ARCHITECTURAL REPRESENTATION: SPATIAL COMPREHENSION AND ASSESSMENT

THROUGH VISUALIZATION TECHNIQUE

by

Donald Alberto
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ABSTRACT

There are two distinguishable parts to this thesis. Part I is a discourse on architectural representation. It defines the theoretical boundary for Part II, research on a particular spatial representation system, physical models, and their use as a design aid.

In Part I, representation is discussed as it pertains to the design process. An opinion is built around the excessive 'visual' nature of the topic. The many types of representation systems are described. Finally, a brief historical survey, as well as two current design processes provide insight into applications of these systems.

Part II is the documentation of a research project that attempts to visualize physical phenomena (energy behavior) as they act on physical models representative of architectural form. A statement is put forth postulating a design approach that addresses energy behavior in a 'qualitative' sense.based on its comprehension through these established visualization techniques. A procedure for tesing physical phenomena on models is described and finally, the documentation of such tests for wind, solar shading, convection and light are presented. A conclusion forecasts potential applications of this research.

The multi-disciplinary exploration of visual communications and energy conscious design is addressed in the content, as well as the communicative technique and medium of this presentation. The author is responsible for reproducing all the images in this book. Reproductions from other sources were copied photographically. In its original form several pages were printed in offset. This process was completed entirely by the author, from original photograph to paste-up, printing preparation and running the press. An experimental video production is being prepared as well.

Thesis Supervisor: Harvey J. Bryan
Title: Assistant Professor of Building Technology

Acknowledements

Many individuals have had an impact on my development and knowledge which is ultimately presented in this work. I wish to extend a warm 'thanks' to all those who have been concerned with this project:

Harvey Bryan has had the most significant influence on the direction of my studies. I am grateful for his efforts in the development of my career; working with him has prompted a positive stimulus to my learning experiences.

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And finally, 'thanks' to my good friends and family in New York who have kept me sane and smiling through this endeavor.

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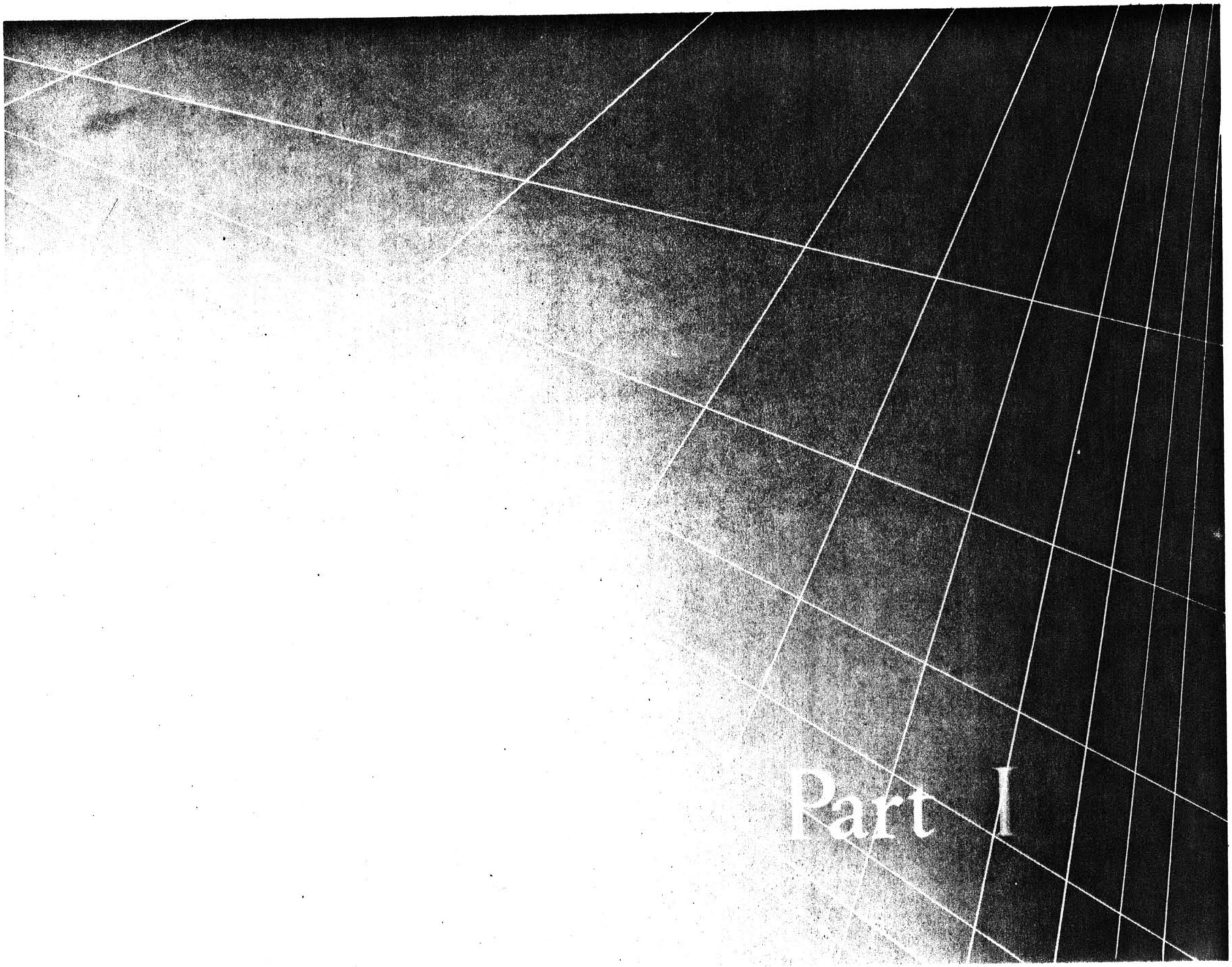
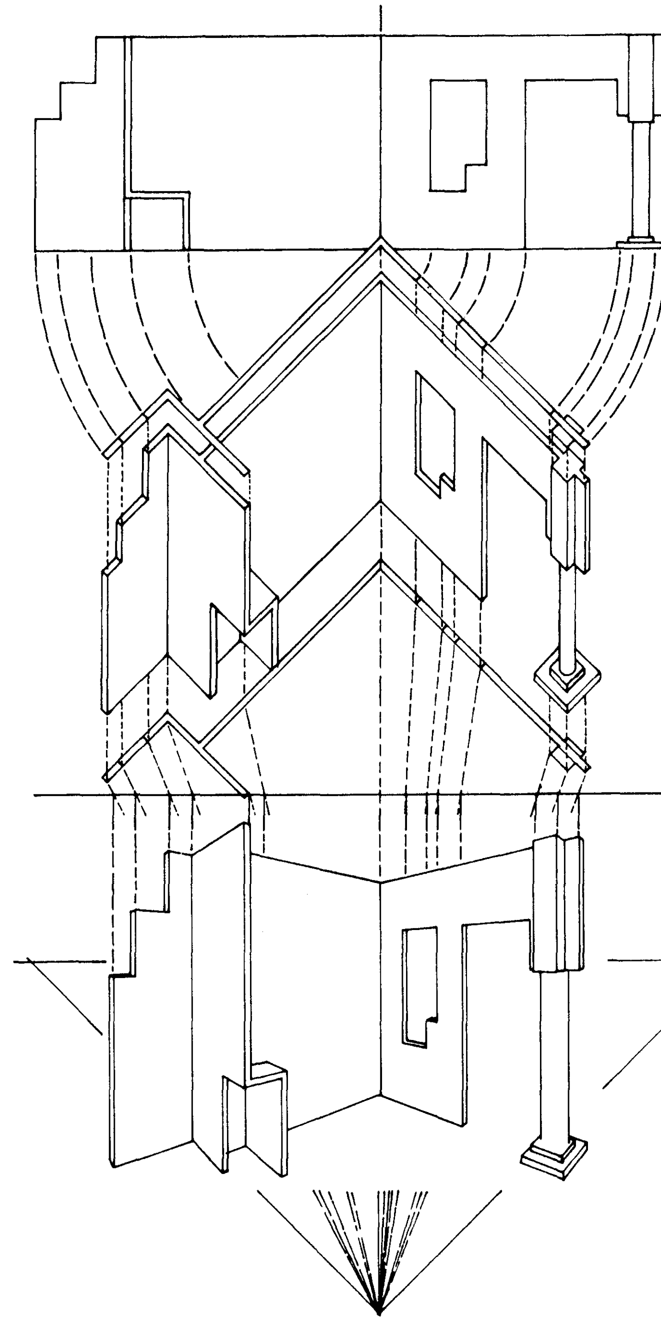


Part I

Chapter 1

Spatial Representation Systems and Architectural Design



Opposite side: 'Eleplanaxonospective Drawing', a combination of two-dimensional spatial representation systems, Don Alberto, 1982.

"Communications can take place through motions, sounds, odors, or sensorial vibrations.

Through symbols, images, mental impressions which are perceptual or even telepathic.

Through mechanical, electronic, physical or chemical impulses or vibrations.

They can be individual or universal in scope;

Visual, verbal, or pantomimic;

They might even happen through new unpredictable, visionary media which will require receiving through an inner ear, inner eye, inner mind, or some new extended composite form of human antenna."

Elwood Whitney, from Symbology: The Use of Symbols in Visual Communication.

All disciplines included in the study of a particular field contain a progressively generated 'body of knowledge'. Each of these disciplines in turn, evolves a vocabulary for the explanation of their epistemological boundaries. In the case of architecture, entire languages have been developed for communication purposes.

Communication involves the ability to exchange ideas, to present ideas to others through some recognizable medium. Architecture is such a medium; the experience of built places is an information gathering process, both in a conscious and subconscious sense. Charles Moore has stated "Architecture speaks (but not through a mouth)."[1] Some have gone as far as labeling architecture a language. Umberto Eco the semiologist has seen 'architectural language' as an "authentic linguistic system obeying the same laws that govern the articulation of natural language."[2]

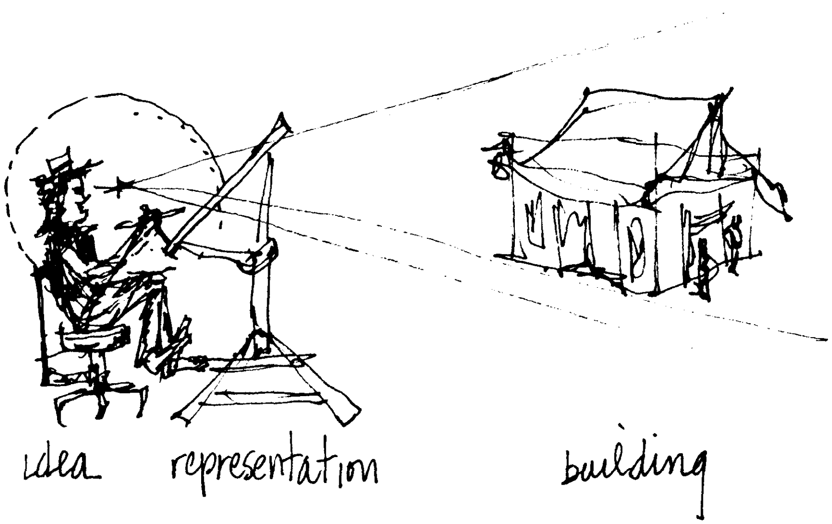
Aside from communication through the experience of architecture-as-object, designers encounter an entirely different realm of communication in their practice. For a building to be created, formed, presented, and eventually built, the 'master builder' must communicate, not through the object (for it does not yet exist), but through representation of that object.

Fundamentally, representation in architecture is a matter of describing through some ordered system the placement of objects in space and the space between them. Such systems are basically 'languages' and are primarily visual in nature. Here, they will be referred to as spatial representation systems. Information passing through these media can vary from the physical description to social, political, theological and many other thought provoking statements.

Hence, it could be said that spatial representation systems offer the architect a medium where he/she can address a body of knowledge larger in scope than the architectural object itself.

Below: The 'disjuncture' in architectural design.

Opposite page: McKim, Mead and White, Pennsylvania Station, N.Y., from <u>200 Years of American Architectural Drawings</u>.



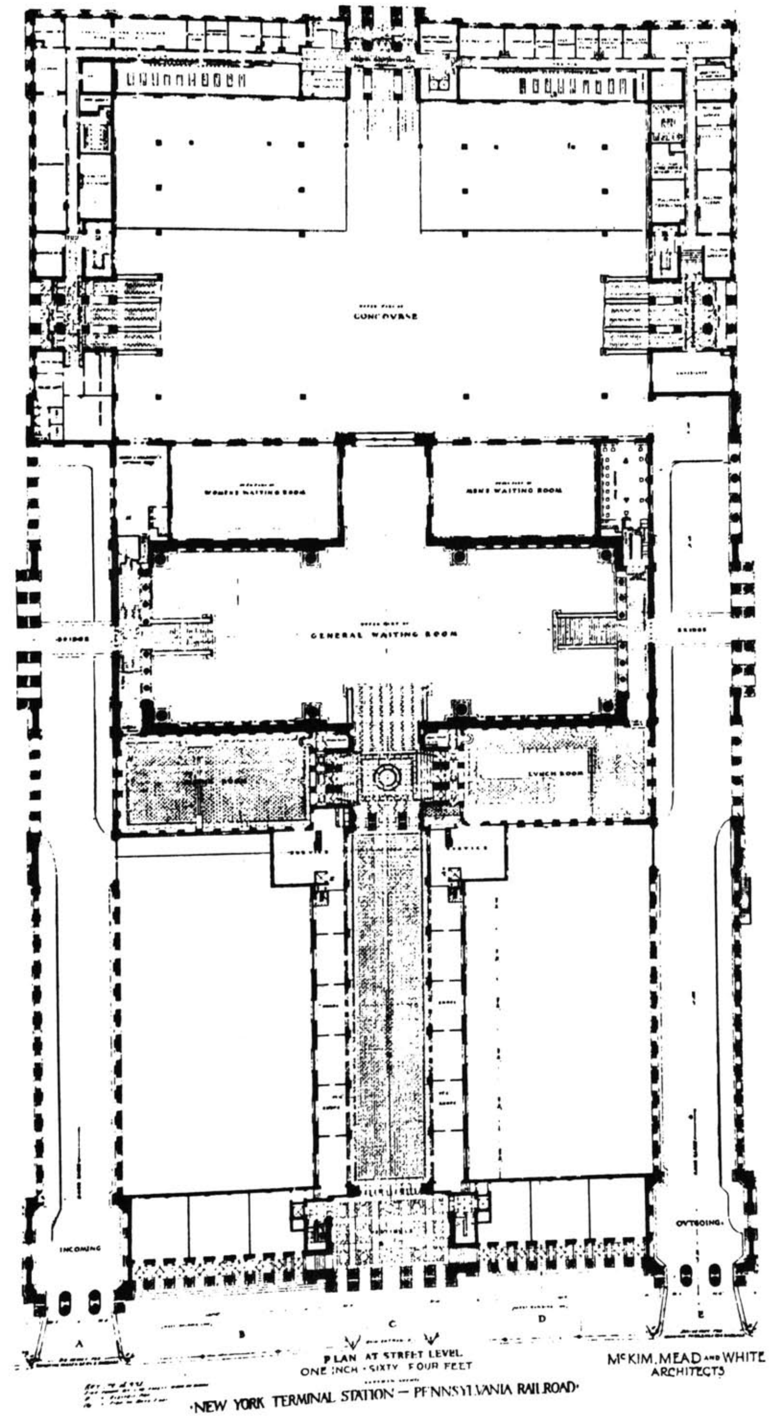
Architectural design uses representation by necessity. The tremendous size and cost of buildings makes the use of 'miniatures' one of the only practical alternatives for forming the object. There is also a need for some degree of plasticity of form, the ability to manipulate elements to develop the design. Drawings and physical models offer these possibilities.

The need and reliance upon representation in the design process interjects an added level of abstraction that is not found in other creative searches. For example, the painter applies paint to canvas, the sculptor molds material with his/her hands participating directly in the evolutionary process of idea (mind) to form (medium). But in architectural design, the relationship between creator and form is less direct, a disjuncture occurs in the process. This disjuncture which is an act of representation, takes on three distinguishable forms.

One is objective physical representation, a second is the representation of the experience of architecture, and a third is the experience of the representation of experience of architecture, which is, in essence, the treatment or representation as art.

Objective Physical Representation

Rather than address how we perceive space, these systems utilize an empirical ordered organization. They are considered conceptual, for the object is represented as it is, not as it is seen. We often use these systems internally as a means to understand spatial arrangements. For example, a floor plan is an objective physical representation. We never see in plan, but we can easily organize a space in plan in our mind or on paper. (Consider the room you are in as you read this.)



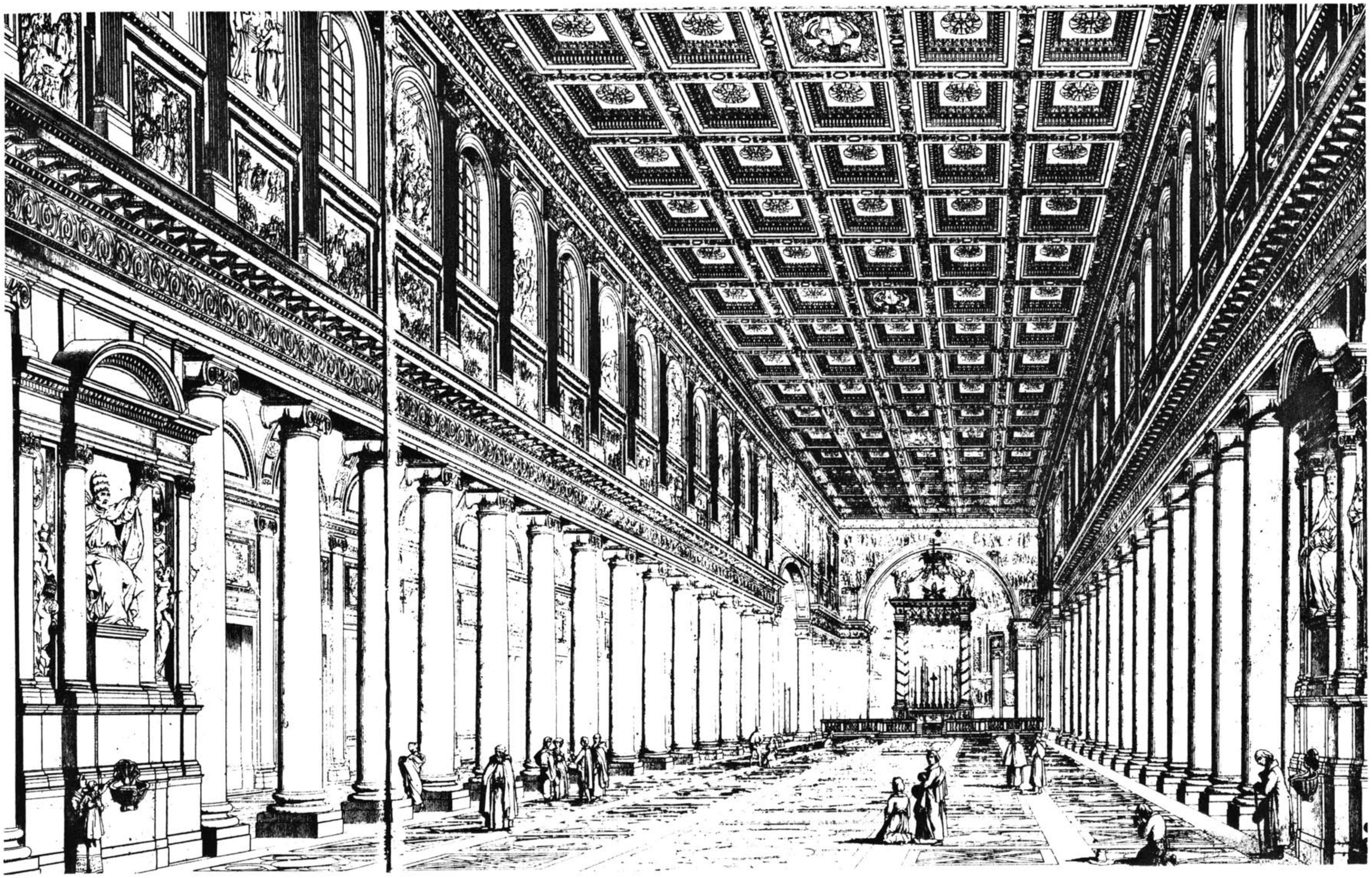
Opposite page: P.M. Letarouilly, Interior of S. Maria Maggiore in Rome, drawn 1868, from Drawings of Architectural Interiors.

Representation of the Experience of Architecture

The representation of the experience of space, a problem addressed since antiquity, is built around assumptions defining what spatial experience is. In its most general terms, spatial experience is the process of receiving information from the world around us. Aristotle cited the five senses as the tools we use to receive this information. All are a function of body organs; sight, sound, smell, taste and touch. However, since the sence of touch has no specific organ - the eye, ear, nose or mouth - it has always been considered a bit obscure.

Gestalt psychology formed in the early 1900's offered an interesting hypothesis on environmental information reception. This psychological discipline demonstrated through experiments that "irrational forces in the act of perceiving reacted on and transformed the objects being perceived."[3] In other words, data suggested that the perception of information is affected by the translation of that information.

J.J. Gibson, an environmental psychologist, focused his study of space perception on the types of environmental information the body deals with rather than on the variety of sensory apparatus and responses the body has. Instead of the senses, Gibson describes systems; the auditory system, the taste-smell system, the visual system, the basic orienting system and the haptic system. These latter two were new to environmental perception. The basic orienting system refers to our sense of up or down. As we detect gravity, we establish the position of the ground plane. Our orientation may also be shaped by the sun. Because of its dynamic character this mode of orientation is not as conscious as gravity. The haptic is an extended sense of touch, encompassing our entire body. Included are the sense of bigness, far or close, enclosed or unenclosed. Some of these qualities might be transmitted through spatial representation systems, and the underlying operation used in recognizing these qualities is vision. The haptic or basic orienting abil-



ities are usually translated in conventional representation, or require interpretation from them. A later discussion will take a closer look at why vision is the tool for perceiving spatial representation systems.

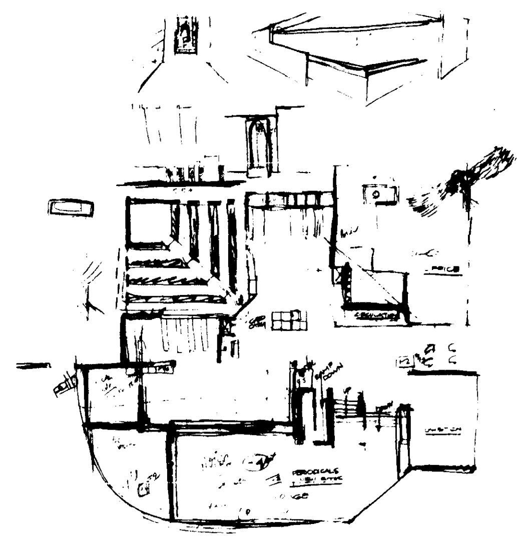
Below: Mark Mack, Condominiums for high divers and surfers, from Architectural Drawings; The Art and the Process.

Experience of the Representation of Experience

"Kahn believed drawing to be not only a mode of representation, but an act of architecture."[4] Experience of the representation of experience is found in presentation, special significance is placed on these objects and the perception of them is often seperate from its intention as a representation of architecture.

This notion is a current trend in architectural practice. There is renewed interest in architectural drawings as art; it is common to find museum and gallery exhibits on the topic and many large corporate firms, as well as medium sized offices, place much attention on presentation.

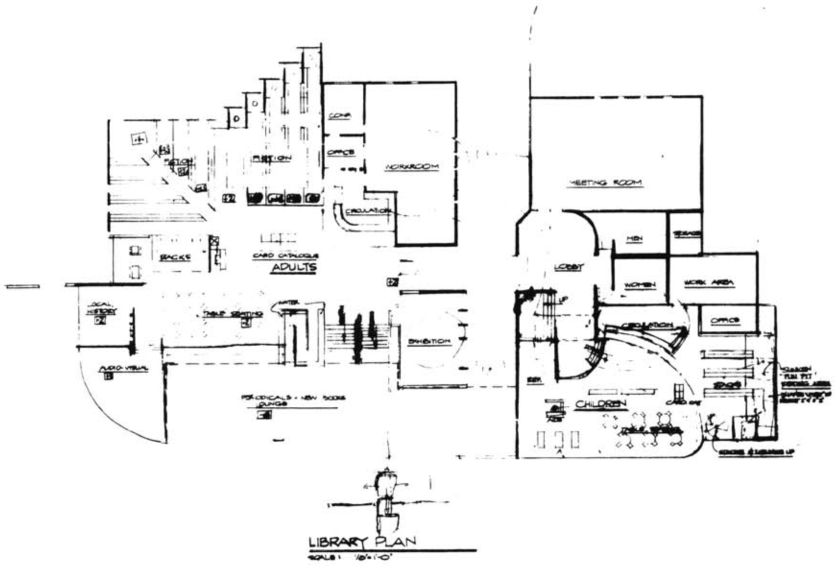
Below: Ideation sketch, design for Southampton Library, N.Y., 1980 (D.A.)

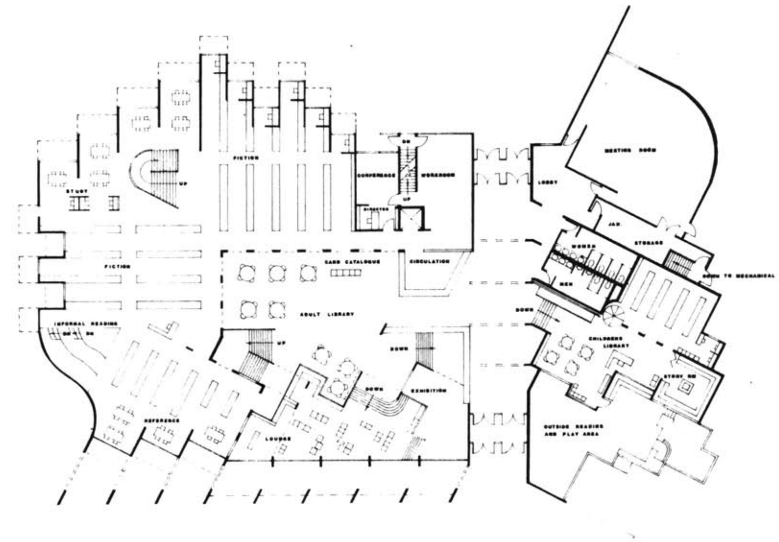


Besides the limitations posed by the available systems, how one chooses to represent space is in part dictated by the level the 'idea' of a building is undergoing. One must consider the audience the information is intended for, as well. Based on these two considerations there are basically four levels in the design process: design ideation, development, presentation and construction information.

Ideation

Design ideation is the process of creating the idea of a building. It is the result of program contemplation, the socio-cultural/political setting, and the physical context. It is the beginning attempt to give form to internal thought; a process of externalization. Using the familiar soft pencil lead and yellow tracing paper (Saarinen was known to use a napkin in a restaurant), ideation is a moment where the hand captures the gesture of the building to be.





Development

It is difficult to pinpoint where ideation ends and development begins. For the purposes of this discussion, design development will be referred to as the testing of an established building concept. Testing the visual (aesthetic), functional and physical properties, it is a process of clarification, assessment and articulation. In effect, it is an optimizing effort. Some often-used types include perspective sketches, study models and test models.

Presentation

Design presentation takes place when the idea has undergone ample development and refinement and it is ready for communication to others for feedback, or to persuade them of its merit. It places the idea in its intended context (time and place). Through specific techniques, (often stylistic) the idea is made obvious, sometimes visionary, metaphoric, and even humurous. Presentation today can be said to be a means to an end (architecture realized) as well as an end in itself.

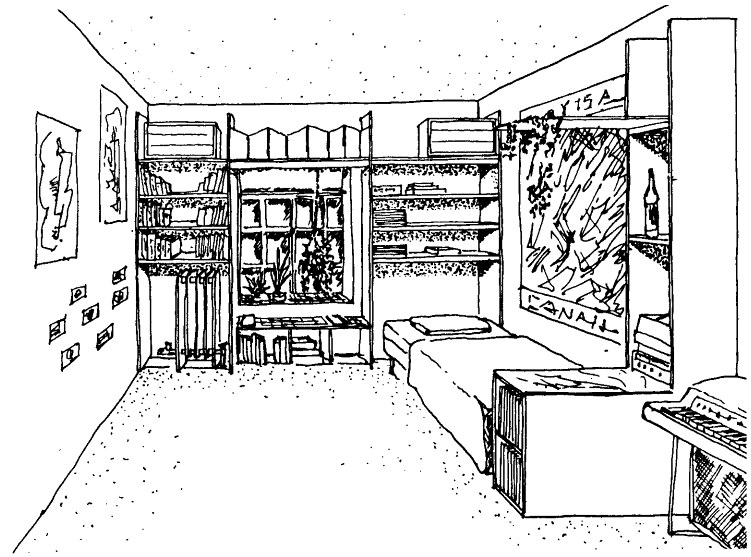
Construction Information

Design construction information is the last representational stage the idea undergoes before it is built. It is the presentation of the necessary information for the developed design to be constructed. The primary media are construction drawings, specifications and details.

Opposite page far left: Design development drawing for Southampton Library, N.Y., 1980, (D.A.)
Opposite page left: Presentation drawing for Southampton Library, N.Y., 1980 (D.A. and C.S.)

Besides the level of the idea, these phases have particular characteristics as a means of communicating to some audience. We can observe these stages in a different light by analysing these audiences:

Ideation	This is communication with oneself. The representation does not need to have any meaning except to the originator. Each line or scribble on paper has special significance to the designer, even though they may appear ambiguous to others.
Development	During development one must begin grappling with conventional languages. There is comprehensive value in observing the idea through an existing system, and an added ability to reach others familiar with these languages for feedback. The representation systems will help determine if the developed idea exhibits a correctness, appropriateness or feasibility about it.
Presentation	Here the purpose is to communicate the idea to others, usually those not familiar or trained in conceptual representation. An attempt is made to simulate the experience of architecture.
Construction	This is an objective physical description, a scientific notation, not at all based on our perceptual processes. The audience is well trained to 'read' and apply this information.



Seeing and Spatial Representation Systems

Close your eyes and form a description of your bedroom.

How did you choose to represent this space? Probably by forming a 'picture', a visual recollection from a certain viewpoint, or possibly by looking straight down from above like a plan view. We often use images as a way to interpret, understand and record spatial experiences. Actually, visual perception closely parallels the way we think since many people think visually.

Thinking involves the use of several vehicles, several operations and it occurs on several levels. Good thinking can be said to have access to at least the levels of the conscious and the subconscious, to be proficient in several mental operations, and to utilize several vehicles.[5] Operations include abstraction, rotation, superimposition, analysis, synthesis, induction and deduction. Some vehicles are verbal, non-verbal, feelings, thinking, seeing, imagining and drawing.

