Stanford University's Center for Clinical Sciences Research:
A Case Study in Connecting the Two Cultures of Building Design

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INTRODUCTION

In 1959, C. P. Snow published *The Two Cultures*, a brief essay lamenting the gulf between the intellectual worlds of the sciences and the humanities. In his argument, the 'two cultures' had much to offer one another, but collaborations were unlikely and difficult because the two sides had vastly different training, social structures, and models. Such a gulf has existed in architecture since the split of engineering into a separate discipline in the eighteenth century. Architecture is unique among professions and disciplines in that it can be seen as both art and science, however this fortunate circumstance is not often borne out in actual practice. Aesthetic and technical aspects of building design are often separated by personnel, firms or schedule, and the wide separation between architectural and engineering education presupposes careers spent perhaps in contractual relationships, but not in genuine collaboration.

Recently, the term "Integrated Design" has surfaced, describing an attempt to re-link engineering and architecture into a holistic discipline. A 1989 conference in New York entitled "Bridging the Gap" was a key moment in defining the potential for such a re-integration, and a significant body of work in the past decade has demonstrated the aesthetic, economic and performance benefits of such an approach. Our work with the engineering firm Ove Arup Partnership and architects Foster and Partners, quite consciously sought to connect the conceptual richness of architectural practice with the rigorous approach of engineering, and the experience of such collaboration has led us to promote this approach in academic settings. Here again, attempts to link aesthetic and material concerns have proven fruitful, and we believe such an approach has particular benefits in the education of engineers and architects.

In 1995, Stanford University held an invited competition to design new laboratory facilities for its School of Medicine. The School had recently constructed new labs adjacent to its original 1959 Hospital building by Edward Durrell Stone, and wanted to continue to develop state-of-the-art labs while making its campus, adjacent to the historic University, more pedestrian-friendly. Foster and Partners collaborated on the competition with Ove Arup and Partners, and with laboratory designers Research Facilities Design, of San Diego, and landscape architects Peter Walker and Partners, based in Berkeley. In the six-week competition phase, the design team simultaneously analyzed the program, the site conditions and the likely requirements for the user group, a collection of clinically oriented research groups.

The collaborative nature of the team led to a series of unconventional solutions. While Stanford's program had carefully detailed individual laboratory groups, it became apparent that there were significant parallels between each of them. Simultaneously, initial meetings with structural engineers emphasized the need to consider a modular, regular system of gravity and lateral resistant elements, and discussions with landscape architects brought out the need to create a pedestrian precinct on the site, located between major blocks of laboratory buildings on the Medical School campus. Foster and Partners, Ove Arup Partnership, Research Facilities Design and Peter Walker and Partners approached the problem as an integrated team. We sought out solutions that solved more than one problem at a time, seeking ways to address the complex network of functional and performance requirements that would simultaneously lead to legible, expressive design solutions.

The competition scheme was initially based on the revelation that the program could be organized in a radically simple way. Every lab group required similar facilities-bench space, equipment space, and office/meeting rooms-in slightly different proportions. Numerous precedents separated these into individual precincts, leading in our collective view to fragmentation and isolation among and between work groups. Picking up on Stanford's charge that the design should encourage interaction, RFD and Foster and Partners suggested a 'loft' approach that provided large plates of generally open laboratory space, arranged in long rectangles with parallel zones of equipment and office space. A lab group could therefore occupy a single section of this plan, tailored to fit their size, that would offer all three major spaces within a 30-second walk of one another. This arrangement had the added benefit of providing maximum exterior exposure to work spaces-offices and labs-while burying equipment space in the middle of the floor plate.

Simultaneously, work on the site plan with Peter Walker and Partners revealed the need for a social 'heart' on the School of Medicine's campus and a formal pedestrian path between two groups of research buildings. This suggested a diagonal route across our site with a large shaded exterior area, as Palo Alto's climate is famously benign throughout the year. Arranging the ideal laboratory blocks on the irregular footprint of the site suggested that this could be achieved with two wings surrounding a central courtyard, staggered to suggest the diagonal route, which would respond to the geometry of the site and open up formal entrances at opposite corners. On the exterior, the new building's massing needed to relate to the three-story Stanford Hospital, designed in 1959 by Edward Durrell Stone. Our ideal plan did not fit on the site plan as issued, and in the formal competition submittal an internal 'land swap' was suggested, trading a triangle of space on the northern edge of the site for an additional strip to the south. The design team did not know it at that time, but this solution allowed Stanford to get around a difficult jurisdictional issue: the original site plan had straddled the city/county line, and the competition proposal located the project entirely within the County of Santa Clara.

