feedback

OPERATION BREAKTHROUGH

U.S. Department of Housing and Urban Development

PHASE I

DESIGN AND DEVELOPMENT OF HOUSING SYSTEMS

Design and Development of Housing Systems for

OPERATION break-through

U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
WASHINGTON, D.C.

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PREFACE

Operation BREAKTHROUGH introduced a new cooperation and partnership of Government and private industry, directed to finding a better way of meeting the nation's housing needs. The dimensions of the problem facing HUD in 1969 and the challenge set before HUD in the Housing Act of 1968 are outlined below. This report, the second in a series that will report on and describe BREAKTHROUGH, discusses one aspect of HUD's response to that challenge—the technical program.

The BREAKTHROUGH technical program has these principal aspects: the selection of the housing systems from the many proposals received in the 1969 competition; the program adopted to support and guide their development and design; and the methods used to evaluate the innovative features which could not be properly tested by procedures current at that time.

Throughout this program the Department has remained convinced that a partnership of Government and industry and labor can provide the skills and energy to find the needed solution. By taking advantage of the technical and financial resources of industry, supported by the interest and willingness of the building trades to cooperate, HUD has been able to effect a breakthrough of some of the traditional forms of administrative restrictions on innovations and to encourage new forms of evaluation, code administration and finance.

Much also is owed to the producers selected for this program. Theirs was not an easy task, particularly because our funding limitations precluded full support of their activities. They were really breaking new ground in Phase I, exploring with us new materials and methods, developing new teams and working relationships, and responding to increasingly detailed technical inquiries from HUD and the National Bureau of Standards.

At this writing, Phase I is complete, Phase II is well along, and Phase III is in full operation. It is too soon to judge whether all of the designs discussed in this report will be viable in the marketplace, but it is not too soon to be certain that BREAKTHROUGH has indeed changed the face of the housing industry and is bringing into the industry new interest, new resources, and a new understanding of how to provide good housing for all Americans.

Arthur S. Newburg
Director of Operation BREAKTHROUGH

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INTRODUCTION

This document is a compendium of the 22 housing systems designed for Operation BREAKTHROUGH, a research and technology program sponsored by the U.S. Department of Housing and Urban Development (HUD). It is intended to be a general report suitable for many purposes. The technical content, although oriented to the builder or developer, is readily understandable to the average homeowner.

As part of the formal documentation of Operation BREAKTHROUGH, the report covers the design, during Phase I, of the 22 housing systems. In historical sequence it follows "Housing Systems Proposals for Operation BREAKTHROUGH" (U.S. Government Printing Office, Washington, D.C., December 1970), which contains technical descriptions of the hundreds of proposals originally submitted to HUD.

Individual Phase I final reports prepared by the various Housing System Producers (HSP) are the principal sources of data for this work. The narrative on the BREAKTHROUGH Guide Criteria was written by the National Bureau of Standards, which was responsible for this important aspect of the program.

High quality, innovative housing systems suitable for volume production are the technological foundation of Operation BREAKTHROUGH. The designs successfully completed by the HSP's range from split-level to high-rise, and use wood, concrete, metal, and plastic as building materials. Still, the construction methods are few and basic. The result is housing with marked distinctions but uniform quality, over a wide price range—housing, furthermore, that can be built quickly, with every promise for cost economies to the householder.

PROGRAM OBJECTIVES

The simplest statement that has been made of Operation BREAKTHROUGH's goal is "to improve the process of providing housing." Rather than just build more houses, BREAKTHROUGH seeks better ways to build houses. Supplementing other programs, it adds the new dimension of industrialized housing, testing fresh ideas in materials, labor, standards, financing, and marketing.

The BREAKTHROUGH Program was conceived by HUD Secretary George Romney and his staff in 1969 to attack, on a broad front, the national housing crisis. What were the dimensions of that crisis? A good illustration is that investment in housing declined between 1950 and 1960 by 52% as a share of the Gross National Product. Because of the large population growth during that interval, a cumulative housing shortage, estimated at several million units, developed.

A ten-year goal of 26 million new or rehabilitated dwelling units was set by the Congress in the 1968 Housing Act. Contrast this proposed yearly average of 2.6 million units with the achieved yearly average in the period 1959-1968 of under 1.5 million. The largest previous production year ever, 1950, saw 1.97 million housing starts.

Clearly, there was a gap between production and need. Given the existing capabilities of the housing industry, this deficit seemed certain to grow in the next decade.

Many of the limitations on the conventional housing industry are beyond the industry's control. Among them is a whole series of economic constraints. There are outmoded laws too, and there are shortages of materials, labor, and money.

Perhaps the most important constraint is the fragmentation of the market. Houses are ordered singly or in small numbers, and the result of fragmented orders is a fragmented industry. Even the largest builder does not produce more than 1% or 2% of the total supply. HUD Assistant Secretary for Research and Technology, Harold Finger, says "You don't get economies of scale. A builder never produces enough houses to be able to cut his costs, to permit effective procurement of materials or scheduling of labor forces. He can't supply a large market because of the various codes and restrictions that exist throughout the country."

To find a solution to this part of the housing problem, BREAKTHROUGH had two tasks to accomplish: first, give a significant impetus to modernizing the housing industry so that production capacity would be greatly enlarged. Second, with this major commitment as a lever, reduce the outside barriers to market aggregation. These tasks, although interdependent, could be conducted separately and concurrently.

The key to updating the housing business is industrialization: the use of advanced technology to increase production. It involves a high degree of prefabrication and factory building of major components. While progress is being made in the conventional housing industry, it is slowed by the many outside constraints, by consumer attitude, by the influence of tradition.

Before BREAKTHROUGH, industrialized housing amounted to perhaps 5% of the total units built. However, this figure does not account for mobile homes, a sort of industrialized building that holds great portent. The growth of mobile homes sales has been rapid, approaching by 1969 one third of the total housing units built per year. This proves that (1) assembly line building works, and (2) the public will buy factory-built houses—at least if the price is right.

The mobile home is an adequate shelter, with few technological novelties. But the BREAKTHROUGH units were to be a whole new look at human habitation, utilizing any practical innovation known, and pointing the way to those economies of scale possible only through volume production.

To sum up the aims and ambitions of BREAKTHROUGH, HUD defined its objectives as follows:

> This program has as its primary objective the establishment of self-sustaining mechanisms for rapid, volume production of marketable housing at progressively lower costs for people of all income levels, with particular emphasis on those groups and individuals who have had difficulty in obtaining satisfactory housing in the past . . .
>
> To assist in reaching the primary objective, the program will address the following secondary objectives:
>
> 1. Stimulate the modernization and broadening of the housing industry through increased emphasis on better design and greater utilization of improved techniques within the current housing industry and through increased participation by other organizations that possess the necessary talents, interests, and capability for such a commitment.
> 2. Increase participation and leadership by state and local governments to providing on-going planning and market and site aggregation for housing, its environment, and the community.
> 3. Waive or remove constraints to the introduction and use of tested and proved innovations in design, construction, land acquisition and use, financing, labor utilization, materials, components and systems, sponsorship, consumer participation, management, and maintenance.
> 4. Introduce new organizational concepts and management techniques for market and site aggregation and for design, production, and marketing of living units.
> 5. Coordinate the application of all available government resources appropriate to a given site or sites for housing, environment, community services, and facilities.
> 6. Encourage identification and development of performance standards for evaluation of innovations, working with authorities in this area.
> 7. Develop an on-going testing and evaluation mechanism and technique for judging the effectiveness of innovations.
> 8. Develop techniques for increased effective participation by consumers and community groups in planning and developing the total housing environment.

The Operation BREAKTHROUGH housing systems were intended to modernize the American housing business by breaking through the established constraints. This modernization could be done by research and development: a systematic R&D program of the type employed successfully in electronics and aerospace but notably lacking in the housing sector.

PROGRAM PHASING

Operation BREAKTHROUGH was conceived as a three-part program. First, private enterprise would compete for contracts to design industrialized housing systems; then significant numbers of units would be built to these designs and demonstrated on several prototype sites across the country. Finally, successful systems would go into volume production.

The three parts of the program were Phase I: Design and Deveopment; Phase II: Prototype Construction; and Phase III: Production.

HUD described Phase I as follows:

"It is expected that some 15 to 20 contracts will be awarded for the opening portions of a three-phase program. The first phase will consist of a 2- to 4-month design and development period, to consist of final system integration design and architectural design of the system for the specific prototype cities. The length of this period and the funding level will be negotiated with each successful proposer."

(As it turned out, the design and development phase took longer than the 2 to 4 months expected. There were many reasons, among them mainly the inherent complexity of the program and the great interest shown by private industry. The selection process required to select a limited number of HSP's merits separate coverage later in this report.)

In Phase II, perhaps 2,000 prototypes were to be built of these designs, on about eight sites, representing a variety of climatic and market conditions. (In fact, almost 3,000 units were built on nine sites.)

After Phase II, the housing systems proven by the desmonstration and by a rigorous program of laboratory testing (conducted by the National Bureau of Standards with the National Academy of Sciences and the National Academy of Engineering) would receive certificates of acceptability.

With the new housing systems ready for the market, and for volume production in Phase III, private enterprise would assume the leadership from HUD.

ORGANIZATION AND PARTICIPATION

The problem confronting Operation BREAKTHROUGH was one that neither government or private industry could solve alone. Therefore a partnership was created. Figure 1 shows that this partnership became a nationwide effort.

Administration of the program is the responsibility of the HUD Research and Technology Office. State and local governments nominated the prototype sites. From industry came the 22 HSP's, 11 Prototype Site Planners (later reduced to 9), and 8 Prototype Site Developers. Labor unions cooperated to arrange new contractual agreements, which recognize the production and erection of industrialized housing. The public is fully involved, as critic, as supporter, and ultimately as consumer.

The participant relationship that is most pertinent to this survey of the Phase I HSP designs is that between the HSP's and the Prototype Site Planners. HUD provided strong coordination among these principals as they determined the allocation of housing systems to the sites (see Chapter 4). Each site had distinctive features and requirements that influenced the emerging HSP designs. The converse was also true: the site plans made use of the best characteristics of the selected housing systems.

SELECTION OF HOUSING SYSTEM PRODUCERS

The number of contracts that could be awarded for design of innovative housing systems was necessarily limited. In order to get the best concepts, from sound business firms, a procurement competition was held. Requests For Proposal (RFP #H-55-69, "Operation BREAKTHROUGH—Application of Improved Housing Systems Concepts for Large Volume Production") were issued to approximately 5,000 companies beginning on June 23, 1969. Two kinds of proposals were sought: Type A for the design, testing and evaluation of complete housing systems, and Type B for research and development of advanced concepts and components. Of the 601 proposals received by September 19, 1969, Type A comprised 236.

This volume of replies was far greater than expected. To screen the proposals, detailed evaluation procedures, within the framework of HUD procurement policies, had to be used. The steps were:

RFPs Issued	5000
Proposals Received	601
Classified as Type A	236
Determined to be Responsive	136
First Rank Order Vote	37
Announced by Source Selection Officer	22

Operation of a Proposal Evaluation Board is defined by HUD Handbook 2210.7. It specifies the composition of the Board, including a designated chairman, voting members, advisors, consultants, and various committees. The HSP Proposal Evaluation Board consisted of 14 members. It was assisted by four committees: Building Systems, Site Systems, Management Systems, and Financial Systems. The 80 or more committee members were drawn from many government departments as well as from HUD.

Initial filtering to eliminate proposals clearly inadequate or nonresponsive to the RFP reduced the total number to 136. Then each proposal was read by the four committees, making expert reviews of their specialty areas. Evaluation criteria and rating methods had been established by the Board before proposals were read.

The Board then took a rank order vote and made recommendations to the Source Selection Official. On December 16, 1969, the Source Selection Official announced that 37 systems merited further consideration.

During the next iteration, proposers were interviewed by the Board. An ad hoc committee on Marketability was formed of specialists outside government; this committee helped the Board assess local market potentials and cost realism.

Visits were made to the finalists' plants, and the Board then completed formal narrative evaluations and recommendations. On February 26, 1970, Secretary George Romney announced the 22 housing systems that had been selected for contract negotiations.

It is clear from this account that the selection process was an exhaustive one. Undoubtedly, it came as close as possible to satisfying not only the legal requirements but also the more challenging criteria for number (limited by available funds to 22), types (a wide variety) and competency of housing system producers.

Some laymen have complained that the BREAKTHROUGH winners did not include wholly new, previously unheard of, systems (they assert that pneumatic houses, transparent houses, organically grown houses have been featured in the popular press for years . . . overlooking that none of these visionary schemes have yet been found to be practical, economically feasible, or suitable for volume production). Even some architectural critics expressed disappointment because "radically innovative" proposals were not selected.

There are two explanations: first, the Type B competition covered those proposals, some of them quite imaginative but not sufficiently developed to give promise of reaching the prototype stage in a matter of months. (It must also be noted that many Type B proposals were not responsive to the terms of the RFP, leaving voids of information and doubts as to the fairness of the competition if they should be awarded contracts.)

The second explanation is in the criteria prudently established to guide the selection process. Criteria listed 21 evaluation factors, in three groupings: Concepts, Capacity, and Plans. The Concepts factors consisted of the physical housing system qualities, flexibility, efficiency in use of men and materials, and schedule forecasts. Capacity considered the strength of the proposing firm, including financial soundness (the industry partners on BREAKTHROUGH must make substantial investments of their own). Plans covered the perception the proposer had of the BREAKTHROUGH program and his intentions for production and marketing.

Overall, there is the goal stated in the HUD handbook for proposal selection: "It is the policy of the Department of Housing and Urban Development to select only those business entities having the best capability to perform contract tasks and exhibiting the greatest probability of delivering completed work conforming to the highest professional standards." The 22 HSP's chosen proved, even in a field as speculative as the one BREAKTHROUGH assayed, good testimony to that goal.

And, withal, the systems represented a rich diversity of building types and construction methods (Figure 2). A similar variety was to be expected in the price range of the planned housing units; emphasis was on the lower-middle and middle price levels. Prototype units would include single family detached, single family attached (townhouses), and multi-family (apartment) units, from low-rise to high-rise.

VARIETY OF WINNING HOUSING SYSTEMS

a. Basic Structural Concept	
Volumetric (Modular)	10
Panel	9
Component Subassemblies	3
b. Principal Material Used	
Concrete	6
Metal	1
Wood	8
Plastic	2
Composite	5

NOTE: These classifications are somewhat arbitrary. The tabulations reflect the characteristics of the 22 BREAKTHROUGH systems at the time of selection. Several systems were wholly revised during the design phase.

THE HOUSING SYSTEM PRODUCER TASKS

On February 26, 1970, Secretary Romney announced the 22 winners of the HSP competition. These firms are listed in Figure 3. Several of them became identified with BREAKTHROUGH under different names, which are used later in this report (for example: Ball Brothers as Pantek, Henry C. Beck as Building Systems International, Forest City Enterprises as FCE-Dillon, Keene Corp. as Townland, Module Communities as CAMCI). The name changes came about as new companies were set up especially to carry out the HSP work.

Following announcement of the winners, HUD began negotiations with each firm to award contracts for Phase I design and development. Negotiations took place over the next 4 months; the first contract was signed in May and all 22 were completed by July 7, 1970.

The contracts were on a cost plus fixed fee basis, to cover the preparation of designs, development of engineering data, and planning construction of almost 3,000 prototype units at nine sites. Specifically, each contractor was to perform these tasks:

Task 01 Subsystem Design and System Integration

Complete design and development of subsystem elements and integration of all parts and components into a complete building system; perform component and subsystem tests as required for system development.

Task 02 Preliminary Housing Design

Prepare preliminary design drawings and outline specifications for housing types selected for manufacture and erection on each assigned prototype site. Prepare a preliminary cost estimate based on this design for each type of housing at each site.

Task 03 Contract Working Drawings and Construction Control Specifications

Prepare contract working drawings and construction contract specifications for manufacture and erection of the assigned prototype housing units on the designated sites.

Task 04 Phase II Price Quotation

Prepare price quotations for the manufacture and erection of the assigned prototype housing units on the designated sites, supported by a detailed cost breakdown of all cost elements.

Task 05 Prototype Site Planning

Comment on preliminary conceptual site plans by the Prototype Site Planner for the prototype sites.

Task 06 Prototype Site Codes and Regulations

Review local building and housing codes and other administrative requirements for each of the assigned prototype sites and identify those items requiring waiver, variance, or other action to permit the use of the building system on each site.

Task 07 Extended Warranty Feasibility Study

Investigate and report on the feasibility and value of providing an extended 5-year warranty on the building system and housing units being developed under the contract, including required modifications to the building system.

Tasks 11 - 18 Program Planning

Prepare detailed plans for (1) management of prototype construction, (2) prototype production, (3) prototype testing and analysis, (4) quality control, (5) transportation, (6) equal opportunity and community participation, (7) marketing and production in Phase III, and (8) financing.

Individual HSP reports in Chapter 3 will describe the accomplishment of various of these tasks.

22 SELECTED HOUSING SYSTEM PRODUCERS

1. Aluminum Company of America (Alcoa), Pittsburgh, Pa.
*2. Ball Brothers Research Corp., Boulder, Colo.
*3. Henry C. Beck Co., Atlanta, Ga.
4. Boise Cascade Corp., Boise, Idaho
5. Christiana Western Structures, Inc., Los Angeles, Calif.
**6. Descon/Concordia Systems, Ltd., Montreal, Quebec, Canada
*7. Forest City Enterprises, Inc., Cleveland, Ohio
8. General Electric Co., Phildelphia, Pa.
9. Hercules, Inc., Wilmington, Dela.
10. Home Building Corp., Sedalia, Missouri
*11. Keene Corp., New York, N.Y.
12. Levitt Technology Corp., Lake Success, N.Y.
13. Material Systems Corp., Washington, D.C.
**14. Module Communities, Inc., Yonkers, N.Y.
15. National Homes Corp., Lafayette, Ind.
16. Pemtom, Inc., Bloomington, Minn.
17. Republic Steel Corp., Youngstown, Ohio
**18. Rouse-Wates Co., Columbia, Maryland
19. Scholz Homes, Inc., Toledo, Ohio
20. Shelley Systems, Inc., San Juan, Puerto Rico
21. Stirling Homex Corp., Avon, N.Y.
22. TRW Systems Group, Rendondo Beach, Calif.

*Representing a consortium later renamed
**Major joint venture

2

Criteria and Tests

Criteria and Tests

ROLE OF THE NATIONAL BUREAU OF STANDARDS

Early in the planning of Operation BREAKTHROUGH, it was recognized that no adequate methods existed by which the sought-after housing innovations could be measured. Technical evaluation, which would thus have to be based on performance, should reflect the best professional opinion as to requirements, criteria, and tests.

HUD therefore obtained the consultation services of the National Academies of Sciences and Engineering, and commissioned the National Bureau of Standards (NBS) to develop recommended housing system performance criteria. An interagency agreement with the U. S. Department of Commerce provided for NBS to render research and technical support to the HUD Office of Research and Technology. The initial assignment given NBS called for the preparation of recommended criteria for the evaluation of the housing systems proposed by the 22 selected Operation BREAKTHROUGH producers.

The NBS Center for Building Technology had the experience and resources to provide this support. Its past tasks included the preparation of performance documents and studies of performance concepts in building systems, as well as in research economics. Among its resources are a staff that is expert in all areas of building technology and laboratories that are available and well equipped.

PHILOSOPHY OF THE BREAKTHROUGH PERFORMANCE CRITERIA

Proposed innovations in materials, fabrication, and erection techniques made it clear at the outset of Operation BREAKTHROUGH that traditional codes could not serve completely for the evaluation of the housing systems. It was equally clear that a performance-based approach would have to be taken. Therefore, the first activity in NBS technical assistance was the development of performance criteria recommendations.

A team was assembled that represented various technical disciplines and had available at its disposal inputs from other government agency specialists and from private consultants. The team made a concerted effort to develop performance recommendations that would reflect accepted, state-of-the-art requirements where possible. As a result of this development, NBS Report 10200, "Guide Criteria for the Evaluation of Operation BREAKTHROUGH Housing Systems," (in four volumes) was submitted to HUD. The Guide Criteria differ from existing building codes both in language and in scope. First, most building codes tend to be prescriptive in nature and component or material oriented. On the other hand, the Guide Criteria, so far as current technology permits, are performance based and systems oriented.

Second, building codes are concerned primarily with public health and safety. The Guide Criteria cover not only public health and safety but livability and durability as well.

This broader scope was considered necessary because of the innovative nature of the BREAKTHROUGH housing systems, many of which had never been tested for either marketability or durability. Furthermore, one of the BREAKTHROUGH goals was aimed at producing housing that was safe and would satisfy the needs of its occupants.

In the area of health and safety, the Guide Criteria were written to achieve, at minimum, the level of performance implicit in present building codes. In many cases, code writers intended certain kinds of performance, but in the translation to prescriptive language, this desired performance was not necessarily achieved. Because the Guide Criteria were written in performance language, it was possible to call for the kind of performance intended in regulations based on current technology. They were written to establish the best balance of performance possible. Opportunities to make trade-offs from one performance attribute of a system to another were taken when such trade-offs were appropriate.

In the process of generating these performance statements, every effort was made to avoid working in isolation. The first priority was to study in detail various building codes and standards that were in use throughout the United States. Research reports were reviewed, consultants contacted, and experts brought in from other laboratories.

ORGANIZATION OF THE GUIDE CRITERIA

The Guide Criteria for Operation BREAKTHROUGH housing systems were organized in four volumes: (1) multi-family high rise; (2) multi-family low rise; (3) single family detached and (4) single family attached. (There is also a Volume 5 on Quality Assurance that was developed for HUD by another contractor.) The Criteria format is uniform throughout, consisting first of a requirement which is a qualitative statement of performance, followed by one or more criteria which are quantitative measures of the desired performance. A test is then specified for demonstrating compliance with each criterion. Finally, the intent and background of a given performance statement are explained in the commentary.

The commentary, although not an important part of the performance statement, is considered to be important background. Because BREAKTHROUGH is a research and development program, and because the criteria represent translations of the most advanced practices, it was judged desirable to state clearly the origin and intent of the requirement and the degree of confidence in the criteria and tests specified.

REVIEW OF THE GUIDE CRITERIA

HUD carefully designed a process for criteria review. A special Advisory Committee to the Department of Housing and Urban Development (ACHUD), formed by the Technical Panel of the National Academies of Sciences and Engineering, served as an important factor.

The formal procedure established for the review process required NBS to recommend criteria; to transmit these to HUD for review and comment; and finally, for HUD to transmit them to ACHUD for final review and recommendations.

Upon completion, HUD issued the Guide Criteria to the Housing System Producers (HSP) for their guidance in the design phase. During the early design and development of the housing systems, NBS worked very closely with the HSP's, and valuable information was exchanged on the practical use of the performance-based Guide Criteria.

The Guide Criteria were also distributed to the building community so that the industry could submit comments for consideration in the refinement process. The criteria are scheduled for continual refinement and improvement on the basis of this commentary, the results of current research, and experience gained during the Operation BREAKTHROUGH prototype construction process.

Lastly, during prototype unit occupancy, significant data are expected from a documentation of the performance of the housing systems at the demonstration sites. A point that should be made is that even at the end of Phase II of BREAKTHROUGH, the criteria will not be final: they must be the subject of continual refinement. Figure A illustrates the events that would make up the life cycle of the Guide Criteria.

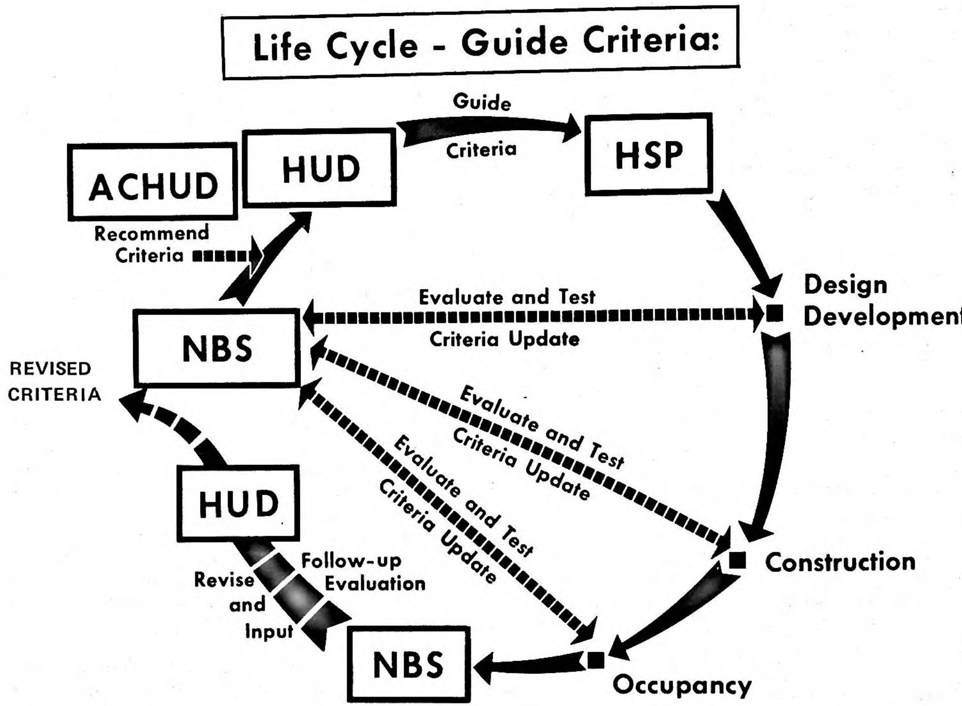

Figure A

EVALUATION PROCESS FOR THE HOUSING SYSTEM DESIGNS

As the conceptual designs of the proposed housing systems began to take form, an NBS technical review was initiated. An evaluation team was established, composed of members of the Center for Building Technology with expertise in the disciplines of fire, structures, health and safety, illumination, acoustics, durability, architectural arrangements, and mechanical, electrical and plumbing design.

The evaluation team's mission was to ascertain, through a review of drawings and specifications, the compliance of each housing system design with the recommendations contained in the Guide Criteria. The basic tools with which the evaluators worked included the drawings and specifications as submitted by the HSP's along with supporting material such as structural, electrical, and heating-ventilation-air conditioning-plumbing calculations, previous data gathered in development of specific products or new components, and experience and insight of the individual reviewers through activity in the various disciplines.

One of the considerations in the review process was the establishment of a channel for technical communication between the NBS technical evaluators, HUD Government Technical Representatives, and the project managers for the HSP's. To assist in this process, NBS Technical Representatives were assigned to monitor three or four of the HSP's for the purpose of communicating directly with HUD and HSP personnel. The NBS Technical Representatives kept abreast of the housing systems' development and of the problems encountered in system design evaluation. It was of utmost importance that problem areas be identified as early as possible to permit corrective action to be initiated by HUD or the HSP. All technical evaluation reports transmitted from NBS were the responsibility of the NBS Technical Representative and it was his immediate duty to coordinate with HUD and insure that all evaluation results were transmitted to them promptly and accurately.

In compliance with their Operation BREAKTHROUGH Phase I contractual requirement, the HSP's submitted to HUD design drawings and specifications at the levels of conceptual design, 25% completion, 95% completion, and 100% completion. NBS conducted individual technical reviews by discipline for each building type and for each particular prototype site location.

Generally, a decision as to the adequacy of the design could be based upon a technical evaluation of the material submitted by the HSP. In some cases, because of innovative features of particular designs or the use of new materials, complete assessment of system performance could not be made without additional information. This in some cases resulted in physical testing of components or subsystems. When physical testing was required, every effort was made to identify needs early in the design development of the systems to aid in prompt assessment of adequacy.

As one of the final steps in the review process, post-100% reviews were made of the contract drawings and specifications to assess any changes requested at the final review prior to signoff. A review of this type was considered necessary to identify any life-safety related items that may have been missed previously, or to ensure that changes requested by one discipline did not adversely affect another discipline with respect to life safety.

During the prototype construction phase, additional technical reviews of specific design details were sometimes necessary. Because of the developmental nature of some of the housing systems, the design/construct process was dynamic and it was at times necessary to modify the final design during production to accomplish the required engineering objectives. These design changes, where applicable, were submitted by HUD to NBS for technical review. NBS comments were then forwarded to HUD for appropriate action.

PHYSICAL SIMULATION

As the evaluation program was initiated, it became evident that some selective testing would be necessary. This would ascertain compliance with recommended structural and fire performance. After all, some of the innovative composite systems had never been constructed in full scale; the system engineering properties were not fully known. Feasibility test programs were identifed for the more innovative systems in order to answer any questions regarding their mechanical or fire properties or design limits. To the greatest extent possible, component testing was used to assist in predicting full-scale system performance. Many of the designs proposed by the HSP's were modular which presented some new and interesting problems both with criteria application and system evaluation. Because of the innovative techniques by which some of the modules were connected, standard tests in many cases did not adequately evaluate the performance of the elements in question. Thus, modifications to the conventional test methods were necessary to more nearly simulate actual conditions.

Some performance limits could not be identified adequately because of a lack of information or understanding of the system's structural reaction when certain loading conditions were applied. In one such area, a testing program was planned to determine, for conventional types of floor and wall construction, the damage caused by impact loading. Various impact loads were applied to selected types of conventional construction and from these test results, recommended limits were established for the level of performance.

Because of the capability of the NBS staff in test development and their specially equipped laboratories, most of the nonstandard tests were conducted under the direct supervision of NBS personnel at NBS facilities. However, testing was also done at other laboratories having special capabilities, such as the U. S. Department of Agriculture Forest Products Laboratory and the Naval Civil Engineering Laboratory. In addition, many standard tests required to predict or establish system performance were conducted by private laboratories. Fire testing was done by National Gypsum Co., Underwriters Laboratories, Inc., Ohio State University, University of California, Southwest Research Institute, and U. S. Testing Company.

For several of the more innovative designs, structural testing was conducted on wall, floor and roof elements to determine their bending and compressive load capacity, resistance to racking and reduction in strength when exposed to varying environmental conditions. One of the innovative composite floor systems (Figure B) was evaluated for bending stiffness and strength, and was

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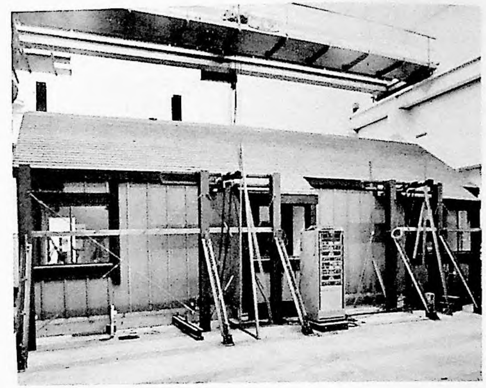
stressed to its ultimate load to determine the design limits. Structural joints made of the newer bonding materials were also evaluated by physical simulation of cyclic loadings to determine ultimate strength and creep characteristics.

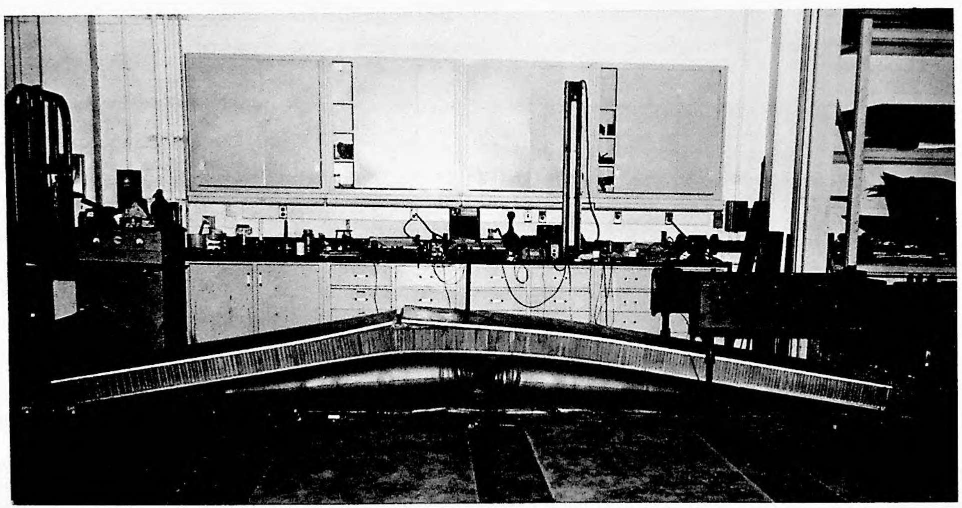
Physical simulation programs were generated in cooperation with the HSP's for several of the housing systems to demonstrate the structural performance of the assembled system. Material Systems Corporation and TRW, Inc., because of the innovative nature of the construction method and materials, required full scale physical testing evaluation programs. Tests were conducted on full-sized test modules for system analysis in the light of criteria compliance and determination of ultimate load.

The BREAKTHROUGH program encouraged HSP's to explore all practical methods of transportation to achieve economic and scheduling benefits. NBS assisted in this effort. It conducted several small testing programs to determine the retention of structural integrity during loading, transportation, and unloading of the modular units from factory to site.

As part of a transportation study involving a Levitt Technology module shipped from Battle Creek, Michigan to Gaithersburg, Maryland, NBS implemented a laboratory test of the full-scale modular unit to determine its resistance to dynamic loading. During transportation the module was instrumented to record the stresses and movements resulting from rail transportation. The modular test unit was placed in the NBS Structural Laboratory at the completion of the transportation study and anchored to simulate the in-place boundary conditions (Figure C). Upon completion of anchoring and instrumentation of the assembly, dynamic loading was applied to the unit to simulate wind or earthquake conditions. From these tests it was possible to determine the modular system's performance with respect to racking resistance of the wall system and shear resistance of the connections.



C. Levitt module under test in structures lab



B. A floor system taken to failure

Other consultants under contract to HUD had the responsibility for inplant inspection to ensure that the housing units were constructed in accordance with the BREAKTHROUGH contract drawings and specifications. However, NBS did identify for HUD and the quality support contractor any critical production or construction processes which must be adequately monitored in the individual producer's quality assurance program.

QUALITY ASSURANCE

In late September 1970 HUD selected the Quality Assurance/Urban Planning Division of Computer Sciences Corporation (CSC) to supply quality assurance program support to Operation BREAKTHROUGH during Phases I and II.

Three major tasks were performed during Phase I: (1) a survey of existing quality assurance systems being used by the factory-built housing and mobile home industry; (2) development of guideline criteria for the evaluation of HSP quality assurance programs, and (3) reviewing those programs, as submitted by the HSPs, before prototype unit construction.

Contacts were made with twelve manufacturers, five of which agreed to detailed surveys. Visits were made to three housing producers, one mobile home builder, and a manufacturer of steel framing used in modular construction. The objectives were to determine quality control in the industry, and use the results to help develop guideline evaluation criteria.

It was found that quality assurance methods were not being applied consistently in the housing business. Formal techniques have been generally available for 25 years, but review of documentation showed that much of the housing industry didn't even start quality programs until 1970 or later. Quality assurance practices apparently were initiated then to lessen the impact of various jurisdictional codes and inspections. There was no evidence in the documents reviewed that quality products, or control of costs caused by rejected or reworked materials, were goals. In many cases the objectivity of quality inspections was doubtful, because the functions were performed by the production supervisor. Although quality assurance checkoff sheets were being used, it was clear that completion of the forms was not a prime responsibility.

In general, at the time of the survey, no standards for the development and implementation of quality assurance procedures existed in the manufactured housing industry. Several organizations were becoming interested in the subject, but no concerted efforts had yet been made.

Considerable industry interest developed when CSC made available the first (interim draft) copies of the "Guide Criteria for the Evaluation of Housing Systems," Volume V. This volume was concerned with the "Quality Assurance Program Provisions" for Operation BREAKTHROUGH participating manufacturers. The document established requirements and associated guidelines for the development of appropriate quality assurance programs for BREAKTHROUGH housing. The guidelines were developed after a thorough review of existing government and industrial documentation on quality assurance. Discussions were held with various industry and government personnel, including building code officials, scientists and engineers of the National Bureau of Standards, the National Academy of Sciences and Engineering, the National Association of Building Manufacturers, the National Association of Home Builders and the Forest Products Laboratory of the U. S. Department of Agriculture.

The 13 sections of the document cover all aspects of a quality assurance program: management; organization; receiving, in-process and final inspection and controls; record keeping; and procurement, manufacturing, delivery, field, and site controls. It was used as a basis from which to evaluate each of the quality assurance programs submitted by the BREAKTHROUGH HSP's. As each of the HSP program documents was received, CSC reviewed it for general content and conformance with the Guide Criteria document. The evaluations were recorded on appropriate forms and submitted to HUD for concurrence and forwarding for corrective action by the manufacturer. When approved, the quality assurance program became the operational framework within which the prototype housing units were manufactured.

3

The Housing System Producers

	Area of Best Use	Optimum Density/Acre	Dwelling Type	No. of Bedrooms
Alcoa Construction Systems Inc.	Periphery, suburban	3-75+	SFD, SFA, MFLR, MFMR, MFHR	1-5
Boise Cascade Housing Development	Urban, periphery, suburban	4-30	SFD, SFA, MFLR	0-5
Building Systems International	Urban, periphery	10-150	SFA, MFLR, MFMR, MFHR	0-5
CAMCI, Inc.	Urban	50-250	MFMR, MFHR	0-6
Christiana Western Structures	Periphery, suburban	4-25	SFD, SFA, MFLR	1-4
Descon/Concordia Systems Ltd.	Urban	20-200	MFLR, MFMR, MFHR	1-4
FCE-Dillon Inc.	Urban, periphery, suburban	4-125	SFA, MFLR, MFMR MFHR	1-6
General Electric Company	Periphery, suburban	5-30	SFA, MFLR	1-4
Hercules Inc.	Periphery, suburban	5-15	SFA, MFLR	1-4
Home Building Corporation	Periphery, suburban	10-20	SFD, SFA, MFLR	1-4
Levitt Technology Corporation	Periphery, suburban	3-27	SFA, MFLR	1-4
Material Systems Corporation	Periphery, suburban	4-20	SFD, SFA, MFLR	1-4
National Homes Corporation	Periphery, suburban	3-18	SFD, SFA, MFLR	1-5
Pantek Corporation	Periphery, suburban	10-30	SFD, SFA, MFLR	1-4
Pemtom Inc.	Periphery	8-15	SFD, SFA	2-3
Republic Steel Corporation	Suburban	4-7	SFD, SFA, MFLR	1-5
The Rouse-Wates Company	Urban, periphery	15-100+	MFLR, MFMR, MFHR	0-6
Scholz Homes Inc.	Periphery, suburban	8-16	SFA, MFLR	1-4
Shelley Systems Inc.	Urban	10-200	MFLR, MFMR, MFHR	0-6
Stirling Homex Corporation	Urban	50-300	MFHR	0-5
Townland Marketing and Development Corp.	Urban	10-100+	SFA, MFLR (Structure is MFMR/HR)	1-5
TRW Systems Group	Periphery, suburban	13-25	SFD, SFA, MFLR	1-4

Structure	Principal Innovation	Off-Site Construction	Estimated System Cost	Availability of System
Wood/aluminum panels; wood service modules.	Service modules are core around which any home may be custom designed and built.	Panels and service modules.	$10 to $20 per sq. ft.	NE, Middle Atlantic, SE, SW, NW and West Coast U.S.
Steel and wood-frame box-modules.	Wide variety of modular arrangements—determined by planned interior usage.	Finished box-modules.	Medium.	National.
Precast concrete panels, slabs and service modules.	Ballency (European) system combines materials and techniques.	Panels, slabs and service modules.	Unknown.	National.
Precast reinforced concrete panels for walls and floors.	Combination of precast concrete wall and floor panels and improved joint techniques.	Wall and floor panels.	Less than conventional.	National.
Wood framing and pre-cut panels.	Standardized factory-built framing sub-assemblies.	Wood framing and pre-cut panels.	Compatible to conventional.	Plans being developed.
Precast concrete panels.	Elements and assemblies produced in existing facilities.	All concrete elements and service modules.	Comparable to conventional.	Calif. and New England and expansion plans.
Precast concrete panels and service modules.	Combination of precast concrete wall and floor panels, and service modules.	Pre-cast walls and floors, and service modules.	$16 to $23 per sq. ft.	Ohio, Florida, Calif. and possibly 2 other locations.
Box-modules with steel studs and plywood stress-skin panels.	Cast-plaster walls.	Finished box-modules.	Medium (235/236 apply).	Northeastern U.S.
Wood-frame box-modules.	Vertical and horizontal arrangement of modules.	Finished box-modules.	Costs vary.	New England, Middle Atlantic, and Midwest States.
Wood-frame box-modules.	Factory-built modules.	Finished box-modules.	$14 per sq. ft.	Missouri, Pennsylvania and Colorado.
Wood-frame box-modules.	Modules produced in modern (1971) built-for-purpose factory.	Finished box-modules.	Comparable to conventional.	Currently Great Lakes area. Planned in 7 market areas.
Box-modules assembled from plastic wall panels or field erected panel construction.	Man-made (plastic) material.	Finished box-modules or panels.	Low to medium-low (235/236 apply).	400 miles radius from Sacramento, Cal. and Indianapolis, Ind.
Wood/steel-frame box-modules or panel assemblies.	Factory-built modules or panel assemblies.	Finished box-modules or panel assemblies.	Costs discussed by specific project only.	National.
Load-bearing aluminum edge sandwich panel and service modules.	Home can be built by owner with little equipment due to small panel system.	Panels and service modules.	Less than conventional.	Franchising plans nationwide.
Wood-frame box-modules.	Factory-built modules with 12-ft clear span capability.	Finished box-modules.	Comparable to higher price conventional construction.	No plan for production.
Steel-faced floor, wall and roof panels; steel angle frame.	Structural panel system.	Panels; mechanical, plumbing and electrical subsystems.	$20,000 for 3BR, $25,000 for 4BR.	Plans being developed.
Precast concrete panel and slab.	Wates (English) structural system.	All concrete above first floor; K/Bath modules.	6% less than conventional.	Missouri, Md., Conn. Next: Fla., Ill., N.Y.
Wood-frame box-modules.	Factory-built modules with conventional appearance.	Finished box-modules.	$14 to $16 per sq. ft.	Great Lakes and Midwestern States.
Precast concrete box-modules.	Vertical checkerboard arrangement of modules.	Finished box-modules.	10-20% less than conventional.	New York, New Jersey and Puerto Rico.
Box-modules and steel framing combined in field.	Erection technique.	Finished box-modules.	Medium.	Eastern U.S.
MFMR/HR super-frame with modular or panel dwellings.	"Created land" in air.	Precast super-frame, panels/modules. Utility distribution packages.	Unknown.	Future plans undeveloped.
Box-modules assembled from plastic wall panels or field erected panel construction.	Man-made (plastic) material.	Finished box-modules and panels, and service units.	More than conventional.	400 mile radius from Sacramento, Cal. and planned in New Mexico.

Table of Housing System Characteristics

Alcoa Construction Systems Inc.
Boise Cascade Housing Development
Building Systems International
CAMCI, Inc.
Christiana Western Structures
Descon/Concordia Systems Ltd.
FCE-Dillon Inc.
General Electric Company
Hercules Inc.
Home Building Corporation
Levitt Technology Corporation
Material Systems Corporation
National Homes Corporation
Pantek Corporation
Pemtom Inc.
Republic Steel Corporation
The Rouse-Wates Company
Scholz Homes Inc.
Shelley Systems Inc.
Stirling Homex Corporation
Townland Marketing and Development Corp.
TRW Systems Group

The Housing System Producers

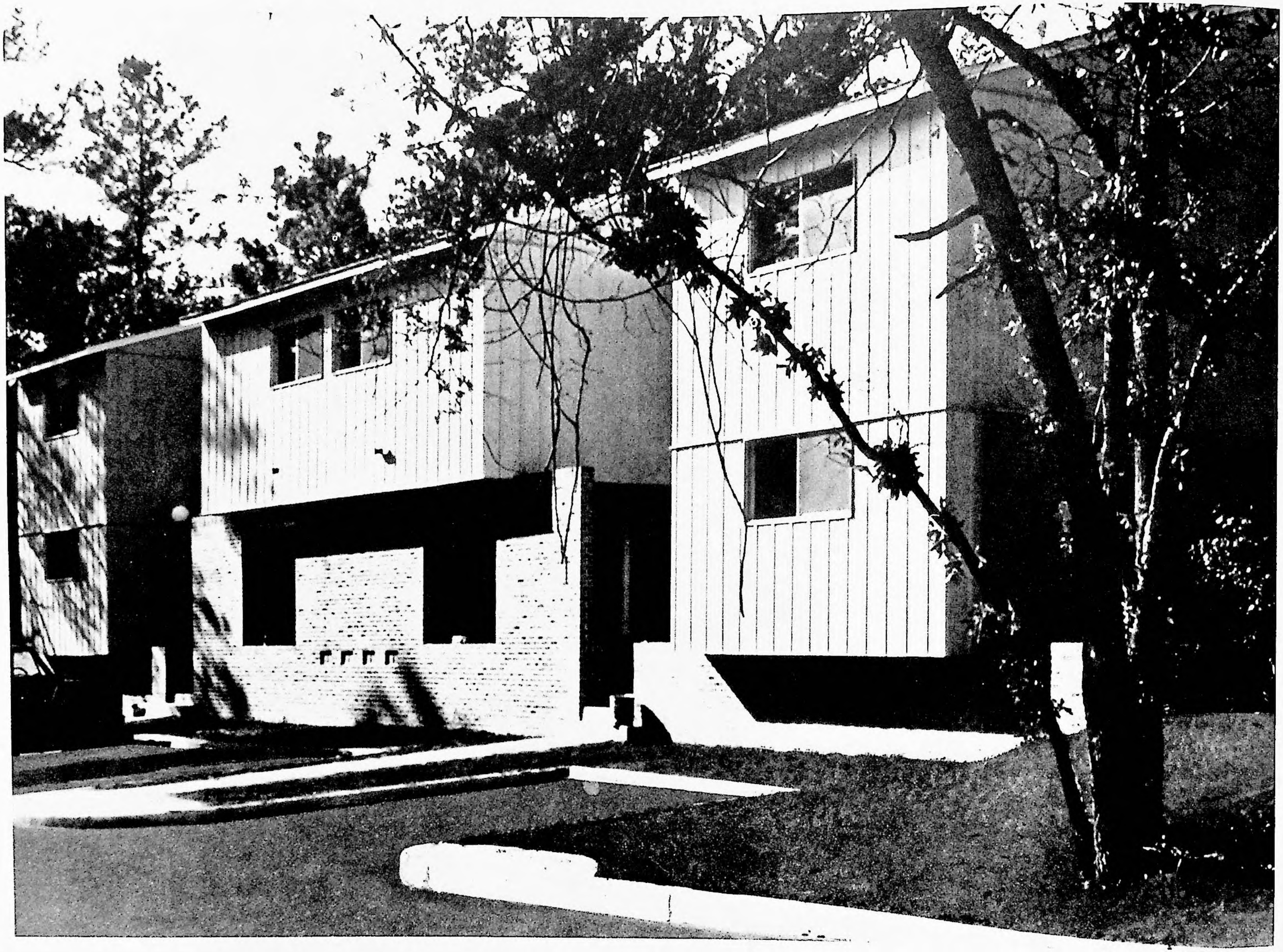
FOREWORD

The reports prepared by the 22 Housing Systems Producers (HSP) about their Phase I design and development activities varied widely in purpose, content and thoroughness. For use in this composite report, a large amount of material had to be organized or developed. Questionnaires answered by the HSP's helped complete the data available.

Credit is due the producers for supplying the facts and the direction of their individual reports. No attempt has been made here to validate all data or claims made by HSP's. The inputs were rewritten or extensively edited to create 22 descriptions of substantial consistency. Such variations as occur in the accounts reflect the understandable differences in contributions.

Abstracted from the reports, the basic characteristics of the 22 Operation BREAKTHROUGH housing systems are shown in the table opposite (the Appendix contains a complete tabulation and a glossary). Each HSP was identified with one specific system in Phase I, although many companies proposed two or more. During the selection process, HUD evaluated each system on its merits and reduced the number to one per HSP.

Subsequently, some systems were developed to offer variety beyond that actually employed at the prototype sites. These additional capabilities usually have been described in the text and thus may be reflected in the table.



Alcoa Construction Systems, Inc.

INTRODUCTION AND APPLICATION

Alcoa Construction Systems, Inc. (ACSI), a subsidiary of Aluminum Company of America, has designed and tested a core and panel housing system that features a sophisticated, three-dimensional service module. This system, allowing the interchange of materials and products to fit various market conditions, is being applied to Operation BREAKTHROUGH prototype sites at King County, Washington, Sacramento, California, and Macon, Georgia. All units are conventionally designed and use conventional materials to optimize marketability and consumer acceptance.

The ACSI system has been applied to single-family detached houses, duplexes, townhouses and garden apartments for Operation BREAKTHROUGH. (The same system is being successfully used in elevator apartments more than three stories high separate from the Operation BREAKTHROUGH program.)

Each ACSI housing project requires a local development team that includes a developer, an architect, a builder or contractor and ACSI as the Housing System Producer. The system results in fully utilized local resources, buildings designed to fit actual site conditions, buildings meeting local codes and standards and a housing market with broad acceptance.

SYSTEM DESCRIPTION

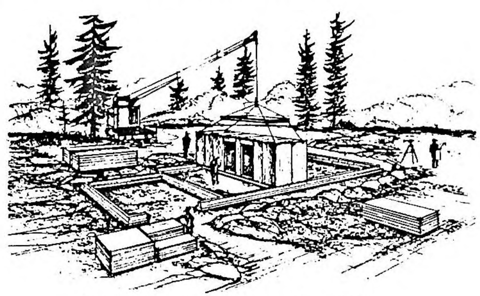
The ACSI system consists of service modules and a variety of subsystems broadly classified as foundations and site work, walls, roofs and floors, exteriors and interiors. Some of these subsystems are factory built and some are produced at the site in the combinations that optimize the special-purpose factories, available local resources and local economic conditions (Figure A). Detailed descriptions of the various subsystems follow.

Service Modules

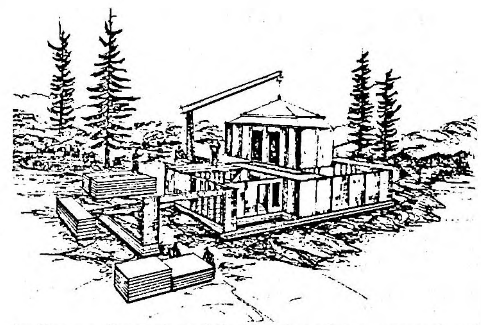
The high value operating elements of a living unit are contained in the ACSI service module (Figure B). Each module includes a kitchen, one or more bathrooms, laundry facilities and principal elements of the plumbing, heating, ventilating, air conditioning (HVAC) and electrical services. It also contains the lighting, doors, finishes and fire and acoustical treatments associated with the principal module elements.

The service modules are mass-produced in three-dimensional forms at special-purpose factories (Figure C). These basic cost-sensitive elements have been standardized for efficient purchasing, inventory control, fabrication and assembly. However, the completed modules are available in a wide selection of finishes, colors, appliances, fixtures and mechanical subsystems, which are customized for each project.

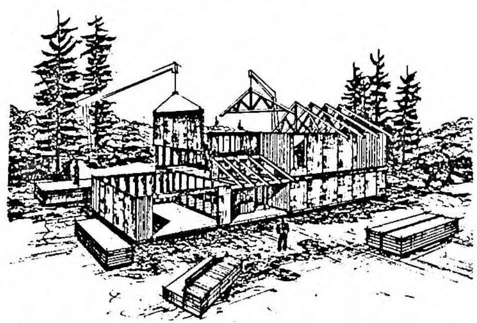
Length of a service module may range from 2 to 30 feet depending on the need. However, a module is always 8 feet wide for economical handling and ease of shipping by a full choice of transportation vehicles.



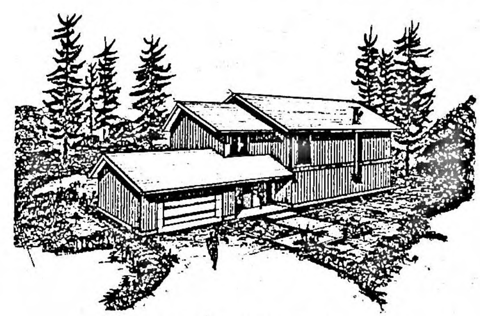
Service core is placed on foundation.



Ist floor wall panels and 2nd level service core are placed.



Completion of wall panels and addition of roof trusses.



Completed single family home.

A. Site construction sequence

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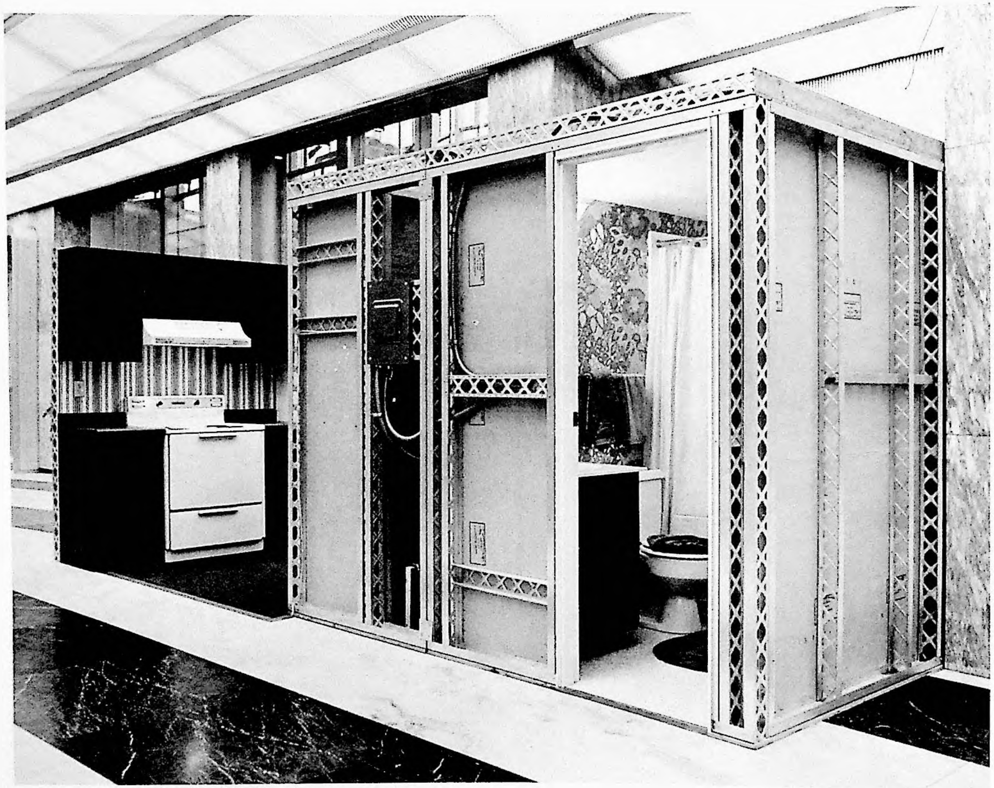
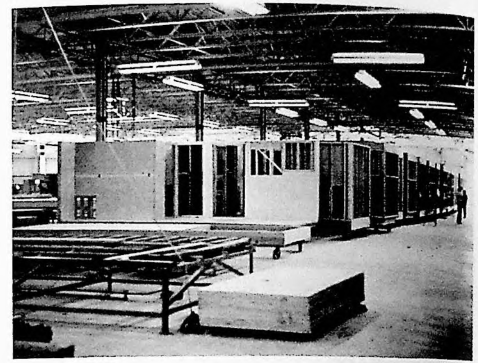


B. ACSI incombustible bathroom/kitchen module utilizing Alcoa Alumiframe.



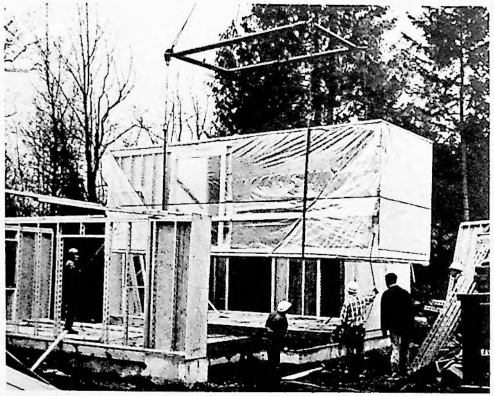
C. ACSI Service module production line.

Studs are 2 x 3 and 2 x 4 wood or aluminum, structurally braced. Where fire resistance is a primary requirement, Alcoa Alumiframe lineals are used for wall, floor and ceiling structure. A special system of joists is used in the ceiling structure to allow free horizontal distribution of mechanical and electrical components. Wall partitions serve an important bracing function, and all door and window openings are reinforced at fatigue-sensitive areas to avoid cracking of gypsum board and finishes.

The modules are packaged in weatherproof covering for transportation and protection until the building is enclosed. All ACSI service modules are delivered with framing exposed on the outside. This allows for onsite mechanical and electrical continuity and facilitates matching of field coverings and finishes from the service module to adjacent panels (Figure D).

Fire and sound conditioning between rooms and at storage areas and vertical continuity openings are provided by gypsum board and blocking and by the installation of sound-attenuating blankets where required.

Most service modules are designed to contain a complete heating, ventilating and air conditioning system complete within the module. The basic heating system is ducted warm air. Energy can be provided by gas or

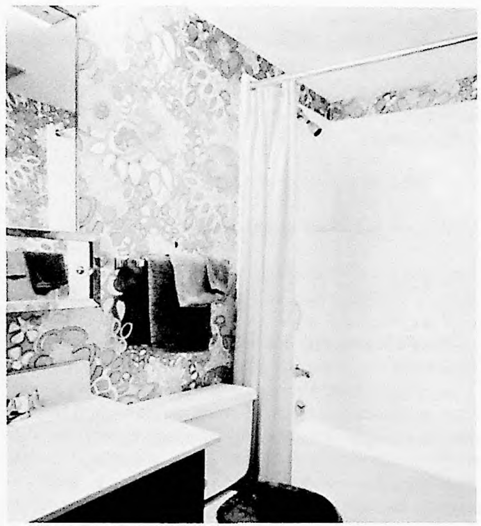


D. Placement of ACSI core and panel system at King County prototype site.

electricity. If desired, the ducted warm air system can be replaced by hot water pumped in from a remote boiler to baseboard heaters. Heating can be omitted from the service modules if electrical baseboard or unit heaters are specified elsewhere. Ventilation equipment and ducts are provided for bathrooms, dryers and kitchens, when specified.

The electrical service panel and conduit for the main service line and some major circuits are part of the ACSI service module. Wiring for all house circuits is installed from the service panel: (1) to switches, outlets, and fixtures within the service module; and (2) to junction boxes on outside surfaces of the module for easy connection to fixtures and outlets outside the module. All lighting fixtures, outlets and switches within the module are factory installed. If local regulations allow, conduit for telephone and television services can also be factory installed. For two-story living units in Operation BREAKTHROUGH, smoke detection devices are included in the upper service module of the two-story stacks.

The entire house plumbing system above the foundation is completely installed, tested and operable when it leaves the factory. The plumbing system in the service module includes the main water supply line; gas supply lines when required; drain, waste and vent system; dishwasher and clothes washer connections and fittings for field connections of module-to-module or module-to-site utilities. Plumbing fixtures within the module include electric or gas water heaters, toilets, bathtubs, shower stalls, kitchen and bathroom sinks. Plumbing can be provided in any approved material allowed by the applicable codes and specified by the customer (Figure E).



E. Service module bathroom furnishings are bright and practical.

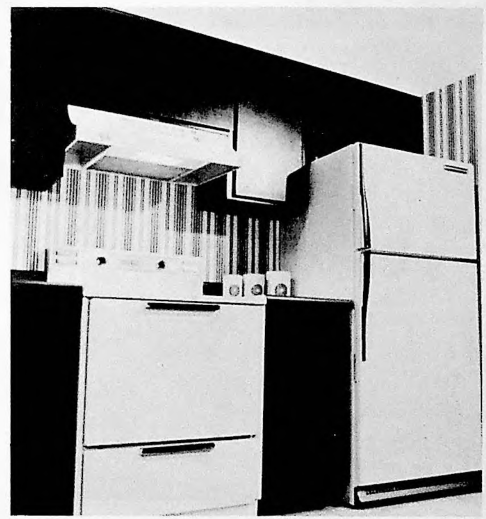
Full kitchens are shipped with or as part of the ACSI service modules (Figure F). All cabinetry and hardware are standard. Appliances, however, are available at the customer's option, including such items as gas or electric ranges and ovens, dishwashers, disposers, clothes washers and dryers, refrigerators, ironing boards, intercoms, entertainment centers, trash compactors, range hoods, bathroom and kitchen ventilators and a full line of bathroom accessories.

Foundations and Site Preparation

Conventional foundations and site preparation are adequate for ACSI housing systems, although this site work varies in response to local preferences and economics. These may include poured concrete basements, piers, crawl spaces, slabs on grade and slabs on grade in combination with masonry units.

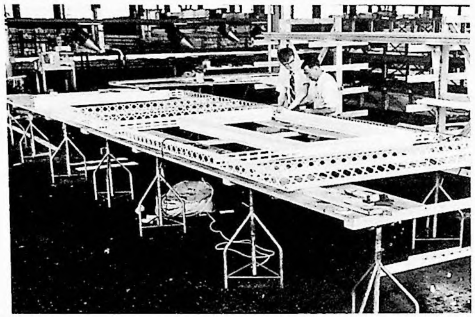
ACSI Wall Subsystems

Exterior walls for single-family detached units are primarily factory fabricated from Alcoa Alumiframe lineals and preassembled window and door components (Figure G). Windows are factory glazed and doors are prehung, and both are complete with all necessary hardware. Opaque wall panels are factory sheathed with plywood. Exterior walls for townhouses and garden apartments are primarily factory fabricated from wood 2 by 4's, sheathed with fiberboard or plywood. Aluminum windows and sliding glass doors, as well as prehung

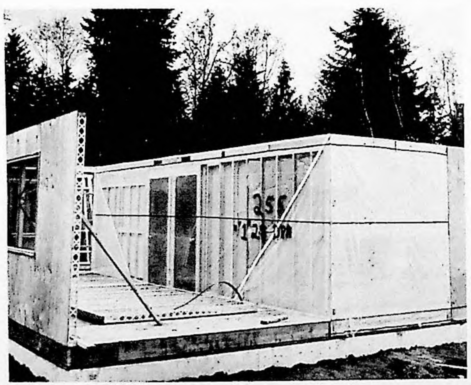


F. ACSI service modules contain a completely equipped kitchen.

entry doors, are shipped in most exterior wall panels. All wall panels are shipped with framing exposed to the inside for field installation of appropriate insulation, vapor barriers, fire resistance and interior wall coverings (Figure H).



G. Shop fabrication of Alcoa Alumiframe wall panels.



H. Wall panels arrive with framing exposed to the inside for field installation of insulation and interior wall coverings.

Interior partitions are available in the open-framed condition with Alcoa Alumiframe subsystems. Interior door frames are integral components, while doors can be specified as either factory installed or site installed. Prehung doors can be delivered in the wood-framed partition panels, if specified, or can be shipped loose for installation after other site work is complete. Wall coverings and appropriate acoustical and fire treatment are applied at the site after installation on the partition panels.

Party walls for townhouses and garden apartments are framed with wood 2 x 3's or 2 x 4's and are double walls with staggered studs and an air space for acoustical isolation. Where local codes require fire resistance between the split party wall, fire-resistant sheathing is factory applied to the blind side of party wall panels. The accessible side of each panel is open for field installation of appropriate acoustical and fire resistance treatment and wall coverings.

ACSI Roof and Floor Subsystems

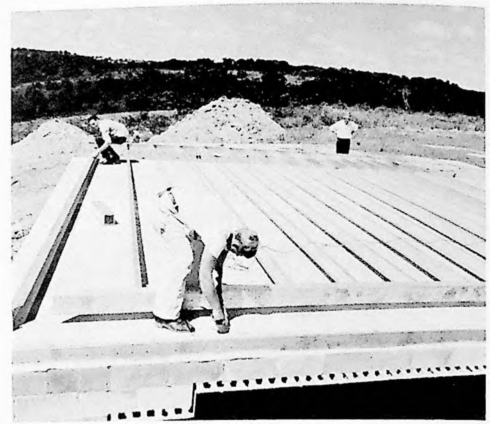
Roof and floor subsystems are the least definitive of all parts of the ACSI housing system. Roof subsystems vary with architectural style. In areas where concrete slab-on-grade foundations are accepted and offer economic advantages, no first-floor panels or framing are required.

Floor subsystems consist of wood or aluminum framing (Figure I) with plywood subflooring, except for slab-on-grade concrete first floors. ACSI uses the American Plywood Association loading tables and technical services for design standards, but limits joist sizes to 2 x 8's for dimensional coordination with the standardized service modules.

Exterior Subsystems

ACSI provides a housing exterior that is nearly maintenance-free over the life of the housing unit.

Weathering wall surfaces are available in maintenance-free veneers such as brick, stone, stucco, concrete or aluminum, or in maintenance-free applied coatings such as texcote or special plastic laminates.



I. Alcoa Alumiframe components are used in the floor panel assemblies.

Traditional roofing systems are used throughout. Weather resistant covering may be site-applied to roofing panels or the plywood sheathing of trusses, depending on the desired architectural effect and quality requirements.

Interior Subsystems

Interiors (other than the ACSI service module) include those customized items that give houses their warmth, fire protection, acoustical features, color, texture and other aspects of "character."

Thermal insulation is site-installed in all exterior walls and in upper-floor ceilings (typically using fiberglass or mineral wood applied in batts, or loose, depending on local costs). Vapor barriers are typically aluminum foil, factory applied.

Fire resistance and acoustical treatments utilize appropriate sound-attenuating blankets, carpets and pads, finishes and gypsum board, site-installed to meet the guide criteria and building code requirements.

Wall, ceiling and floor coverings, as well as mouldings and trim, are by customer choice. Any commercially available products can be specified by the architect or customer to provide the desired style and character.

The site-installed electrical package includes necessary wiring, switches, outlets, and fixtures to complete all circuits from the service module junction boxes. Connections are completed to switches, outlets and fixtures in all rooms. In some cases, the connections provide for coordinated outdoor or garage/carport lighting. The electrical package is best kept conventional to avoid controversy or confusion among building inspectors, subcontractors, and suppliers. It should be carefully coordinated with the electrical components in the service modules to complete a total electrical subsystem.

HOUSING DESIGNS

During Phase I of Operation BREAKTHROUGH, ACSI's independent architects designed housing units based upon ACSI subsystems. During Phase II of Operation BREAKTHROUGH, prototype units were constructed on demonstration sites in King County, Washington, Sacramento, California and Macon, Georgia.

Typical designs shown on the following pages give some indication of the versatility of the total ACSI housing system and its responsiveness to Phase II requirements. The full range of these designs included single-family detached one-story houses, single-family detached two-story houses, single-family detached split-entry houses and one- and two-story townhouses and duplexes, as well as one-, two- and three-story garden apartments. Many additional ACSI housing system designs are now available for Phase III of Operation BREAKTHROUGH.