The way we think is extremely affected by how we perceive. The first parameter of perception is physiological; limits imposed by the quality of our eye for instance. Perception is selective, it is an information seeking process. From this premise we can draw pattern forming tendencies. There are four laws commonly used as a reference. The law of Pragnanz suggests that the perceptual field is synthesized into as large a meaning as possible. The law of proximity states that forms close together tend to be grouped. The law of equality shows that equal or similar elements are immediately recognized as such and the law of continuity illustrates our tendency to continue a figure as it was started.[6]

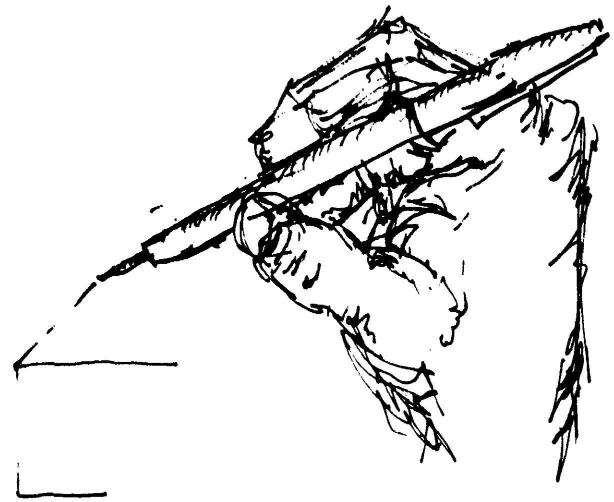
Perception is always affected by meaning: an environment is never seen in isolation, but always in some context.

Spatial perception is said to be both innate and learned.[7] As there are perceptual tendencies, there are certain 'cues' we have learned to apply in the understanding of space. Some cues are overlap, where objects in front

Opposite page: Description of a bedroom, 1980 (D.A.)

cover objects behind; some are atmospheric or aerial perspective, objects far away are hazier; others are height in plane or relative size, things get smaller as they get farther away; and some cues involve focus, closer objects are more sharply defined. It is the utilization of these cues which gives us the ability to make an 'educated guess' to understand space around us. When our guesses are incorrect, we see illusions.

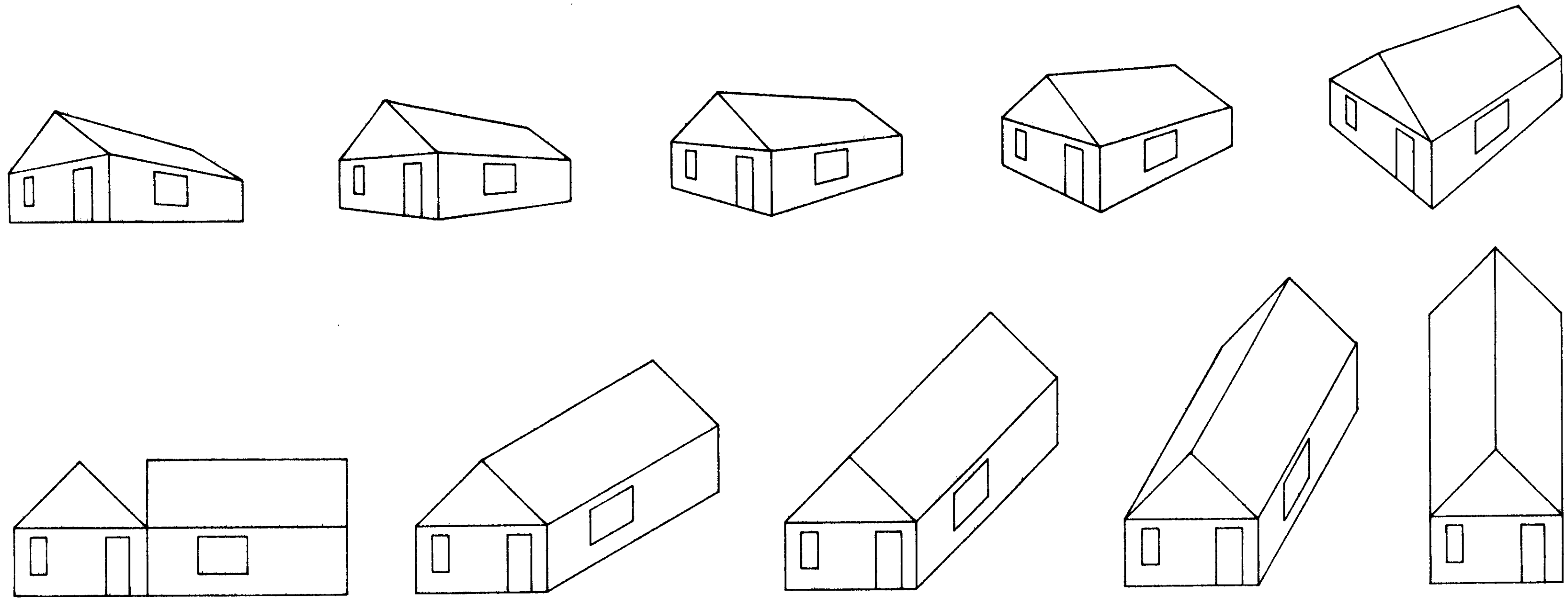
These cues which all rely on being seen can be considered our primary indicators of space perception. (J.J. Gibson's haptic and basic orienting systems are secondary.) Representation in architectural design is therefore the translation of these visual cues as they occur in reality, into another dimensional system or scale.



externalizing → thinking visually

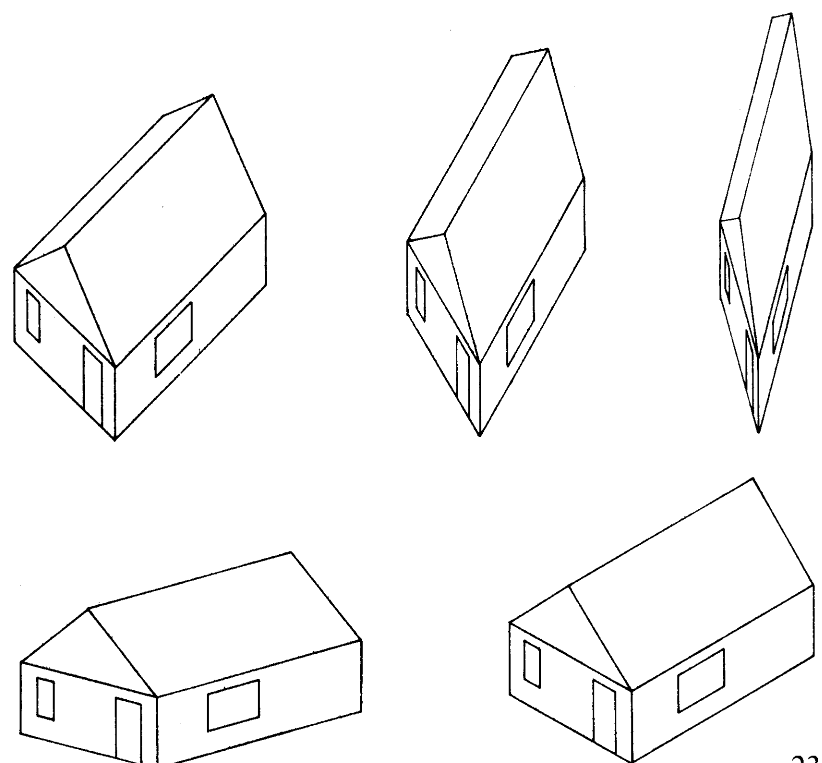
Notes: Chapter I

1. Charles Moore, lecture: "Two Agendas", Harvard GSD, March 9, 1982.
2. Jacques Guillerme, "The Idea of Architectural Language: A Critical Inquiry", Oppositions, Fall 1977.
3. K.C. Bloomer and C.W. Moore, Body, Memory and Architecture.
4. David Howard Bell,"Unity and the Aesthetics of Incompletion" from Representation in Architecture, Pre-conference Proceedings of the North-East Regional meeting of ACSA, Oct., 1977.
5. Robert H. McKim, Thinking Visually.
6. Niels L. Prak, The Visual Perception of the Built Environment.
7. Ibid.



Chapter 2

Spatial Representation Systems:
Various Types

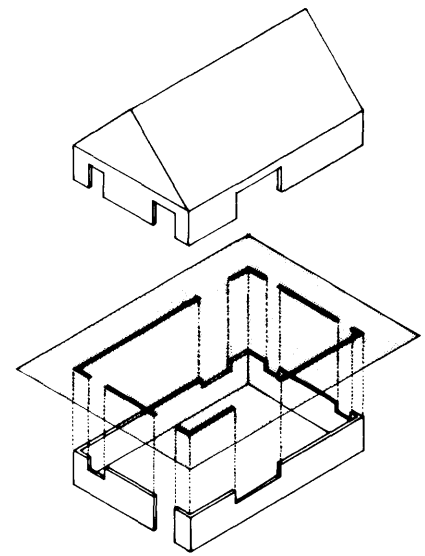


Opposite side: A series of two-dimensional spatial representation systems for the same object.

The issue of representation has at all levels during the twentieth century engaged our consciousness in ways fundamentally different from previous ages. It was perhaps acknowledged first in physics at the time of Herty in the late nineteenth century and later by Viennese philosophers of the early twentieth century that the devices for describing the phenomena of the world are not necessarily identical with those phenomena, but are other phenomena which can be made capable, i.e., shaped, to replicate the original set of phenomena being examined.

Susan Buck-Morss, from
The Origin of Negative Dialectics.

Right: Parallel projection lines form a plan view.



The various types of representation discussed in this chapter will be grouped into three categories, based on the dimensional composition of the system. Those systems that are two-dimensional are presented on a single plane; a piece of paper. Three-dimensional systems are physical models. Systems of the fourth dimension are those which capture a fourth dimension; time. Film and video are the discussed systems.

The purpose of this chapter is to reveal some of the underlying characteristics of each system and the particular aspect of architectural design they most clearly define or represent.

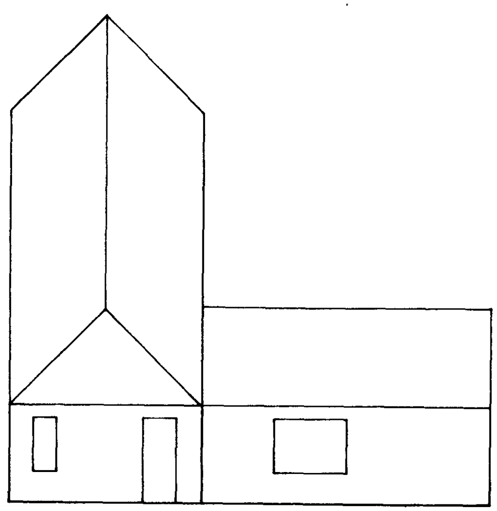
Two-Dimensional Systems

Two-dimensional systems are projection systems dependent upon the idea of straight lines running from points on an object to corresponding points on a flat surface. The various systems are distinguished by the relationship of these lines to each other; whether they diverge, converge, or run parallel, and the angle which they strike the surface.

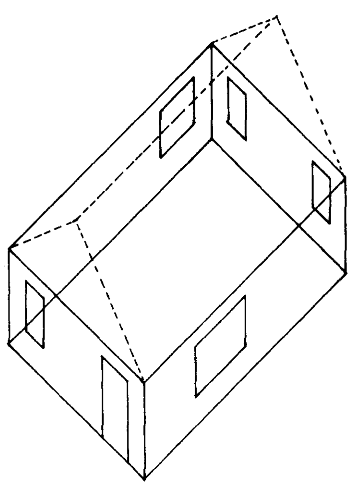
Orthographics

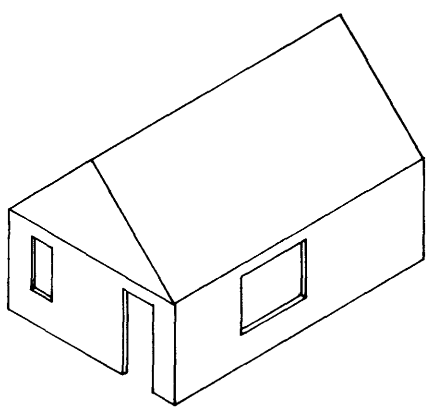
Orthographics are systems where projection lines run parallel from the object to the surface plane. Here objects appear without reference to a spectator, as if the viewer is an infinite distance away. The first use of orthographics were at the cave paintings of Altimira. Up to the Fifth Century B.C., all objects were described in terms of orthographic projection. [1]

Plan, section, and elevation are ordered by a cartesian plane. They describe two dimensions of an object: length and width or length and height.



Left: A vertical oblique and horizontal oblique added together.
Bottom left: An axonometric.
Bottom right: An isometric.
Opposite page right: Albrecht Durer, "Artist Drawing a Vase", 1538, from Perspective.
Opposite page bottom: Abraham Bosse, circa 1665, from Perspective.





Obliques show two sides simultaneousely. In this method two sides are empirically added and drawn. They act as a working drawing with some hint of the three-dimensional view of the object.

Axonometrics involve turning the plan view to 45° to the horizontal. The two elevations are added to this plan. This was first introduced by the De Stijl group in the early Twentieth Century. They were more concerned with space than with facade.

In isometric drawings, the floor plan is transposed to an axis of 30° to each side of the horizontal. It is then projected in elevation similar to axonometric.

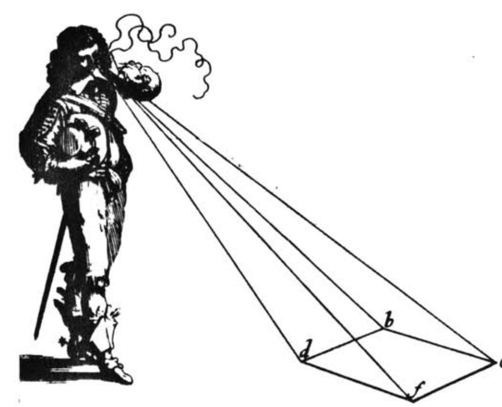
Perspective

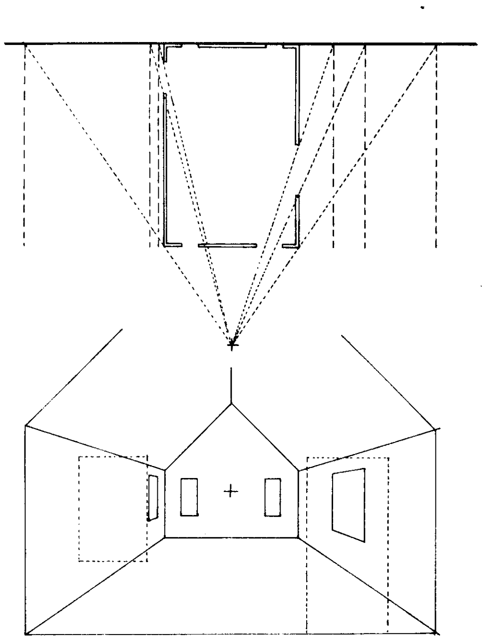
The first treatise on perspective was published in France in 1505 by Jean Pelerin. However, facts were definitevly manifest in Italy by Filippo Brunelleschi, Leone Battista Alberti and Piero della Francesca. These technical descriptions were communicated through treatises or discourses in humanist writing.[2]

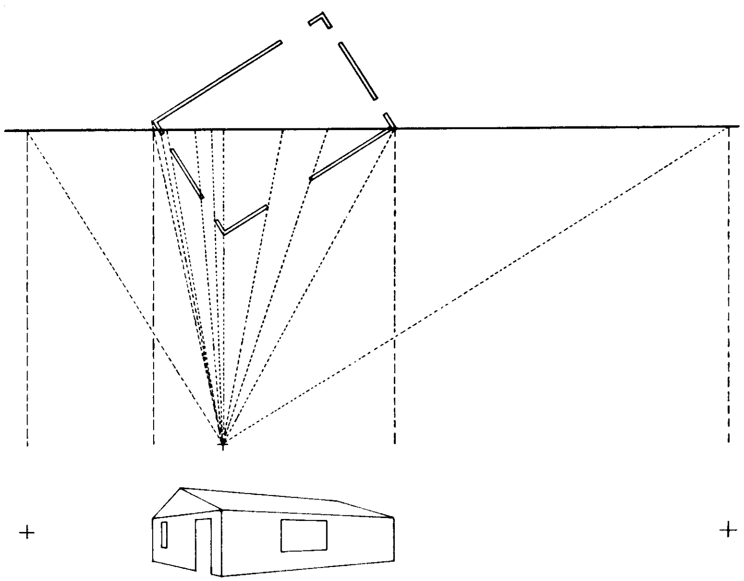
Perspective was born under the auspices of the philosophic trend during the Renaissance. This stated that man was the center of the universe:

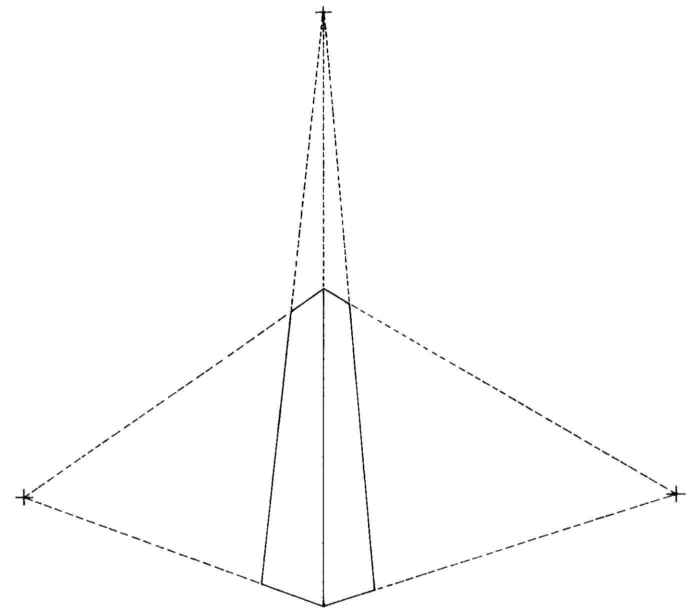
> ...the advocates and users of perspective were resolutely maintaining in every painting, engraving, every bird's eye view of a city or garden that the center of the universe is the individual looking at it. All things were reduced to signals received on the retina, all things led to man.[3]

Such is the nature of perspective, it is a projection system where all rays from an object converge to a single point: the station point, the position of the viewer's eye. It is a single view, it represents an instant in time when an individual is at a certain location point. Perspective drawing is the picture plane that intercepts the projecting rays before they reach the eye.









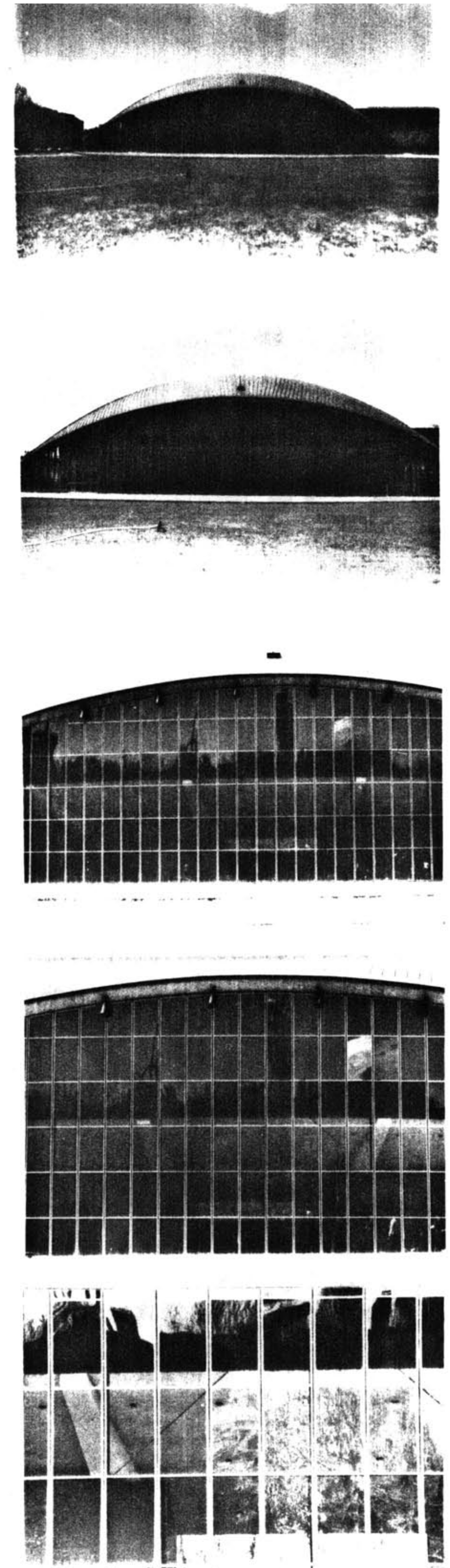
One point perspective occurs when one side of a rectilinear object is perpendicular to the center of vision causing lines parallel to the center of vision to vanish to a single point.

Two point perspective occurs when the same object is not perpendicular to the center of vision causing each set of parallel lines to vanish to one of two vanishing points.

Three point perspective deals with the location of the object in the same manner as two point except that instead of viewing horizontally, parallel to the ground plane, the viewing plane is lifted or lowered, causing the verticals to vanish to a third point. (For example, looking uo at a skyscraper, the verticals converge.)

Opposite page: left- One point perspective.
bottom- Two point perspective.
right- Three point perspective.

Right: Photographs of Kresge Auditorium, designed by E. Saarinen, taken from 30 yards away using lenses of (from top to bottom) 24mm, 35mm, 70mm, 105mm and 210mm (Photographs by L. Silverman).

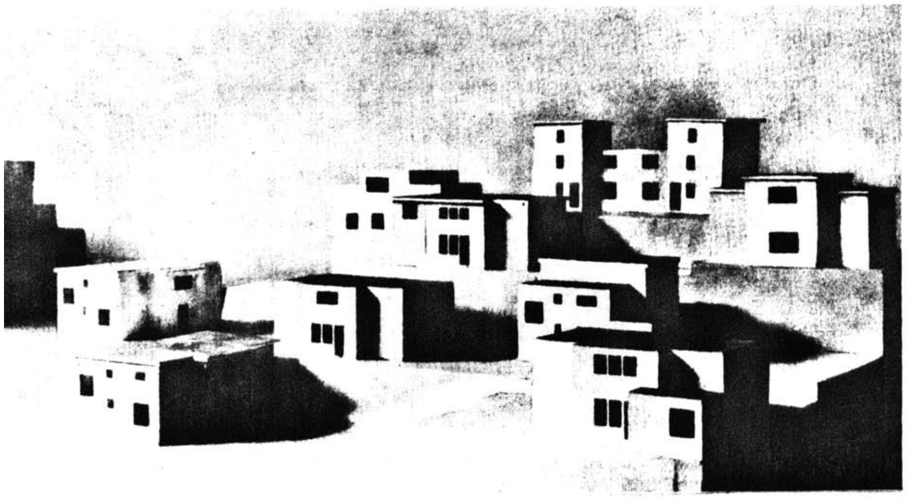


<u>Photographs</u>

The lens of a camera acts in a similar way to the lens in our eyes. The photographic image is formed by the same physics of light as the image produced in our eye.

The photograph is a representation medium we are accustomed to seeing; it is culturally accepted as literal or truthful. Since many of our life experiences are captured on photographs, we develop a translation mechanism to understand what a photograph is, what it represents.

A value of photography is that the final image can be controlled. The ability exists to change what the eye would normally see into what the eye would like to see. Information can be altered to stress a point. Most often, photographers adjust the appearance of reality by using lenses of various types.



Left: Walter Gropius, Model zu Serienhausern, from Staatliches Bauhaus Weimar 1919-1923.
Opposite page right: Thermoheliodon at Princeton University, 1957, from Solar Control and Shading Devices.
Opposite page bottom: Structural model of Santa Colona de Cervello by Antonio Gaudi, from Gaudi.

Three-Dimensional Systems

Physical Models

History

Physical models have been used since buildings have been planned systematically.[4] The evidence existing today traces the earliest models to the Gothic period where wooden models of parts of buildings were made for testing purposes. Paper cut-outs were often used to illustrate patterns of vaulting ribs.

While models during the Middle Ages were used purely for structural experimentation, in the Renaissance they were design aids in the visual orchestration of mass and space. Michelangelo used full size wooden models of parts of buildings as a visual check.

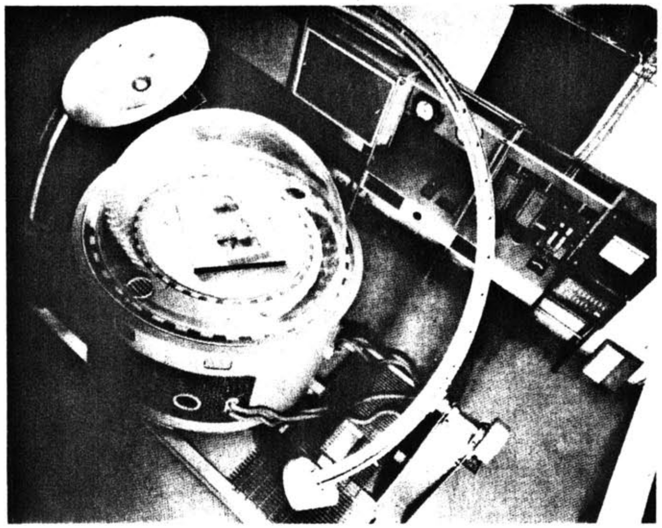
By the end of the Renaissance the value of the model as as an explanatory device was founded. Christopher Wren wrote:

> ...a good and careful large model should be constructed for the encouragement and satisfaction of the benefactors who comprehend not designs and drafts on paper.[5]

The emergence of the architectural profession in the 18th Century resulted in the declined use of physical models. The architect had fine-line drafting skills and often used these for an 'artist's impression' of the proposed design. Architects were also less concerned with the sculptural qualities of form and space, more interest was placed on facade and silhouette not requiring models.

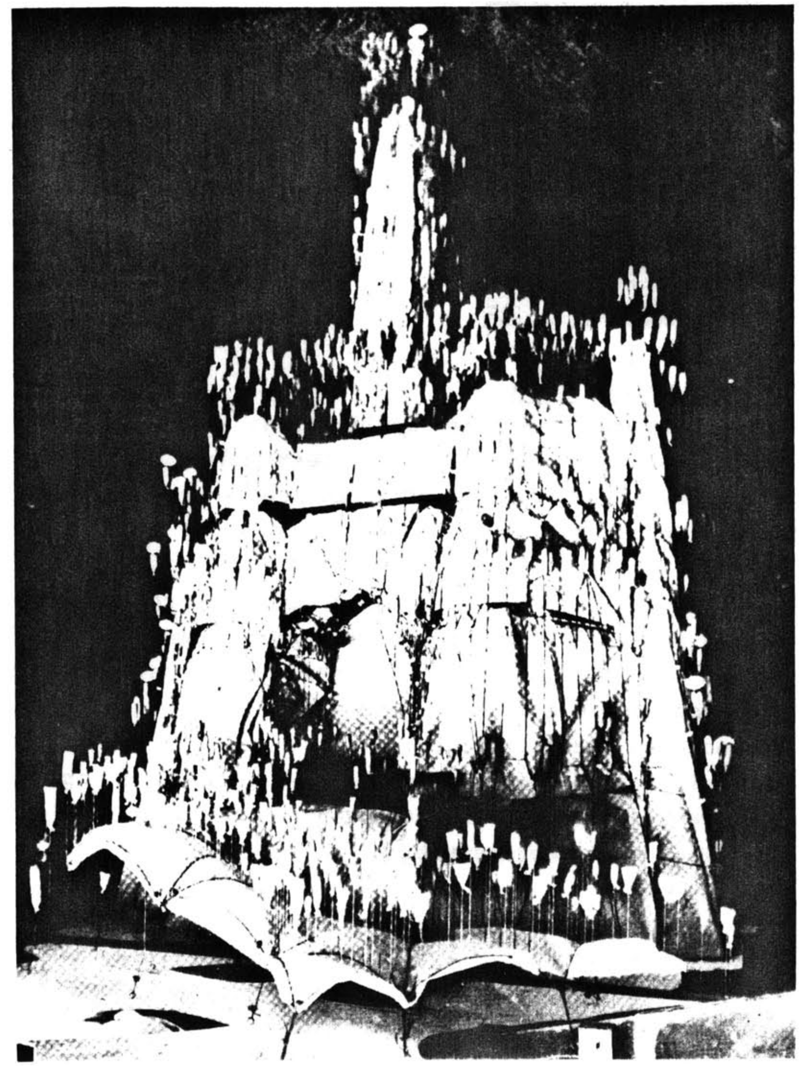
Additionally, the development of print and publication of architecture had an impact on architectural design. Two-dimensional representation became the vocabulary for designing.

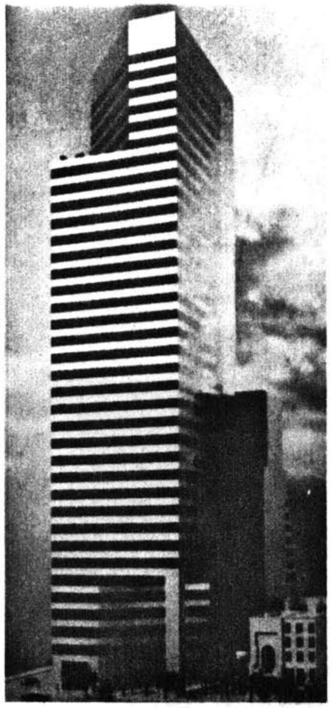
Physical models did not appear in architectural design again until the emergence of the Bauhaus. The exploration of volume and space, combined with the interest of the



dynamics of light, made physical models an appropriate representation system. Eero Saarinen created sculptural forms that were typical of the freedom taken in the exploration of three-dimensional composition. Like other designers he used physical models to develop a design. As he explained: "TWA could not have been achieved on paper alone."[6]

Through the 1940's and 1950's, models were discovered as a tool to test environmental qualities. Architectural science institutions like the British Research Station and Princeton University developed sophisticated model testing techniques. These have yielded valuable information about the environment as it acts on buildings, especially climatic behavior. From this research design standards have been developed which are still used today.





Left: Model of 535 Madison Avenue office building, N.Y. by Edward Larrabee Barnes, from Progressive Architecture, Dec. 1980.
Opposite page right: Model of One United Center, Denver, by Johnson/Burgee, from Progressive Architecture, Dec. 1980.
Opposite page far right: Model of Lever House, N.Y., by Skidmore, Owings and Merril, from Progressive Architecture, Jan. 1951.