The team's submittal consisted of two offset, three-story lab blocks surrounding a central courtyard, each topped by a fourth floor administrative and mechanical penthouse. After the competition, we were told that our scheme was the least 'developed', in that the jury had a difficult time telling what the project would 'look like.' Yet the overall logic was clear, the flexibility and functionality of the basic premise obvious to the reviewers. Stanford awarded the scheme to our team based on its potential for re-defining the laboratory environment using a model of flexibility, open planning, and integration of campus planning concerns with the daily life of the research groups.

Following award of the commission, Foster and Partners teamed up with San Francisco architects Fong & Chan to begin schematic design. As anticipated, the roster of lab groups anticipated for the new structure was already in flux, validating the idea of a generic, 'ready-to-wear' laboratory module that could be slightly altered to accommodate individual groups. This was an alternative to the interstitial floor section used on previous lab buildings that had proven inefficient, as major ductwork had not been changed out over given building's history. CCSR would be a hard-wired building where functionality would be based on extensive interviews with user groups to determine common denominators, rather than a 'soft-wired' building that relied on a largely mythical 'ultimate' flexibility in terms of services and bench planning.

Our design work proceeded in close collaboration with each other and with RFD. Numerous engineering issues became apparent as soon as design work began in earnest, in particular the need for a high-performance seismic strategy and a logical services distribution network. The School of Medicine location, approximately three miles from the San Andreas Fault, necessitated a fully integrated structural scheme. We agreed upon basic principles early on, namely modularity, a logical approach to lab design, and even dispersal of seismic-resistant elements. The fundamental design questions became: first, how to provide laboratory space that would allow research groups to move in and around the building without 'tailored' spaces, second, how to meet Stanford's stringent seismic requirements while providing a structure that would permit usage of sensitive instruments anywhere in the building, and third, how to take advantage of Palo Alto's climate while creating a new social hub for the Medical School campus.

Planning the laboratories became an exercise in surveying and assessing the services required throughout the proposed lab groups. We explored two philosophies, one in which an interstitial space allows ultimate flexibility, and one in which the bulk of the presumed services are provided to each bench. Stanford had built an interstitial building next door to our site in the early 1990s, and they reported little if any changing out of ductwork or piping. Unlike institutional labs such as the Salk, Stanford anticipated a fairly predictable roster of researchers for CCSR, obviating the need for such an investment. Instead of carefully tailoring each space, or over-providing for changing out of services, we adopted a 'ready to wear' approach, meeting the needs of 90% of all lab groups in a typical module that was then deployed throughout. This meant that some groups were relocated to other, more flexible buildings by the University, but it allowed a consistent approach throughout the project, enabling mass-produced elements for piping, ductwork and benchtop services.

Stanford suffered several seismic failures in the 1989 Loma Prieta earthquake, and thus instituted some of the most stringent seismic requirements in the nation for new construction. Under these guidelines, CCSR is to remain operational with no damage due to an earthquake measuring up to 7.0 on the Richter scale, and remain operational, but with minor cosmetic and mechanical damage following an 8.0 event. While steel is currently preferred in seismic resistant structures for its ductility, its light weight presented a serious laboratory design problem. Researchers working with sensitive instruments and microscopes required absolutely still floors, and our initial calculations showed that a structurally adequate steel frame would incur unacceptable vibrations from mere foot traffic. To overcome this would have required an extra foot of beam depth. This in turn would have driven the height of the building up, incurring significant cladding costs, but – as importantly – throwing off the massing relationship between CCSR and the Edward Durrell Stone hospital building. Concrete provided the mass needed to dampen footfall vibration within a reasonable structural section, but at the cost of reduced seismic performance and increased weight. Arup's thus had to work out a scheme for an extremely stiff concrete frame, one that relied on extreme regularity with shear walls in both directions. The shear wall arrangement progressed through three significant iterations, each responding to architectural and mechanical concerns. First, major shear walls were arranged to form an 'H' shape consisting of a continuous longitudinal wall with two "book ends" that might be expressed to the outdoor public areas. As this scheme developed, initial mechanical studies reinforced the need to provide large quantities of supply and exhaust air across the line of this wall. Faced with the problems of moving air across such a formidable barrier, however, we broke this large wall down into several 'C' shaped walls which "cupped" the office modules. Continued work with Arup's MEP engineers suggested that these be broken down into longitudinal and transverse systems, leading to isolated modular walls. Architecturally, these helped define the lab, support, and office zones. They also allowed the contractors to reuse formwork from quadrant to quadrant and floor to floor, allowed for better circulation between zones, and eliminated wall penetrations for services while allowing for a desirable failure progression of the walls that met the university's seismic performance design criteria. The concrete structure addressed multiple performance issues as well. While it provided an ideal solution to the problems of seismic performance and vibration, the walls are also exposed on the interior, providing a durable surface against the constant movement of steel carts and a visual reinforcement of the building's modular grain. During the design process, Arup's mechanical engineers noted that the massive concrete shear walls also formed an ideal source of thermal mass, and that their exposure to the main spaces of the building would contribute to stabilizing the interior temperature of the labs and working spaces.