ECONOMICS OF THE SYSTEM

The ACSI system is compatible with the existing building industry. Organized labor, subcontractors and local inspectors have the opportunity to participate, in addition to architects, developers and builder/contractors who perform their traditional roles. When effectively utilized by the development team, the ACSI system provides superior housing designs of consistent high quality at a cost lower than conventional systems.

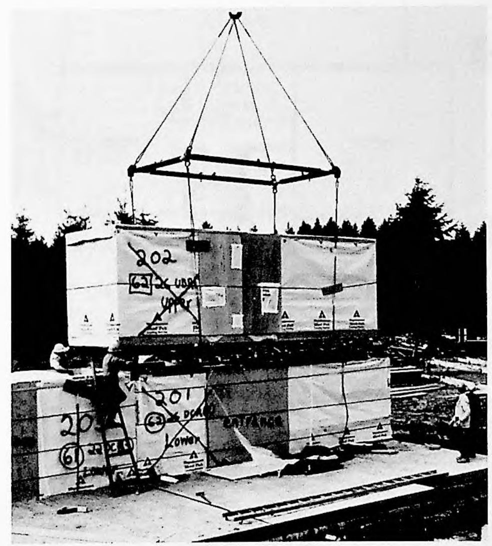
In addition to savings in materials and labor, the system provides the builder with improved logistical control, less dependence on the weather (because important work is done under cover—Figure J), and a greatly reduced construction cycle. This saves interim construction financing and provides fixed prices on a major portion of the total construction job. Because it avoids stereotype designs and the low-cost image generally associated with industrialized housing, ACSI's system is applicable to a wide range of housing types and price ranges.

J. Factory assembly of Alumiframe wall panels.

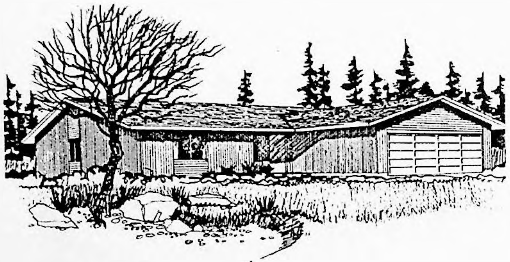
By concentrating on compact, high-value subsystems, ACSI avoids the transportation problems of large, low-value conventional modules, and can serve wider marketing areas from each production facility. All subsystems are designed with sizes and weights that can be easily transported and handled by common means (Figure K). Units weigh less than 5 tons and fit well within conventional legal highway limitations and can be easily handled by ordinary highway carriers. ACSI units also fit within the existing railroad capabilities without need for special railroad equipment or routings. If distance or natural barriers dictate, ACSI subsystems can also be handled by barges, helicopters, or specialized carriers having experience with mobile homes and modular construction.

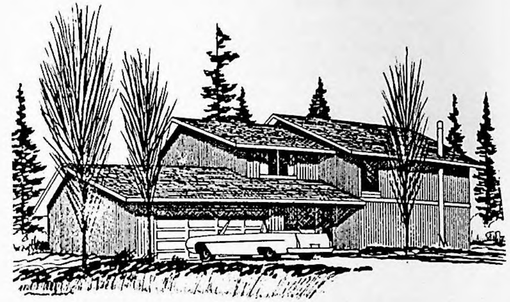
Prices for ACSI service modules and other key subsystems have been developed for each market area, based on costs at specific production facilities. As a Housing System Producer, ACSI will only be involved in pricing of the hardware package; prices for finished housing will be established by the developer or builder who utilizes that package. Prices of specific housing units designed with the ACSI system or key subsystems will vary with the number of units, timing and scheduling of the housing project, terms and conditions of the sale, the area of the country and the degree of success in efficiently adapting the system to local conditions.

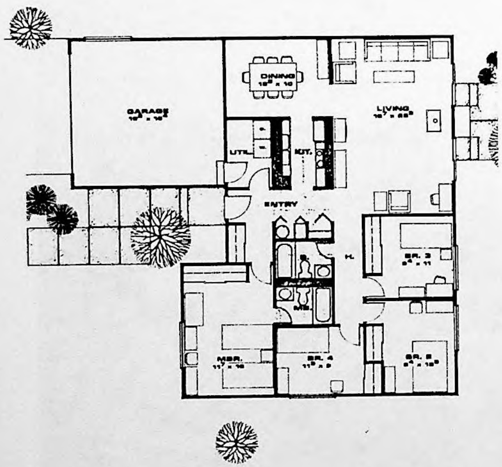
Current experience in Phase II indicates that, when effectively used, the ACSI system provides housing of superior quality at directly competitive prices, while saving time and indirect costs. The ACSI system has been used successfully for FHA Section 235 and 236 projects as well as in luxury housing units.



K. ACSI service core units are easily handled by mobile cranes.







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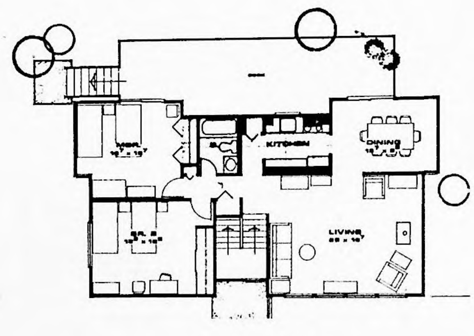
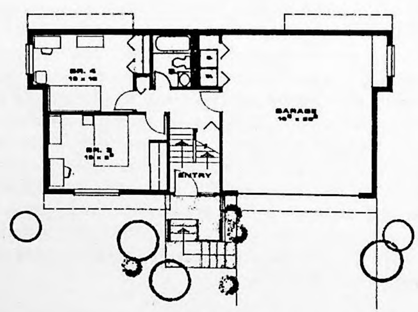
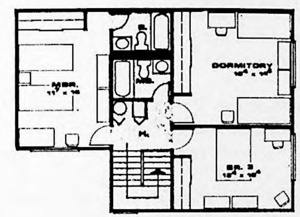


UPPER LEVEL

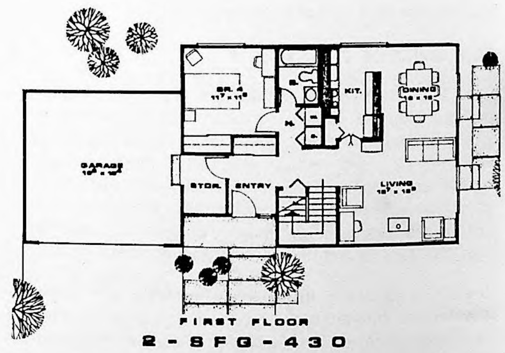


LOWER LEVEL

2a - S F G - 4 2 0 A



SECOND FLOOR



FIRST FLOOR

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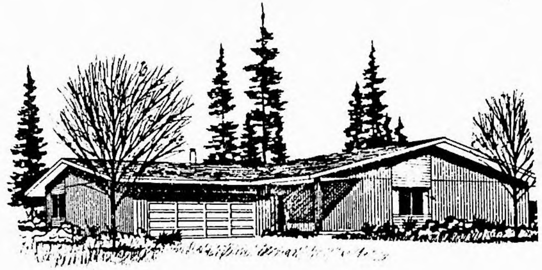

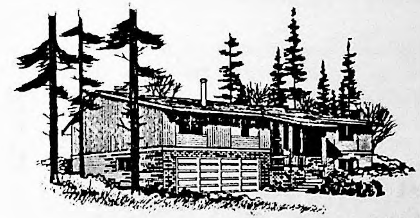

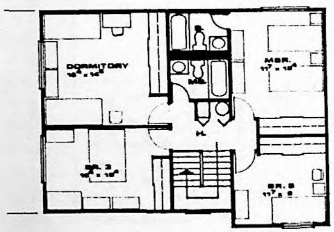

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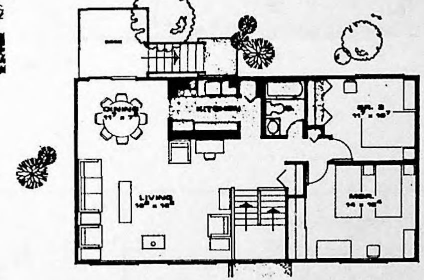
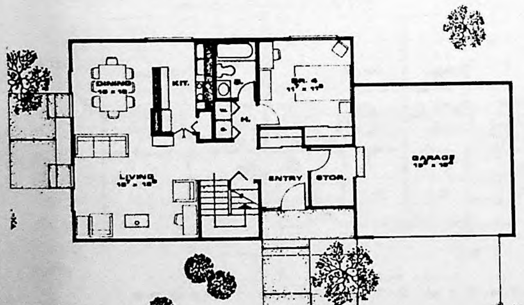
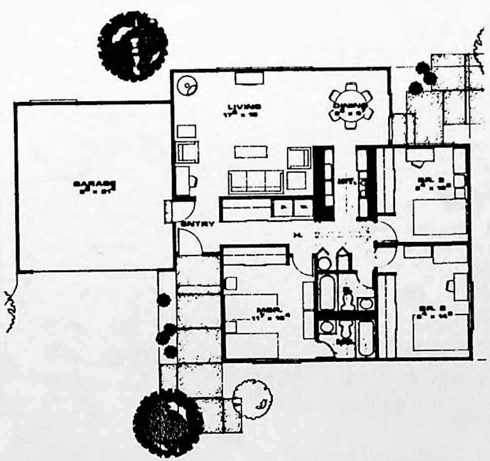


UPPER LEVEL

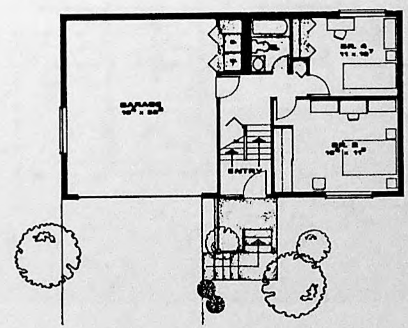


FIRST FLOOR

2-SFG-530

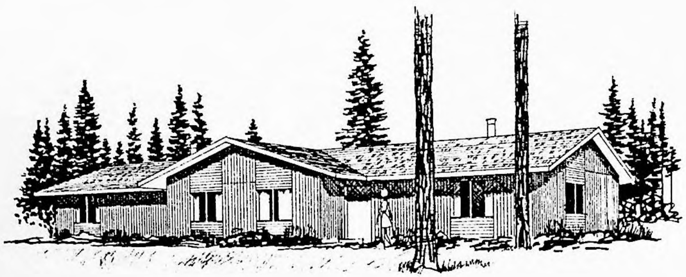


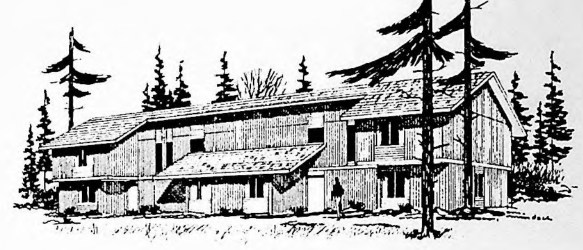
1-SFG-320

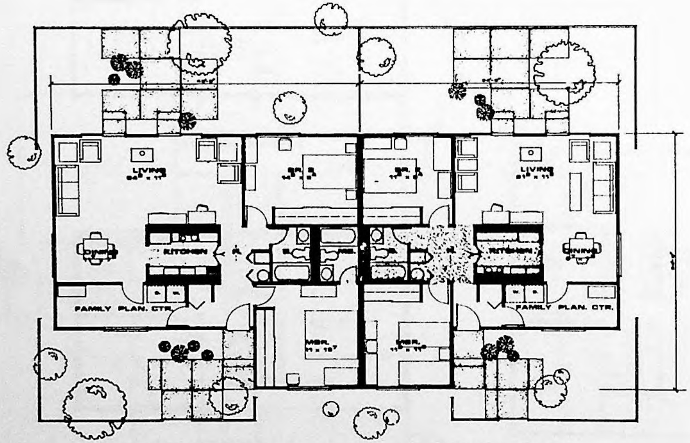


LOWER LEVEL

2s-SFG-420s







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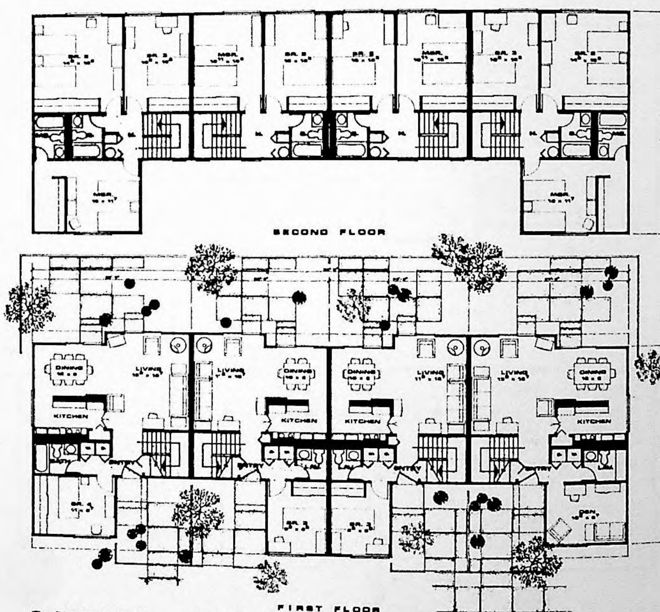


2-TH-430   2-TH-315   2-TH-315   2-TH-3D25

DEPARTURE FROM CONVENTIONAL SYSTEMS

The principal innovative features of the ACSI system have been previously discussed. They include:

- The service module concept that aggregates costly, principal functional elements into a compact, easily-transportable factory-built core unit.
- A wide latitude in choices available to architects and owners.
- ACSI local involvement concept that makes maximum use of labor and materials available at the construction site.
- Maintenance free features, particularly on exterior surfaces.

PRODUCTION PROGRAM

Major subsystems for the single-family detached homes and townhouses for King County, Washington, were produced about 25 miles away, at ACSI's Housing 601 Division plant in Kent, Washington. This plant is currently in operation and is producing service modules for builders in the Northwest, Alaska and Hawaii. Contracts for other major subsystems required at King County were awarded by competitive bidding to local fabricators in the Seattle area (Figure L).

ACSI subcontracted the fabrication of all required subsystems for its 40 townhouses and 12 garden apartments to local firms near Macon, Georgia. These firms had demonstrated their capabilities and interest in BREAKTHROUGH participation and were willing to accept the constraints imposed by ACSI's quality assurance, equal opportunity plans and competitive bidding. Peachtree Housing fabricated the 92 ACSI service modules in their existing plant for mobile/sectional homes at Moultrie, Georgia, approximately 130 miles away.

The 76 service modules required for Sacramento, California (Figures M and N) were fabricated and shipped from ACSI's plant in Kent, Washington. Other subsystems were obtained by competitive bidding.

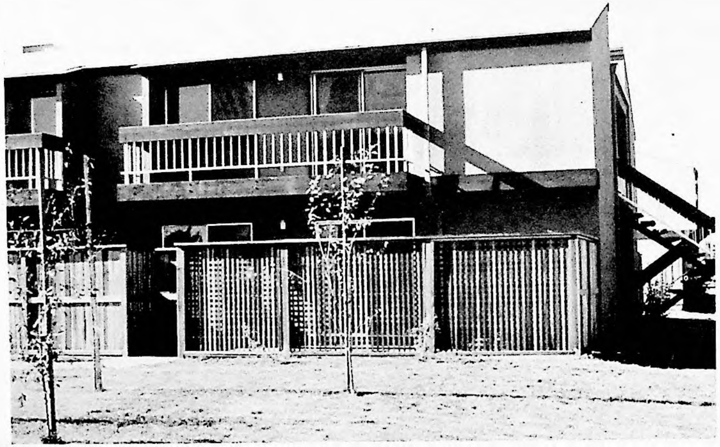
During Phase II ACSI also established a wholly-owned service module production facility in Tyrone, Pennsylvania (Housing 602 Division).

MARKETING

ACSI is moving into Phase III of Operation BREAKTHROUGH systematically. Emphasis is placed on expanding and integrating existing operations of ACSI and its affiliated companies under the Alcoa Building Industries (ABI) umbrella. ACSI's marketing effort will be supported with complete technical services. Volume marketing of housing will be concentrated in HUD Regions II (New York), III (Philadelphia), IV (Atlanta), VI (Forth Worth), IX (San Francisco) and X (Seattle).

ACSI is interested in the total range of housing types and potential customers. Their goal is to achieve profitable sales of housing and housing projects utilizing the ACSI core and panel system. This would be accomplished by reducing housing costs without sacrificing quality. In addition to the core and panel system, ACSI and its ABI-affiliated companies will participate in the volume marketing of all segments of housing systems. They will sell products and components, as well as building subsystems and complete systems.

L. Completed ACSI Townhouse units at King County prototype site.



M. ACSI Garden Apartments at Sacramento BREAKTHROUGH site.

N. Sacramento site Townhouse units by ACSI.

Volume production and marketing will be achieved by involving a wide variety of participants in a wide variety of projects within the most promising market areas. ACSI has determined that it will concentrate its efforts with existing proven producers in regions where Alcoa and/or ACSI have established operations. The selected markets will be those determined by research to have the best combinations of opportunities and minimum constraints. The initial concentration of effort is therefore planned for the West Coast, the Southwest, the Northeast and Southeast where existing production facilities are in operation or planned by early 1973.

Current and future developments are directed toward simplifying all elements, making components fully interchangeable, developing wider variety of subsystems, improving marginal performance areas, improving ease of installation and hook-ups, and minimizing double handling and traffic through finished areas in key subsystems.

Many details superior to those shown in Phase I and utilized in Phase II are known but could not be incorporated in those phases because of program schedules and constraints. Phase III designs and production facilities are incorporating such improvements for execution during the volume production phase.

For additional information, please write:

Alcoa Construction Systems, Inc.
1501 Alcoa Building
Pittsburgh, Pa. 15291
Attention: Paul Vosburgh
or call [412] 553-4281

ACSI Phase II units are located at three prototype sites:

- Macon – 40 SFA, 12 MFLR
- Sacramento – 4 SFD, 24 SFA, 24 MFLR
- King County – 62 SFD, 24 SFA

Summary Information

SYSTEM APPLICABILITY	
Location	Rural, suburban, urban.
Density Range	Unlimited except by local code.
Environmental Adaptability	Adaptable to most climates, topography, soils, sites.
Non-Residential Functions	Not applicable.
Site Planning Services	Not applicable.
BUILDING SYSTEM DESCRIPTION	
Housing Types	SFD, SFA, MFLR, and MFHR.
Unit Variations	1 to 5 bedrooms.
Structure	Wall, floor and roof panels (optional aluminum or wood frame).
Exterior Elements	Aluminum, brick veneer, or stucco stone surfaces; conventional trim and finishing materials.
Foundations	Conventional poured concrete walls and slabs; hollow clay masonry and concrete blocks.
Comfort System	Optional fuel for central forced air heating; integrated cooling.
Plumbing	Conventional; bathroom and kitchen integrated in service module.
Electrical	Conventional; integrated with subsystems.
Furnishings	Not applicable.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Integration of cost-sensitive elements into a factory-produced service module; mass production that permits individualization.
Codes	Design criteria and certification compliance; adaptable to all national model codes.
Deviations from Original Proposal	No significant deviations.
PRODUCTION PROGRAM	
Delivery Rate	1500-2500 service modules per plant per year.
Off-site Production	Panels; service modules; stairways; trusses.
On-site Installation	Panel and wall erection; service module placement; utilities hook-ups; exterior and interior elements.
On-site Construction	Roof and floor subsystems where cost-effective; foundations and site development.
External Functions	Architectural design; environmental design; construction; financing.
Internal Functions	System design; fabrication of service modules.
LABOR REQUIREMENTS/TRAINING PROGRAM	
Requirements	Local unskilled and semi-skilled; equal opportunity; prevailing wage scales.
Training	On-the-job training.
ECONOMICS OF THE SYSTEM	
Construction Cost	$10.00 to $19.90 per square foot.
Transportation Limitation	Largest subsystem can be transported by common highway and rail carriers, specialized mobile home carriers, barges, helicopters.
Useful Life	50 years for structure; appliances and mechanical depends on quality, usage and upkeep.
MARKETING FOR PHASE III	
Market Areas	Northeast, Middle Atlantic, Southeast, Southwest, Northwest, West Coast.
Market Objectives	Total range of housing types using Alcoa core and panel: comprehensive reduction of all costs relating to Alcoa building systems.

Boise Cascade

INTRODUCTION & APPLICATION

The volumetric housing systems developed by Boise Cascade Housing Development (BCHD) introduce a new generation of manufactured housing. Modern production concepts have been utilized and innovative components and subsystems have been carefully combined with traditional, time-proven construction materials. But the most important innovations relate to the basic design process adopted for this development program. It started with a definition of building systems performance including consumer needs such as comfort, convenience, variety, aesthetic appeal, and economy. Then a series of promising technical solutions was devised, incorporating a full spectrum of fundamental design approaches to volumetric (modular) housing. Finally, the most promising housing systems were subjected to an exhaustive evaluation of comparative performance, incorporating hundreds of variables. In the process, many pet theories and widely-shared beliefs were shattered. The product line which evolved from this process offers many consumers what they are looking for, i.e., superior reliability, tasteful design applicable to a wide range of environments and reasonable costs.

To demonstrate the potential of the BCHD volumetric housing system, 244 prototype townhouses and garden apartments are being erected on Operation BREAKTHROUGH sites in Sacramento, Macon and Memphis. Projects employing FHA Section 236 set-aside housing subsidies are being studied and a specialized product line has been developed to satisfy the unique needs of the HUD-assisted rental housing program.

Operation BREAKTHROUGH housing ranges from 696 square feet to 1536 square feet.

SYSTEM DESCRIPTION

The Boise Cascade proposal to HUD included a wide variety of housing types to be built with a mix of construction technologies. The negotiated R&D contract was limited to one element of the work originally proposed—a multi-family modular low-rise system. A steel structural system was used on the sites in Memphis and Macon and a wood system was used on the Sacramento site.

The modular concept of construction relies on optimizing the efficiencies of in-factory construction techniques. Modules are assembled separately in the plant then transported by rail or highway to the site, where they are crane-erected on site-prepared foundations. Each module is designed to resist, independently of the others, all loads normally encountered in residential construction.

Structural Concept

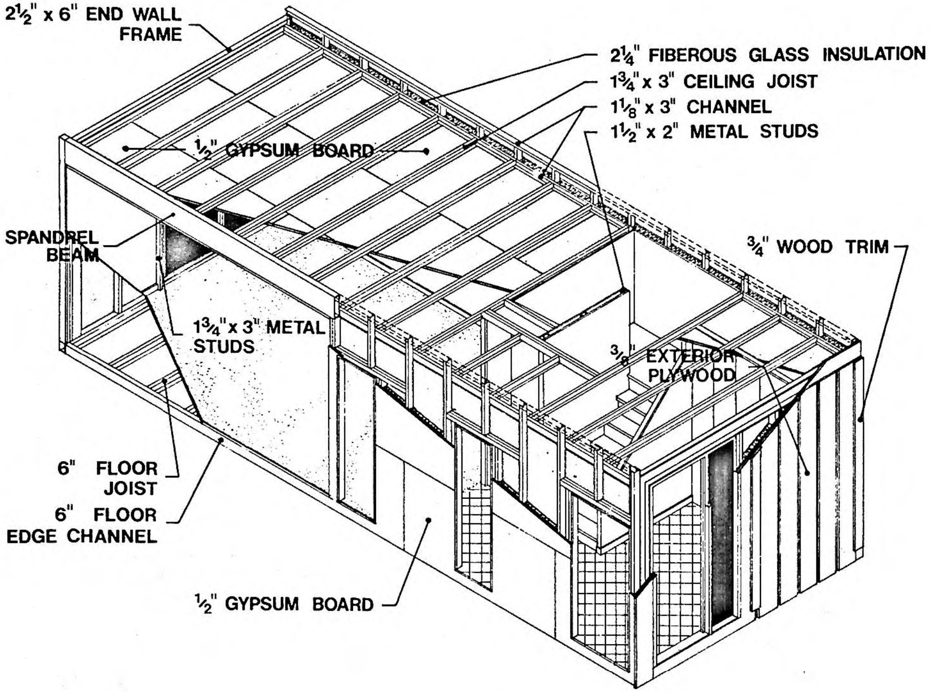
The primary structural elements are light gauge galvanized steel sections, framed into panels and brought together in the plant to form the structural skeleton. Sheathing, insulation and other components are installed during this panel assembly process. All interior partitions are non-load bearing elements. Intra-module connections are welded, and those between modules are bolted.

Gypsum board is used both as an interior sheathing material and as a substratum for sound and fire insulation. A structural diaphragm is provided by plywood floor sheathing. Fiberglass insulation (rated R-11) aids in the thermal and acoustical control. Foil backed gypsum is used for vapor control where necessary, supplemented by exhaust fans in humid zones.

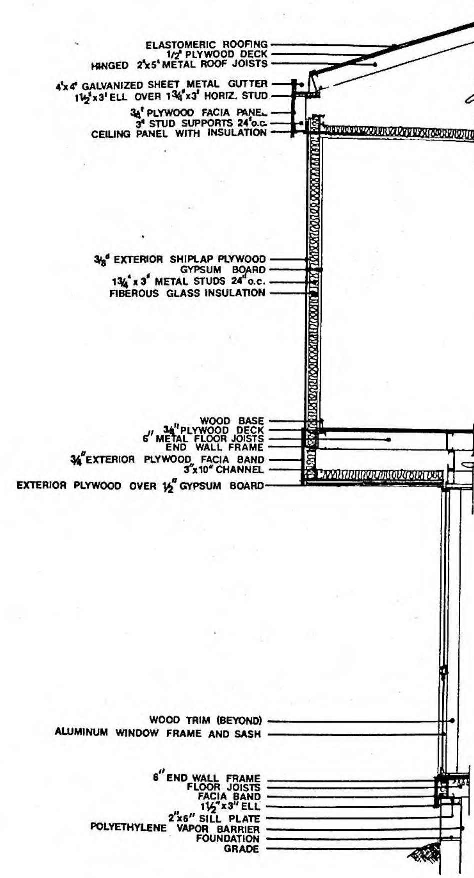
As an alternative to the steel framing shown in Figures A and B, wood framing has economic advantages under certain circumstances for low rise housing. In general, BCHD studies conclude that:

- Steel is at a distinct advantage where wood prices are over $180 per thousand board feet (MBF). In the range of $140 to 180/MBF, either wood or steel can be used economically, depending upon framing technique, degree of fire protection and other design factors. Below $140/MBF, steel can be competitive if used in highly sophisticated designs.

- Labor costs do not materially affect the relative economies of wood and steel.



A. Structural Isometric



B. Typical Wall Section

Finishes

Gypsum wall board encloses the steel frame on the interior and exterior of the modules, providing protection against both fire and the transmission of sound. On the interior, this wall board can be finished and painted to serve as the interior wall surface or it may be covered with a variety of materials including vinyl, wood or composition panels. Exterior gypsum is covered with plywood or a simulated exterior finish. Elastomeric roofing is used when the roof is sloped; built-up materials are used in flat roofs.

Finish Materials

Ceilings

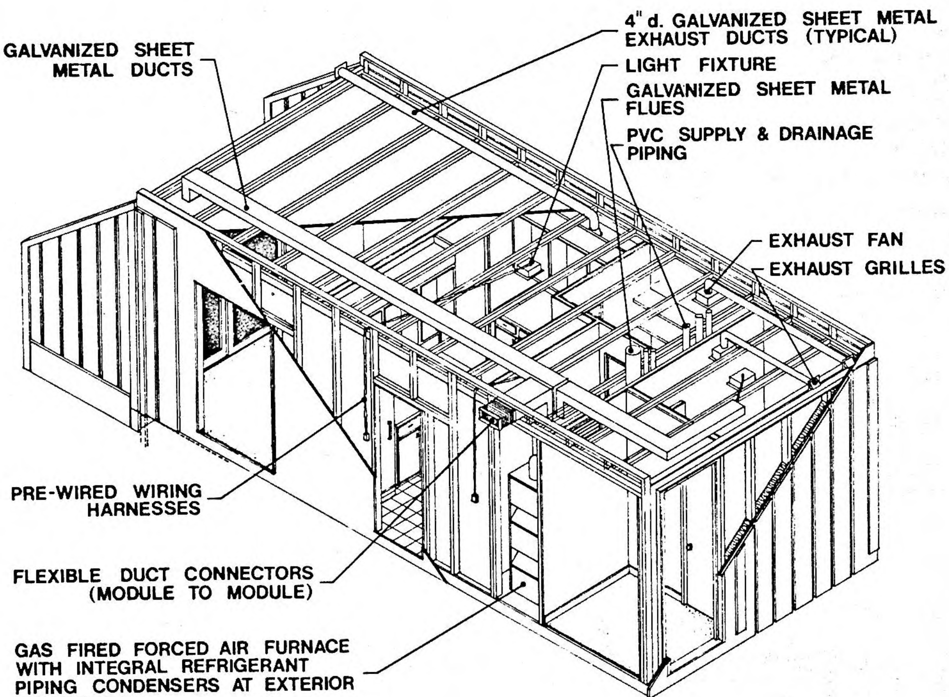
- Painted gypsum board (latex)
- Painted gypsum board (enamel)
- Unpainted gypsum board
- Acoustical tile
- Wood slats

Walls

- Painted gypsum board (latex)
- Painted gypsum board (enamel)
- Vinyl wall covering
- Prefinished wood paneling
- Wood slats
- Unpainted gypsum board

Floors

- Ceramic tile
- Roll vinyl flooring
- Carpet
- Wood parquet blocks
- Unfinished plywood



C. Mechanical Isometric

Mechanical Subsystems

All mechanical subsystems, shown in Figure C, are factory installed and tested before shipment. On-site connections are facilitated by expandable joining mechanisms. The major mechanical systems are options:

- Forced air heating and cooling systems
- Gas or electric water heaters
- PVC plastic or copper pipes
- Fiberglass tubs and showers
- Vitreous china water closets
- Enameled cast iron lavatories
- Hookups for laundry equipment
- Stainless steel kitchen fixtures

INNOVATIVE FEATURES OF SYSTEM

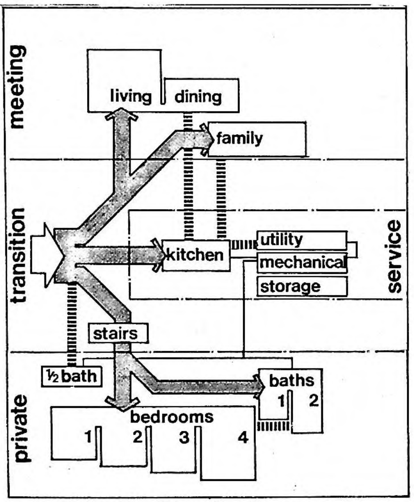
The two principal innovative features of the BCHD system involve the planning approach used in the selection or arrangement of modules to form an almost infinite number of floor plans and building configurations and the application of a system concept to the design and production of a prefabricated electrical distribution system harness.

PLANNING APPROACHES

Interior Plan Theory

By establishing a plan theory based on user needs for dwelling units in general, a design framework has been created. The internal design of the Boise Cascade housing system is based on a theory of usage "zones" and "rules." Four "zones" have been identified:

Private — Quiet, personal spaces (bathrooms, bedrooms)
Meeting — Less quiet, communal spaces (living, family and dining rooms)
Transition — Connection spaces (stairs, corridors, entries)
Service — Support spaces (kitchens, storage rooms, mechanical spaces, unility room)-



D. Internal Flow Chart

The approximate locations and relationships of these "zones" are determined by "rules." Some of the "rules" which evolved during the planning study can be summarized as follows:

- Ground-level living areas should be oriented to the opposite side, since most units (townhouses or garden apartments) will have parking on the entry side of the building.
- Entries should not open directly into living spaces but should open into a circulation space from which various parts of the unit can be reached.
- Townhouse plans should allow all bedrooms to be on the second floor, and stairs to be accessible from entry space.
- Family rooms, when included, should have access to the kitchen.
- Plans should allow for inclusion of eat-in kitchens and/or separate dining room arrangements.

The Building Block Concept

The "Building Block" approach is the theory for Boise Cascade's modular or volumetric housing system, in which the module is the basic component of the system. Using this base, certain combinations of individual modules will create the desired housing unit.

The primary objective was to design a minimum number of like modules that can be assembled in different combinations to produce a wide variety of dwelling plans.

Sample house plans have been studied and their basic components such as types of living spaces, circulation spaces, mechanical systems, special features and equipment have been catalogued. Investigation has shown that standardization of certain key areas can provide the greatest production efficiencies. In addition, further savings are possible if these critical portions of the system are grouped together in "cores" containing shared utility connections, flues, chases, stairs and major carpentry.

Two categories of cores were identified: "wet" cores and "dry" cores. Wet cores include all plumbing and mechanical equipment (furnaces, water heaters, bathrooms, kitchens and laundries). Dry cores are made up of vertical and horizontal circulation (primary carpentry—doors, stairs, closets and halls). Each Boise Cascade module can contain either a wet or dry core in which the complex elements of that module are concentrated and standardized. The remainder of the module is filled out with the simpler living spaces such as bedrooms, living rooms and family rooms. To allow for wide plan variations, these spaces can be adjusted in size and shape or eliminated completely during production.

A module width of twelve feet is the maximum uniformly permitted in all states for over-the-road shipments. Length and height are set by transporter design and road rules at about 55′ and 11′ respectively.

Dimensional ranges within these parameters, however, are quite flexible. Investigation indicated that modules of 10′ and 12′ in width, and 20′ to 42′ in length provide an extensive array of floor plans.

Plan Array

Figure E reflects the range of building types and widths that can be created by combinations of modules selected from the array to meet various programmatic requirements. It can be seen that for every plan type (townhouse and garden apartment) a variety of unit widths, room counts and interior amenities is available. In addition, for many of the plan configurations, a range of unit sizes in square feet can be obtained. Using only the basic module designs in the module array in different combinations, over 150 distinct plans have been assembled for townhouses alone.

Within the "Building Block" concept are several alternatives for floor plans including separate living, dining and family rooms and a variety of combinations for these rooms. Also available are other bedroom and bathroom arrangements. Other module combinations may be used to obtain a range of square foot sizes or to change the relative room sizes or unit width for a specific application.

	TH			GA	
	20'	22'	24'	24'	36'
BEDROOM					
ZERO				●	
ONE				●	
TWO	●	●	●	●	●
THREE	●	●	●		●
FOUR		●	●		
BATH					
1				●	●
1.5	●	●	●		
2				●	●
2.5		●	●		
AMENITY					
LIVE, EAT-IN KITCHEN	●	●	●	●	●
LIVE-DINE COMBINATION	●	●	●		
LIVE, DINE DISTINCT	●	●	●	●	●
LIVE-DINE OR FAMILY-DINE	●	●	●		
LIVE, DINE, FAMILY DISTINCT	●	●	●		

E. Plan Array

Operation BREAKTHROUGH Plan Application

BCHD is producing a total of 244 dwelling units for Operation BREAKTHROUGH sites located at Macon, Georgia; Memphis, Tennessee and Scaramento, California. Using the building programs specified by the Prototype Site Developer on each site, plans were selected from the plan array that most nearly satisfied the development program and local housing requirements. These plans reflect space planning rules established by HUD's Operation BREAKTHROUGH guide criteria, which specify the use of space rather than abstract size requirements. Use of the criteria has allowed somewhat more space planning flexibility, yet final design plans appear to be compatible with most FHA and Model Code Standards. Plans produced for Operation BREAKTHROUGH are:

Garden Apartments

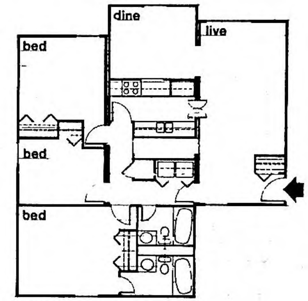
Six different plans (three of which are shown in Figure F):

1 bedroom, eat-in kitchen	696 sq. ft.	(not shown)
1 bedroom, dining room	744 sq. ft.	
2 bedroom, eat-in kitchen	864 sq. ft.	(not shown)
2 bedroom, dining room	912 sq. ft.	
2 bedroom, 2 baths	1008 sq. ft.	(not shown)
3 bedrooms	1128 sq. ft.	

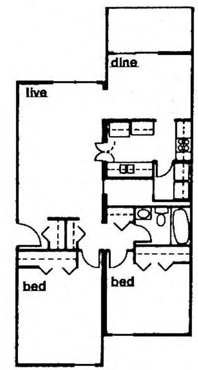
Townhouses

Four different plans (three of which are shown in Figure G):

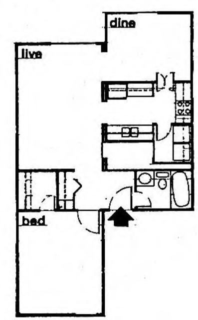
2 bedroom	1036 sq. ft.
3 bedroom, 1.5 baths	1248 sq. ft.
3 bedroom, 2.5 baths	1348 sq. ft.
4 bedroom	1536 sq. ft.



3 Bedroom, 1 Bath



2 Bedroom, 1 Bath



1 Bedroom, 1 Bath

F. Garden Apartments

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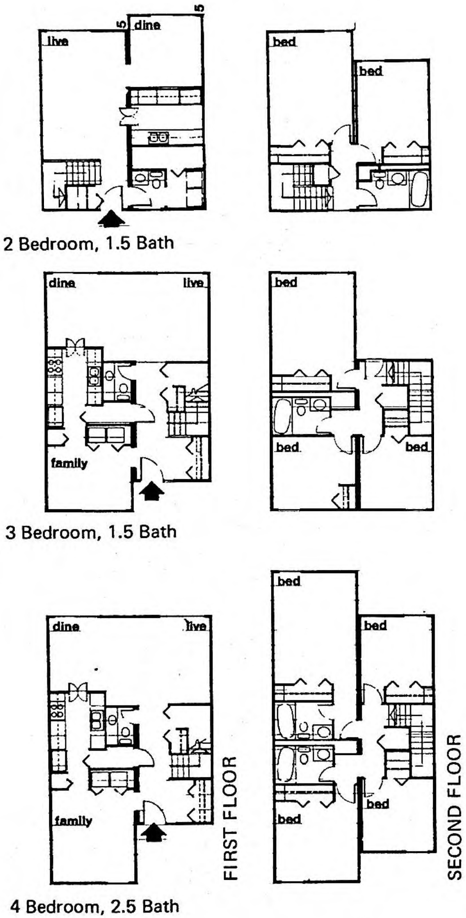


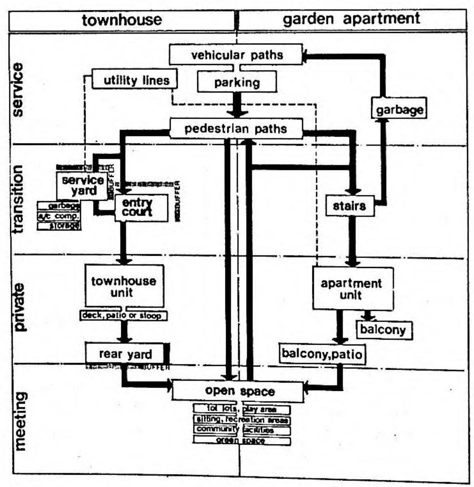
G. Townhouses

Exterior Plan Theory

A theory complementing the "interior plan theory" (Figure H), has been developed for the exterior spaces of a dwelling unit. The external design is based on categories or "zones" of usage, not unlike these identified previously.

Private	Personal or family areas (dwellings unit, rear yards, balconies)
Meeting	Communal, public areas (open space, parks, etc.)
Transition	Connecting spaces (entry courts, stairs)
Service	Support functions (roads, paths, utilities)

The "rules" that determine the location and interrelationships are functions of particular localities and therefore not explicitly definable. As a general rule, however, a linear movement (Service to Transition to Private or Meeting) is made.



H. Exterior Plan Theory

THE APPLICATION

Under the Operation BREAKTHROUGH program, Boise Cascade is producing housing units for Macon, Sacramento, and Memphis. The Macon site is predominantly suburban in character—wooded and sloping land, surrounded by low-density detached housing. The Sacramento and Memphis sites are to be developed to higher density on a rectilinear street system, in flat terrain. All sites employ a broad mixture of housing types, from multi-family high rise to single family detached.

In the Operation BREAKTHROUGH sites, the prime planning concern has been the linear flow through zones previously defined. Individual site shapes and terrains led to the application of this rule in different forms. In Macon, where the land is wooded and sloping toward a central lake, the major artery encircles the parcels. The Boise microsite, defined by this loop road and the lakeshore, places units in a curvilinear form oriented toward the lake with service and transition zones toward the road. Garden apartment groups define the center of activity in the parcel, with townhouses extending out into less public zones. Maximum allowances for open and green space have been made.

A similar cluster theory is used in Sacramento where the dwelling units border on a large open space intended for use by the entire community. Unlike the other site, apartment units in Sacramento are separated from townhouse dwellings.

The modular construction system provides a structural framework in which it is possible to alter exterior treatment of the dwelling unit by changing only the exterior finish of the modules or by attaching a variety of accessory pieces to the module.

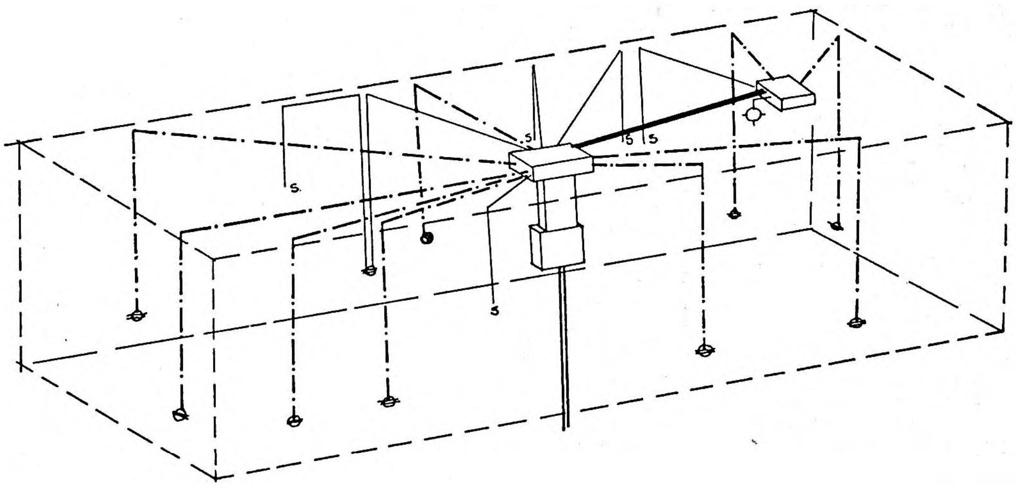
CONCEPT OF ELECTRICAL WIRING HARNESS

The concept of a preassembled wiring harness for modular housing units was a joint development between BCHD and General Cable Corporation. Initial guidelines established that the electric power distribution system should incorporate the overall objectives and philosophy of Operation BREAKTHROUGH: meet the intent and concept of the National Electric Code; improve the quality, reliability, safety, performance, installation and design of existing wiring techniques; maintain compatability with existing equipment and functions; be competitive with conventional electrical construction and be specifically suited for use in factory built housing.

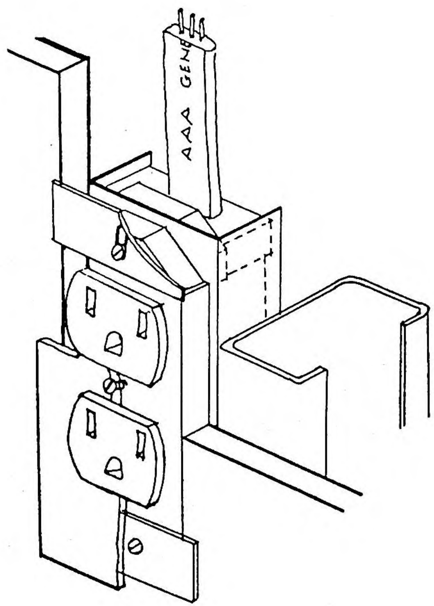
A detailed analysis of conventional requirements and accepted performance highlighted deficiencies in safety and performance; hence these became key design objectives. The strategy of design of the innovative principles should therefore meet or exceed the standards of safety or performance normally acceptable. To ensure satisfactory functional performance and durability, it was decided to use proven and readily available conventional materials.

The concept of a preassembled "spider" or "octopus" wiring harness complete with fittings attached was evolved. The harness consists of a central junction from which a number of "legs" of predetermined length with outlet receptacles or switches extend. These legs are connected into the central box (Figure I). The junction boxes and circuit breakers utilize buss bars which eliminate wire splicing and offer an improved connection for the "legs." Outlet receptacles (Figure J) and switches incorporate integral strain-relief clamps to eliminate undue strain on the conductor wires.

In the development of the harness a unique case and cover seal were introduced to provide a stronger attachment for switch and outlet receptacle terminals and to simplify grounding of the exposed face plates. The cover seals and case are of phenolic resin which, when combined with the fixing method, improve the safety of the harness by retarding the spread of fire (Figure C). The switches and outlet receptacles incorporate integral grounding of circuits for the unit and for the decorative cover plate.



I. Electrical Wiring Harness



J. Outlet Receptacle

The installation of the harness within the module can be carried out by semiskilled labor, using only a screwdriver. The outlet receptacles, switches, and fixtures are fixed in precut holes in the wall and ceiling.

As the harness is assembled, a sequential series of tests is carried out and final testing is done after installation. This ensures that quality control can be maintained throughout manufacture and installation.

The harness concept for factory built housing incorporates the advantages of increased system reliability and quality at a lower total installed cost. The desired levels of quality and reliability are maintained through the application of a comprehensive quality assurance program. This concept of power distribution is possible due to volume production of standard units, using parts specifically designed and produced from proven materials. Conventional parts and techniques have specific functions, but the application cannot be controlled. All conceivable applications have been considered in the design of the BCHD electrical harness.

The design of the total system incorporates the intent and concept of the National Electric Code, the National Electric Equipment Manufacturers Association, and Underwriter's Laboratories regarding safety, reliability and performance. This system also upgrades the technology of home building procedures. Innovation has been restricted to performance improvements.

PRODUCTION

The housing challenge of the '70's is clear. Two and one half million new dwelling units will be required every year. To meet this urgent need, truly innovative designs and construction methods must be developed and implemented without delay.

BCHD has enthusiastically accepted this challenge and committed itself to achieving major innovations in industrialized housing. Recently national attention has been focused on Boise Cascade's new line of multi-family housing being developed under the Operation BREAKTHROUGH Program. Utilizing the most modern concepts and manufacturing techniques that incorporate both wood and steel construction, these modular housing units are now being produced for sites in Macon, Georgia; Memphis, Tennessee; and Sacramento, California.

The Boise Cascade Company now has major production plants located in Arabi, Georgia and Meridian, Idaho. Other production plants in Alabama, Ohio and Utah are readily adaptable to production of this nature.

The strategic location of these plants makes it economically feasible to deliver factory built housing units to most of the United States market.

In today's ever-changing economic environment, the need for dependable delivery has never been greater. Boise Cascade's production line is designed with this in mind. Capable of being transported by rail, water or road, modules from one of our production facilities can be on site within 24 hours. This delivery capability can greatly reduce costly delays, theft and vandalism and cut construction financing to the bone.

MARKETING

For further information on BCHD Systems, call or write:

Boise Cascade Housing Development
61 Perimeter Park East
Atlanta, Georgia 30341
Phone: (404) 458-9411

Summary Information

SYSTEM APPLICABILITY	
Location	Urban, suburban, rural, urban renewal, new towns.
Density Range	4-30 per acre.
Environmental Adaptability	Adaptable to all climate conditions, topographical and soil conditions.
Non-Residential Functions	Recreational facilities, library, medical clinic, social facilities.
Site Planning Services	BCHD can provide a total system, i.e., site planning, engineering, design, production and jobsite management or will work as a producer only.
BUILDING SYSTEM DESCRIPTION	
Housing Types	Single family attached and garden apartments (MFLR) furnished on Operation BREAKTHROUGH. System equally adaptable to single family detached and multi-family mid-rise.
Unit Variations	Efficiency to 5 bedrooms. Flexible open planning.
Structure	Steel and wood frame modules (including wet cores).
Exterior Elements	A wide variety of finished and accessories such as balconies, decks, bay windows, sky lights, pitched roofs and canopies are available.
Foundations	Conventional or designed to fit site conditions.
Comfort System	Uses all conventional energy services in all conventional forms.
Plumbing	Conventional and approved plastic materials integrated with module building subsystem.
Electrical	Wiring harnesses integral with module building subsystem.
Furnishings	Includes closets and storage spaces. In some cases built-in appliances integrated into utility module. In other cases, appliances are optional.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	An approach to planning and design resulting in a wide variety of modular arrangements and a prefabricated electrical distribution system harness.
Codes	Applicable to all model codes.
Deviations from Original O/B Proposal	Only one of the five systems proposed was selected for BREAKTHROUGH.
PRODUCTION PROGRAM	
Delivery Rate	Open. Depends upon the area and production commitments outstanding.
Off-Site Production	Completely finished sectional modules.
On-Site Installation	Erection, joining of modules, utility hookups.
On-Site Construction	Foundations and utility services.
Internal Functions	All functions performed by Boise Cascade except by agreement.
LABOR REQUIREMENTS/TRAINING PROGRAM	A majority of the on-site construction workers can be unskilled.
ECONOMICS OF SYSTEM	
Construction Cost	Medium cost range — depends upon the location area, etc.
Transportation Limitation	Most areas of the nation are within feasible transportation range of BCHD factories.
Useful Life	Structural system should be good for more than 50 years. Finishes, fixtures, and appliances in accordance with usage and maintenance.
MARKETING FOR PHASE III	BCHD units are available on a national basis.

Boise Cascade Phase II units are located at three prototype sites:

- Macon — 31 SFA, 18 MFLR
- Sacramento — 47 SFA, 28 MFLR
- Memphis — 69 SFA, 51 MFLR

Building Systems International, Inc.

INTRODUCTION AND APPLICABILITY

The housing system furnished by Building Systems International, Inc., (BSI), is one of the more versatile systems involved in the Operation BREAKTHROUGH Program. This proven industrialized concrete building system incorporates the economies and qualities of mass production while offering flexibility without restraint as to size of unit, foundation conditions, climatic conditions, variations in profile, exterior and interior finishes. The system can be adapted to meet varied requirements of different areas of the United States to insure best economic and functional performance.

Architecturally, the BSI system offers complete design flexibility from single family attached to deck house designs and high rise structures. All their various options provide a quality living environment in urban areas where land availability and cost are at a premium. By offsetting succeeding decks, and through use of varied architectural treatments on exterior panels, considerable variety in appearance as well as added living space can be achieved.

The use of concrete as a principal material of this system has many advantages. It is relatively low cost, easy to prepare and place and can be molded into a variety of shapes. The same material can be either an exterior or interior finish. It is highly resistant to weather, fire and mechanical abrastion. Its density provides good sound resistance and thermal capacity.

SYSTEM DESCRIPTION

The basic structural system is a series of precast, prefabricated concrete panels and slabs that can be produced at a central plant, trucked to the site and assembled. Essentially, this system is predicated on large, load-bearing interior and exterior concrete panels, supplemented by floor and roof panels to create an integral structure. The only onsite work that is contemplated, other than normal foundation preparation, is the possible casting of the floor slabs if local conditions make this economical. Where a specific task is to be performed on site, standardized, prefabricated metal forms, reinforcing steel assemblies and assemblies of any required mechanical services to be incorporated in these slabs are all supplied to the builder.

Components are prepared in highly mechanized but easily serviced casting machines, made of steel and heated to expedite curing time. After removal from the casting machines, the components are placed in vertical racks for complete curing before being transported to the erection site in special trailers and erected directly in position by cranes. The concrete components are connected by means of grouted joints, with reinforcing steel used where structural requirements dictate.

On site, the panels are aligned with adjustable temporary brackets. The wall panels are erected with a 1/2-in. horizontal and vertical spacing between each panel to allow for movement and provide erection tolerance. The inner side of these joints is grouted, with reinforced steel where necessary, and the outer side is caulked. This forms the needed connection, allowing an air space between the grout and the caulking to permit balancing air pressures and drainage of any condensation.

The interior panels are floor-to-floor in height and normally of room length. The thickness of the panel varies according to the structural and acoustical requirements. Interior panels are produced in vertical casting machines and, with the aid of vibration, a smooth-finished surface is obtained.

Exterior panels are made up of several layers of materials produced in horizontal casting machines. Each layer has a specific function to perform (see typical section next page). The layers are placed in the following sequence in the machine.

1. EXTERIOR VENEER – Its main function is esthetics. The material can be exposed aggregate, brick, tile, special formed concrete or many other varied finishes.

2. EXTERIOR LAYER OF CONCRETE – Its function is to anchor the exterior veneer, to protect the insulation and form a mass for thermal accumulation which serves to offset the variations of temperature. Due to the steel plate

of the casting machine and vibration, this layer is very dense and resists water penetration and freezing very well.

3. INSULATION (usually expanded polystyrene) – The function of the insulation is to increase the thermal resistance of the panel. This layer is placed in such a position as to balance the exterior and interior temperatures and to prevent condensation. Thickness is varied to accommodate specific climate conditions.

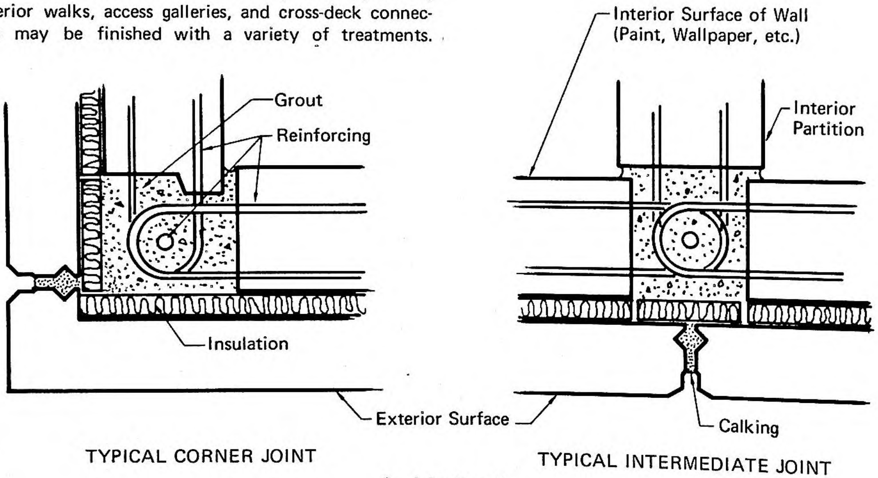
4. INTERIOR LAYER – This is the structural layer and includes the reinforcing steel.

The wall panels contain necessary electrical, plumbing and heating-ventilating subsystems, so that only connecting to adjoining units is required onsite. More complete subassemblies, such as bathroom and kitchen walls, complete with fixtures and accessories, and closets and stairways, are also made in concrete at the central factory and shipped to the site for erection.

In addition to containing all needed service subassemblies, the panels also incorporate window and door frames and other required openings. Inside faces of any balcony dividers, public stairwalls, and both exterior and interior panels are finished smoothly. Balcony floors, exterior walks, access galleries, and cross-deck connectors may be finished with a variety of treatments. Interior finish includes paint or various wall covering. Floor finishes include felt and rubber backed vinyl asbestos coverings. Bathrooms have ceramic or other hard tile or plastic enclosure walls at the tub, while all other walls are normally painted.

The mechanical subsystem is designed with full consideration of the inherent thermal features of the structure, specifically, the high inertia of the concrete panels prevents transmission of any sudden temperature changes. Hence, several methods of heating and cooling are practical and may be installed, depending on the availability of various energy sources. These include radiant panels, gas or electric furnaces in combination with an air conditioning coil and remote condenser, or a combination of radiant heating system with a package cooling unit.

Plumbing services are grouped in special technical blocks or panels, which are then stacked on above the other as the building rises to form complete mechanical service cores. Electrical, telephone, and television antenna wiring are included in the panel sections.



A. Joint Details

INNOVATIVE FEATURES OF SYSTEM

The innovative feature of the BSI Housing System involves the unique combination of conventional and unconventional elements of design, materials, production and erection techniques. Actually the basic concrete deck house (Balency system) has been used in Europe for a number of years, and has been used to construct elevator serviced apartment buildings up to 20 stories. This system, however, has not been extensively used in the United States. When taken separately, all specific material used in the BSI system is common to the building industry. The combination utilized in the BSI system is however uncommon. Any system involving the field erection of factory built components requires detailed planning and scheduling. In general the BSI system utilizes a higher percentage of factory built components and modules and thus requires more precise planning and scheduling than would normally be required.

The BSI system combines the above elements in such a manner as to use the best features of each element. The net result is a housing system that is attractive, functional, economical and adaptable to a majority of housing requirements.

OPTIONS

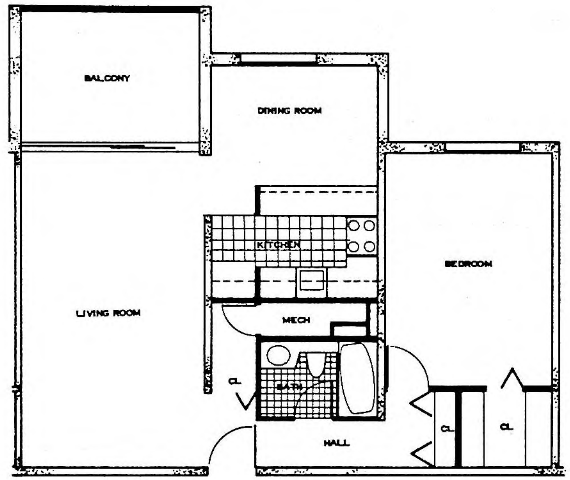
The basic structural and enclosure system has been briefly described in the previous narrative. This primary system is carefully coordinated and integrated with selected subsystems for each project. This enables the system producer complete flexibility in the selection of interior finishes, mechanical and electrical subsystems. The system producer is not restricted to rigid limitations in such important subsystems as heating, ventilating, and electrical, but can design the system to use the most functional and economical subsystem and require careful considerations for such items as performance, ease of installation, initial cost and maintenance. However, the flexibility of the basic system enables it to receive a variety of types for each subsystem, thereby insuring that housing units can be provided with the most modern, innovative, and functional subsystems available.

A wide variety of the floor plans and room arrangements are readily adaptable to the BSI system. The basic principal is to break up the design of a building into panels, slabs and modules which can be produced in a factory, transported to the erection site and quickly assembled to form the building. Typical apartment floor plans are shown in Figures B through F.

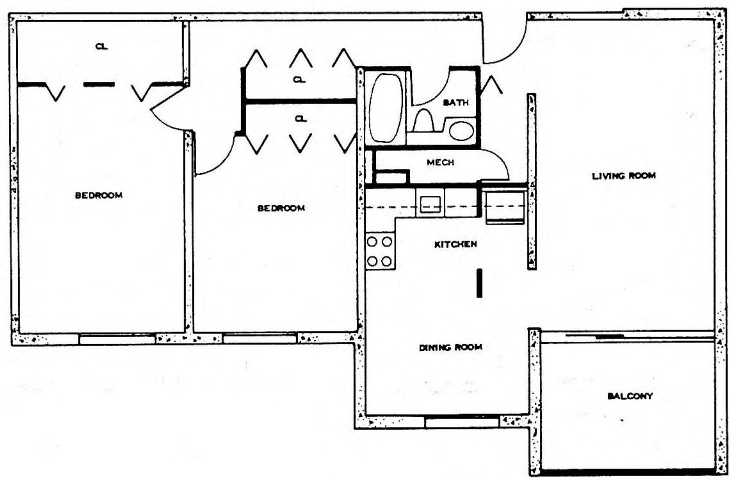
ECONOMICS OF THE BSI SYSTEM

The economics of applying the BSI system to a particular project are determined by several factors. These include project size; the availability of a good precast concrete plant in the area, or the ability of the area to support a new precast concrete plant on a continuous basis; the degree to which components of a job can be standardized; the total number and size components required; and the amount of the task that can be accomplished with machines rather than manual labor.

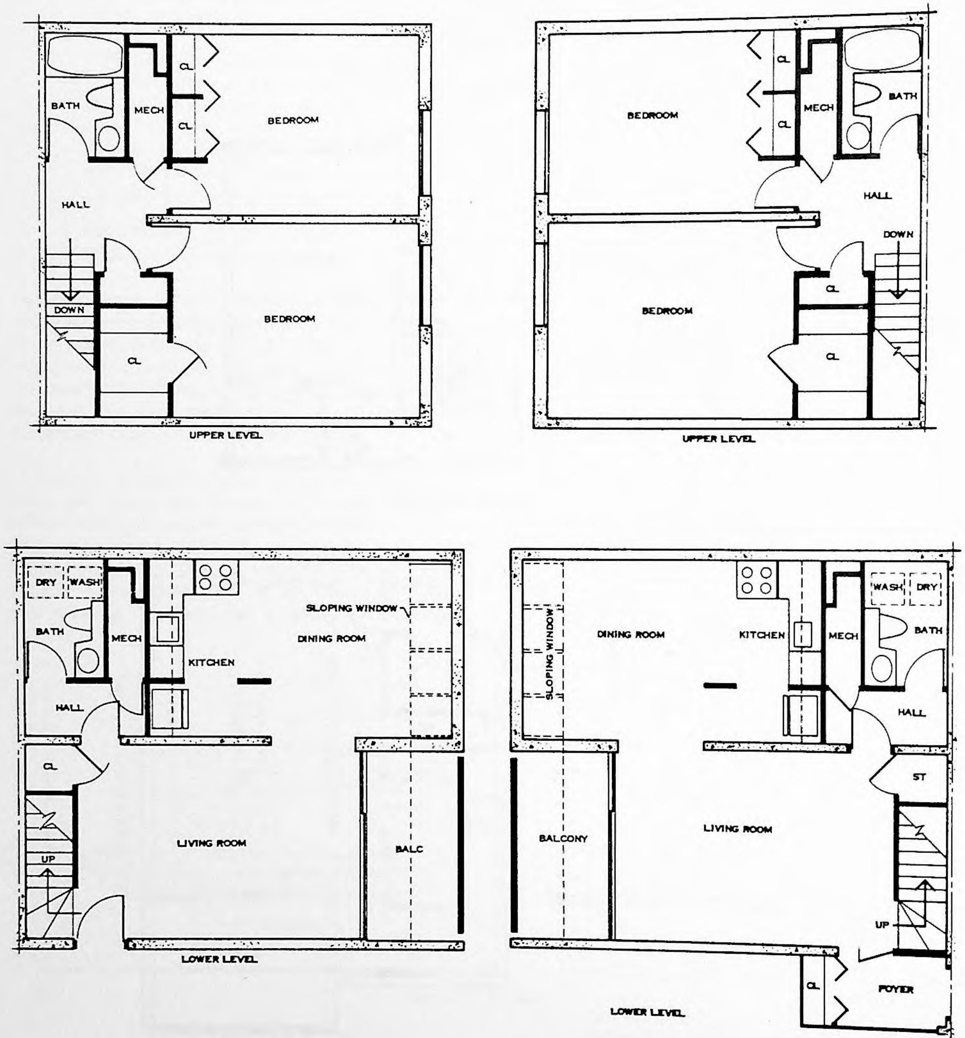
Most medium to large jobs in a generally industrialized area can utilize the BSI system to good economic advantage. Where the BSI system is applicable, the total manpower required for a project can be 50% less than if other more conventional systems of construction were used. Of the labor required for the BSI system, 85% can be local and unskilled.



B. One Bedroom Highrise



C. Two Bedroom Highrise



D. Midrise Two Bedroom Duplexes

PRODUCTION

In developing a production plan for the Macon Prototype Site, many restraints had to be considered which are unique to the Phase II Development. To begin with, BSI was awarded 94 apartment units. This was too small a number to realize the advantage normally associated with a mass produced housing system. Second, the construction not be justified on the basis of a continuous demand in the Macon area. Third, the standardization of all components wherever possible was not followed to the same degree at the Macon site that would be expected on other more conventional job. This was done primarily to demonstrate the design potential which can be achieved within the system.

E. Midrise Three Bedroom Duplexes

MARKETING

BSI offers a total system concept that includes site planning, engineering, architectural design, production and jobsite management. All are carried out through centralized management overseeing a coordinated team. The savings over conventional procedures of construction planning and management are substantial.

Providing proper answers to housing needs begin with proper planning. BSI is totally capable in all areas of planning, flexible in the type of clientele it can serve as well as in the type of projects it can develop.

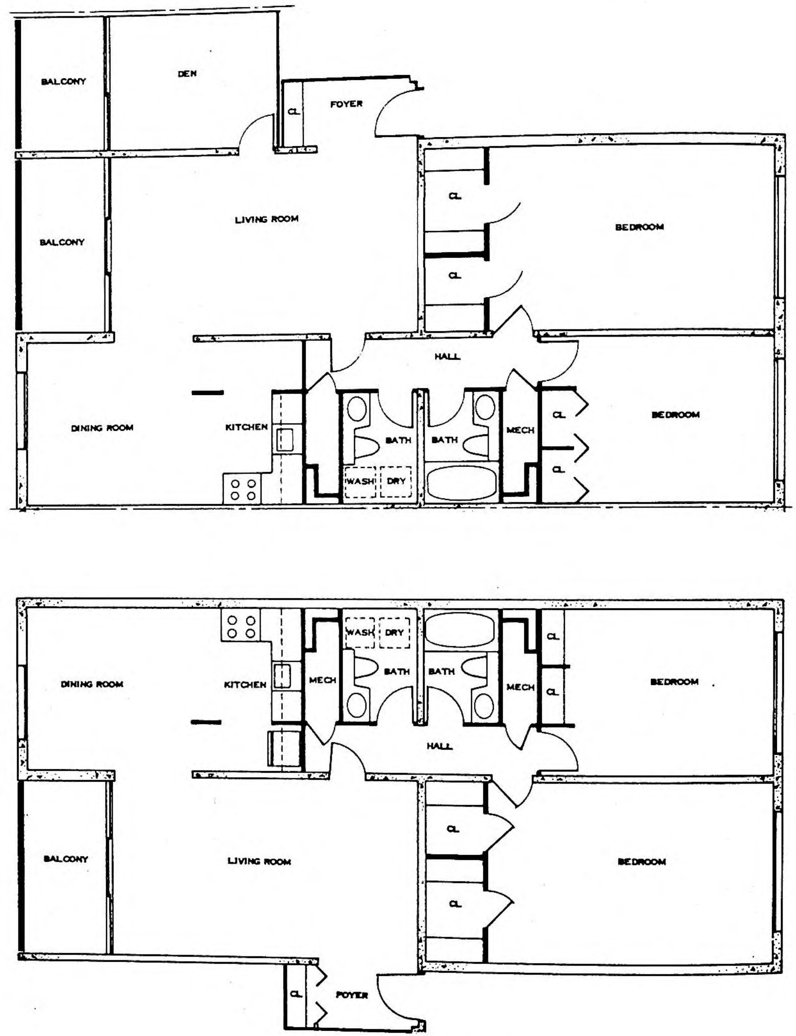
BSI can work with and carry out programs initiated at any level of government from federal housing programs to state and city-sponsored urban development programs. The company is equally capable of serving private investors and developers on a wide scale of projects. BSI has the in-house expertise and financial resources to participate in joint venture efforts as well as develop its own housing developments to meet a given market.