Physical Models Today

Physical models have three applications in the design process today. Study models and test models appear in design development, while finished models are prepared for design presentation.

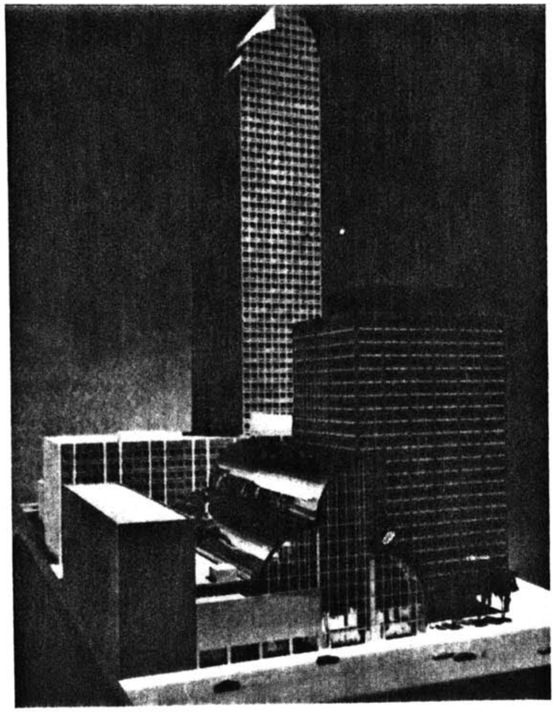
As stated earlier, design development is a process of testing pre-established ideas. The study model is used to test spatial appearance and volumetric relationships. These models are quickly crafted, little attention is placed on the care of construction. By working directly in space, concepts can be easily reshaped, options remain open that might not appear available in two-dimensional representation.

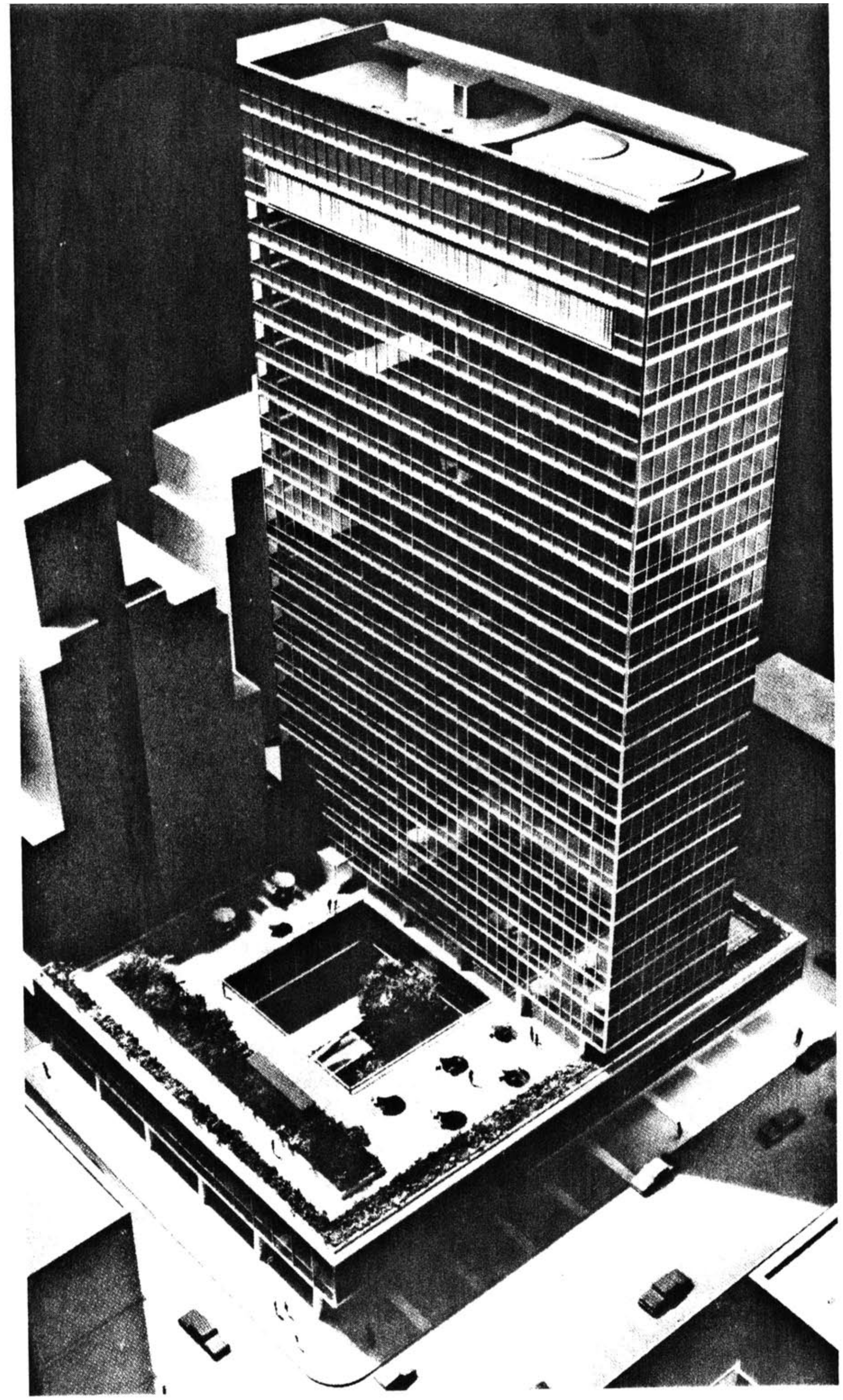
Although few architects would disagree that study models have tremendous value, there is a reluctance to use them because of the expense involved (labor). On the other hand, models don't offer nearly as much plasticity of form that pencil lines on paper does.

Test models are also prepared during design development. Structural, lighting, ventilative, acoustical and thermal models are the most common for test purposes. However, they are not typically used unless there is a special concern, innovation or potential problem involving one of these phenomena, like wind problems caused by a skyscraper in a city. (Test models will be elaborated upon in Part II.)

Presentation models are conventional in practice today. Their purpose is to explain the building design to the client or layman; ie., the untrained eye. They are intended to be persuasionary. They appease the client, who has something tangible to react to, a visible product to account for the architect's fee.

Presentation models require a level of abstract interpretation to comprehend. Too often individuals have the tendency to observe models on a table or from anywhere above it. In scale with the model, this could be 50 to 100 feet above the project, a view rarely seen and not





representational of the experience of that environment.

Carefully planted visual cues act as indicators so this transpositional scale difference can take place. Entourage such as people, trees and cars immediately cue us in.

Fourth-Dimensional Systems

Addressing time in spatial representation systems was made possible through technological development. Film and video are capable of simulating spatial experience with an ever-changing viewpoint. Today we are accustomed to such media in the same manner as photographs. There is a high level of credibility in these media, we easily associate images with life experiences. A local Boston video producer claims "Television is reality to the viewer."[7]

The application of these media to architectural design is being explored today. An obvious application is the documentation of existing buildings and places. This can give the designer a catalogue of experiences, which he/she can use as a reference for a particular project. A much more exciting and challenging application is the use of these media to predict or represent a proposed design.

Several architectural firms have explored video architectural presentations with the aid of a video production house. Although the cost is exceptionally high compared to conventional presentations, these media are so new they are an eye-catcher. (Video productions can cost $15,000.00 for a ten minute sequence, plus the necessary drawings and models. Sasaki Associates recently prepared a video piece for a developer, spending $60,000 for a model and $15,000 for perspective reenderings.[8])

Film and video can be valuable to both the architect and the client. The architect can call out particular aspects of the design that might otherwise be unnoticed or difficult to represent. The recorded presentation can be played back anywhere, anytime, and because the entire presentation is prepared earlier on a storyboard, information can be logically presented. Clientele benefit by gaining insight of the design through a medium they are comfortable with. The current media technique of 'cinema verite' and 'suspending disbelief' brings the viewer into scenes and space in a most realistic manner, sometimes even emotionally. If one intends to duplicate movement through a building, flim/video seem to offer the most potential. The combination of sight and sound add to the believability of the experience.

There are several techniques utilized for spatial representation of proposed designs. Physical models and drawings act as 'stage-sets' as the camera pans in and out, superimposes and fades images, or moves laterally or vertically. The many images on the screen heightens the value of an isolated drawing or model. The dynamic view more closely represents the experience of the space. However, the picture is still obviously that of a drawing or model. Although more representative of spatial experience, the believability of being there is not portrayed. The several productions I have seen are not utilizing this powerful medium as well as it could be used.

This is partly due to our high expectations of television and movies. The American public is fed such superquality images, that unless the simulation is well done, it will look 'fake' or not believable. Changing technology will have an affect on this situation. The sophisticated 'Star Wars' production capabilities will make these media an important tool in architectural presentation in the future. Computerized and digitilized imaging, although too costly now, will provide the quality that will make spatial representation in these media 'believable'.

Notes: Chapter 2

1. Fred Dubery and John Wilats, <u>Drawing Systems</u>.
2. Pierre Descargues, <u>Perspective</u>.
3. Ibid.
4. H.J. Cowan, J.S. Gero and G.D.Ding, <u>Models in Architecture</u>.
5. Tom Porter, <u>How Architects Visualize</u>.
6. Ibid.
7. Elaine Purcel (Director of Videocom, video and film producers), seminar at <u>Architectural Essentials</u> titled "Video Presentation of Architectural Projects", April 15, 1982.
8. Peter Thomas (Principal, Sasaki Associates) same seminar as note 7.

Chapter 3

Spatial Representation Systems: Applications

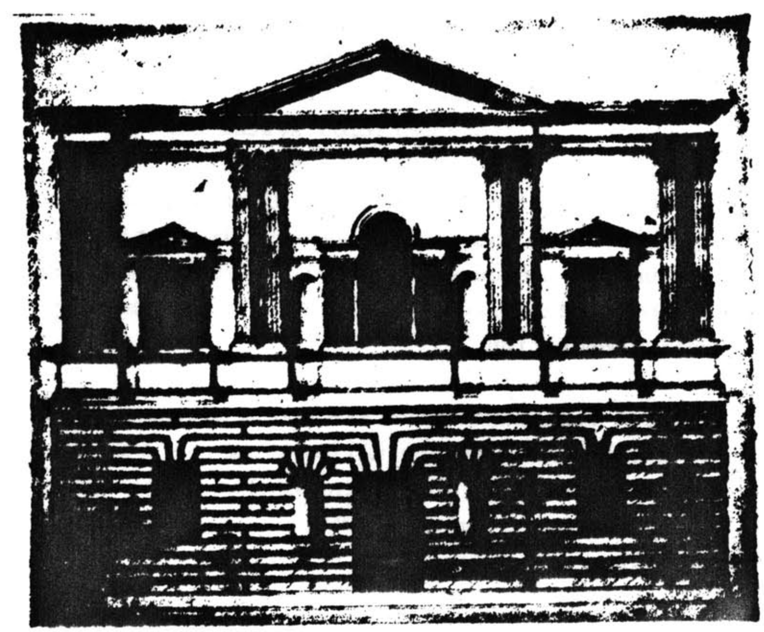


Illustration on opposite page: "Palladio's Seventh Generation", Don Alberto, 1982.

The seven generations are:

1. Ektachrome 400 slide (Kodak) of the original drawing.
2. Photo-enlargement on copyproof CPN negative (Agfa).
3. Copyproof transfer to CPP positive (Agfa).
4. Photo transfer to Kodalith ortho film 2556 (Kodak).
5. Transfer to metal plate for printing.
6. Ink transfer from plate to offset blanket.
7. Ink transfer from blanket to paper.

Presented in this chapter are three case studies illustrating possible applications of various spatial representation systems. The first study, the MIT Time Line, is a survey of presentation drawings from the MIT Archive dating 1877-1967. The time line gives some indication of possible correlations between the representation system employed and the resulting architectural emphasis and style. The second study, House El Even Odd by Peter Eisenman, is an exercise in representation and its evolution into architecture. The final study is a documentation of the design process of a project by Goody, Clancy Associates, which recently won a national competition.

To manifest some conclusive statement between spatial representation system and resulting form would be an exhaustive effort, nor is it the intention here. Instead the reader will hopefully summize his/her own hypothesis from the illustrations and information presented.

The M.I.T. Time Line 1877-1967

Ever since the School of Architecture at MIT was formed, it has been Institute policy for students to submit original thesis work, which is then carefully stored in the MIT Museum. The MIT Time Line is a selection of theses projects chosen as typical examples of the spatial representation systems most available for the decade they were taken from, both in the academic and professional worlds.

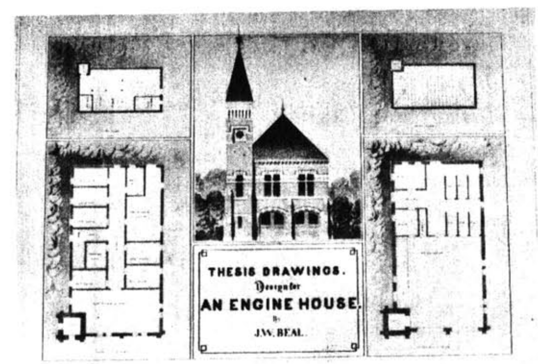
After reviewing these ninety years of architectural representation, certain patterns between spatial representation system and architectural form became evident. The type of two-dimensional representation utilized had an obvious purpose for depicting aspects of the architectural design. For example, in the late 1800's large elevations were the most popular view that described the external appearance of buildings. Exorbitant time was spent detailing the facade, little attention was given to the three-dimensional character. On the other hand, in the 1940's, perspective drawings of the entire building seen from a distance were common, treating architecture as a building-mass organization having no ornament at all.

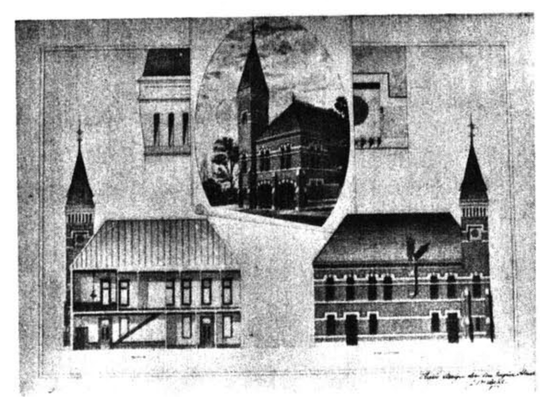
Not only did each type of representation act as an aid in describing a particular design feature, it also imposed a limit on the architectural qualities one could address. It would be difficult to pursue three-dimensional massing studies in just plan and elevation.

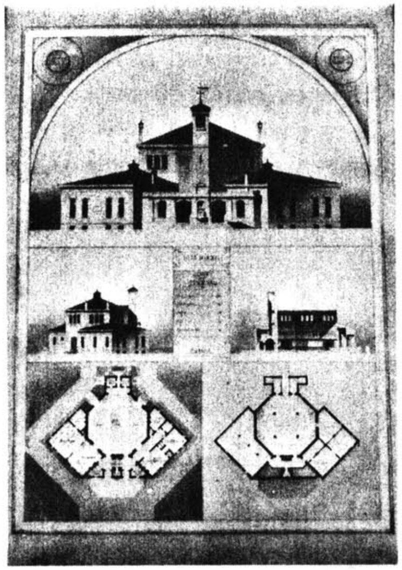
Aside from the type of representation, the style and medium of each piece affected architectural values. The Beaux Arts water color elevations forced individuals to think about materials, construction, and how buildings realistically 'fit' into a certain context. The hard line pen and ink drawings often isolate buildings.

Finally, it is interesting to note the changing position of the viewer of these buildings. This gives us some hint of the creators attitude towards architecture and representation. In the 1940's, site plans were referred to as 'pilot plans' and perspective drawings were taken from great heights as if from an aeroplane. Architecture was observed from afar, not at all as if experienced.

1877- John Williams Beal
An Engine House





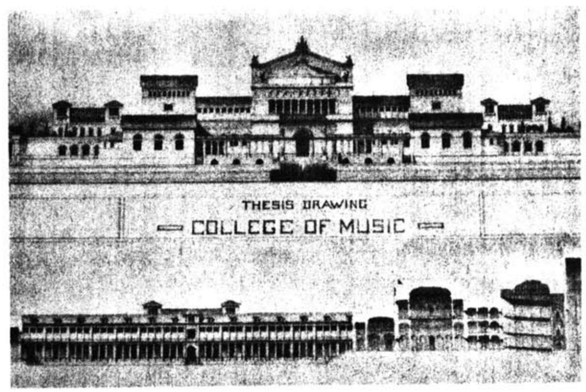


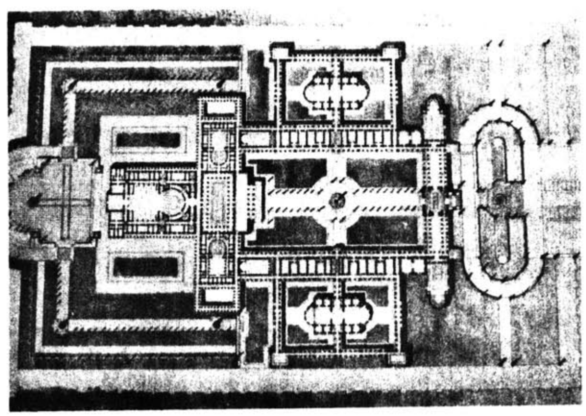
1878- Charles M. Baker
Town Hall

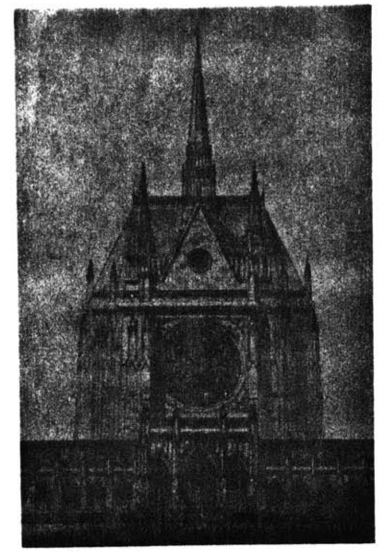
1875 1885

1885 1895

1891- Elwood A. Emery
A College of Music





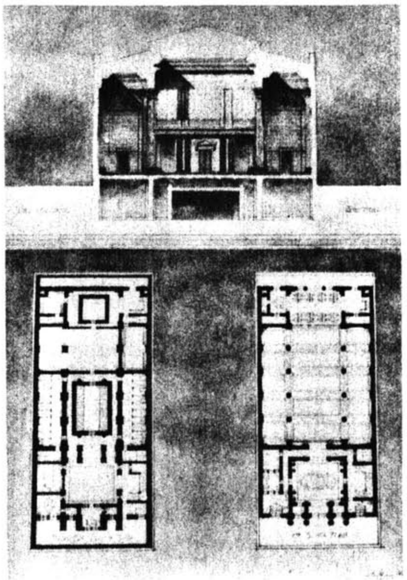


1904- James M Baker
Chapel of a Prep School

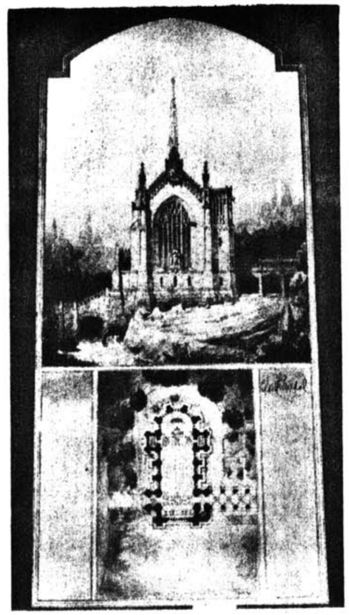
1895 1905

1905 1915

1915- B.H. Byrnes
Citizens National Bank



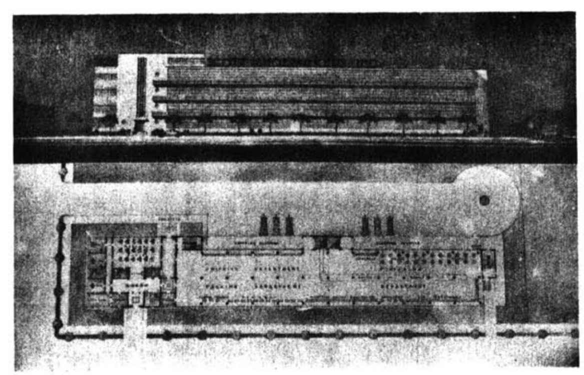
1923- Marvin Eickenroht
The Chapel

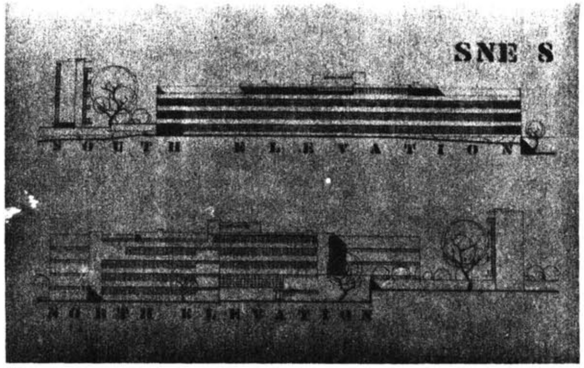


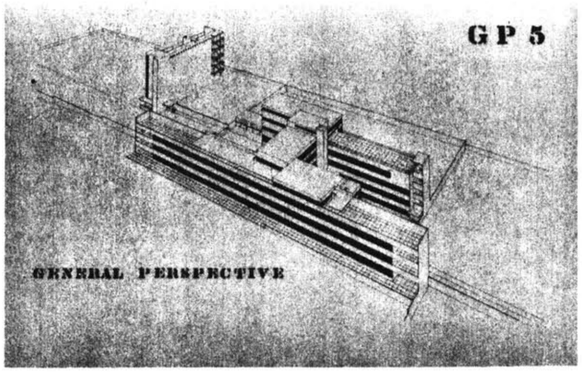
1915 1925

1925 1935

1934- Charles Burwen
A Shoe Factory





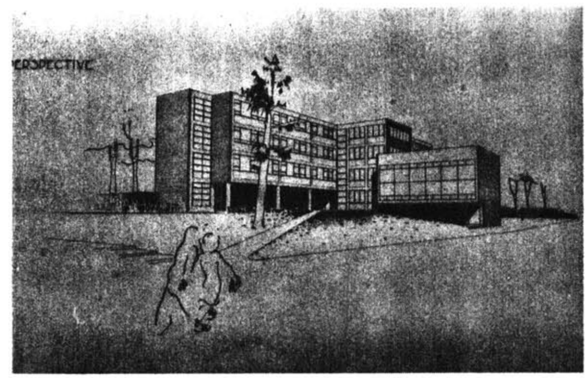


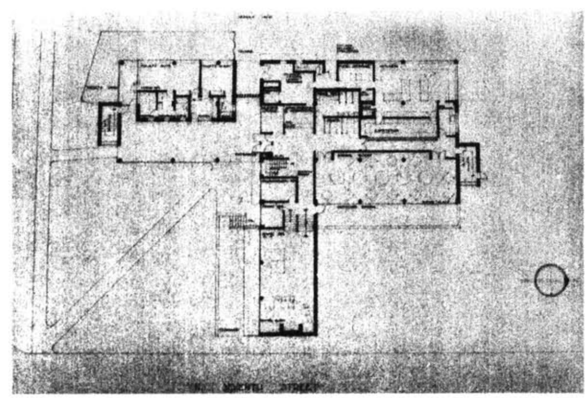
1940- Robert H. Hose
A Psychiatric Hospital

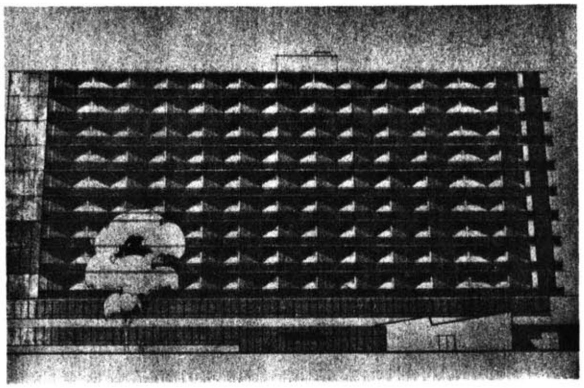
1935 1945

1945 1950

1946- Norman P. Anderson
A College Center

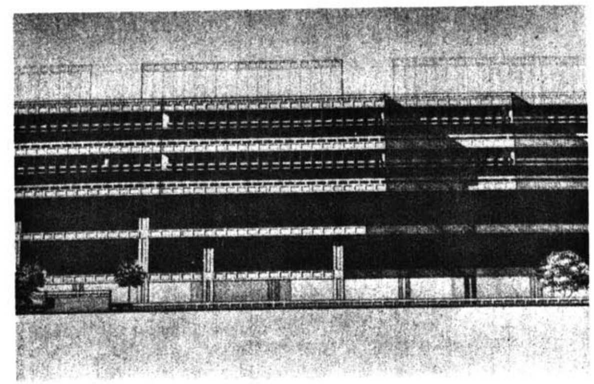






1952- Richard L. Tavis
A Rehabilitation Center

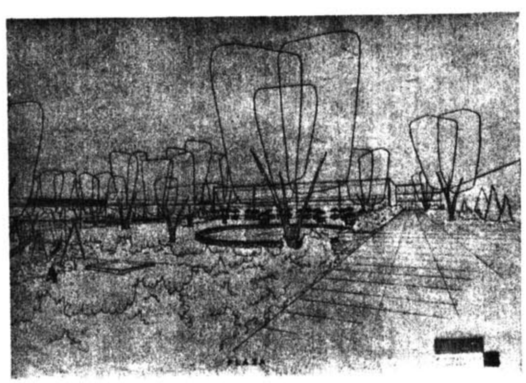
1965- James Bonar
Building System Based on Growth



1950 1960

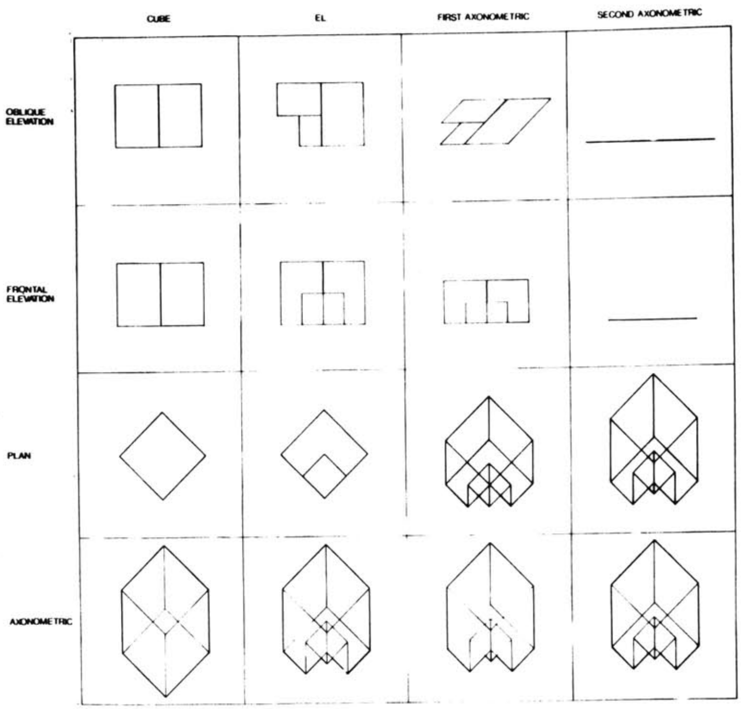
1960 1970

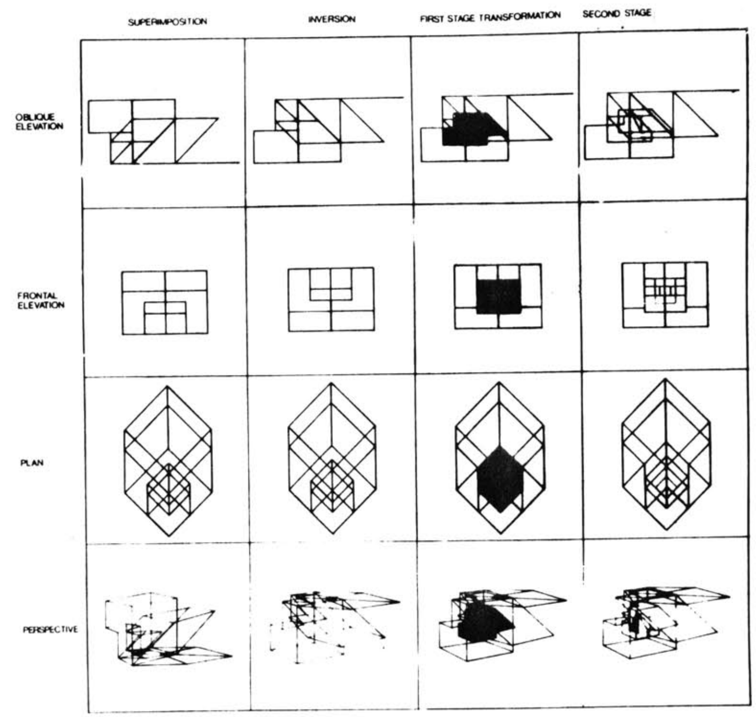
1952- Clifford H. Morse
A Shopping Center



House El Even Odd: 1980
Peter Eisenman

An international group of eight architects was invited to respond to a program specifying the design of a family house. House El Even Odd was Peter Eisenman's submission. His solution was a study of a spatial representation system, the axonometric. Eisenman generated an object form through the transformation of the axonometric principle. Below are excerpts from his explanation of the design process, taken from the Rizzoli publication Houses For Sale.