Each floor was designed with two pedestrian bridges to allow easy circulation between wings. Structurally, the bridges needed to be isolated from one of the towers in order to accommodate "unsynchronized" movement between the towers. The first option was to anchor one end of each bridge to one tower and to rest the other end of the bridge on frictionless pads at the other. The required joint width proved to be a problem when accommodating the expected movement between the two towers. The final solution implements a unique application of frictionless pendulums where the devices are placed at each tower and the bridge are allowed to "float" in space when a major seismic event strikes. The use of the frictionless pendulums allowed for movement joints one-half the distance required for the initial concept design. OSHA requirements mandated that the gap between the end of the bridge railing and the face of facade be no greater than three inches. In order to accommodate the code requirement and the eight inch seismic movement requirement a sacrificial piece of glazing was included in the end railing panel. The gap is less than three inches, but this piece will crush if the buildings come together during a seismic event.

While the structure presented the greatest performance challenge, we were also quite keen to develop an environmental strategy that took advantage of Palo Alto's famously mild climate. For nine months of the year, the outdoor ambient temperature during working hours at Stanford is within 10° of room temperature. We therefore wanted the building to open up as much as possible. The central courtyard proved to be an ideal location for planting, shading and operable facades. Peter Walker and Partners proposed a long line of bamboo to provide both shading to the south-facing offices and bio-mass to provide a micro-conditioned space. Sliding window in the offices allow occupants to take in naturally conditioned air directly, while the louvers and bamboo reduce direct sunlight, eliminating heat gain and glare while providing significant ambient light. Laboratories required carefully conditioned and filtered air, which is brought in at rooftop level under another louvered screen. While this is necessarily energy intensive, the massive concrete frame and shear walls offer significant thermal mass that reduces the conditioning load.

The louver design over the courtyard incorporated three-inch diameter tubes with a two-inch clear spacing, allowing ample light for the users and ample shade to reduce solar heat gains. Our contractor had identified the sunshades as a high profile item in terms of materials and schedule, and Arup's therefore devised a scheme that incorporated a modular double steel tube framed louver system that could be "mass produced" and craned into place. This allowed most of the fabrication to occur on the ground, though we also developed a 'stick system' that would have assembled each piece in place. Because the louver screens spanned between the two towers, we again were concerned about differential movement. We used digital simulations of previous seismic events to understand how the two towers could move out of phase, that is, toward and away form each other, instead of in tandem. In this situation, which we discovered was quite likely one of the two wings could tear the roof structure from its anchorage, sending it crashing to the courtyard below. Thus, we used friction pendulums similar to those on the pedestrian bridges to support the roof sunshade structure. The pendulums will remain motionless under a Level I (7.0) seismic event and code level wind loads. But when the building is subjected to Level II (8.0) seismic forces the pendulums will break loose from a minor restraining device and float in space so that the two towers can move independent of one another.

As the project progressed into design development, the overall scheme was refined with the input of the contracting team, fabricators and suppliers. Particularly in the case of the penthouse steelwork, the laboratory fire glazing and the office curtain walls, the overall solutions were the results of processes involving close collaboration. In each of these, the design team investigated fundamental principles of the systems involved to arrive at configurations that not only solved the problem but also remained true to the overall design ideas. Curved louvers above the rooftop mechanical plant were supported by large curved-steel elements, bent to precise radii by a petroleum pipe fabricator in Oakland specializing in precise steel bending for oil companies. Fire separation within laboratory areas was achieved with a previously untested use of Pyrostop fire glazing, allowing continuous views from one end of the lab blocks to the other. This was achievable only once TGP, the supplier, had been persuaded to test a detail that recessed a large, bulky frame within a drywall container. The successful test provided us with an aesthetically consistent detail, and provided the supplier with a high-profile installation that now features in their product literature.