For more specific information about the BSI system please write to:

Building Systems International
1415 Peachtree Center
230 Peachtree Street NW
Atlanta, Georgia 30303

or call:

Lawrence A. Wilson (404) 577-7650



F. Midrise Two Bedroom Flats

Summary Information

SYSTEM APPLICABILITY

Location	Urban, Suburban, Urban Renewal, New Town
Density Range	10 to 150 Dwellings/area
Environmental Adaptabilitv	Adaptable to all climate conditions, normal topographical and soil conditions.
Non-Residential Functions	Adaptable for use as commercial, office, social or service facility.
Site Planning Services	BSI provides total system; i.e. site planning, engineering, design, production and jobsite management. Will work as consultant or producer only.

BUILDING SYSTEM DESCRIPTION

Housing Types	Multi-family low-rise and high-rise
Unit Variations	Efficiencv to 5 bedrooms. Flexible open planning.
Structure	Precast concrete panels, slabs and modules assembled into an integral load bearing structure.
Exterior Elements	Balconies, decks, porches, patios.
Foundations	Conventional or designed to fit site conditions.
Comfort System	Heating and cooling using all normal energy sources.
Plumbing	Service lines integrated in precast panels or utility modules.
Electrical	Electrical distribution system integrated in panels or utility modules.
Furnishing	Includes closet and storage spaces. Built in appliances optional.

DEPARTURES FROM CONVENTIONAL SYSTEMS

Innovative Features	Unique combination materials, production and erection techniques.
Codes	Adaptable to all National Model Codes (except for electrical distribution system).
Deviations from Original O/B Proposal	Insulation glued to inside of wall panels and covered with gypsumboard (Technique used at Macon only to provide cost saving to HUD).

PRODUCTION PROGRAM

Delivery Rate	Unlimited—Can utilize the production of existing precast plants, or build new precast plant per requirement.
Off-site Production	All off-site for repeating items.
On-site Construction	Foundation
On-site Installation	Crane erection of components; leveling, grouting, caulking, applying roofing and finishing.
Internal Functions	BSI perform all functions per agreement with customer.

LABOR REQUIREMENTS/TRAINING PROGRAM

Eight-five percent of total labor force unskilled under optimum conditions.

ECONOMICS OF SYSTEM

Transportation Limitation	Approximately 100 miles under normal conditions.
Useful Life	Structural system essentially permanent. Finishes, fixtures and appliances in accordance with usage and maintenance.

MARKETING FOR PHASE III

System is available in all parts of United States.

BSI Phase II units are located at Macon prototype site – 24 MFMR, 56 MFHR.

CAMCI Inc.

INTRODUCTION AND APPLICABILITY

CAMCI, Inc. is a wholly owned subsidiary of Module Communities, Inc. (MCI), a division of Starrett Housing Corp. CAMCI was selected to design and build 153 dwelling units for Operation BREAKTHROUGH at the Jersey City prototype site.

Before BREAKTHROUGH was announced, MCI studied European prefabrication techniques and chose Tracoba No. 1 as the system best suited to American needs. Somewhat modified, this is the system that is being demonstrated on BREAKTHROUGH and marketed by CAMCI.

Tracoba, designed by Omnium Technique d'Habitation (OTH) of France, is one of the most widely used prefabrication methods in Europe. The No. 1 System is responsible for more than 70,000 housing units built in France, Switzerland, Italy, the United Kingdom and Algeria since 1961. It is thoroughly adaptable to U. S. building code safety regulations, construction methods and standards of living. The American version was designed for MCI by a consortium of Paul Weidlinger, Consulting Engineer; Cosentini Associates; Rouse Construction Corp. and OTH.

One of the most attractive features of the Tracoba System is the architectural variety possible. There is no limitation on forms other than the basic requirement of load-bearing cross walls. The system is adaptable to all climatic, topographic, seismic and soil conditions. Density range is limited only by local zoning codes.

Multi-family medium-rise and multi-family high-rise buildings are being constructed at the present time. Low-rise buildings may be feasible depending on the location of the project and its size.

Non-residential facilities can be located in the conventionally constructed base of the building. Structural modifications to the base floor or floors can be economically designed for commercial, office, social and service functions.

CAMCI/MCI and their associates can provide total site planning, project development and consulting design services.

SYSTEM DESCRIPTION

The Tracoba System combines the advantages of prefabrication, assembly-line techniques and systems engineering. It brings a new level of speed and efficiency to high-rise construction.

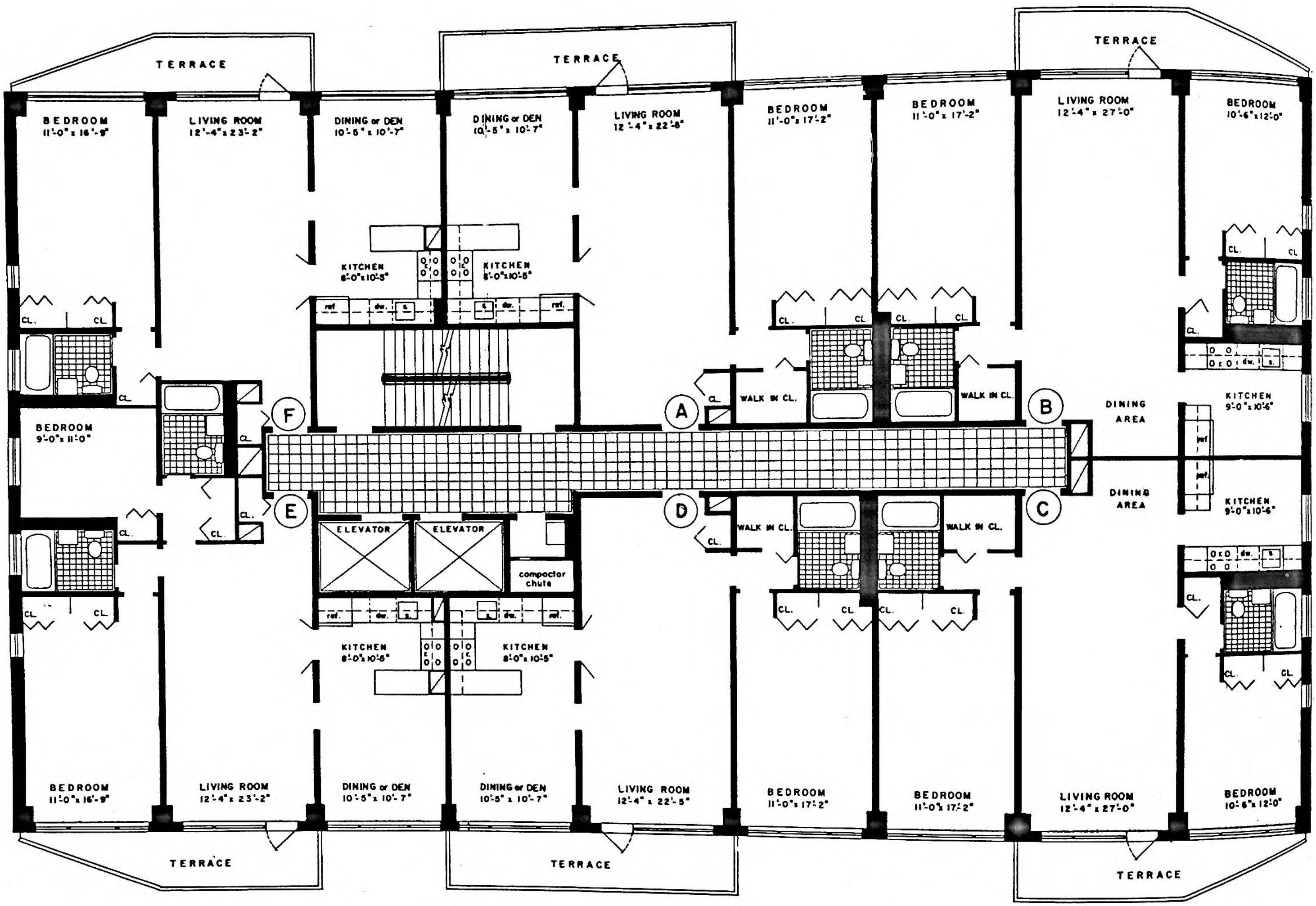
The system is based on the complete prefabrication of structural and architectural elements, and the programmed coordination of factory production with on-site assembly. Reinforced concrete wall and floor panels are pre-cast in a factory. Windows, doors, piping, electrical conduits and other features can be incorporated in the panels at the plant. The panels are erected on site by crane.

Elements of the system are load-bearing cross walls, shear walls, facade walls, gable walls, floor panels, roof panels, elevator shafts and stairways. Most of the interior walls are load-bearing, but there is complete flexibility as to material and configuration for nonstructural partitions, closets, bedrooms, kitchens and service quarters. The main facade walls are not load bearing and can be designed in any configuration from small window openings to curtain walls. End walls or gable walls are load bearing and are, therefore, limited in the size and number of openings. Balconies may be prefabricated in a variety of architectural and structural designs, including a simple slab span between bearing walls or a closed box attached to the facade.

Foundations are conventionally cast in place, using pile structures where necessary.

The system allows complete flexibility in the choice of heating, ventilation and air conditioning methods. Any type can be incorporated as a subsystem. Baseboard radiation units, distribution piping and wiring are easily integrated with the structure. Sleeves can be included for air conditioning, either at initial installation or as a future option.

At the present time, empty conduit and junction boxes are placed in the concrete panels at the factory. Prewired conduit can be used. Electrical outlets, lighting, appliance circuitry and ground wires are built into individual apartments in accordance with local requirements.



A. Floor plan of one- and two-bedroom apartments in non-Breakthrough design.

Finishes range from simple flat concrete to highly complex sculptured forms with a wide variety of textures. Mosaics, tiles, molded shapes, and bricks may be built into the exterior walls, or the surfaces may be sandblasted, bush hammered or have exposed aggregate.

Building elevations can be varied: staggered heights towers or slab designs. The number of bedrooms available extends from none, in "efficiency apartments," to six. Floor plans of one- and two-bedroom apartments are shown in Figure A. There are no items of loose furniture considered to be part of the system. Closets and cabinetry can be mass produced as subsystems by other manufacturers.

The system is completely adaptable to all codes in all parts of the country.

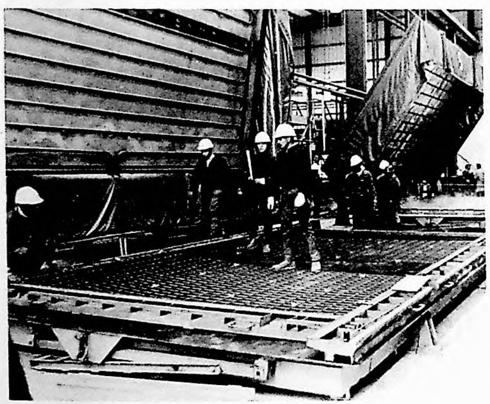
DEPARTURES FROM CONVENTIONAL SYSTEMS

Innovations of the CAMCI System are:

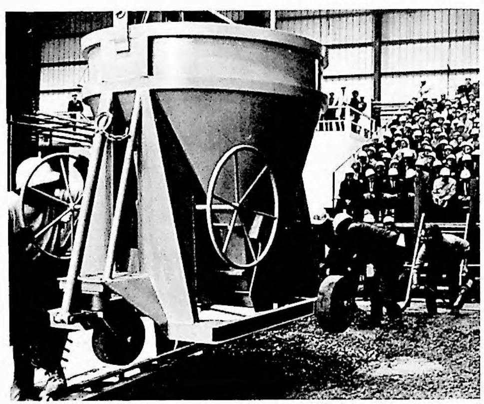
- Unusually large precast concrete panels increase fabrication and erection productivity due to the small number of panels per dwelling unit (10 panels per 900 gross square feet).
- Floor slabs use reinforced concrete rather than prestressed or cored plank. Upon erection they are ready for flooring materials with no further preparation.
- Mechanical connectors in load-bearing walls help prevent progressive collapse and improve handling, leveling and erection efficiency.
- Exterior panels can have sandwich-type insulation, eliminating additional on-site preparation.
- All panels are ready to accept paint.
- Structural modifications for all mechanical systems are easily made.
- 80% of the interior partition walls are prefabricated concrete panels incorporating door frames, electrical conduits and switch boxes.

Other features include the production of a very large, dimensionally controlled floor slab. The system employs a jointing technique that effectively and inexpensively distributes the load to resist earthquake stresses and progressive collapse. The concrete floors and walls that separate apartments and rooms within apartments exceed normal acoustical requirements.

One of the major advantages of the system from a planning point of view is the architectural flexibility. Many apartment designs, many building plan innovations and overall massing variations can be accomplished with relatively few standardized components.



B. Cooking table being prepared for concrete pour. Floor panel is heated with hood and vibrated with compressed air.



C. Concrete is poured into steel table.

D. Table with finished floor slab tilted to upright position for slab removal.

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Major deviations from the original Operation BREAKTHROUGH proposal resulted from a joint analysis by CAMCI/MCI and the National Bureau of Standards during Phase I. Changes in jointing techniques now have been incorporated into the system. Among the improvements are:

- A mechanical connector for the load-bearing walls to improve resistance to progressive collapse and earthquakes. This device also improves the positioning, leveling and site erection operations.
- Redesign of parapets to make them a more integrated part of the building structure.
- Addition of shear keys at the bottom of walls to increase the horizontal load transfer capacity of horizontal joints.

PRODUCTION

Off-site production is accomplished at an MCI factory within 50 miles of the site. The factory is designed for assembly-line production of four major building elements:

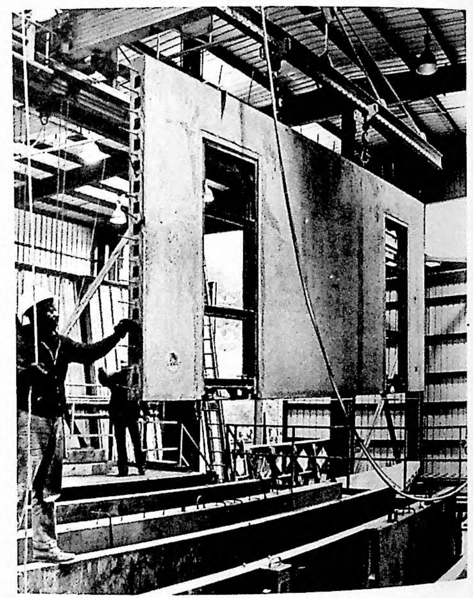
1. Load-bearing wall panels. The panels incorporate door frames, electrical boxes and conduits and are ready for painting.
2. Large floor slabs. These also incorporate electrical boxes and condiuts and are ready to receive floor and ceiling finishes.
3. Non-load-bearing facade panels, either spandrels or full facade. Window frames, door frames, balcony supports and openings for air conditioning equipment are incorporated in the panels.
4. Load-bearing gable walls. These walls include sandwich-type insulation and have restricted horizontal openings of approximately 4 feet.

The factory consists of one or more bays, each containing a series of molds serviced by an overhead crane. The basic molding devices are:

- Heated, vibrating steel tables which can be tilted for handling convenience.
- Vertical 10- to 12-leaf battery molds, also heated and vibrating.
- Molds for stairways and other special units.

E. Finished floor panel still steaming from heat of cooking table.

F. Heated battery, vibrated by compressed air. Ten wall panels are poured at one time and removed in three hours.

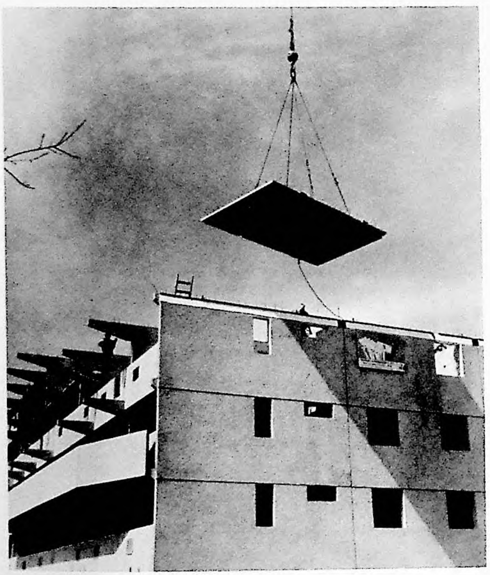


G. Wall panel containing two door bucks, electrical conduit and gem boxes, being removed from battery.

Built-in elements such as windows, doors, conduits and fixtures are set in place in the molds before the concrete is poured. Adjustable edges regulate the size and shape of the panels. A wide variety of finishes may be incorporated during prefabrication. Sandblasting or retarding agents may be used to expose the aggregate.

On-site construction consists mainly of foundation work and erection of the panels. Lower floors are built on site if necessary to accommodate offices or other commercial functions.

Erection is by crane, and access to each building site for 30-ton trucks is required. As the walls go up, panels are temporarily supported by steel connectors projecting from the walls beneath. Floors are supported by reinforced concrete spurs which rest on the walls. Non-load-bearing facades are hung from the ends of cross walls by steel brackets.



H. Erection of 20-story, 110-unit tower in Yonkers, New York.

The next step, cast-in-place jointing, is one of the outstanding safety features of the system. After the horizontal and vertical elements are positioned and checked for plumb and level, concrete is poured into channels between the components. This creates a continuous, integral structure, without welding. It has proven resistant to explosions and exceeds the minimum requirements of all standard codes.

Once the prefabricated elements are erected, mechanical subsystems are completed in the conventional manner. Future plans include replacing much of this work with modular units produced by other manufacturers.

The finishing is also done conventionally at present, but there are plans to purchase prefinished service cores (kitchens, bathrooms, etc.) and other subsystems.

I. Interior wall and floor slab placement in Yonkers tower.

Labor in the plant is mostly unskilled. On-site tasks are performed by both semi-skilled and skilled workers. The conventional finishing work is done with skilled construction tradesmen.

ECONOMICS OF SYSTEM

Prices vary by geographic region and are currently quoted in the New York area at equal to or less than conventional costs for units of similar design and quality. Significant savings in construction financing are possible because of reduced construction time for the total system.

No major cost differential is expected for distances within a one-day, one-trip turnaround for tractor and trailer.

The building's life expectancy is unlimited except by functional obsolescence. Due to the structural superiority of the basic system and the special attention given to the accessibility of mechanical subsystems, maintenance costs are low in comparison to conventionally built projects.

MARKETING FOR PHASE III

Future marketing plans cover a broad range of joint ventures and business relationships with qualified corporations and housing authorities throughout the United States.

New designs are now being prepared that include efficiency and one-, two-, three-, four- and five-bedroom units. These are different from the BREAKTHROUGH designs, which have only efficiency, one- and two-bedroom units, and will have a wider market appeal in the New York area.

The CAMCI-MCI staff does planning, project development, design, fabrication, erection, general contracting and marketing. Arrangements can be made for financing and legal services.

For additional information about the CAMCI-MCI System, write to:

CAMCI, Inc.
c/o Starrett Housing Corp.
301 East 57th Street
New York, New York

or call Paul R. Sussman, Project Developer, (212) 751-3100.

J. 20-story, 110-unit tower under construction in Yonkers, New York. First MCI/Tracoba system building in the U.S. Not a Breakthrough project.

Summary Information

SYSTEM APPLICABILITY	
Location	Urban.
Density Range	Governed by local zoning codes; e.g., NYC: 250/acre. Maximum height 26 stories.
Environmental Adaptability	Adaptable to all climates, topography and soil conditions.
Non-Residential Functions	1st floor(s): office, social, service; upper floors: residential.
Site Planning Services	Wide range available from CAMCI-MCI staff.
BUILDING SYSTEM DESCRIPTION	
Housing Types	MFMR, MFHR; MFLR under certain conditions.
Unit Variations	0 to 6 bedrooms.
Structure	Prefabricated reinforced concrete panels for walls and floors.
Exterior Elements	Non-load-bearing facades; end walls and gable walls (load bearing); balconies.
Foundations	Conventionally cast in place.
Comfort System	All HVAC types can be used.
Plumbing	Conventional installation or integrated into the pre-cast system.
Electrical	Factory installed in the pre-cast system.
Furnishing	N.A.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Factory production of large wall and floor panels; improved joint techniques; electrical, insulation, plumbing, and HVAC subsystems may be incorporated.
Codes	Adaptable to all codes.
Deviations from Original O/B Proposal	Improved mechanical connectors for load-bearing walls; parapet redesign for structural integration; addition of shear keys at bottom of walls.
PRODUCTION PROGRAM	
Delivery Rate	500 - 1000 units per year.
Off-site Production	Factory produced floor and wall panels with integrated utilities, insulation, doors and windows.
On-site Construction	Foundations. Lower floors (where required). Wall and floor panel erection.
On-site Installation	Mechanical systems, utilities, flooring, wall finish.
Internal Functions	Project planning, design and development; fabrication and erection; purchasing and transportation.
External Functions	Financing, legal services.
LABOR REQUIREMENTS/TRAINING PROGRAM	
Factory	Unskilled and semi-skilled, instructed in production operations.
ECONOMICS OF SYSTEM	
Construction Cost	Equal to or less than conventional.
Transportation Limitation	One day round trip for tractor and trailer.
Useful life	Limited primarily by functional obsolescence.
MARKETING FOR PHASE III	Future market plans include joint ventures and business relationships with qualified corporations and housing authorities throughout the U.S.

CAMCI Phase II units are located at the Jersey City prototype site — 153 MFHR.

Christiana

INTRODUCTION

Christiana Western Structures is a wholly owned subsidiary of The Christiana Companies, Inc., a major national company listed on the American Stock Exchange. Over 5,000 housing units had already been produced by Christiana prior to becoming an active participant in the Operation BREAKTHROUGH program.

Its prior building and development operations include Huntington Harbour, a completely master-planned marina and residential community just south of Los Angeles; and Tierrasanta, an award-winning community in San Diego of 2,600 acres and an eventual population of 25,000. This experience is reflected in every dwelling constructed by Christiana. Christiana was selected to install a total of 153 units at three Operation BREAKTHROUGH sites: Sacramento, California; Macon, Georgia; and King County, Washington.

The original proposal of Christiana for participation in the three phases of Operation BREAKTHROUGH was presented to HUD in September 1969. It was based upon a system that was considered to be fully developed, tested and proven. The system was covered by a National FHA Bulletin, an ICBO Report (International Conference of Building Officials), and a Southern Building Conference Approval. Its principal advantages were the durability of an innovative finishing material, flexibility of architectural design and availability for construction upon prototype sites during Phase II. The tasks to be completed during Phase I were thought to be substantially complete, since Christiana had or was gaining experience in many areas. As events developed, it became apparent that the proposed system had to be substantially modified. Thus considerably more effort was required to complete contractual obligations under the Phase I contract than was originally anticipated. The evolution is described under the section heading "System Evolution" below.

SYSTEM APPLICABILITY

The Christiana system is suited to urban, suburban and rural environments as well as adaptable to usual topography-soil conditions and all national climates. Recommended density ranges from 6 to 25 dwelling units per acre.

BUILDING SYSTEM DESCRIPTION

Christiana has developed module designs for two bedroom MFLR units and for two, three, and four bedroom SFA units. There is a wall-panel system design for the complete line of products: one and two bedroom MFLR; two, three and four bedroom SFA; three and four bedroom MFLR; three and four bedroom SFD; and duplex three and four bedroom units with garages. Typical plans representative of the variety of dwellings available at the Operation BREAKTHROUGH site in Sacramento, or through Christiana's home office, are portrayed in Figures A, B and C.

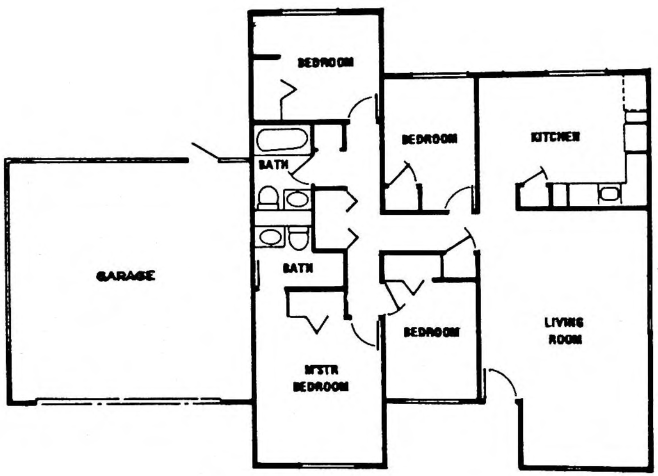
The erosion of innovative features during Phase I left Christiana with essentially a conventional system insofar as material and design were concerned. Walls consist of 2 x 4 wood studs with exterior plywood skins and gypsum board for interior covering. Floors are of standard construction, i.e., 2 x 8 joists, 16" o.c. with 5/8" plywood sub-floor. Variation from gabled roof lines is obtained with mansard roofs.

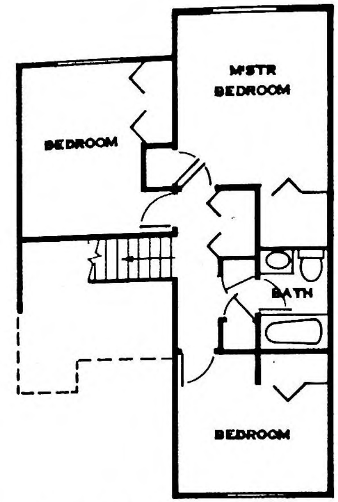
Subassembly of wall panels and wall-floor-ceiling modules is a variation from the conventional in that this is accomplished for the most part in a factory. These subsystems, partially completed under contract with a local manufacturer, are assembled on site. Both lower and upper level modules are lifted into place rather than jacked. Each dwelling unit, as well as each individual module, contains its own service systems. Installation of insulation, wall-board, wiring, plumbing, heating, etc., follows in the usual manner by appropriate subcontractors.

SYSTEM EVOLUTION

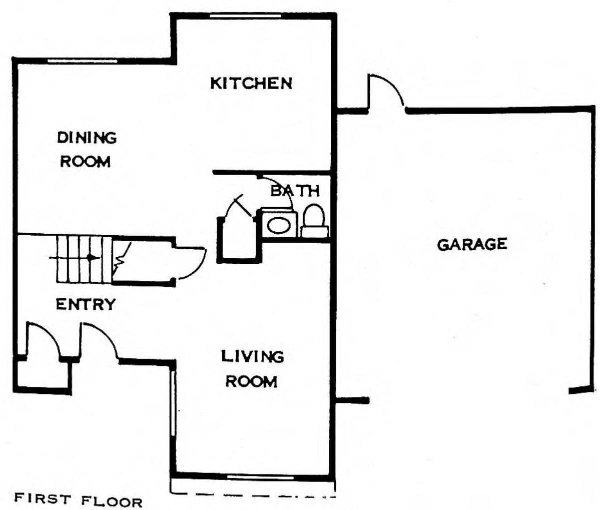
Christiana originally proposed a structural system of wall panels framed of 2 x 4's covered on both sides with 3/8 inch plywood skins and finished with a polyester-fiberglass coating. The panels were to be completely shop-fabricated closed panels. Portions of the insulation, electrical, plumbing and mechanical systems inside the walls were to be installed in the fabrication plant rather than at the job site.

The structural connections of the walls to foundation, wall to wall, wall to trusses, and wall to ceiling and floor



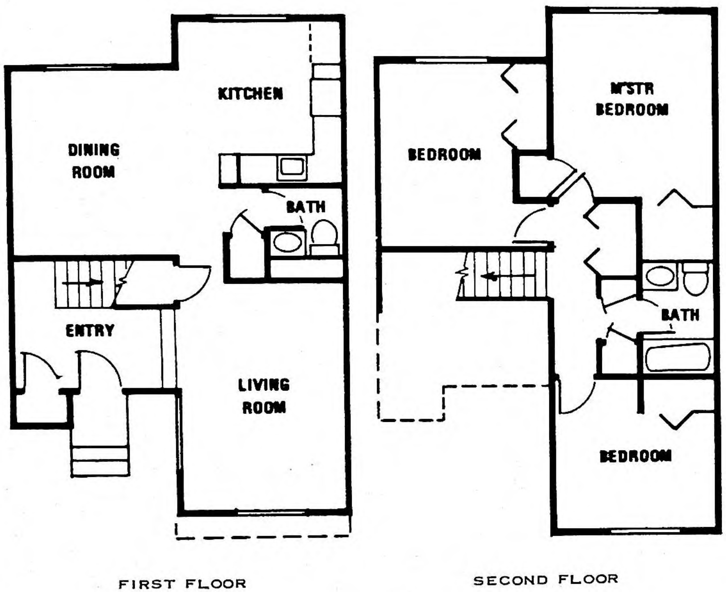


SECOND FLOOR

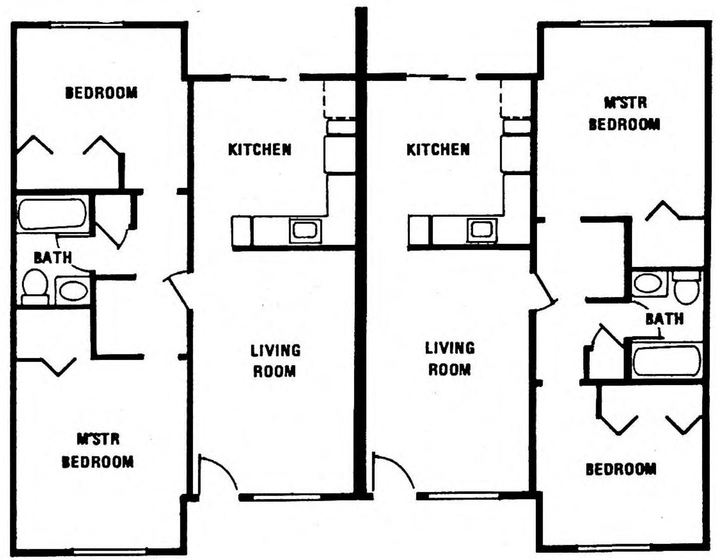


FIRST FLOOR

A. Single family plans include attached garages



B. Typical plan—Single Family Attached (Townhouse) unit.



C. Multi-Family Low Rise (Four-plex) Floor Plan.

joists were to be made without benefit of access to the interior of the wall panel itself. In the original system, other shop fabricated or pre-cut and field applied items included trusses, joists, interior and exterior trim, cabinets, stairways and underslab plumbing assemblies. All appliances and other such job-specific amenities were to be purchased on the open market and installed in the field.

Early in Phase I of the program, review of the plans indicated that off-the-shelf designs originally submitted did not satisfy the space criteria. Shortly thereafter, serious doubts developed regarding the performance of the system to Operation BREAKTHROUGH life safety criteria. The most obvious shortcomings were with respect to fire containment, smoke generation and acoustics.

Flame spread and smoke generation test results forced substitution of gypsum wall board for the polyester-fiberglass plywood wall finish. Problems with penetration of fire barriers required redesign of the utility systems. Further review of this concept revealed, however, that with gypsum board instead of plywood for the wall skins, the original attachment system was no longer valid. The most practical solution suggested leaving the gypsum board skins off the factory produced wall panels so that attachments could be made inside the walls.

It became obvious that a factory produced, closed wall panel was not economically feasible. As previously discussed, this idea was abandoned in favor of a panel open on the inside with only an exterior plywood skin.

In spite of the reduction of work accomplished in the factory, some advantages were preserved. A high degree of panel standardization was maintained and larger continuous panels were developed.

Innovative features of the original panel design concept had so eroded that it appeared that the advantages of factory production had virtually disappeared. A decision was made to utilize the module production potential of the design though it was obvious that the timing for the site development schedules would not permit such demonstration on the Sacramento site. Although the framing of the wall panels was identical and the wall skins could be identical for the panel and module systems, most other components of the module system required redesign. To compete economically with conventionally built structures, double walls and floors used by most other "box" manufacturers had to be eliminated to conserve material and labor. Rail shipment was eliminated in favor of the less severe requirements of truck transport.

In addition to "hardware" problems, "software" problems were also encountered. The accepted format for presentation of architectural plans and specifications for review and evaluation by jurisdictional authorities and financial institutions is deleterious in industrialized housing business. To satisfy industrial producers, drawings must be converted to shop and field erection production and contract documents. This forces the industrialized producer to bear additional expense and delay not encountered by the conventional builder.

There is a need to develop and gain acceptance of a format for presenting plans and specifications that the industrialized builder can use for as both contract and production documents.

D. Christiana single family home in Tierrasanta, near San Diego.

PRODUCTION PROGRAM

The original production plan was based on the use of the polyester-fiberglass coated walls. The factory was located in Blythe, California. Wall panels were to be produced at that plant and shipped to the various Phase II construction sites at King County, Washington; Sacramento, California; and Macon, Georgia.

The effectiveness of this method had been proven. Panels have been shipped from Blythe to Anchorage, Alaska without damage.

A polyester-fiberglass facility would be added to panel production plants selected to handle increased production needs in other parts of the nation. It appeared that by associating with a few panel fabricators in other regions, a unique nationwide production organization could be developed. When it became apparent that the fiberglass coating would be eliminated from the system, that plan was abandoned.

Christiana's housing system emerged from Phase I without any unique features. It could be produced by existing facilities in any part of the nation. There appeared to be no unique need for the Blythe production facility so it was closed down and contracts were let with local facilities to produce the Phase II prototypes.

E. Christiana's six-plex townhouses in Ontario, California.

ECONOMICS OF SYSTEM

The factors required to assure viability of a housing factory have been analyzed and discussed over and over again, and conclusions are always the same as for any other manufacturing facility; e.g., to reap the benefits of factory operation, a standard product must be produced at a reasonably constant rate. To do this, there must be a constant absorption of the product by the market or sufficient capital and an understanding of the future market must exist to justify an inventory of finished goods.

Housing factories that have only produced finished housing have a poor track record. Those that principally produce specialty items for conventional builders yet occasionally produce finished housing have proven more successful as panel fabricators. Panel fabricators supply only about 20% of the material and labor required to produce a dwelling and, therefore, do not take advantage of the benefits afforded by industrialization. A higher utilization of factory methods results when modules are produced; however, savings are reduced by higher transportation costs. Large capital investments are difficult to recover. One alternative is to engage a mobile home factory to produce modules for a broader range of housing programs as a specialty item. In this way, continuity of production is more easily achieved. Both systems utilize high percentages of material and labor in the industrialized process.

The economics of Christiana's dwelling units from the viewpoint of the consumer-buyer are compatible with conventional structures. Innovative features of components, e.g., fiberglass wall panel coverings, were eliminated during Phase I and conventional materials substituted. Useful life and maintenance costs will approximate those of other frame structures.

F. Huntington Harbour townhouses by Christiana.

MARKETING PLANS FOR PHASE III

Christiana welcomes the opportunity to participate in Phase III Operation BREAKTHROUGH in joint ventures as a developer, or a system producer. Interested parties should contact

The Christiana Companies, Inc.
3025 Olympic Boulevard
Santa Monica, California 90404

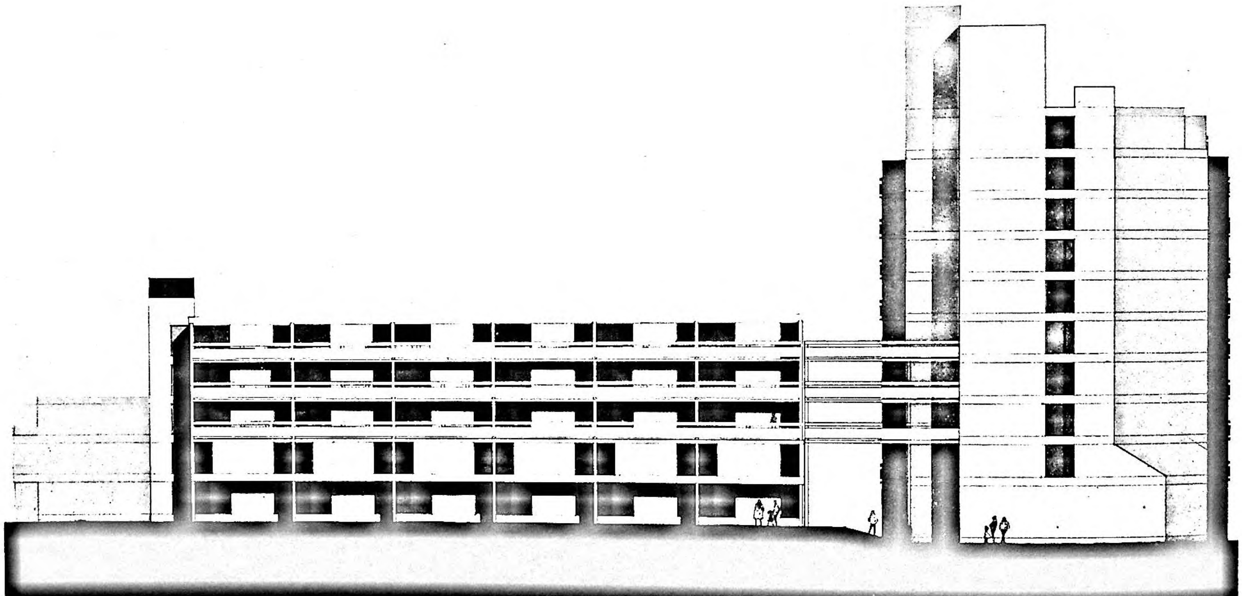
or call

Phil Taylor, Development Manager
(213) 829-2956

Christiana Phase II units are located at three prototype sites:
- Macon – 26 SFA
- Sacramento – 45 SFA, 28 MFLR
- King County – 4 SFD, 34 SFA, 16 MFLR

Summary Information

SYSTEM APPLICABILITY	
Location	Urban, suburban, rural.
Density Range	SFD: 4-6 units per acre; SFA and MFLR: 15-25 units per acre.
Environmental Adaptability	Adaptable to all U.S. climates and normal topography-soil conditions.
Non-Residential Functions	Child care and recreational facilities.
Site Planning Service	Available.
BUILDING SYSTEM DESCRIPTION	
Housing Types	SFD, SFA, MFLR.
Unit Variations	1 to 4 bedrooms; 1 or 2 baths.
Structure	Wood frame and panel system.
Exterior Elements	Porches, patios, decks, storage facilities.
Foundations	Design for site.
Comfort System	Package units using all standard energy sources.
Plumbing	Conventional copper and galvanized iron.
Electrical	Wired at site to local code requirements.
Furnishing	Optional.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Standardized factory-built framing subassemblies.
Codes	No deviation from code requirements.
Deviations from Original O/B Proposal	Shop fabricated wall panels: Left open on one side rather than closed; gypsum board substituted for fiberglass coating; on-site installation on insulation, electrical and plumbing instead of factory; transport: rail shipment eliminated.
PRODUCTION PROGRAM	
Delivery Rate	To be determined.
Off-site Production	Partial fabrication and assembly of wall panels and modules.
On-site Installation	Heating, plumbing, electrical, insulation.
On-site Construction	Inter-module assembly, interior and exterior panel finish, ceiling, roof, foundations, utilities lead-in, grading.
Internal Functions	Design.
External Functions	All but design may be subcontracted.
LABOR REQUIREMENTS/TRAINING PROGRAM	Unskilled, skilled and semi-skilled.
ECONOMICS OF SYSTEM	
Construction Cost	Comparable to conventional.
Transportation Limitation	200 miles from wall panel subcontractor.
Useful Life	Comparable to conventional.
MARKETING FOR PHASE III	Plans under development.



Descon/Concordia

INTRODUCTION AND APPLICATION

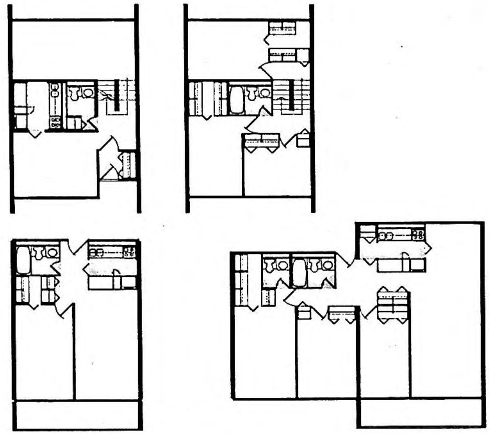
Descon/Concordia Systems Ltd. of Canada was the only non-U.S. company to be awarded a Housing System Producer contract in the Operation BREAKTHROUGH Program. Subsequently incorporated in New York State, Descon/Concordia (D/C) was selected to participate in two of the nine sites, i.e., St. Louis and Jersey City. A total of 269 dwelling units was involved.

The D/C system was planned and organized to permit a licensing operation by small entrepreneurs using local, existing fabrication facilities. It is intended that the licnesee, through subcontracting for the manufacturing of structural and other components, can avoid extensive investment for capital equipment. Two licensees have been established—one in California and another in New England; two more are anticipated by spring of 1973.

The D/C system was designed primarily for multi-family medium rise (MFMR) and multi-family high rise (MFHR) construction application to inner city development or urban renewal projects. The system is adaptable to various climatic conditions and to areas of high earthquake potential. Design features make all-weather erection feasible. The system provides for parking under the building and other amenities such as community activities.

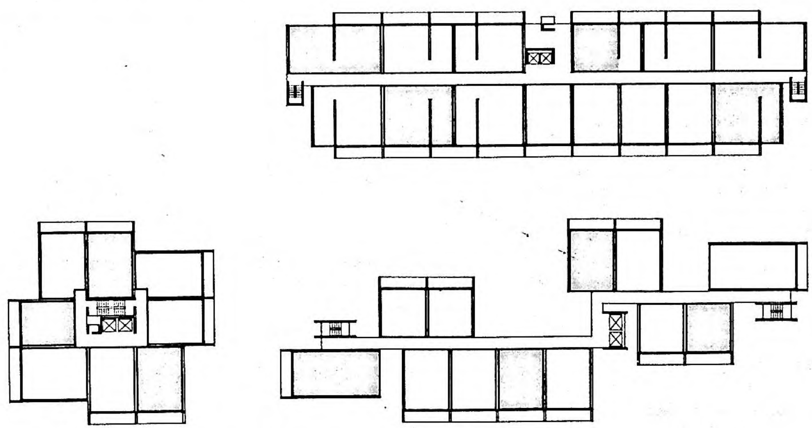
Site planning is provided by employing the services of professionals from the locale where the system is to be installed. For supervision of this function, a planning staff is maintained by D/C.

VARIETY OF UNITS—Components can be selected, designed and assembled to meet the special conditions of the building to which the system is applied. The assemblies produce a broad range of unit types from studio apartments to four-bedroom maisonettes.



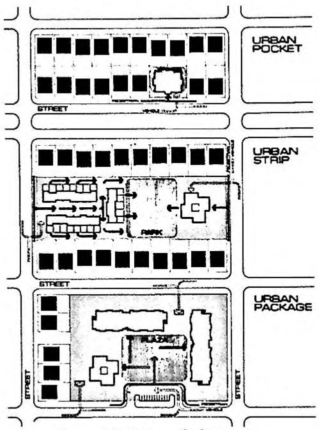
A. Variety of units

VARIETY OF FORMS—The assemblies can produce a wide variety of building forms, including towers, slabs, townhouses, single- and double-loaded corridor types and buildings from 6 to 22 stories.



B. Variety of forms

VARIETY OF SITES—Building forms can be arranged to meet a spectrum of site situations, including urban pockets, infill and planned unit development areas.



C. Variety of sites

Conceptually, the structural module is 21'-4" or 24'-0" wide; lengths vary. It is tied to a horizontal and vertical movement system, supplied with a service assembly for plumbing and power. With a kit of parts, many varieties of plans are possible. The unit space may be expanded horizontally (with varying facades), vertically, and laterally by additive modules. Parts, interchangeable for different building configurations, are mutually exclusive to the extent that they do not depend on each other, and can thus be simply replaced or changed. Because of the interchangeability and variation of the parts, unit space can be adapted to changing marketing demands and user need. Further, this adaptability permits taking advantage of new products and styles.

The assembly provides a broad range of unit space from efficiency to four-bedroom apartments and from single level to double level apartments (with interior stairs).

With any plan variation, circulation is free, tied only to a point of entry and the service assembly around which all primary movement patterns begin. Space around the service assembly can be opened for access, or closed, according to tenant desire and life style.

BUILDING SYSTEM DESCRIPTION

Major elements of the building system are the structure (consisting of precast concrete wall and floor-ceiling panels); weather envelope (nonstructural curtain wall); plumbing; HVAC; kitchen; bathroom; storage units; partitions and doors.

The structural subsystem may be categorized as a bearing wall panel system. It is composed of 6-1/2" prestressed concrete floor panels, simply supported on 8" precast concrete bearing wall panels. Shear walls provide the necessary rigidity in the longitudinal direction.

The various elements are interconnected by mechanical joints, bolted together on the site to make permanent connections. They can be installed with unskilled labor. The jointing system consists of a number of connections which allow for discrete movements at ultimate load. The building behavior in response to earthquake load has characteristics of ductility. The prevention of progressive collapse of load bearing panels, in the event of local explosion, is provided for in the structural subsystem. Bearing panels are tied to the total structure by positive mechanical connections.

Dimensions and configurations of structural members are as follows:

Floor Panels

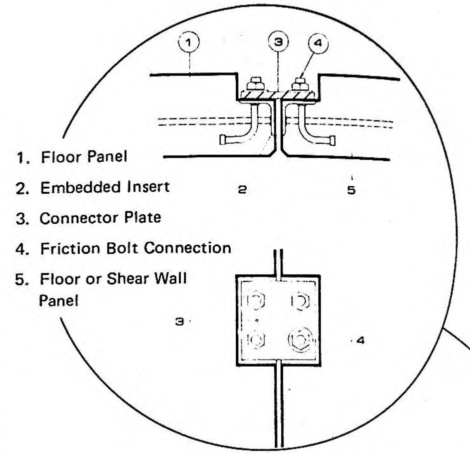
- Nominal length (direction of span): 22' 1" and 24' 8"
- Nominal width range: from 3' 8" up to 10' 8"

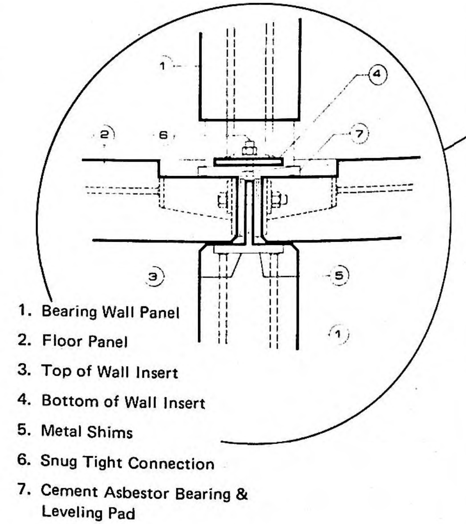
Bearing Panels

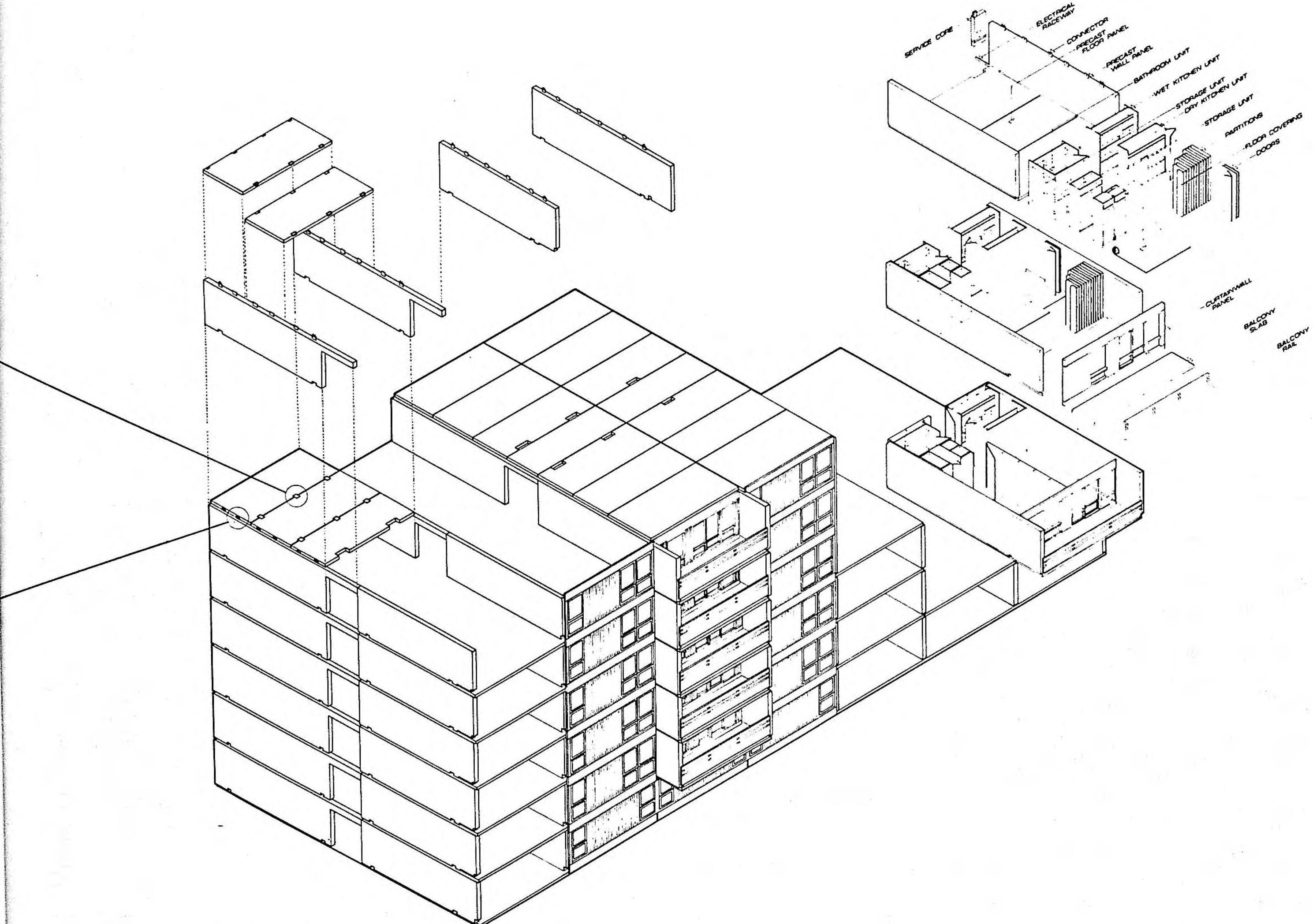
- Bearing panels are fully reinforced for local explosive forces up to 5 psi and are finished ready to receive paint
- Lengths are modular, up to 40' 0" length

Balconies

- 5' 4" prestressed slab, full width of bay (21' 4" or 24' 0") supported by standard extended-bearing panels







D. Exploded view of system components

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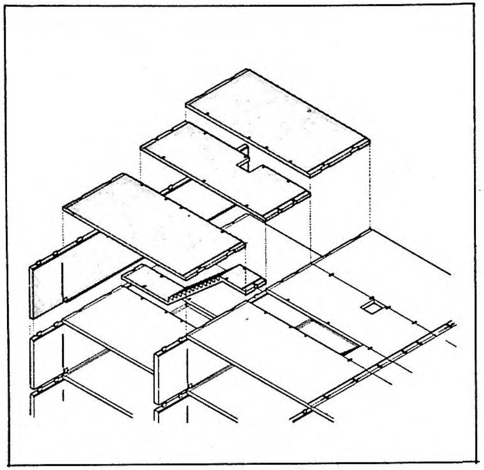


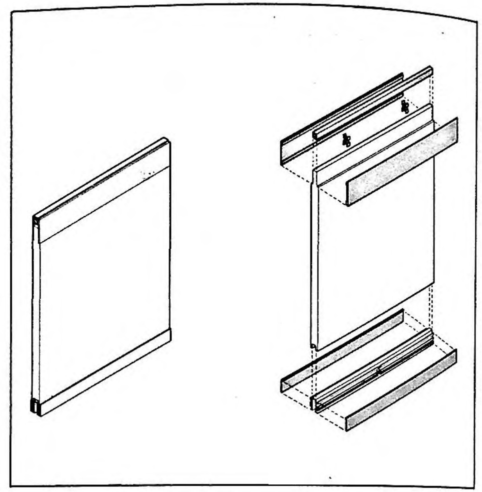
E. Structure

Structure

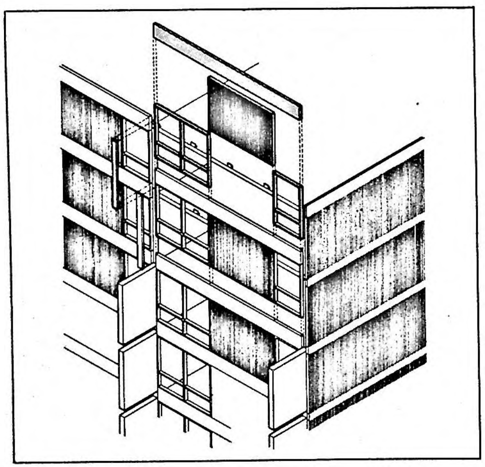
The structural system is of precast concrete, with panelized bearing walls and floor slabs. The system features a dry mechanical connection, which speeds construction time and makes it possible to erect under varying weather conditions.

Interior Partitions

The full-length, lightweight concrete, papercoated, ready-to-paint partition provides excellent sound insulation and fire ratings between apartments and rooms. Low in cost and easy to install, the partition is held by a jig and attached to the ceiling and floor slabs. The base is recessed for later installation of a prefabricated electro-communications raceway.



F. Interior Partitions



G. Weatherscreen

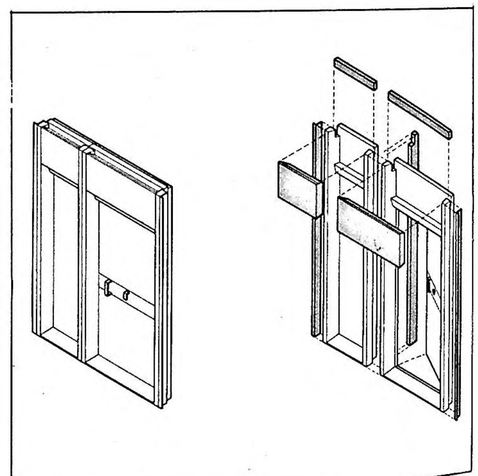
Weatherscreen

The weatherscreen is a subassembly, complete with spandrel panels, windows and/or doors, etc. It hangs from ceiling to floor, is nonstructural and carries all its own hardware, outlet boxes and finishes. The interior face is prefinished. All HVAC equipment and electrical wiring can be preattached as an alternative.

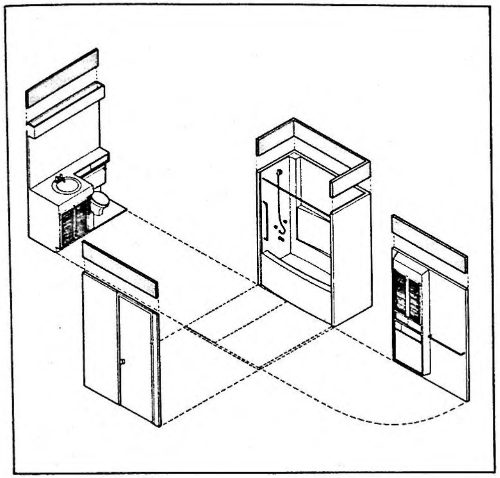
Door Assemblies

Various modular doors, complete with hardware and locks, come mounted in frames with gaskets for easy installation between other components in the field.

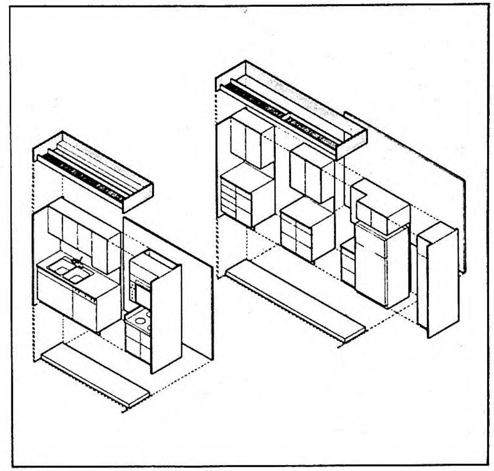
A special entrance door assembly includes hardware, communications equipment, side panels, mail delivery slots and electric light for both public corridor and apartment entrance.



H. Door Assemblies



I. Bathroom Modules



J. Kitchen Modules

Bathroom Modules

The bathroom is made up of preformed standard modular components of three basic units, i.e., bath/shower, sink/water closet and filler units. All are designed for speedy field connection to the mechanical/plumbing module. Standard parts can be assembled to form simple powder rooms or large multi-use bathrooms. Storage and other accessories are available for all bathroom assemblies. Many safety features have been incorporated.

Kitchen Modules

A dry-and-wet assembly, made up of preassembled standard modular components, parts and equipment. The wet section has pre-engineered, easy snap-together connections to be linked up to the prefabricated mechanical/plumbing module. Standard components are utilized to provide an almost infinite variety of kitchen arrangements, from galleys to large L-shaped dining-kitchen types with pass-through bar counters.

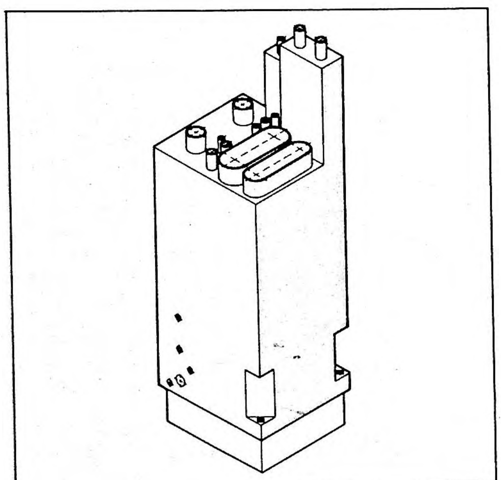
Plumbing, Ventilation, and Electrical Service Module

A lightweight prefabricated unit placed floor to floor. Water, drainage, venting and electrical connections may be tapped on any of three faces. Highly industrialized, the unit offers great flexibility at low cost. Units are linked vertically with speed connectors.

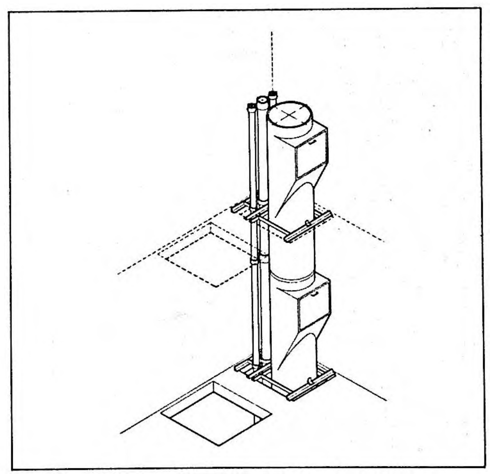
Service Modules

A number of service modules have been developed, including:

1. A precast concrete panel elevator shaft with prefabricated machine room, preassembled cab, inserts and accessories.
2. A precast concrete panel stairwell with shop assembled steel stairs and landings, handrail, all vertical distribution, exit lights, fire doors, lights and ventilation.
3. A garbage chute and janitor closet assembly with chute, unitized HVAC systems and other major vertical distribution systems of electricity, air and water. Modules are dimensionally coordinated, prefabricated and assembled to varying degrees on the site.



K. Plumbing, Ventilation and Electrical Service Module



L. Service Module

DEPARTURES FROM CONVENTIONAL SYSTEMS

This system has been developed with existing processes and products adapted to local requirements through a "systems approach" to building. Within this context it is a unique structural system which can be readily manufactured in most existing precast concrete plants. No D/C plants or equipment are required for manufacture.

This system provides for the use of completed modules for kitchens, bathrooms, storage, HVAC systems, etc. All modules are manufactured in strict accordance with design and performance specifications established by D/C.

Simplified connections for structure and electrical-mechanical hookups result in maximizing use of field labor and increased on-site production speed. Use of local resources keeps capital investment low.

Because of the high degree of flexibility of the system, it is possible to adapt it to meet most building codes throughout North America. The system meets the present stringent code requirements for Zone 3 earthquake potential.

There were no major deviations from the original Operation BREAKTHROUGH proposal.

M. St. Louis prototype wall and slab erection.

PRODUCTION PROGRAM (PHASES II AND III)

The ease of erection of the system was proved on the St. Louis prototype site. Within the limits of the logistics of transporting and handling the various elements of the building, it is quite possible to erect 10,000 square feet of structure complete, with interior modules, in a 16-hour working period. Additional time is required for interior connections of modules and installation of curtain wall and finishes. It is estimated that a ten-story building of 100 dwelling units can be completed in approximately 4 months after completion of substructure work (excluding the installation of elevators). Design time is also reduced to approximately 50% of normal scheduling. It is anticipated that each regional D/C licensee organization can produce up to 2,000 dwelling units a year.

D/C has no manufacturing facilities for off-site production. All elements of the system are produced in existing local plants, as in the case or prestressed concrete, or in regional plants as in the case of bathrooms, kitchens, etc. Special plants or equipment are not required for any aspects of the D/C system. A strict quality control program has been developed, adapted largely from the aerospace industry. It assures quality, from design through to completion.

On-site construction is expedited by the in-plant quality control program. This program assures conformance with dimensional tolerances, which permits quick installation of the modules arriving from various plants. The erection process is very rapid and permits quick enclosure of the building for finishing operations. The interconnection of plumbing and electrical elements has been greatly simplified and an apartment can be painted, carpeted and all mechanical connections made within 2 working days. Prefabricated elevator assemblies are not yet available in the American market causing a scheduling constraint for high rise structures.

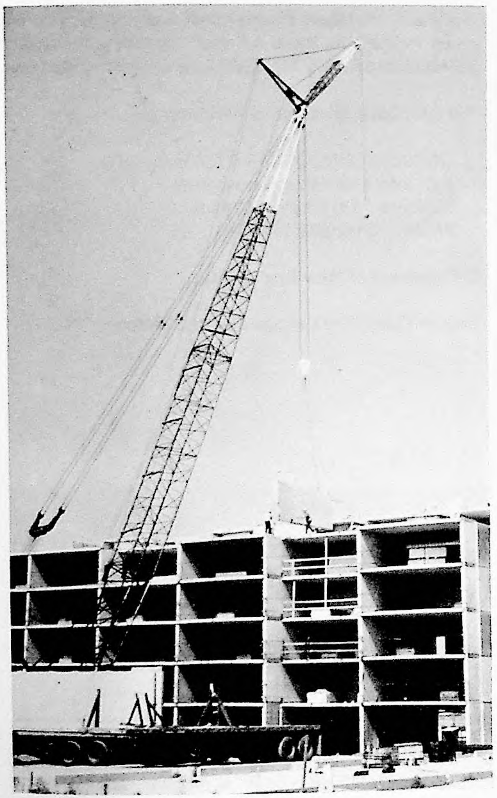
No on-site production other than non-system work i.e. foundations, is required, except for the erection and installation of subassemblies.

The internal functions performed by the parent organization of Descon/Concordia will be concerned primarily with continuing research and development, the marketing of the system to regional developers, central purchasing of building elements common to all regions and the collection and dissemination of information from all projects.

The licensees in each region will be responsible for assisting individual developers in the design and development of projects and will be responsible for providing the housing systems to the developer.

The regional licensees will have the capability to provide entire projects. It is the intent, however, to encourage the developer to provide the foundations for D/C projects.

Unskilled labor can be utilized for most on-site jobs (after completion of company training programs). Instruction, covering all phases of production, construction, erection and installation will be available for all levels from unskilled labor to middle management. Planning and control tools for all of the administrative functions are being developed in such a manner as to be readily understood by young professionals and inexperienced personnel. The on-site processes have been simplified so that unskilled workers in all trades can be employed.



N. St. Louis prototype erection under progress

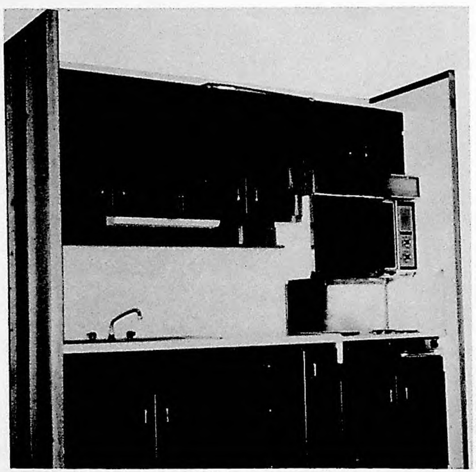
O. Crane hoists prefabricated Bathroom Module into place at St. Louis prototype site.

ECONOMICS OF THE SYSTEM

The combined Phase III market in California and New England has permitted major price reductions of the D/C system from Phases I and II Operation BREAK-THROUGH prototype units. Although the system is designed to meet all requirements of the HUD Guide Criteria and exceeds the FHA Minimum Property Standards, it appears that it will be possible to design and build in the above two areas within cost limits of conventional construction for similar buildings. Expansion of the marketing base, through the addition of more licensees, should continue the trend of price reduction inherent in factory mass production.

Transportation is not a limiting factor for the D/C system as local prestressed concrete plants can be utilized in most areas. Other elements of the system are easily transported by rail or truck from centralized plants across the United States.

The D/C system consists of primary, secondary and tertiary subsystems. Primary elements such as the structure have an indefinite life span in excedd of 100 years. Secondary elements such as plumbing cores, HVAC systems, kitchens, bathrooms, etc., are designed for a minimum 25-year life and can be removed and replaced entirely from within the structure as they become obsolete. Tertiary elements such as fan coil units, kitchen appliances, etc., have a minimum 10-year life and can be easily replaced within the subsystem.



P. Preassembled Kitchen "wet" unit before shipping

Maintenance has been simplified by system design. Interior finishes consist of painted exposed concrete for bearing walls and ceilings; partition systems are generally of painted gypsum boards. Interior apartment maintenance is reduced by using high quality carpeting and laminated plastic finishes in kitchens and other critical areas. The inverted roof provides a continuous protection for the waterproof membrane and simplified balcony details eliminate costly flashing maintenance and other waterproofing problems. Epoxy cement finishes on curtainwalls, exposed concrete on end walls and balconies, and anodized aluminum window frames and exterior doors, eliminate the need for painting on the exterior.

Replaceability and interchangeability have been designed into the system for all levels of preventive and long term maintenance.

MARKETING FOR PHASE III

Two major marketing areas have been developed for the two licensees now in operation. During the 1972-73 period approximately 2,000 dwelling units will be started. The marketing program forecasts the establishment of four additional regional licensee groups by the end of the same period. Probable new regions will be Maryland, Michigan, Pennsylvania and Illinois. The long range forecast indicates a 5-year marketing potential of licensees producing 10-20,000 dwelling units per year.