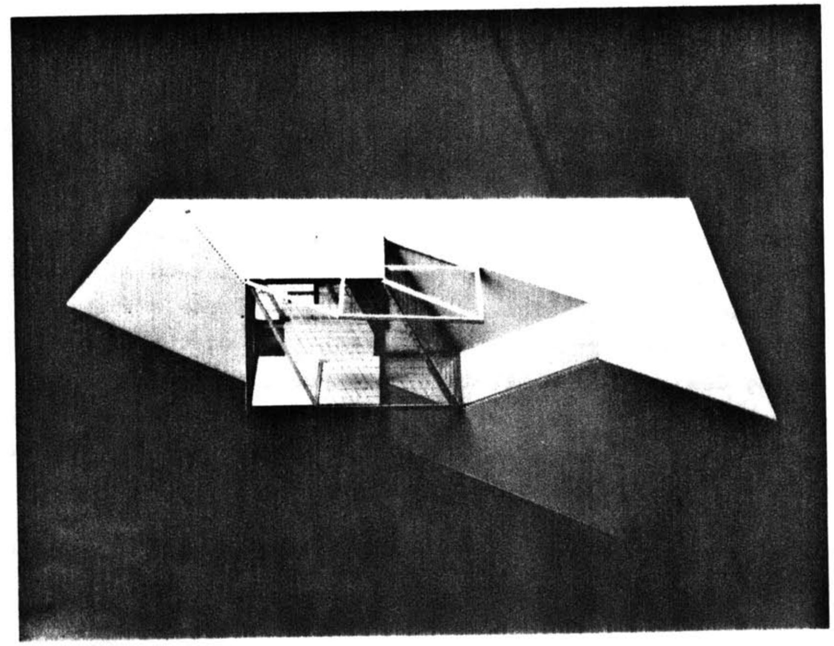


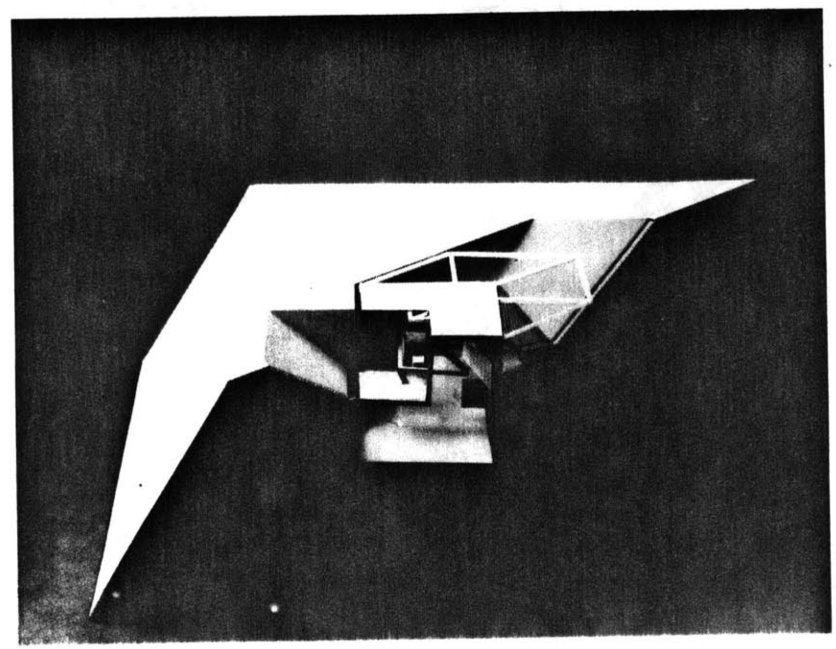


"House El Even Odd is an axonometric odject. It explores the conditions of representation and reading in architecture. As such it is concerned with the limits of the discipline of architecture."

An axonometric model, as opposed to an axonometric drawing, is the transformation of a three-dimensional representation of a three-dimensional reality - it is both process and reality. It differs from an axonometric drawing in that while it is a representation, it is not representing an actual object but a transformation of an object."

"House El Even Odd begins with an el-shaped axonometric object as its intial condition of reality. Its sides are 45 degrees to the horizontal and vertical planes. Two axonometric transformations of that object then take place. The first produces an object that is a flattened surface. (Since an axonometric projection is taken at a 45 degree angle to the vertical and horizontal, when an already 45 degree condition is projected another 45 degrees, all lines fall into the horizontal plane.) The second transformation produces a reversed axonometric projection, which also becomes a rectilinear el-shaped volume. All three states projected simultaneously are House El Even Odd. A model of this house appears to be simultaneousely a three-dimensional object, an axonometric projection, and a plan."

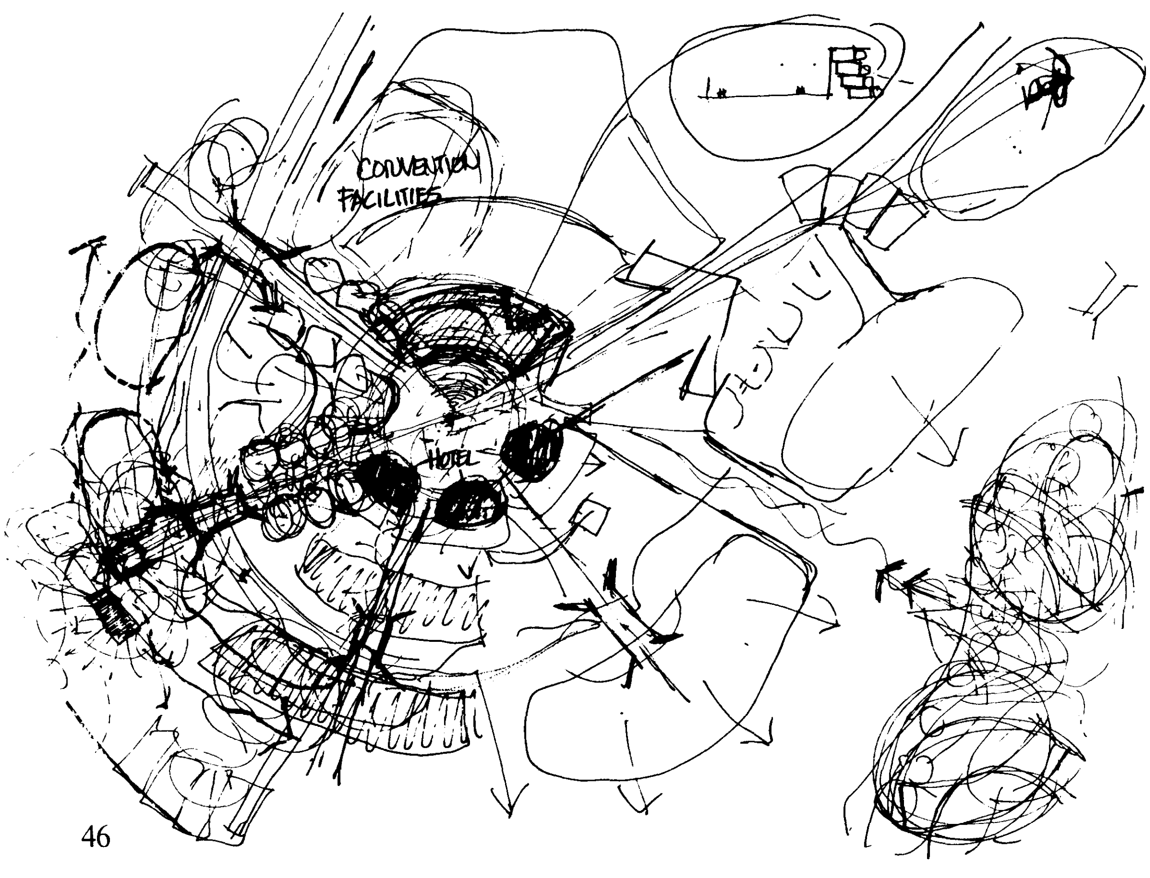


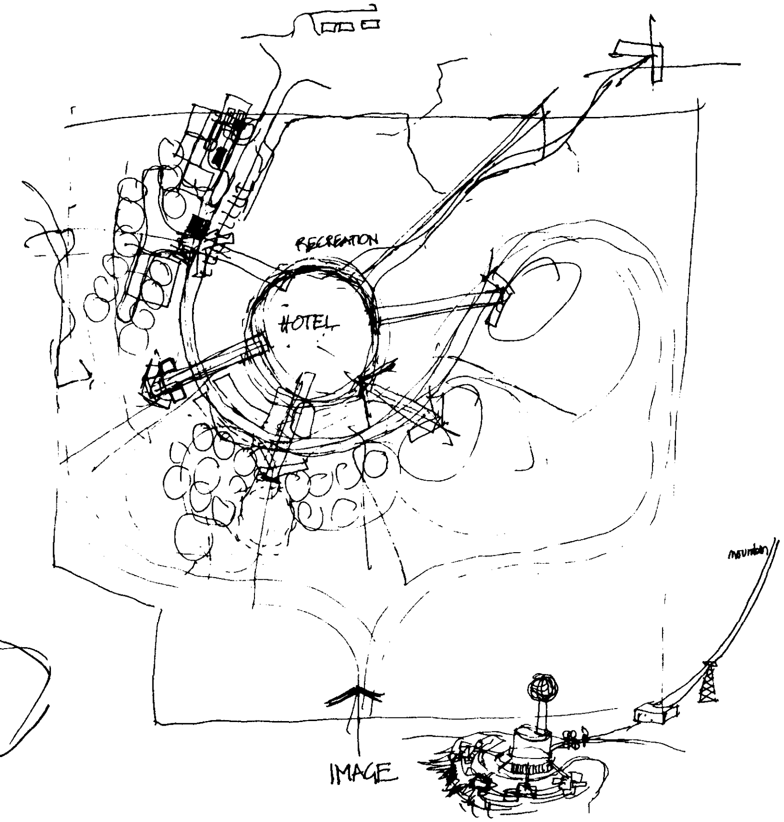


EagleRidge Design Competition: 1981
Goody, Clancy and Associates Boston

The design team for this complex site and building design program utilized several different spatial representation systems during all stages of the design process. Physical models played an especially important role in the determination of the firms proposed winning design. All three types of models were used: study models for concept development and compositional (volumetric) decision-making, test models for solar access studies and a presentation model for concept communication.

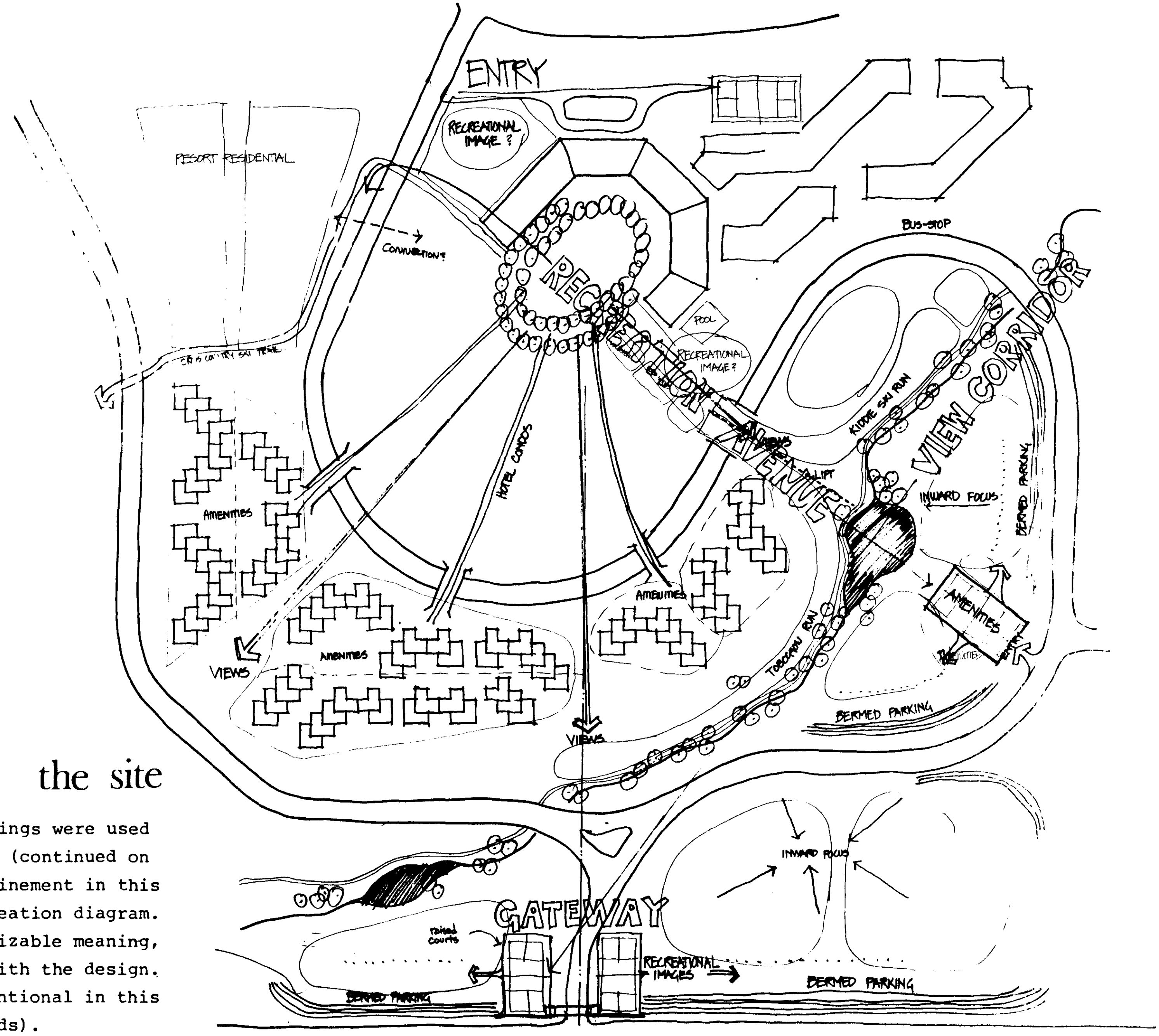
There were two interrelated processes that occurred simultaneously: the site design and the dwelling unit design.





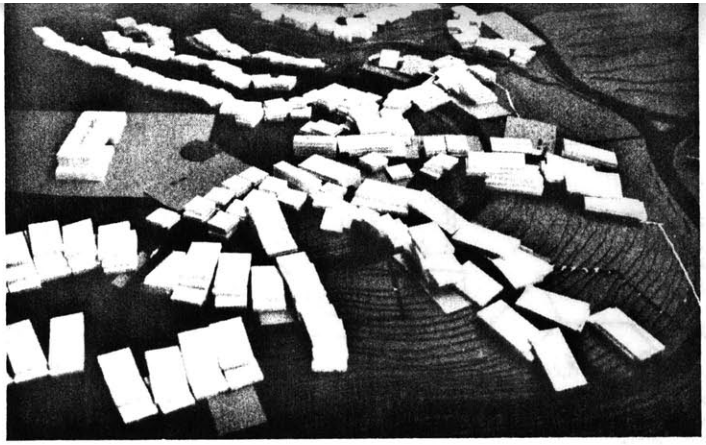
1. Ideation: the site

These are two of the first site analysis drawings. The fluid looseness, referred to as a 'bubble diagram' depicts the gesture of building form and location. The process involved here is one where internal mental thoughts are externalized onto paper. Although these may seem nondescript to the viewer, to the originator the amount of information is profound, packed with meaning. Note the symbology of line, a system was invented as the thoughts were being born.



1. Development: the site

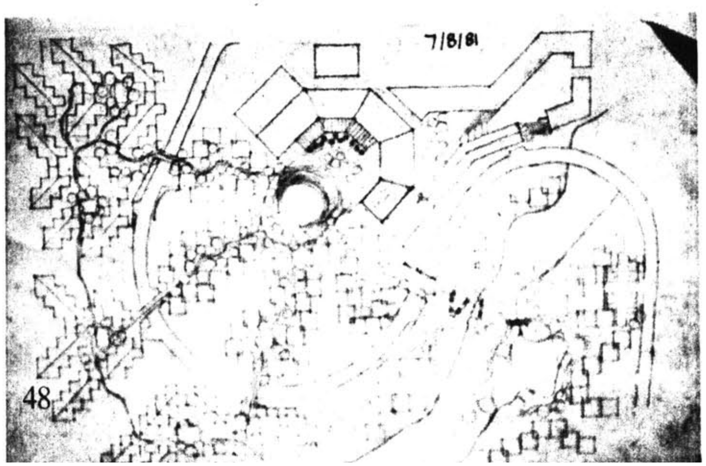
Both study models and drawings were used for the design development (continued on next page). There is a refinement in this drawing compared to the ideation diagram. All lines take on a recognizable meaning, even to one not familiar with the design. The symbols are more conventional in this drawing (trees, water, words).



1. Development: the site

The use of the study model (pieces of foam core board) offered a 'plastic' medium for arranging and juxtaposing predetermined units. Actually, due to the unique sloping site combined with a previously decided site concept of radiating axial views (see drawing on previous page), the study model was an appropriate tool revealing spatial qualities that would otherwise require interpretation from two dimensional systems.

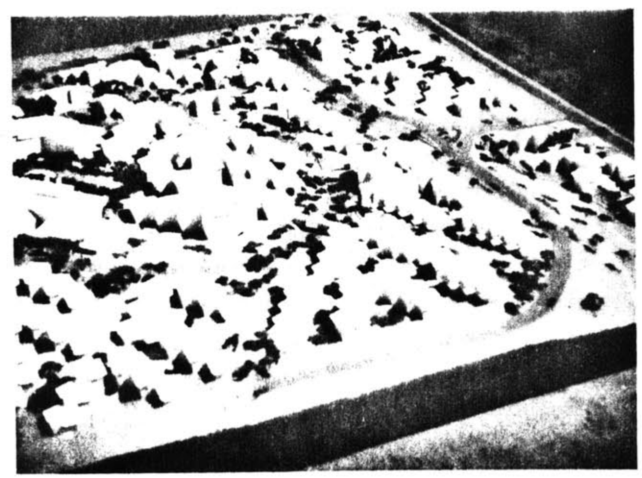
The drawing below is one of the last stages of site development before presentation. In this drawing there exists a clarified definition of form, the results of many design decisions.

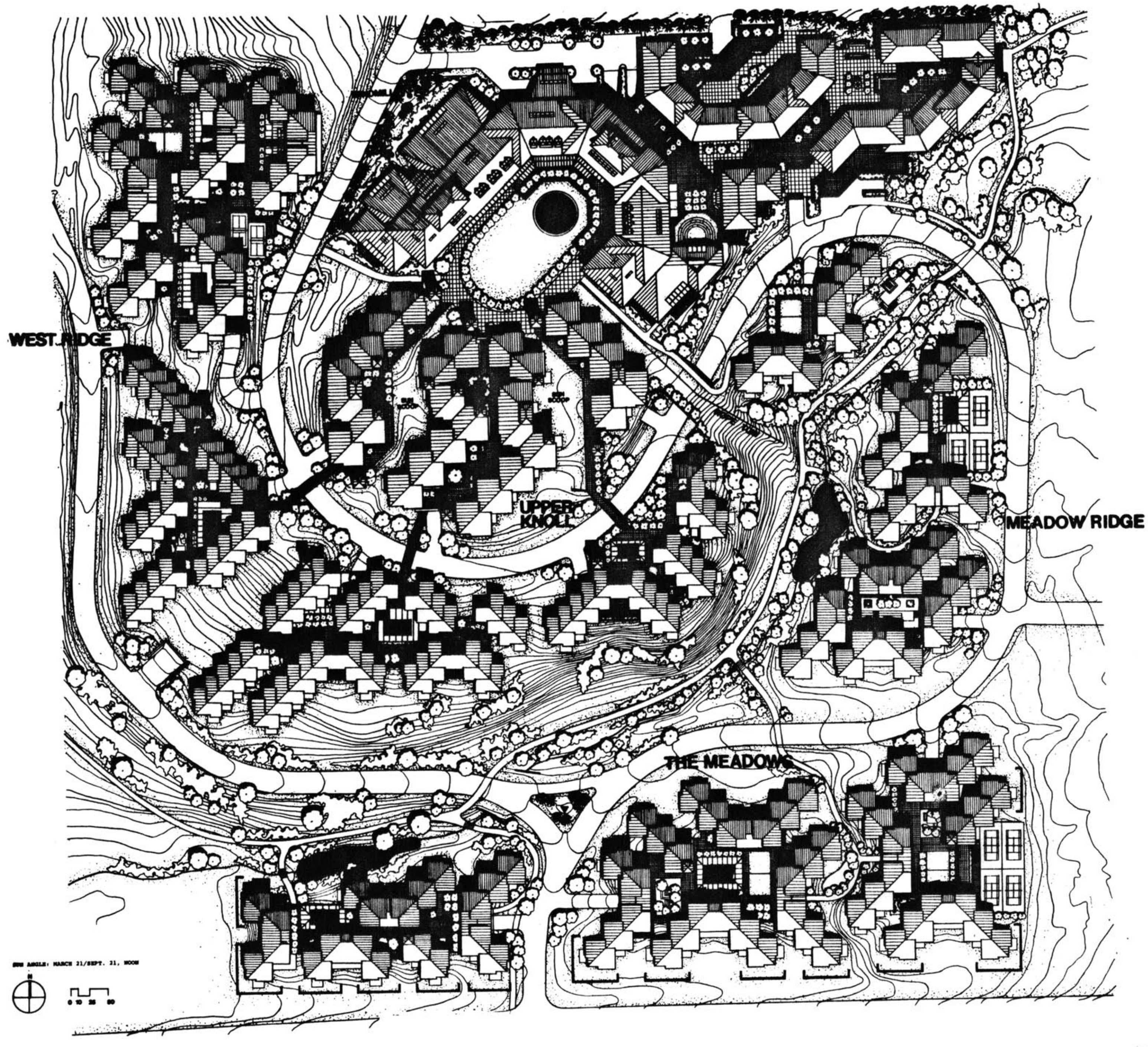


1. Presentation: the site

Below is a photograph of a presentation model, to the right is a reduced copy of the final submitted site plan. These representations are intended to communicate as much information about the site necessary for its comprehension by those unfamiliar with its concept.

Both representations are professional conventions. They are usually easily recognized by those in the profession and its related fields. However, the model communicates concept information to a much larger audience then the drawing. The spatial articulation is briefly translated by the use of shadow on the drawing, where it exists in the model.



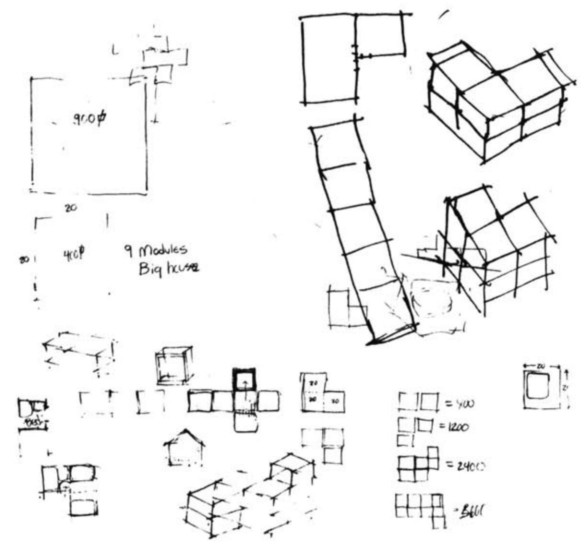

WEST RIDGE
UPPER KNOLL
MEADOW RIDGE
THE MEADOWS
SUN ANGLE: MARCH 21/SEPT. 21, NOON
N
0 10 25 50

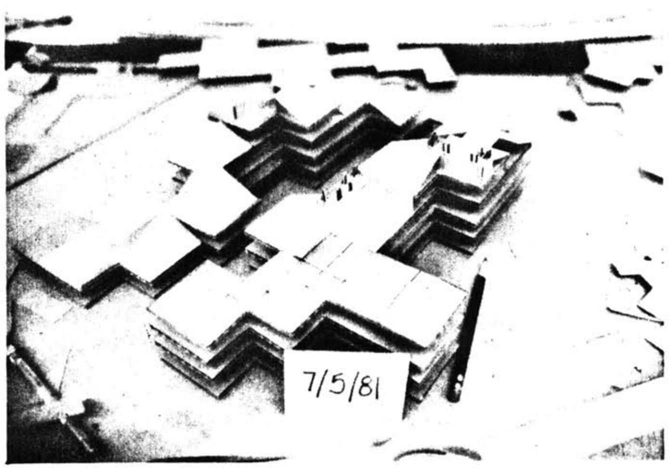
2. Ideation: the dwelling unit

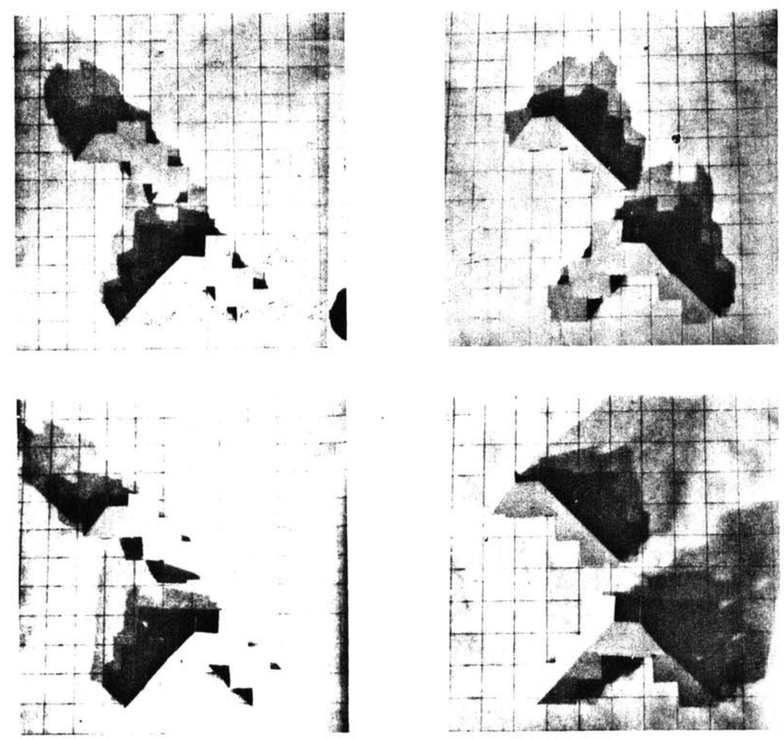
The freehand plans and axonometrics to the right were the original thoughts that generated the dwelling unit design. Ideation progressed from these sketches to the use of study models.

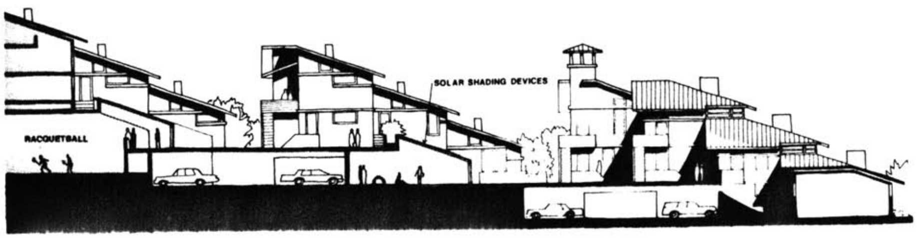
2. Development: the dwelling unit

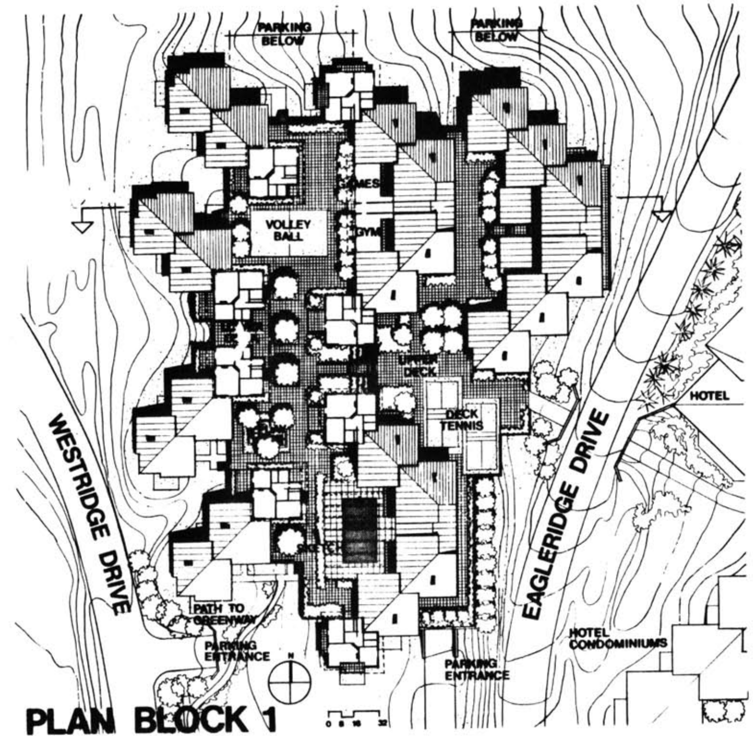
The program called for solar considerations, access to the sun by each unit. The building roof line and cluster arrangement was formed by fitting the model into the boundaries of a solar envelope. This was accomplished with a study (test) model and season shadow simulator. The photos illustrate some of the building-sun relationships, an easy method for visualizing changing pattern.







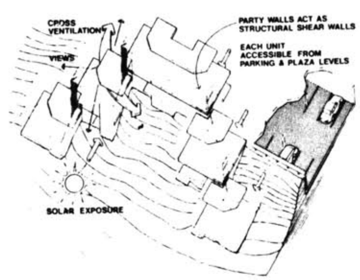


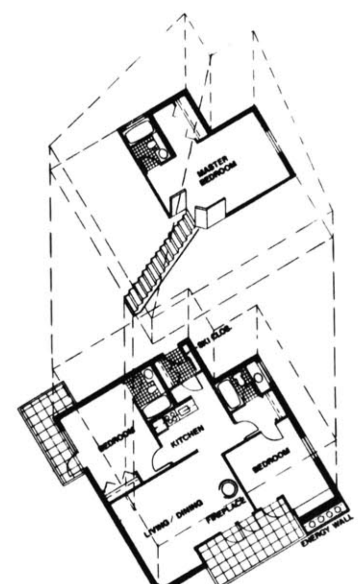


2. Presentation: the dwelling unit

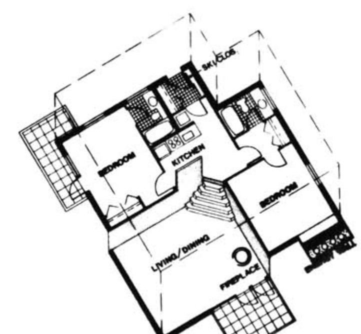
These drawings are from a typical presentation board. Notice that five different two-dimensional spatial representation systems were presented, each with a particular purpose, emphasizing a spatial aspect of the design.