Perhaps the most successful collaboration from an aesthetic standpoint was that with Architectural Glass and Aluminum, a curtain wall contractor also based in Oakland, and Wausau Metals, a fabricator located in Wausau, WI. Our initial scheme for the office modules showed a regular pattern of round bay windows, designating these as cellular spaces. The shape of the window was popular in the early design stages, as it offered large quantities of sunlight, a convenient shape for meeting tables, and an acoustic baffling to the courtyard. Fabricational and seismic concerns, however, dictated a meticulously designed system, one that could be provided for a reasonable cost and that would perform in a variety of ways. Working with the two subcontractors, Arups and Fosters developed a panelized system that allowed adequate seismic movement while offering a convenient way to fabricate the individual windows. Sliding panels allow outside air, while a system of shoji-like screens on the interior were custom-designed using new aluminum shapes and yacht hardware for the sliding mechanisms. In the courtyard, these bay windows clearly articulate the 11'-0" planning module of the complex, but they also cast intriguing reflections and shadows on the landscaped floor. Many visitors remark on their similarity to stacked test tubes, an unintentional reference, but one that has become a signature of the building. Here, as with other components and systems, a carefully worked out, integrated solution has gone beyond a simple efficiency, and its appeal to the functional, performance, and aesthetic sensibilities of the building is a key example of the success of the approach. In some ways, elements like this suggest that integrated solutions set designs up for fortunate coincidences, as the carefully thought out and expressed logic of the overall building is paid back by synergies and architectural effects that were never consciously considered, but have worked out better than anticipated.

CCSR opened in Summer, 2000, within 15% of its initial budget. Due in part to a contractor change midway through the structural work, the opening was six months later than its initially planned date, but a phased move-in of researchers enabled a smooth transition. A year after its opening, an informal post-occupancy review was conducted by Stanford's Medical School, polling occupants and analyzing the energy and functional features of the building. Concerns were largely about quantities of space, although initial worries regarding the open lab ideas seemed to dissipate. We did not anticipate, in the design phases from 1996 through 1998, the explosive growth of laptop computers in laboratory work, and significant retrofitting of data cables and jacks has been necessary in write-up spaces. Overall, however, researchers report that they appreciate the emphasis on social interaction provided by the courtyard, and the quality of spaces within the lab modules themselves. Foster and Partners were asked to continue working with the University on the Clark Center, an interdisciplinary laboratory building near the CCSR site. This project, which adopted a much different lab planning approach to its clientele of physics, bio-engineering and medical researchers, opened in Fall, 2003.

CONCLUSIONS

Current work by practitioners such as Arups and Foster's suggests that there are untapped possibilities in reconnecting the architectural spheres of science and art. These include obvious economic and performance aspects, as close collaboration between architects and engineers tends to arrive at efficient, logical solutions. Yet the conceptual and aesthetic potential of such integrated work also suggests a deeper, more meaningful connection between building art and building science. In projects like CCSR, the ultimate 'aesthetic' of the building is one of clear expression, presentation, and revealing of the forces at work in the design, construction and performance of the building. While some decisions have been made for largely aesthetic reasons, these are consistent with an attempt to communicate an understanding of the project's overall organization and conception. In short, this is architecture that is 'about' architecture, building that is 'about' building. People who use these buildings welcome their expressive elements, their performance and the often striking qualities of light and space they provide. The possibility for integrated design to reinforce the importance of these aspects of architecture remains a provocative story to be told by architects, engineers and designers, particularly as ecological aspects of construction and function become paramount in daily life.

More directly, our work on this project has formed the basis of teaching careers that hope to nurture an appreciation for the value of integration among our students. Architecture students are done a disservice by separating technology and design coursework into 'lecture' and 'studio' classes. Likewise, engineering students do not get a fully developed understanding of their work's context by focusing on abstract problems away from the complexities of actual practice, where cultural, aesthetic and functional demands create a rich, if difficult, set of balances that must be addressed. While the inspiration of collaborating on CCSR has fueled successful student explorations over the past four years, the two authors are looking forward to Spring, 2005, when we will teach a combined design studio of engineering students from Cal Poly and architecture students from Iowa State, for a high rise complex in downtown San Francisco. This studio will stress the role of collaboration, the challenges of synthesizing engineering and architectural knowledge, and the logistics of coordinating a team in a long-distance effort.