For additional information, write to:

DESCON/CONCORDIA SYSTEMS, LTD.
P.O. Box 239, Place Bonaventure
Montreal 114, Quebec, Canada
Phone: (514) 878-3781

D/C Systems of New England Inc.

Descon/Concordia Corporation of California

Summary Information

SYSTEM APPLICABILITY

Location	Urban.
Density Range	20-200 units/acre.
Environmental Adaptability	Variety of climates; areas of high earthquake potential.
Non-Residential Functions	None.
Site Planning Services	Available through consultants.

BUILDING SYSTEM DESCRIPTION

Housing Types	MFMR, MFHR.
Unit Variations	1-4 bedrooms; 1-2 baths.
Structure	Pre-cast concrete panels for floor-ceilings and walls.
Exterior Elements	Pre-cast concrete balconies, sundecks.
Foundations	Conventional; designed for site conditions.
Comfort System	Varied per requirements; gas and/or electric; central or separate units.
Plumbing	Conventional, integral with core units; bathrooms and kitchens "plug" into cores.
Electrical	Conventional, integral with core units. Appliances "plug" into cores.
Furnishing	Optional.

DEPARTURES FROM CONVENTIONAL SYSTEMS

Innovative Features	Pre-cast concrete components and subassemblies designed to be produced in most existing facilities; mechanical structure joints; simplified electro-mechanical hook-up.
Codes	Adaptable to meet U.S. building codes; meets Zone 3 earthquake requirements.
Deviations from Original O/B Proposal	None.

PRODUCTION PROGRAM

Delivery Rate	10,000 sq. ft. in a 16-hour period or 2,000 units/year/region.
Off-site Production	All concrete elements are produced in local concrete fabrication plants. Bathroom and kitchen subassemblies are made in regional plants.
On-site Installation	All subassemblies, service modules, and storage units.
On-site Construction	Panel erection, foundations, utilities lead-ins, grading.
Internal Functions	Parent company: common element purchasing, system marketing, research and development. Licensee: Housing system supply.
External Functions	Manufacturing operations, on-site construction and installation; financing.

LABOR REQUIREMENTS/TRAINING PROGRAM

Training available for all categories of personnel involved with factory or site work.

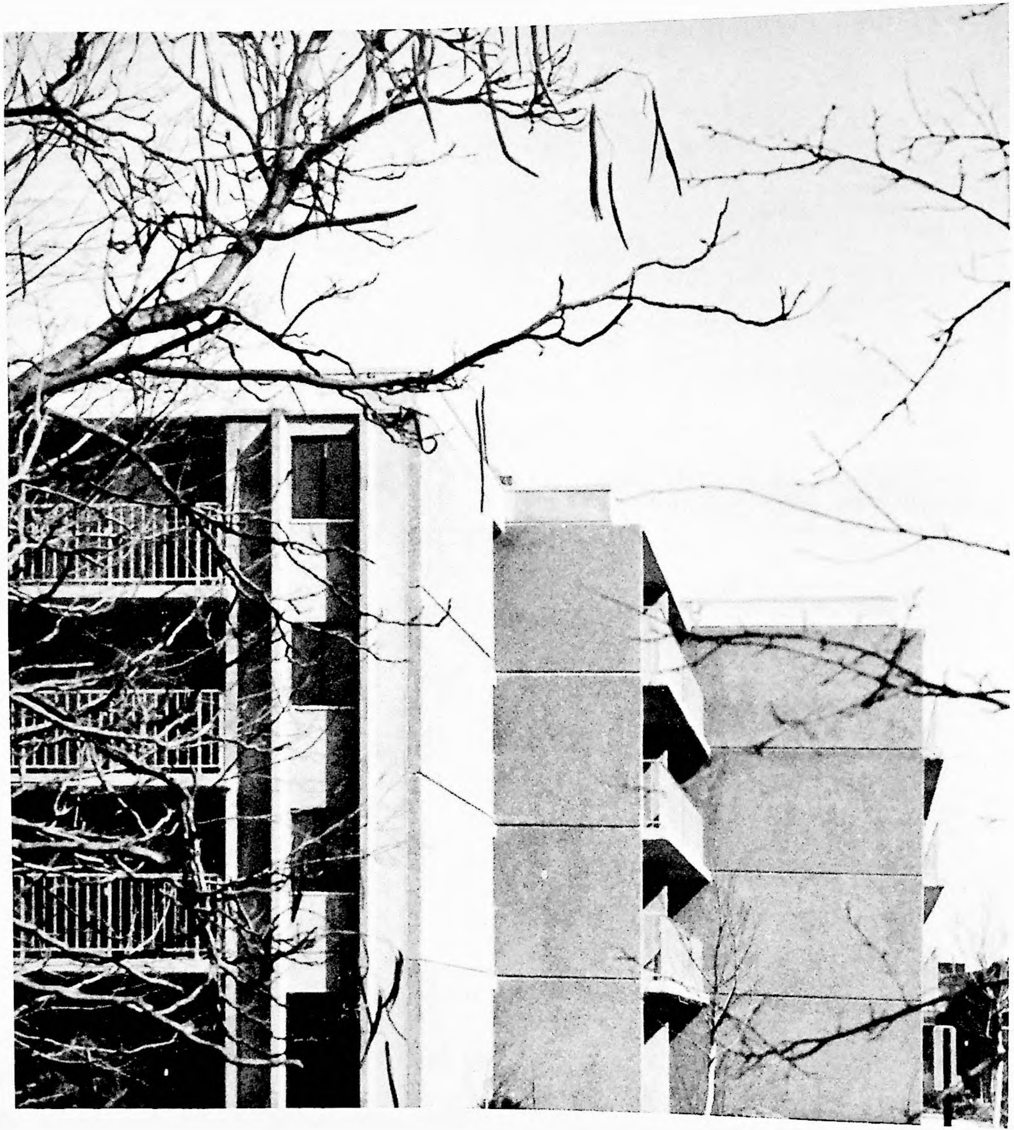
ECONOMICS OF SYSTEM

Construction Cost	Within cost range for similar conventional structure.
Transportation Limitation	Depending on component but averaging 200 miles from major metropolitan areas.
Useful life	Primary structures: 100+ years; other subsystems and appliances determined by usage and maintenance.

MARKETING FOR PHASE III

Two major marketing areas organized to produce 2000 units by 1973. Four licensee groups in operation by 1974 are planned, with a 5-year potential of 10-20 thousand units per year.

Descon/Concordia Phase II units are located at two prototype sites:
St. Louis – 14 MFLR, 24 MFMR, 90 MFHR
Jersey City – 12 MFLR, 18 MFMR, 111 MFHR



FCE-DILLON, INC.

FCE-Dillon, Inc.

INTRODUCTION AND APPLICATION

FCE-Dillon, Inc., developer and producer of the FCE-Dillon system (a precast concrete monolithic structure which combines precast concrete components and site-cast concrete), is a subsidiary of Forest City Enterprises, Inc., a publicly-held company headquartered in Cleveland, Ohio. FCE-Dillon has a 20-year history of building and developing residential and commercial structures, of which the last 8 years have seen a concentration of this activity in the highrise multi-family field.

Development of the Dillon System was an evolutionary process. Prior to its participation in Operation BREAKTHROUGH, FCE-Dillon utilized three field-cast concrete systems to construct apartments and hotels in Ohio, West Virginia, Pennsylvania, Indiana, Florida and California.

The FCE-Dillon shelter system is intended for such locations as urban, suburban and urban renewal projects. Depending on prevailing conditions and types of structure, the density range varies from 4 to 125 dwelling units per acre. The housing is adaptable to all national climates, and to all normal soils with slopes up to 12 degrees.

SYSTEM DESCRIPTION

The industrialized shelter system developed by FCE-Dillon, Inc., in connection with Operation BREAKTHROUGH was designed to meet requirements of flexibility, durability and efficiency. These objectives were evaluated in terms of a production flow process which could capitalize on the developments of modern technology, factory production efficiencies, transportation economics and modular assembly. The resulting shelter concept, the FCE-Dillon system, incorporates all of these factors.

The system is flexible in a variety of ways. Through various configurations of the basic components, buildings of various shapes and sizes, suitable for a number of shelter uses, can be accomplished. Thus, the same basic system can be used for highrise structures, multi-family lowrise apartments, single-family attached dwellings, hotels, dormitories, hospitals and certain non-shelter structures.

Durability is achieved by the use of a patented building system which combines precast concrete components and site-cast concrete. The product of this system is a monolithic structure with the low-maintenance characteristics of concrete and the quality of finish available only under controlled factory-casting conditions.

The efficiency of the system is predicated upon the production flow concept which is employed and which permits a predictable and fast erection process. The components have been treated as modular elements to the extent feasible. This assures maximum efficiency in the manufacturing stage and provides for simplicity and precision during erection of the structures.

Subsystems

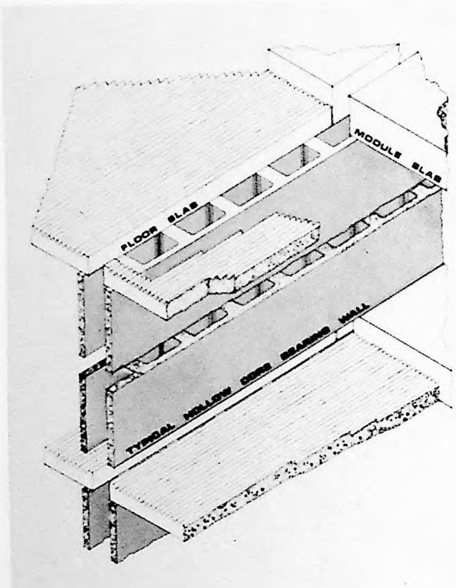
The FCE-Dillon system comprises three major subsystems: (1) the Structural System, (2) the Heart Module, and (3) the Elevator Module. Following is a brief summary of each.

Structural System (U. S. Patent No. 3662506. Foreign patents pending.)

The precast concrete component subsystem is the basic structural nucleus of the system. This subsystem consists principally of walls and floors which are partially precast under controlled factory conditions. The components of this subsystem are as follows:

The precast concrete bearing walls are steel reinforced and cast to a normal thickness of 8" and a maximum length of 30'. They have hollow core openings which are formed during the casting process by the insertion of mandrels (specially designed rectangular cores) to form voids in the center of the wall (Figure A). These voids, similar to those found in concrete block, run vertically the entire height of the wall, and accomplish two objectives: (1) they reduce the weight of the walls, facilitating transportation and handling; and (2) they play an important part in the structural integrity of the system. Exterior end walls can be finished with exposed aggregate, sandblasted, or have a variety of architectural form finishes as required for an individual building.

The floors or deck slabs (Figure A) are precast, prestressed concrete members. These slabs are cast either 4" or 6" thick and 6' or 8' wide, and are available in lengths up to 32'.



A. Precast concrete

Both faces of the hollow core walls and the underside of the deck slabs are precast with smooth dense surfaces suitable for painting or receiving other finishes as required.

Precast balconies may be provided for all dwelling units above the ground floor. Designed to be an integral part of the monolithic structure, they are used to help shore the hollow core walls during erection and as a form for the front edge of the site-cast concrete that is placed on the apartment unit's floor slabs during the construction process.

The balconies (Figure B) are precast, prestressed concrete slabs with sleeves cast into them to accept a railing. They are so designed that the inside end and sides of the slab are the same thickness as the final interior floor will be after the on-site concrete is cast, and they taper down one inch to the front to allow for water run-off. The railings are factory prefabricated and are inserted into the sleeves in the balcony at the jobsite.

If balconies are not desired, a 3'-0" high precast concrete spandrel component may be utilized. The spandrel is erected in place of the balcony and may have the same variety of exterior finishes as the end wall.

B. Balconies on Sacramento Operation BREAKTHROUGH units

Heart Module (Patent Pending)

The Heart Module (Figure C) is a factory-built service and utility core component which contains the kitchen and bathroom. Its service chase contains all the central mechanical and electrical connections for each dwelling unit. These modules are assembled on 8" thick pre-stressed concrete slabs, which can be lifted into the structure and tied into the structural subsystem to assure the structural equivalent of a cast-in-place concrete system.

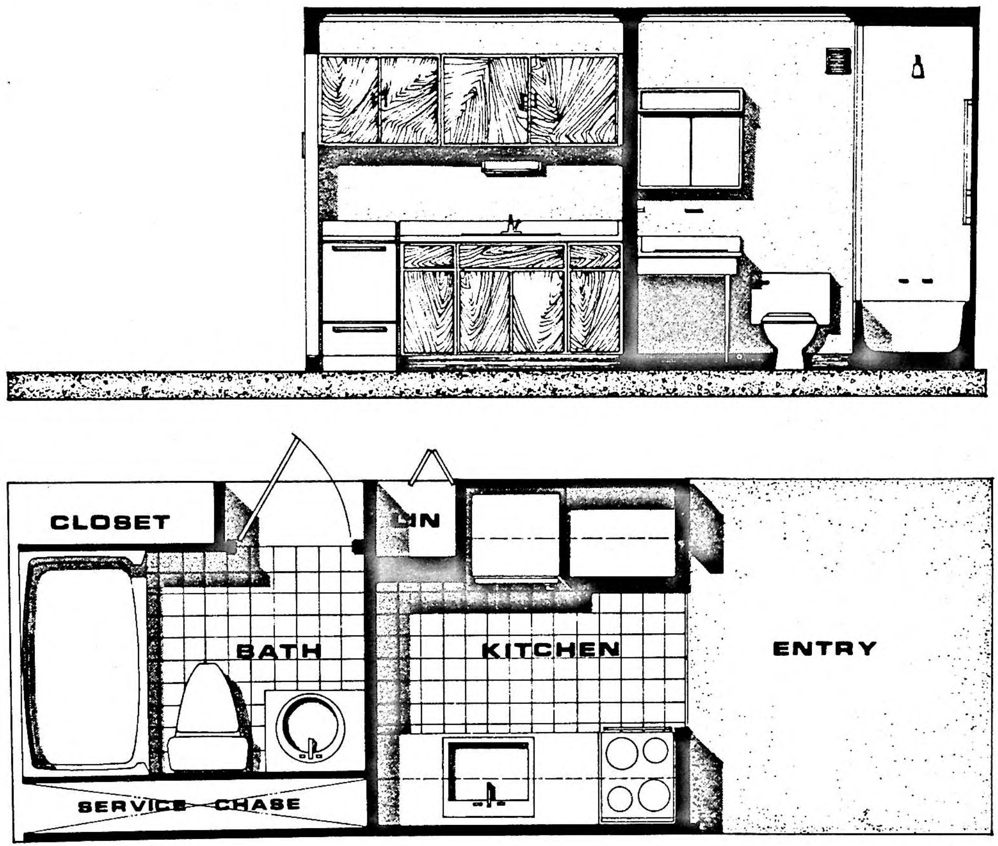
There are numerous advantages to both the design and use of this innovation. A major objective is that the factory construction of the Heart Module will reduce labor costs and on-site construction time. The Heart Module is delivered to the building site completely finished with factory-installed fixtures and equipment, including the refrigerator, range, sink, garbage disposer, kitchen cabinets, closets, bath-shower unit, water closet, lavatory, floor tile and light fixtures. In the top of the unit is the heating and air conditioning equipment for the apartment. The module contains all of the electrical panels and cables for making the connections to the building's electrical supply system, and to provide the cable or conduit for outlets, switches, electrical fixtures, telephone service, TV antenna connections and suite communication equipment for the entire apartment.

All of the plumbing and heating equipment, as well as the central electrical and communications connections, are connected to pipes, conduit, venting stacks and ducting in the Heart Module's service chase. In the building erection process they are easily connected to similar pipes, conduit and ducting in the modules above and below. This connection of the various services at the Heart Module's service chase, from floor to floor, reduces on-site labor and eliminates any need to enter the interior of the module during construction.

The reinforced precast concrete base of the module also provides rigidity to allow the units to be transported a considerable distance without damage to their fixtures or mechanical equipment.

Elevator Module (Patent Pending)

Elevator Module assembly has also been developed for the FCE-Dillon system multi-family highrise buildings. The elevator shaft is precast in one-story-high concrete modules which are erected in sequence with the remainder of the building. The modules contain elevator rails, framed door openings, doors, call buttons and wiring, floor indicator, and positioning pins for use in erection. The top module of the elevator shaft is a covered box which will be used for cab overrun in hydraulic systems or will contain the necessary motors, support beams, pulleys, and control equipment in an electric system. Both single and double shaft modules are available.



C. The Heart Module

Other Elements of The Dillon System

Non-load bearing walls are factory-constructed as pre-finished components. They arrive at the site complete with windows and sliding glass doors. A wall is attached to the concrete bearing walls of the unit and to the inside lip of the balcony slabs above and below with mechanical fasteners. The exterior finish of the panels can vary, and the interior finish is wallboard or an equivalent material which can be painted. The walls are built with insulation to provide the proper thermal barrier for local conditions.

The interior partition walls for each unit are prefabricated into metal stud sections. They contain boxes for electrical outlets and switches and may contain other outlet boxes such as the TV antenna, as design requires. The wall sections are finished on-site with dry wall or an equivalent material. The doors for these walls are prehung as an integral part of the panel.

Heating, Ventilation and Air Conditioning

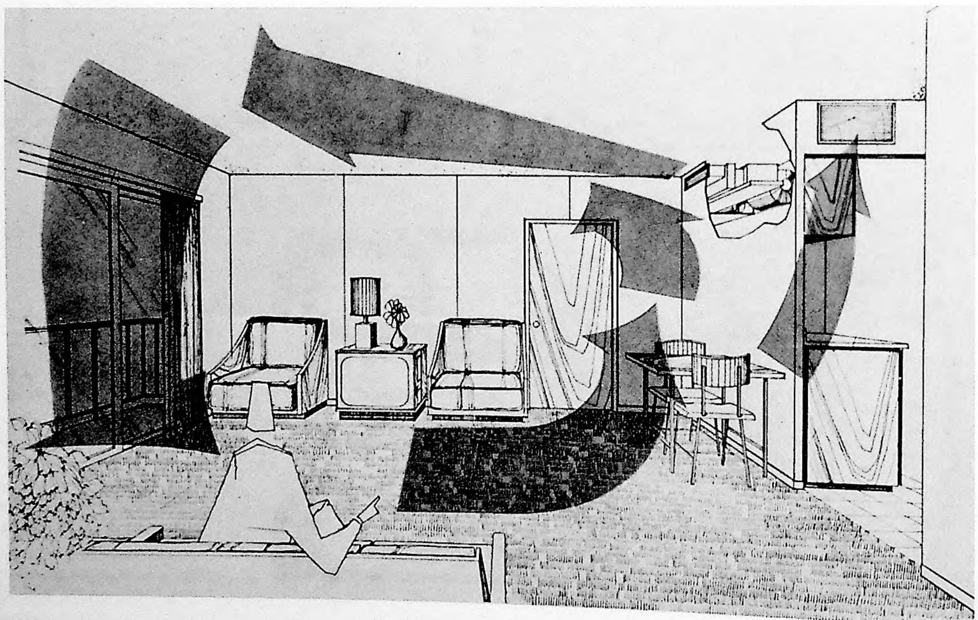
There are two basic types of heating, ventilating and air conditioning methods incorporated in the FCE-Dillon system.

The first is a two-pipe, central distribution, hot and chilled water system, which feeds fan coil units in each apartment. This unit is factory-installed in the ceiling of the heart module and discharges air through slot defuser registers which are nearly flush with the ceiling (Figure D). The conditioned supply air is carried directly to the outside wall by means of the "Coanda effect." Rapid movement of the air from the outlet creates a negative pressure by entrapping the air in the space between the air stream and the ceiling. The resulting pressure differential causes the stream to attach itself to the ceiling until velocity slows near the opposite wall. Gradually induced room air mixes with the stream, tempering the supply air before it reaches the occupied space.

Two types of temperature controls can be used with this unit. One type regulates the amount of water which is fed into the fan coil unit and thereby controls the temperature of the coil while the air velocity remains constant. The other type of control regulates the fan speed and, thereby, the velocity of the air flow. Both types of regulation have proved acceptable. However, the regulation of the air flow is superior in certain adaptations of the system such as in the use of the electric heating coils to supplement or replace the water-fed coils.

The second HVAC type is an electric incremental unit installed in the exterior wall of each living unit. Individual apartment controls are provided which allow the choice of heating or cooling at any time during the year.

Plumbing in the building's mechanical system is a single stack waste and venting system which conforms with the National Bureau of Standards and Operation BREAK-THROUGH criteria. The waste water stack allows gases to escape upward through the same pipe in which waste is carried down to the sanitary sewer connections at the foundation of the building.



D. Air circulation pattern

DEVIATIONS FROM CONVENTIONAL SYSTEMS

The primary innovative concepts of the Dillon housing system are: (1) the structural system, (2) the Heart Module, and (3) the elevator system, which are explained in detail in the "System Description" portion of this report.

PRODUCTION PROGRAM

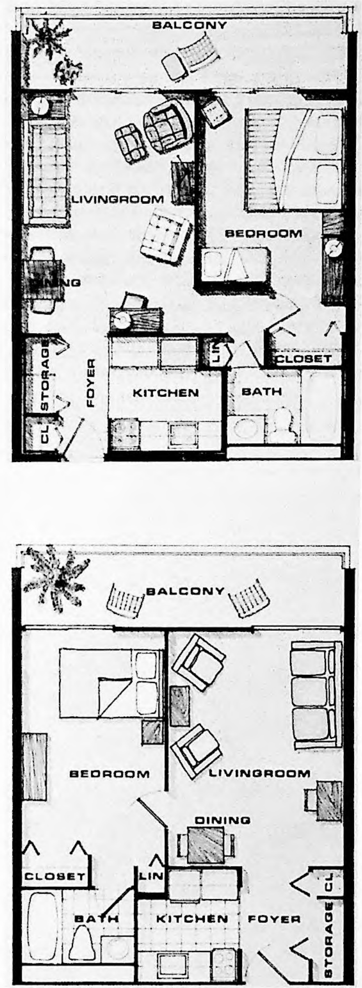
The production rate for the Dillon housing system is planned for 600 to 2400 units per factory per year. The housing is adaptable to all national model codes and consumer protection is provided by warranty.

Erection Procedure

The highrise structure illustrated (Figure E) was designed specifically for the Operation BREAKTHROUGH program. The building is made up totally of one-bedroom units (Figure F). This was a requirement of the market for which it was designed. Larger or smaller units can be incorporated into a similar structure where the market demands. The basic difference is in the size of the components used and not in the erection procedure.

Compatibility with poured-in-place construction is shown in the building. Eight residential floors of the building were designed to be constructed with the FCE-Dillon system's industrialized concept; however, the first floor required a lobby area, offices, community rooms, service areas, and commercial areas. This design was accomplished through the use of a cast-in-place field system for the first floor which serves as the foundation of the modular component structure above.

E. High-rise structure for Operation BREAKTHROUGH Sacramento site



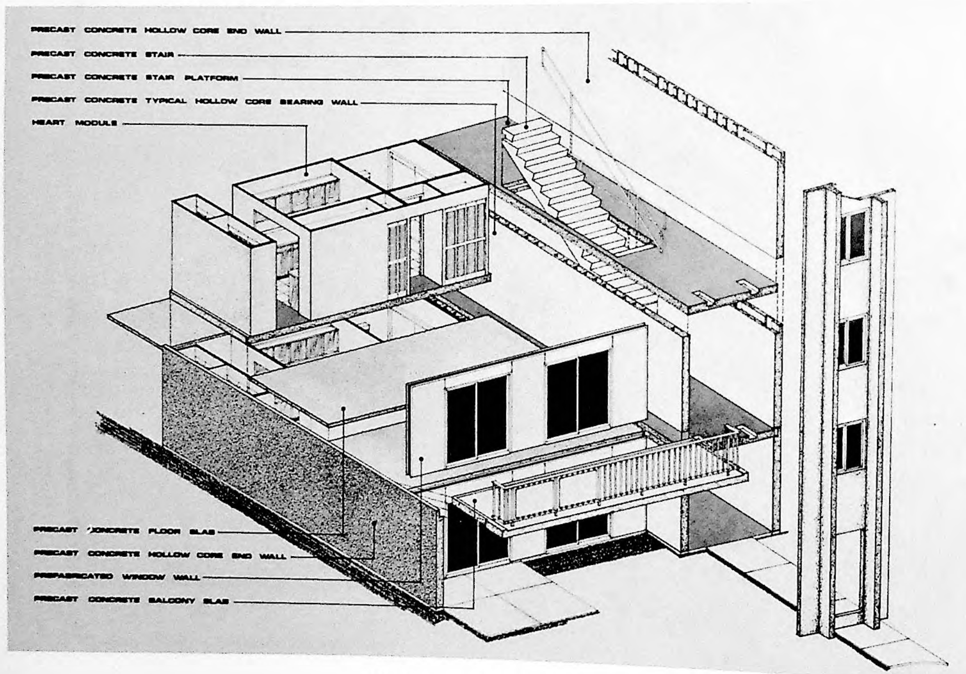
F. One-bedroom apartment floor plans

The erection procedure of the FCE-Dillon system (Figure G) is such that each apartment is assembled in a fixed sequence on each floor. In the example building, a heart module is set in place on top of the first floor walls. Once the heart module is aligned, the deck slabs for the unit and for the corridor outside can be set in place. These slabs are tied in place with steel rods (Figure H) which are inserted both into the base of the heart module and into the top of the bearing walls or beams below. The balcony slab is then set in place, braced and steel inset rods are placed in its inside base to tie it back into the rest of the building. The same procedure is then followed with the next unit.

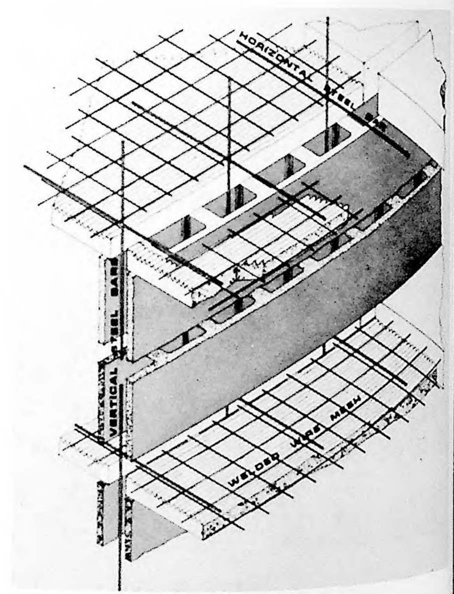
The walls of the first unit are then lifted into place. Since the first unit has an exterior wall it requires two walls to be placed. First the exterior wall is lifted into place. This wall is positioned on pins and is braced in a conventional manner. Second, an interior hollow core bearing wall is lifted into place. This wall is also positioned on pins and will be shored on the inside lip of the balcony slabs and the base of the heart modules for the two apartments. If the building design called for a number of apartments side by side this process would be repeated until the plans call for an exterior wall or stairwell. The next step is to set the stair platform and stairs on top of the first floor walls. Then a second hollow core wall is set on the balcony slab and heart module base within the apartment and the edge of the stair platform and is positioned with steel pins. This second wall has to be braced temporarily. Another exterior wall is then positioned and braced and bolted on the exterior of the stairway.

An exception to the assembly is caused by the placement of the elevator module in the center of the building. As previously noted, the elevator assembly is in floor-high modules. The module for the second floor is set in place prior to the heart modules of the units around it. Once in place the elevator is tied into the corridor slabs that are adjacent to it with threaded inserts similar to those used to tie the heart module slab into the corridor slab.

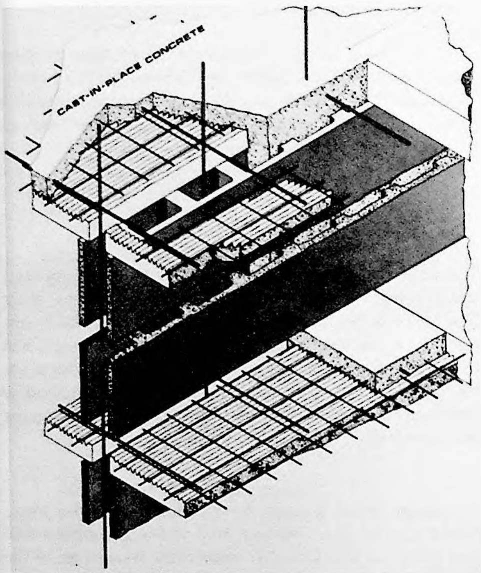
Once an apartment unit is erected, the factory-installed electrical and TV cables are pulled from the heart modules across the floor slabs and brought up at the proper place for outlets, switches and fixtures. This cable is buried in concrete during the subsequent processes. As an alternative, the cables may be incorporated in the partition wall with the use of baseboard electrical raceway employed at the concrete bearing walls.



G. Construction components



H. Reinforcing steel



I. Cast-in-place concrete

When the walls and deck slabs are in place, wire mesh is laid over the decks and concrete is placed on them and pumped into the walls (Figure I) to fill the voids or cores and to raise the floor to the 8" thickness of the heart module and balcony slabs. The floor is finished on the site to accept various floor coverings. The job of casting the floors is simplified because the heart module slab and the balcony slab are used as bulkheads for the cast-in-place concrete. In effect the hollow core walls and deck slabs are used as forms for the cast-in-place concrete. The result is a monolithic structure the equivalent of a cast-in-place building.

The erection process described above is repeated for each floor of the building. Once the floor and walls of living units are erected, the exterior window wall panels are installed. The window walls are mechanically fastened to the inside lip of the balcony slabs above and below the unit and to the concrete bearing walls.

The mechanical and electrical connections for each unit are made as soon as the heart modules and corridor slabs are in place. These connections are all made in the heart module wet-wall service chase on the corridor side of the unit. This procedure not only allows an orderly, systematic installation of the utilities throughout the building but also allows for easy inspection of the connections. Once the utility connections are made in the heart module service chase, the chase is sealed by spraying it with urethane filler which acts as a form for a 4" concrete topping. This topping provides a fire stop in the service chase between floors.

The roof of the FCE-Dillon system is erected using precast components. Precast deck sections similar to those used in the decks of the apartment units are set in place between the bearing walls or corridor beams. Holes provided in the slabs allow the ventilation pipes and ducts from the vertical chases to protrude. Steel rods are placed in the hollow core walls and extended over the top of the deck slabs. Concrete is then placed on top of the decks in such a manner that the proper slope for drainage is provided. Insulation is placed on top of the concrete, flashing is installed and three-ply felt and gravel roof is placed on top of the insulation.

The elevator is topped off with a prefabricated enclosure which is set before the roof concrete is placed and is tied into the roof with steel insert pins. Once the enclosure is complete the elevator is installed.

The pre-built mechanical penthouse is then lifted to the roof and fastened into place. Connections are made between the penthouse and HVAC distribution systems which are brought to the roof through the vertical chase adjacent to the elevator shaft.

		Performed By:		
	Function	FCE-Dillon, Inc.	FCE-Dillon Affiliates	Others
1.	Development	X		X
2.	Community Relations	X		X
3.	Design		X	
4.	Engineering		X	X
5.	Site Planning		X	X
6.	Financing		X	X
7.	Manufacturing—Precast Panels		X	X
8.	Manufacturing—Heart Modules		X	
9.	System Erection	X		
10.	Major Subcontracts			
	a. Electrical			X
	b. Mechanical			X
	c. Concrete	X		X
11.	Other Subcontracts			
	a. Landscaping			X
	b. Carpentry	X		X
	c. Masonry	X		X
	d. Site Work	X		X
12.	Rental		X	X

TABLE 1. Internal-External Functions

Once the principal components of the structure are assembled, miscellaneous elements such as trash chutes, interior and exterior lighting, flooring, and painting are accomplished on site to complete the building.

Internal/External Functions

As a well-integrated shelter corporation, FCE-Dillon, Inc. has the facilities and personnel to perform many of the functions required to develop and produce residential properties. In addition, subsidiaries and sister corporations of FCE-Dillon are experienced in other areas of responsibility, such as manufacturing, financing and rental management. Table 1 shows functions performed by each.

Labor Requirements

Skilled and semi-skilled labor is required for plant production. FCE-Dillon has established training programs for all building trades.

Options

In addition to highrise apartment structures, the FCE-dillon system can be utilized for garden apartments, townhouses and hotels by employing most of the same components and techniques.

Architectural renderings (Figure J) of various lowrise projects illustrate possibilities available for these types of structures.

J. Low-medium rise architectural variations

Garden Apartments

Heart modules, walls and floor panels are assembled for garden apartments in a manner identical to the highrise structures. Precast stairway and landing components are introduced, and a wooden roof truss subsystem may be utilized where desirable.

Townhouses

The townhouse design is a blend of the basic concrete structural subsystem used in the other structures and a new complementary subsystem. Other adaptable elements are the steel stud-and-dry-wall interior wall, and the truss roof introduced in the garden apartment design. In addition, wooden or precast concrete window walls are required to provide shear strength opposing the bearing walls.

The major new subsystem introduced into the townhouse studies is a wet-wall for centralized mechanical and electrical equipment in each unit. In the case of the electrical tie-in, an individually metered single service system would be brought into each unit. In addition, individual heating and domestic cold water and hot water systems have to be installed in each unit. The wet-wall is a two-story chase which can be factory assembled to provide fast on-site connection of the mechanical and electrical utilities. It is located in the unit in such a manner that it can contain the plumbing, electrical and heating connections for the kitchen, utility room and upstairs bathroom. Using the wet-wall subsystem, the kitchen equipment, bathroom, lavatory, and utility room fixtures must be installed in a conventional manner; however, a considerable amount of onsite labor is saved by the use of the standardized subsystem.

ECONOMICS OF SYSTEM

Construction costs depending on locality, bedroom mix and subsurface conditions vary from $16 to $23 per square foot, with an estimated "lifetime" useful life for concrete panels. Maintenance costs are estimated to be lower than for conventional construction.

MARKETING FOR PHASE III

Marketing of the FCE-Dillon system is oriented to present and projected plant locations. As of June, 1972, FCE-Dillon has manufacturing facilities operating in Akron, Ohio and expects to begin producing system components within a few months in California and Florida. Additional plant locations are being studied; it is anticipated that a total of five market areas will be operational by 1974.

Sale and transportation of housing is limited to approximately 250 miles from each factory. The estimated maximum production rate is 2400 units per factory per year.

Additional information or questions relative to the FCE-Dillon Housing System may be directed to John Mogen or Anthony Rodriguez.

FCE-Dillon, Inc.
1730 Akron-Peninsula Road
Akron, Ohio 44313

Phone: (216) 929-4244

FCE-Dillon Phase II units are located at four prototype sites:

- Kalamazoo — 52 MFMR
- Sacramento — 112 MFHR
- Indianapolis — 36 MFMR
- Memphis — 206 MFHR

Summary Information

SYSTEM APPLICABILITY	
Location	Urban; suburban; urban renewal.
Density Range	4 to 125 dwelling units per acre.
Environmental Adaptability	Adaptable to slopes up to 12 degrees; all normal soils and national climates.
Non-Residential Functions	Recreational, library, community, craft and shopping facilities.
Site Planning Services	Consortium member; outside consultants.
BUILDING SYSTEM DESCRIPTION	
Housing Types	Single family attached; multi-family low rise; multi-family high rise.
Unit Variations	One to six bedrooms.
Structure	Concrete wall and floor panels; concrete roof and stairs.
Exterior Elements	Prefabricated infill panels.
Foundations	Conventional; as required.
Comfort System	2 pipe fan coil unit each living unit or electric incremental HVAC.
Plumbing	Conventional; integrated with "heart modules."
Electrical	Conventional; integrated in panel system.
Furnishing	Kitchen appliances.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Patented precast concrete monolithic structure; "heart module."
Codes	Adaptable to all national elevator module codes.
Deviations from Original O/B Proposal	Use of prestressed concrete walls and roofs instead of wood in low rise.
PRODUCTION PROGRAM	
Delivery Rate	600 to 2400 dwelling units per year per factory location.
Off-site Production	Precast wall and floor panels; elevator modules; heart modules.
On-site Installation	Panel and component erection; utility connections; interior finishes.
On-site Construction	Foundations; utility lead ins; placing reinforcing steel and cast-in-place concrete.
Internal Functions	Development; community relations; system erection; subcontracting.
External Functions	Engineering; site planning; financing; manufacturing.
LABOR REQUIREMENTS/TRAINING PROGRAM	Skilled and semi-skilled for plant production. Apprentice training program for all building trades by HSP.
ECONOMICS OF SYSTEM	
Construction Cost	$16 to $23 per square foot depending on locality, bedroom mix and subsurface conditions.
Transportation Limitation	250 mile radius of plants.
Useful Life	Concrete panels—lifetime.
MARKETING FOR PHASE III	As of June, 1972, plant location in Akron, Ohio; plans include plants in California and Florida with additional locations being studied.

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General Electric

INTRODUCTION AND APPLICABILITY

Factory built, three-dimensional closed modules are the building blocks of the General Electric Industrialized Housing System. Shipped to the builder/developer's site, the modules can be quickly erected on foundations prepared in advance to form an attractive, planned community.

Utilizing its 15 years of aerospace technology experience, GE's Re-entry and Environmental Systems Division has developed and applied totally new methods and processes to the industrialized production of modular homes. This organization has succeeded in efficiently producing high quality, structurally sound, low maintenance, esthetically pleasing dwelling units. Offered directly to the builder/developer, these dwelling units include modern, attractive garden apartments, adaptable to all climate, topographic and normal soil conditions. The GE housing system is applicable to government subsidized and military family housing as well as independently developed projects.

One key to the design and application flexibility in the GE housing system is the effective use of materials. Maximum advantages are made of the individual characteristics of steel, wood and gypsum as they are used in various combinations.

A unique feature of the GE modular homes is the use of cast plaster walls. One piece reinforced plaster wall surfaces are continuously cast on a semi-automated endless belt at a maximum rate of 20 feet per minute. Galvanized steel framing members are emplaced in the uncured plaster which, within 30 minutes, hardens around the framing.

The completed wall is smoother, dimensionally more accurate, and stronger than a traditional wall, yet provides the quality and beauty usually found only with conventionally applied wet plaster walls.

The cast plaster process is rapid and accurate, and lends itself to the ultimate industrialization of the production of modular housing. It is a direct spinoff from the Re-entry and Environmental Systems Division's extensive research and development of aerospace materials.

Efficient assembly line manufacturing methods and tooling are now being used in the General Electric housing factory. Assembly line production provides a method of manufacture whereby the ultimate in product quality control and production efficiency can be achieved. Every element from which the dwelling is fabricated—roof, floor, walls, electrical and mechanical system—is installed under precise, controlled factory conditions.

The Belmont Garden Apartments (1, 2 or 3 bedrooms—shown in Figure A) and the Allendale Townhouses (3 or 4 bedrooms) have been designed specifically for government funded low to medium income market and are the types designed, developed and furnished for the Operation BREAKTHROUGH Program. These units afford spacious interiors (room sizes meet or exceed FHA minimum) and practical floor plans that provide for gracious living in rural, suburban or urban situations.

SYSTEM DESCRIPTION

Factory-produced modules, 12'-0" wide, by 10'-0" high and from 19' to 30' long are crane erected on conventional basement or crawl-space foundations to form complete housing units. Modules contain factory installed electrical, plumbing and heating and/or air conditioning units as appropriate. Modules connect rapidly and accurately. The connection process entails a minimum of trim details; all required materials are shipped to the site with each module. The rapid modular connection sequence can be accomplished under adverse weather conditions. A typical erection photo is shown in Figure B.

Townhouse units furnished on Operation BREAKTHROUGH consist of 4 modules. Apartment units are made up of 2 or 3 modules. Each apartment has its own individually controlled electric heating and air conditioning system and hot water heater as well as connections for a washer and dryer.

A. Belmont Garden Apartments

Acoustical control is excellent because of "dead" air spaces between the modular units of the second story floor and the first story ceiling and between the dwelling units.

The mechanical distribution systems are located in a central chase, which includes air ducts, hot and cold water, drains, vents, gas flue, and electrical load connections. Heating, ventilating and air conditioning systems are designed as a part of the building rather than as independent items. Insulation is batt fiberglass with an integral vapor barrier.

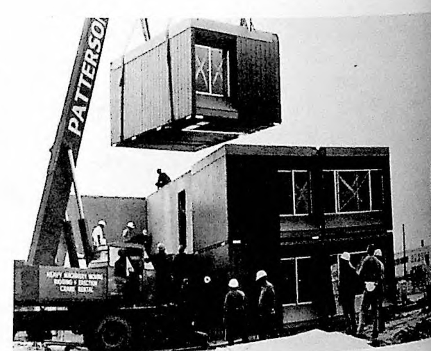
Plumbing, also factory fabricated and installed, makes use of performance-rated plastic piping throughout, although copper can be substituted if desired. A single-stack venting system can adequately handle all the fixtures, and standard bathroom fixtures are factory tested and included in the subassemblies.

Electrical systems are designed as an integral part of the delivered structure. Modules are wired at the factory in a conventional manner with Romex cable. At least 100 amp service is provided.

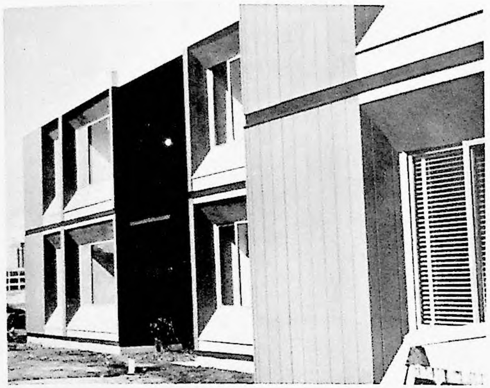
The structural system is similar to standard frame construction. Steel was selected for the framing because of easy availability, because strength can be increased simply by a change in gauge, and because metal lends itself readily to automated fabrication. However, there is also considerable use of wood in the floor panels, roof/ceiling sheathing, plywood exterior siding, exterior and interior doors, and interior wood stair treads and risers carried on wood stringers. (See Figures C and D for typical exterior treatment.)

All sheathing, siding and paneling materials are attached to framing members to provide stressed-skin structural strength. Maximum moisture content of all framing is maintained below 19%. All plywood meets U.S. production standard P.S.-1-66, manufactured with exterior glue as approved by the American Plywood Association. Modules for use in both townhouses and garden apartments have been approved by FHA Structural Engineering Bulletin No. 704.

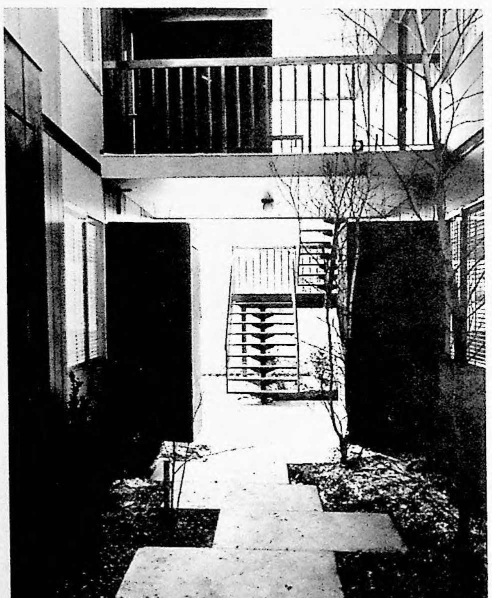
The cast plaster used for ceilings and sidewalls is basically a 5/8 in. thick, unreinforced gypsum plaster, cast in a flat bed. Punched loops on the steel studs are imbedded in the plaster for attachment. Sections up to 8 ft. x 30 ft. have been cast and handled in factory and on site, without damage or special problems. On-site finishing operations are held to a minimum. Much interior trim has been eliminated; its main use is at floor to wall connections. (See Figure E for typical interior view.)



B. Module Erection



C. Building Exterior

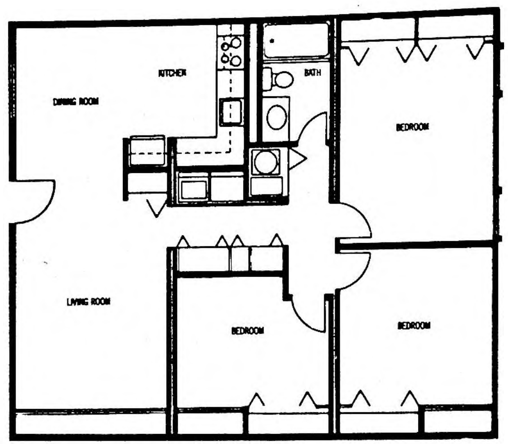


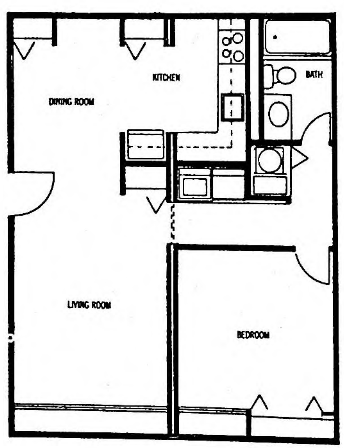
D. Balcony and Courtyard

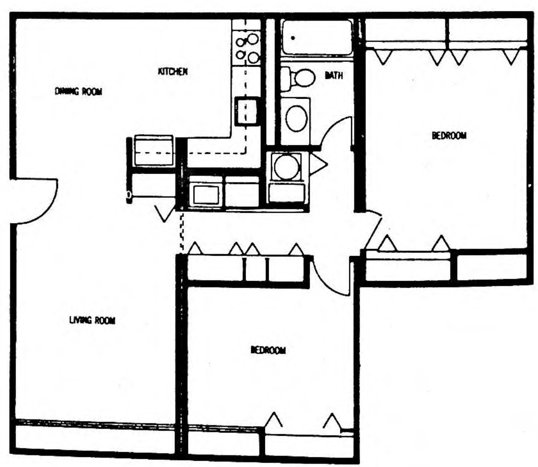
FLOOR PLANS

Floor plans for typical 1 BR, 2 BR and 3 BR apartment units are shown in Figure F. Floor plans for typical 3 BR and 4 BR townhouse units are shown in Figure G.

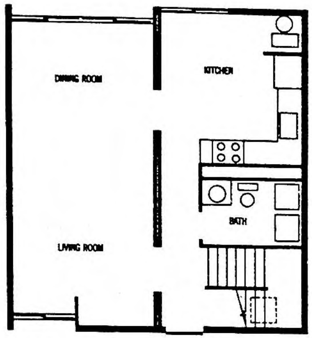
E. Apartment Interior



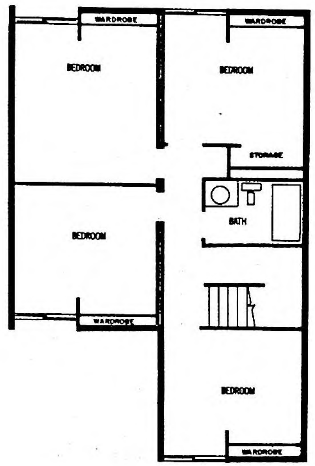




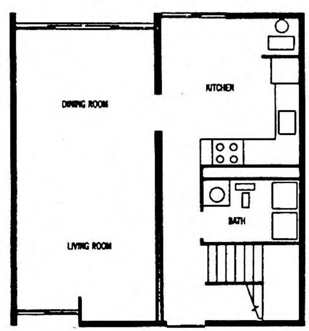
F. Floor Plans—Garden Apartments



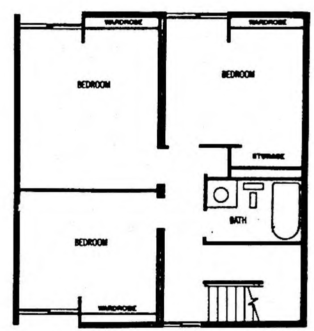
FIRST FLOOR



SECOND FLOOR



FIRST FLOOR



SECOND FLOOR

G. Floor Plans—Townhouse

INNOVATIVE FEATURES OF SYSTEM

Innovations include the central chase to carry all utilities, and use of steel instead of wood studding.

The principal departures from conventional construction involve the use of steel framing of cast plaster. These items were previously discussed under System Description. The GE system is adaptable to meet all national model and local building codes.

PRODUCTION

Operation BREAKTHROUGH modules for both the Memphis and Indianapolis sites were produced at GE's prototype manufacturing facility located at King of Prussia, Pennsylvania. In addition, GE has used this facility to produce garden apartments of the Operation BREAKTHROUGH type for a HUD-subsidized apartment complex in Nashua, New Hampshire, and for other projects at Providence, R.I., Middletown, Conn., and Taunton, Mass.

One unique feature of the development facility at King of Prussia, Pennsylvania involves the plaster casting line (see Figure H). Nearly a quarter of a mile of wall per hour rolls along this belt-line. Wet plaster formulation is spread over a belt and steel framing is lowered into it. One-piece cured plaster and steel wall sections are tilted up for vertical storage until walls are incorporated into housing modules.

In the west, General Electric has completed a 200-unit military family housing project at George Air Force Base, California and a 250-unit project at Norton Air Force Base, California. A housing factory in Apple Valley, California produced this housing and BREAKTHROUGH-type apartments for a 352-unit project in Las Vegas, Nevada.

The factory concept utilizes a controlled factory production system that permits tight construction timetables; increases the builder/developer's site efficiency and speed; accelerates the builder's cash flow in project completion while reducing construction time and costs. Innovations and improvements are continuously being introduced into the system to improve efficiency and increase quality.

SITE DEVELOPMENT

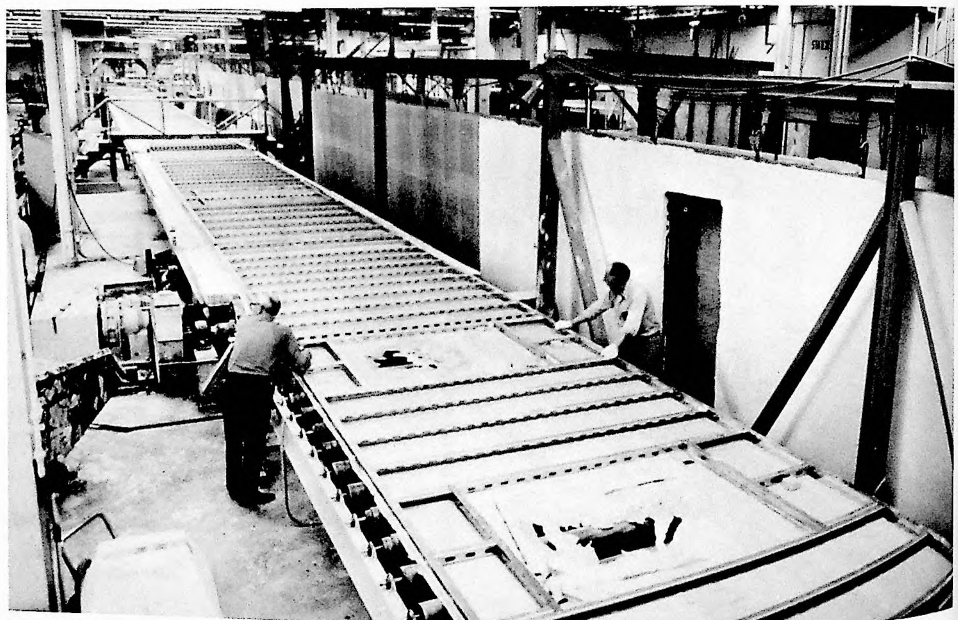
Site development and land planning consulting services are available from GE's Re-entry and Environmental Systems Division to the builder/developer.

Modular townhouses and apartments readily lend themselves to high density land planning and planned unit development. With the GE designs, it is possible to preserve large natural areas of common community space for recreation, while at the same time achieving tighter unit densities. Increased densities provide many site economies, such as shorter utility lines and roads, centralized utilities, and landscaping of the housing area only. The rest of the site can be left in its natural state.

Foundation costs are reduced by using common party walls and piers. Utility connections for each unit may be grouped centrally for ease of connection to site utility lines.

ECONOMICS OF SYSTEM

Units provided are in the HUD Section 235/236 price range as well as meeting market rate requirements. GE sees modular housing as a way to aid the builder/developer by permitting savings in interim interest costs, increasing his cash flow and annual production of housing while reducing losses from theft and weather damage.



H. Plaster Casting Line – King of Prussia, Pa. Facility

MARKETING

The General Electric Industrialized Housing System is currently available in the northeastern United States.

For additional information, please contact:

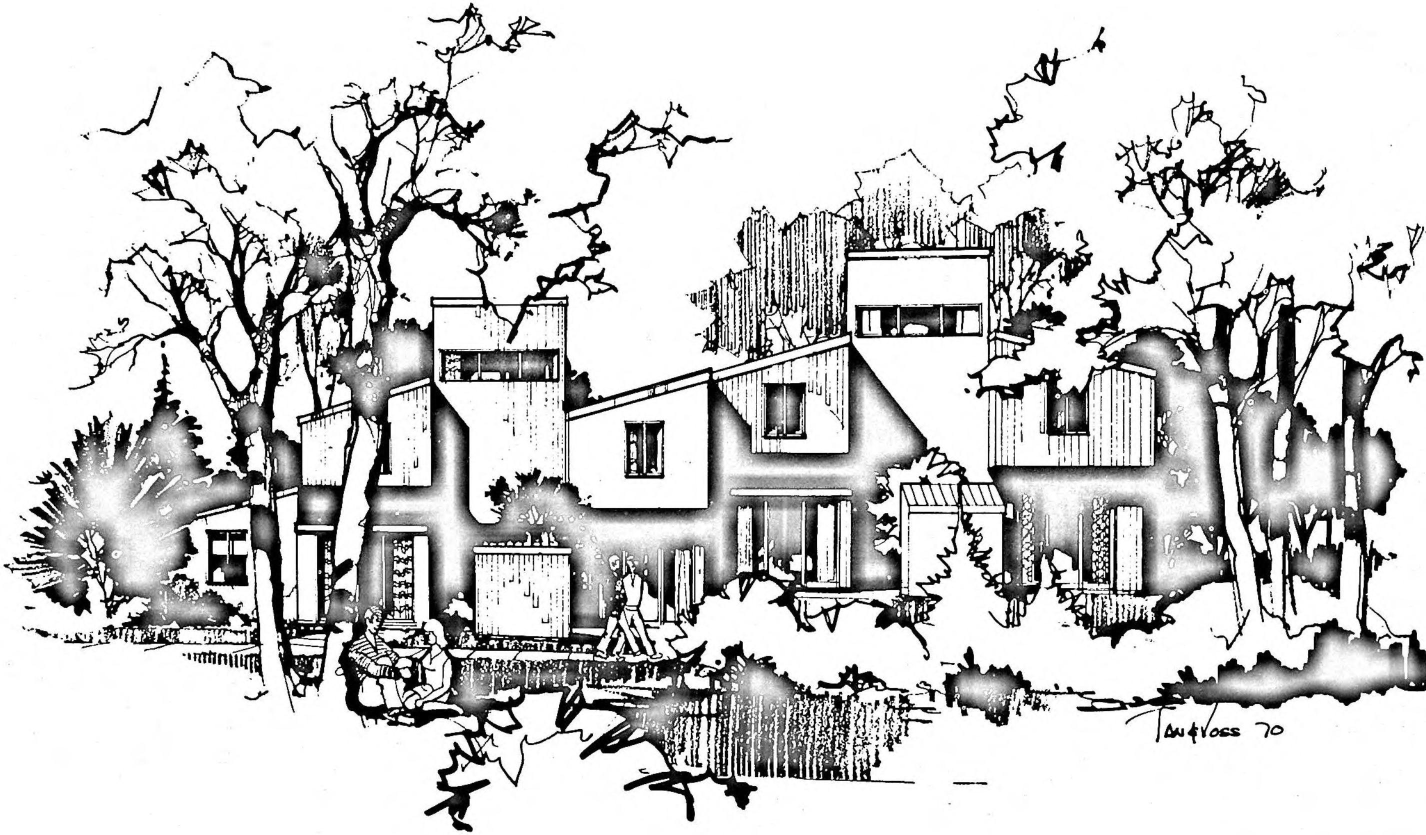
Marketing Manager
Industrialized Modular Housing
General Electric Company
Re-entry and Environmental Systems Division
3198 Chestnut Street
Philadelphia, Pennsylvania 19101

or call: (215) 823-3866.

General Electric Phase II units are located at two prototype sites:
Indianapolis – 48 SFA, 8 MFLR
Memphis – 48 MFLR

Summary Information

SYSTEM APPLICABILITY	
Location	Urban, suburban, rural, and military family.
Density Range	Per local code for townhouses (2 stories); and garden apartments (up to 2 stories).
Environmental Adaptability	All climatic, topographical and normal soil conditions.
Non-Residential Functions	Social, recreational facility.
Site Planning Services	GE will assist builder/developer's architect as appropriate.
BUILDING SYSTEM DESCRIPTION	
Housing Types	Multi-family low rise (apartments) and single family attached (townhouses).
Unit Variations	One to four bedrooms.
Structure	Modules utilizing steel studs and plywood stress-skin panels.
Exterior Elements	A wide variety of finishes and exterior treatments available.
Foundations	Conventional basement or crawl space.
Comfort System	Gas or electric-forced air.
Plumbing	CPVC plastic integrated with module building system.
Electrical	Conventional, integrated with module building system.
Furnishing	Includes closets and storage space. Appliances by GE.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Structural steel studs, cast-plaster walls, central utilities chase.
Codes	Adaptable to all local and national model codes.
Deviations from Original O/B Proposal	Paper honeycomb sandwich panel floor system deleted.
PRODUCTION PROGRAM	
Delivery Rate	Depends upon location and conditions.
Off-site Production	Essentially all work done in off-site factory.
On-site Installation	Erection of modules on foundations, connecting modules and weather proofing.
On-site Construction	Foundations preparation, utility connections.
Internal Functions	GE provides site supervision skills to assist builder/developer.
LABOR REQUIREMENTS/TRAINING PROGRAM	
ECONOMICS OF THE SYSTEM	
Construction Cost	Medium. Applicable to HUD Section 235/236 Program.
Transportation Limitation	Approximately 400 miles from plant.
Useful life	Major system 40 (plus) years. Furnishings according to usage and maintenance.
MARKETING FOR PHASE III	Northeastern United States.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Hercules, Inc.

INTRODUCTION AND APPLICATION

The Hercoform Modular System consists of completely assembled, factory-fabricated, wood-framed, volumetric modules transported to the construction site and joined together to form dwelling units on prebuilt foundations. The living units range in size from one to four bedrooms. The dwellings vary in architectural appearance and present both contemporary and traditional styles. The building system is flexible and is adaptable to town-houses and garden apartments.

Hercules, Incorporated, the parent company, is one of the nation's ten largest chemical firms. With head-quarters in Wilmington, Delaware, Hercules has 41 major manufacturing plants in the United States alone. It employs more than 25,000 people in 18 countries around the world. It supplies more than a thousand different products to plastics, paper, textiles, protective coatings, agriculture, rubber, food, building materials and several other industries. In general, these products include pesticides, fertilizers, synthetic fibers for carpet-ing and upholstery, explosives, food additives, resins, and others. For the building materials industry, Hercules has long been a principal supplier of basic materials ranging from paint ingredients to plastics to lightweight aggregate concrete.

Recent diversification moves have carried Hercules into the fields of modular homes, magnetic technology, intensive lighting, solid and liquid waste disposal, and recycling among other new areas of endeavor.

The Phase I or prototype design stage was completed under the direction of the Industrial Systems Depart-ment of Hercules Incorporated located in Salt Lake City, Utah. The design was accomplished by Hercoform Marketing, Inc., a wholly owned subsidiary of Hercules Incorporated, established for land development and marketing modular housing, and Armstrong and Salomonsky, Architects, Richmond, Virginia. Hercoform Marketing, Inc. was the firm to which the Phase II prototype development contract was awarded.

Hercoform is presently supplying modular homes for several commercial developments (including luxury resort condominiums) and for HUD's Operation BREAKTHROUGH. Under the BREAKTHROUGH Pro-gram, Hercoform has designed and erected 50 units at Macon, Georgia and 51 units at Kalamazoo, Michigan. These include contemporary townhouse apartments, traditional townhouse apartments, and garden apart-ments at each of the two sites. The dwellings are grouped in clusters in accordance with the concepts of open space planning and planned unit development. This results in an atmosphere of pleasant residential living in comfortable, well-planned surroundings.

The Hercoform concept for modular housing can be adapted to a wide range of dwelling densities with few restrictions. In general, the system is applicable for urban and suburban usage. Densities at Macon and Kalamazoo are from 11 to 13 dwelling units per acre. According to national standards the optimum dwelling density for quality living should be about 10 to 15 units per acre for single family attached and multi-family low rise mixes. Hercules is well within this limit.

The Hercoform modular unit has a high degree of flexibility with possibilities for a great variety of architectural styles. It permits almost as much diversity as custom designed conventional construction. Size and configuration of the module make it convenient for use on flat land or steep slopes. Modules may be stacked horizontally, vertically, or stood on end to form a tower. This feature not only gives many interesting approaches to project development through the elimination of stereotyped developments, but may decrease the need for land sculpturing. This, of course, not only preserves natural beauty, but can help reduce overall project cost.

SYSTEM DESCRIPTION

The module is of conventional wood frame construction designed for mass production. Mass production of the modules, coupled with exact planning and scheduling, provides a precision impossible with conventional hous-ing. This has enabled Hercoform to achieve significant time savings.

Design of the individual modules facilitates transporting and handling in the factory, over the highway, and at the dwelling site. The size and general shape were deter-mined by: (1) laws relating to highway movement of large loads, (2) clearances of highway structures and utilities, (3) the required living space to provide for furniture arrangements, circulation, storage, etc., (4) module arrangement to form living complexes, and (5) erection considerations.

The basic module is 12 feet wide, can be up to 11 feet high (not including the transportation dolly), and can be up to 65 feet long in most states. Structural members are spaced and configured conventionally to provide stability. Additional bracing is provided to withstand fabrication, transportation, and erection loads which the conventionally constructed dwelling is not required to meet. Exterior sheathing, roofing, insulation, partitions, windows (including glazing), floor coverings, interior and exterior doors, wiring, plumbing, furnaces, air conditioning, ductwork, kitchen appliances, cabinetry, bathroom fixtures and lighting fixtures, are completely factory installed. Floors, walls, and roofs are constructed of standard materials and insulated as required. Units are heated by either gas or electricity. Utilities are brought to common connecting points to facilitate the joining of modules. Typically, about 12 days are required to build a cluster of five complete living units of Hercoform's modular homes in the plant, ship them to the home site and make them ready for occupancy.

The Hercoform designs meet national codes and require minimal waivers to local building code requirements.

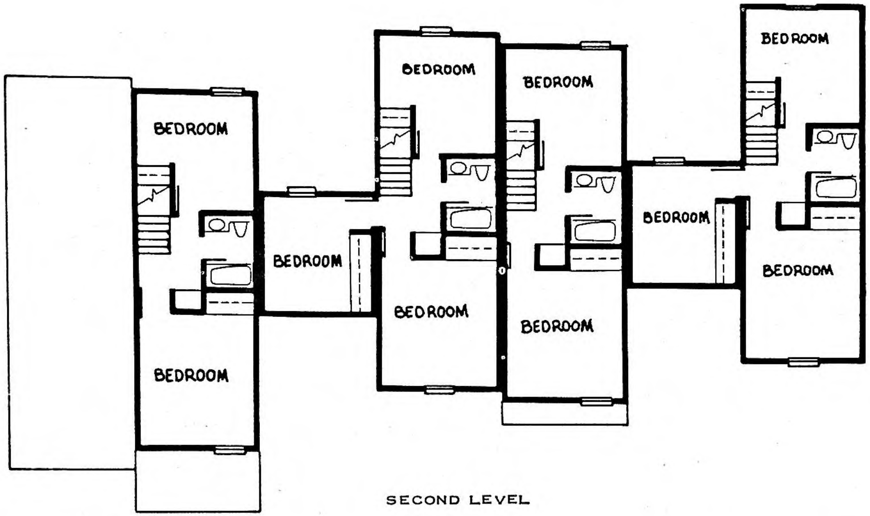
DESIGN OPTIONS

The Hercoform housing system includes two basic types of dwellings: (1) single family attached (SFA) and (2) multi-family low rise (MFLR). The SFA units are offered in contemporary or traditional styling. The MFLR units or "garden apartments" are of contemporary architecture.

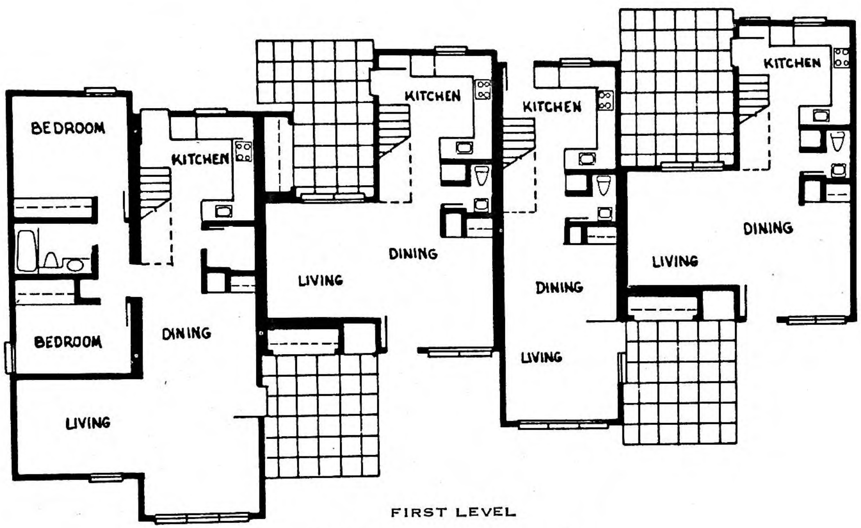
Both the SFA traditional (Figures A, B, and C) and contemporary (Figures D, E, and F) dwellings are two stories. There are three modules per unit in three- and four-bedroom dwellings, two modules per unit in two-bedroom dwellings. The size of the dwelling units varies from 828 to 1,320 square feet. A typical cluster with a mix of one four-bedroom, two three-bedroom, and one two-bedroom dwellings consists of eleven factory-built modules. A one-bedroom dwelling consists of one module, 12 feet wide by 46 feet long which occupies 552 square feet.