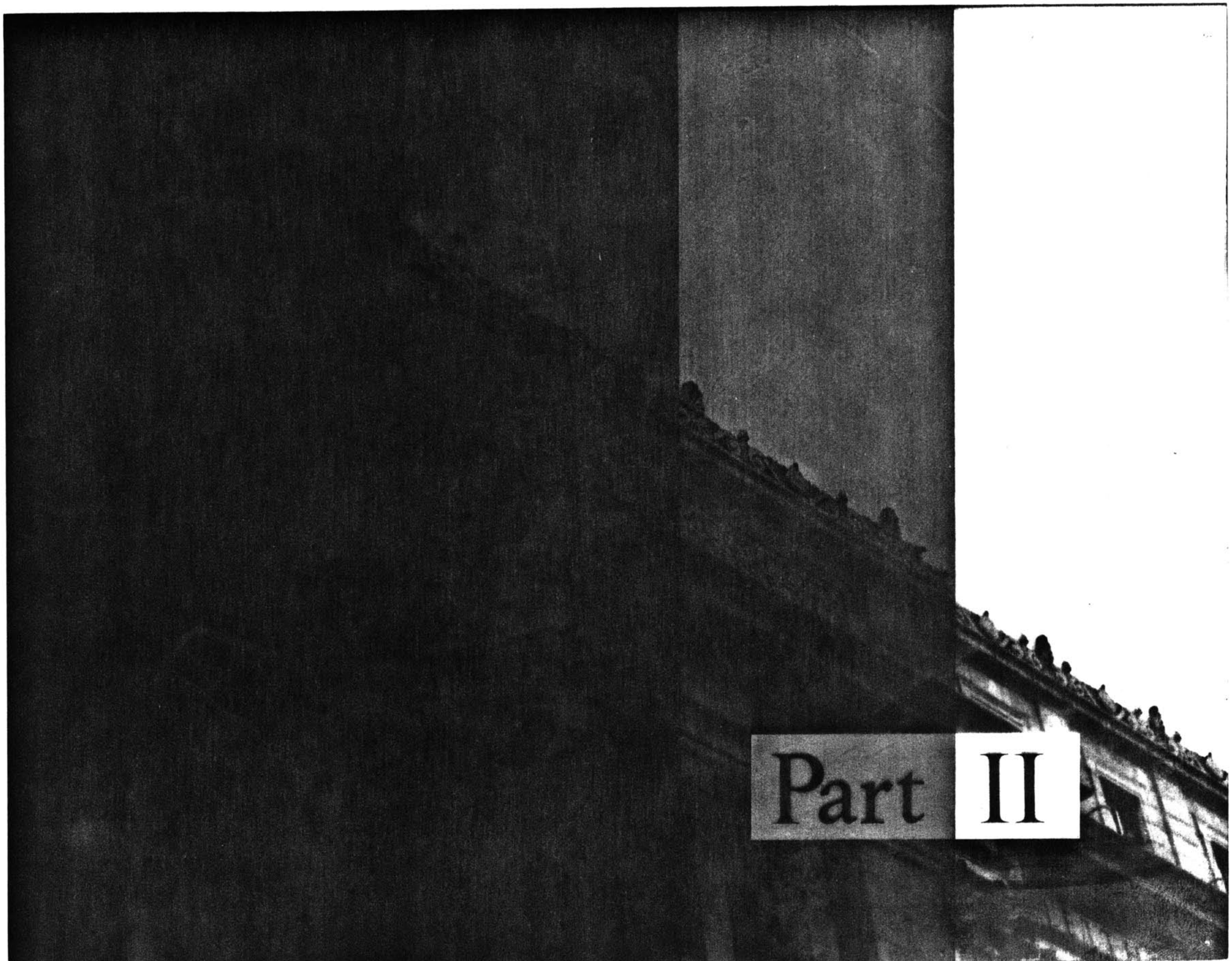
MARKETING FEATURES





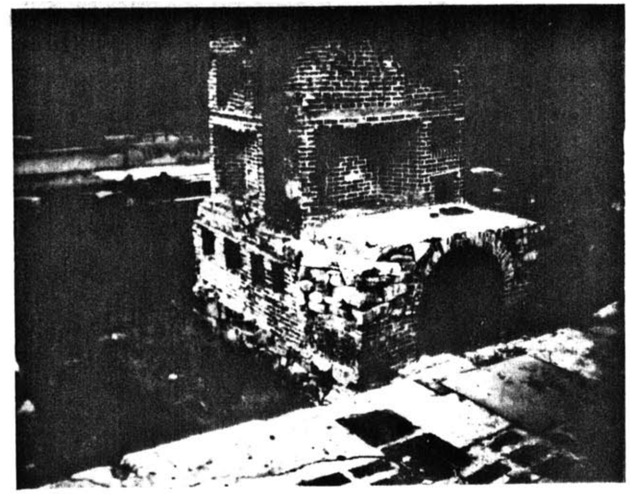
'L' SHAPED PLAN SEPARATES BEDROOMS FOR MULTI-FAMILY PRIVACY

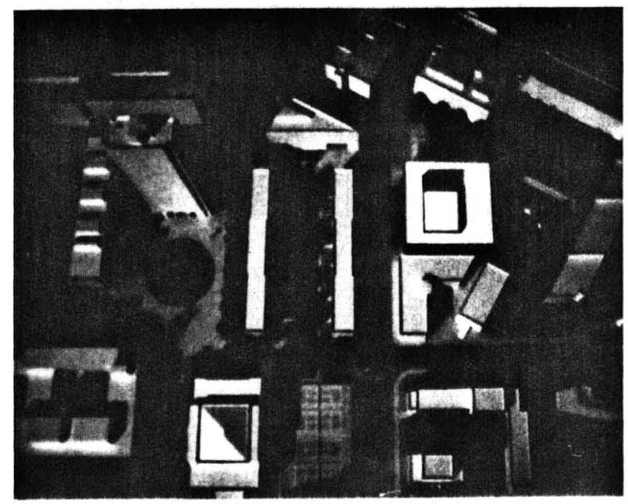


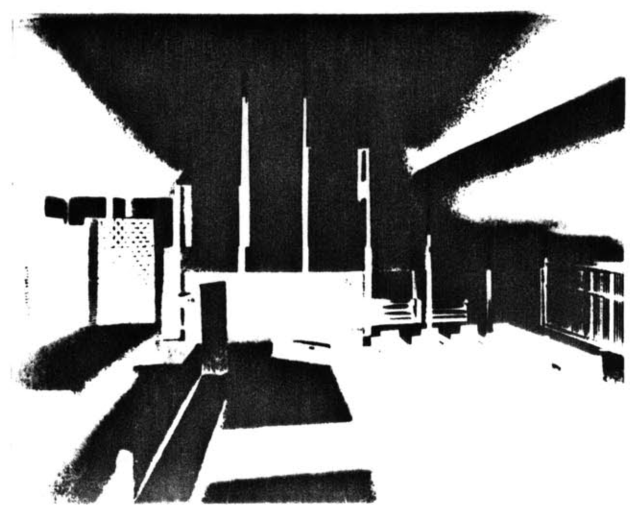

Part II

Chapter 4

Energy Conscious Design;
Physical Modeling;
Documentation Techniques







Opposite side: top- The centrally located 'hearth' surrounded by the building 'envelope' provided a thermally comfortable environment in this remains of a typical colonial house. It is located in Lexington, Ma.

center- A site model of MIT with the Arts and Media Technology Building. Model by I.M.Pei and Associates.

bottom- A negative copy (Kodalith) of a photograph of a model of a church.

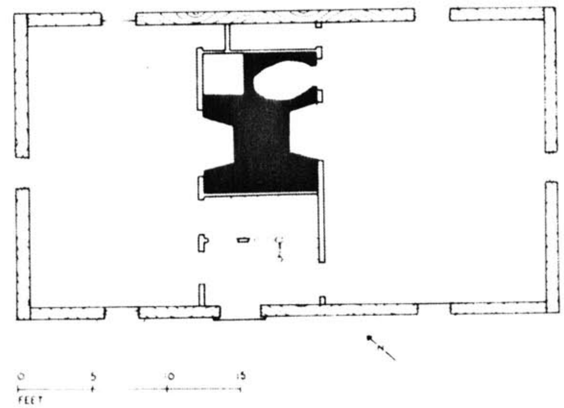
The project discussed in this part is a research study that has been underway for the past year at MIT. Initially, its purpose was to explore potential applications of models as a medium to analyze and understand physical phenomena, or energy behavior as it acts on buildings. After conducting a literature search and speaking to professionals and educators, research proceeded in the form of actual building and testing of physical models. Special attention was directed to documentation of testing as it occurred.

The project, therefore, has three different research components, all of which are contemporary concerns in professional practice. First, there is the topic of energy behavior. Each test was prepared to demonstrate certain dynamics of energy behavior on structures, and reveal new knowledge that is unavailable in visual form. This research was accomplished through the scientific method.

A second component of the project is investigation of physical models applied to architectural design. Their use as a design aid and educational tool is appropriate for both the nature of the topic and the research audience.

A final aspect of the work is the documentation of the research; in essence, the communication of research. Documentation of the processes under study posed difficulties that required further exploration in several communicative media.

Energy Conscious Design



Energy Behavior: A Design Approach

Ever since the species Homo sapien has consciousely recognized recurring patterns of natural forces around itself, attempts have been made to change or control the dynamics of these forces when they became uncomfortable: if the burning sun made one too warm, one sought shade either by finding a natural formation that made a shadow or by creating a shadow; if the blowing wind made one cold, protection was sought behind a barrier either by finding one or constructing one; if snow or freezing temperatures made survival impossible, an envelope was built around a fire. These first attempts at building were in response to identifying, understanding and controlling undesirable climatic conditions. The continued exploration and use of built objects acted as a means for experimentation. From generation to generation, and from building to new building, knowledge about architectural form* in relation to its surrounding climate was made evident and passed along. An evolution of buildings in various regions throughout the world exhibited patterns of architecture in each locale. These patterns developed out of the search for comfort in man made structures.

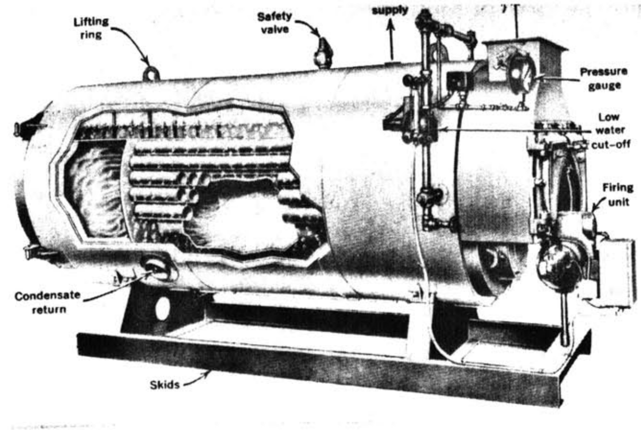
In fact, until the 20th Century, the primary generator of architectural form which people inhabited was the attempt to create thermally comfortable environments for particular human activities. This is not to say that thermal comfort was the only design parameter. Many other concerns ultimately affected the design of 'beautiful' buildings: the association of beauty with a god, human being, powerful or ideological society; the beauty of

*architectural form: 1. The three-dimensional character of a building; 2. The shape of spaces and their compositional synthesis; 3. The character of the material and non-material elements which could be perceived and therefore form the boundaries of a space.

Opposite page: Photograpgh and plan of McIntire Garrison House, Scotland, Maine, circa 1707, from American Architecture 1607-1976.

Right: Package type fire-tube steam boiler, from Mechanical and Electrical Equipment for Buildings.

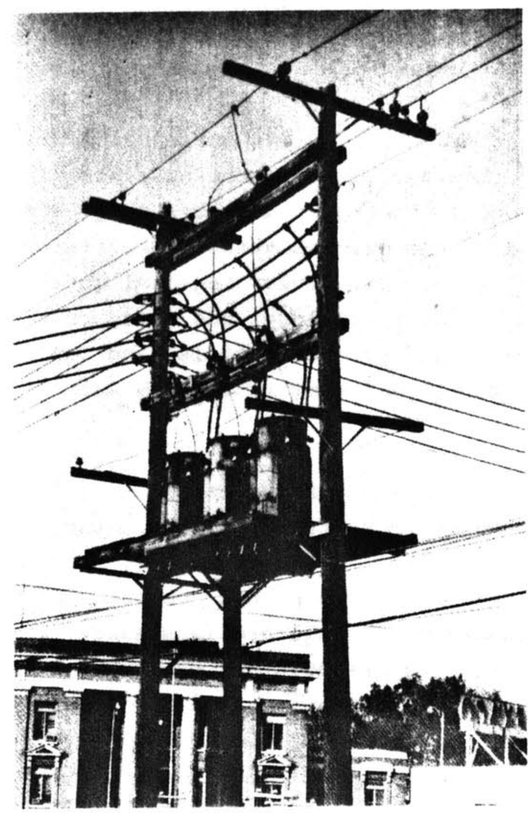
Bottom: A 3- phase 'H-frame' electrical transformer bank, from Mechanical and Electrical Equipment for Buildings.

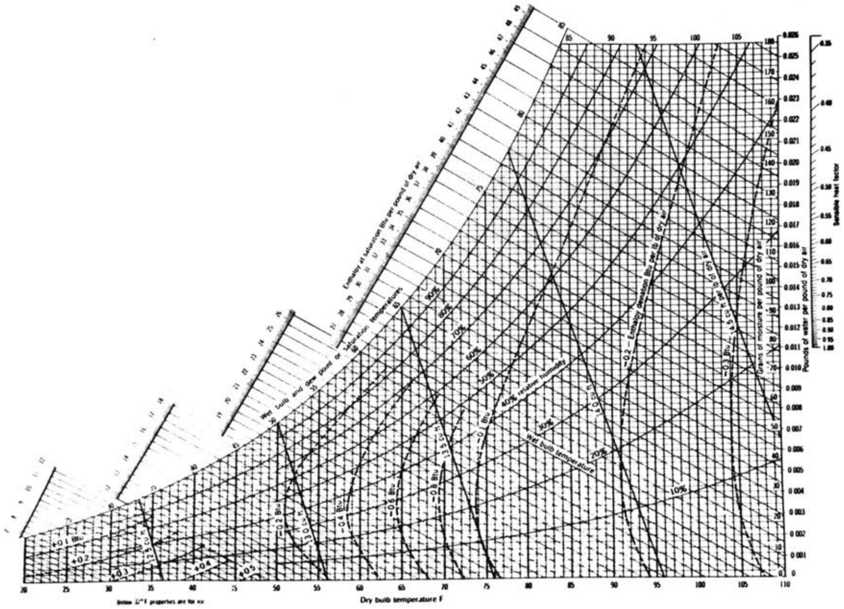


the intellect, knowledge and prediction; or even the beauty of architecture as art, as a creative expression, as an abstract medium, metaphor or humor. Yet these considerations still payed primary tribute to a buildings life supporting value, its purpose for being built: utility as shelter.

The 20th Century: The Dilemna of Technology

Looking at the Western World during the 20th Century we encounter the mass production of machinery for environmental control of buildings, the recognition and ability to change the form of energy, and the technology to harvest, transport and deliver fuel for such purposes. This is compounded by economic frameworks that perpetuate and strengthen as these things are consumed. These global developments have had noticeable affects on the building industry. The established architectural profession can now create an internally controlled environment,





one exclusive of its surround. A previousely developed technology based on the understanding of physical phenomena (thermal, luminious and ventilative properties) which had evolved through generations of building, and which had particular regional qualities, was replaced by a new technology, one based on machines, limited and pollutant producing fuels, and removed from concerns like thermal comfort through natural or climatic modifying means.

There are some recognizable differences in lifestyles between these two eras, which will be referred to as the natural (pre 20th Century) versus the technological (20th Century) thermal comfort control approach. For one, today people are less aware of the source and dynamics of the physical phenomena around them that affects their comfort level. Control systems are hidden; the visual and perceptual shape of contemporary buildings is not formed to react, integrate or have dialogue with external climatic conditions. One likely reason is that designers are not aware of the fundamental principles of energy behavior in buildings. Actually, they are not required to be: sophisticated control systems monitor internal comfort levels, standardized quantifiable environmental control methods for designing are employed, and consultants or mechanical engineers can design systems for almost any building type conceivable. As a result, the qualities that provide thermal comfort in buildings are not synthesized into the design process, they are attached to it.

'Internalization' of Physical Phenomena

The difference then, is that with the 'naturally' controlled approach, the designers and builders understood phenomena around them that determined ones degree of thermal comfort, and they saw its relation to building form. The understanding was, in fact, 'internalized', capable of being an innovative synthesis in design. The 'technologically' controlled approach, explicit in much

Opposite page: The Psychometric chart, a quantified environmental control system design tool, from Mechanical and Electrical Equipment for Buildings.

Right: Gandhi Smarak Sangrahalaya, Ahmedabad, India by Charles Correa, from Architectural Record, July 1980.

of the Modern Movement, has left many practitioners, educators and students ill-equipped to deal with the subject of climatic control and thermal comfort as part of a wholistic synthesis in architectural design.

In all due respect, there has always been some architects, educators and researchers sensitive to energy conscious design, some even utilized design methodologies that incorporated these issues. However, it took a dramatic economic disaster for the idea of energy conscious design to be recognized by the profession at large, and it is only in the more recent years that designers, not technicians or engineers, have explored means of teaching and presenting architectural design with an 'internalized' understanding of physical phenomena.

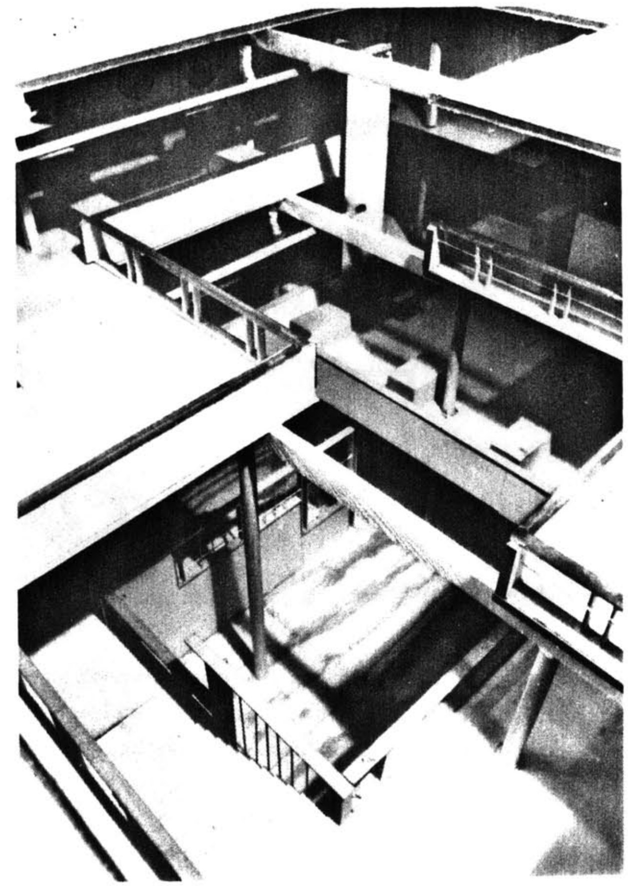
Internalization: Design and Educational Application

How does one teach and practice using this internalized approach? A realistic methodology, which is the basis of this study, prescribes two criteria:

1. The presentation of information displaying or 'visualizing' the basic principles of physical phenomena relative to architectural form. A good foundation of knowledge should be established in an architects diet, especially when the design skills are being developed;
2. The preparation of design tools that are congruous to the design process, that use the same type of analysis, visual thinking, and creative externalization. This approach is one of qualitative assessment and three-dimensional decisionmaking, using tools that maintain a continuous, unhalted design process.

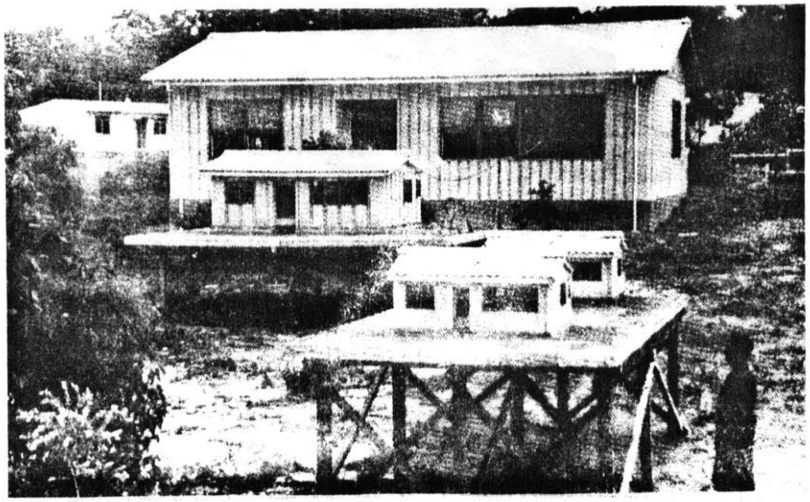
The medium ideally suited for these two criteria is physical models. Scaling factors permit models to be effectively used to summize principles of physical phenomena. The model is a spatial representation system common to the architects vocabulary, as one makes a qualitative judgement of the energy behavior of each design, the usual visual, aesthetic and spatial decisions can be made concurrently. More importantly, the design continuum is not broken. Where quantifiable design tools need translation from alternate thinking modes, design changes along with visual analysis can be made instantly.

Right: A model provides a case for environmental analysis as well as spatial assessment. Model and photograph by J. Crowley.



In conclusion, the process of architectural design utilizing physical models as formgivers, will help architects 'internalize' the basics of energy behavior relative to architectural form, will give a realistic qualitative evaluating grounds for designers to test innovative design concepts with energy concerns, and it will bring a more quality-adjusted, comfortable environment to the users, that is responsive to the climate in an energy efficient manner.

Physical Models



Physical models, a spatial representation system that architects commonly use, are well suited for analysis and comprehension of these phenomena. They can provide the three-dimensional 'setting' for the observer, depicting changing patterns in relation to building configuration.

Modelling, in effect, is a science. Prior knowledge of the topic is essential before testing, and test procedures must be carefully thought out and organized. The following is a description of physical model testing for environmental assessment.

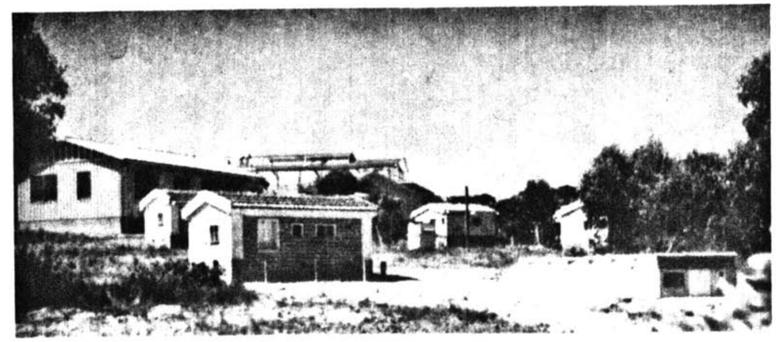
Types of Assessment

There are two types of information one can obtain from testing physical phenomena on models: qualitative and quantitative. Qualitative, or psycho-physical analysis, depends upon seeing or experiencing phenomena as they occur. Quantitative analysis, a process of gathering hard data, involves the interpretation of biological or sensory perception into numerical terms. It requires the use of measuring devices to gauge the quantity of a phenomenon's behavior.

For the purpose of building an 'internalized' understanding for architects, as well as subjecting proposed architectural designs to physical tests, a qualitative approach is the most valuable. In addition to requiring added levels of translation, quantification cannot be presented in the model (the three-dimensional space).

Opposite page: Thermal models tested in Australia, 1949, from *The Theory and Method of Construction of Thermal Models of Buildings*.

Right: Thermal models of domestic and industrial type buildings, from *Models in Architecture*.



Types of Models

There are basically two types of models used for environmental assessment: reduced physical scale models and analogue models. Reduced physical scale models involve subjecting the model to the actual phenomenon under study. This is the case for daylighting, wind tunnel and thermal models. Reduced physical scale models can be used to deduce basic principles of a phenomenon as well as specific results for a particular design. It is sometimes difficult to conduct a qualitative analysis for some phenomena are not visible (air movement).

Analogue models rely on an analoguous physical system to obtain the necessary information. Heat flow models are based on hydraulic or electrical systems, ripple tanks (water) are used for geometric acoustics and waterflow used to demonstrate air movement, are common applications. In an analogue model, one must define and translate boundary conditions from the original phenomenon to another medium. This requires prior knowledge of the phenomenon under study.

Dimensional Analysis and Similitude

In order to use physical scale models accurately, one must have an understanding of dimensional analysis and similitude. If proper scaling does not occur, the test results can be a negative influence on design; i.e. results can be erroneous or misleading.

To complete physical similarity between the full scale and the model, the physical conditions must be such as to make all aspects dimensionally similar. Several dimensionsless products are therefore used. These are quantities, physical constants or any group formed in such a manner that all dimensions (units) cancel identically.

Some typical products are:

Reynold's number: $R = \frac{VL}{\mu}$

Froude's number: $F = \frac{V^2}{Lg}$

Mach's number: $M = \frac{V}{C}$

where:
F = force
L = length
V = velocity
μ = dynamic coefficient of viscosity
g = acceleration due to gravity
C = speed of sound

To obtain dimensional similarity, the products for the full scale and the model must be equal:

$$\frac{\rho V_1 L_1 \; 1}{\mu_1} = \frac{\rho VL}{\mu} \qquad \frac{V_1{}^2}{L_1 g} = \frac{V^2}{Lg} \qquad \text{and so on . . .}$$

Therefore, the choice of scale is not an arbitrary geometrical choice, but one necessarily based on principles of physical similarity in testing. Thus, four points can be drawn:

Right: The Classical Theory of Similitude, from "Models in Design of Buildings".

1. In order to reduce scale effects, it is desirable to use as large a scale as possible.
2. The conditions of testing should be such to ensure physical dimensional similarity as far as possible.
3. The relative importance of the different dimensionless parameters should be carefully considered in relation to the problem under study. Highest priority should be given to achieving dimensionless similarity for the most critical problem.
4. The limitations of the model test should be clearly stated in putting forward any experimental conclusions.

The Classical Theory of Similitude:

Two phenomena are similar, if the characteristics of one can be obtained from the assigned characteristics of the other by a simple conversion, which is analogous to the transformation from one system of units of measurement to another.

The two phenomena are the prototype and model respectively, whilst the conversion factors constitute the scaling factors between the systems.

To ensure similarity between prototype and model systems certain design conditions govern the model design.

By dimensional analysis using the Pi-theorem, the general equation for the prototype may be written as

$$\Pi_1 \quad F(\Pi_2, \Pi_3, \Pi_4 \ldots, \Pi_{r-n}) \quad . \quad . \qquad (1)$$

where r number of physical variables in system.
n number of basic dimensions.
F represents some functional relationship of the $\Pi_2, \Pi_3, \ldots, \Pi_{r\ n}$ terms.

This equation, being completely general, applies also to another kindred system, which is a function of the same variables. Hence it applies to a particular system called the model, for which we have

$$\Pi_{1m} \quad F(\Pi_{2m}, \Pi_{3m}, \Pi_{4m}, \ldots, \Pi_{(r-n)m}) \qquad (2)$$

Dividing equation (1) by (2)

$$\frac{\Pi_1}{\Pi_{1m}} \quad \frac{F(\Pi_2, \Pi_3, \Pi_4, \ldots, \Pi_{r-n}}{F(\Pi_{2m}, \Pi_{3m}, \Pi_{4m}, \ldots, \Pi_{(r-n)m})} \qquad (3)$$

Now, if design conditions are such that

$$\Pi_2 \quad \Pi_{2m}$$
$$\Pi_3 \quad \Pi_{3m}$$
$$\Pi_{m-n} \quad \Pi_{(m-n)m}$$

Then $F(\Pi_2, \Pi_3, \Pi_4, \ldots, \Pi_{r-n}) \quad F(\Pi_{2m}, \Pi_{3m}, \Pi_{4m}, \ldots, \Pi_{(r-n)m})$

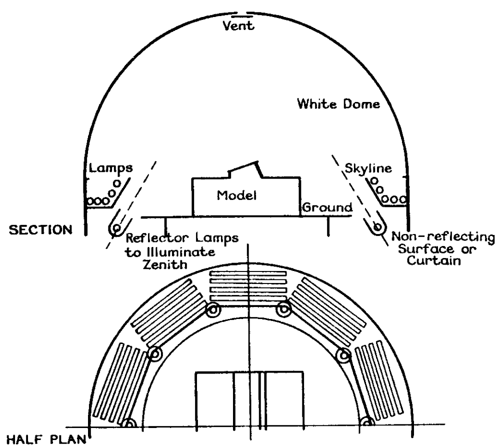
Hence $\Pi_1 \quad \Pi_{1m}$, giving the conversion factor for variables making up the Π_1 term.

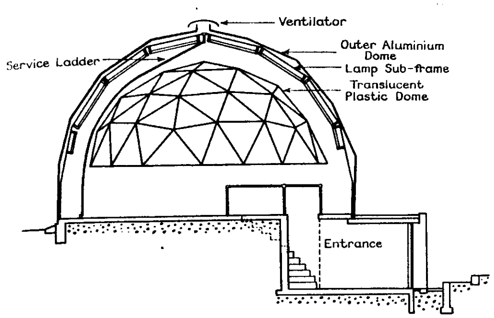
Prototype and model are then said to be completely similar and *all* significant characteristics of **the prototype are accurately predictable from the model, which is called a *true model*.**

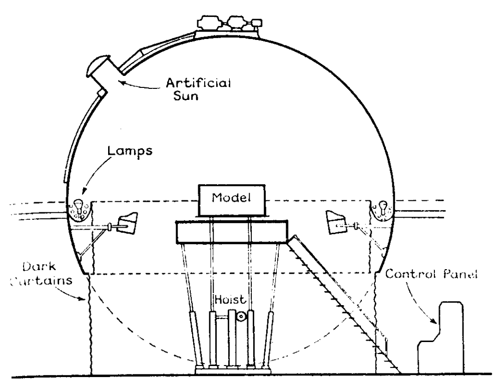
***Adequate models* are models from which accurate prediction of *one* characteristic of the prototype may be made, but which will not necessarily yield accurate predictions of other characteristics.**

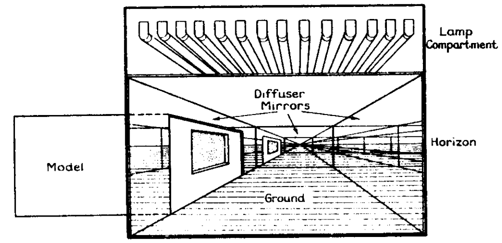
A *distorted model* is one in which some design condition is violated and a correction may or may not be readily deducible.