ACKNOWLEDGMENTS

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REFERENCES

Lisa Findley, "Court of Appeals: Research Centre, Stanford." *World Architecture*, Nov.-Dec., 2001, no. 101, 24-29.

Lisa Findley, "Solar Protection in Norman Foster's Hands Creates an Elegant Gathering Place for Scientists at Stanford University's New Center for Clinical Sciences." *Architectural Record*, June, 2001, v. 189, n. 6, 130-137.

Foster Catalogue 2001. (London: Prestel, 2001), 168-69.

James MacNeil, "Foster's Quake-Proof Stanford Research Project Goes on Site." *Architect's Journal*, Sept. 3, 1998, v. 208, no. 8, 24.

The Master Architect Series II: Norman Foster, Selected and Current Works. (Victoria: Images Publishing Group, 1997), 222-223.

"Norman Foster: Center for Clinical Science Research [sic.], Stanford University, Stanford, California, U.S.A." *GA Document*, Jan., 2001, n. 64, 66-73.

"Norman Foster: Center for Clinical Sciences Research, Stanford University, California, 1995-2000." *Lotus International*, 2002, n. 112, 38-41.

ILLUSTRATIONS

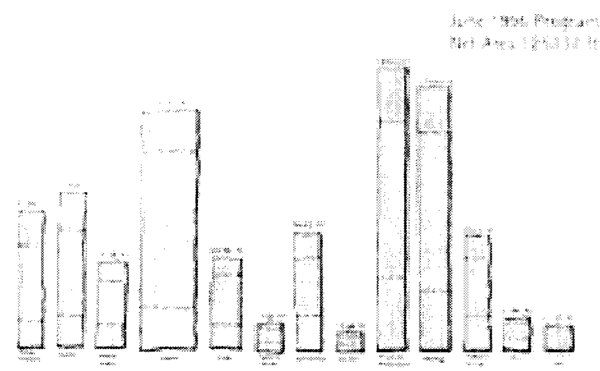

Fig. 1. Stanford's initial program, broken down into laboratory, lab support, and office space. Foster and Arup's initial response was to look at a horizontal solution, focusing on space types rather than departments.

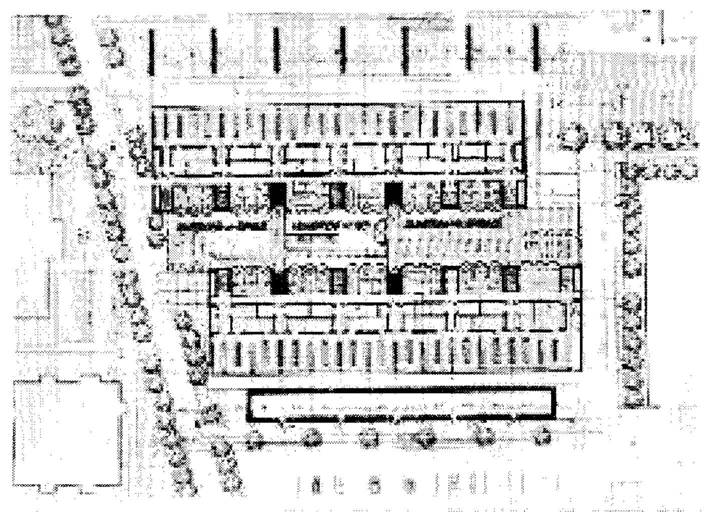

Fig. 2. First floor plan showing division into laboratory (blue), lab support (red) and office (green). The two wings surround an exterior courtyard, which connects the historic Governor's Lane path (left) with the main hospital campus (right).