A. Traditional Townhouses

B. Traditional Townhouses—Macon, Georgia

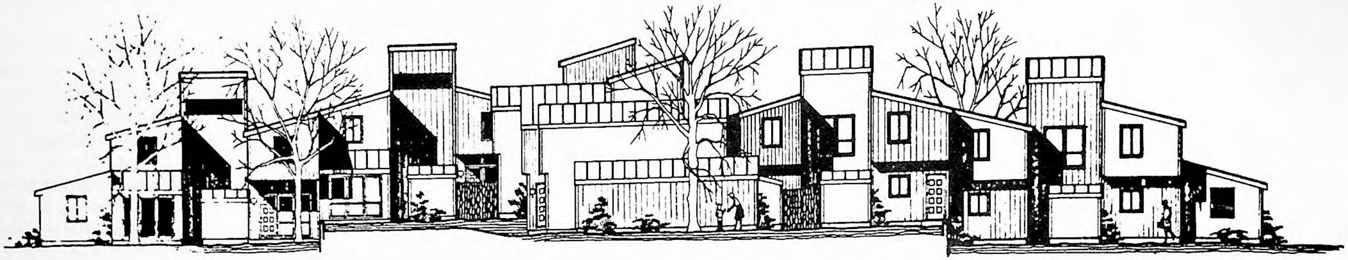


SECOND LEVEL

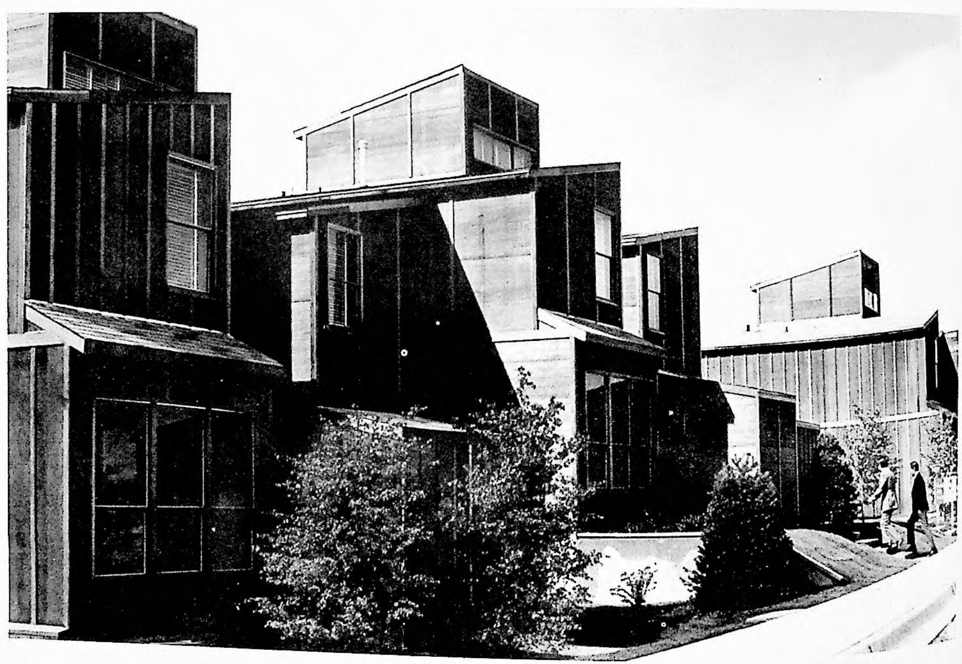


FIRST LEVEL

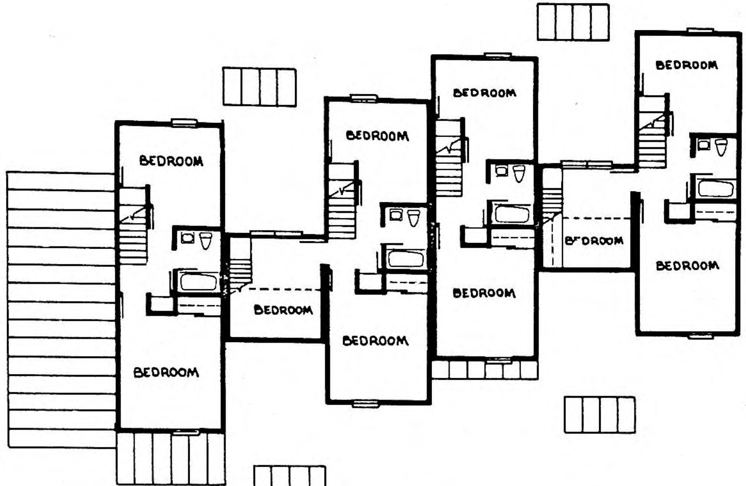
C. Traditional Townhouse floor plans



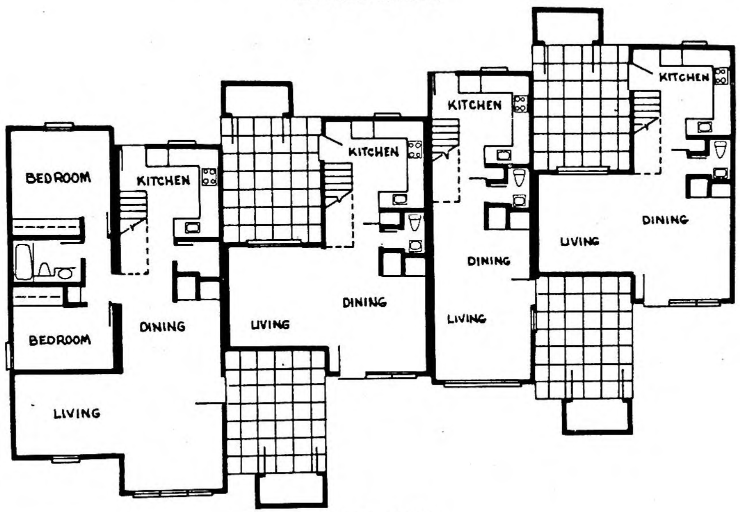
D. Contemporary Townhouses



E. Contemporary Townhouses—Kalamazoo, Michigan



SECOND LEVEL

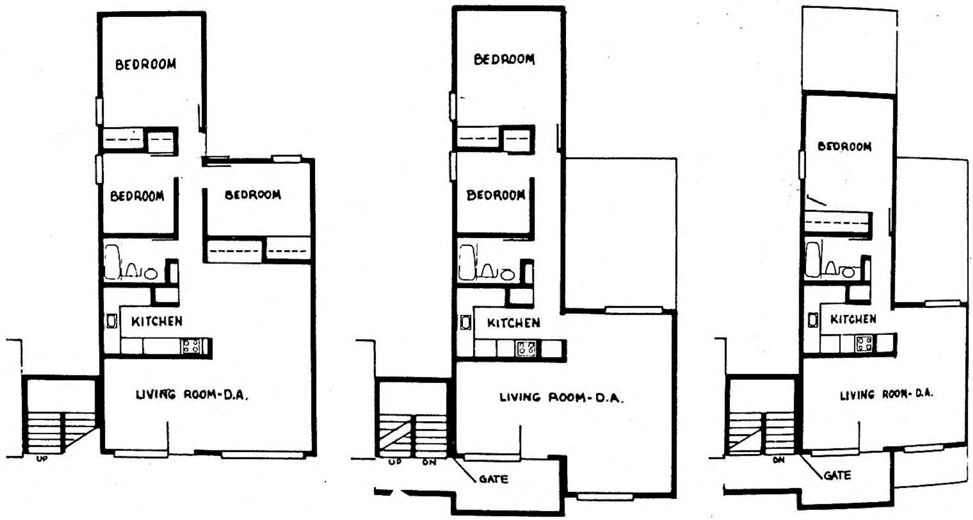


FIRST LEVEL

F. Contemporary Townhouse floor plans

The MFLR dwelling (see Figure G) is designed for three living units per building. Six factory-built modules are required per building. The building is three floors high with no living units occupying more than one floor. Each building contains one one-bedroom, one two-bedroom, and one three-bedroom living unit ranging from 732 to 960 square feet of living space. These buildings may be joined to form architecturally pleasing clusters.

The Hercules design satisfies customer preference for conventional construction appearance and materials and yet provides them in a finished dwelling constructed of modules. Eye-catching architecture coupled with the warmth of wood exteriors or other custom finishes has an immediate appeal to potential buyers. The flat roof characterizing many modular construction is almost completely absent in the Hercules designs. Various roof pitches are utilized and the direction of the roof slope is varied to suit the conditions of each individual site. The conventional interior finishes are those that have been developed over the years to provide a gracious living atmosphere with minimum maintenance. Construction features and amenities include conventional 2" x 4" studs, gypsum wall board and decorative paneling. Floors are attractively tiled and carpeted. The units are easily cleaned and can be redecorated—qualities preferred by housewives everywhere. The use of open riser stairs and sloped ceilings gives an open feeling in spite of the 12 foot exterior width (dictated by transportation limitations) of individual modules. The single family attached, contemporary styled, three-bedroom unit features a multi-purpose loft in the upper portion of the tower module. This area is accessible by conventional stairs and may be utilized as a den, sewing room, spare guest bedroom or play room.



G. Multi-family low rise designs

PRODUCTION

The Hercoform factory, located at Bloomsburg, Pennsylvania (see Figure H), is one of the first ever designed specifically for industrialized modular housing production. This plant will serve New England, Middle Atlantic, and nearby Midwest marketing areas. The plant manufacturing area is 77,200 square feet. The current production rate of approximately 4,000 square feet of dwelling units per day can be increased by making moderate changes to the plant.

Hercoform is experiencing the following advantages of modular construction: (1) materials are handled more efficiently—modern machinery makes simple acts of sawing and nailing a precision process; (2) work can continue in the plant all year long, virtually immune to bad weather; (3) problems of delivery of materials to isolated construction sites are minimized; and (4) erratic availability of skilled labor at construction sites is unimportant.

The modules are built on a movable conveyor traveling through 16 work stations at a rate of less than 2 hours per station. More than one-half of the plant floor space is used for material storage and subassembly work.

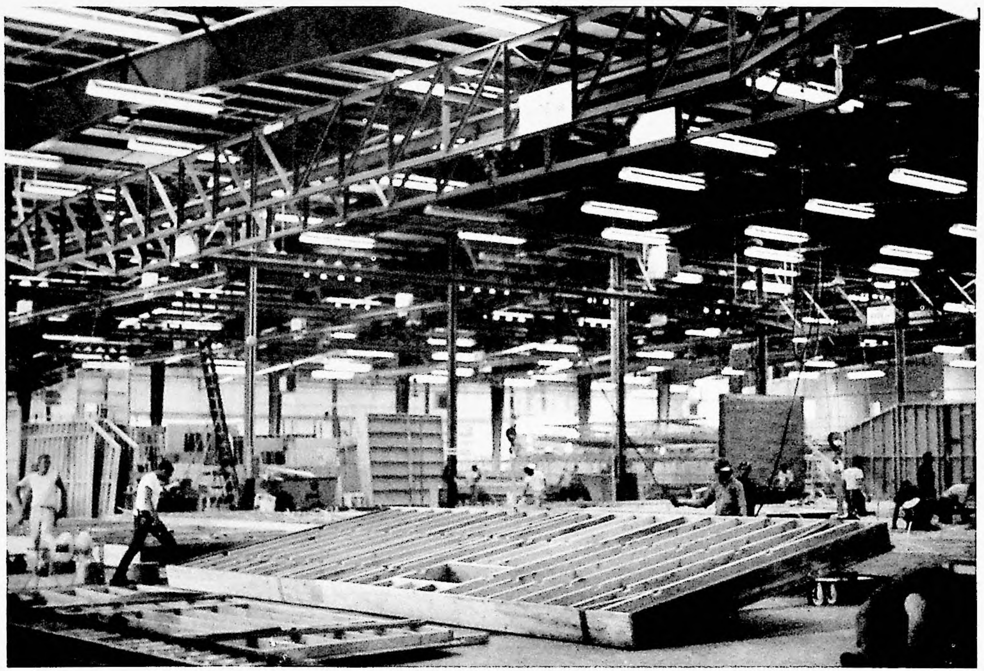
To achieve high standards of quality control, inspection is carried on continuously during the production process.

Shipments are scheduled in coordination with the erection sequence.

TRANSPORTATION

The completed modules are transported from the Bloomsburg, Pennsylvania plant on specially designed telescoping modular transporters. These are moved to the site by a common carrier specializing in moving modular units.

The module is prepared for shipment at the final production station. This preparation includes wrapping the module with tarps, installing weather-proofing over floor insulation, and mounting temporary clearance lights. The prepared module is then moved out of the production area by means of a straddle-type carrier to the module storage and loading area. The straddle carrier places the module on the transporter. At their destination, the modules are stored in a staging area near the construction site.



H. Bloomsburg, Pennsylvania factory

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SITE WORK

Site preparation for module erection is under the direction and responsibility of a Hercoform Site Superintendent. Subcontracted work for this effort includes clearing and grading, foundation construction, parking lot and road construction, module erection, and utilities hookup. Utilities are generally placed underground. Local contractors are used.

Erection in the field (see Figure I) involves placing the modules by power crane or cranes in the proper architectural configuration on conventionally-constructed foundations. Tower modules, though fabricated and transported in a horizontal plane, are erected in a vertical plane thereby creating a pleasing contrast appearance and accommodating desirable functional features (Figure J). Approximately ten modules can be erected per day. The modules are aligned horizontally and vertically, and are joined to make complete units. Units are then attached to each other to properly secure them for wind loading, snow loading, and to meet other code requirements. After the attachments are made, exterior trim, roof flashing, and caulking are installed to conceal the joints where one module is fastened to another. Electrical connections between modules and to site power and on-site electrical inspection are then made. Plumbing connections between modules and to laterals are made concurrently, along with the necessary testing and inspection. The module erection process is completed with touch-up painting if required. Since the modules arrive at the site completely finished and equipped, including appliances and utilities, the on-site time for erection and finishing is kept to a minimum.

FURNISHINGS

The Hercoform houses designed and furnished for Operation BREAKTHROUGH include stoves, refrigerators, central air conditioning, and carpeting—all factory installed. Dishwashers and garbage disposal units are included in the Kalamazoo houses. Typical interior view is shown in Figure K.

INNOVATIVE FEATURES OF SYSTEM

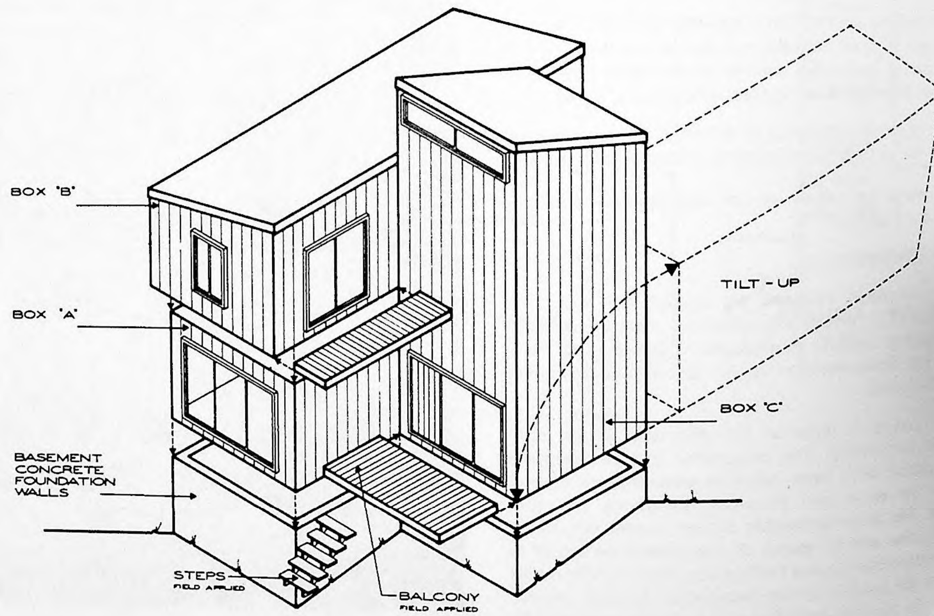
The principal innovative features of the Hercoform system are these:

(1) All townhouses have patios designed for maximum privacy. Patios are separated by a distance of 24 feet, and are also physically separated by the building structure itself. This provides each occupant with a private outside location to relax, even in a townhouse atmosphere.

(2) Housing units are appropriate for hillside locations as well as flat ground. The nature of the system and size of modular units requires a minimum of land sculpturing.

(3) Housing units depart from the conventional "boxy" appearance associated with many modular home designs. This is done without the sacrifice of their functional characteristics.

I. Field erection of tower module



J. Module placement sequence

BUILDING CODES

The design has been based upon general conformance to both national and local building codes. The Hercules Operation BREAKTHROUGH concepts require minimal waivers to local building codes, although economies can be gained by relaxation of some of the more restrictive code provisions. The design can be readily changed to meet all codes whereas other concepts may require extensive code revision with attendant delays and increased costs.

MARKETING

From its manufacturing plant in Bloomsburg, Pennsylvania, Hercoform supplies New England, the Middle Atlantic states, and the near Midwest with quality-built modular homes that range from FHA-sponsored apartments to luxury resort condominums.

For further marketing information write to:

Hercoform Marketing, Inc.
910 Market Street
Wilmington, Delaware 19899

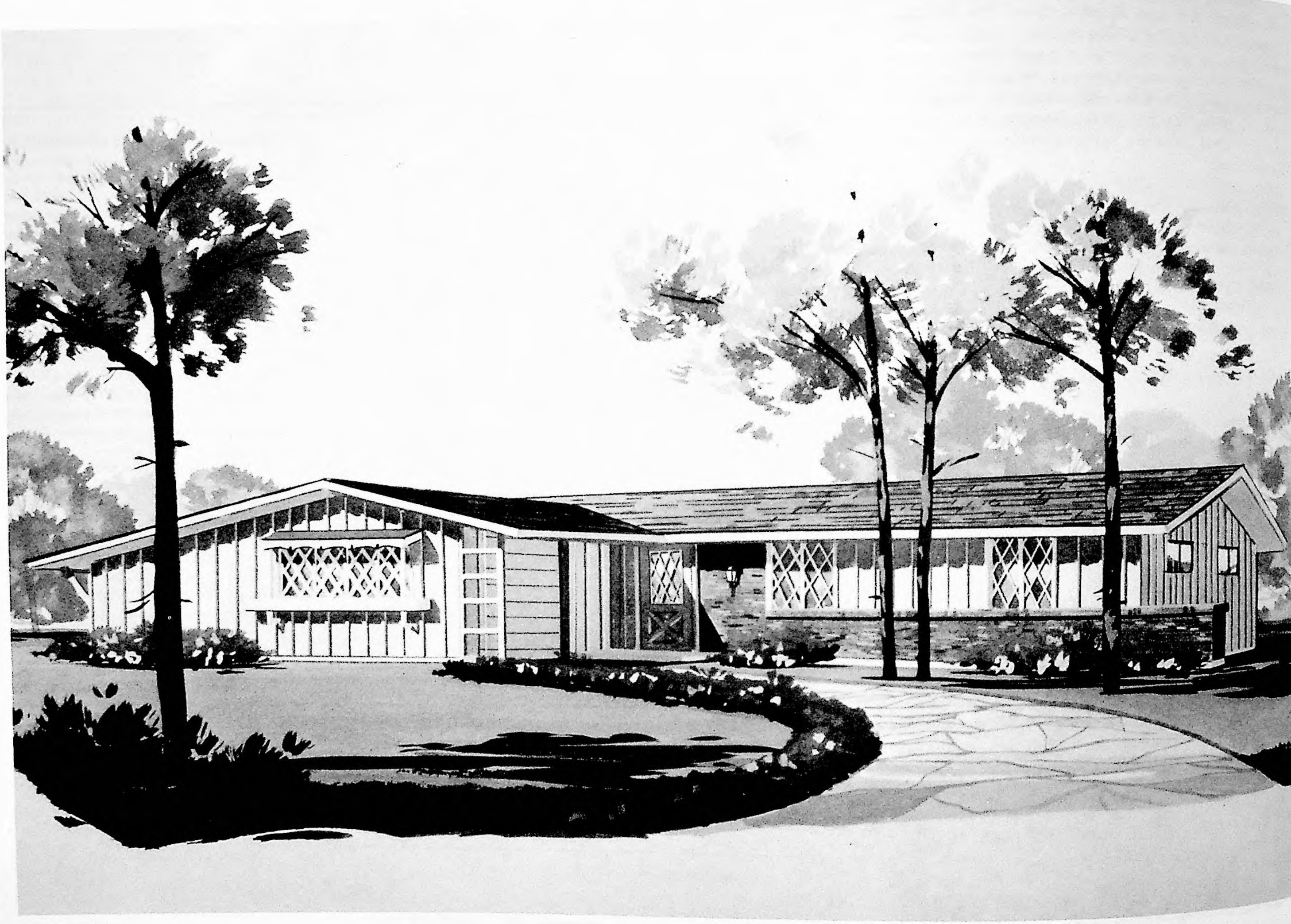
or call Mr. Edward F. Lacy, III, at (320) 652-3427.

K. Living room interior

Summary Information

SYSTEM APPLICABILITY	
Location	Urban; suburban planned unit development.
Density Range	5-15 dwelling units/acre.
Environmental Adaptability	Adaptable to all climatic, topographical and normal soil conditions.
Non-Residential Functions	Recreational or social facility.
Site Planning Services	Normally subcontracted.
BUILDING SYSTEM DESCRIPTION	
Housing Types	Single family attached and multi-family low rise.
Unit Variations	1-4 bedrooms.
Structure	Self-supporting wood frame modules.
Exterior Elements	Plywood and wood siding.
Foundations	Conventional—design to fit conditions.
Comfort System	Conventional—gas or electric forced air or radiant heating; optional integrated cooling.
Plumbing	Conventional—integrated with building system.
Electrical	Conventional—integrated with building system.
Furnishing	Stove, refrigeration, central air conditioning, carpets, other items optional.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Modular design and arrangement, patio layout.
Codes	Adaptable to all national model codes and local codes.
Deviations from Original O/B Proposal	MFLR and SFA selected by HUD; MFHR deleted.
PRODUCTION PROGRAM	
Delivery Rate	4,000 sq. ft. of dwelling space/day.
Off-site Production	Essentially all done in factory.
On-site Installation	Connect modules and utility services. Apply exterior trim.
On-site Construction	Foundations; placing of modules; utility hookups.
Internal Functions	Design; production; assembly.
External Functions	Land planning, financing.
LABOR REQUIREMENTS/TRAINING PROGRAM	Skilled and semi-skilled for factory and site.
ECONOMICS OF SYSTEM	
Construction Cost	Low, moderate and luxury—depending upon location and amenities.
Transportation Limitation	Approximately 500 miles from plant.
Useful Life	Building and utilities 40 years; furnishings depending upon usage and maintenance.
MARKETING FOR PHASE III	Present plant serves New England, Middle Atlantic states and near Midwest. Units range from FHA-sponsored apartments to luxury resort condominiums.

Hercoform Phase II units are located at two prototype sites:
Kalamazoo – 39 SFA, 12 MFLR
Macon – 38 SFA, 12 MFLR



Home Building Corporation

INTRODUCTION AND APPLICATION

The Home Building Corporation housing system consists of factory built, pre-roofed, pre-plumbed and wired, wood frame, self-supporting modules which are delivered by trailer directly to the home site, where they are erected on the foundation.

Residential units are available in single family one-story units to be placed on full basement, crawl space or split level foundations, or two-story townhouses or apartments on such foundations.

Density range is four to eight units per acre for single family detached units, and 10 to 20 units per acre for two-story townhouses. The system is adaptable to all national climates and all normal topography and soil conditions. Location is intended for urban, suburban and rural areas.

While the system is primarily a residential one, it is adaptable for use such as offices, clubhouses, churches and other small buildings.

SYSTEM DESCRIPTION

The HBC residences consist of one to four bedrooms. The modules (Figure A) are 12 ft. wide and are complete including heating, central air conditioning, plumbing, finishing, carpeting and appliances. The principal component in the module system is a 4 ft. by room height panel which is the basic building block. This standard dimension can be modified to a degree. For example, one panel may be designed to serve as a completely closed interior wall section, but for exterior use can be extended to include a 45 inch by 76 inch thermal pane window section. The components can also accommodate expansion of living units from a minimum of 16 ft. to more than 60 ft.

Exterior wall panels are a "sandwich type" designed to provide thermal control in any climate. Outer surfaces are usually plywood with a paintable plastic sealer for application at the factory or on site. A variety of surfacing is also available, ranging from aluminum covered plywood to brick and stone. The system makes extensive use of gluing to eliminate "nail-popping" and similar problems. The inside of the exterior surface has glued-on fiberglass insulation batts, then an air space, and finally a foil-backed gypsum board (also glued to the studs) (see Figure E).

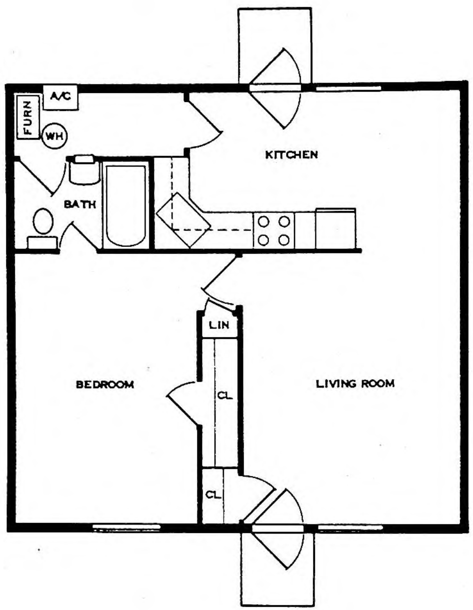
Roof panels are constructed similarly, with foil-backed gypsum board glued to 2" x 4" joists backed by fiberglass batts, and exterior plywood covering. Two layers of felt and asphalt shingles complete the roof. The roof panels are carried on 4" x 8" exposed beams which form both part of the interior decor and the structural system. The paintable interior face of the roof panels serve as the ceiling surface as well (see Figure F).

The stressed-skin floor sections are created by gluing tongue-and-groove plywood to 2" x 6" joists 16" on center, thus forming a T-beam that has greater strength characteristics than traditional 8" joists and eliminates floor squeaking as well. The whole floor section is built around an 8" junior I beam which rests on sitecast foundation piers; the other three sides of the floor panel rest on previously poured concrete foundations and steel beams. The system also can be used on wood or concrete pile foundations, depending on the overall design of the home (see Figure G).

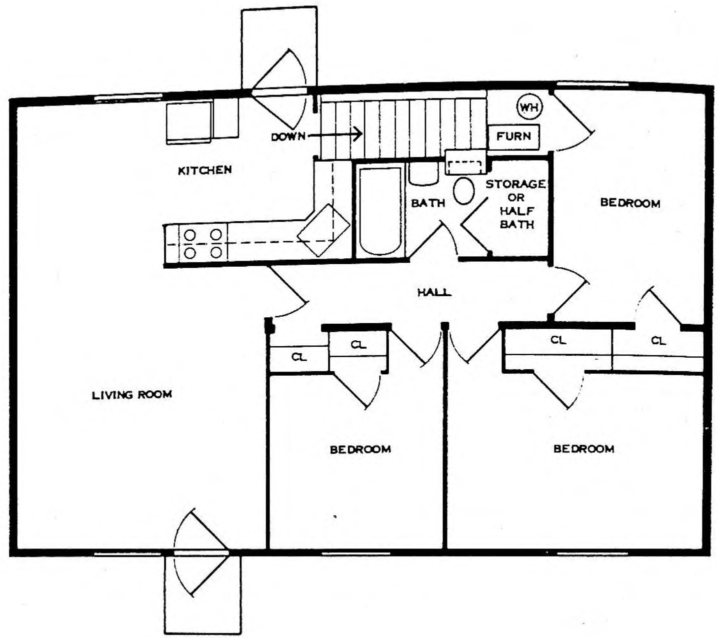
The posts of the structural system are included within the two longitudinal exterior walls and the two walls that form the interior hallway. The perimeter panel studs serve as bearing points, and the interior area of the panel supports no more than its own weight. Thus the interior can be modified without weakening the load-bearing structure.

Factory construction includes addition of necessary utility components (electrical and plumbing fixtures and wiring), which are fully tested before installation. At the site, erection crews first apply a 1" x 3" strip of fiberglass insulation to the perimeter of the floor structure to improve the air seal between the foundation and living areas. The complete modules are then set in place, to be secured to concrete foundations by steel bands embedded in the concrete at 6" centers and nailed to the floor. When a steel grade-beam foundation is used, the beam is bolted to a concrete pier.

Some advantages of the system are: (1) acoustical control, achieved through use of floor covering, and a design for two-story structures which does not permit joists and beams to touch and thus transfer sound; (2)



A. Single Family Detached One-Bedroom Unit



B. Single Family Detached Three-Bedroom Unit

the insulation and air space included in each sandwich panel; and (3) double party walls (used in townhouses and apartment variations) are surfaced with two layers of gypsum board which contain additional insulation. This results in a 2 hour fire rating and a 52 decibel sound rating.

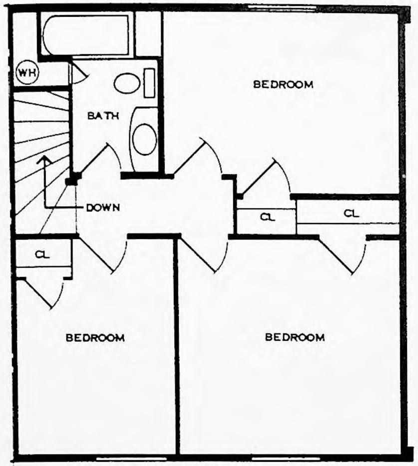
Heating may be by natural or bottled gas or electricity using a forced air system which enables use of the air conditioner in conjunction with the heating. The compressor is installed within the unit.

All plumbing is installed and tested in the factory. Field installation consists of connections to a ground drain and a water supply. In case of the two-story units, connections include heating and air conditioning, vents and water in the utility closet.

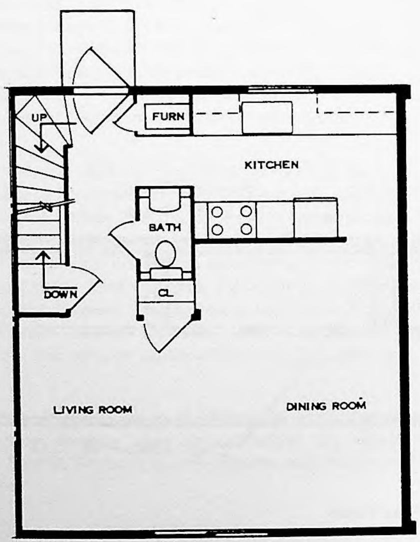
The electrical system is also factory installed. Field installation consists of connections from one module to another in the junction boxes of two-story houses, and to one box in the one-story houses.

DEPARTURES FROM CONVENTIONAL SYSTEMS

The primary innovative concept for the HBC housing system is the factory complete module that requires a minimum of skilled labor on the construction site. Other innovative concepts include: (1) supplemental glued bonded surfaces, and (2) use of a beam system instead of ordinary rafters for "cathedral ceilings" in the single family detached houses and in the second floor of two-story houses.



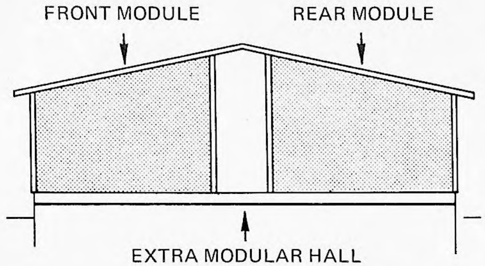
Second Floor



First Floor

C. Three-Bedroom Townhouse

The HBC system is adaptable to all national model codes.



D. Module Arrangement

Some prototype units feature a 3-foot wide extra modular hall which was assembled from pre-cut and pre-finished components delivered to the site with the modules. This will be eliminated from production versions for economic reasons.

OPTIONS

There are a variety of designs available in this modular housing system. Each design can be varied by such options as: (1) garages, (2) carports, (3) porches, and (4) some projections which are panelized for addition to basic modules. External walls are prepared for brick veneer or other cosmetic treatment. In addition, windows of various sizes with varied grid treatment of the glass are available. Standard finish for interior walls is "dry wall treatment," however, any readily available material is acceptable.

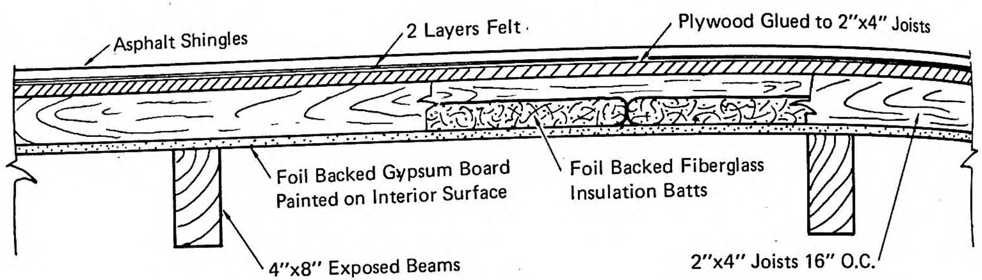
PRODUCTION PROGRAM

HBC is now producing 500 units per year in the Sedalia, Missouri plant. Current plans provide for utilizing a second shift, which will raise production to 750 units per year. These units are expected to be sold and installed within a two hundred mile radius of the Sedalia, Missouri plant. Two new factories are operating in Colorado and Pennsylvania. Plans call for production rates of 1,000 units per year from each factory.

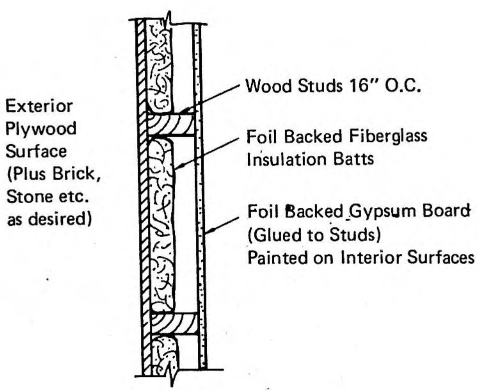
E. St. Louis prototype units feature extra modular hall.

Off-site production consists of the entire superstructure above the foundation. On-site construction consists of foundations, assembly of modules and utility connections. It takes one-half hour to set each module on its foundation. It takes one-half hour to connect the plumbing and electrical work and about twenty man-hours for the rest of the carpentry. The amount of touchup and cleanup depends on how much field work is done before the house arrives. The schedule for delivery is set on the basis that all site work except landscaping is finished before the arrival of the modules.

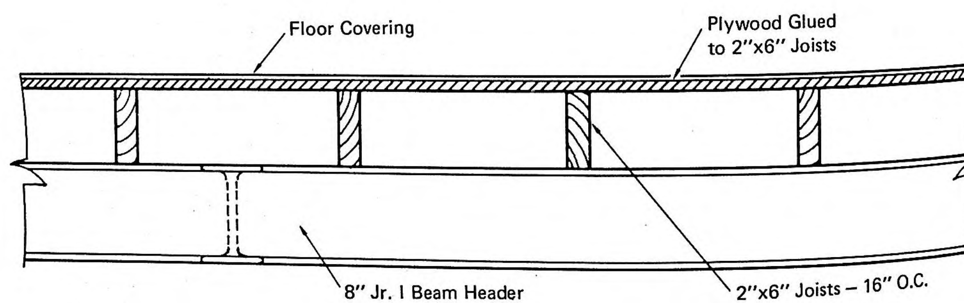
Factory labor is essentially semi-skilled. HBC has an inplant training program which lasts for three months. Skill requirements have been identified and trainees are selected and trained to perform specific tasks in the production programs. On-site labor can be performed by semi-skilled personnel. Experience to date, however, has been that local trade unions will not permit construction to be accomplished unless skilled craftsmen are hired. As a result, total cost savings for the HBC housing system have not been realized.



G. Section through Roof Panel



F. Section through Wall Panel



H. Section through Floor Panel

ECONOMICS OF SYSTEM

Construction costs for the HBC system are averaging approximately $10.50 per square foot, and field costs approximately $3.50 per square foot through the first half of 1972. Transportation costs are $1.50 per mile per housing unit. At a 200 mile delivery area from the plant, this is satisfactory. Studies have indicated that deliveries beyond 200 miles from the factory would make the package non-competitive with conventionally constructed housing.

The useful life for the HBC housing system is estimated to be 40 years assuming normal maintenance activities. No special maintenance is required on HBC housing units.

MARKETING FOR PHASE III

Sale and transportation of housing is limited to approximately 200 miles from the factory. In addition to the existing factory in Sedalia, Missouri, HBC has established factories in Colorado and Pennsylvania. Funding has been established for full production at all three factories through July 1973. This will provide an annual production rate of approximately 3,000 housing units.

An integral part of the HBC marketing program is continued research to locate areas of possible cost reduction. While the current HBC housing costs are competitive or lower than conventional housing, it is felt that full production (1,000 units per year per plant) will reduce costs. This will give a distinct marketing advantage over conventional builders. Additional cost reductions that may be identified and incorporated in the system will serve to increase the marketing advantage.

Further information on the Home Building Corporation Housing System may be obtained by contacting Mr. Neal O. Reyburn at the address and phone number below:

Home Building Corporation
303 N. Park Street
Sedalia, Missouri 65301
Phone: (816) 826-4550

Summary Information

SYSTEM APPLICABILITY	
Location	Urban, suburban and rural.
Density Range	Ten to twenty dwelling units per acre.
Environmental Adaptability	Adaptable to all national climates, normal topography and soils.
Non-Residential Functions	Offices, clubhouses, churches.
Site Planning Services	Local architect-planner in cooperation with proposer staff.
BUILDING SYSTEM DESCRIPTION	
Housing Types	Single family attached and detached; multi-family low-rise.
Unit Variations	One to four bedrooms.
Structure	Factory fabricated wood-frame self-supporting modules; roof panels.
Exterior Elements	Wood or composition plastic coated vertical siding.
Foundations	Conventional or designed for site.
Comfort System	Conventional heating, cooling optional, integrated with modules.
Plumbing	Conventional; plastic waste lines integrated with modules.
Electrical	Conventional, integral with modules, underground or overhead distribution.
Furnishing	At the developers or buyer's option.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Factory complete modules with stressed-skin floor panels and roof beam system.
Codes	Adaptable to all national model codes.
Deviations from Original O/B Proposal	No major changes for Phase II.
PRODUCTION PROGRAM	
Delivery Rate	1,000 units per factory per year (three factories).
Off-site Production	Volumetric modules, mechanical services.
On-site Installation	Assembly of volumetric modules; connections.
On-site Construction	Foundations; utility services.
Internal Functions	System design; production.
External Functions	Site preparation; foundations; utilities and connections.
LABOR REQUIREMENTS/TRAINING PROGRAM	Essentially semi-skilled labor; 3-month training program for identified skills.
ECONOMICS OF SYSTEM	
Construction Cost	Average $14.00 per sq. ft. (depending upon amenities).
Transportation Limitation	Within a 200 mile radius of factories.
Useful Life	Forty years.
MARKETING FOR PHASE III	Full production in three factories through 1973.

Home Building Corporation Phase II units are located at two prototype sites:
St. Louis – 75 SFA
Indianapolis – 45 SFD

Levitt Technology Corporation

INTRODUCTION AND APPLICATION

The modular wood-frame housing system provided by Levitt Technology Corporation is designed to retain the warmth and charm of the English mews houses. Levitt's unique method of constructing quality homes, under completely controlled plant conditions, will help meet the growing demand for housing. This housing system is intended for location at urban, suburban and rural sites with a density range of 8 to 27 dwelling units per acre and is adaptable to all normal topography, soil and climate conditions.

The system is adaptable to non-residential buildings such as swim and tennis clubs, recreation buildings, motels, libraries and schools.

SYSTEM DESCRIPTION

Housing Types and Unit Variations

The Levitt Technology system includes nine different townhouse and two garden apartment designs. Construction is based on a wood-frame module plan which is adaptable to both single family and high rise construction. These modules are shipped from factory to site and assembled on site into various housing unit variations. The housing units consist of one-, two-, three- and four-bedroom floor plans (Figures A through E) ranging in area from a 631 sq ft one-bedroom garden apartment to a 1,986 sq ft four-bedroom townhouse.

Eleven designs were grouped into five basic building configurations to identify housing options as follows:

Group I	Designs 1, 2, and 3—Low Cost Housing
Group II	Designs 4 and 5—Moderate Cost Housing
Group III	Designs 6 and 7—Moderate Cost Housing
Group IV	Designs 8 and 9—Higher Cost Housing
Group V	Designs 10 and 11—Garden Apartments

The structural quality and the living environment is the same for all housing units. The prices vary with the degree and type of amenities provided in excess of those required to meet the basic criteria for a comfortable and safe living environment.

Structural Design

The system was designed differently than a conventionally built structure. Inherent constraints of the modular system such as maximum transportation sizes and ease of assembly resulted in a stronger structure. This resulted from double wall systems and ceiling-floor sandwiches, as well as from designing each individual module to withstand transportation stresses.

Wood was selected as the basic material for fabrication of the Levitt Technology modular housing system because of its flexibility, proven performance, and the availability of automated woodworking machines.

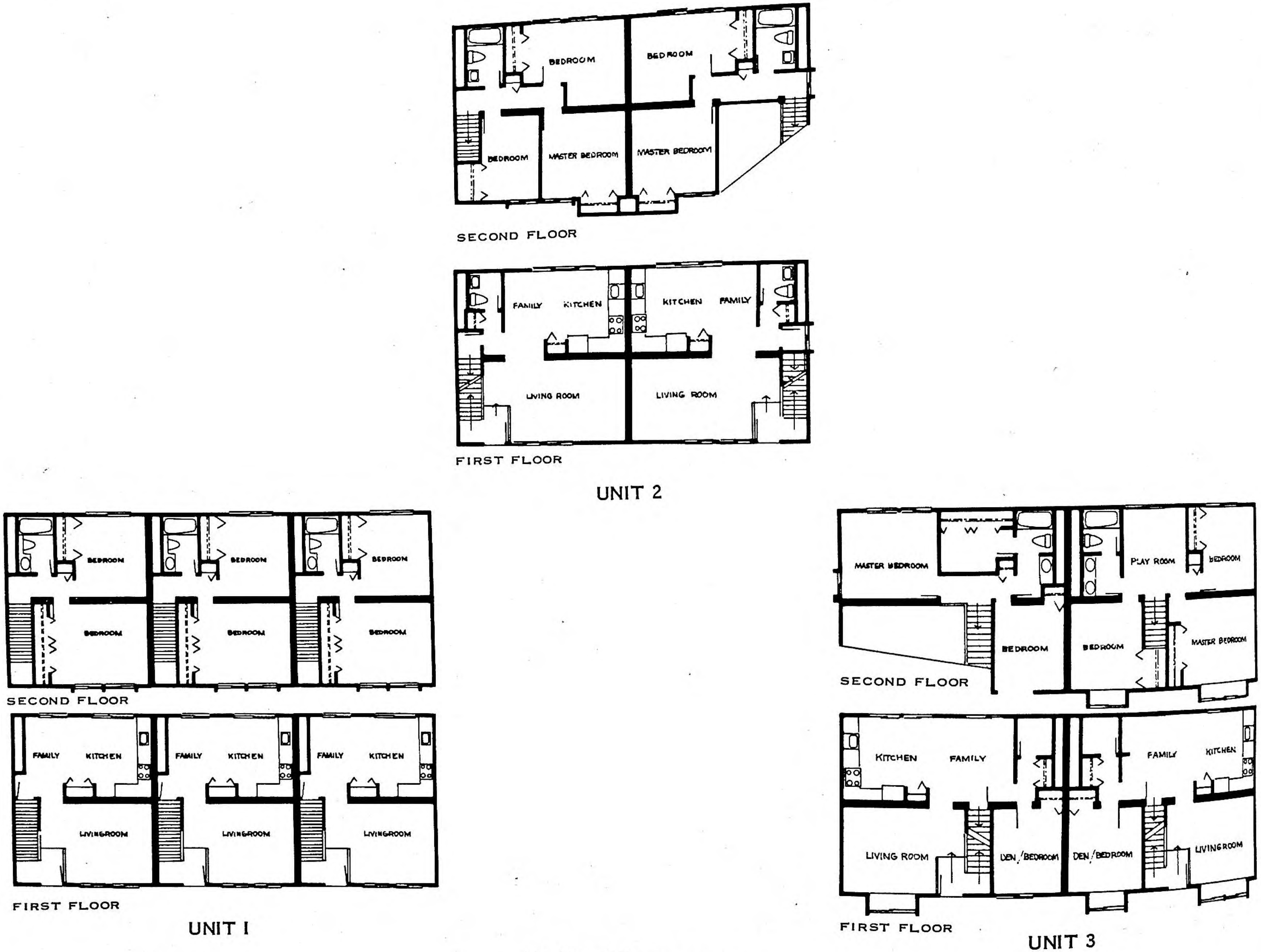
Elements of the module system are constructed as follows:

Floor Space—The floor system is based on conventional floor concepts. It is constructed of 2 x 8 wood joists 12 and 16 inches on center, framed into a perimeter beam or rim joist built up from a 2 x 10 and a 2 x 12. The deck of 5/8 inch plywood is glued and nailed with the grain running parallel to the joists. An analysis and test of this floor system proved that it was very rigid and met all appropriate standards.

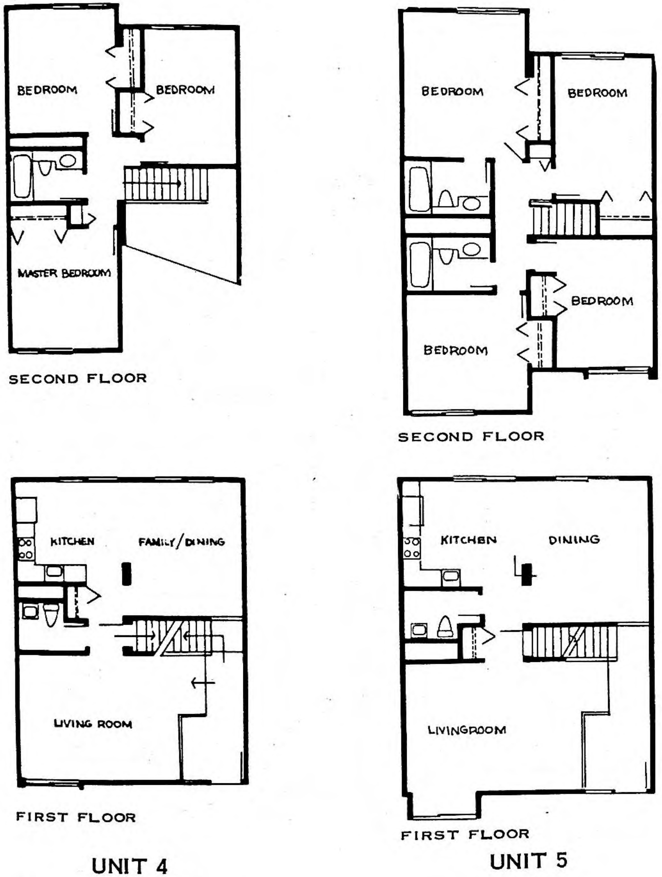
Wall System—The wall system transmits all vertical loads to the foundation. Walls are machine framed from 2 x 4's spaced 16 inches on center. They are braced laterally with 5/8 inch plywood siding on the exterior walls. At module interfaces, bracing is 1/2 inch on walls internal to the unit. The wood sheathing and the interior gypsum serve as shear diaphragms and transmit lateral loads from the floor diaphragm to the foundation below.

Ceiling System—The ceiling system is composed of 2 x 4's spaced 16 inches on center, covered with gypsum board that is nailed and glued.

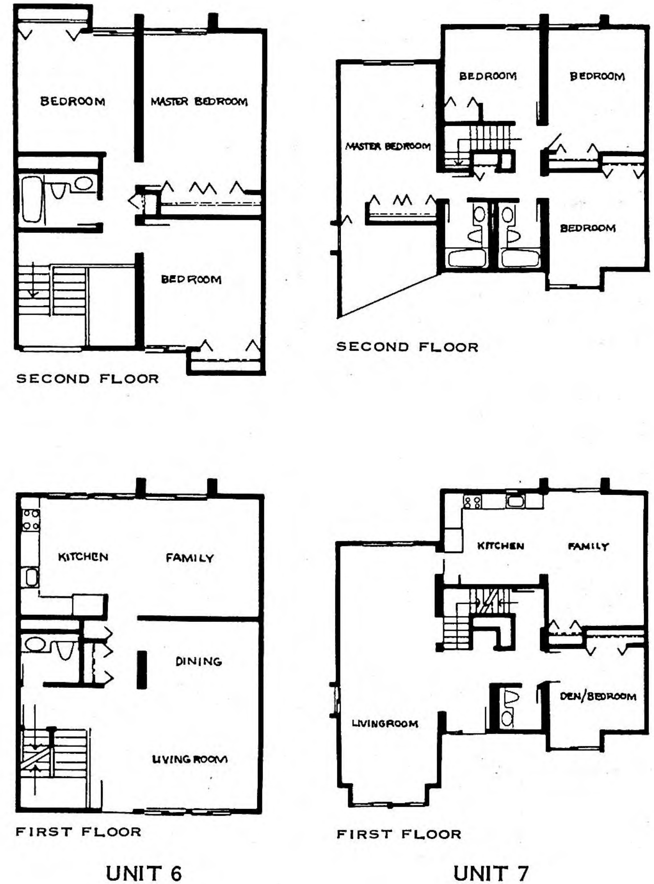
Roof System—The roof system for Groups II, III, IV, and V is flat. For Group I a pitched roof is employed. Both systems are framed with 2 x 6's, spaced 16 inches on center, and covered with 1/2 inch exterior plywood which is nailed and glued to the rafters. In Group V the ceiling panel lies flat while being transported. It is hinged up during erection and braced by means of 2 x 4 chords 16 inches on center.



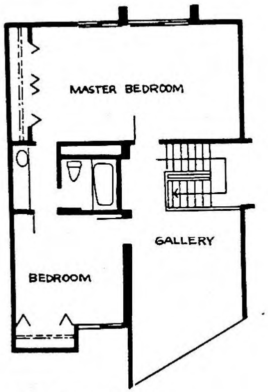
A. Group I Townhouse units



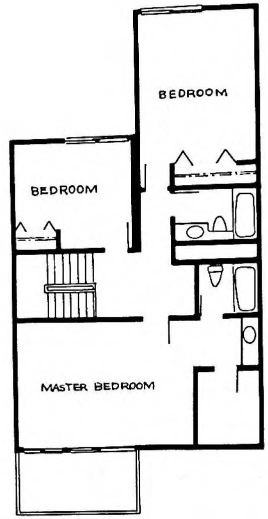
B. Group II Townhouse units



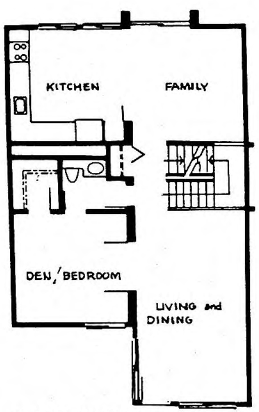
C. Group III Townhouse units



SECOND FLOOR

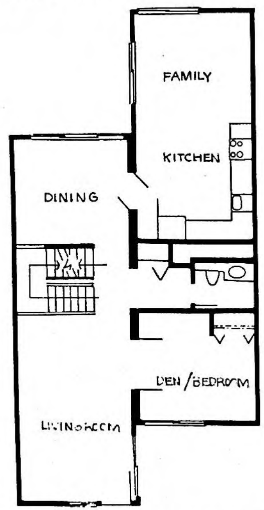


SECOND FLOOR



FIRST FLOOR

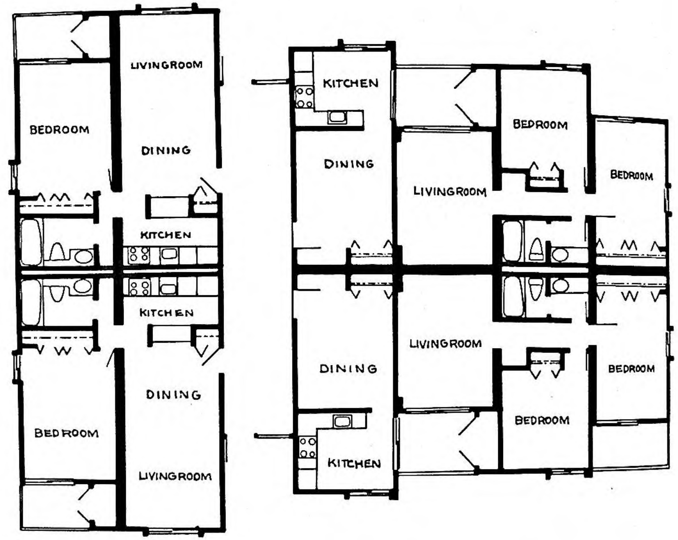
UNIT 8



FIRST FLOOR

UNIT 9

D. Group IV Townhouse units



UNIT 10 & 11

FIRST FLOOR ONLY

E. Group V Garden Apartment units

Living Unit as a Total Structural Entity

The basic structural system common to all units is independent of the foundation system. The top of the lower story module is shaped in such a way as to create a continuous registration that, during the erection of the upper module, eliminates the necessity of a guiding system. At the same time, it aligns the upper module automatically with the lower one.

The two lower modules comprising the same dwelling unit are positioned to form a "receiving cradle." Space is created in which a continuous 5/8" thick strip of plywood is nailed to both modules on 8" centers. This effectively secures the lateral position of the lower modules and enables the transmission of horizontal loads through the floor and ceiling diaphragms. The upper and lower modules are also joined by a continuous bond of glue which helps to make the four modules a rigid unit.

The vertical shear loads are transmitted to the foundation through the wall systems. The modules are connected to the foundation with metal connectors which transmit the shear load at end walls. Bracing at the foundation is either hot-rolled angles and lag screws or metal cross-bridging between the sill plate at the foundation wall and the floor diaphragm of the lower module.

Exterior Design Concepts

The exterior style is known as "California Contemporary." This has demonstrated marketability and lends itself to modular methods. Its architectural characteristic, emphasizing vertical and horizontal exterior finish lines, makes modular joints relatively undetectable. The use of rough-sawn lumber for exterior trim provides much of the needed architectural relief, as well as another means for covering the joints. The architects have used imagination well, providing some of the more effective and attractive designs in the BREAKTHROUGH program (Figures F and G).

A major innovation is the hinged-up roof. This adds contrast to the already striking horizontal lines of the design. The horizontal lines are further developed by the addition, on site, of some strategically placed porches. The total appearance is enhanced by the development of either push-out windows or push-out closets. These assemblies are stored within the module while in transit, and are set up at the site.

The use of modules does not necessarily mean a stereotyped architectural appearance. Some townhouse units present a lower silhouette by the use of a flat roof. This is accented by the introduction of long horizontal eyebrow roofs both at the front and rear.

Levitt modules are placed on the foundation of the unit front to rear instead of from side to side. This allows considerable architectural variety in the elevation by sliding one module out ahead of an adjacent module. It also enables upper modules to be larger than the lower modules, thus creating a cantilever effect in elevations. Both of these treatments give a greater depth to the unit by eliminating the harsh flat appearance. This depth creates shadows within the configuration of the building which radiate the feeling of a warm, pleasant environment.

The low-rise apartment building shows the flexibility of this architectural style. A sterile appearance has been avoided by the use of color contrast and depth definition.

F. Considerable architectural variety is offered by Levitt townhouses.

Interior Design Concepts

The interiors of the units have a definite relationship to the exterior design. Though the interior space is occasionally limited dimensionally by the modular system it provides a comfortable, pleasant living environment (Figures H and I). This feeling is especially obvious in the kitchen-family room where one area flows into the other without definition. The use of "studio" or "volume" ceiling in general designs avoids the "tunnel effect" common in many modular housing systems. Other methods employed to create the free, open atmosphere include the use of more windows and the use of a raised foyer.

Foundations

Foundations for all housing units will be conventional concrete or masonry. The possibility of precast concrete is being considered.

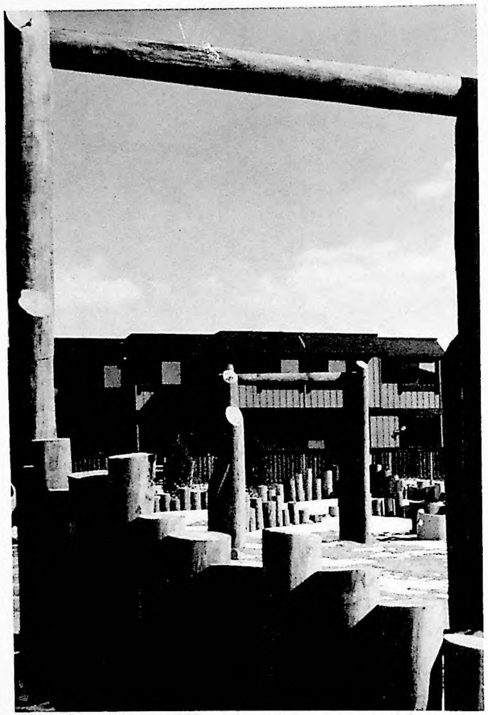
Electrical Design Concept

The electrical system satisfies the guidelines established by the BREAKTHROUGH Criteria. The service system, panel and branch circuitry are for the most part conventionally designed in accordance with the National Electrical Code. Major fixed appliances, including heating and cooling equipment, are individually circuited to provide a greater degree of flexibility and safety. The service provided is 125% of the total calculated loads, to ensure additional flexibility for potential increases in appliance loading or future expansion.

Heating and Cooling Design Concepts

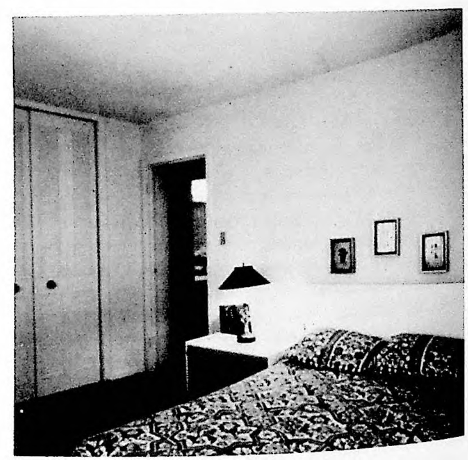
For complete total year-round comfort, a low velocity ducted air distribution system serves to heat and cool the living units. This system is designed to accommodate the future addition of winter humidification and electrostatic air cleaning.

Temperature is controlled by a single thermostat located on the first floor. Through proper initial balancing of the system and subsequent adjustments by the homeowner or housing management, an acceptable range of temperature control can be achieved.



G. Eyebrow rooflines accent the low silhouette of flat roofs.

H. Kitchen–family room arrangement.



I. Bedrooms are spacious with large closets.

Plumbing Design Concept

The Levitt system employs the British single-stack plumbing system for drain, waste, and vent. When installed as suggested in CP 304 (published by the Council for Codes Practice, British Standards Institution), this system has proven, over the last 20 years, to be hydraulically sound.

An extensive testing program on the single-stack system was carried out at the National Bureau of Standards. The simplicity of the design results in savings of labor and material without sacrificing any sanitary function. This same simplicity of design makes the system very adaptable to the mechanical chase concept.

Furnishings

Built-ins and related furnishings offered as standard installations include shag carpeting throughout, metal bifold closet doors, a bathroom vanity, melamine plastic counter tops, a stainless steel sink, a 30-inch range exhaust hood, a fiberglass bathtub, a vitreous china water closet and lavatory sink. Standard equipment and fixtures include a glass-lined water heater, a gas-fired furnace, electrical fixtures, a 14.1 cubic foot refrigerator, and a 30-inch four-burner slide-in range with oven.

Options

The Levitt Technology housing system provides interior style variations including carpet colors, appliances, and kitchen cabinets. Exteriors may be varied with the addition of bay windows or front porches.

Housing options available for various income levels and desires are discussed under "Housing Types and Unit Variations."

DEPARTURE FROM CONVENTIONAL SYSTEMS

Innovations

The system has several structural innovations. (1) Hinged roofs lie flat during shipment and then are raised to provide architectural variety. (2) Roof overhangs are hinged and folded down over boxed bay windows which are shipped pushed into the modules and then extended when modules are placed on foundations. (3) A packaged air-conditioning-heating system uses small flexible ducts that fit easily between wall studs and facings. (4) Module strength is great enough to permit offsets that create almost as much open space as the modules themselves. (5) Factory-installed wiring harnesses, plumbing assemblies, and other mechanical systems require only field connections. (6) British single-stack plumbing.

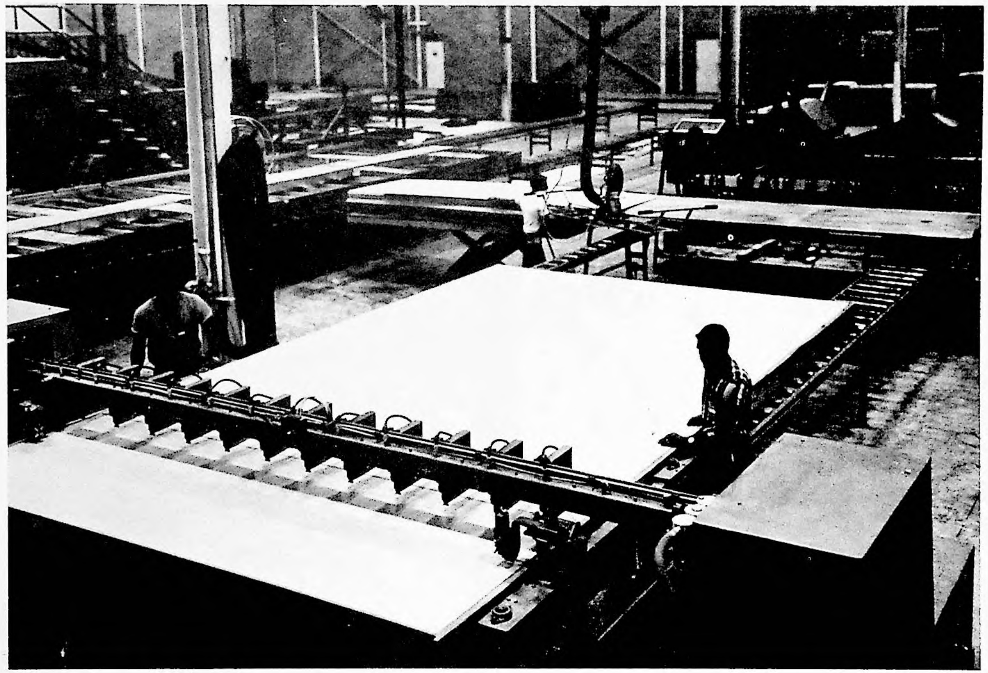
Codes

The Levitt Technology housing system is adaptable to all national model codes.

PRODUCTION PROGRAM (PHASES II AND III)

Minimum production run for any model will be 100 units.

Off-site production consists of module construction and add-on units. (A typical production scene is shown in Figure J.) These functions are performed by semi-skilled and unskilled employees.



J. Sheather (nailing machine) on ceiling assembly line—Levitt Battle Creek plant.

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Labor training programs are established for direct labor and indirect production support personnel.

On-site construction consists of foundations, erection of modules (Figure K), exterior components, finishing and utility hook-ups. These functions are performed by unskilled employees.

Internal functions to be performed by Levitt Technology are management, engineering, production, construction, marketing and financing.

External functions to be performed by affiliates are design, planning, systems engineering, and development of concrete systems.

ECONOMICS OF SYSTEM

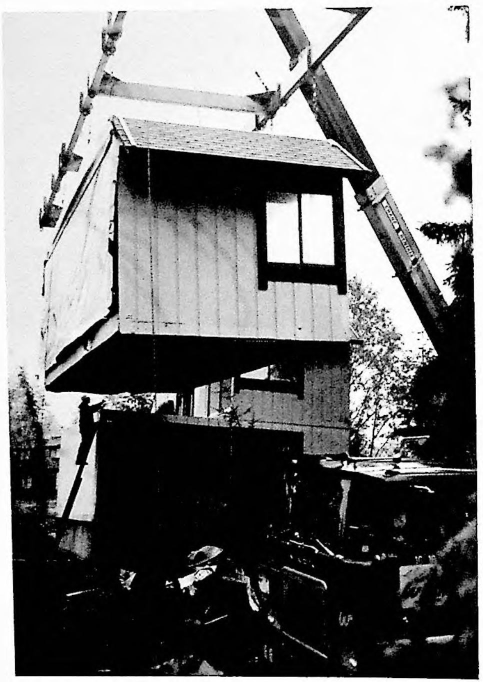
Specific cost of the Levitt housing units is significantly affected by location, local labor costs, quantity and amenities. Transportation of the housing system is by rail or truck (Figure L).

Estimated life of the wood module is 50 years, and estimated life of the heating and air conditioning is 25 years. Maintenance costs should be comparable to or less than costs for conventional construction. All Levitt housing units are backed with a five-year warranty.

MARKETING FOR PHASE III

Levitt Technology Corporation is currently marketing their housing system in a suburb of Detroit, Michigan and in Columbus, Ohio. The units are fabricated at the Battle Creek, Michigan factory and trucked to the construction site where they are erected on previously constructed foundations.

Planning studies include establishment of six additional factories in primary market areas of the United States.