***Scale effects* will arise whenever true similarity is violated.**







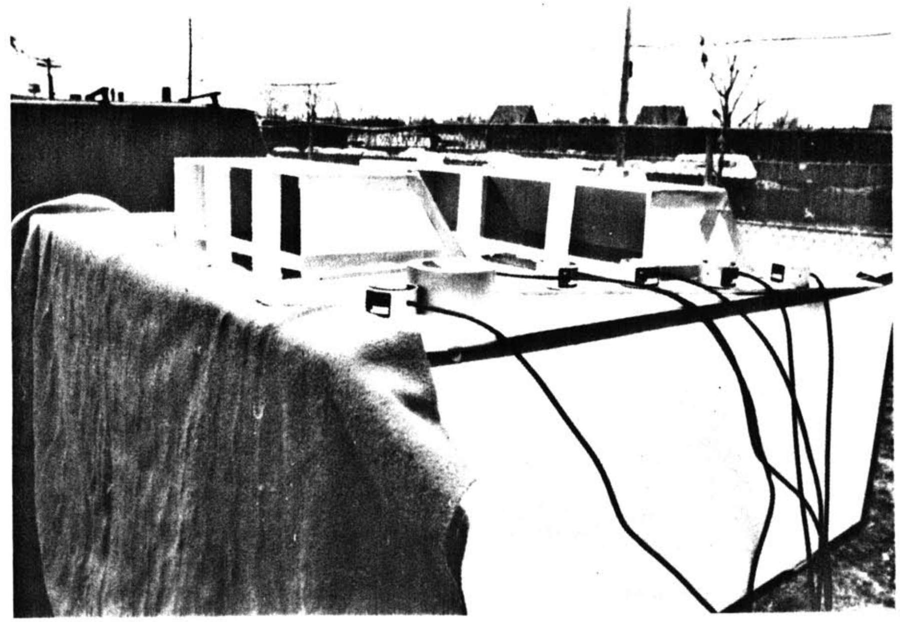


Testing Fields

There are two fields in which reduced physical models are tested: natural and artificial environments. Natural environments involve testing the model under the actual environmental conditions under study (outdoors, ideally at the site). This enables one to meet the full range of boundary conditions that will be encountered in practice. However, such environments rarely provide the actual design condition that it is wished to study. For example, when testing the effects produced in a building on an overcast day, the design condition may be hard to meet and may be continually changing, making data difficult to compare.

Artificial environments require that the environment be duplicated with attention to the design condition accepted in practice for design purposes. The artificial environment allows parametrics to be easily compared. The effects of design changes can be interpreted with precision

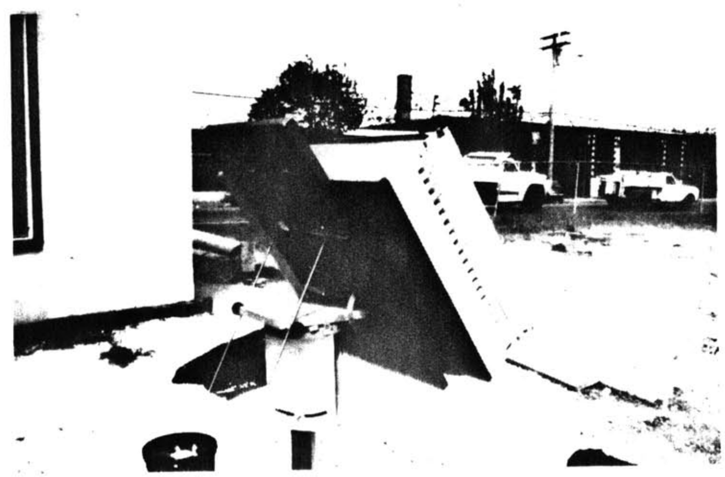
Opposite page- far left(from top to bottom): A hemispherical artificial sky, the transilluminated artificial sky at the Cambridge School of Architecture, the artificial sky at the Academy of Building and Architecture in Moscow;
left: A rectilinear mirrored artificial sky, from Daylighting.



Right: A daylight model being tested under the natural environment. Model construction and photograph by J. Crowley.
Bottom: A daylight model tilted for direct sun analysis.

and thus, the user has a better chance of converging on an optimal solution.

While the artificial environment offers an attractive research possibility, it may be difficult to replicate certain environmental conditions. Natural environments require less elaborate and cheaper facilities, but the variability of the external climate may make interpretation of results difficult.



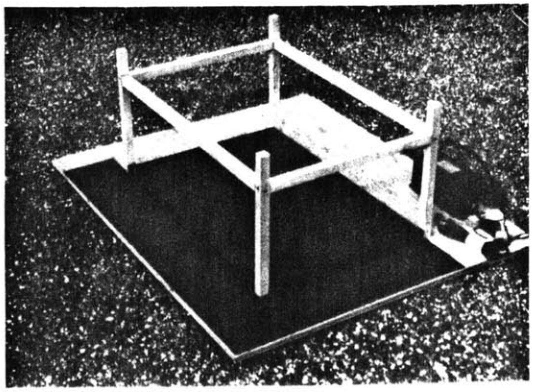
Opposite page: Modular type of construction for a daylight model. Model construction by C. Mathis, A Lohr, and J. Rosen. Photograph by J. Rosen.

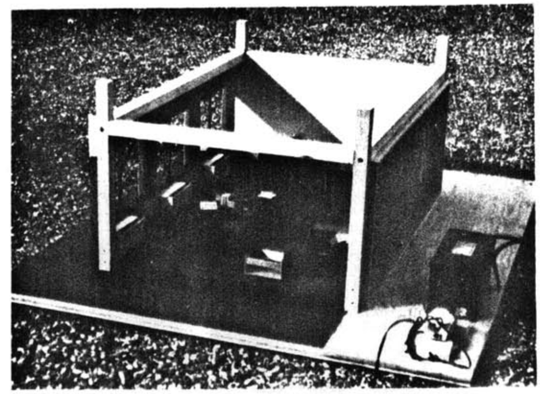
Model Construction

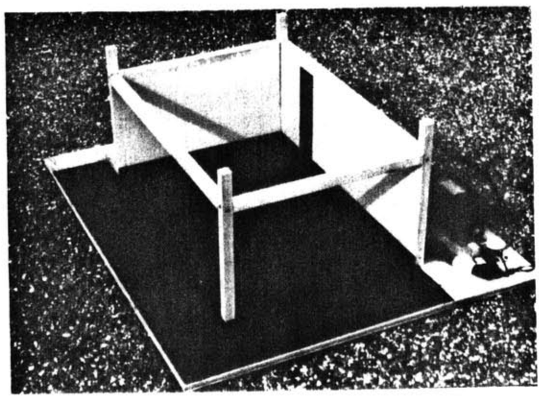
Depending upon the environmental phenomena being tested, models will have different construction constraints. In most cases, testing requires the isolation of a particular phenomenon within or around a building so that the test is not interferred with by external factors. This isolation calls for construction methods that can 'seal' that phenomenon from entering or leaving the model. For example, in lighting studies, the model must be "light-tight," allowing light to enter only through established windows or openings; in thermal studies, the model should be "air-tight," and, if necessary, insulated against external conditions that would interfere inside the model.

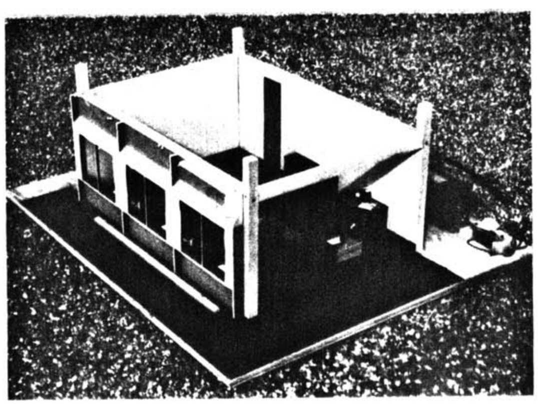
Models should have a flexible design and construction method, so architectural parameters can be tested. A modular type of construction offers the most flexibility. For example, a structural frame should be made so walls of different sizes and materials can be easily replaced and sealed. One must always be prepared for unpredictable changes that will need to be made as testing progresses.

Various measuring devices are often placed in models and sometimes require moving to specific test points. The design of the model should accommodate the position and ability of these without interfering with test results.







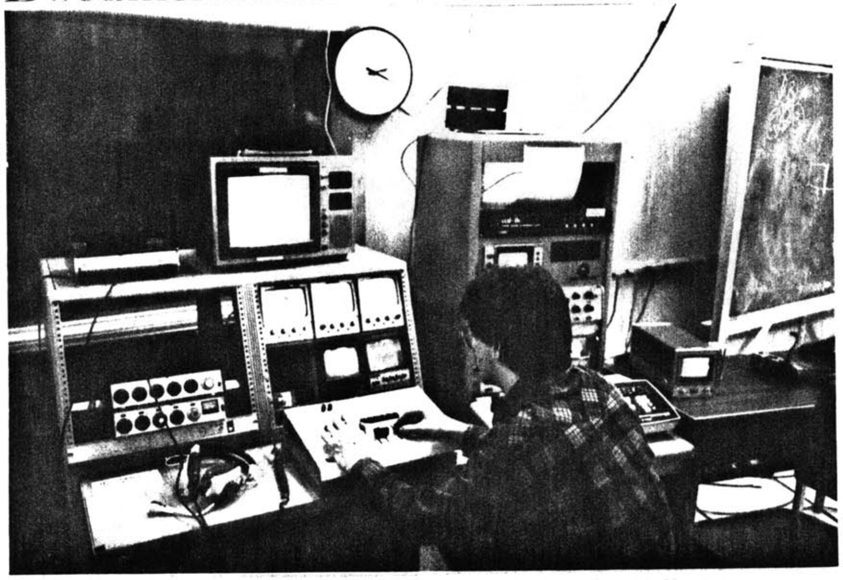


Testing Procedure

Like any good test procedure, the entire process should be organized and identified before starting. Below is a practical procedure for physical model testing:

1. Decide what is to be observed and what kind of information is desired (quantitative or qualitative).
2. Decide what type of model is appropriate; what testing field best accommodates the study (analogue or reduced physical scale; artificial or natural test field).
3. Choose the correct scale and boundary conditions by dimensional analysis and similitude.
4. Decide the format that test results will take (numerical, photographic, etc.).
5. Design and build the model with the proper observation and/or measurement accommodations.
6. Run the test, document results.

Documentation: Research Communication

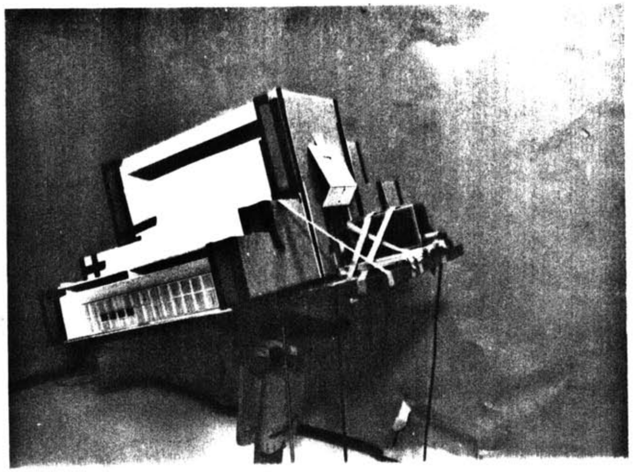


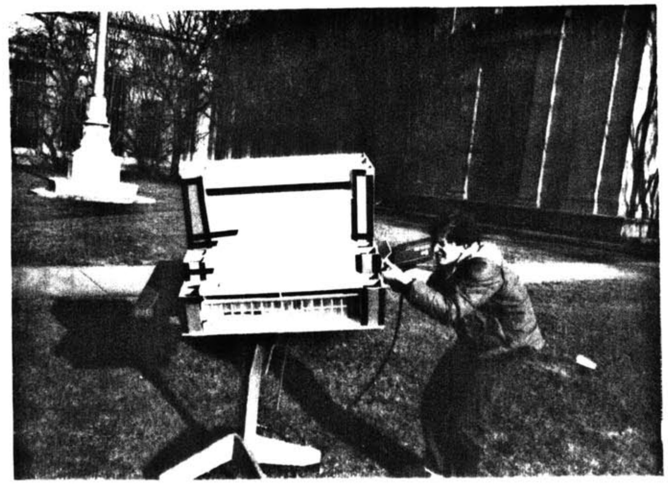
left: Video editing at Educational Video Resources, MIT.
Opposite page right: A daylight model with a video camera attached,
far right: video-taping the same model outdoors,
bottom left: from The Passive Solar Energy Book,
bottom right: video-taping the flow table,
photographs by C. St. Clair.

The documentation of any experimental research depends upon the nature of the experiments and the audience for whom the research is intended. In the case of the physical model studies, where the characteristics of each test are both spatial and temporal, any documentation medium selected should successfully represent both space and time.

As established in part I, spatial representation is visual. Architects, in particular, rely on the visual presentation of information. A recent publication on a related topic that has had overwhelming success in the architectural profession, The Passive Solar Energy Book by Ed Mazria, acts as a model for communication to architects. This book utilizes graphic presentation of material whenever possible. Such information is not new, but the way it is presented has given architects a valuable resource to turn to. Learning from this book's effectiveness, the attempts to communicate the test results using models were decided to be visual and qualitative from the start. This had a serious effect on the testing that could be addressed. For thermal and ventilation studies, most often an analogue or visual additive had to be introduced. (Although, one convection test was documented without any visual additive!)

Photography offered the most variation and potential for these tests --various lenses, films, papers, and special effects helped document the actual behavior of physical phenomena. Video has enabled the documentation to register behavior over time. Light levels and clarity of pattern are sometimes a serious problem; however, a video presentation of this research is being prepared.





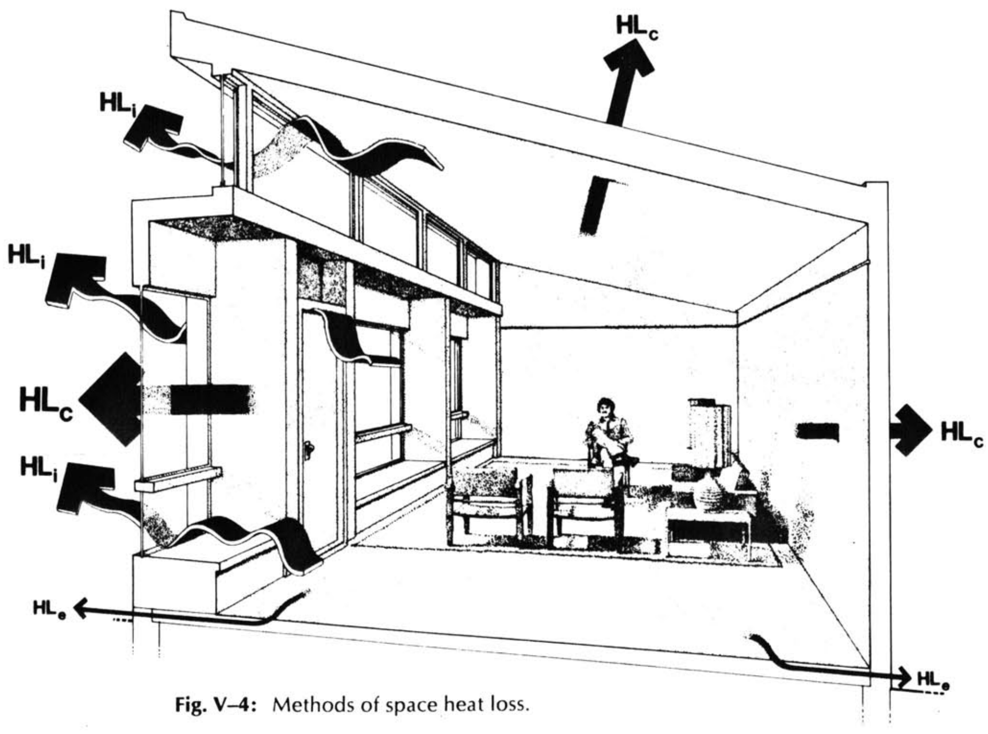
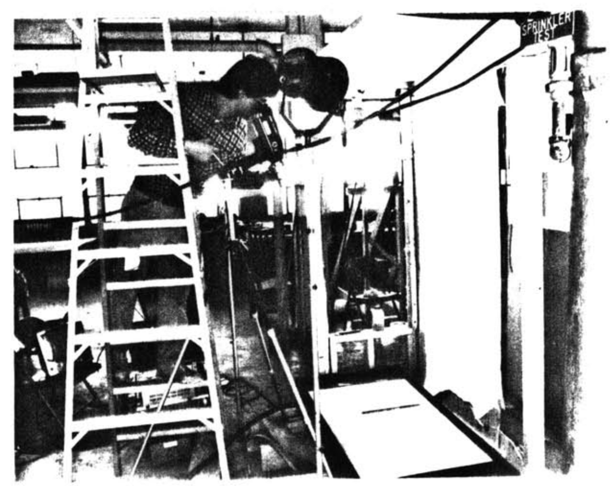
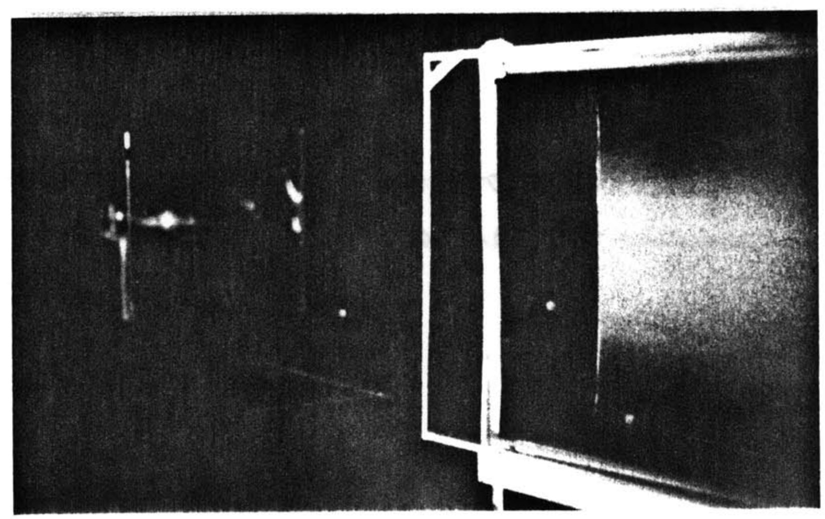


Fig. V–4: Methods of space heat loss.

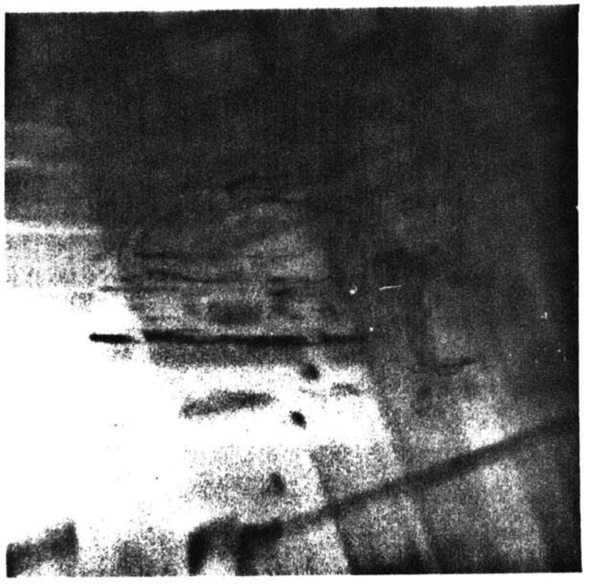


Chapter 5

Test Results

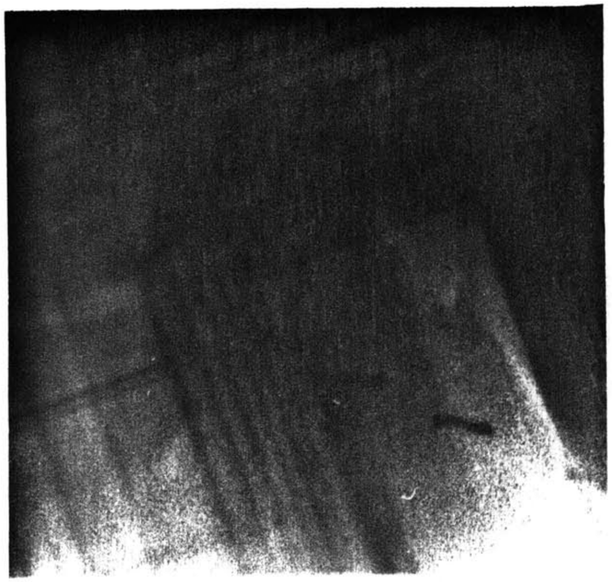


Opposite side: A high contrast print showing a laser light slicing through a convection model, a study developed in this project.



"Every extension of knowledge arises from making conscious the unconscious."

Nietzsche

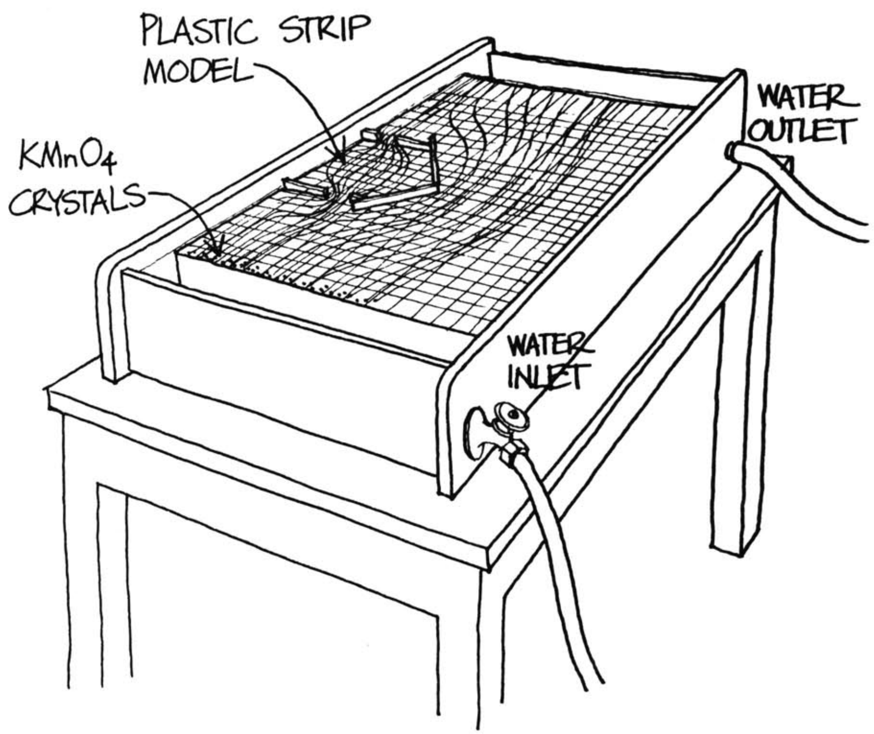


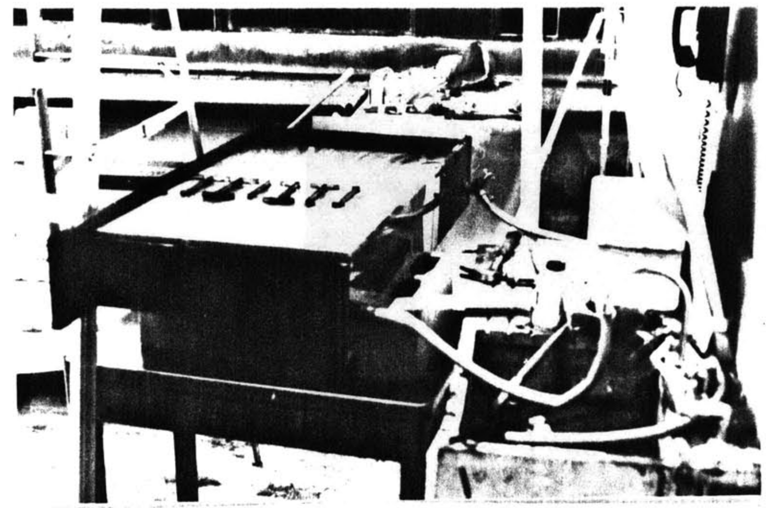
Technical Notes

The photographs in this chapter, unless otherwise de-noted, were taken by the author using a Nikon FE 35mm SLR camera with either a 28mm or 50mm Nikor lense. Black and white photographs were taken with Kodak tri-X (400 ASA) film; color slides were taken with Kodak Ektachrome (tungsten 160 and 400ASA). Photograpns were enlarged by the author onto Kodak Polycontrast II RC type F, Kodak Polycontrast type F, or Agfa-Gavaert Copy-proof CPN and CPP.

WIND...

The Flow Table

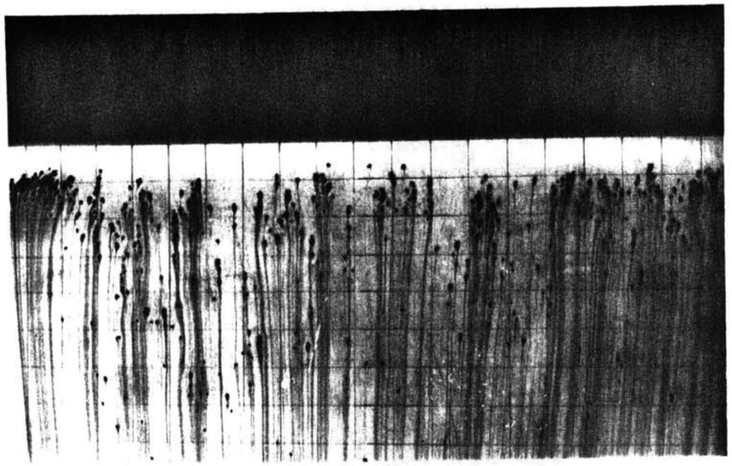




The flow table is an analoguous modeling system that utilizes flowing water to simulate wind flow. A thin layer of water will naturally flow down a slightly tilted glass surface. Pieces of plastic placed on this surface will cause the water to flow in various directions around these obstructions. The plastic pieces can be arranged to represent a section or plan of a building. The patterns formed by the water as it flows in and around these cross-sections will be analoguous to wind flow as it would occur in the real scale.

A coloring agent, potassium permanganate, which turns purple when placed in water, can be used to visually trace these patterns. As water passes over each crystal it pulls a line of color. Each line will flow continuously downstream. The production of these lines allows the phenomena to be visualized.

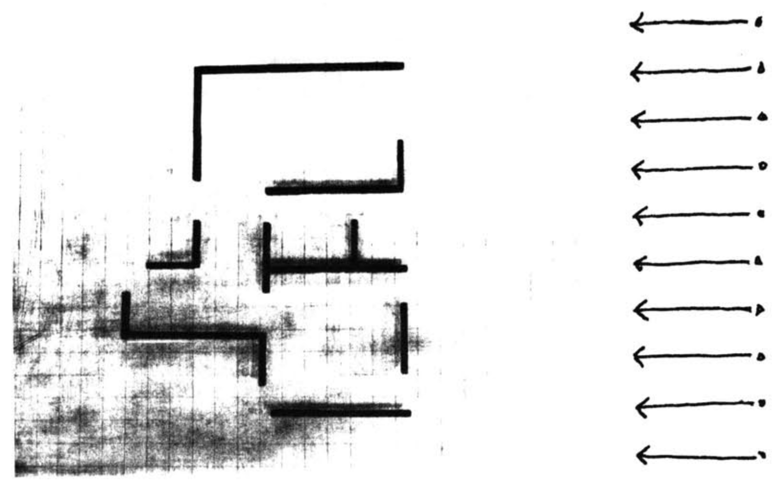
The flow table is a qualitative method that can be surprisingly accurate and powerful for building an under-



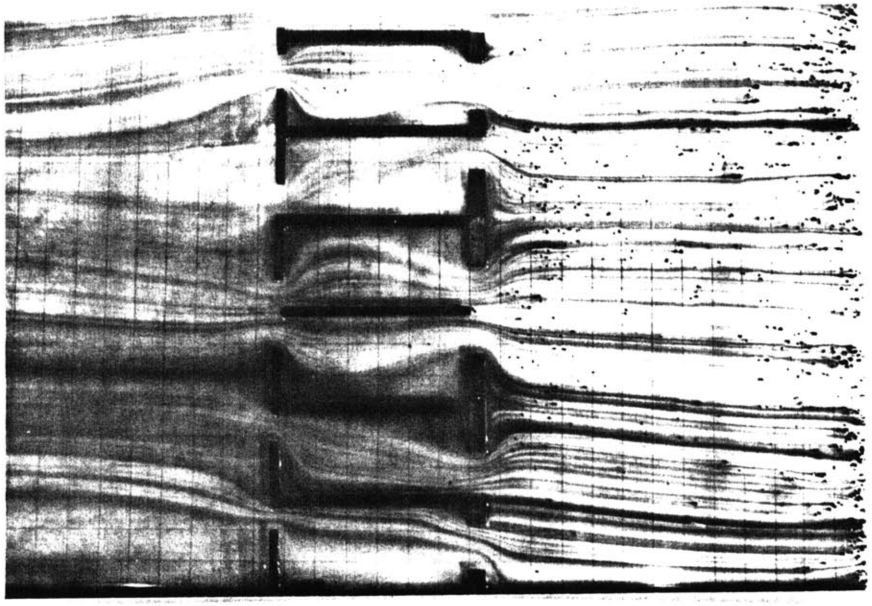
Opposite page: left- Drawing by E. Allen
top- Photograph of flow table in use.
Left: Potassium permanganate crystals with water flowing over them.

standing of wind flow in structures. Keeping in mind that it is two-dimensional and the introduction of another opening in three-dimension will cause a difference in behavior, the flow table can help internalize this phenomena at least to the level where it can be addressed in the design process. It introduces a visual system for comprehending and predicting wind performance. As one continuously uses this tool (as I have) it becomes easier to predict wind patterns for each building. Like designing at ones desk, one can 'picture' the design on the flow table, how wind flows around it, and how changes in openings will affect wind behavior.

The flow table was conceived by N. Mitchell and built by I. Garabieta. It was used extensively by E. Allen at MIT for a building technology course.

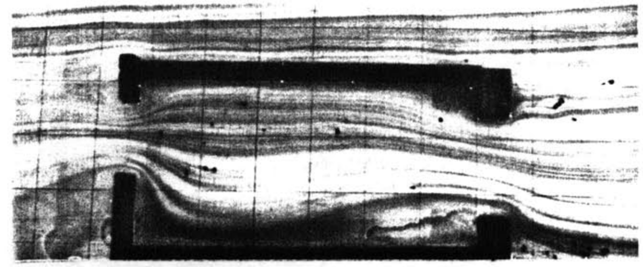


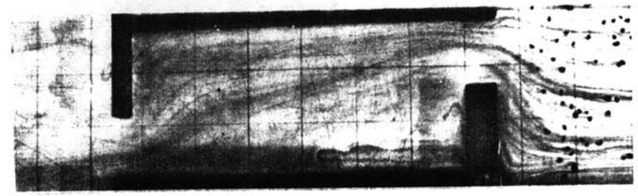
Question: Put tracing paper over this house plan and draw the flow 'lines' as you think they would occur. On the following page is the result of this test. Is your intuitive sense correct?