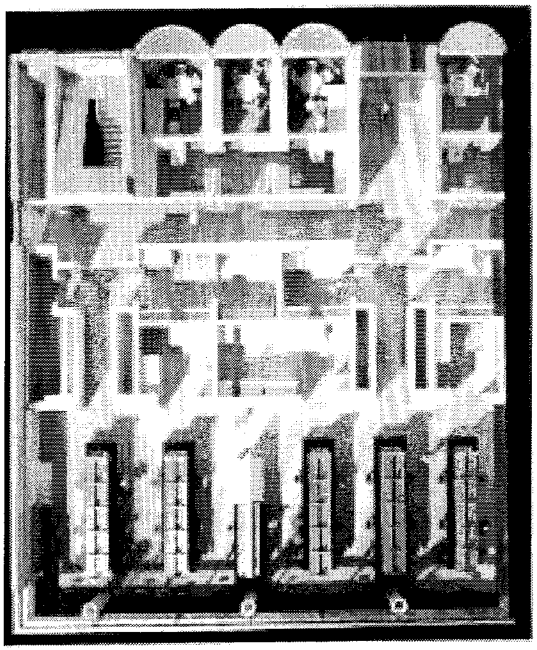

Fig. 3. Detail view of model showing typical module.

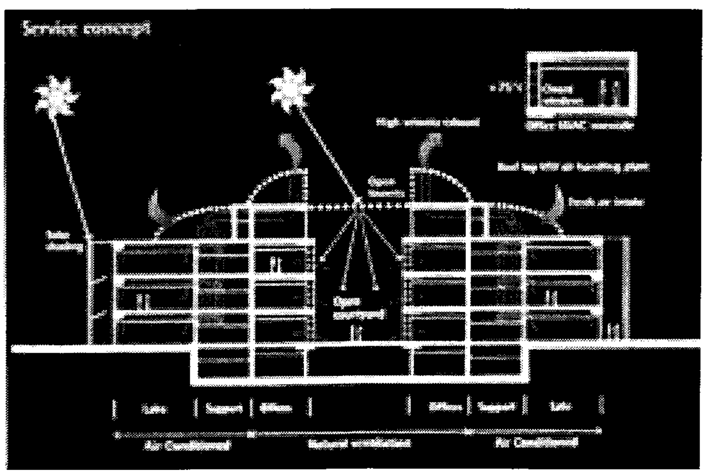

Fig. 4. Section of CCSR showing mechanical and solar strategy.

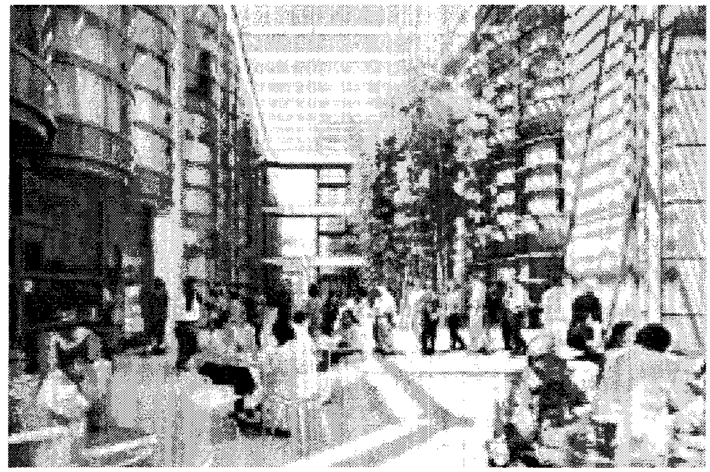

Fig. 5. Finished courtyard from the café with elevator core in background. The courtyard takes advantage of Palo Alto's moderate climate, offering light shading and naturally diffused daylight to the surrounding offices.

Fig. 6. Typical lab aisle showing ceiling light fixture.

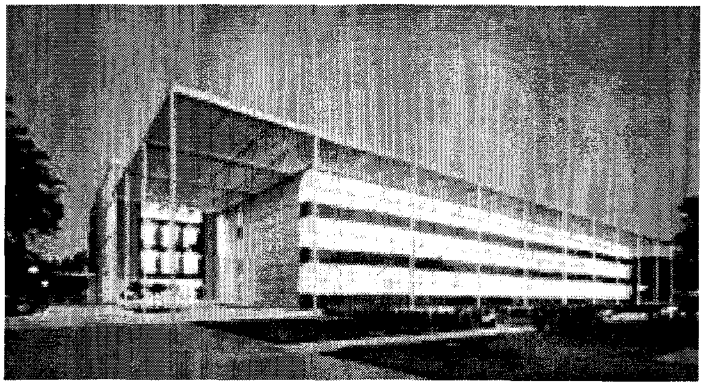

Fig. 7. The Center for Clinical Sciences Research from the main Hospital drive. Exterior paving and landscape by Peter Walker and Partners is part of an overall campus plan to knit Stanford's diverse collection of buildings and spaces into a coherent whole.