K. Module erection at King Co, Wash. prototype site.

L. Train load of Levitt modules enroute from Battle Creek plant to King County prototype site.

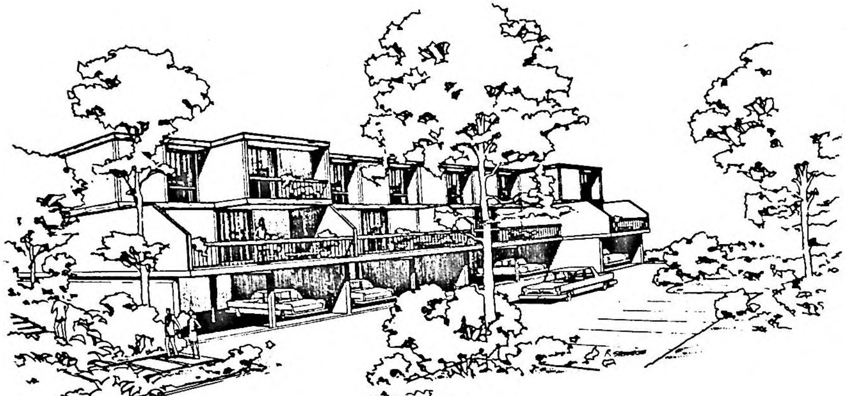
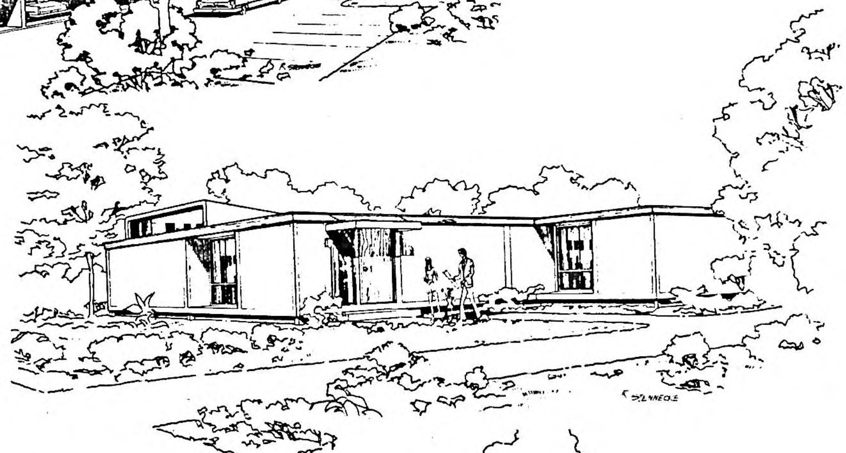
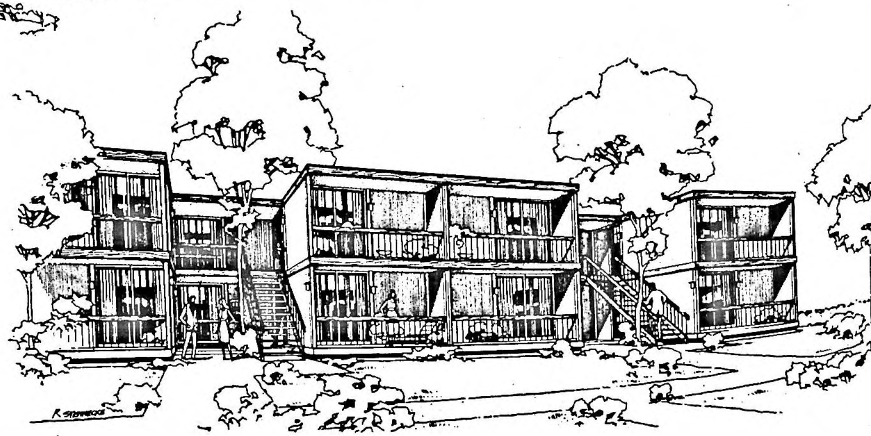
Questions pertaining to the Levitt Technology Corporation housing system may be directed to:

Levitt Technology Corporation
10250 F Drive North
P.O. Box 155
Battle Creek, Michigan 49016
Attention: Werner Zirkelbach
Vice President
Phone: (616) 968-9111

Levitt Phase II units are located at two prototype sites:
Kalamazoo – 51 SFA, 32 MFLR
King County – 20 SFA, 8 MFLR

Summary Information

SYSTEM APPLICABILITY	
Location	Urban; suburban; rural.
Density Range	8 to 27 units per acre.
Environmental Adaptability	Adaptable to all U.S. climates, normal topography and soils.
Non-Residential Functions	Recreation buildings; motels; libraries; schools.
Site Planning Services	Provided by Levitt and associates.
BUILDING SYSTEM DESCRIPTION	
Housing Types	Single Family Attached; Multi-Family Low Rise.
Unit Variations	SFA–2 to 4 BR; MFLR–1 and 2 BR.
Structure	Wood-frame self-supporting modules.
Exterior Elements	Conventional finishes; balconies; porches; decks; parapets.
Foundations	Conventional concrete or masonry; possibly with precast concrete.
Comfort System	Low-velocity ducted air distribution heating and cooling system.
Plumbing	British single-stack plumbing system.
Electrical	Wiring harnesses; integrated with building system.
Furnishing	Appliances.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Hinged roofs; single-stack plumbing; electrical harness.
Codes	Adaptable to all national model codes.
Deviations from Original O/B Proposal	None.
PRODUCTION PROGRAM	
Off-site Production	Module construction and add-on units.
On-site Installation	Module placement; utility hook-ups; add-on exterior elements installed.
On-site Construction	Foundations; joining of modules; utility lead-ins.
Internal Functions	Management; engineering; production; construction; marketing; finance.
External Functions	Design; planning; systems engineering; development of concrete systems.
LABOR REQUIREMENTS/TRAINING PROGRAM	Factory labor, unskilled and semi-skilled; On-site labor, primarily unskilled; Training, direct labor and indirect production support personnel.
ECONOMICS OF SYSTEM	
Transportation Limitation	400-mile radius from factory.
Useful Life	Module, 50 years; heating and air conditioning, 25 years.
MARKETING FOR PHASE III	Planned for 7 primary market areas in the U.S. Present factory in Battle Creek, Michigan.

Material Systems Corporation

INTRODUCTION AND APPLICATION

Material Systems Corporation (MSC) of Escondido, California, designed residential dwellings utilizing manufactured composite materials. Modular units were assigned to six of the nine Operation BREAKTHROUGH prototype construction sites: St. Louis, Macon, Indianapolis, Kalamazoo, Sacramento and King County, Washington. The architectural firm, Skidmore, Owings and Merrill of Chicago, was engaged as consultants during the Phase I design period.

During the past two decades, the aerospace industry has developed an assortment of extraordinary structural composite materials for use in space vehicles and high performance aircraft. MSC has refined, expanded and applied this aerospace-bred composite material technology to the creation of new material systems which are uniquely suitable for the construction of quality residential housing. The composite materials used are a proprietary blend of resins, reinforcing fibers and special additives.

The MSC design philosophy is based upon a modular dimensional concept which permits exceptional flexibility in space utilization and dwelling configuration. Modules can be combined to create single family detached homes, townhouses and low-rise garden apartments. The resulting quality and features inherent in MSC housing systems are superior in many respects to homes constructed of conventional building materials. Extensive tests confirm outstanding strength, durability, thermal efficiency, weather and fire resistance; additionally, MSC's composite materials are insect and vermin proof and maintenance free.

Units are applicable to a density range up to 20 units per acre, dependent on site conditions, and to both normal and extreme climate conditions. The thermal insulation incorporated in exterior walls and roofs exceeds recently upgraded FHA insulation requirements. The composite wall panel and roof panel system is applicable to residential, commercial, recreational, and office and service facilities.

The system is suitable for factory built modules or field erected panel construction. MSC demonstrated this suitability during Phase II by both factory modular production and field panel construction. Garages at the Sacramento site and garden apartment units at the St. Louis site are designed for field erected panel construction.

MSC's Architectural and Engineering Division can provide site planning services for total projects or can coordinate activities with joint venture site planners. The Division, in either type of venture, retains design responsibility for building groupings and building foundations to assure structural integrity responsive to site conditions and efficient operation of utilities at minimum installation cost.

SYSTEM DESCRIPTION

MSC's housing unit designs for Phase II include single family detached, single family attached (one-story and two-story), and multi-family low rise. Typical units are shown in Figures A, B and C.

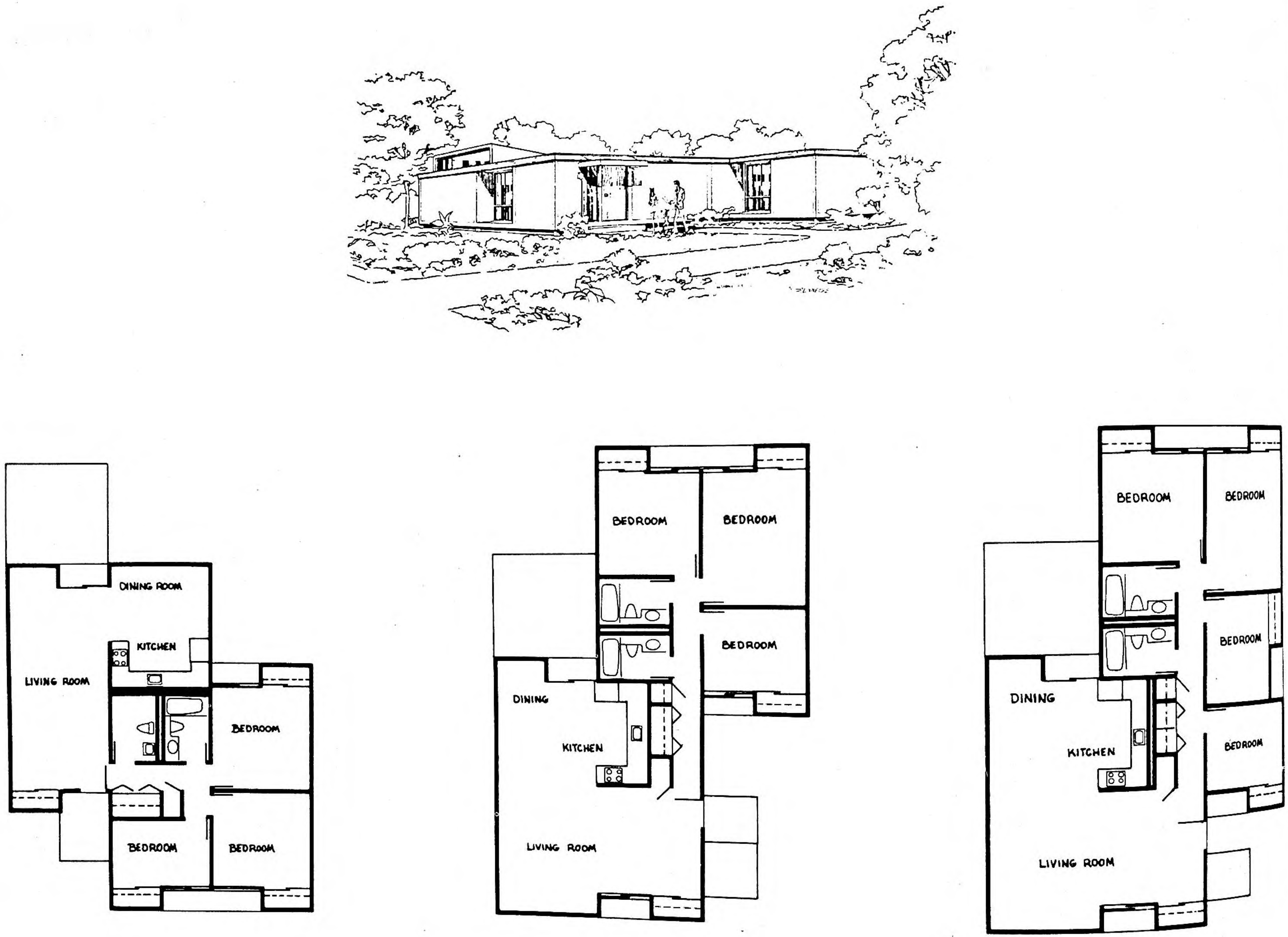
Bedroom unit variations include one and two bedroom apartments, three and four bedroom single family detached, and two, three and four bedroom townhouses.

Apartment building planning is based on standard plans of one bedroom and two bedroom apartments grouped with a common entry area. This grouping is repeated for buildings having 4, 8, 12, 16, 20 or more units.

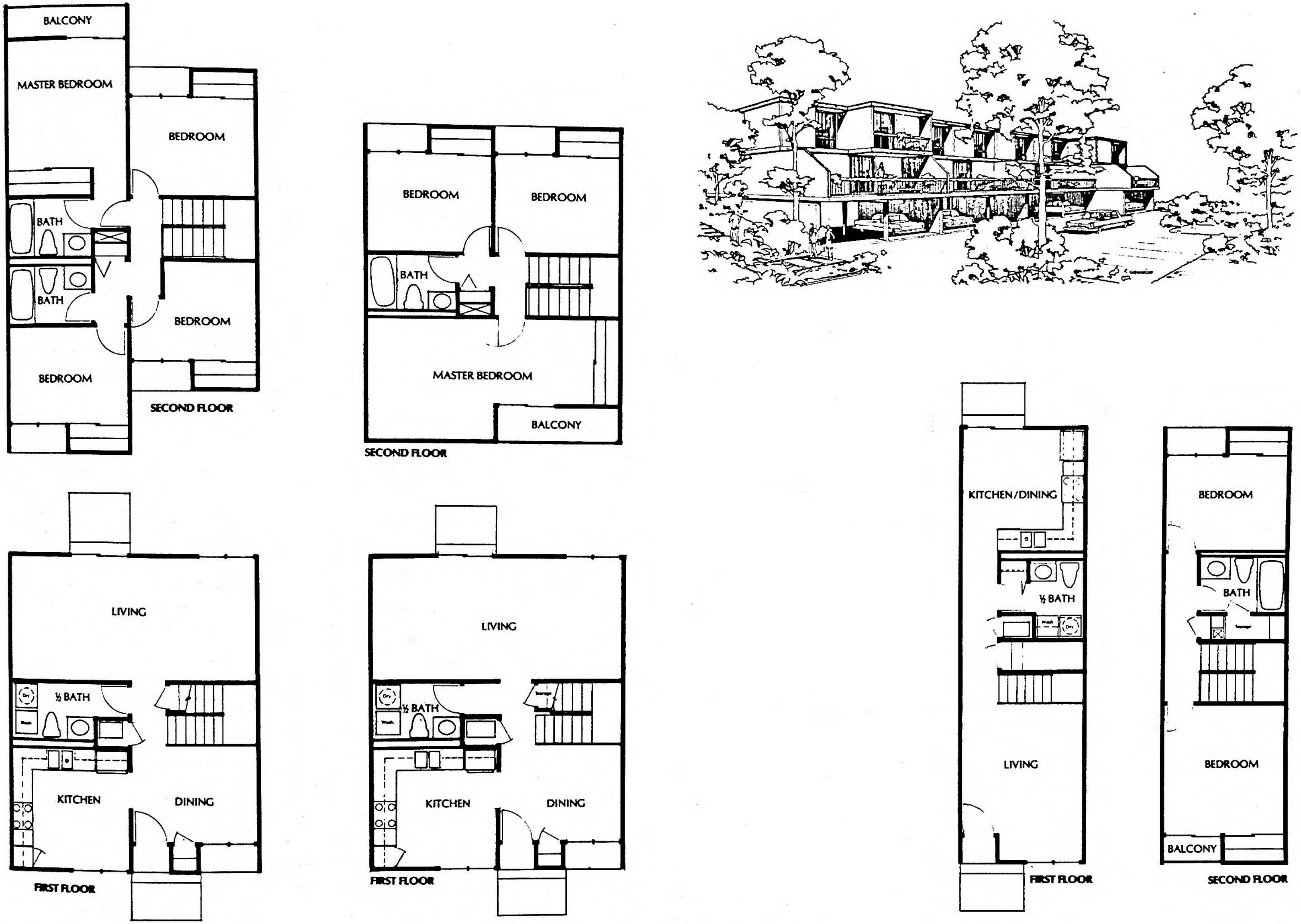
Factory finished three dimensional volumetric modules are delivered to the site, connected together and attached to foundations to create efficient dwelling units. These dwelling units have features noted below:

- Low-maintenance finishes
- Resistant to cracking and chipping
- Insect and vermin proof
- Acoustically and thermally insulated
- Fire retardant
- Earthquake resistant
- Esthetically attractive
- Cost effective

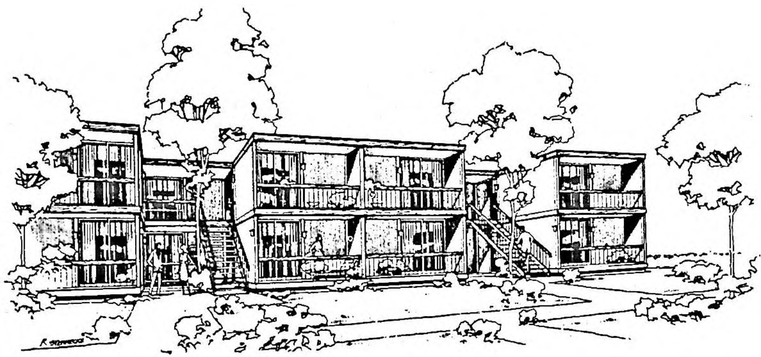
The selection of materials and their formulation are such that the panels are designed to last indefinitely. Accelerated aging tests and observation of prototype installations are expected to verify predicted performance.

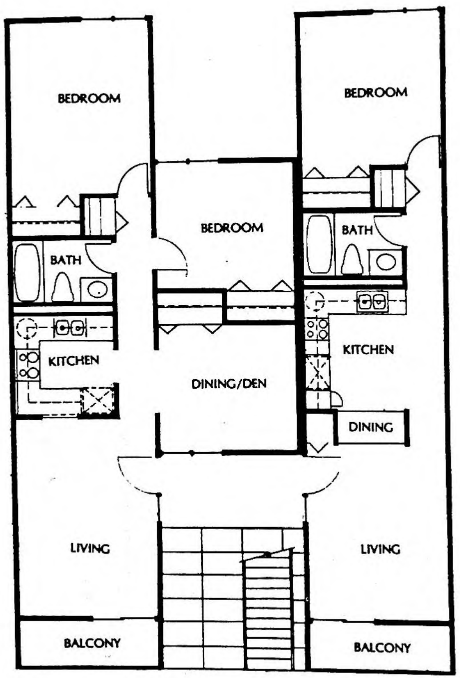


A. Three- and four-bedroom single family homes



B. Two, three- and four-bedroom townhouses





C. One- and two-bedroom garden apartments

The standard wall panels, roof panels, floor panels, joints, and other assemblies (doors and windows) are shown in Figures D and E. The structural system of MSC dwelling units is an innovative approach specifically developed to meet the constraints inherent to manufactured modular housing. The concept developed utilizes self-framing, full load bearing modular standardized roof and wall panels, assembled into self-supporting modules.

Wall panels—there are five wall panel widths: 2'-0", 2'-10", 5'-4", 7'-10" and 11'-2". All are 8'-0" high. These self-framing, load-bearing panels are of sandwich construction, made by bonding skins to a corrugated core. Core cavities may be filled with fire-resistant insulating material, which results in a 20-minute fire rating. A 1 1/2-hour rating for party walls, where two panels adjoin, is achieved by attachment of gypsum board to the exterior surfaces of the interfacing panels.

Roof Panels—The roof panel is constructed from composite materials in the same manner as wall panels. Insulation is provided by a fibrous filler placed in the core cavities. A fire endurance rating of up to 45 minutes can be achieved by use of the specially developed fire resistant insulation and intumescent coatings. The upper composite skin of the roof panel provides an excellent base for applying a low maintenance roofing material.

Floors—Floor panel subassemblies correspond to roof panel sizes. Floors are conventional wood construction utilizing 2 x 8 joists at 16" o.c. and 5/8" T&G plywood sheathing. Electrical and utility distribution is installed in the floor system during subassembly. Thermal insulation required to meet site conditions is installed in the floor subassembly.

Adhesives—Specially formulated adhesives are utilized in the MSC system in conjunction with mechanical attachments to join all structural elements together. A different type of adhesive is utilized for the low and the high stress levels.

Foundations—MSC housing units can be installed on conventional wall type concrete or concrete block foundations. MSC also designs foundation systems responsive to special site conditions, i.e., deep frost lines, poor soil, and basement or hillside locations.

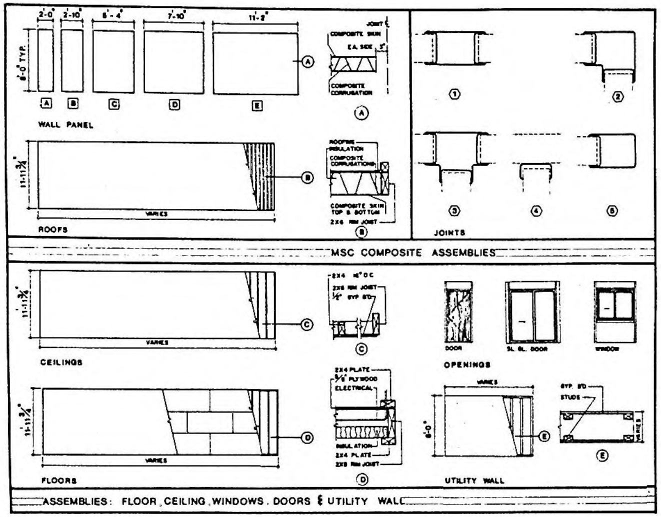
Comfort Systems—All SFD and SFA units have factory installed, gas-fueled, upflow forced air furnaces distributing warm air through insulated flexible ducting. Furnaces and ducting are designed to accommodate air conditioning as required by site conditions (all MSC Phase II units at Sacramento, Macon, Indianapolis, Kalamazoo and St. Louis are air conditioned).

All HVAC installations comply with the Uniform Mechanical Code.

Plumbing—All waste and vent piping incorporated into factory produced modules is heavy duty ABS. All hot and cold water piping within modules is copper. Gas distribution is through wrought iron piping. All waste, vent, water and gas piping complies with the Uniform Plumbing Code.

All plumbing installations are incorporated into special utility walls, built as separate subassemblies and standardized as much as possible for each dwelling unit type.

Electrical—The electrical system is incorporated into the floor and wall panel joints wherever possible to facilitate the high degree of standardization necessary for efficient wall panel production. All electrical installations comply with the National Electrical Code.



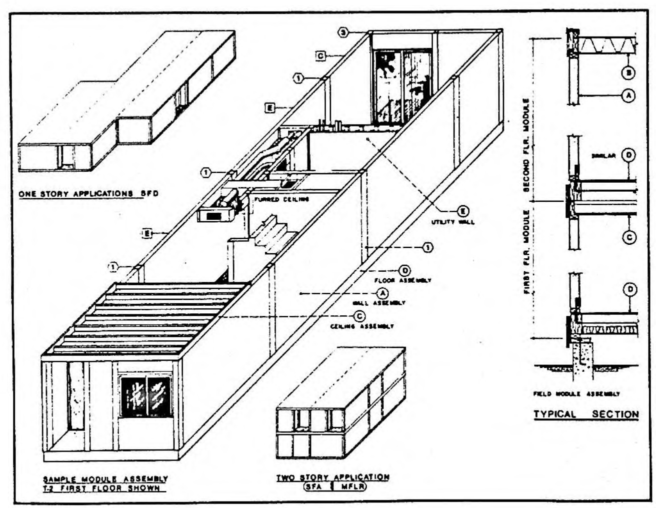
D. MSC system description—Subassemblies

DEPARTURES FROM CONVENTIONAL SYSTEMS

Although MSC composite material wall and roof panels are not listed in the model building codes (e.g. UBC), a full scope testing program has substantiated that these panels meet or exceed the Operation BREAKTHROUGH structural and fire endurance performance criteria and requirements of most of the major national model codes. All composite construction elements have been tested by the National Bureau of Standards or by other independent testing laboratories with guidance from NBS. Detail specifications of tests and results may be obtained from the MSC office in Escondido, California.

It is significant that the Operation BREAKTHROUGH performance criteria were directly responsible for obtaining approvals of MSC composite materials for use in specific dwelling units.

Based on the tests referred to above, the MSC system has been approved as meeting the factory-built housing laws in the states of California, Indiana and Washington.



E. MSC system description—Application

INNOVATIVE FEATURES OF SYSTEM

The MSC system encompasses the complete cycle from basic raw materials conversion to completed dwelling units. Innovation is evident in the construction of structural wall panels, roof panels, and wall panel joints of resin/fibrous glass composites. These new composite materials meet HUD Operation BREAKTHROUGH performance criteria and provide a new basic building material.

The MSC system is also innovative in achieving efficient volume production of factory built units.

The composite materials utilized in the housing system are a blend of resins, reinforcing fibers, and special additives formulated by MSC engineers to meet specific dwelling requirements. The polyester resins are adapted for use with large volumes of filler, ultra-violet absorbers and filters for improved weather resistance. The resulting composite material is fire retardant and odorless after cure.

Minimum design properties established for composite structural components compared with conventional materials such as wood are as follows:

MODE	MSC COMPOSITE	WOOD*
Compression	10,000 psi	1500 psi
Tension	10,000 psi	2200 psi
Modulus of Elasticity	1 x 10^6 psi	1.6 x 10^6 psi

*Douglas Fir

F. MSC single family home at Operation BREAKTHROUGH Sacramento prototype site.

G. Bedroom wing and garage of Sacramento single family unit.

PRODUCTION PROGRAM

The MSC production line is composed of four stages beginning with forming of individual parts such as wall and roof skins from raw materials—resins, glass fibers, fillers and special coatings. Wall panels, roof panels and floor sections are subassembled separately. Operations through subassembly are accomplished at the factory in Escondido, California. Modules are assembled at either of two plants, in Indianapolis or Sacramento. Dwelling unit final assembly occurs at the site selected.

The production rate during Phase II is approximately 6 dwelling units per month, split equally between the two assembly plants. Optimum output during Phase III is 240 units per year; maximum delivery rate from present facilities is approximately 480 units per year. All conversion of raw materials into formed components occurs at the facility in Escondido. Processes and special equipment were designed or developed by MSC for volume production of skins, corrugations for wall and roof panels and joint components.

On-site activities for MSC units are limited to foundations, site utilities, crane installation of modules, making intermodular structural connection, finish fascias and utility hookups.

All operations associated with fabrication (materials conversion), subassemblies and factory assembly of three dimensional modules (including plumbing, electrical, mechanical and finish installations) are performed by MSC personnel. Field finish operations are performed by a specially trained MSC field crew or, in some cases, by local trades supervised by an MSC site construction manager.

All site related activities except as noted above are performed by local contractors and subcontractors. These activities include grading, excavation, foundations and site installed utilities.

H. Sacramento townhouse units.

ECONOMICS OF SYSTEM

Construction costs are projected in the low to medium-low cost range for Phase III operations. The specific range applicable is dependent upon the class, i.e., SFD to MFLR, and proximity to assembly plants. System economics make it compatible with FHA Section 235 and 236 programs.

Assembled modules can be transported to the site by truck, rail-truck, or ship-rail-truck combinations as determined most feasible. The principal limitations are highway restrictions.

The anticipated useful life of the structural shell units should meet or exceed the useful life of comparable units constructed of conventional materials. The composite portions of the structural shell are designed to be virtually indestructible under normal conditions and, in addition, are earthquake resistant and impervious to insects and vermin.

All elements have been designed for lower maintenance costs than conventional systems. The composite materials are virtually immune to impact and abuse. Any normal required maintenance of finish surfaces can be accomplished at low cost using conventional materials and techniques.

MARKETING FOR PHASE III

MSC's basic goal is to build quality low cost housing. The initial market selected for post-Phase II production is subsidized housing (FHA 236 and public housing). Marketing studies for Phase III concluded that Phase II units were too big for initial Phase III 236 programs. Experience with Phase II units dictated revision of design criteria to achieve the required degree of production efficiency, transportabiilty, and efficient field operations.

Two-story townhouse units were selected as the best approach to achieve cost effective producibility and meet both 235 and 236 type programs. Phase III design utilizes two modules per dwelling unit for the two- and three-bedroom units. The back-to-back one-bedroom unit is achieved with one module per dwelling unit. Newly designed units for Phase III range from 743 to 1161 square feet. The number of bedrooms available varies from 1 to 3, with 1 or 2 bathrooms per unit.

Additional information may be obtained from:

Material Systems Corporation
751 Citracado Parkway
Escondido, California 92025
Telephone (714) 746-9663

Material Systems Corporation Phase II units are located at six prototype sites:

- Kalamazoo – 10 SFD
- St. Louis – 20 MFLR
- Macon – 16 SFD, 14 SFA
- Sacramento – 10 SFD, 20 SFA
- Indianapolis – 18 SFD, 32 SFA
- King County – 10 SFA

Summary Information

SYSTEM APPLICABILITY	
Location	Urban, suburban, rural.
Density Range	SFA & MFLR: 6-20/acre SFD: 4-6/acre.
Environmental Adaptability	Adaptable to all U.S. climates, topographic and soil conditions.
Non-Residential Functions	Light commercial, recreational and service facilities.
Site Planning Services	Complete services available from MSC staff.
BUILDING SYSTEM DESCRIPTION	
Housing Types	SFD, SFA, MFLR.
Unit Variations	1 to 4 bedrooms; 1 or 2 baths.
Structure	Module/panel system of composite materials.
Exterior Elements	Patios, decks, porches, storage facilities.
Foundations	Conventional materials and construction.
Comfort System	Gas furnaces; air conditioning optional.
Plumbing	Conventional materials integrated with building system.
Electrical	Conventional materials integrated with building system.
Furnishing	Optional.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Modules factory assembled from panels fabricated from fiber reinforced polyester composites.
Codes	Adaptable to national model codes.
Deviations from Original O/B Proposal	Five bedroom model eliminated; conventional materials used in floors and roofs.
PRODUCTION PROGRAM	
Delivery Rate	480 units per year.
Off-site Production	All fabrication and assembly of completed modules (walls, roof, floor) including plumbing, electrical and mechanical installation.
On-site Installation	Joining of modules; utility hook-up.
On-site Construction	Foundations; utilities lead in; grading and excavating.
Internal Functions	Off-site production.
External Functions	Finance; marketing; on-site construction.
LABOR REQUIREMENTS/TRAINING PROGRAM	Semi-skilled and skilled; traning provided for unskilled.
ECONOMICS OF SYSTEM	
Construction Cost	Applicable to Section 235 and 236 programs—dependent upon area and ancillary features.
Transportation Limitation	Highway restrictions and 400 mile radius of assembly plant.
Useful life	Structure: 40 years.
MARKETING FOR PHASE III	Production planned to satisfy requirements of FHA Section 235 and 236.

National Homes

INTRODUCTION AND APPLICATION

National Homes furnished housing systems to Operation BREAKTHROUGH prototype sites at Indianapolis, Indiana, and Kalamazoo, Michigan, which included both panel and 3-dimensional modular housing units. These are assembled as single family detached homes, townhouses and garden apartments. Self-supporting wood or steel frame module assemblies or panels are fabricated at the factory and shipped to construction sites, where they are erected on previously prepared foundations.

The density range for the system is from a minimum of 3 dwelling units per acre for single family detached homes to a maximum of 18 dwelling units per acre for garden apartments. The system is environmentally adaptable to all U.S. climates, normal topography and soil conditions.

The National Homes Housing System is intended primarily for residential usage; however, in the panel form, it is adaptable to such non-residential functions as recreation buildings, community center buildings, day care buildings and schools.

SYSTEM DESCRIPTION

Structural Elements—The basic structural elements for the system are load-bearing or shear panels built with wood or steel studs, two feet on center. Both interior and exterior panel covers are used to develop shear strength in the panels. The units are offered with factory finished 2.5/12 pitched roofs or with higher pitches, field erected from factory-supplied components.

Exterior Elements—Exterior elements include garages, private fencing, and outside storage, which are constructed in the field from factory-supplied panels and components.

Interior Elements—Most interior partitions are non-load-bearing, and are metal framed with gypsum board covering.

Foundations—Foundations are conventionally constructed and may be crawl space, basement or slab foundation type, depending on design response to site conditions.

Comfort System—The comfort system consists of a central heating and cooling unit with ducted air handling systems. Air is cooled by an individual exterior unit or heated by an individual gas or electric furnace. The system is constructed of conventional materials and equipment and is factory-installed in the modular housing system. In the panelized housing system, it is installed on the construction site.

Plumbing—The housing system is plumbed by conventional systems using the least expensive materials permitted by local codes. Plumbing is factory installed in modular units and installed at the construction site in the panelized housing system.

Electrical—Electrical systems for both panels and modules are wired in the factory. Wire, fixtures and service equipment are conventional products. The electrical system for each product is designed to meet local codes.

DEPARTURE FROM CONVENTIONAL SYSTEMS

Innovations—The major innovative concept in the National Homes Operation BREAKTHROUGH Housing System is the factory fabrication of panels and modules. This technique provides stricter supervision and quality control than on-site construction. In addition, work schedules are unaffected by weather conditions.

Another innovation is the distribution system of National Homes. It offers single responsibility for the entire process including initial site selection, design, financing, construction, marketing and management.

DEVIATIONS FROM THE ORIGINAL OPERATION BREAKTHROUGH PROPOSAL

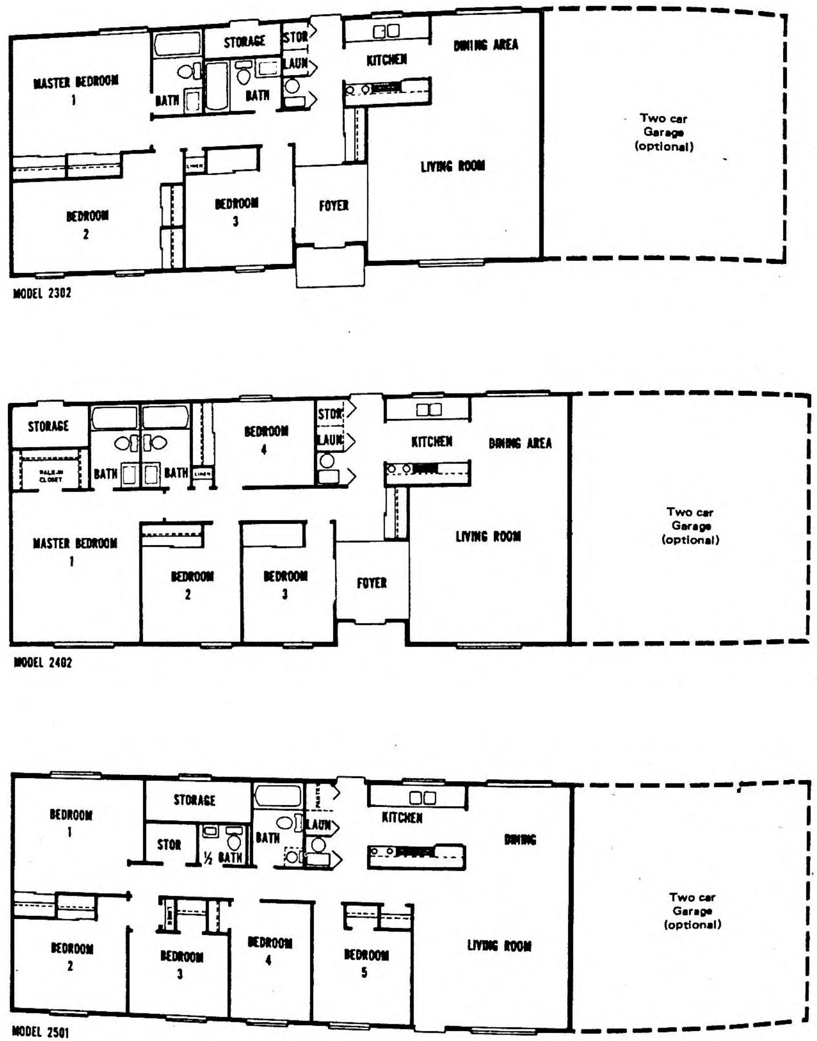
The original proposal for Operation BREAKTHROUGH was for a building system with mid-rise and high-rise structures using non-combustible materials. The proposed system was discontinued due to: (1) removal of a material manufacturer's usage approval which left the system without an economical exterior covering, and (2) difficulty in designing structural connections of sufficient strength between completed modules to permit high-rise use. As a result, HUD directed National Homes to restrict the system to low-rise applications and permitted the use of combustible materials.

CODES

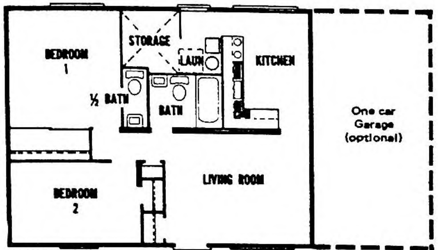
The National Homes Housing System is adaptable to all national model codes.

OPTIONS

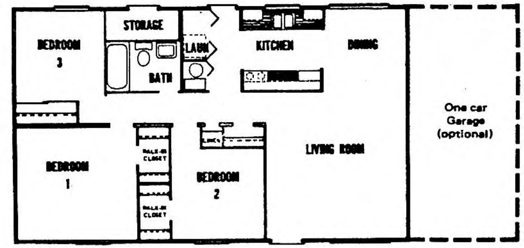
The National Homes Housing System provides two to five-bedroom single family detached homes (Figures A and B), one to four-bedroom townhouses (Figure C), and one to two-bedroom garden apartments. These are available with either wood or steel studs and floor joists, acoustical ceilings, vinyl-covered or painted walls and maintenance-free exteriors of aluminum, rough-sawn cedar or brick.



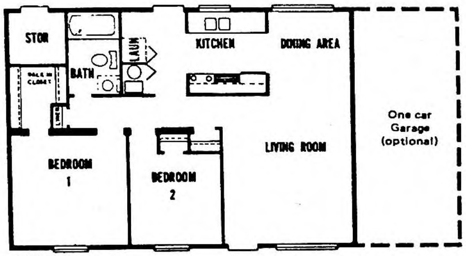
A. Single Family Detached Floor Plans



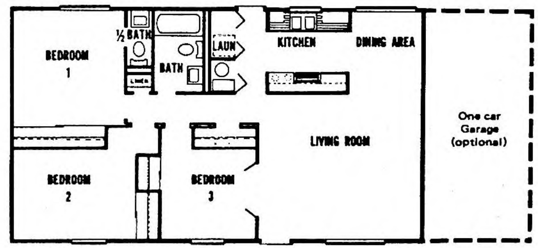
2 BEDROOM 1½ BATH



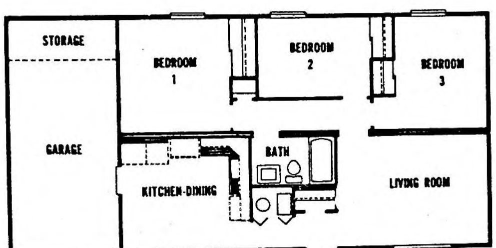
MODEL 2300



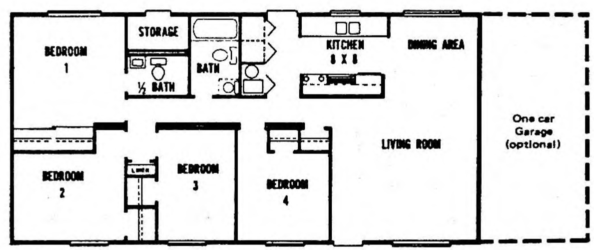
MODEL 2200



MODEL 2301



MODEL 2343 AG



MODEL 2401

B. Single Family Detached Floor Plans

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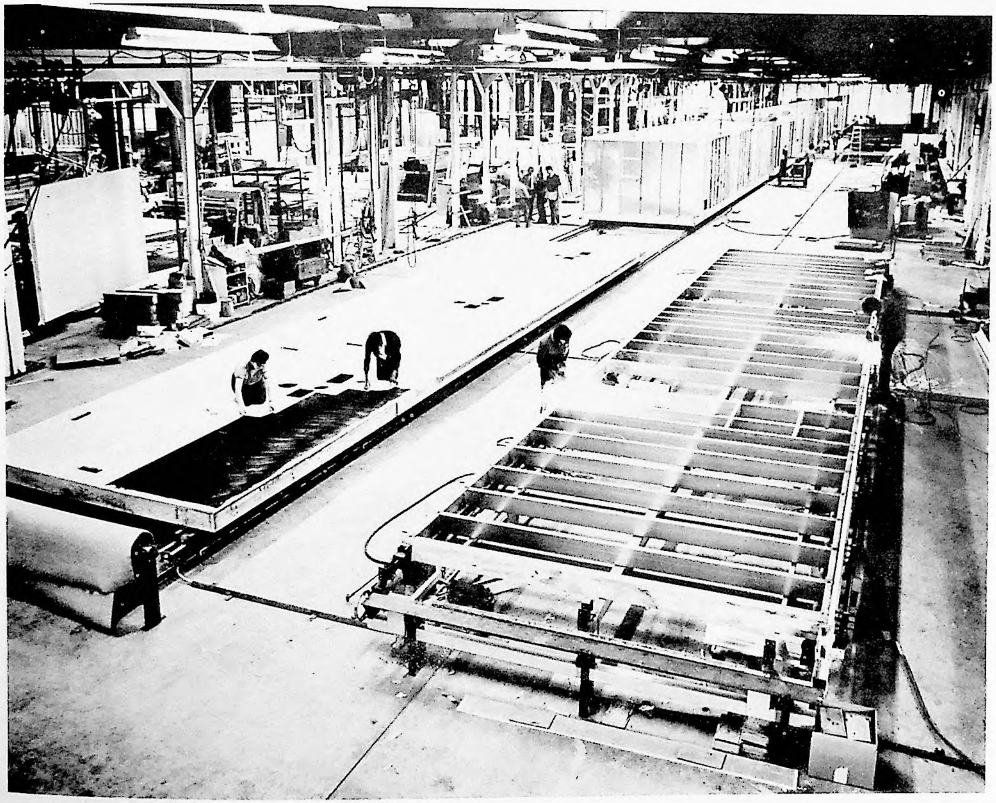
C. Townhouse (SFA) Floor Plans



D. Panel assembly operations

PRODUCTION PROGRAM

Panels, modules, outside storage facilities, garages and architectural embellishment are factory fabricated. Housing units for the Operation BREAKTHROUGH program were fabricated in the National Homes factory in Lafayette, Indiana. Typical production scenes are shown in Figures D and E.

Delivery rates for Phase III will be negotiated for specific project requirements.

On-Site Activities

On-site construction consists of: (1) foundation preparation, (2) joining of modules and panels, (3) utility lead-ins, and (4) mechanical and electrical hookups.

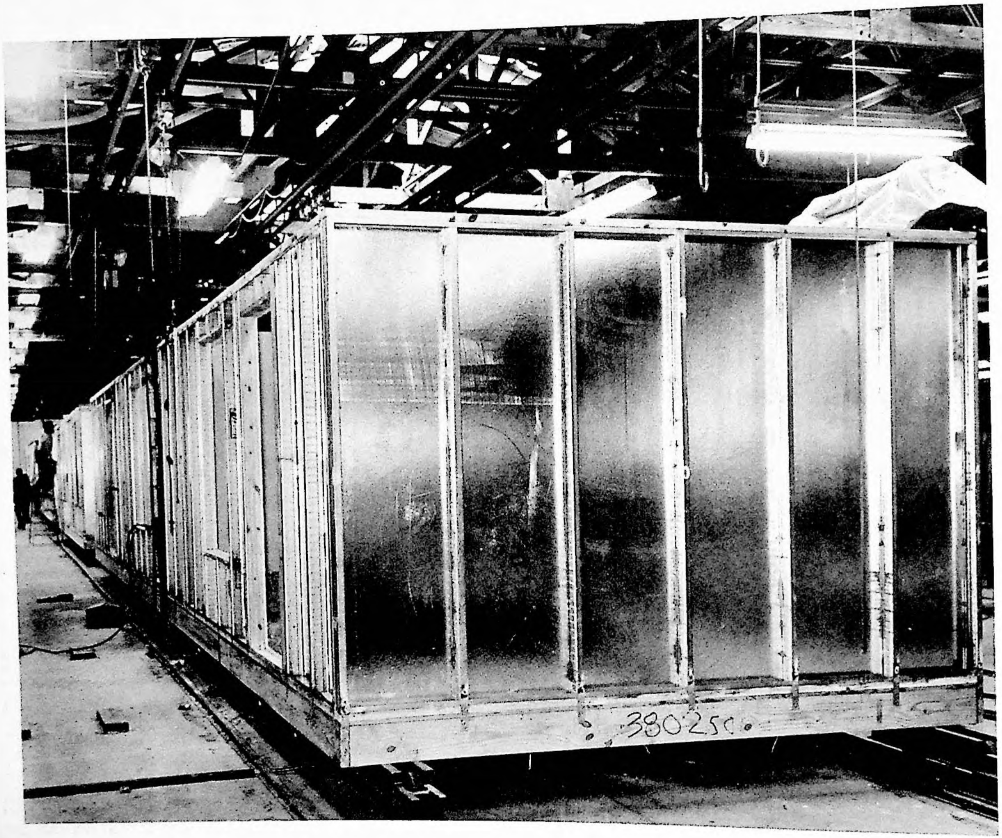
On-site installation for the modular system consists of module placement (Figure F), intermodule connections, utility hookups, the application of trim around the various connections and the erection and/or assembly of exterior elements.

On-site installation of the panelized system consists of panel erection, exterior trim, plumbing system, HVAC, electrical connections, interior trim, interior finish and ancilliary facilities.

Labor Requirements and Training Programs

On-site construction and installation activities require skilled labor able to perform carpentry, plumbing, electrical, HVAC, concrete and masonry work.

Factory production activities require semi-skilled personnel. These workers are trained by National Homes at factory locations.



E. Module assembly

F. Module placement using mobile crane

ECONOMICS OF SYSTEM

System costs are partly dependent on particular specifications desired, costs required to meet local codes, and local trade union wages. For these reasons, National Homes prefers to discuss costs only as related to a specific building or project. The building system has proven its economic feasibility over a wide geographic area.

Transportation

Transportation for the modular housing system is usually by truck (Figure G) and is limited to a 200 mile radius from the factory.

Transportation of the panelized housing system is by rail or truck and is limited to a 350 mile radius from the factory.

Useful Life and Maintenance

Useful life and maintenance costs for the National Homes Housing System should be comparable to the life and costs of conventional housing of similar construction and specification.

G. Module readied for lifting from trailer

MARKETING FOR PHASE III

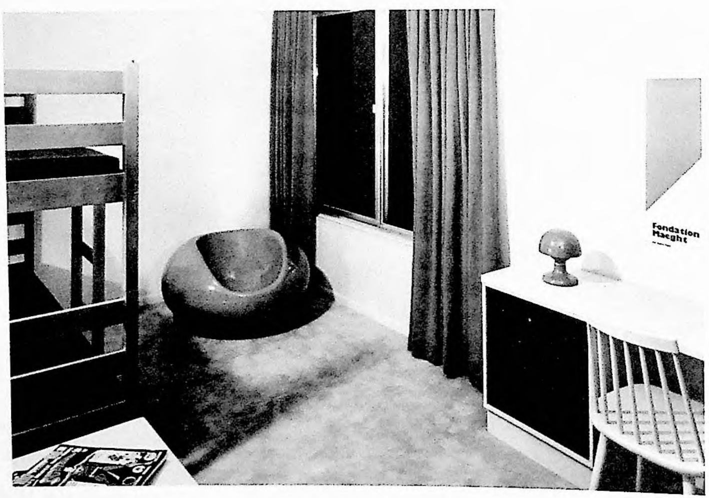
National Homes Corporation is currently marketing the housing system developed for Operation BREAKTHROUGH Phase I and Phase II. In addition they are marketing follow-on designs utilizing the BREAKTHROUGH building system.

National Homes Corporation operates 18 plants nationwide and has produced over 400,000 homes. The corporation operates 8 plants located in Lafayette, Indiana; Terryville, Connecticut; Horsehead, New York; Martinsville, Virginia; Thompson, Georgia; Meridian, Mississippi; Tyler, Texas; and Ontario, California which can produce Operation BREAKTHROUGH building systems.

Typical interior scenes of housing marketed under Phase III production programs are shown in Figures H through L.

H. Living Room Arrangement

J. Bedroom Interior



I. Bedroom Interior

K. Kitchen - Dining Area

Questions pertaining to the National Homes panel or three-dimensional modular housing system may be directed to:

National Homes Corporation
401 South Earl Avenue
Lafayette, Indiana 47902
Attention: Donald MacLaughlan
Phone: (317) 447-3131

L. National Homes Operation BREAKTHROUGH housing - Kalamazoo, Michigan

National Homes Phase II units are located at two prototype sites:
Kalamazoo – 15 SFA
Indianapolis – 14 SFA

Summary Information

SYSTEM APPLICABILITY

Location	Urban, suburban.
Density Range	3-18 units per acre.
Environmental Adaptability	Adaptable to all U.S. climates, normal topography and soils.
Non-Residential Function	Recreation; community center; day care center; schools.
Site Planning Services	Available from associated professionals.

BUILDING SYSTEM DESCRIPTION

Housing Types	Single Family Detached; Single Family Attached (Townhouses); Multi-family Low Rise (Garden Apartments).
Unit Variations	SFD–2 to 5 BR; SFA–1 to 4 BR: MFLR–1 and 2 BR.
Structure	Self-supporting wood or steel-frame module assemblies or panels.
Exterior Elements	Outside storage; garages; architectural embellishments.
Foundations	Conventional basement, crawl space or slab.
Comfort System	Central heating and cooling systems.
Plumbing	Conventional–ABS drainage piping.
Electrical	Conventional.
Furnishing	None.

DEPARTURES FROM CONVENTIONAL SYSTEMS

Innovative Features	Factory fabrication of modules and panels.
Codes	Adaptable to all model codes.
Deviations from Original O/B Proposal	Change from high rise structure made of non-combustible materials to low rise combustible materials

PRODUCTION PROGRAM

Delivery Rate	Identified only to a specific project.
Off-site Production	Module assemblies and panels.
On-site Installation	Modules–Module placement; utility hookups; assembly of trim pieces. Panels–Erection; plumbing; HVAC; utility hookups; interior trim and finish.
On-site Construction	Foundations; joining of modules and panels; utility lead-ins.
Internal Functions	Development; financing; construction; production.
External Functions	Land planning; design; management.

LABOR REQUIREMENTS/TRAINING PROGRAM

On-site–Skilled labor; Off-site–Semi-skilled labor. Training–Unskilled trained for semi-skilled performance at factory location.

ECONOMICS OF SYSTEM

Construction Cost	Competitive with conventional construction.
Transportation Limitation	Modules–200 mile radius from factory. Panels–350 mile radius from factory.
Useful Life	Comparable to conventional construction.

MARKETING FOR PHASE III

Nationwide from eight production plants throughout the United States.

Pantek Corporation

INTRODUCTION AND APPLICABILITY

The Pantek Corporation, a wholly owned subsidiary of Ball Corp., has designed and tested a panel system of housing that encourages local community involvement in production and marketing. The system has two aspects: (1) the structural panel and (2) a unique franchising plan that offers an opportunity for the unskilled to design, build and own their homes.

Ball Corporation studied the possibilities of industrialized housing and identified the traditional patterns that continue to restrict the rapid design, construction and marketing of new homes. They explored new approaches and developed the Pantek System, which is now being applied to Operation BREAKTHROUGH sites in Indianapolis and Sacramento.

Panels are factory prefinished and can be handled without heavy equipment. As a result, the techniques needed to construct a house easily can be taught to people unskilled in the customary building trades.

The system includes single-family detached and attached housing types, as well as multi-family low-rise units. Variations range from one to four bedrooms.

The system is suitable either for suburban areas or for mid-city locations. Suburban projects are the main topic of this report, and provide many opportunities for practical application of the Pantek system. Mid-city units have not yet been constructed, but would probably take the form of a vertical community, achieved by aggregating urban lands into super-blocks. Dwelling units and their related community facilities would then be clustered to achieve maximum open space as a buffer between housing and adjacent commerce.

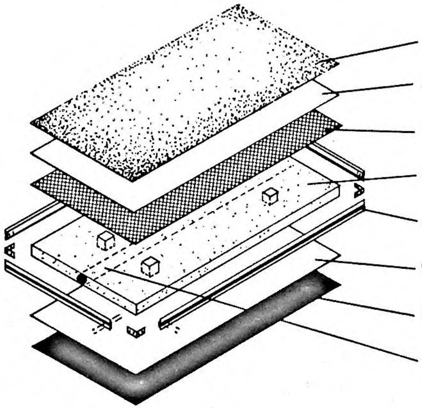
SYSTEM DESCRIPTION

The Pantek System depends on a structurally sound, load-bearing panel that can be erected by unskilled labor using readily available equipment.

The panel design is an outgrowth of more than eight years of continuous effort by Ball Brothers Research Corp. (a subsidiary of Ball Corp.) to find chemical-resistant flooring for laboratories. The result proved to be as sound for walls as for floors.

Around the panel, a building system was designed, with industrial fabrication in mind, and with erection simplicity the key factor in its application.

The panel (Figure A) is lightweight and inexpensive. It consists of two 4 by 8 sheets—one of 5/16 inch plywood and the other of cement asbestos board—with low-density polyurethane foam poured between them. Aluminum extrusions frame this sandwich, serving both as edges and as part of the panel locking system. The exterior asbestos skin is coated with a mixture of epoxy and stone aggregate. The interior face may be prefinished with paint, wallpaper, surfaced hardboard or drywall.



A. Structural panel

Panels are used for walls and partitions. Doors, windows and other hardware can be accommodated, and there is a vertical tube through the foam for electrical wiring. Wall panels are interlocked to each other and are joined to floor and ceiling channels by means of special splines, sealed with an elastomeric material.

A panel with rock surface is 3 inches thick and weighs about 6-1/2 pounds per square foot. Typical interior panels weigh about 3-1/2 pounds per square foot. Panel units may be stacked to form two-story dwellings but require a concrete or steel superstructure for three or more floors.

Floors are of concrete or steel joists, with plywood sub-flooring, vinyl tile and carpeting. Roof and ceilings consist of Bucoa steel pans, 18 inches wide, of extended length with 4 inch waterproof joints. The pans are filled on site with insulating material.

The mechanical-utility core will be selected from a series of basic units containing a complete kitchen, an associated mechanical-electrical-plumbing core, and a complete bathroom. Options include washer/dryer, dishwasher, refrigerator-freezer, extra storage units, air conditioning, gas or electric fuel, and all major appliances. They may be located anywhere in the dwelling and may be stacked one over the other to a maximum of three stories.

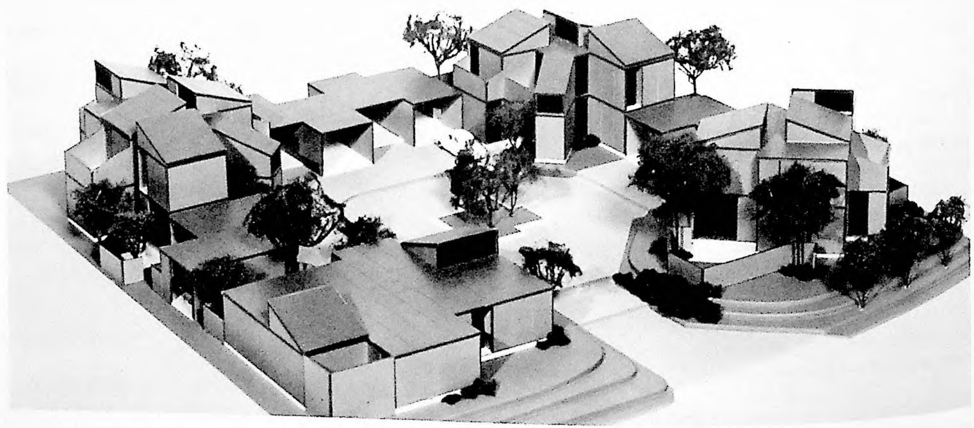
B. Developmental model demonstrates the distinctive appearance of the Pantek house

The heating and air conditioning unit is centrally located in the master chase so that it may be repaired or moved. Heating and air conditioning distribution is made from the central core through flexible ducts over the bathroom and kitchen bulkheads and ceilings or through floor ducts. Fresh air is introduced through the roof or through an exterior wall. The plumbing system is a complete element using the "plumbing tree" concept. The drain, waste and vent system is plastic. The main electrical control boxes and circuit breakers are situated in the master chase. Raceways extend electricity, telephone and TV wiring throughout the system.

Normal built-ins are provided as standard furnishings. Other furnishings and equipment, including major appliances, are optional.

Housing Designs

A panel system is one of the most flexible of building systems. It offers almost unlimited design application to rural, suburban and urban developments (Figures B and C).



C. A variety of rooflines and floor plans is possible with the Pantek panel system

One- and two-story units, either stacked or free-standing, are easily built on flat land or on slopes. These may be single family detached, single family attached (row houses or townhouses), or multi-family low-rise dwellings. Higher densities are possible by incorporating the units with a multistory superstructure.

Outside appearances are distinctive, but do not conflict with existing houses. The roof-line, flat or pitched, is one of the exterior aspects that can be readily changed.

Prospective tenants and owners are consulted regarding their wishes and needs for design of the dwellings and for social and service facilities. These householders will participate in the actual design phase. A "housing game", based on the management games used by modern corporations, is proposed to contain all of the elements necessary for planning space assignments and the construction of simple floor plans. This design package will be computer aided, to achieve maximum effectiveness of the system.

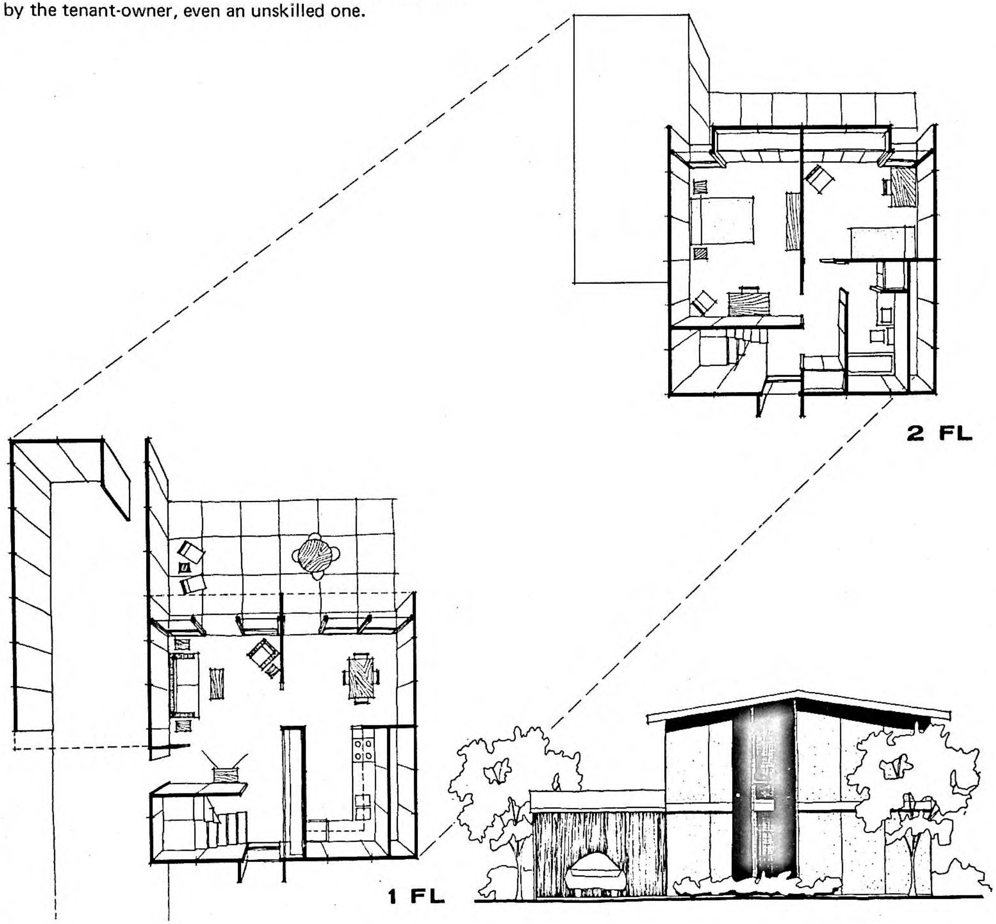
The game board will be a stiff sheet with information and grids printed on it. The package includes prints of the various kitchen and bathroom cores, living rooms, family rooms, dining rooms and bedrooms. Pressure-sensitive paper lets the player select his own spaces and size and arrange them on the grid.

A guidebook containing sample floor plans (Figures D, E and F) and elevations will be part of the package.

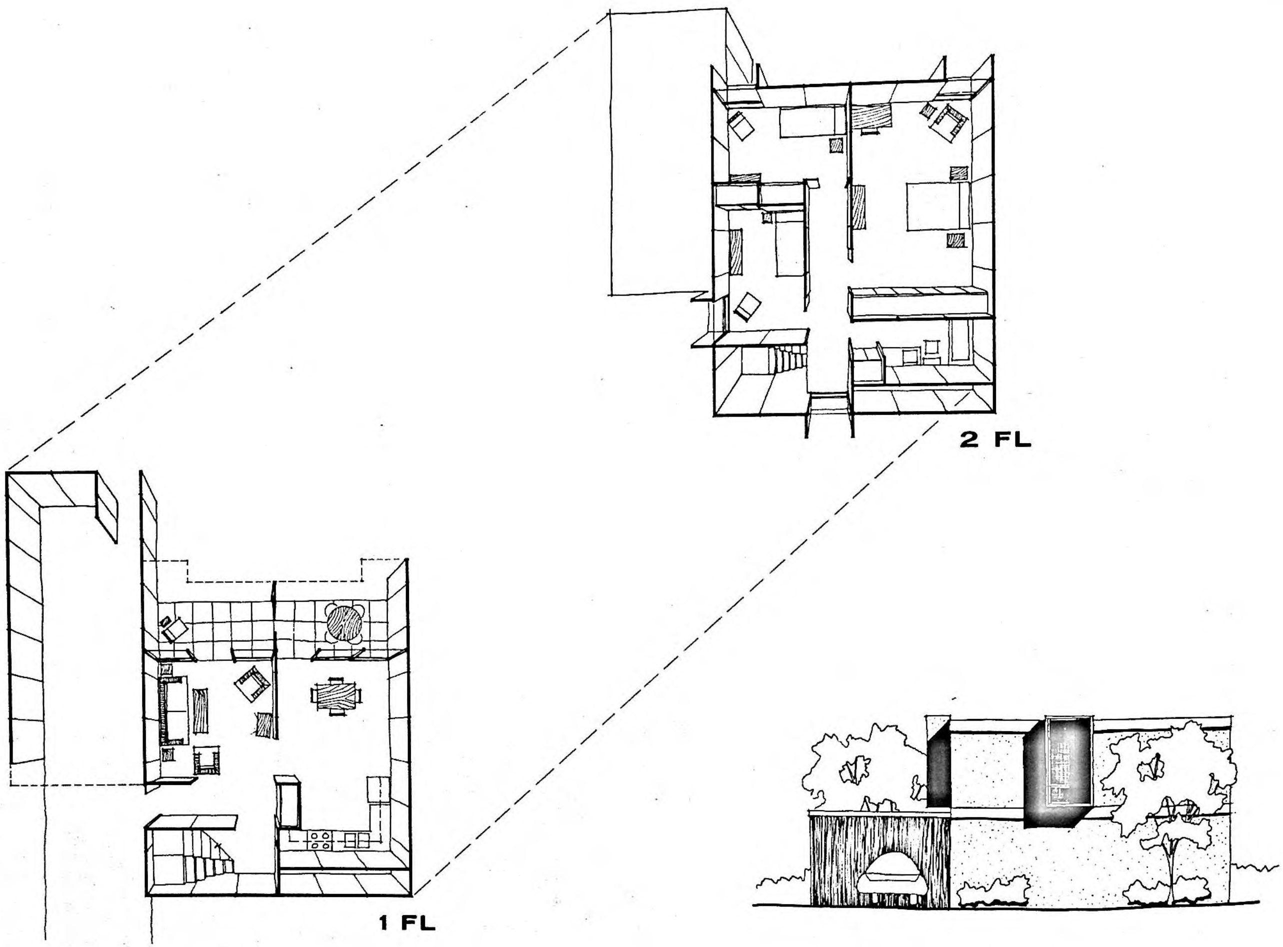
Typically, the player will search for a floor plan similar to the one that best suits his family, possibly with some slight variations in room size or arrangement. The player will fill out a form to choose texture or color or orientation. In other words, the player will make up a very simplified set of specifications.

The data from the game will be fed into a computer, which will produce schematic floor plans, elevations, plot plans, and perspective studies of the home. If changes must be made, they can be made quickly. All the player need do is play the game again. When the design is complete, the computer will produce all necessary drawings, a complete bill of materials, and detailed cost estimates as well as production and erection schedules.

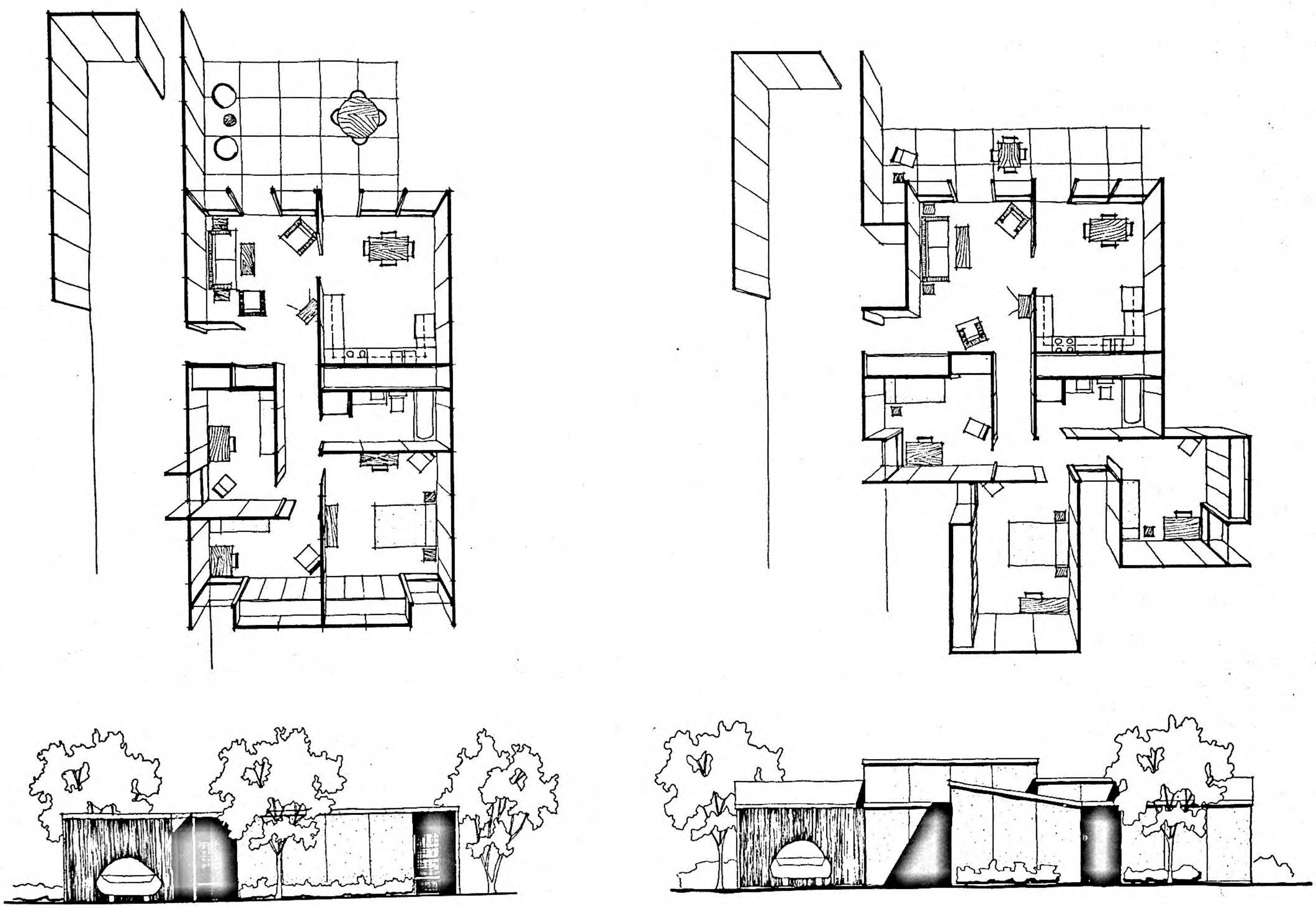
The game further serves the tenant as a means of rating the overall design, construction and management of the project. This tenant-owner involvement continues into the future because repair, maintenance and modification of the housing units are simple and easily accomplished by the tenant-owner, even an unskilled one.