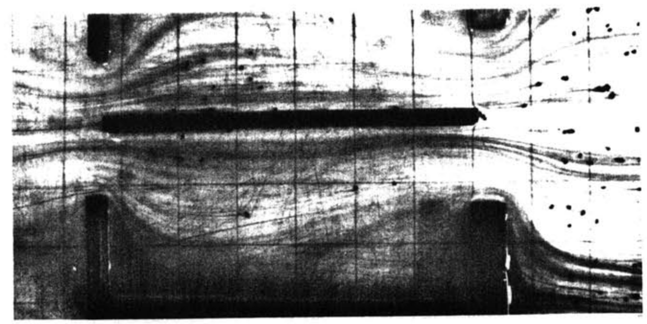


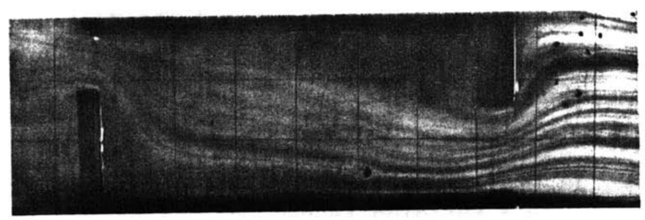
Test 1: Development of Principles

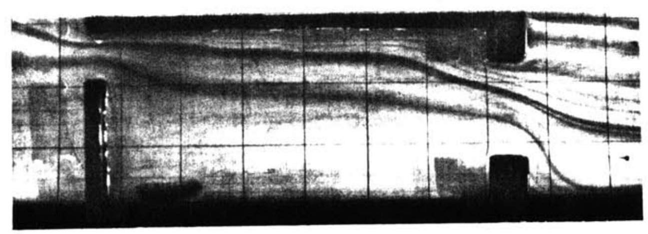
Consider the building configuration to be a section through a six story building. (Each square box is equal to three feet) One can notice that each window placement causes wind to converge and diverge in various patterns. Depending on the activity in the building, one can control the wind flow where it is desirable. For instance, the bottom configuration will cause the strongest wind flow pulling heat near the ceiling from the room. However, it would not cause air movement to pass by a person standing in the space, as the configuration above it would.

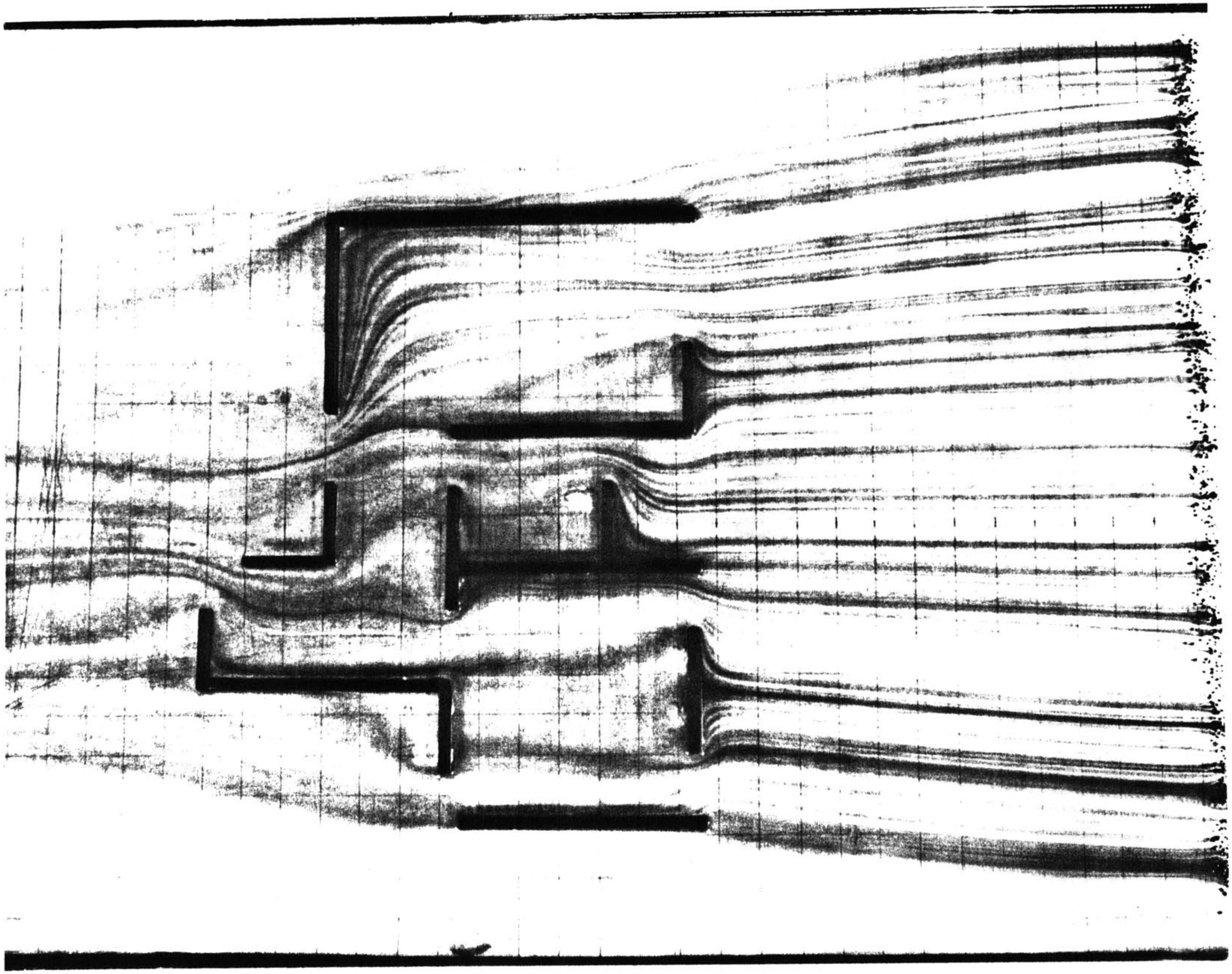


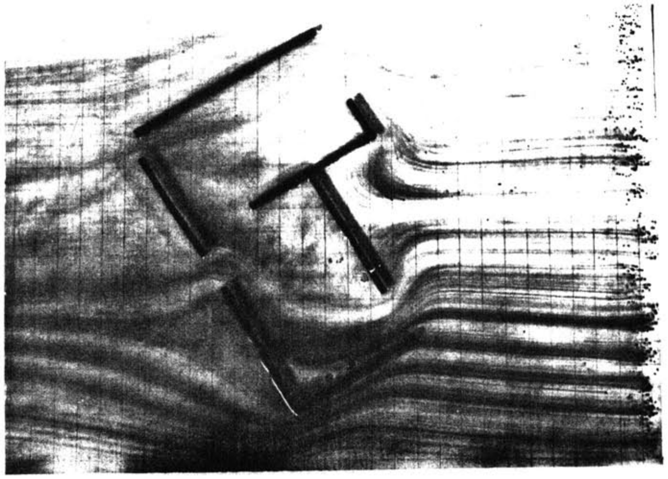


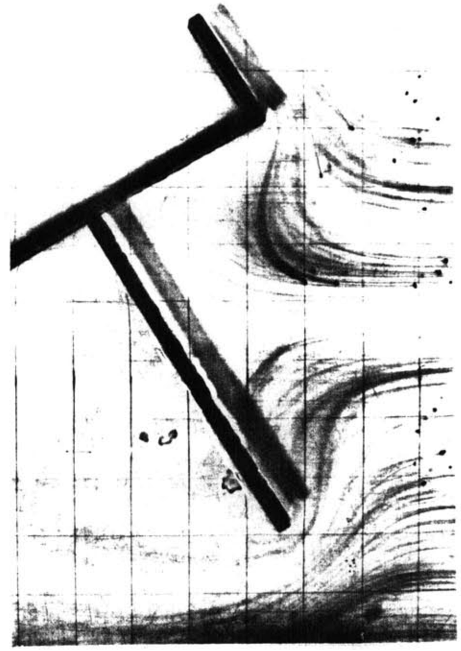


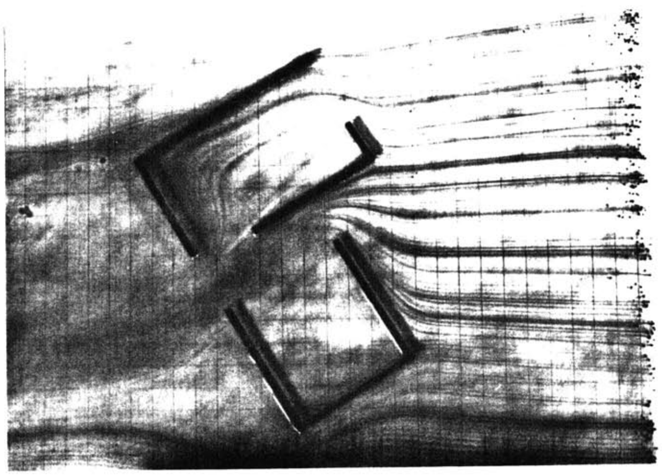








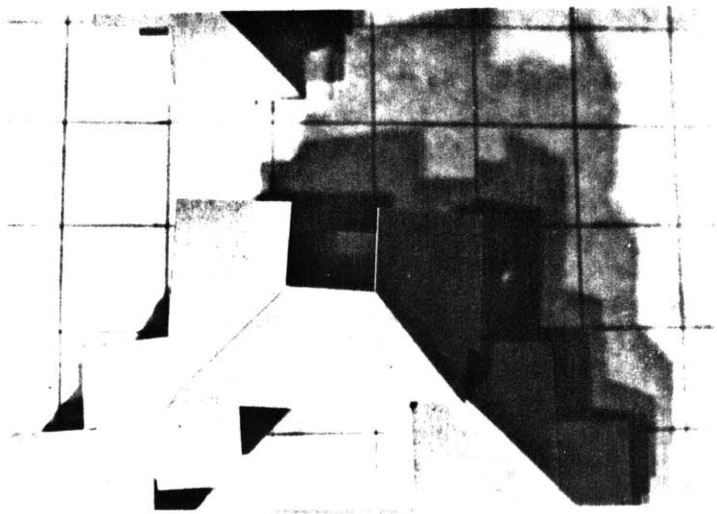


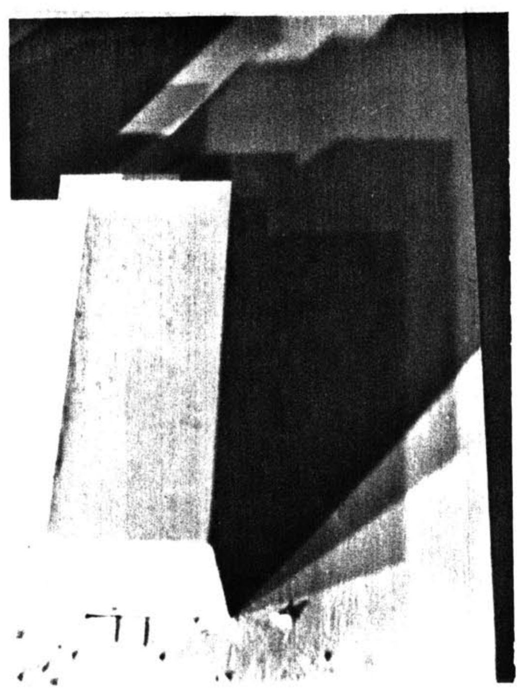


Test 2: Use as a Design Tool

First, the simple design was prepared. As it was being tested it became obvious that there was a strong current through the center of the building and very little wind flow in the upper space. Changes were made as the water was flowing. The top configuration offered a reasonable solution, providing air movement in both spaces, as the program required. This design tool allows designers to make changes and visualize results immediately. In fact, the visual patterns 'hint' at changes for optimal solutions.

SOLAR SHADING...



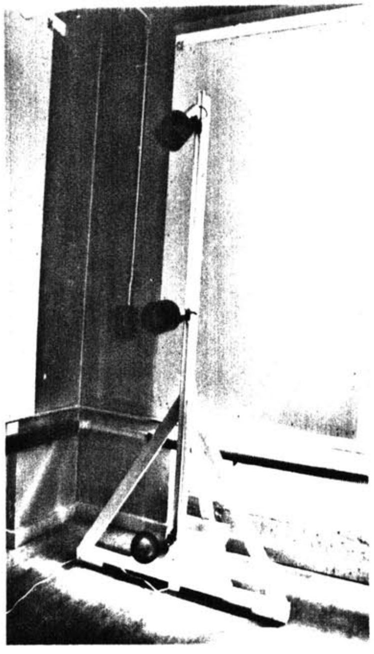


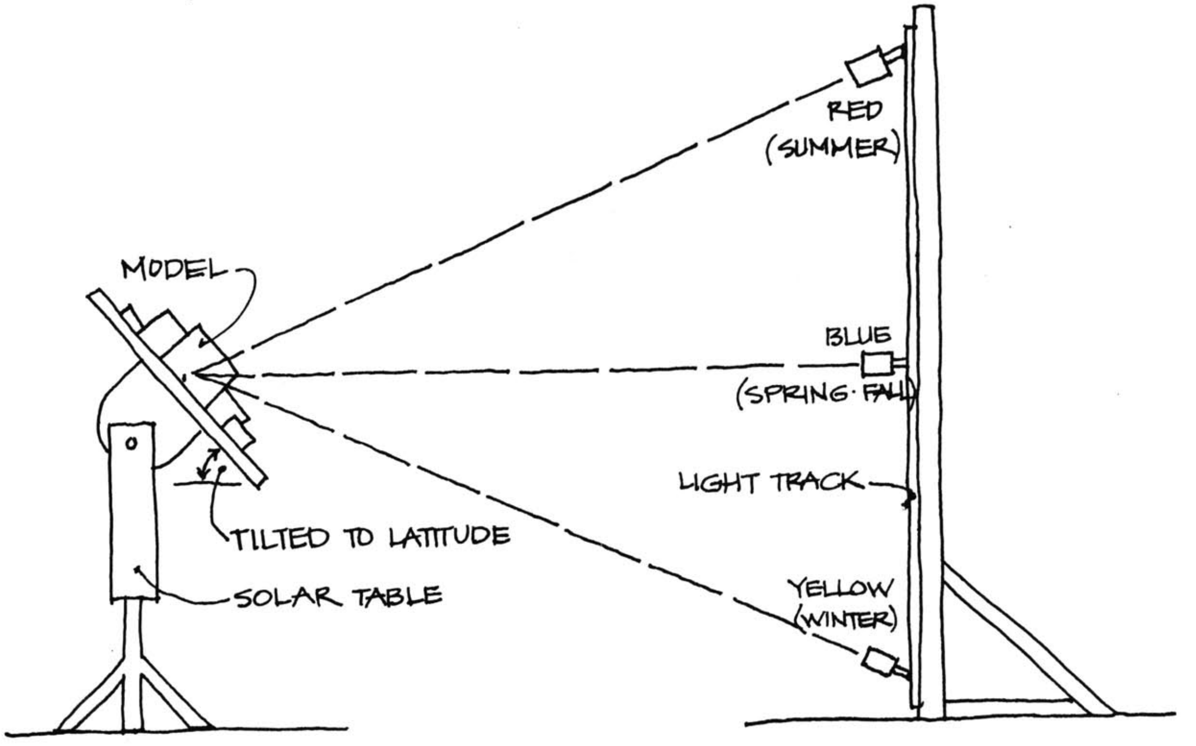
The Season Shadow Simulator

Understanding the continuousely changing position of the earth in relation to the sun is a difficult endeavor. Each hour the height of the sun in the sky (altitude) as well as its position from the north-south axis (azimuth) changes. Furthermore, this daily pattern is different for each day of the year.

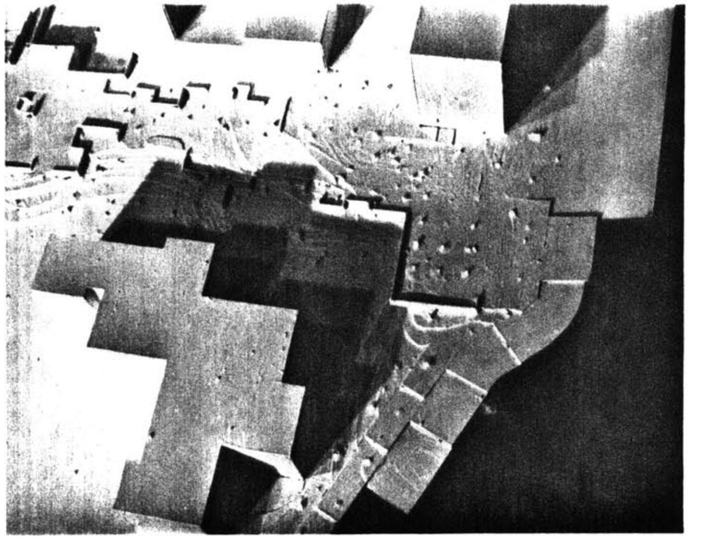
The sun has been one of the primary generators of architectural form for pre-20th Century architecture, and for a good part of the architecture built in this century. Such an approach to architectural design involves manipulating this light and heat source through three-dimensional volumes, different materials and fenestrations.

The Solar Shadow Simulator is a tool that makes explicit the relationship between the sun and a building for the three major sun positions during the year (winter, summer, and the equinox conditions), or for any time of the year if desired. It relies on the use of three different colored light sources, all positioned in a specific relation



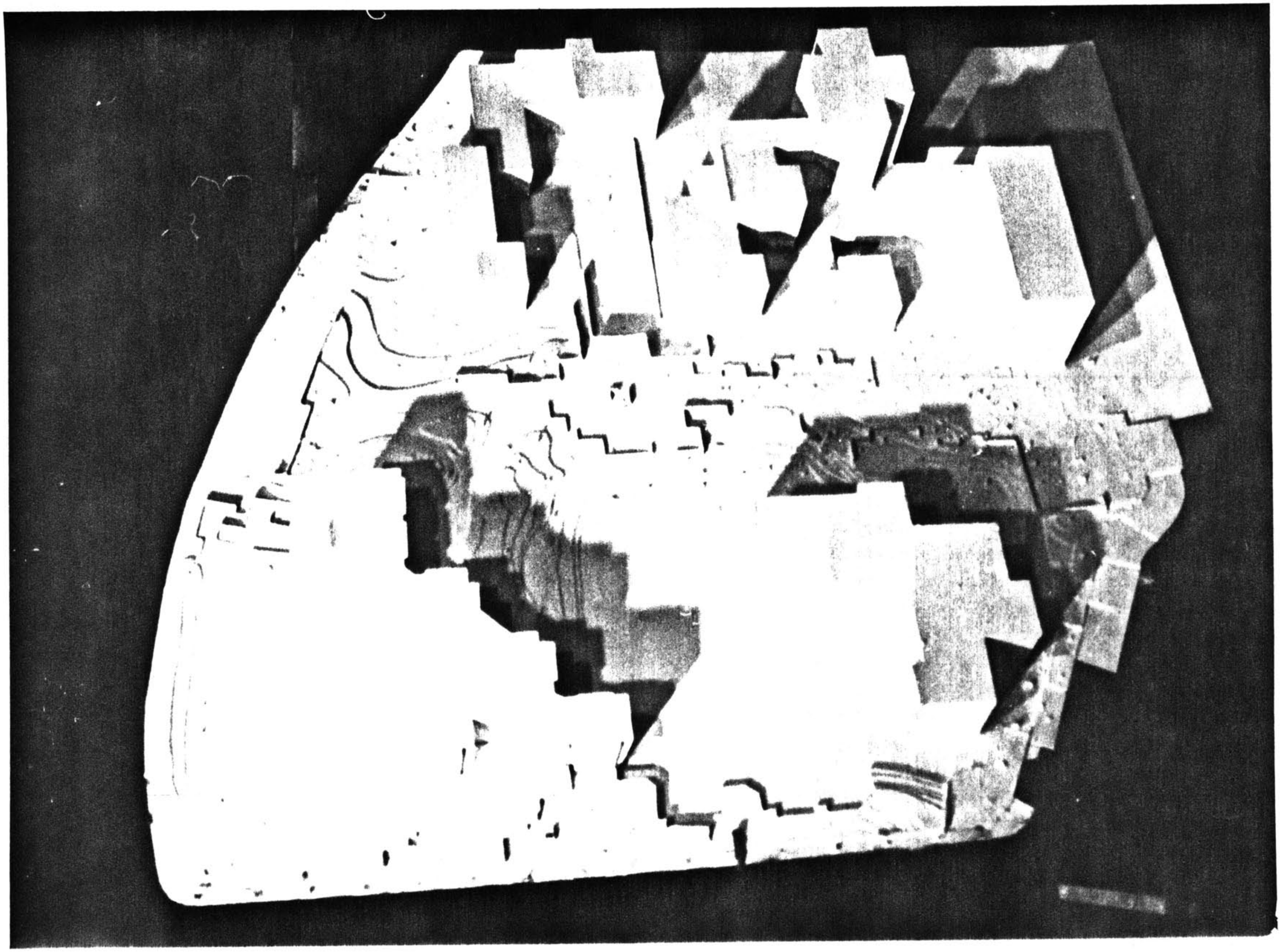


to the building model. These three lights will form different colored shadows. The viewer can observe the shadows caused by the building and the internal penetration of the sun for different times of the year simultaneousely. If the model is placed on a rotating solar table that is tilted to the proper latitude, one can visualize shadow patterns for the entire day for these three different times of the year.



Besides testing shadow patterns of a particular design solution, one can begin to 'internalize' the three-dimensional dynamics of this important energy source.

The Solar Shadow Simulator was conceived by Harvey Bryan, Architect and Educator, and it was built by Donald Alberto.



CONVECTION...

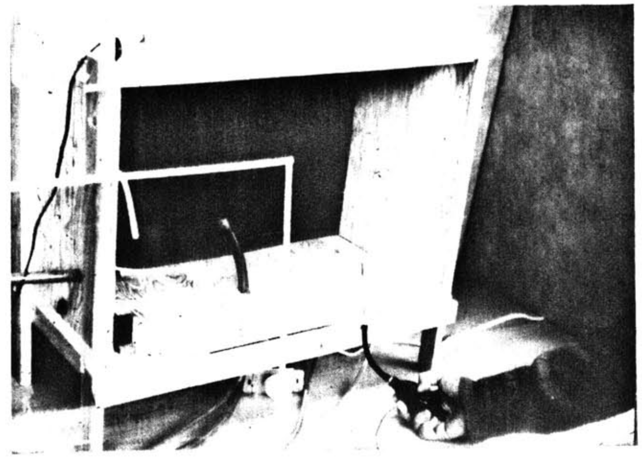
Visualizing Convective Air Flow: 2 Methods

Thermal Modeling

Convection or natural air circulation in buildings which is caused by the differences in temperature in a space, is poorly understood. Convective heat transfer from interior surfaces and the heat transfer between adjoining areas due to air circulation for typical interior geometries are so complex that reliable theoretical solutions are not yet available.[1] Physical models can be used to deduce such information for both specific design criteria and the expansion of the theoretical base on the topic.

The program for thermal model testing is one of rigorous boundary condition control through mathematical computation. Proper similitude can be attained in an exact thermal and hydrodynamic model if the following considerations are met[2]:

1. Identical geometry.
2. Identical Grashoff numbers to reproduce free convection patterns. Since the walls generally have varying temperatures, the wall dimensionless temperature distribution needs to be preserved.
3. Identical Prandtl numbers to reproduce the distribution of free convection heat transfer coefficients. In conjunction with requirements 2, this implies identical Rayleigh numbers.
4. Because of requirement 2, the free convection Reynolds number, as well as the flow patterns will be identical. Together with requirement 3 this would imply identical free convection Nusselt numbers as well as their distribution.
5. To accurately portray transient responses the ratios of all thermal inertas should be preserved. In addition, the ratios of transient conduction penetration distances to wall thicknesses needs to be the same over the thermal cycle time scale.



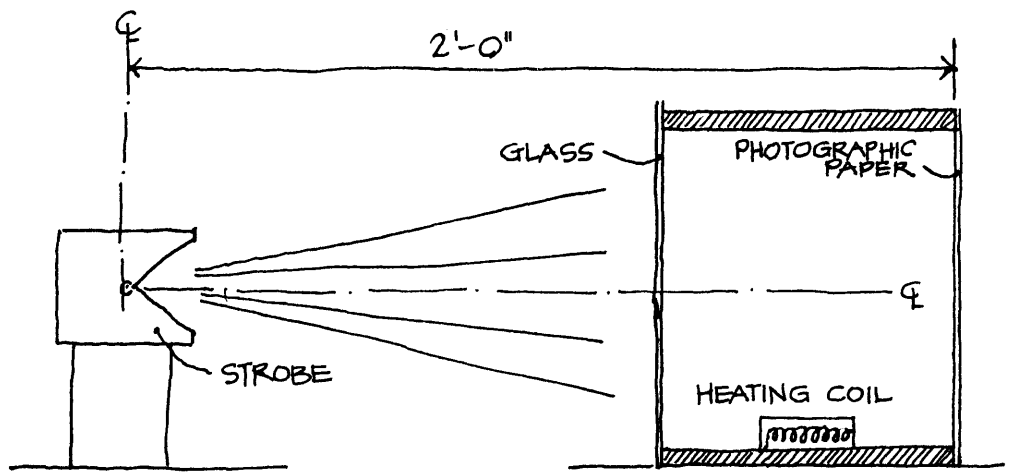
Preparing the Tests

Visualizing convective flow accurately is as difficult as monitoring the phenomenon's behavior. It presented the most difficulty of any of the modeling studies that were conducted. Several months of experimentation yielded two visualization methods that produce valuable and recognizable results. One method explored the visualization of convection without the addition of any visual additives, the other used smoke as a means to identify air movement patterns.

The Test Box

A rectangular box representative of a typical dwelling space was prepared at a scale of two inches equal to one foot. The box was constructed of wood in a modular frame. It was well sealed and the frontal plane was plate glass to allow viewing and photographing. A small heating coil with an adjustable control was placed in a corner of the model. Various holes and slits were made when needed; these allowed smoke or light to enter when required.

Several dimensionless characters were established (Grashoff and Reynolds numbers). It was calculated that a temperature of approximately 250% F produced by the coil would simulate the action produced by a radiator in a room.



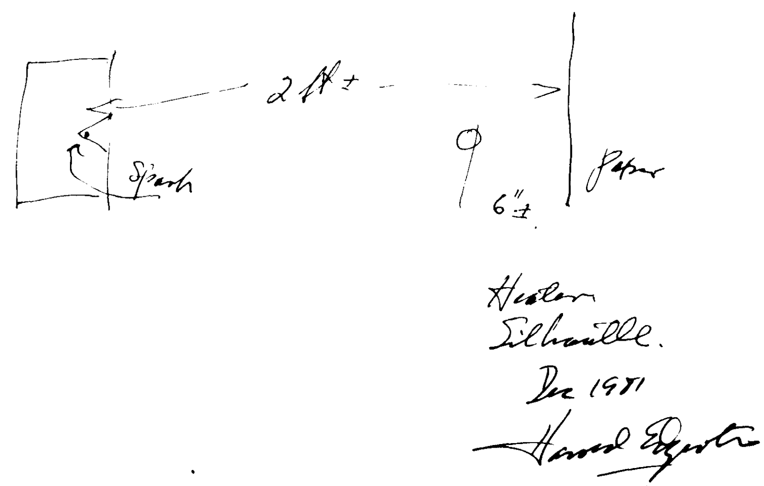
Test I: Shadowgrams, High-Speed Photography

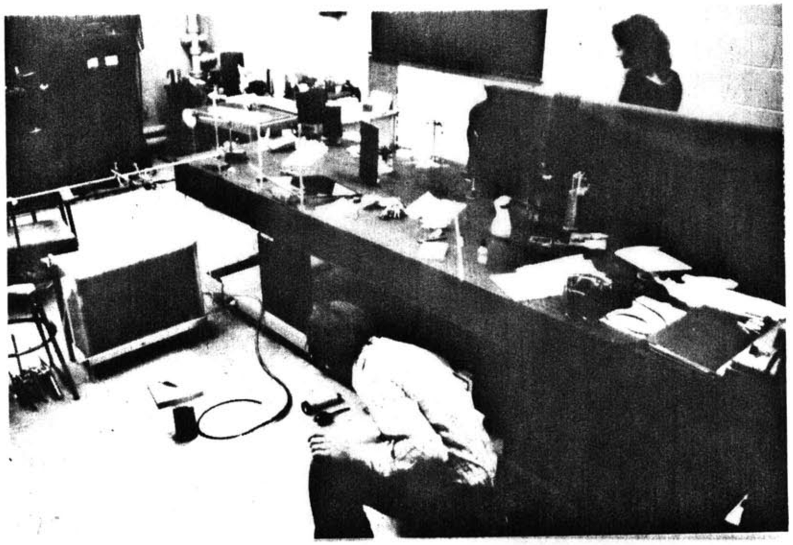
The visualization of convection is basically one of depicting changing patterns in the temperature of air which produce changes in the density of air (causing hot air or less dense air to rise due to gravity). The physical property utilized to 'see' convection was the fact that various densities of air cause different refractions or bending of light. By directing a light source through a convective loop, refracted light can be recorded on photographic paper.

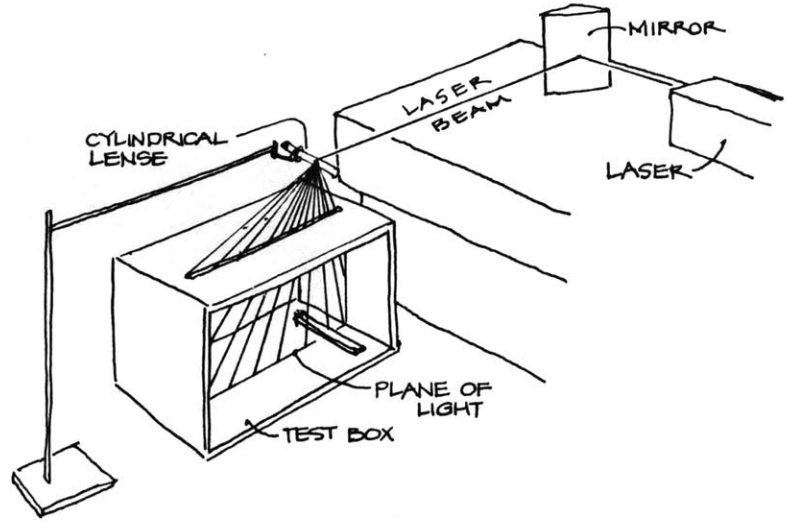
Preliminary tests showed that a high speed light source had to be used. A strobe that flashes light for a micro-second (10^{-6} or one-millionth of a second) was directed through the model as a convection cycle developed internally. A high contrast black and white photographic paper was placed on the rear wall of the model. The slight refraction of light caused by the changes in density of the air were recorded on the photographic paper.

These refractions produced clear images of the air movement above the heating coil.

The test was conducted with the help and equipment of Harold 'Doc' Edgerton and his stroboscopic laboratory at MIT. His valuable aid is deeply appreciated.



