciplinary research that can be either “open” or highly controlled. They must allow for spatial flexibility over time, and be designed to foster the integrated use of highly sophisticated technology. Laboratory spaces must also include office facilities and presentation spaces associated with fund-raising and business needs. Increasingly, architects are designing science buildings to operate more efficiently and effectively over time.

Payette, based in Boston, Massachusetts is a leading architecture firm in the design of laboratories and science facilities.