D. Two-bedroom, two-story plan



E. Three-bedroom, two-story plan



F. Three-bedroom, single story plans

DEPARTURE FROM CONVENTIONAL SYSTEMS

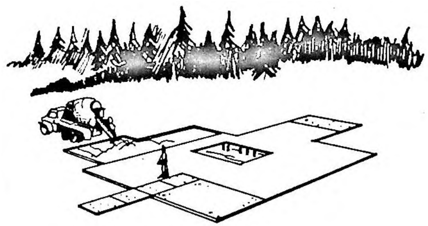
The Pantek System is flexible and can accommodate changing family conditions or desires. Alterations in building arrangements can be made easily. A young married couple establishes a residence by purchasing enough panels to provide minimum enclosure. The house then grows with the family (Figure G). As the house gets larger, the cost per square foot gets smaller. Much of the work can be done by the owner himself. A professional contractor is needed for little more than preparing the foundation.

The Pantek panel system enables selective renewal, on a lot-by-lot basis such as scatter sites, for improving land use.

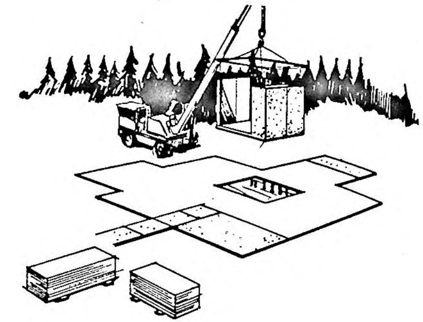
In the past we have not had inventive ways to increase occupied land density. There has never been an economical way to update land use for conditions we cannot predict. A mix of low-rise panel structures with large central structures could provide a flexible method for improving land-use density.

The first step in the construction of such an urban living complex might be garden apartments or townhouses or a combination of the two. As densities increase and land values go up, more efficient land utilization would be needed. Since the Pantek System can be readily moved in its unitized form, the existing panel structures would be disassembled. After constructing a central superstructure of concrete and steel with a massive platform, the townhouse living units would be reassembled on the platform at a higher level, using the ground floor for commercial and industrial enterprises. Or, the platform could be built over existing dwelling units, and then those units could be replaced on the platform, one at a time, without disrupting the neighborhood or the community. Additional platforms could be erected in the future, with the original units moving higher in the frame or with new units being built on top.

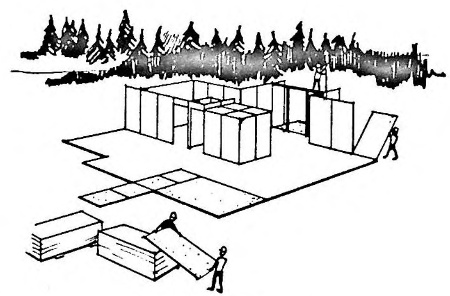
A major factor in this housing system is the involvement of the people for whom homes are being built. The Pantek System includes a complete housing approach, from design through construction, marketing and financing. This system provides the means to create local, minority-owned businesses and is intended to



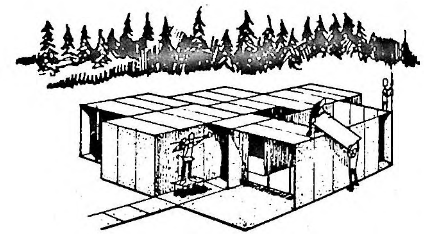
1. Site preparation and slab construction



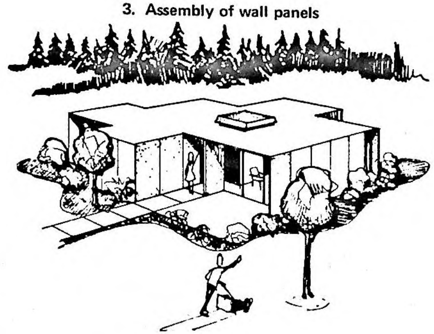
2. Installation of utility core



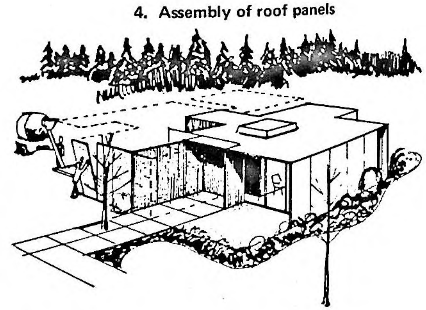
3. Assembly of wall panels



4. Assembly of roof panels



5. Landscape- move in



6. Expansion- remodel and addition

G. Construction sequence

involve the people who will live in, and own, the completed community.

Community involvement in the process is an integral part of the system. Local sponsors from the community will be sought for both planning and construction; such sponsors will include minority business, cooperative and nonprofit groups. Franchises will be negotiated in the local community. No special skills are required on the part of either management or labor. After the franchises have been selected, construction workers will be thoroughly trained in the building system techniques to be used.

The formation of locally-owned enterprises will be encouraged, particularly those that provide such necessary community services as groceries, barbers, day care centers, clinics and recreational facilities.

The franchise system (described later in detail) provides the practical means for mass marketing, and for mass financing with risks spread over a broad base. At the same time, local businesses can engage in home building and home selling. Also, an individual home owner can obtain equity in his home by doing some of the construction work himself.

PRODUCTION PROGRAM

The panel fabrication process is shown in Figure H.

A factory capable of producing up to 400 homes annually can be established within about 90 days. Its cost is minimal; it can be located on any reasonable site and is easily expanded.

Volume production rates can be 200 to 400 units per year for each plant. The plants could supply projects within a 250-mile shipping radius.

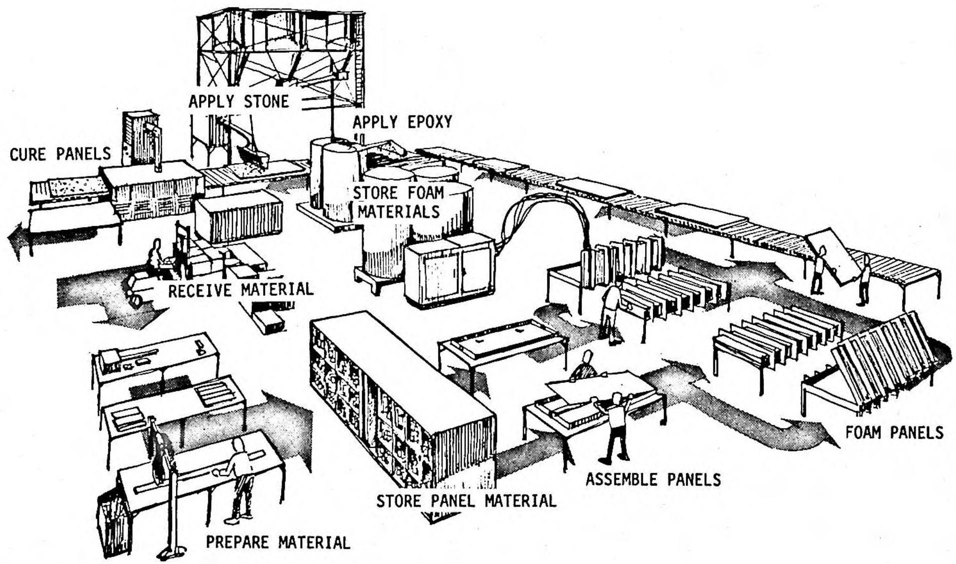
In the future, Pantek expects to be able to tailor the formula of the plastic sandwich material to meet almost any requirement. It should be possible to eliminate the cement asbestos skins and provide instead some form of sheet plastic. Limiting factors would be the strength of the material, physical characteristics and cost per square foot. The aluminum edges are now the most expensive element of the panel, but for high volume production, integral skins with edges would be economically feasible.

ECONOMICS OF SYSTEM

Factory-manufactured panel systems have many advantages. Panel systems are not new to the building trade; therefore retraining of skilled tradesmen is unnecessary. The technique of constructing a building is so simple it can easily be taught to people unskilled in the traditional building trades. Panels can be factory pre-finished. Shipment of panels is easy with existing equipment, and storage of panels requires no special areas. Small relatively lightweight panels can be handled without complicated equipment. This ease of production, transportation and erection of panels is the primary attraction for local involvement in the Pantek housing business.

The construction cost of prototype Pantek units for Operation BREAKTHROUGH is equivalent to the cost for conventional construction. These costs can be reduced by high volume production and erection.

Maintenance costs will be very low. The primary structure and the flat surfaces are almost maintenance-free.



H. Panel fabrication process

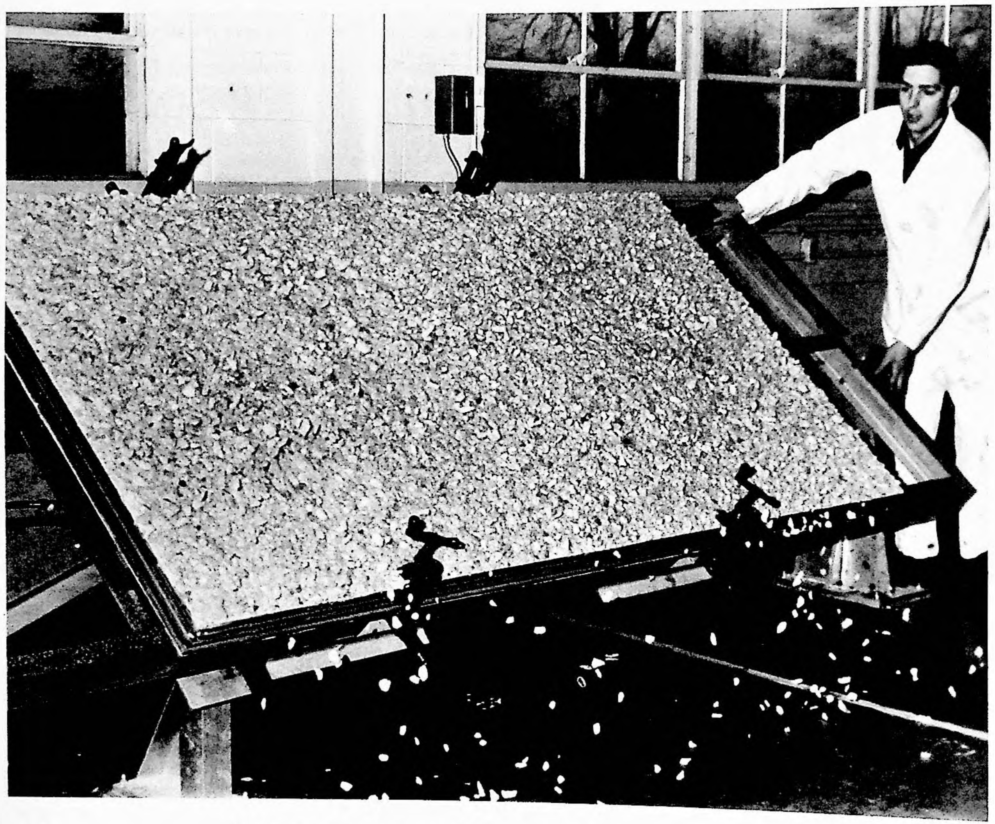
MARKETING FOR PHASE III

Perhaps the best, and most unique, feature of the Pantek system is its adaptability to a franchise operation. Locally-owned businesses can be franchised to engage in the home building business in their own communities. These firms will produce building components in a local factory employing local unskilled labor. They will also market their products locally, and will have the capability of handling the complete development of a project.

This franchise system offers a significant opportunity to create a real industrial revolution in the housing business. Many companies have the resources and technical know-how to mass-produce housing, especially if present code, zoning and trade practices are relaxed to permit innovations in materials and methods. But the manufacture of houses alone will not solve the basic problem. Local firms must truly understand their own markets. Developers and owners must get relief from the crippling limitations imposed by present house financing methods. Local builders must be able to obtain excellence in design without prohibitive cost. Each project demands effective management and inventory control. Ways must be found to spread the risks on long-term housing investments.

The franchise system can solve these problems. Through a national organization, with expertise in market research, the franchisee will be able to determine how many of what kinds of homes he can expect to sell. The national financial contacts of the franchisor will open avenues of financing never before available to the local builder. With thousands of houses to finance, instead of a dozen, the scheduling of financial requirements is an absolute necessity, not an optimistic hope. Production can be scheduled to meet market demands, and the slack season can become a thing of the past. By using the same people in the factory and at the site, the franchisee can stabilize his work force and increase its flexibility.

With access to real design capability and a truly versatile system, the local franchisee will penetrate markets never before available to any one builder. This broad market base will be enhanced by national referrals, a national advertising campaign and the management methods made possible through today's data processing equip-



I. Excess stone is removed from structural panel before curing.

ment and know-how. The quick construction afforded by the system will eliminate the requirement for major capital commitment in essentially unproductive land and will free that capital for expansion of capability and decrease in costs.

For further information contact:

Pantek Corporation
P. O. Box 2117
Boulder, Colorado 80302
Telephone: 303/449-1882
Attention: Ernest S. Malachowski

Pantek Phase II units are located at two prototype sites:
Sacramento — 29 SFA, 16 MFLR
Indianapolis — 40 SFA

Summary Information

SYSTEM APPLICABILITY	
Location	Peripheral, suburban.
Density Range	SFD up to 10 per acre; SFA up to 15 per acre; MFLR up to 30 per acre.
Environmental Adaptability	Adaptable to all normal climates, soils, topography.
Non-Residential Functions	Dormitories, motels, commercial.
Site Planning Services	Available from HSP, HSP affiliates and local planners.
BUILDING SYSTEM DESCRIPTION	
Housing Types	SFA, SFD, MFLR.
Unit Variations	1 to 4 bedrooms.
Structure	Basic load-bearing aluminum-edged sandwich panels; supporting up to three stories.
Foundations	Conventional, designed for site conditions.
Comfort System	Forced air heating and ventilation, gas fuel, ducts in 1st floor slabs and in 2nd floor hallways.
Plumbing	P.V.C. distribution lines. Bathroom and kitchen back to back.
Electrical	Raceway through panel centerline and through extruded panel base.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Lightweight, inexpensive, maintenance-free wall panels. System ease of production, transport and erection.
Codes	Complies with HUD/NBS Guide Criteria.
Deviations from Original O/B Proposal	Wall thickness increased from 2-1/2 to 3 inches. Steel joists and wood flooring in lieu of panels for floors. Bucoa steel pans in lieu of panels for ceilings and roofs.
PRODUCTION PROGRAM	
Delivery Rate	Annual output per plant: 200 minimum; 400 optimum; 600 maximum.
Off-site Production	Sandwich panels.
On-site Installation	Subsystems by all trades.
On-site Construction	Foundations. Erection of panels.
Internal Functions	Design and production of panels.
External Functions	Service modules. Site development. Erection of panels. Subsystem hook-ups and other trades work.
LABOR REQUIREMENTS/TRAINING PROGRAM	High school or equivalent for factory work, unskilled for erection, skilled for finishing.
ECONOMICS OF SYSTEM	
Construction Costs	Equivalent to conventional for Operation BREAKTHROUGH; lower cost for high volume.
Transportation Limitation	200 miles.
Useful Life	Successfully tested under conditions simulating 80 to 100 years of life.
MARKETING FOR PHASE III	For information, contact Pantek Corp.

498-488 O - 73 - 12

Pemtom

INTRODUCTION AND APPLICABILITY

Pemtom, Inc. has designed, developed, and built a two-story wood frame housing system called 'UNIMOD.' Capable of mass production, this system exhibits flexibility in architectural relief, exterior and interior treatments, and environmental awareness.

Pemtom, Inc. has drawn on its experience as a major developer, designer, and contractor of single and multi-family housing in the Upper Midwest to produce this attractive and functional townhouse system. These SFA units offer variety and interest, with large offsets and setbacks, large overhangs, prominent relief and many amenities that reflect careful attention to environmental control. Numerous innovations are used that successfully demonstrate Pemtom's community living concepts.

UNIMOD has the capability of expanding beyond the eight unit per acre density developed on the Operation Breakthrough prototype site at Indianapolis, Indiana to a system exceeding fifteen units per acre on sites requiring greater densities. UNIMOD is adaptable to all climates, varied topographic and soil conditions.

SYSTEM DESCRIPTION

Pemtom restricted its development to a two-story townhouse for single family occupancy. Each of the four basic designs for townhouses may be used within the microsite limits to provide either a two- or three-bedroom unit of varied relief. Amenity packages include appliances, carpeting in bedrooms, decks, fences, service doors in kitchens, air conditioning, basements, and varied roof configuration.

The basic structural system consists of volumetric modular units made up of floor, wall and roof panels. The basic modules are 13' 4" wide by 11' 6" high and are 32, 40, or 42 feet long, depending on floor plan. The exterior walls furnish vertical stiffness to the system by acting as shear walls for vertical loads along the full length of the module. The structural system permits stacking of modules two stories high. Interior walls within a module are non-load-bearing.

Dimensional lumber cut to precision lengths is used for framing floors, walls, ceilings and roofs. A glue/nail system is used for the attachment of the plywood floors, roofs and exterior skins. A new polymer bonding adhesive developed by the 3M Company is used in lieu of heavy nailing. Some stapling or tack nailing is required to ensure contact and alignment of the sheathing. The modules are connected by glue and by mechanical means. The lower level module end walls and concrete piers or block foundations are connected by mechanical ties. The mechanical ties provide resistance to wind loads of 25 pounds per square foot.

Load bearing exterior walls are designed with 2" by 4" studs 24" O.C. around the module perimeter. Exterior structural prefinished plywood, 1/2" or 5/8" thick is used on the exterior, 1/2" gypsum wallboard on the interior and fiberglass insulation in between. In areas where unit-to-unit contact occurs, 5/8" firecode gypsum wallboard is used in lieu of the exterior plywood.

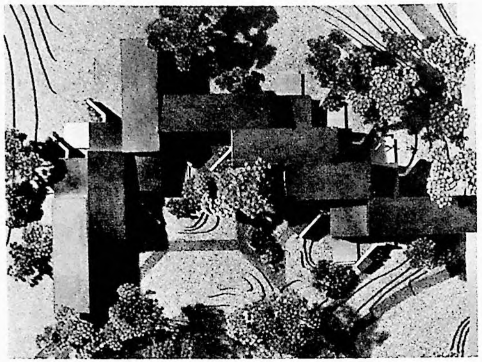
Windows are factory installed in a prefinished, double glazed wood sash/jamb configuration. Exterior doors are steel with rigid foam insulation.

The floor assemblies are one-way, stressed-skin plywood panels, consisting of 2" by 8" joist, 24" O.C. with a 3/4" top skin of premium plywood. Joints are tongue and groove. Maximum clear span in the floor is 12'-7".

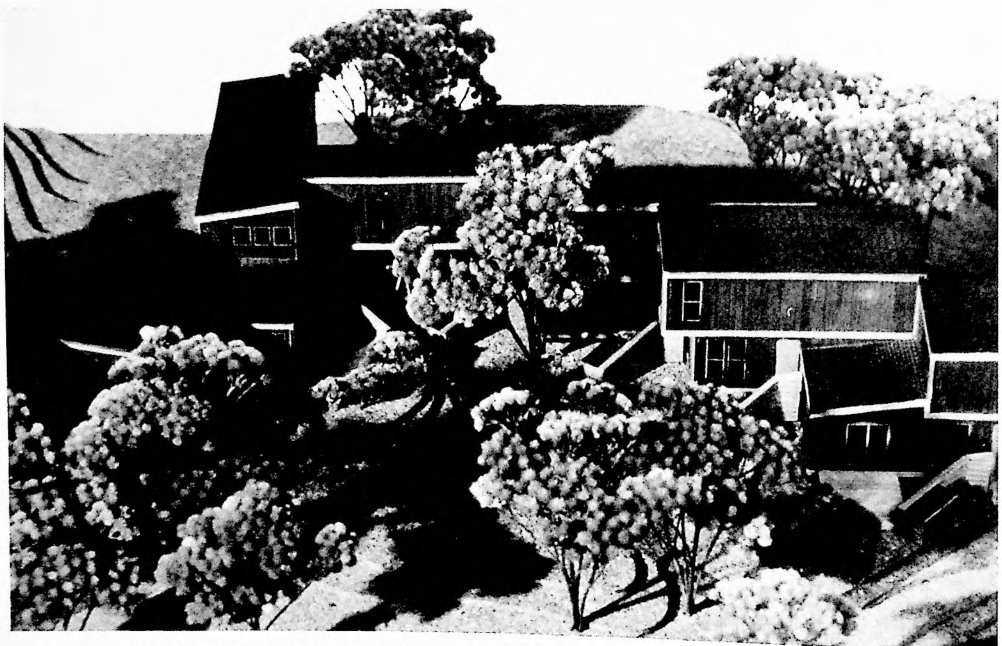
The ceiling panel of the lower module is completely finished and is made up of 2" x 6" joists 24" O.C. Joists run parallel to the length of the module and have intermediate support at interior walls. The heating ducts for the upper and lower level module are located between the ceiling joists. The surface of the lower level module ceiling is 1/2" gypsum wallboard.

Roof panels are constructed with 1/2" plywood sheathing on top of roof trusses and 1/2" gypsum firecode wallboard on the underside of the bottom chord. Roofing consists of 24-lb asphalt shingles, and insulation is fiberglass.

Interior walls within a module are non-load–bearing except for ceilings. Interior walls are designed with standard 1/2" sheet rock on either side of 2" x 3" wood studs.



A. Developmental model of Pemtom UNIMOD 2 units.



B. Model demonstrates the unique appearance of the UNIMOD 2 SFA residential units.

Finish on all interior wall surfaces and ceiling is latex paint over 1/2" gypsum wallboard. Floors are covered with shag carpeting or vinyl flooring. Cabinets in the kitchen and bath are prefinished and have plastic laminate countertops and backsplashes.

Foundations are designed for individual site conditions and can be varied to give architectual relief through the use of vertical and horizontal offsets. A soil bearing capacity of approximately 3,000 lbs per square foot is required when modules are stacked two high. Piers and spread footings are required on large overhangs. Concrete block basements are optional.

Each dwelling unit has its own central, forced air heating system with a natural gas furnace. The furnace discharges conditioned air into a plenum above the equipment room. From there it is distributed to registers along outside walls of the upper and lower module through a metal duct system built into the ceiling of the first floor. Air quantities to each register are adjustable by means of dampers on the supply air registers. Return air is filtered before it is recirculated to the conditioned space.

Supply air ductwork is round or rectangular galvanized steel. Duct interface connections between modules are equipped with flange and gasket or with flexible ducting.

Mechanical refrigeration is added to the forced air heating systems as an option by the addition of a direct-expansion cooling coil to the furnace and a remote air-cooled condensing unit. Cooled and dehumidified air is distributed to each module through the same system used for warm air. The remote condenser unit is factory installed in an exterior wall of the dwelling unit and has resilient mounts to minimize noise and vibration.

Bathrooms are provided with fans that exhaust to the outside. Kitchens have non-ducted range hood-fans. Movable windows, with screens, are used for natural ventilation.

Water is supplied from the underground water main to each housing unit through an all copper system. An individual water meter is located in a pit near the front of each unit. Hot water is provided by a gas water heater factory installed in the utility room of each dwelling unit. Piping is not insulated except when the modules are to be installed over a crawl space.

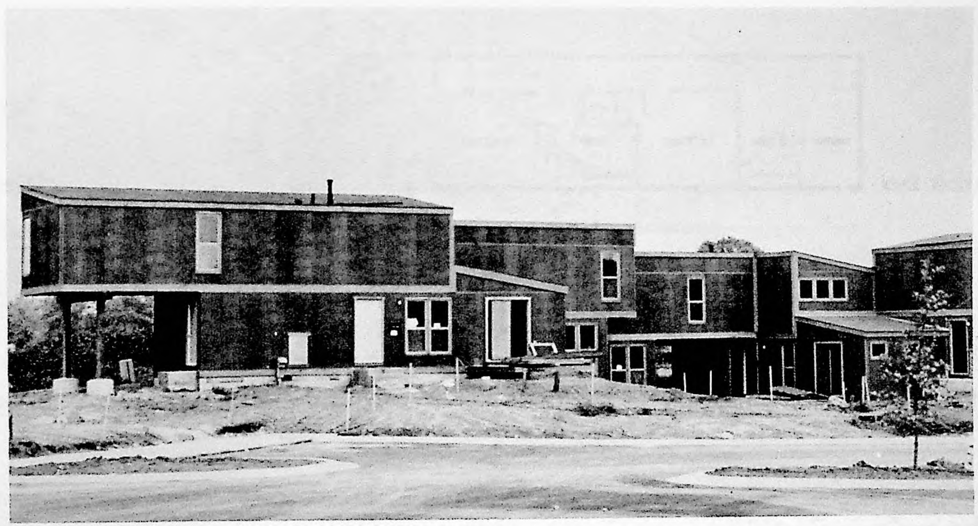
The factory installed drainage, waste and vent piping is field connected to an underground cast iron sewer system at the first floor utility room. Piping within each module is ABS pipe.

All water distribution piping, waste and vent piping within each module is factory installed. Interconnections between modules are made in the ceiling of the furnace room.

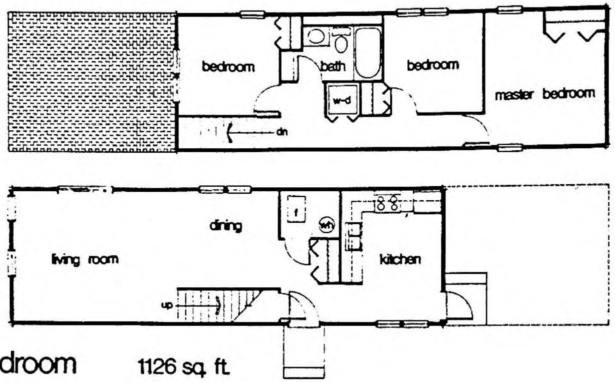
Plumbing fixtures are conventional with the exception of a one piece fiberglass tub and enclosure. A laundry area is provided for the installation of a washer and dryer by the homeowner.

Electrical service is connected from an underground distribution system to a meter on the outside of each housing unit. The 115/230 volt system feeds through a 100 ampere service panel.

Grounded, non-metallic sheathed cable is factory installed before the exterior siding is applied, except for that required for furnace room intermodular connections. If branch circuits are required to extend beyond a floor panel, a sufficient amount of cable is provided to connect wall, ceiling fixtures, outlet receptacles or switches when wall or ceiling panels are assembled into modules in the factory. All lighting fixtures, including exterior lighting, are factory installed. Telephone service is factory installed in the floor or wall panels before assembly into modules.



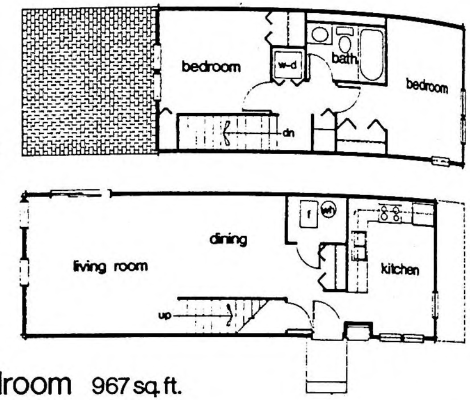
C. Pemtom units nearing completion at Indianapolis BREAKTHROUGH site.



upper level

lower level

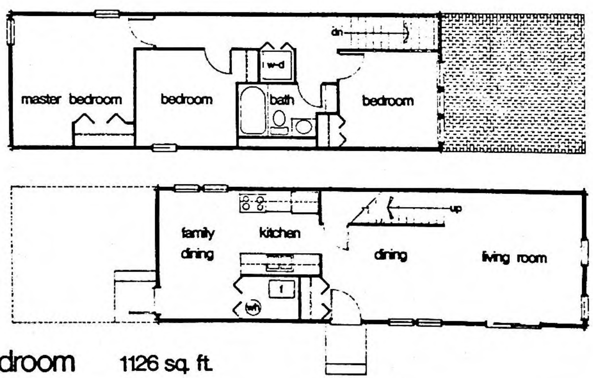
three bedroom 1126 sq. ft.



upper level

lower level

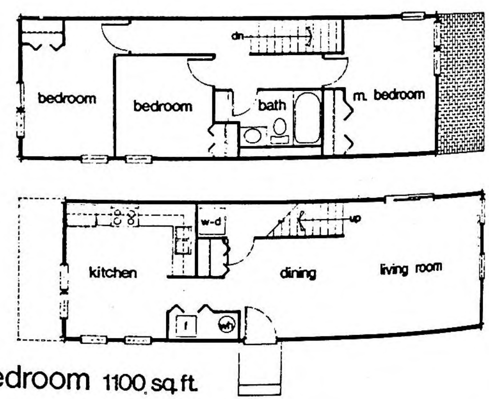
two bedroom 967 sq. ft.



upper level

lower level

three bedroom 1126 sq. ft.

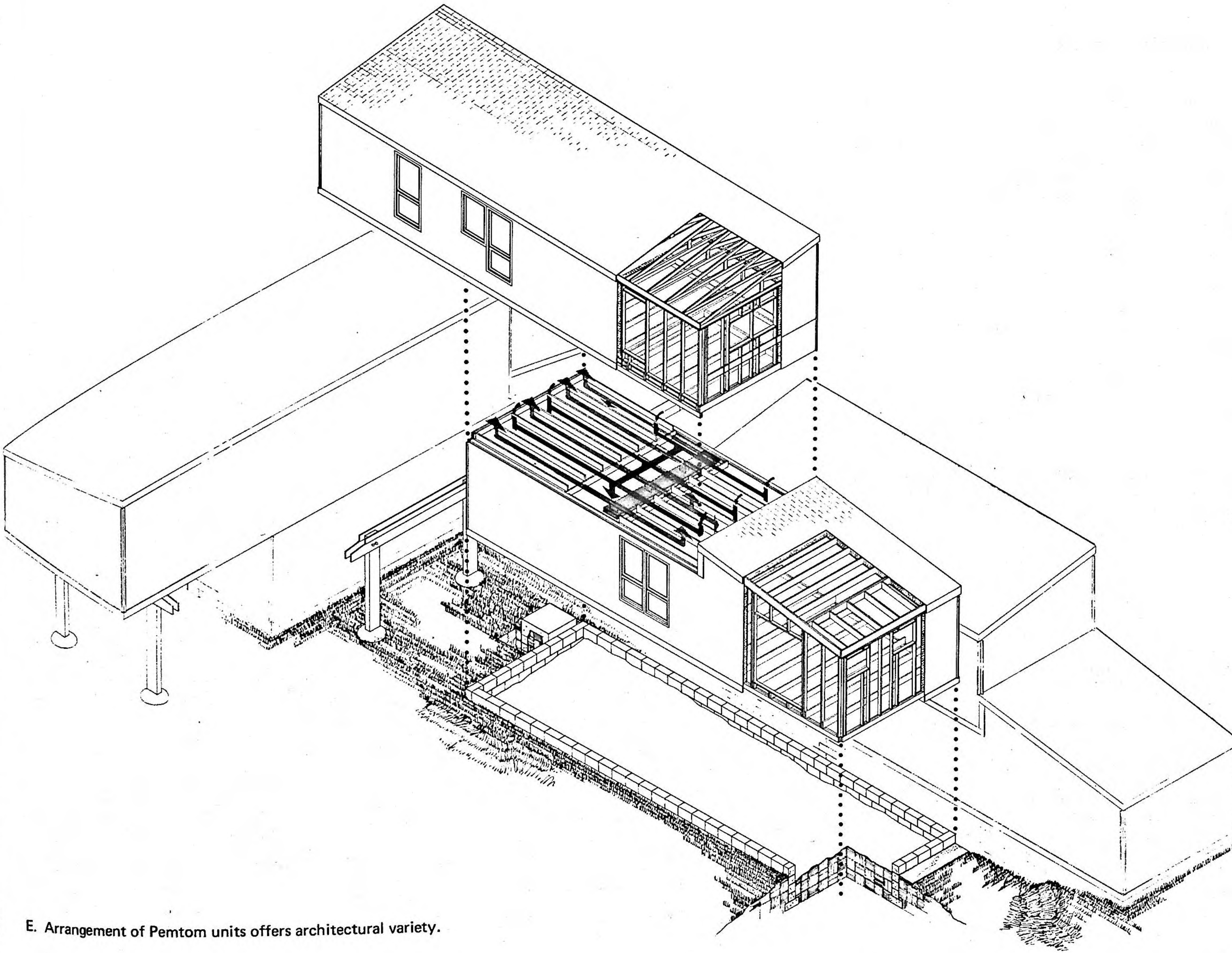


upper level

lower level

three bedroom 1100 sq. ft.

D. Floor plans.



E. Arrangement of Pemtom units offers architectural variety.

INNOVATIVE FEATURES

Pemtom's system combines the benefits of factory production and conventional elements of construction, resulting in a uniquely designed two-story townhouse. By using a structural adhesive, nailing is required only to assure proper panel alignment and adhesive contact. An innovative method of connecting the wall panel to the floor panel is used. Pemtom uses 24" stud spacing with the stud extending below the floor line to lap the end of the floor joist. This provides superior strength for shipping, wind loads, and clear spans of up to 12 feet.

Pemtom completes all work on each module in the factory to the greatest extent possible. Thus, under controlled working conditions and at a low plant labor wage rate, Pemtom is able to avoid the high field wage scale, uncertainties of bad weather, and the uncertainty of labor availability at the site. Pemtom has minimized the number of modules involved for one living unit thereby minimizing handling, transportation, weatherproofing, and connection costs.

The housing system components are incorporated into a design that is based on existing codes and the Operation BREAKTHROUGH Guide Criteria.

MAJOR DEVIATION FROM THE ORIGINAL PROPOSAL

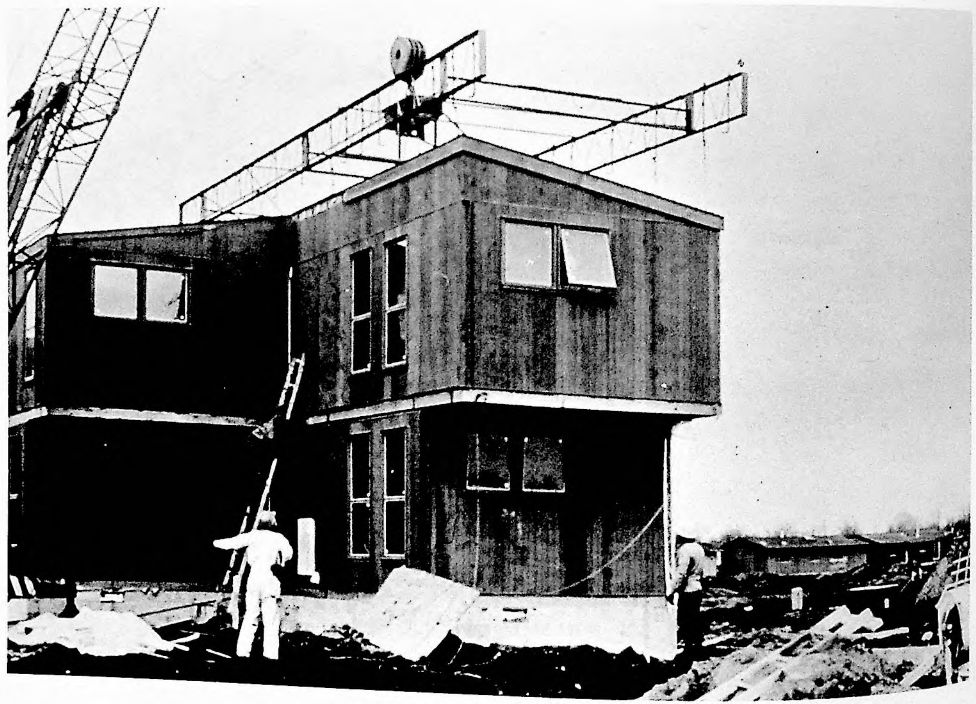
During February 1971, the original concept proposed by Pemtom for Operation BREAKTHROUGH was abandoned. This concept, UNIMOD No. 1, was based upon:

1) The use of plywood stressed-skin panels for walls, floors and ceilings, with egg-crate web cores in floors and ceilings. The panels used a 3M polymer adhesive without nails or other mechanical fasteners.

2) The use of multiple modules that could be handled by smaller erection equipment.

During Phase I it became apparent that the adhesive used in the panels could not be tested for long term effects of aging, shear and moisture within the BREAKTHROUGH Program time period. As a result, HUD could not approve its use. Without the approval of this adhesive, the entire structural concept of UNIMOD No. 1 had to be dropped.

During Phase I it also became apparent that the multiple module concept for a single family house had inherent costs higher than those originally anticipated. The existence of so many duplicate components and modules resulted in more handling during loading, transportation and setting. Weatherproofing of so many sides and tops for shipment along with multiple field connections between many modules proved prohibitively expensive.



F. Erection of UNIMOD 2 units at Indianapolis BREAKTHROUGH site.

PRODUCTION PROGRAM

The Pemtom plant was located less than 30 miles by truck from the Indianapolis Breakthrough site. Production of the UNIMOD No. 2 modules demanded both skilled and semi-skilled personnel who were available at a considerably less cost than the prevailing field construction rates.

With only 20 townhouse units required at the Indianapolis site, volume production advantages could not be realized. The 30,000 square foot plant was designed to handle a single assembly line and was not suitable for expansion.

UNIMOD No. 2 modules are shipped from the plant complete on the inside and outside to minimize on site work. The only work to be completed on-site was to be limited to the conventional block foundation and concrete pier, erection of the modules, inter-module connections, utility connections, final trimming and finishing, and the repair of transportation/erection-caused damage. After the first UNIMOD No. 2 modules were delivered, the practice of finishing the gypsum board and painting the interiors in the plant was abandoned. This was done to minimize the quantity of rework required on the job site.

ECONOMICS OF SYSTEM

The cost of completed UNIMOD No. 2 modules, FOB the Pemtom factory, exceeded estimates made at the time the UNIMOD No. 1 concept was abandoned. When the production costs of UNIMOD No. 2 were considered, along with transportation and site erection cost, most of the economic advantages of the UNIMOD No. 2 system appeared to be lost.

MARKETING

Because the UNIMOD No. 2 system does not appear to have the economic advantages originally anticipated, Pemtom has elected not to market this system under the BREAKTHROUGH Phase III program.

> Pemtom Phase II units are located at the Indianapolis prototype site – 20 SFA.

Summary Information

SYSTEM APPLICABILITY	
Location	Rural, suburban, urban.
Density Range	8 to 15 per acre.
Environmental Adaptability	Adaptable to all climate and normal soil conditions.
Non-Residental Functions	Recreational and social functions.
Site Planning Services	Performed by associates.
BUILDING SYSTEM DESCRIPTION	
Housing Types	Single family attached; single family detached.
Unit Variations	Design to suit intended function.
Structure	Self-supporting wood frame module.
Exterior Elements	Balconies, patios, decks.
Foundations	Design to suit conditions.
Comfort System	Individual heating and cooling systems using natural gas.
Plumbing	Conventional and P.V.C. pipe where applicable; integral with module.
Electrical	Conventional; integral with module.
Furnishing	Optional.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Factory produced modular construction; polymer structural adhesive.
Codes	Adaptable to all National Model Codes.
Deviations from Original O/B Proposal	UNIMOD No. 1 based upon stress skin plywood panels using polymer adhesive bonded "egg crate webbing" between plywood skins. All mini modules had to be dropped. UNIMOD No. 2 is more conventional modular construction using dimensional lumber.
PRODUCTION PROGRAM	
Delivery Rate	No current plan for manufacturing beyond original 20 required for Indianapolis.
Off-site Production	Construct complete modules except for finish sheet rock, trim and paint.
On-site Installation	Connect modules and utilities.
On-site Construction	Prepare foundations, erect modules.
Internal Functions	Design and production.
External Functions	Site planning development and erection.
LABOR REQUIREMENTS/TRAINING PROGRAM	Skilled and semi-skilled personnel required for production and erection.
ECONOMICS OF SYSTEM	
Construction Cost	Comparable with higher priced conventional construction.
Transportation Limitation	Approximately 200 miles from plant.
Useful Life	Determined by functional obsolescence.
MARKETING FOR PHASE III	No current plans for marketing units under Phase III Program.

Republic Steel

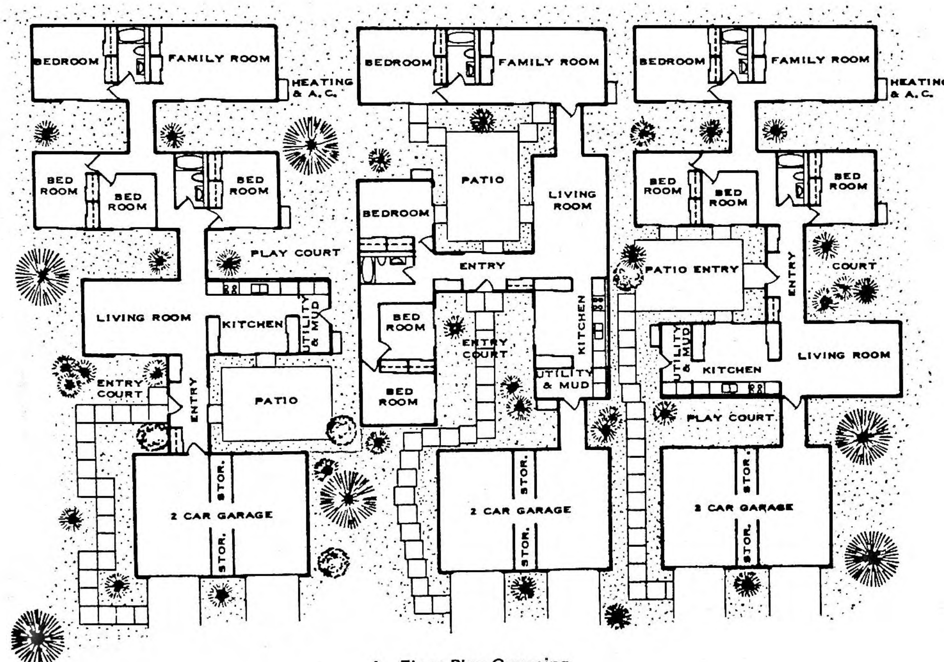
INTRODUCTION AND APPLICATION

The Republic Steel Housing System is a panelized house shipped from the factory to the site for field assembly. A key element in the design has been simplification. Every effort has been made to simplify the field erection so that skilled labor would not be required for erection of the houses.

The components of the house except for the subsystems are of such size and weight that a maximum of three men is required for their erection. The electrical, mechanical, bathroom and kitchen subsystems are completely factory assembled before shipment to the construction site. The kitchen subsystem and the bathroom subsystem are volumetric and require the use of a light crane for unloading and installation. A 1/2 bath in the utility room is optional.

Other unusual features of the Republic Steel System concern site preparation, installation of utilities, and site construction, all of which are completed prior to the arrival of house components on the job. The utility lines are completely and accurately installed to three coordinate dimensions so that after the house is erected the utility connections may be made outside the house with simple, quick acting connectors.

The density range is 4 to 7 dwelling units per acre and the system is environmentally adaptable to all climatic ranges of the United States. While the system lends itself best to flat terrain, it is adaptable to sloping terrain by varying pier lengths above ground or by use of retaining walls to build terraces.



A. Floor Plan Grouping

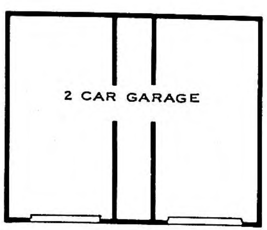
The Republic Steel System is essentially intended as a residential one; however, it is adaptable to non-residential functions such as vacation homes or small offices.

SYSTEM DESCRIPTION

The Republic Residential Housing System was designed to allow the individual owner the privacy and pleasure of his own home. It consists of a single family detached, basement-free, one-story residence so arranged architecturally as to allow for flexibility in floor plans and variations in appearance without sacrificing the standardization needed for industrial production. Houses may be built individually or in groups.

The three bedroom basic house is "H" shaped. One enters the house in the connector module which is the cross bar section of the "H." To the left is the living room, dining room, kitchen, laundry activity module and to the right is the three bedroom and bath sleeping module.

By rotating the "H" shape house 90 degrees clockwise an "I" shaped house is produced. When built in groups of two or more houses, adjacent houses are alternately "H" shaped and "I" shaped (Figure A). This arrangement is an essential part of the system and contributes to the privacy feature of the system design. Each house is planned to have a two car garage. The garage (Figure B) is also an essential feature of the design and it too contributes to the privacy theme inherent in the Republic Steel system.



B. Garage Module

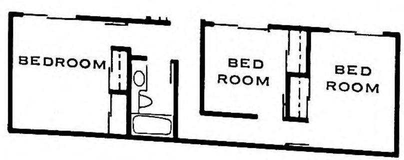
The basic two bedroom house may be expanded to four or five bedrooms by adding on another module. This add-on feature of the Republic Steel system contributes to the design flexibility. It is beneficial to young married families who need not purchase a large house initially. They may start with a basic two bedroom house and add on another module as their family needs increase.

Three basic modules comprise the Republic Steel system: entry module, living room-kitchen-dining-laundry room module and bedroom module.

C. Entry Connector Module

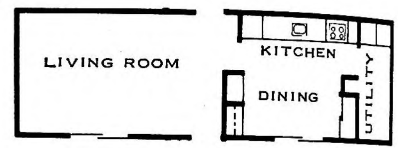
The entry connector module (Figure C) separates the other two modules and allows each to serve its function independently. The entry also is a boundary for each patio and provides access to each. Included in the entry are two closets, one for the occupants and one for guests. The entry module allows guests to enter the home without interfering with activity in any other part of the residence.

The bedroom module (Figure D) provides a master bedroom, two bedrooms for children or guests, and a full bath. Each bedroom has a large patio door opening out onto a patio. The outdoor-indoor effect extends to the bedrooms. The master bedroom has two large closets and each of the other two bedrooms has one large closet. Ample space is provided for normal furnishings. The bathroom is exceptionally well equipped with all usual facilities and two large wall cabinets for towels and supplies.



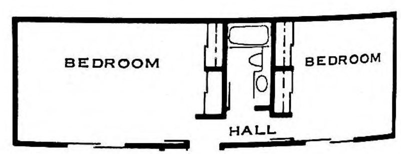
D. Three-Bedroom/Bath Module

The living room-kitchen module (Figure E) provides for the indoor activities of the home. The circulation pattern allows the living room to be free from traffic. The large patio door brings light into the room and provides a pleasant outdoor-indoor relationship. The kitchen portion of the module is located to serve the food preparation function. The dining portion of the kitchen area looks out onto the rear patio. Next to the kitchen is the laundry area where ample space has been provided for this function. A half bath may be installed in this area without impairing the normal functions.



E. Living Room/Kitchen/Utility Room Module

The add-on feature of the design (Figure F) provides for a family room, a master bedroom and a bath for the "H" shaped house or two large bedrooms and a bath for the "I" shaped house. Access to the add-on module is from the kitchen in the "H" shaped house and from the kitchen end of the living room in the "I" shaped house.

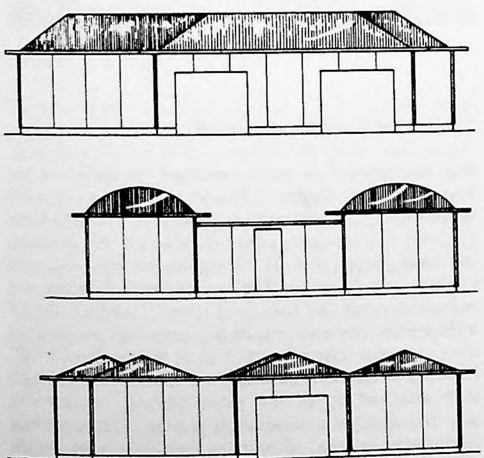


F. Two-Bedroom/Bath or Family Room/Bedroom/Bath Module

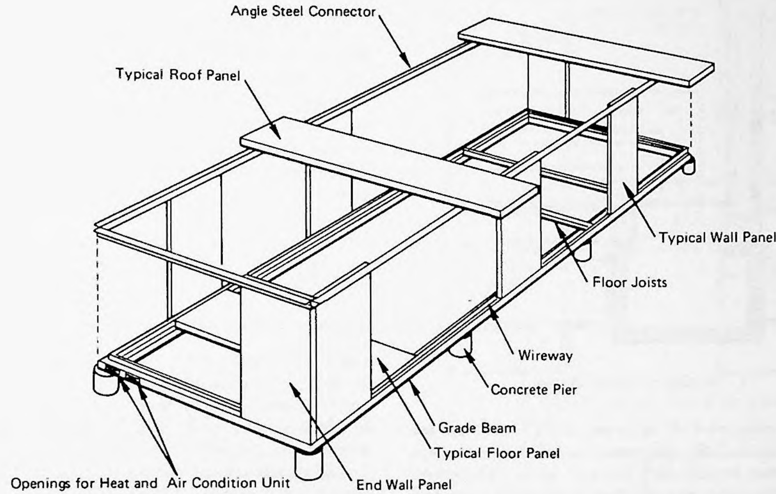
The two car garage is placed in the front of the house. This effectively blocks off the view of the front patio from the street. With a small amount of decorative fencing, the front patio becomes completely private if desired.

The patios which are so much a part of the Republic Steel design provide private spaces for small children to play and also delightful spots for outdoor cooking and entertaining when the weather permits.

A variety of facade treatments (Figure G) individualize the houses in the Republic Steel system. These treatments are principally decorative and add individual style to the flat roof of the house.



G. A variety of rooflines is offered



H. View of Structural Framing

The Republic Steel system is aimed at optimum use of land in relatively high density suburban areas. The system attains this goal while still maintaining the single family detached residential privacy.

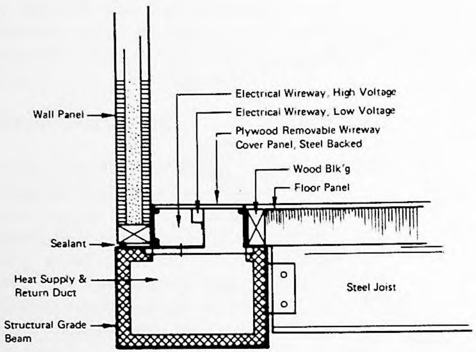
The general structural design of the Republic Steel System (Figure H) consists of components field-assembled into modules. The design incorporates sandwich panels for the roof, floor and walls, and formed steel joists and grade beams for the floor framing. The grade beams rest on concrete piers for the foundation. The panels all have essentially the same cross-section, a requisite for mass production. The grade beam supports the floor joists and the sidewall panels. The sidewall panels support the roof panels.

There are eight 24" diameter concrete piers supporting each module. These piers are easily formed by an earth auger of the proper diameter. While allowable soil pressure may permit the use of smaller diameter piers in some areas, the 2-foot diameter is generally utilized. The two entry connector module grade beams are each supported by piers at mid-span. The ends of these beams frame into the grade beams of adjacent modules.

The grade beam (Figure I) is a galvanized formed steel box beam which serves as a structural support for the floor and wall panels as well as a duct for HVAC air distribution system. It contains a raceway for the electrical distribution system. This multi-purpose member is furnished in convenient lengths. When field spliced, this results in an airtight and watertight duct system. Thermal insulation inside the beam prevents heat loss and absorbs airborne noise resulting in a most efficient air distribution system.

The grade beams span between piers and carry the floor and roof loads to the foundations or serve as forms when the floor is a concrete slab.

Formed steel channel joists spaced on 4'-4" centers to coincide with the floor panel joints provide the floor panels with full perimeter support. These joists frame into the grade beams and are attached with field bolted connections.



I. Section at Grade Beam

The floor panels are 4'-4" wide and 3 3/8" thick and are composed of a 3/8" plywood top skin, a 26 gage galvanized steel bottom skin and a 3" paper honeycomb core. The floor panels are attached to the floor joists and grade beams with adhesive sealant. Each panel is fully supported and sealed on all four sides. This is designed to give the floor maximum stiffness, avoid uneven deflection of adjacent panels, and to seal out moisture.

Electrical-Mechanical Subsystem

The four subsystems of the Republic Steel system are electrical distribution and lighting, heating and air conditioning, kitchen and laundry, and bathroom subsystems. Each of these subsystems has been designed for a maximum of factory assembly and prefabrication and a minimum of unskilled field work for installation. These subsystems are complete packages as shipped from the factory. Simple on-site connections are all that is required to make each of them functional. By careful coordination, the interfaces between subsystems and the interfaces between each subsystem and the main system have been reconciled.

Electrical Distribution and Lighting Subsystem

The power distribution and lighting concepts selected in accordance with basic requirements of Operation BREAKTHROUGH provide an innovative system that will reduce building costs and provide for more rapid and efficient construction techniques. The power distribution concept developed by Republic Steel employs aerospace techniques used for prefabricated aircraft wiring assemblies and reduces to a minimum on-site electrical wiring. The basic lighting concept provides a residential illumination atmosphere that surpasses residential lighting standards established by the Illumination Engineering Society. The subsystem includes factory-assembled wiring, sometimes referred to as a harness, unique surface-mounted receptacles and switches, new lighting fixtures, standard fixtures, low voltage wiring for signal communications and mated color coded connectors for quick, foolproof field installation.

Heating and Air Conditioning Subsystem

The heating and air conditioning subsystem has been designed and developed especially for the Republic Steel system. Each 13' x 43' module has its own heating and air conditioning unit and distribution system. This arrangement permits zone control for each module and simplifies the add-on feature. A unique feature of the system is the placing of the heating and air conditioning unit outside the house or module. This conserves inside floor space. Another unusual feature of the subsystem is the use of the interior of the box shaped grade beams as supply and return air ducts for the air distribution system thereby eliminating costly duct work.

A single self-contained package combining heating and air conditioning and measuring 48" x 37" x 20" is mounted to the grade beam at the bottom of the outside wall at one end of each module. It has a rated cooling capacity of 17,500 BTU/Hr and a heating capacity of 37,500 BTU/Hr with gas or 34,000 BTU/Hr with electricity. No chimney or flue is required for this innovative economical system.

The heating/cooling air distribution system utilizes the house duct beams. Conditioned air is supplied to the grade beam duct down the patio side of the house module and returned in the grade beam duct on the other side. This provides excellent air circulation for occupant comfort.

The air distribution system for each module consists of six supply registers individually adjustable for air flow control. The return air system consists of five non-adjustable registers. All registers are a nominal 2 1/4 x 14 inch size and finished in a neutral color.

The entry connector module gets its conditioned air from the adjacent modules through registers located at each end of the connector directed toward the entry.

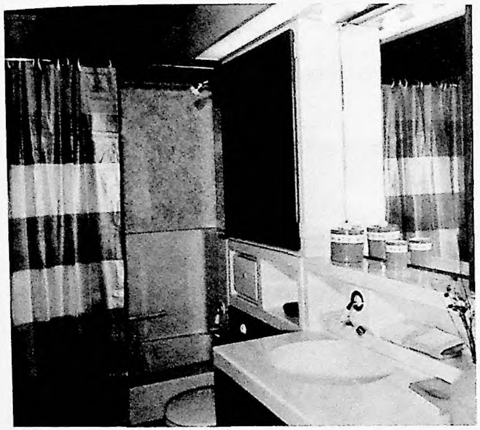
Maintenance is simplified by easy accessibility since the units are in the open and a panel can be quickly removed, exposing the interior. If necessary the entire unit can be easily lifted off the grade beam mounting and replaced by another unit.

J. Kitchen/Laundry Subsystem

Kitchen and Laundry Subsystem

The kitchen and laundry subsystem developed for the Republic Steel System (Figure J) represents a major breakthrough in subsystem design for industrializing housing. The concept permits for the first time economical mass production of an engineered and integrated kitchen and laundry. The completed subsystem is a volumetric unit 20 feet long, seven feet high and 28 inches deep. The elements of the subsystem are mounted on a plywood base and attached at the back to a 1 1/8" Novoply stress wall. Basically, the unit consists of a wall with attached upper and lower cabinets, counter top, and the following selected appliances: 12 cubic foot refrigerator, range, dishwasher, stainless steel double sink, disposal, clothes washer, dryer, wall cabinets and a 30 gallon electric hot water heater.

All of the plumbing and wiring for the entire unit is factory installed. When the water, sewer, and electric lines are connected the unit becomes operable. Lifting hooks located at predetermined positions on the stress wall enable the unit to be lifted by a light crane with a sling.



K. Bathroom Subsystem

Bathroom Subsystem

The bathroom subsystem (Figure K) is a totally integrated volumetric module, containing bathtub, water closet, and lavatory with associated water supply and waste fittings. In addition, the unit contains a pre-plumbed hot and cold water supply system, a pre-plumbed drain, waste and vent system, a point of use (under counter) hot water storage heater, vent fan, and auxiliary heater. The total unit is prewired for all electrical requirements. In addition, a storage "unit," medicine cabinet, mirror, lighting fixture, and tub are provided as part of the subsystem.

Furnishings

Furnishings include: (1) carpeting and (2) valance type indirect lighting, including drapery track over each sliding glass door.

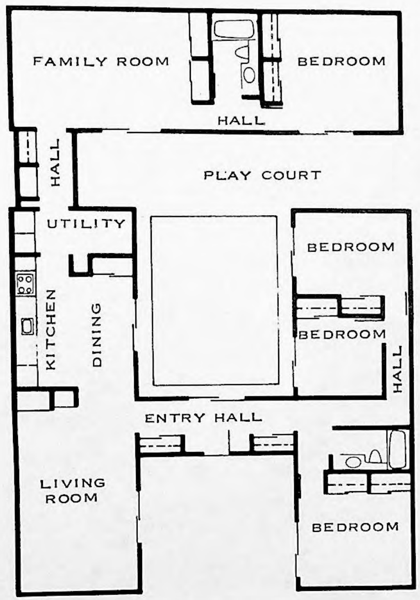
DEPARTURES FROM CONVENTIONAL SYSTEMS

Innovative Features

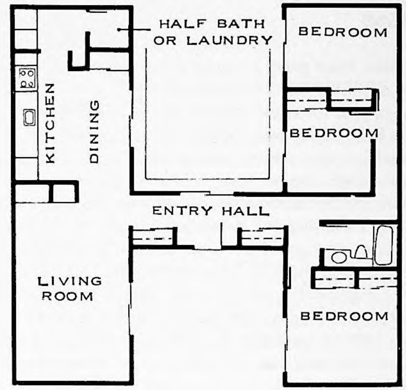
The innovative features in the Republic Steel system are the structural panel system and the mechanical, plumbing and electrical subsystems.

Codes

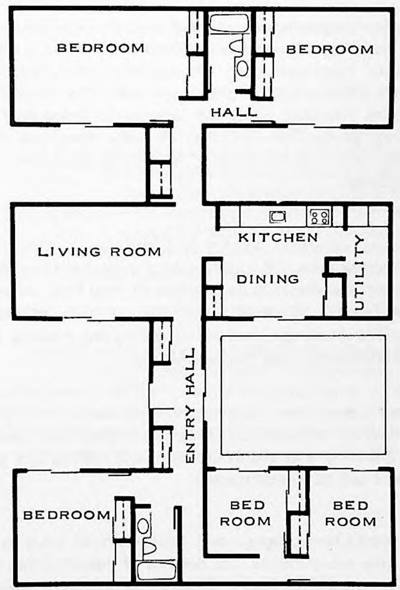
The Republic Steel Housing System is adaptable to all national model codes.



L. Four-Bedroom, Family Room, Two Bath plan



M. Two-Bedroom, one Bath plan



N. Five-Bedroom, Two Bath plan

OPTIONS

The three floor plans (Figures L, M and N) are some of the possibilities of arrangement and illustrate the flexibility of the Republic Steel system. These house plans range from two bedrooms to five bedrooms. Other possibilities than those shown can be very easily arranged. Each floor plan includes the living room, kitchen, utility room module and the entry connector module. Variations are developed by adding modules to these two modules. Each plan utilizes basic floor plan modules. Each module, while constructed at the job site from components, has its own basic floor plan and appearance. Actually, the modules can be arranged in an almost infinite variety of floor plans to satisfy individual needs, proper land use, and environmental variety.

PRODUCTION PROGRAM

The planned production program provides a minimum of 500 housing units and a maximum of 3,000 housing units per plant each year. The optimum production rate will be 2,000 units per plant each year. The number of factories Republic Steel will operate is being studied. Factory production includes: (1) wall, floor and roof panels, and (2) mechanical, plumbing and electrical subsystems.

Onsite construction activity will include: (1) formation of concrete piers, (2) installation of steel grade beams to the concrete piers, (3) installation of steel floor joists to grade beams, (4) panel assemblies to form modules, (5) utility hook-ups, and (6) attaching the heating and air conditioning units to grade beams.

Project management, development, production and coordination will be provided by Republic Steel while design and planning and bathroom and kitchen/laundry subsystems will be subcontracted.

The production program will require skilled labor to set rolls, dies and punches. The balance of inplant effort will require unskilled labor. Except for utility hook-up, unskilled local labor will be utilized for onsite housing erection.

ECONOMICS OF THE SYSTEM

Estimated construction costs for the Republic Steel system are $20,000 for a 3 bedroom unit and $25,000 for a 4 bedroom unit.

Transportation of the housing units will be limited to a 500 mile radius from production plants.

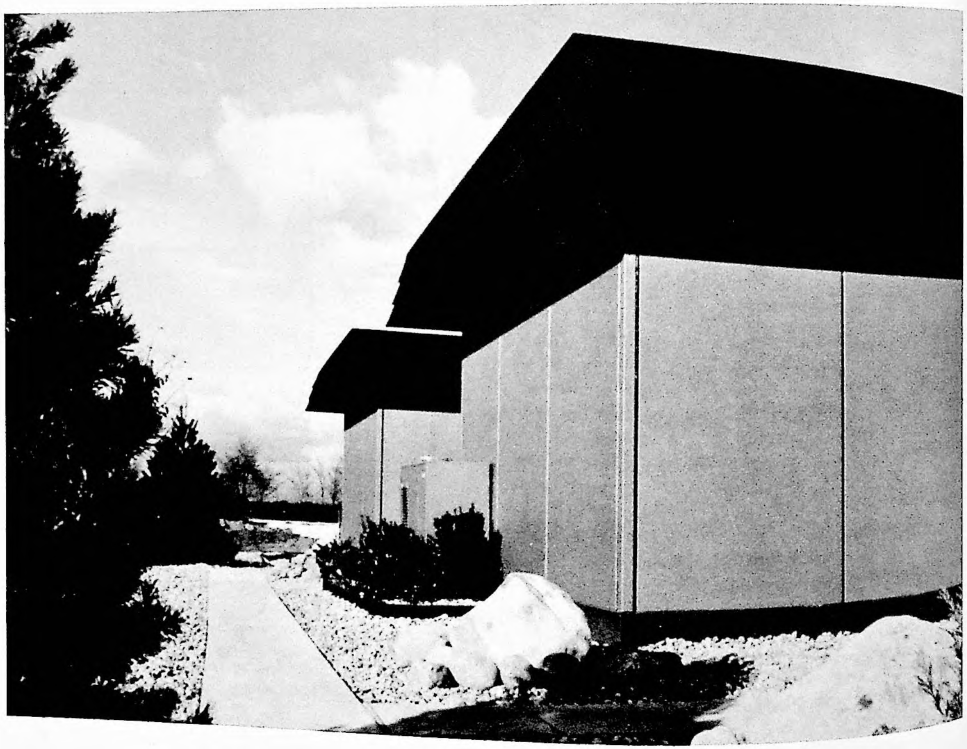
The anticipated useful life of this housing system is 50 years for the structural system and 8 to 10 years for the mechanical subsystems. Estimated maintenance costs are anticipated to be low and somewhat less than conventional housing systems.

MARKETING FOR PHASE III

The Republic Steel Corporation marketing plan for its housing system is to utilize existing conventional techniques. Meanwhile, studies are being performed to improve current methods of marketing or develop new methods.

Other activity in the housing business include: (1) entry into land development and 100% controlled projects, and (2) joint venture.

Currently, Republic Steel is experimentally involved in several projects and plans include participation in others.



Questions or additional information pertaining to the Republic Steel Housing Program may be directed to Mr. P. C. Ziegler at:

Republic Steel Corporation
General Office
Republic Building
Cleveland, Ohio 44101
Telephone (216) 574-7100

Republic Steel Phase II units are located at the Kalamazoo prototype site — 4 SFD.

Summary Information

SYSTEM APPLICABILITY	
Location	Suburban; rural.
Density Range	4 to 7 units per acre; 10 to 50 dwelling units per site.
Environmental Adaptability	Adaptable to all national climates, normal topography and soils.
Non-Residential Functions	Vacation homes and small offices.
Site Planning Services	HSP's land planner; plan review and control process.
BUILDING SYSTEM DESCRIPTION	
Housing Types	Single family detached; adaptable to single family attached; multi-family low-rise.
Unit Variations	One to five bedrooms.
Structure	Steel-faced floor, wall and roof panels combined with horizontal steel angle frame.
Exterior Elements	Conventional finishes possible; entry modules; garages.
Foundations	Steel beam and concrete pier or conventional.
Comfort System	Exterior heating-cooling unit; perimeter ductwork in foundation beams.
Plumbing	Component bathroom and kitchen-laundry wall system.
Electrical	Prefabricated wiring harness and raceway power distribution.
Furnishing	Carpeting; valance type indirect lighting including drapery track over each sliding glass door.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Structural panel system; mechanical, plumbing and electrical subsystems.
Codes	Adaptable to national model codes.
Deviations from Original O/B Proposal	None.
PRODUCTION PROGRAM	
Delivery Rate	3,000 units per plant per year, best rate.
Off-site Production	Wall, floor and roof panels; mechanical, plumbing and electrical subsystems.
On-site Installation	Panel assembly; add-on modules; utility hook-ups.
On-site Construction	Foundations; site preparation; utility lead-ins.
Internal Functions	Project management; development; production; coordination.
External Functions	Design and planning; bathroom and laundry subsystem.
LABOR REQUIREMENTS/TRAINING PROGRAM	Skilled and unskilled inplant and onsite; technical training courses at HSP's industrial education institution.
ECONOMICS OF SYSTEM	
Construction Cost	$20,000 per 3 bedroom unit; $25,000 per 4 bedroom unit.
Transportation Limitation	500 mile radius from production plants.
Useful Life	Structural system—50 years; mechanical subsystem—8 to 10 years.
MARKETING FOR PHASE III	Yes, using conventional marketing techniques. Marketing plans being developed currently.

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Rouse-Wates

INTRODUCTION AND APPLICATION

Intended primarily for multi-family high, medium and low rise structures, the Rouse-Wates system is applicable to a variety of urban, surburban or urban renewal situations. This system, which is based upon pre-cast concrete panels, is also applicable for commercial and institutional functions.

The Rouse-Wates system offers design flexibility. Dimensionally, the precast elements are based upon a one foot grid for buildings up to 26 stories. This system employs the gravity structure principal, minimizes types of components and utilizes the optimum capacity of the cranes and other lifting equipment.

The system's flexibility is displayed in the 241 Operation BREAKTHROUGH units at St. Louis. The housing mix consists of 8 different apartment and duplex types in 13 buildings of the high, medium and low rise categories. Typical floor plans are shown in Figures A, B, and C.

Precasting can be done at on-site factories or in a central factory with elements transported to the job. In either case, as much of the building material as possible is composed of precast or prefabricated elements. To minimize on-site finishing, use is made of such prefabricated subsystems as pre-hung door units, heating, ventilation, air conditioning and plumbing core units, and pre-packaged kitchen/bathroom units.