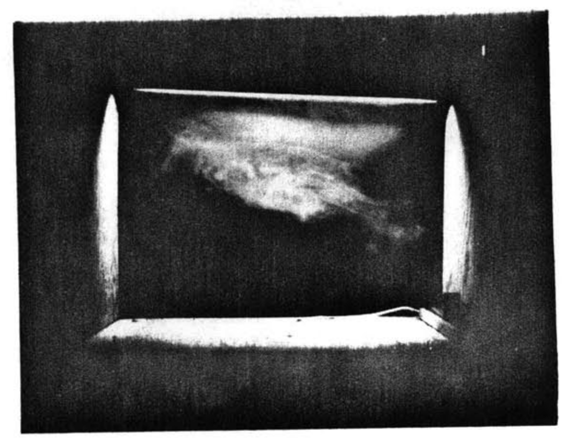




Test 2: Smoke Visualization with Laser Light

Adding smoke to the test was a practical idea for visualizing air movement. One major difficulty arose: finding a proper lighting condition so the smoke can be photographed. After trying several lighting sources and position variables, it seemed the only alternative for producing a clear picture of air movement was to create a planar slice of light through the model. An attempt was made to produce a plane of light with a fluorescent light source by passing it through a deep slit before the light entered the model. This did not provide clear, definable information that would photograph well. Finally, experiments were made with laser light. When laser light is passed through a cylindrical lense (we used a test tube of xylene), the light is dispersed into a plane. This plane was directed through variuos portions of the model. Whenever smoke passed through the plane it was illuminated. Clear patterns of convection became visible.

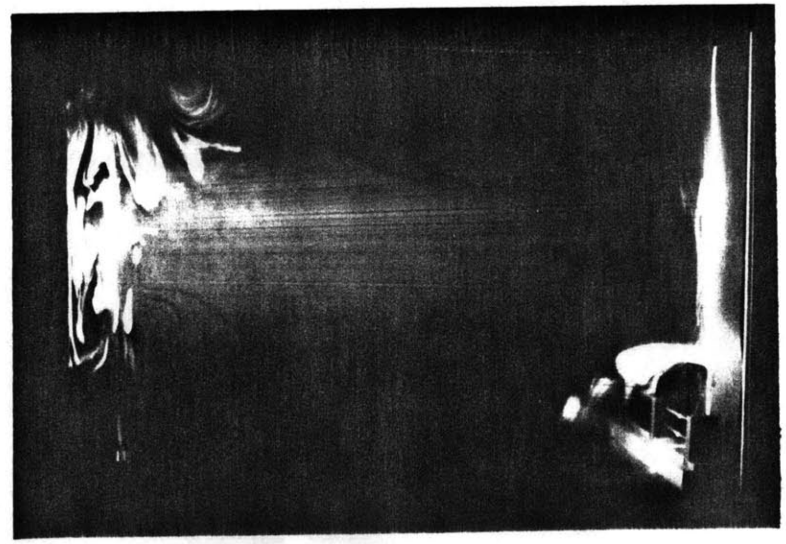
The tests were conducted at a MIT Regional Spectroscopy laboratory with help from Sally Weber from the Center for Advanced Visual Studies, MIT. Her valuable aid and knowledge is greatly appreciated.

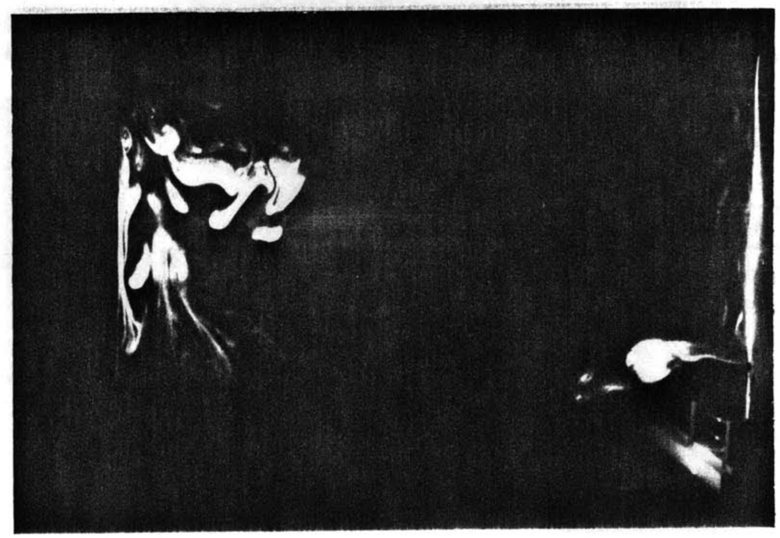


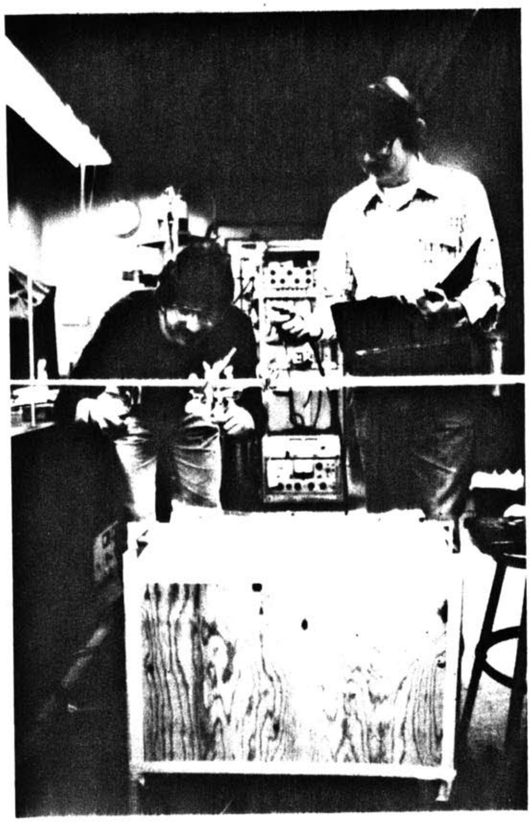
Opposite page: left- Testing in the Regional Spectroscopy lab.
right- Description of the system.
bottom- The 'unclear' results of smoke visualized with a fluorescent light.

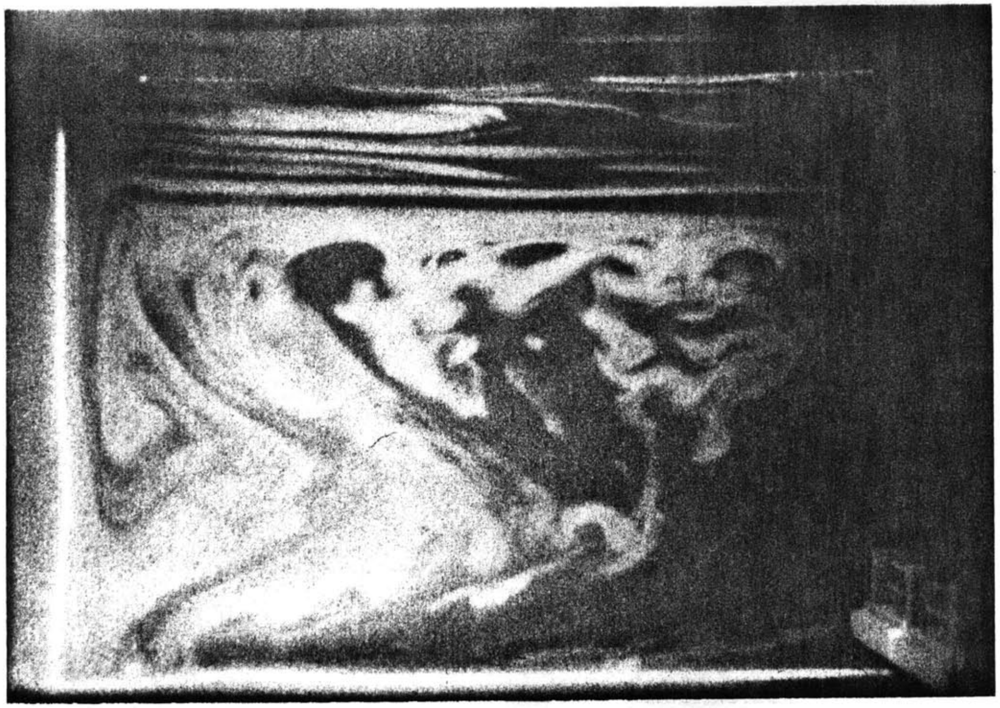
Bottom: D. Alberto and C. St. Claire making test adjustments.

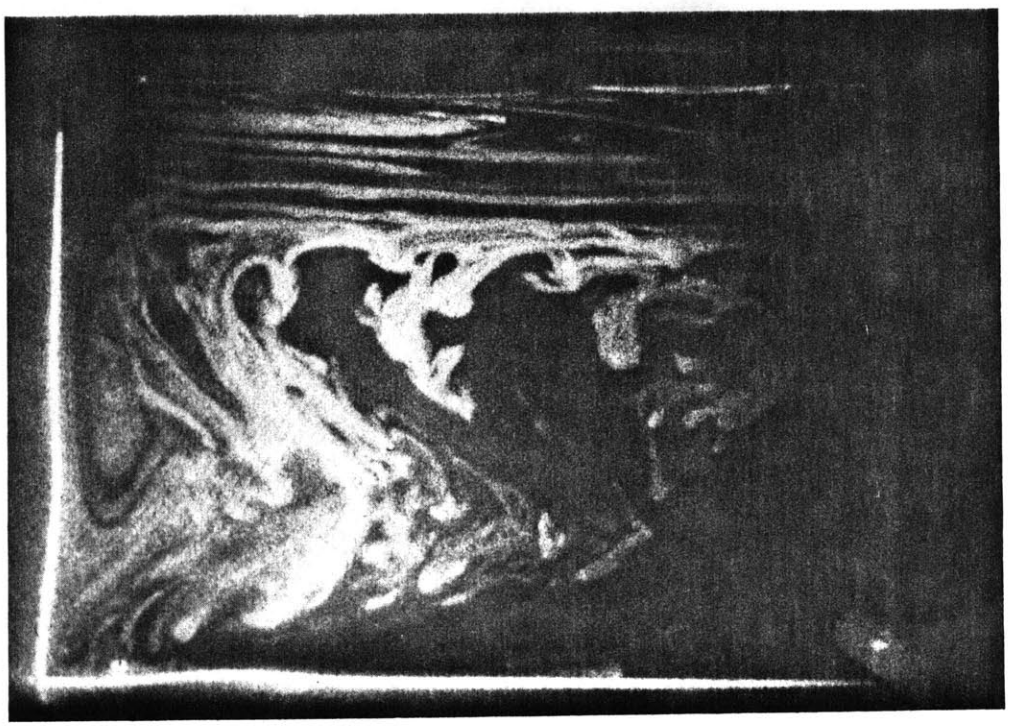
Right top and bottom: A sequence of convection photographs.







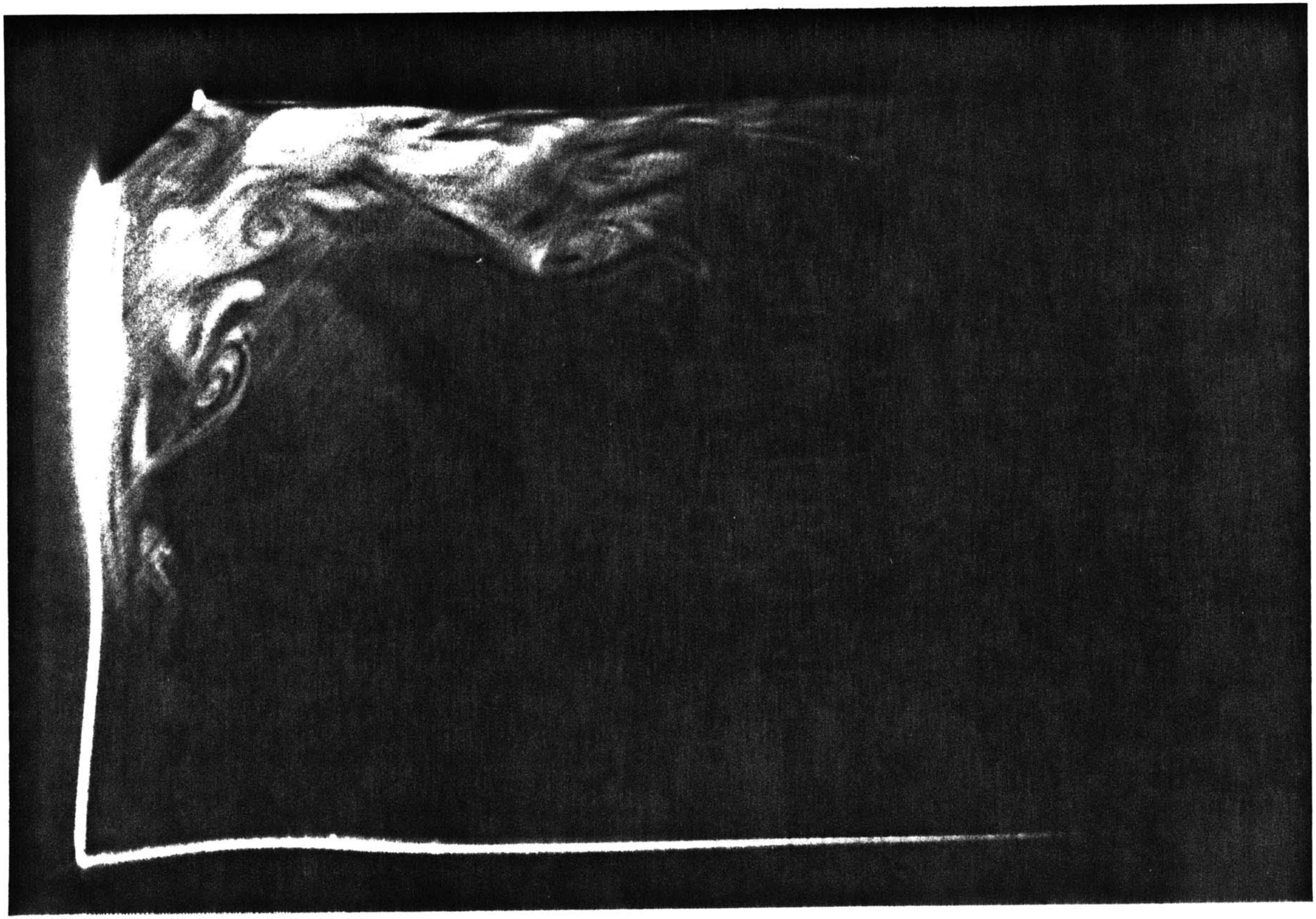




Left top and bottom:

Two laser lit photographs. These were ekta-chrome slides printed on high contrast copy-proof paper with a 150 line dot screen.

Right: A typical photograph using planar laser light.



LIGHT...

Opposite page right and far right: Two photographs of a model of Bagsvaerd Church, Copenhagen, designed by J. Utzon. Model construction by B. Bartovics, T. Turner, and C. Tzannetakis. Photo by C. St. Clair.

Daylight Analysis Using Physical Models

Reduced physical scale models can accurately determine the qualitative and quantitative features of a proposed building design. In fact, it is the most reliable daylighting evaluation method available. The physics of light are such that a physical model that duplicates a full scale space in all respects and tested under the same sky will yield identical results.

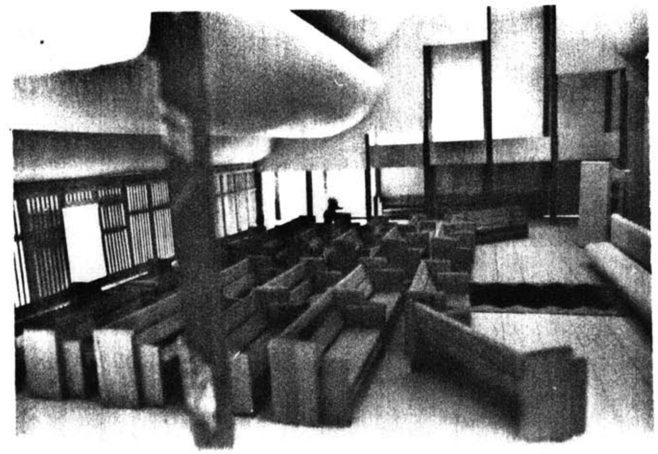
Modeling Techniques

The construction of a daylight model requires the use of materials that are opaque to light. Construction methods must form a 'seal' from external light allowing light to enter only through window openings. These openings must have the same geometric relationship to all light-affecting elements (window frame shape and size, overhangs, etc.) as the life-size scale. Window glass can be monitored by either placing the actual glass in the window frame, or not using any glass and compensating for the transmittivity losses.

Interior surfaces should have the same reflecting values as the proposed design, and should include internal objects that would affect light behavior (furniture, half-walls, etc.). One should choose as large a scale as possible that is practical to build. One inch equal to one foot is usually the smallest desirable scale.

Artificial skies or the natural sky are the two testing fields utilized. Although the actual sky is the easiest and most inexpensive to attain, difficulties arise in the changing character of the sky. One must constantly record the sky condition: test results may require mathematical interpolation to be comparable. Artificial skies allow all test results to be in a constant data base. Design changes can be easily compared.

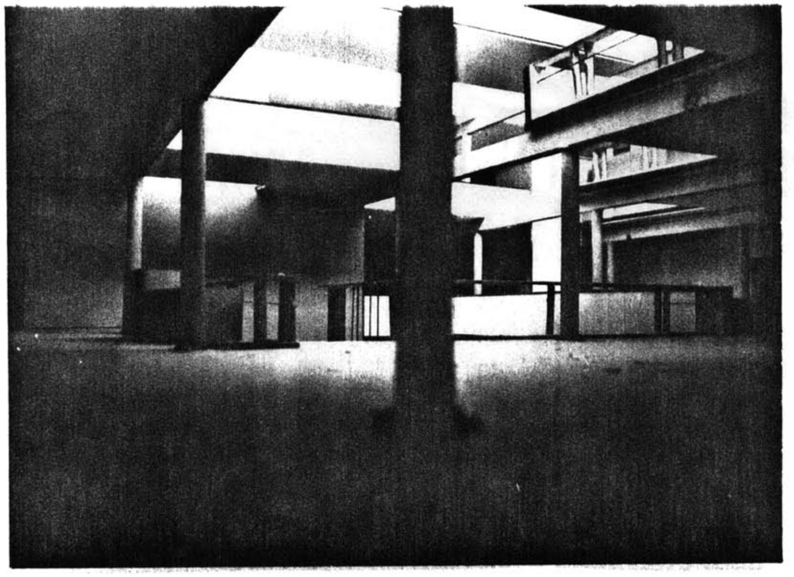
Quantitative testing of daylight models involves measuring the internal light levels for various sky conditions. A photometer ranging from 1 to 10,000 footcandles is the measuring device used. Photo-sensors that are remote (on

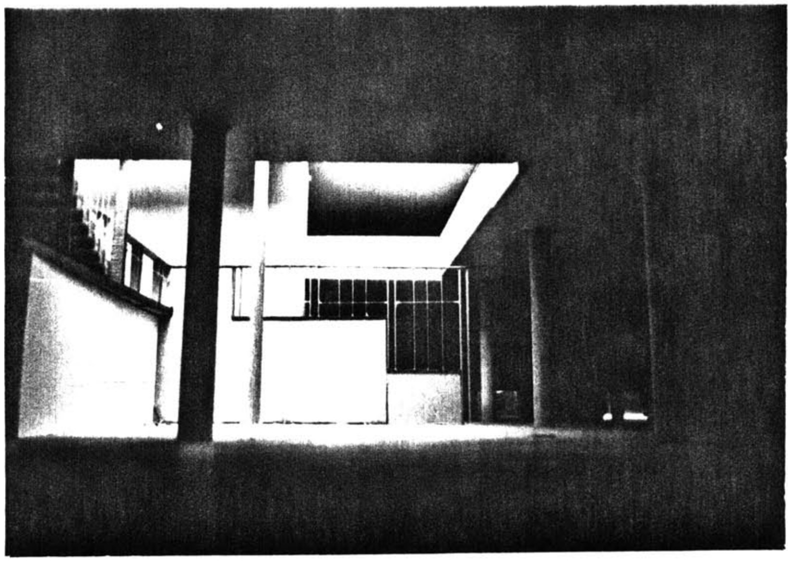
a wire) can be placed inside the model while light level measurements can be observed outside the model. Several photo-sensors can be attached to some photometers, allowing measurements to be taken of several internal and external points without having to stop the test to move a single photo-sensor.

Photographing daylight models is a process that requires experimentation to obtain desirable quality. One should 'bracket' each photograph: take the photograph one f-stop above and one f-stop below the suggested light meter response. One can expect a level of distortion compared to what the eye sees. However, the photographic is a reliable medium to transfer information that qualitative design decisions can be made from.

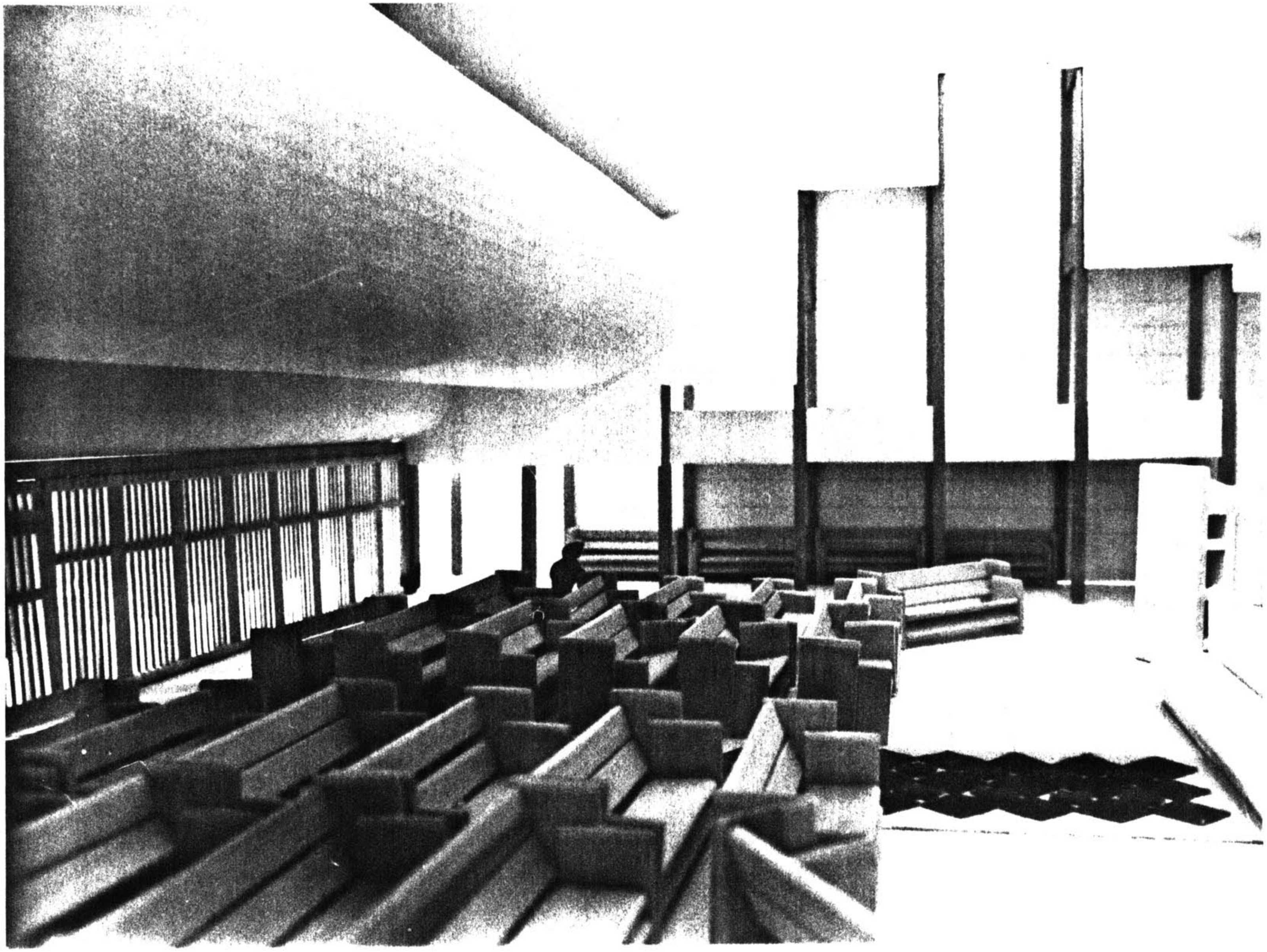
Photographic techniques include using a wide angle lense for the widest visual field, fast films and small aperture openings for the greatest depth of field in focus.



Left and bottom: A model utilized in design development allows three-dimensional experimentation for light and spatial evaluation. Model construction and and photograph by J. Crowley.



Daylight models are a practical tool in architectural design. If one incorporated daylight modeling techniques when preparing study models during design development, a better understanding or 'internalized' sense of the phenomena can be developed, as well as more qualitative and luminousely comfortable design solutions. Actually, with a few simple modifications, the same models that are used for the presentation of the interior of a proposed design can be used for quantitative and qualitative light analysis.



Notes: Chapter 5

1. Glickman and Bryan, "The Use of Physical Models to Study Energy Efficient Building Design , Program for Energy Efficient Buildings and Systems", working paper, 1982.
2. Ibid.

Chapter 6

In Conclusion . . . .

In Conclusion...

Hopefully, the presentation made in this book will lay down the foundations for a working approach to architectural communications, as well as the development of educational and design evaluation methods. The underpinning of these foundations is built on a fundamental vehicle indicative of the nature of architectural representation: seeing. To understand a place we haven't experienced, or to judge the qualities of an environment that is not yet built, we naturally turn to visible languages: hence we administer spatial comprehension and assessment through visualization technique.

The information and research presented in this book is by no means complete. In fact, I believe this work is just a beginning: a basis has been defined and established for the integration of visual communications to architectural design; an application of this theory has been made to a particular architectural and societal concern, energy conscious design. Both of these issues as pursued in this book can use further exploration and refinement.

The next likely step for this study is a bit more difficult. Removed from a research laboratory, these ideas should be brought into the open: to architectural schools, architectural offices, and to the public at large. These will be the real 'testing grounds' for the ideas explored in this book.

There are two potential forms which this research can take in the future:

1. Refinement of research and careful communication
   The visualization techniques need additional exploration for optimal visual definition. At that point a vocabulary builder on basic principles of physical phenomena relative to architectural form can be produced. A series of different spaces, forms and building types can be tested by these established visualization techniques. The results can be published in a book, videotape or film. The audience to benefit from this information would be designers, educators, and students.

2. Design Application
   These techniques can be valuable tools for the assessment of architectural projects being designed on the drawing board now. Developing these tools so architectural firms can conduct inexpensive, reliable tests in their office would have value to the design profession and the resulting qualities benefited by the users of such environments.

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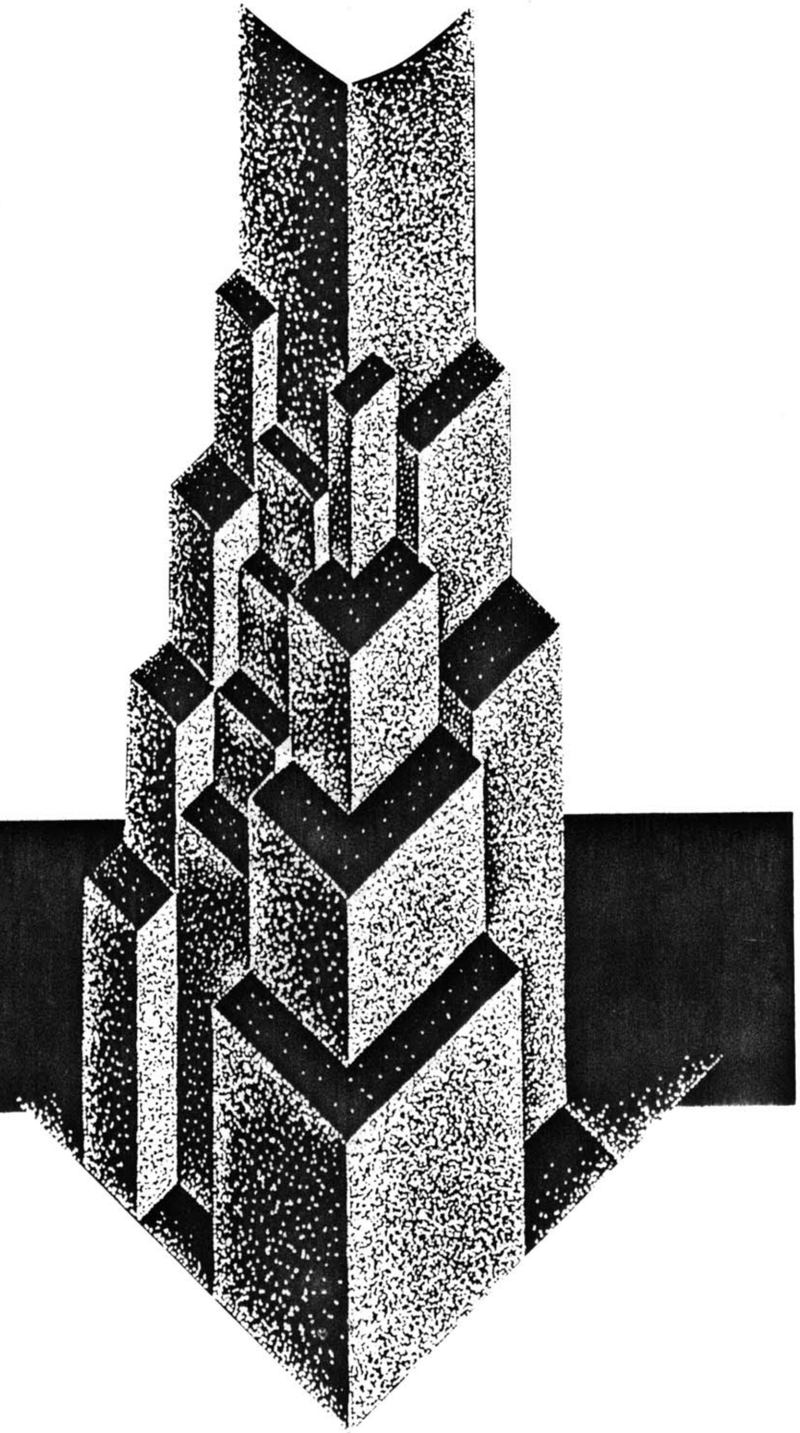

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Opposite side: Skyscraper form generated from the 1916 New York City Zoning Ordinance (D.A., 1981). The sketch was made as part of a research study on the present proposed Mid-town Manhatten Zoning Ordinance.

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