The Rouse-Wates Company, a joint venture between Wates Limited of London, England and The Rouse Company of the United States was formed in May 1970 to:

(a) Develop residential communities for their own account,

(b) Contract to construct apartment projects for others, and

(c) License the Wates system to other developers.

The Rouse-Wates Company has exclusive marketing right to the Wates system in the United States.

Wates, Ltd., the British partner in Rouse-Wates, Inc., is one of the world's largest producers of dwelling units and is responsible for 20 percent of the new housing in post-war London.

The Rouse Company, one of the largest mortgage banking firms in the United States, developer of the new city of Columbia and developer-manager of shopping malls in 10 states and Canada, brings its community development experience to the jointly owned building firm.

The Wates system was developed in Britain during the 1960's. Its development resulted in the refinement of many techniques and quality control procedures applicable to pre-cast panelized housing systems. To date 16,500 dwelling units have been built utilizing the Wates system. The Operation BREAKTHROUGH contract has resulted in expanding and developing additional techniques and procedures as the Wates system was adapted to the U.S. market, codes and construction practices.

The Wates system has recently been described as a cost oriented technology that is geared to the needs of the market while being responsive to the requirements of the client and designer. This system offers optimum balance between factors that naturally interact—economics, speed, aesthetics, and productivity—while at the same time permitting great flexibility.

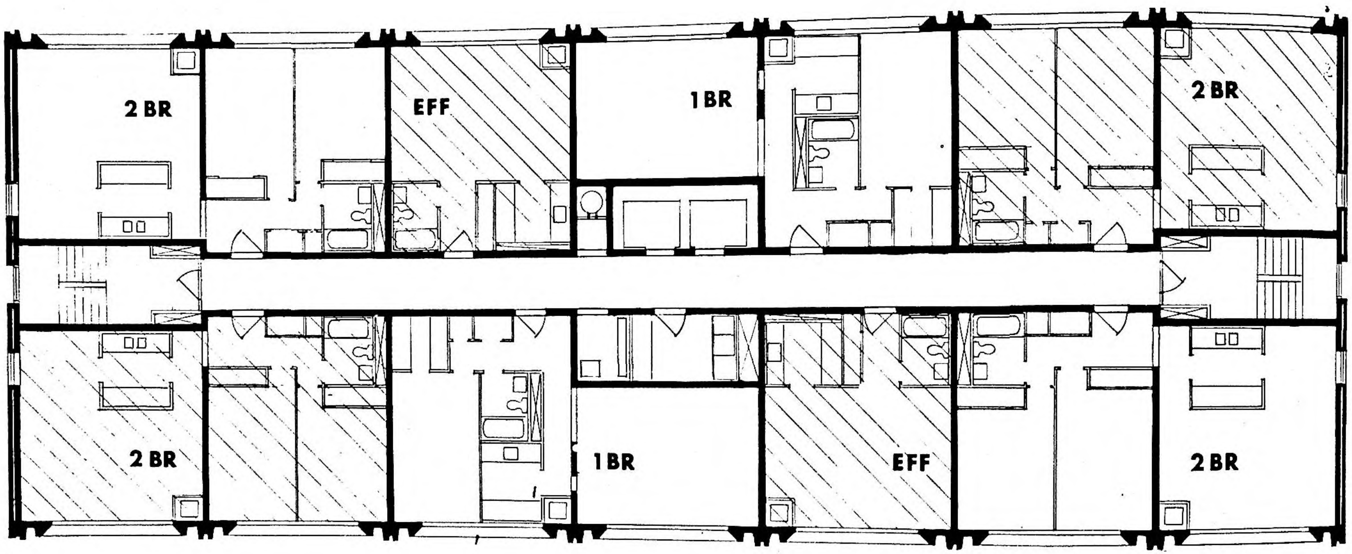
SYSTEM DESCRIPTION

STRUCTURE—The Rouse-Wates system is based upon the gravity structure principal and utilizes story-high precast concrete walls along with floor and roof panels which are hoist into position by tower cranes. This system has been successfully demonstrated in buildings up to 26 stories high. Although this system is designed to prevent progressive collapse, the height of buildings is limited by code to 160 ft. in seismic zones 2 and 3. General photos of the erection process are shown in Figures D through F.

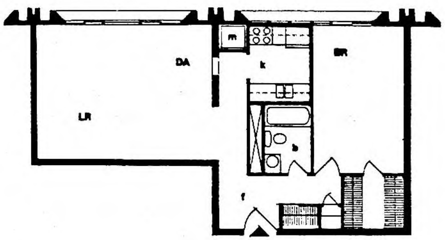
Specific details of the system follow:

FOUNDATIONS—To allow for a variety of site conditions and characteristics, foundations and substructure are cast in place.

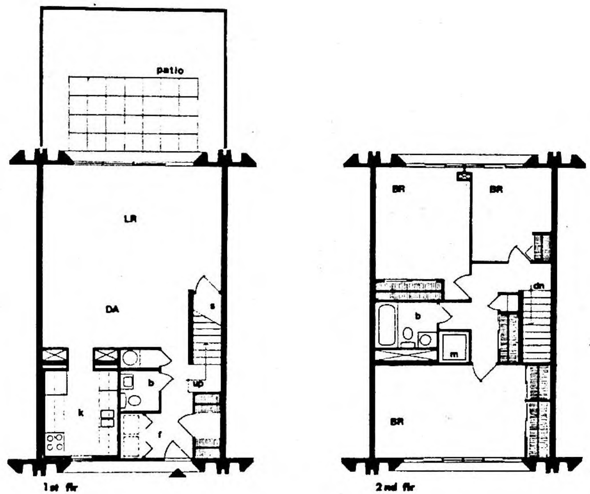
FLOORS—Slabs are of solid normal density, reinforced concrete and are designed as simple supported single span members. Normally, slabs are 6-1/2" thick for spans up to 16 ft., 8" for spans 17 to 20 ft., and 9" for spans between 21 and 22 ft.



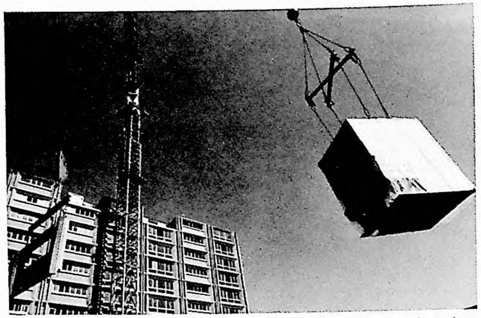
A. Plan – Multi-Family High Rise Structure



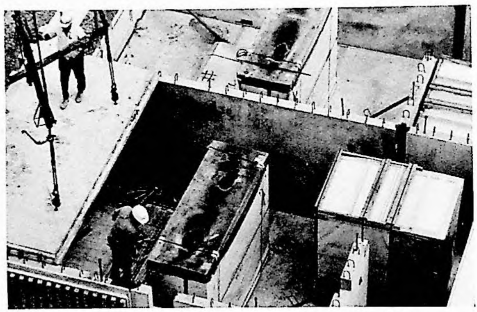
B. High Rise One-Bedroom Apartment



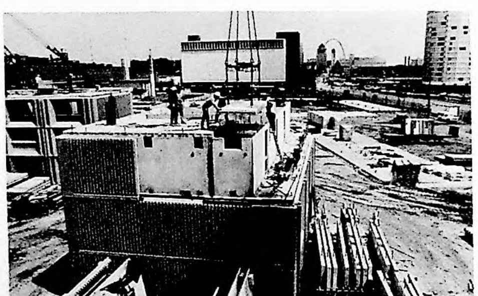
C. Low Rise Three-Bedroom Apartment



D. Tower cranes lifting exterior facade panel and pre-packaged kitchen module



E. Pre-packaged kitchen and bath modules ready for expansion into place



F. Third-floor construction—St. Louis Operation BREAKTHROUGH Site

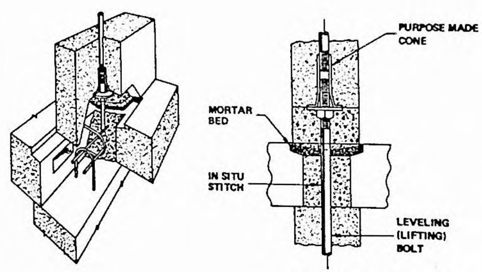
WALLS—Panels are 7" thick, solid, normal density concrete. Loadbearing walls are reinforced to resist forces due to lateral and eccentric loads. When erected, exterior and interior walls are complete with finish.

Acoustical privacy is assured due to the sound transmission loss of the heavy concrete structured walls and floors, which are rated at 51 decibels. Other dividing partitions, if not of concrete (usually gypsumboard assemblies or prefabricated panels, precast to required size and with all holes and cutouts), are rated up to 47 decibels. These ratings are superior to transmission losses normally found in apartments.

JOINTS—Joint design achieves complete continuity between panels to allow the structure to act as a series of monolithic story height rigid tables bedded one upon the other. A sketch showing joint details is shown in Figure G and an actual photo is shown in Figure H.

ERECTION—Precast walls are erected and leveling is facilitated by the use of leveling bolts with bearing washers held on top of hexagon nuts. Floor slabs are positioned upon the walls and joint "stitched" with structural concrete. The exterior envelope is erected at the same time to produce a waterproof enclosure.

Temporary bracing of vertical panels is by adjustable push-pull steel props secured to floor slabs.



U.S. Patent No. 3566560

G. Internal crosswall-to-floor joints feature steel loops and interlocking crossbars. Joints are filled with cast-in-place concrete to provide complete rigidity

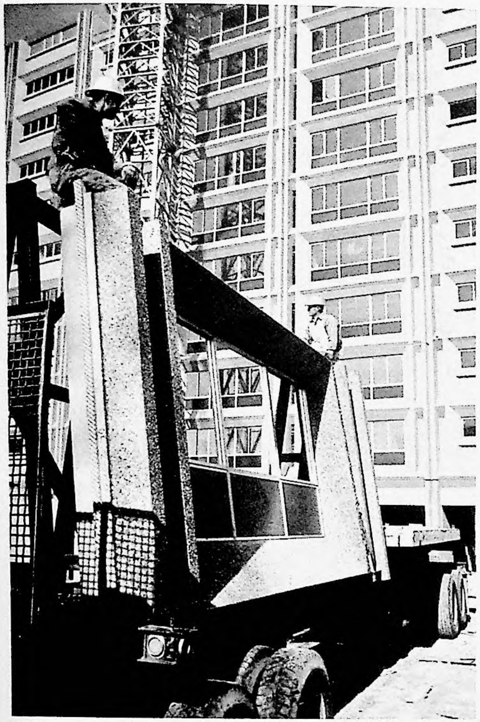
PRE-CAST CONCRETE CLADDING—Cladding may be load bearing or nonloadbearing, insulated or uninsulated, with profile and finish as desired. Exterior appearance of the concrete panels can be varied considerably by the use of exposed aggregate, and sculptured brush or hammered finishes. Brick, stone, wood, or other materials may also be used to provide further variety of appearance. In all cladding, cold bridges are avoided by separating perimeter edges of the concrete structure from the cladding by polystryene insulation board.

Photos of exterior facade used at St. Louis are shown in Figures I and J.

The junction of the horizontal and vertical joint includes a flashing to deflect water to the outer face. This dry jointing method has the advantage of being able to be installed in all weather conditions from the inside of the building. In lightweight cladding, joints are waterproofed with sealants.

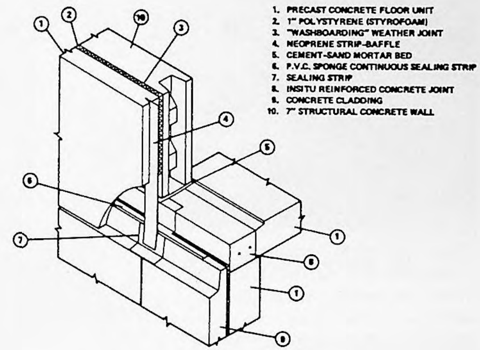
LIGHTWEIGHT CLADDING—Developed with Atlas Minerals, Inc., these prefinished panels have windows and doors installed in the factory. The panel is made up of a 2-1/2" thick core of compressed cement-coated wood fibers, giving a fire rating of 2 hours, and an exterior finish of portland cement, fill-coated with epoxy which is followed by an acrylic stucco finish. The interior face is unfinished for direct field attachment of wallboard. Panels are lifted by crane and installed during concrete erection. This material is a potential replacement for masonry construction.

H. Floor panel installation



I. Exterior facade panel, with window frame and HVAC grill, ready for installation

J. Ribbed exposed aggregate—St. Louis Site

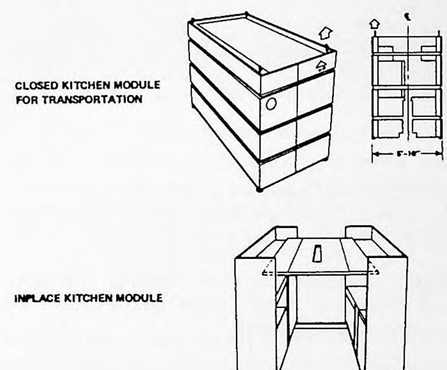


K. Precast concrete weathering joint

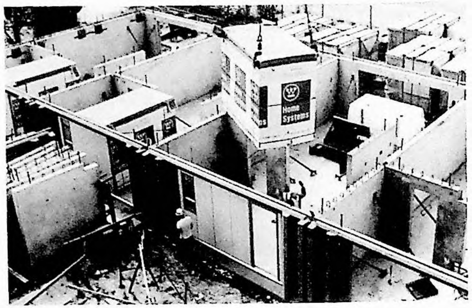
WEATHERING JOINTS—The jointing between pre-cast concrete cladding panels is based on the "open drain" principle. The vertical joint uses a loose neoprene baffle, the horizontal a shiplap principle. (See Figure K.)

KITCHEN MODULES—Developed with Westinghouse Corporation, the kitchen consists of completely furnished interiors including cabinets, range, refrigerator, exhaust ducting and lighting. The module contains the electrical distribution center which is prewired for site connection. BREAKTHROUGH uses a galley type plan which allows the unit to be transported and erected with the appliance walls pushed together to form a protected box. (See Figure L for sketch and Figures M and N for actual photos.) The wood stud structure is drywalled on site.

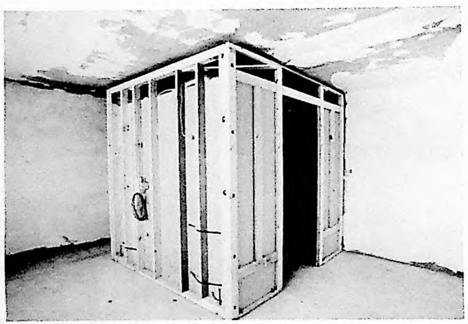
BATHROOM MODULE—Produced by American Standard, the bathroom consists of a completely finished box. The tub, floor and surrounding walls to wainscot height are of molded fiberglass with a "gel coat" finish. Walls are of particleboard with low pressure laminate finish; ceiling is of prefinishes aluminum-faced plywood. The limited area of fiberglass was to overcome fire requirements.



L. Pre-packaged kitchen module



M. Kitchen module lowered into place



N. Expanded kitchen module in place

PARTITION—Non-loadbearing internal partitions utilize steel studs and wallboard erected in the field. Prefabricated partitions proved to be more expensive.

DOORS—Apartment doors are prehung, prefinished, wood doors and frames. These greatly reduce site carpentry and painting costs.

FLOORING—The floor finish is applied directly to the smooth structural slab. For BREAKTHROUGH, a foam-backed sheet vinyl material was used. Other optional floors include: wood blocks, asphalt or vinyl tile, carpet or mosaic tile in bathrooms.

O. HVAC unit

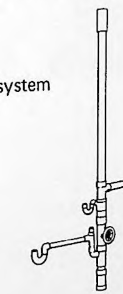
WALL/CEILING FINISH—Prior to decoration, concrete walls and ceiling undergo surface preparation to eliminate imperfections. Walls then receive a splatter paint finish; ceiling, a textured acoustical paint. Options of wallpaper vinyl fabric or acoustical tile are also available in lieu of paint. Similar materials, including wood paneling, may be used for walls. Trim is generally of extruded plastic.

SERVICES—H.V.A.C.—A packaged H.V.A.C. unit was developed with Westinghouse Corporation which affords individual tenant control. The unit consists of a prewired and prepiped condenser/evaporator/furnace that is located inside the apartment. A through-the-wall grill is integrated with the exterior concrete cladding. Electric or gas (with power vented flue) may be used. The complete package is lifted into place during erection. (See Figure O.)

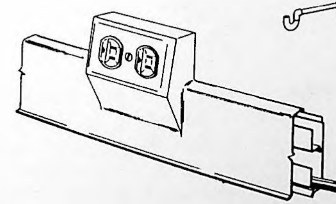
PLUMBING—P.V.C. plastic soilwater and rainwater pipe and C.P.V.C. plastic hot and cold water supply are standard in this system. Fire requirements are met by careful detailing of penetrations of the building systems. Plastic pipes have the advantage of cheaper material costs, lighter weight and simplified jointing techniques over traditional materials.

Single stack plumbing systems (see Figure P) are based on the controlled access of waste into the vertical soil stack, thereby eliminating venting of fixtures. Developed in Britain, its use in BREAKTHROUGH produces significant cost savings.

ELECTRICAL—Power, T.V. and telephone are distributed to apartment load centers in chases or false ceilings. Within dwellings these services run with a P.V.C. baseboard raceway. This raceway, see Figure Q, which is shipped in precut lengths for each dwelling, consists of a backplate and a prefinished snap-on cover. The raceway, which is U.L. approved, comes with receptacle plates, corner and end stops for complete installation.



P. Single stack plastic D.W.V. system



Q. Plastic baseboard raceway and receptacle cover

DEVIATIONS FROM ORIGINAL SYSTEM

In adapting the Wates system to the USA, several changes have been made. In general these changes and the reason for the changes are as follows:

Plant Location—The Wates system in Britain employs a semi-portable factory located at the building site. A reappraisal of conditions in the United States led to an off-site centralized factory with a production of 750-1000 dwelling units a year. The reasons for this change are:

- Lower off-site labor rates outweighed increased transporation costs.
- Typical contract size is not sufficient to utilize optimum size on-site factory.
- Better road transportation system.
- Climatic conditions necessitate greater weather protection and, therefore, greater equipment/ erection costs.
- Restriction on industrial use of residential-zoned land.

FLOOR SPAN—Maximum span employed in Britain is 16′. This was increased to 22′ in the USA for the following reasons:

- Market requirements (larger room sizes and greater open space planning).
- The availability of a lightweight dry partitioning system.
- Fewer concrete units to handle, transport and erect. This becomes significant with the increased handling requirements of off-site factories.
- Reduced foundation requirements.

MODULES—Factory-manufactured kitchen and bathroom modules have been developed for the USA market for the following reasons:

- These functional areas traditionally represent major on-site labor costs.
- Traditional installation frequently results in delays due to lack of trade coordination.
- Better quality produced through factory quality control conditions.
- Favorable jurisdictional rulings on the handling, placing and hookup of modules.

ELEVATORS—In Britain prewired package elevators are employed. In America the traditional on-site method of installation was used due to labor union resistance to any type of off-site fabrication.

DECORATION—In Britain wallpaper is used. In the USA, paint is used as a standard for the following reasons:

- Market preference for paint.
- Shortage of and labor cost for paper hangers.
- The similar preparation required for painting the concrete and gypsum walls makes for a one trade operation.

LABOR AND TRAINING PROGRAMS

The concrete panel system reduces the number of trades necessary for on-site erection and thus saves time and cost. Because most of the electrical and plumbing systems are prefabricated, further labor savings are achieved. Although heating, ventilating, and air-conditioning systems are conventional, piping, wiring and other elements are prepackaged at the factory.

Negotiations with the carpenters, laborers and iron workers union have secured for the BREAKTHROUGH project a mixed union crew for the erection and placing of all concrete units. This represents an advancement from previous jurisdictional rulings. Associated agreements on the handling of service modules and other crane-lifted components have also been made.

In general, training of employees is accomplished in accordance with the following schedule:

Class of Personnel	Location	
	Plant	Site
General Labor—Unskilled	3 Weeks	6 Weeks
Management	3 Months	
Foremen—Skilled		12 Weeks

Training of supervisory personnel will take place on site where individuals will be taught the complete Rouse-Wates system, as well as methods of training unskilled labor, and full management supervision from construction through rental and sale.

ECONOMIC ADVANTAGES OF SYSTEM

The Rouse-Wates system reduces overall cost by speeding construction and decreasing manpower needs by avoiding craft application and jurisdictional disputes. In general, construction time is reduced from 25 to 50% and construction cost reduced by an average of 6% of that anticipated under conventional construction practices.

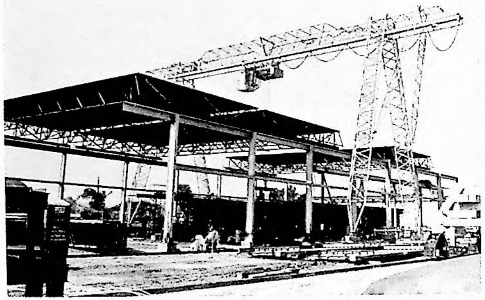
PRODUCTION

As previously stated, precasting can be done in a central factory or at on-site factories. In general, the on-site factory has proved more satisfactory in Britain than in America. For BREAKTHROUGH, an off-site location 180 miles from the site was chosen. Where an on-site factory is used, the entire production facility is usually straddled by a large gantry crane. Typically this crane can span 73 feet, has a 41 foot clearance under the hook and runs on tracks. It is used to perform a variety of tasks inside the plant including placing reinforcing steel, delivering concrete and the removal of precast elements from the forms once curing is complete.

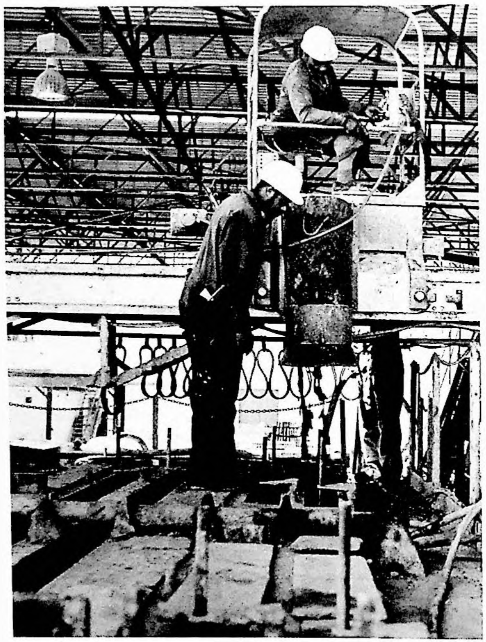
Modern established precast factories in America are usually adaptable to the Route-Wates system. Basically the factory must have overhead crane service and adequate areas for casting and stacking. An estimated volume production of from 500 to 2000 dwelling units per year is projected for a modern factory. Typical production facilities and scenes are shown in Figures R through U.

All forms are made of steel except for several wood forms used to cast special items such as roof beams. Five of the flat forms are hinged so that the panel can be lifted from the forms in a vertical position and thus reduce the amount of handling. Four sizes of steel mesh are used to reinforce the various units. The floor slabs have two layers while the walls have one in the center.

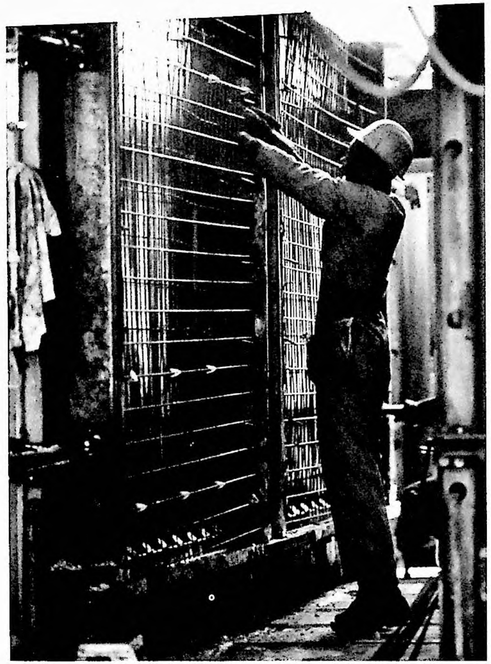
Walls and Slabs—Panels are cast vertically in steel battery molds to produce smooth faced concrete units. Each battery is 27 feet long, contains 6 cells, and can produce walls or slabs or required dimensions and openings. In a typical production schedule a daily casting cycle is used, the concrete being rapid-cured by steam heated serpentine pipes built within the cells.



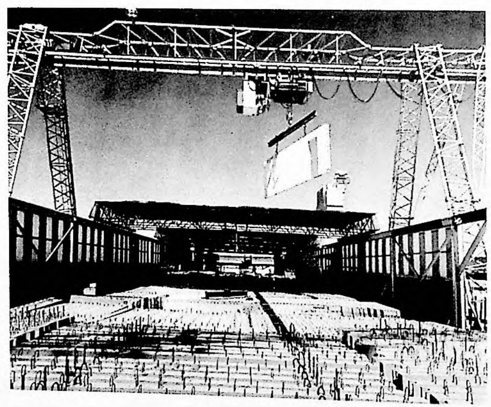
R. Casting area—HRW Systems plant, Washington, D.C.



S. Conveyor system—Washington, D.C. Plant



T. Plant production—Rouse-Wates trained unskilled labor



U. Storage area—HRW Systems plant, Washington, D.C.

Cladding—Panels are cast horizontally, exterior face downward to obtain profile and finish as required. The table molds are lifted to a near vertical position for striking.

Stairs—Flights are cast on their side in steel molds.

Associated with concrete production is the casting in of electrical and minor plumbing fixtures and the installation of windows.

Research and testing with sealant manufactures has enabled caulking of windows to be carried out within 24 hours of striking the cladding panels. This is achieved by careful monitoring of the concrete's moisture content and heat of reaction.

MARKETING FOR PHASE III

Plants have been established in Dexter, Missouri; Edmonston, Maryland; and Meriden, Connecticut. These plants are licensed by or have joint venture relationships with Rouse-Wates.

The joint venture in Edmonston, Maryland is with the George Hyman Company. This plant currently has orders for 800 apartment units which range from low rise conventional financing to high rise subsidy units under the FHA 236 program.

The joint venture in Meriden, Connecticut is with Carabetta Enterprises. This joint venture is currently working on a 1400 unit project in New Haven which will be constructed under the FHA 236 program. The second project is Lincoln Village in Worcester, Massachusetts which will be a total development of 1200 units; 450 of these will be FHA 236 and 300 will be luxury dwelling units under the 221(d)(4) program.

In St. Louis Rouse-Wates is the general contractor and currently has 500 units in process.

The franchise plan which is being offered to builders and developers includes access to the technology of the Rouse-Wates system and training of supervisory personnel in design and engineering The company retains the services of the OVE ARUP partnership as resident structural engineering consultants. Rouse-Wates will perform quality control services and make available results of continuing research in systems building.

The company is receiving applications and also currently negotiating exclusive and non-exclusive franchises with builders, developers and contractors who have resources to produce at least 1000 units per year and not less than 300 on a site. Joint ventures involving Rouse-Wates and other companies also are under consideration.

Rouse-Wates will be concentrating in the New York, Florida, Illinois and California areas for their next licensees. At the present time their plan is to develop one or two licensees per year.

For further information about the Rouse-Wates System, write to:

Rouse-Wates, Inc.
Columbia, Maryland 21045
or call,
Mr. J. David Evans, Director of Marketing
Area Code 301, 730-9000/Tlex: Rousewate 87799

> Rouse-Wates Phase II units are located at the St. Louis prototype site – 130 MFLR, 27 MFMR, 84 MFHR.

Summary Information

SYSTEM APPLICABILITY	
Location	Urban, suburban, new town, urban renewal.
Density Range	15 to several hundred dwelling units/acre. Operation BREAKTHROUGH–30.
Environmental Adaptability	Adaptable to all climates, soil and topography conditions.
Non-Residential Functions	Motels/hotels, schools, hospitals.
Site Planning Services	Services available from Rouse-Wates staff.
BUILDING SYSTEM DESCRIPTION	
Housing Types	MFLR, MFMR, MFHR.
Unit Variations	Efficiency–6 bedroom building. Planning based on flexible open planning using a 1'0" Grid Design Module.
Structure	Heavy pre-cast concrete panel and slab system.
Exterior Elements	Balconies.
Foundations	Conventional, designed to suit conditions.
Comfort System	Packaged HVAC in each residential unit.
Plumbing	Single stack vent system (Plastic pipe) integrated with panel system in most cases.
Electrical	PVC baseboard raceways.
Furnishing	Most furnishings are optional.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Structural system, module application, production and services.
Codes	System adaptable to all building codes. 4 hour fire resistance structure.
Deviations from Original O/B Proposal	Use of central pre-cast factory in lieu of site cast factory.
PRODUCTION PROGRAM	
Delivery Rate	750-1250 dwelling units/year/per factory.
Off-site Production	All precast concrete except non-typical first floor, kitchen/bathroom modules.
On-site Installation	Kitchen and bathroom module installed.
On-site Construction	Foundations. Erection of concrete panels, utility hookups, HVAC, ductwork, carpentry, and finishing.
Internal Functions	Planning (community, financial, physical); residential development; residential management; architectural design; engineering; contracting; construction/production management. Precast concrete manufacturing; structural engineering.
External Functions	Service modules.
LABOR REQUIREMENTS/TRAINING PROGRAM	Training provided for all three categories: unskilled, skilled labor and supervision.
ECONOMICS OF SYSTEM	
Construction Cost	$18-$27 per square foot depending upon area. Generally 6% less than conventional construction cost.
Transportation Limitation	Pre-cast concrete components–200 miles; service modules–1000 miles.
Useful Life	Building indefinite; furnishings depend on usage and maintenance.
MARKETING FOR PHASE III	Existing plants in Dexter, Missouri; Edmonston, Maryland; Meriden, Connecticut. New York, Florida, Illinois and California are target areas for next licensees. Plan to develop 1-2 licensees/year.

Scholz Homes

INTRODUCTION AND APPLICATION

Scholz Homes, Inc., a subsidiary of Inland Steel Development Corporation, is designing and providing volumetric wood frame modular housing for the Operation BREAKTHROUGH prototype sites at Kalamazoo and Indianapolis. Both townhouses and apartments are included. All units were conventionally designed for consumer acceptance and marketability, as well as building code conformance. They represent the culmination of 15 years of modular home design and development.

The objectives of Scholz Homes, Inc. in developing this housing system were to provide: (1) good quality housing with uniform product standards, (2) short building time (in all weather) for lower costs, faster occupancy and quicker capital turnover, and (3) a positive and rapid response to America's critical housing need.

The Scholz system is designed for urban, suburban and urban renewal projects. Density varies from a low of 8 units per acre for two story townhouses, to 15 units per acre for two story garden apartments. The system can be easily adapted to most sites by local planners; site planning services are available from Scholz for low rise residential use only.

The Scholz housing system is suitable for midwestern and northern climates. It is adaptable to most topographical conditions, through the use of terraced site plans. Foundations designed as spread footings are applicable for soil bearing capacities as low as 1500 pounds/square foot.

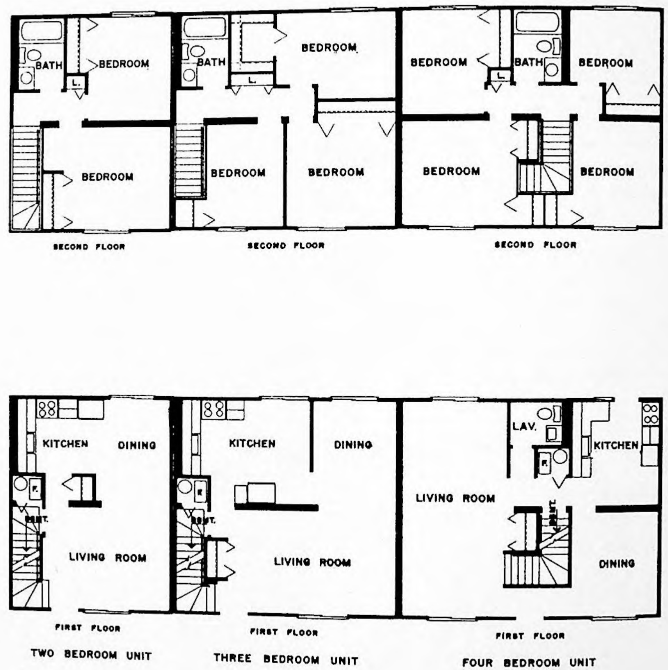
SYSTEM DESCRIPTION

The Scholz housing system is based upon the use of completed, factory-fabricated, self-supporting, wood frame modules. Principal dimensions are 12 ft. wide, 8 ft. high ceilings and up to 56 ft. long. Modules are designed to be combined to form either townhouses (single family attached) or apartments.

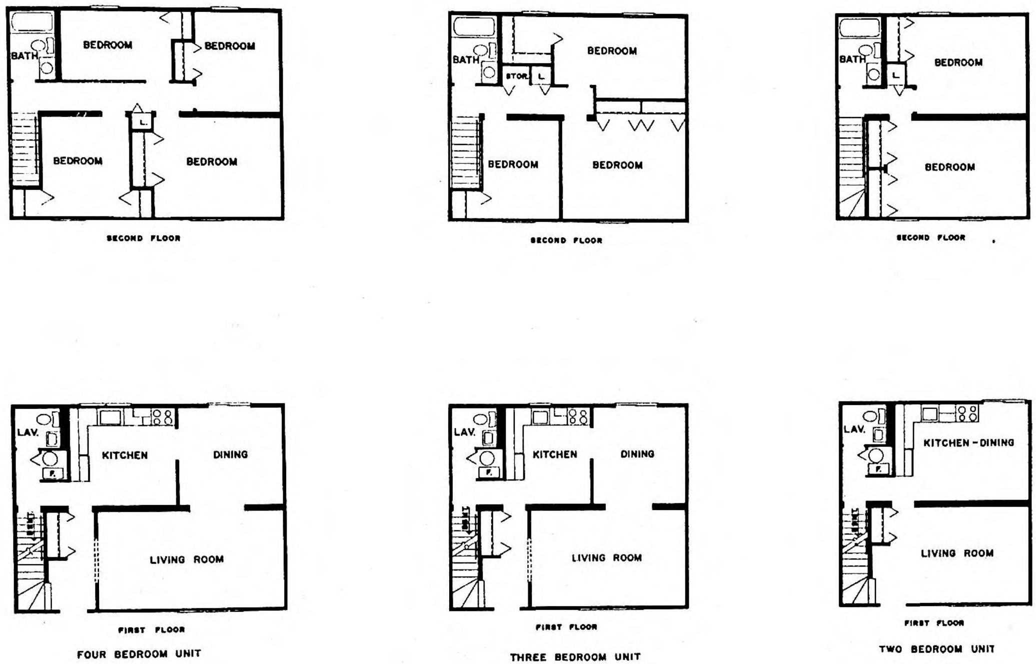
The concept results in completed housing units with the conventional appearance of contemporary townhouses (Fig. A), apartment buildings (Fig. B), and colonial townhouse and apartment buildings (facing page). Considerable variation in floor plan arrangements, however, is allowed. Two-, three- and four-bedroom townhouses (Figures C & D) and one-, two- and three-bedroom garden apartments (Figures E & F) are provided. All have a minimum of two different floor plans, sizes, and elevations. Building configurations are numerous with different arrangements of the modules for townhouses or apartments.

A. Contemporary Style Townhouses, Kalamazoo, Mich.

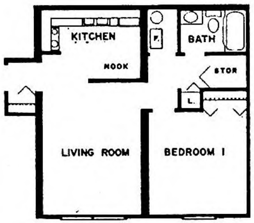
B. Contemporary Style Apartment Building



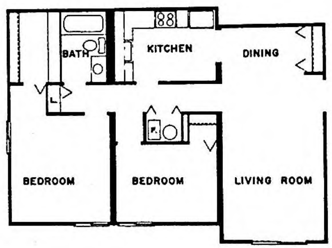
C. Contemporary Townhouse Floor Plans



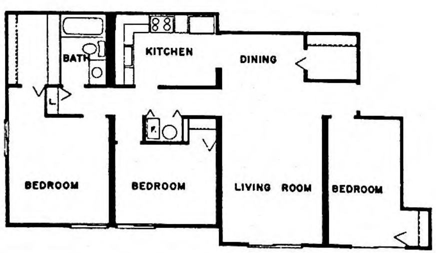
D. Colonial Townhouse Floor Plans



TYPICAL ONE BEDROOM UNIT

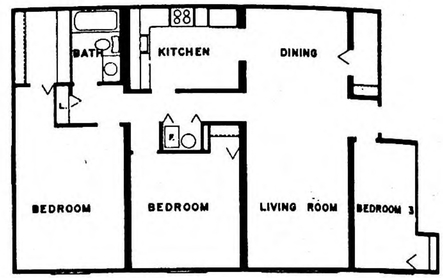


TWO BEDROOM UNIT

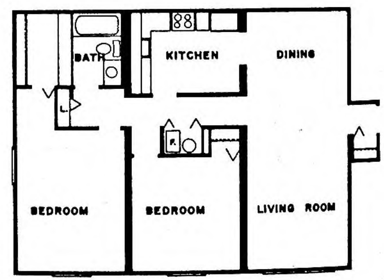


THREE BEDROOM UNIT

E. Contemporary Apartment Floor Plans



THREE BEDROOM UNIT



TWO BEDROOM UNIT

F. Colonial Apartment Floor Plans

Exterior options include patios, assorted porch and entry designs, decorative chimneys and trim, and basement or crawl space foundations. Roofs vary from flat to a slope of 3" per foot for fixed roofs. Any desired steeper pitch may be obtained by using unique tilt-up roof design.

The elements of this system are basically conventional: wood studs and sheathing, maintenance-free siding, built-in plumbing, electrical and mechanical items, bearing walls and partitions, and box beams. The townhouse units are erected on basements and the apartment units are erected on crawl space foundations. All foundations are conventionally constructed using conventional materials. Detailed descriptions of the various subsystems follow.

Structural

Framing — Conventional 2 x 4 wall studs on 16" centers (with a few exceptions) with 3/8" glued and nailed exterior plywood sheathing. The exterior wall panels contain single 2 x 4 bottom plates and double 2 x 4 top plates.

Roof System — The roof system is constructed of factory-fabricated trusses on 24" centers (or, in some cases, finished rafters with knee wall and 1/2" plywood decking) and factory-applied 235# asphalt shingles. Gutters and downspouts, flashing, and trim are all conventional materials.

Wall Finishes — Exterior materials vary, dependent upon elevations, and consist of horizontal and vertical prefinished hardboard siding, Tedlar prefinished panels, and sliced brick or stone set in mortar. Trim is either conventional redwood with paint, or panels with prefinished coatings.

Millwork - Exterior doors are metal-clad, foam-filled, with wood jambs and weatherstripping. Windows are single-hung aluminum with insulating glass. Sliding doors are aluminum with insulating glass.

Interiors

Walls — Framing is conventional 2 x 4's on 16" centers with 2 x 4 top and bottom plates. Walls are filled with acoustical insulation where required. Fiberglass insulation with a vapor barrier is used for thermal insulation where appropriate. Conventional drywall construction, fire rated as required, is used for surface finish. Gypsum wall coat paints, or vinyl coverings, are factory-applied for the finish.

Ceilings — Constructed with plywood stress skin applied to 2 x 4 ceiling joists. Conventional drywall, fire rated where required, and gypsum spray-coat decorative coloring complete the subsystem.

Millwork — Interior doors are hollow (or solid core) prefinished wood, or painted metal, swing and bi-fold type. Trim is wood and/or metal, finished or prefinished. Stairways are conventional wood frame, finished wood or carpeted.

Flooring — Framing consists of double 2 x 10 rim joists with 2 x 8 floor joists on 16" centers. Subflooring is 5/8" tongue and grooved, glued and nailed plywood. Floor finish is primarily carpet and pad, or may be vinyl asbestos tile, vinyl tile, or sheet goods.

Plumbing — Rough plumbing materials are copper, plastic, cast iron or no-hub piping with standard fittings. Fixtures are ceramic, or steel porcelain, with chrome accessories. Bathrooms include ceramic enclosures with chrome, or ceramic, accessories.

G. Living Room Interior

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HVAC — Furnace, central air-conditioning and water heater equipment is contained in standard size enclosures. Heating equipment is generally gas fired forced air with electric remote mounted air-conditioning condensors. Water heaters are standard sized individual units, gas or electric. Vent fans with wall switch control are supplied in all kitchens and bathrooms.

Electric — Wiring is per National Electric Code, 100 amps service, UL approved. Electrical fixtures are supplied and factory-installed in all rooms.

Kitchens — Kitchens are shipped with prefinished cabinets, counter tops, fixtures, vent fans, and appliances installed. All units contain garbage disposals. Layouts will accommodate dishwasher or washer and dryer options.

DEPARTURES FROM CONVENTIONAL SYSTEMS

The principal innovation of this housing system is its flexibility. Factory-produced modules are used to construct dwelling units that appeal to a wide variety of esthetic tastes and are applicable to most site planning techniques. Houses are, however, conventional enough in appearance to be accepted by builders, tradesmen and ultimate consumers as a product with which they are familiar and which they can trust.

The entire present system without major revision, meets or exceeds Local Codes, State Plumbing and Electrical Codes, State Building Codes, National Codes, and industrialized housing codes in the Midwest.

H. Kitchen Interior

DEVIATIONS FROM THE ORIGINAL OPERATION BREAKTHROUGH PROPOSAL

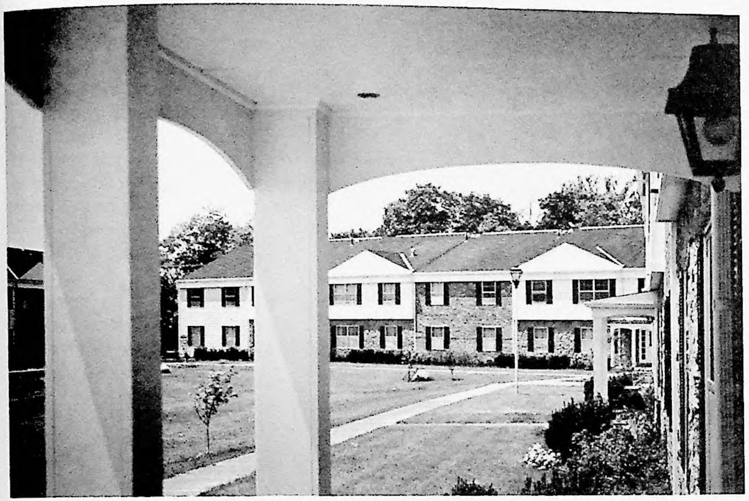
Some of the more significant technical changes to the Scholz system during Phase I included: (1) changes in the roofing system to improve the quality as well as to allow jobs previously done in the field to be done in the factory; (2) changes in the type and location of HVAC equipment and the addition of foam insulation on and around the foundation to improve the operational efficiency; (3) modifications to the modular structural system and to the trailers to improve transportation efficiency.

Housing units being marketed under the Scholz Phase III program differ slightly from the prototype configurations. Primarily these changes involve bedroom mixes, additional windows, changes to interior decorations and more available options.

PRODUCTION PROGRAM

The existing factory in Grand Rapids, Michigan produces 1,000 units a year. New production facilities, currently being built in Milan, Michigan, will more than double the current rate. The planned delivery rate is 200 dwelling units per month. In general, factory work is performed by skilled and semi-skilled employees.

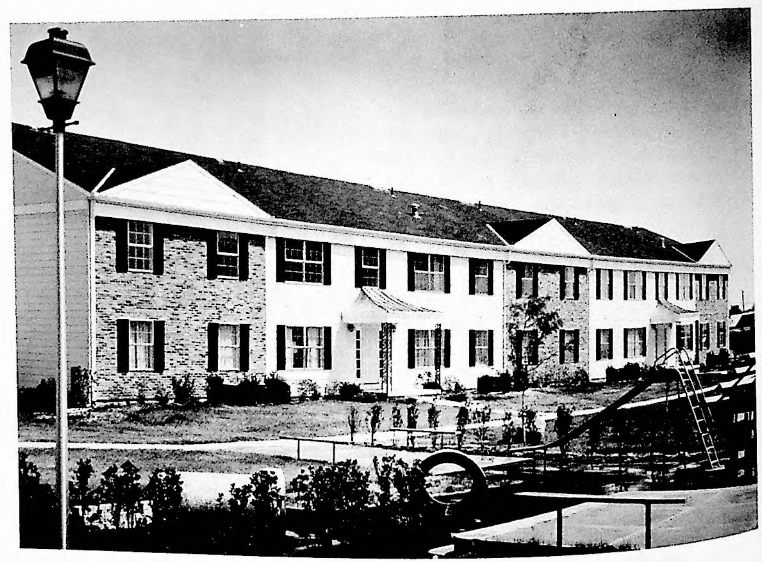
Scholz presently provides the coordination for field erection. However, complete modules are available to builder-developers for their own on-site erection. Normally, when Scholz has the erection responsibility, finishing work is done with conventional construction materials using local labor.



I. Colonial style is prevalent at Scholz' Columbus, Ohio project

J. Rear of Columbus project apartments

K. Swimming pool is part of site amenities at Columbus project



L. Apartments and play area at Columbus

ECONOMICS OF SYSTEM

Costs of units ready for occupancy vary from $14.00 per square foot to $16.00 per square foot depending on the distance from factory, local construction costs, and the type of dwelling unit. Costs do not include land.

It is presently considered economically feasible to ship modules by truck to most sites within 300 miles of the factory. Local conditions which complicate conventional types of construction, however, sometimes justify shipments up to double this distance.

By using prefinished materials and factory quality control procedures, maintenance is lower than for conventional construction. Normal useful life is estimated at 60 years.

MARKETING FOR PHASE III

Marketing plans for Phase III are to sell modules F.O.B. Scholz factories in Milan and Grand Rapids, Michigan. In some cases Scholz may perform all site work. For now, and the near future, the marketing area is limited to the Great Lakes and midwestern states.

Typical scenes of Scholz houses marketed under the Phase III program are shown in Figures I through L. These houses, located in Columbus, Ohio, are among the first Phase III houses completed by Scholz.

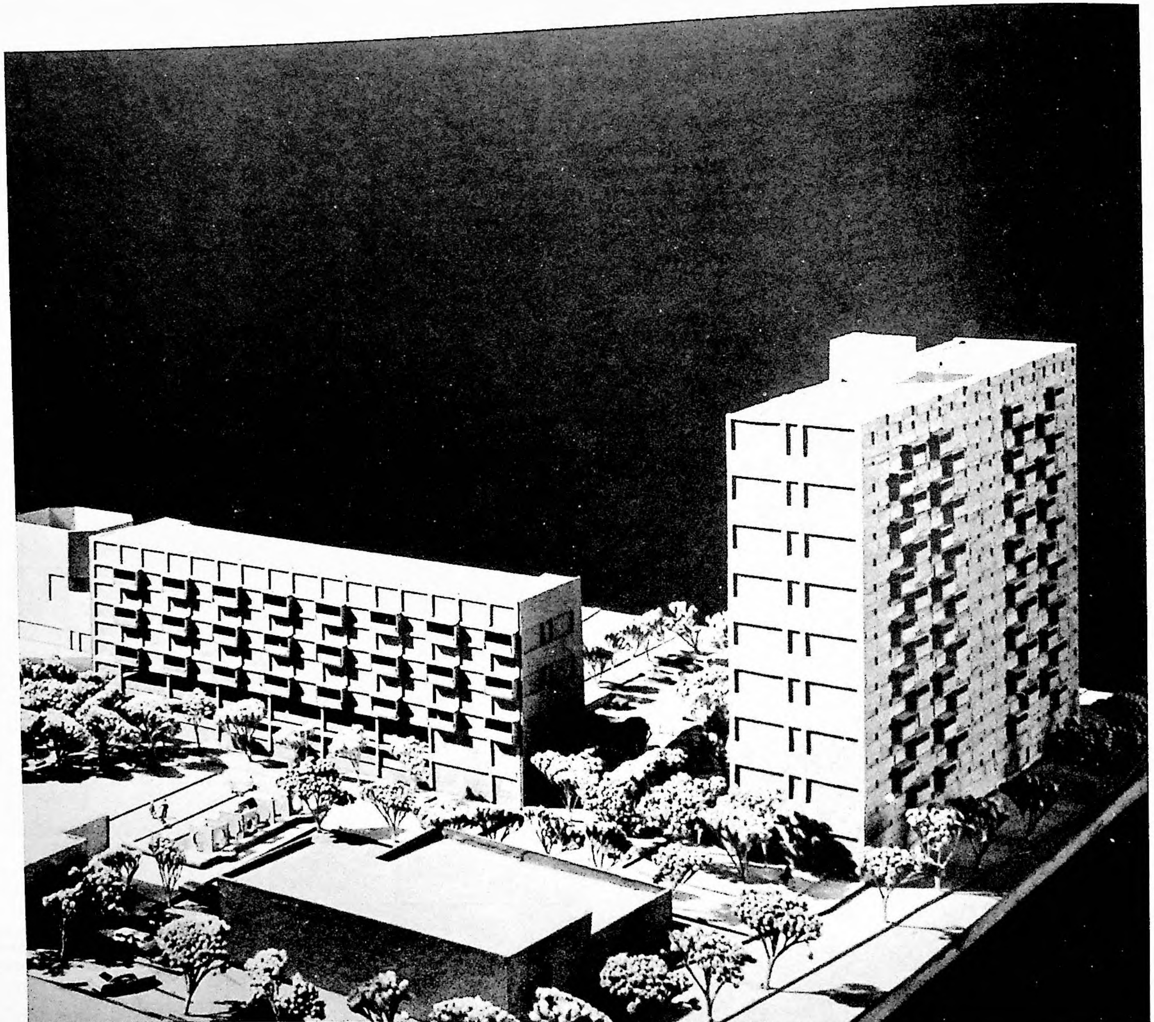
Questions pertaining to the Scholz volumetric wood frame housing system may be directed to:

Scholz Homes, Inc.
3497 East Livingston
Columbus, Ohio 43227
Attention: Donald R. Wick, Project Manager
Phone: (614) 239-9510

Scholz Phase II units are located at two prototype sites:
Kalamazoo – 22 SFA, 8 MFLR
Indianapolis – 26 SFA, 8 MFLR

Summary Information

SYSTEM APPLICABILITY	
Location	Urban; suburban; urban renewal.
Density Range	8 to 16 dwelling units per acre.
Environmental Adaptability	Adaptable to all U.S. climates, normal topography and soils.
Non-Residential Functions	None.
Site Planning Services	Site selection; land planning; design.
BUILDING SYSTEM DESCRIPTION	
Housing Types	Single family attached; multi-family low rise.
Unit Variations	1-, 2-, 3-, and 4-bedrooms.
Structure	Conventional wood-frame volumetric modules.
Exterior Elements	Porches.
Foundations	Conventional.
Comfort System	HVAC integral with modules.
Plumbing	Conventional – integral with modules.
Electrical	Conventional – integral with modules.
Furnishing	Carpeting; light fixtures; kitchen appliances.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Factory-produced housing offering maximum flexibility with conventional results.
Codes	Adaptable to all national model codes.
Deviations from Original O/B Proposal	Structural modifications for transportation.
PRODUCTION PROGRAM	
Delivery Rate	200 dwelling units per month.
Off-site Production	Volumetric modules; porches.
On-site Installation	Assembly of modules; utility hook-ups.
On-site Construction	Foundations; utility lead-ins; site preparation; accessory buildings.
Internal Functions	System design; production; erection; land planning; design; management.
External Functions	Erection, land planning by agreement.
LABOR REQUIREMENTS/TRAINING PROGRAM	Use construction trades available at site locations; labor training on very large projects only.
ECONOMICS OF SYSTEM	
Construction Cost	$14 to $16 per sq. ft. depending on distance from factory, local labor costs and dwelling type.
Transportation Limitation	Great Lakes and midwestern states.
Useful life	60 years.
MARKETING FOR PHASE III	Marketing of modules F.O.B. factory (Milan or Grand Rapids, Michigan); current marketing area includes Great Lakes and midwestern states.



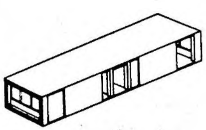
Shelley Systems

INTRODUCTION AND APPLICABILITY

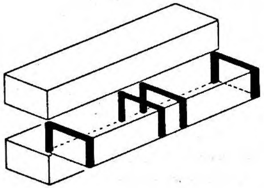
The Shelley system involves three-dimensional "box type" modular units stacked in a vertical checkerboard pattern. By arranging the modules in this pattern, a space is created between two adjacent modules that is complete with walls, floor and ceiling. Only end enclosures have to be added to enclose this "created space." The modular units are almost totally prefinished on a factory assembly line. The patented system provides a unique way to lower building cost and speed construction while providing high quality multi-family housing. The Shelley system is applicable to volume produced housing throughout the world.

Architectually, the Shelley system is applicable to all multi-family living unit situations whether urban, suburban or new towns. It is adaptable to most building shapes, unit arrangements, exterior facade treatments or exterior facing materials. The Shelley system meets all national building codes and construction standards. It is adaptable to all localities, climate and topographical conditions. It is especially suitable for use in areas susceptible to hurricane, winds and earthquakes (including Seismic Zone 3).

Currently the Shelley system is being utilized in Puerto Rico, New Jersey, and New York on projects for HUD. Projects under construction or in the planning stage include: New towns, urban problem sites, housing for the elderly, hotels/motels, hospitals, nursing homes, dormitories and student housing. Included within these projects are low, moderate, middle income and luxury units.



A. Precast Concrete Box Module



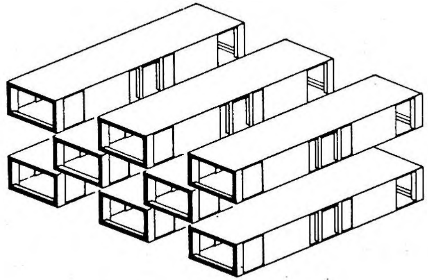
B. Columns and Beams Within All Boxes

SYSTEMS DESCRIPTION

Structure

The precast concrete box modules are stacked one upon another overlapping at their edges to form a patented vertical checkerboard structure. The overlap provides complete vertical matching for the columns, carrying all gravity loads directly to the foundation, and space for the continuous vertical mechanical shafts.

The box module consists of a roof slab with beams, side walls and columns, and a floor slab, all cast as an integral monolithic structural unit. Vertical ducts are contained in the columns. Dowels or post-tensioning tendons (or rods) connect the boxes vertically through the ducts from roof to footing (see figures A-E). In actual practice, the floor elevation of the factory produced module and the "created space" between modules is the same. This is accomplished by having columns shorter than the overall module height.

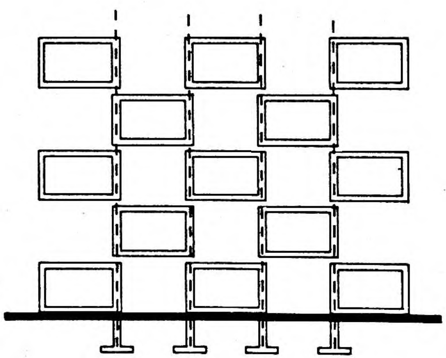


C. Checkerboard Structural System

Elastometric bearing pads are placed at the contact surfaces of the columns between adjacent modules. The shear walls and frames, which are part of the structure, provide for the highest earthquake and hurricane lateral force requirements. The structure exhibits good ductility and is insensitive to temperature change and differential settlement movements.

Items that are totally installed within the precast concrete box module at the factory include exterior walls, spandrels and windows; interior wall and door partitions; kitchens; bathrroms; balconies with railings; painting, flooring, vertical piping and ductwork; and closets and storage walls. These items can be brought to the factory prefinished or built wholly in the factory conventionally.

Items that are installed within the "created" space include exterior wall panels, spandrel and window panels, interior wall panels and closet and storage components. These items are either prefabricated and brought to the factory, or completely prefinished at the factory. Occasionally (for total flexibility), component kitchen and bathrooms are brought to the site out of the precast box module. Normally, only the minimum connections are made at the site.

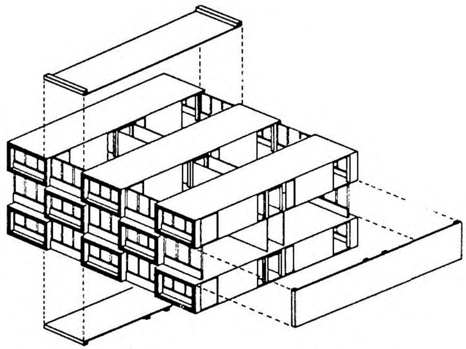


D. Alignment of Columns Vertically

Miscellaneous concrete items that are precast in the factory and installed at the job site include roof closure panels, end wall structural closure panels, closure panels at grade, elevator shaft walls, stair risers, treads, platforms walls and trash chute.

Conventional construction at the site including excavations, landscaping, grading, roofing, flashing and waterproofing is all completed conventionally (like ordinary buildings) as are foundations, elevator installations, basements, lobbies and other special ground floor spaces. All concrete work at the site is poured in place. Foundations may be spread footings, special grillage beams, mat foundations, or wood, metal or concrete piles.

A specially designed trailer is used to transport the boxes. Every city contacted has approved the movement of the modules through the city streets. Shelley also uses a specially designed on-ground erection crane.



E. System Completed By Precast Closure Panels

Mechanical

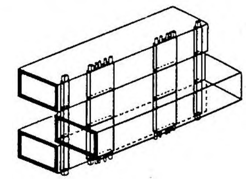
All vertical and most horizontal piping, sheet metal exhaust ducts, and almost all internal connections are factory finished within a mechanical chase or shaftway inside the concrete box module. Plumbing may be installed conventionally at the site, if necessary. There is complete mechanical access at every shaft and every level.

The Shelley system is adaptable to all standard heating, ventilating and cooling systems. The Shelley Company with the aid of a heating and air-conditioning system manufacturer has pioneered in modifications to "vertical type" package units that can provide:

(a) Direct line heating without the need for additional costly duct branch lines.

(b) Installation that can be done in a limited space, permitting more flexibility in furniture placement.

(c) Simplified installation procedures, which reduce overall costs.



F. Mechanical Utility Shafts

Energy sources normally used in conventional construction can be used similarly in the Shelley System without special modification. Current studies are in progress on the incorporation of built-in radiant heat components which will further reduce costs and provide greater efficiencies.

Shelley Systems, Inc. architects and engineers have evolved several major innovations in the unique use of high temperature plastics and the elimination of conventional cross-venting. These designs have been approved by the National Bureau of Standards and are currently incorporated in the Jersey City Operation BREAK-THROUGH structure.

Electrical

All conduits and outlets are cast within the walls, floor and roof of each box before the concrete is poured. Currently under study are modifications in electrical fittings, direct-burial type wiring and unique quick-connect methods of coupling between modules.

Provisions for telephone, television and intercom are incorporated within the precast factory-produced box module.

INNOVATIVE FEATURES OF SYSTEM

The principal innovative feature of the Shelley system is the use of precast concrete boxes stacked in a vertical checkerboard configuration. Details of this innovative system have previously been discussed.

OPTIONS

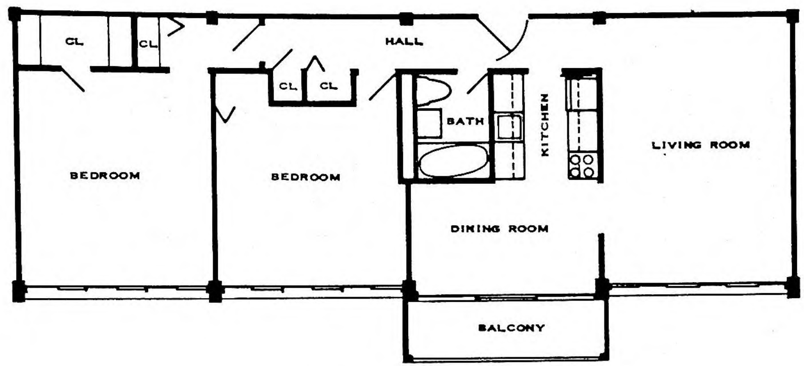
Architecturally the Shelley system can be adapted to any configuration as an individual building, multi-buildings or as a series of macro-structured complexes. It can vary from 2 to 35 stories in height. At the ground level, it can be built all in boxes, all conventionally or as a combination of both. It can have a single-loaded, double-loaded, or skip-stop corridor scheme. Different elevator and stair tower locations are possible, including through the boxes or as separate precast towers.

The exteriors can vary greatly. Bay widths can vary. Modular boxes can vary in length, be recessed, projected and cantilevered, staggered, checkerboarded, stepped, or flush.

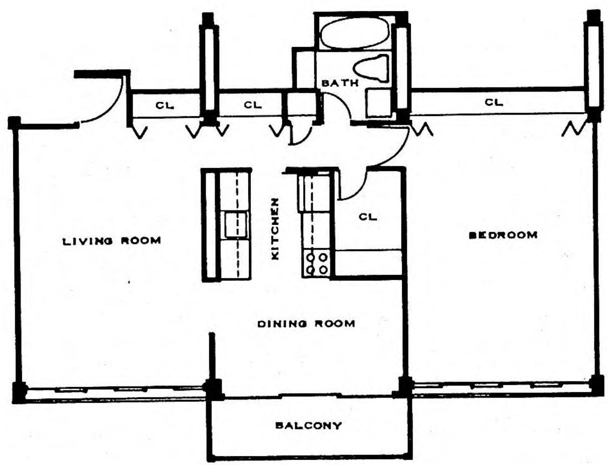
Balconies can be cantilevered into full projecting units, U-shaped slabs or fully recessed. All materials, textures and combinations can be used on the building surface. Every degree of fenestration is possible, either large window openings or small window openings, vertical, horizontal, strip or punctured.

Essentially any variation of apartment arrangement, size of apartment and living unit layout is feasible. Simplexes, duplexes and even triplexes are possible, and apartments may range from efficiencies to six bedroom units.

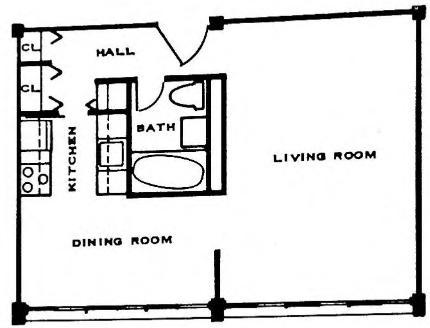
Typical floor plans developed for Operation BREAK-THROUGH are shown.



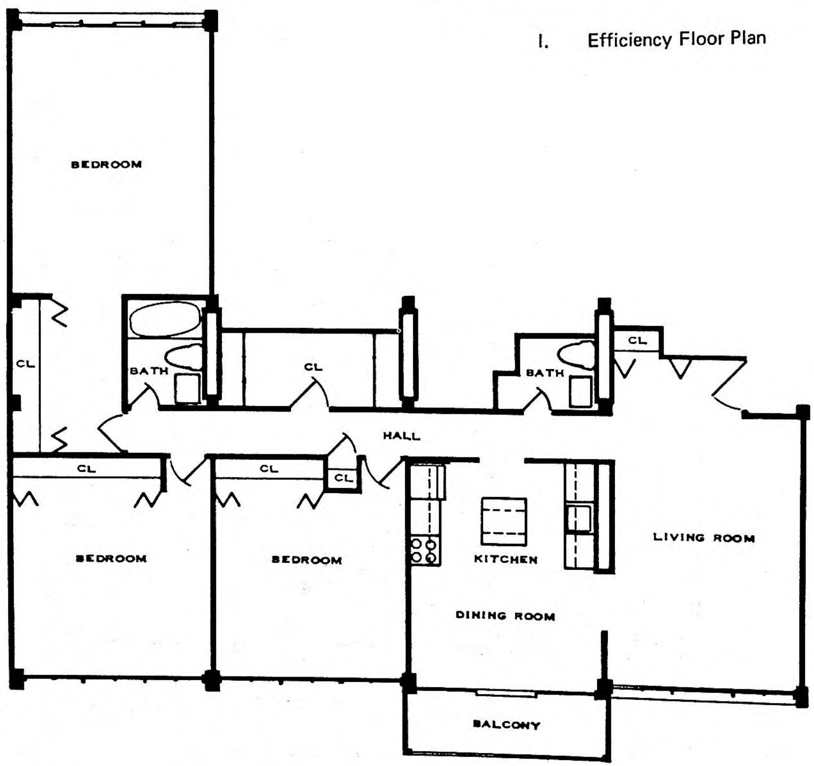
G. Two-Bedroom Floor Plan



H. One-Bedroom Floor Plan



I. Efficiency Floor Plan



J. Three-Bedroom Floor Plan

CODES

The Shelley System was developed to meet the most stringent requirements of the model building codes. The fire safety characteristics of this concrete volumetric system qualify it for Class IA rating. Concrete divider walls which separate individual spaces also satisfy hurricane and earthquake zone requirements.

FACTORY PRODUCTION OPERATIONS

The factory is usually an off-site, permanent, enclosed, fully heated operation. Special, very large complexes might require an on-site temporary factory. Production takes place in all weather, the year around and is free from theft and vandalism. The manufacturing operation is a fully automated assembly line operated under rigid quality control procedures.

The precasting of concrete box modules is achieved by means of a universal metal molding machine that can adjust to most widths, heights and lengths. It is steam heated, wall-vibrated and hydraulically operated. Eventually it will be computerized.

Wood forms are used to pre-form the reinforcing steel and wire mesh cage prior to the pouring of concrete. Electrical conduits and outlet junction boxes are preset against the plywood forms.

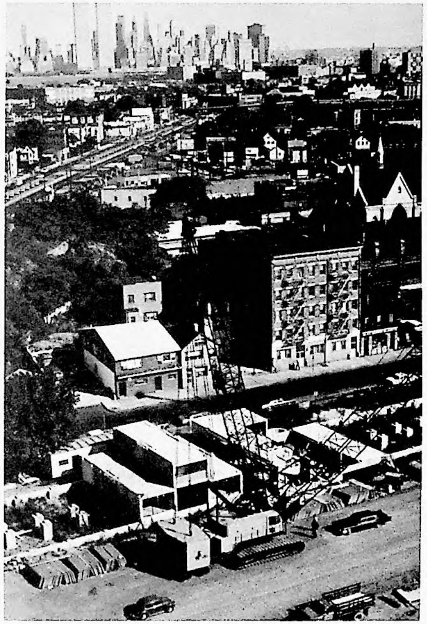
Concrete is furnished by a specially designed, fully automatic, batching plant. Steam heated forms are used in the casting operation. Lightweight or regular concrete may be used. Lifting is handled by a 60 ton travel lift or bridge crane. The precast box module is totally prefinished within the finishing production area before it leaves for the site.

At the present time, a permanent factory producing 1,000 units/year is located in East Paterson, New Jersey. In addition, a temporary factory in the San Juan, Puerto Rico area is also producing 500 units/year. A new factory is under construction in metropolitan San Juan and at least one new factory is planned for New York City within the next year.

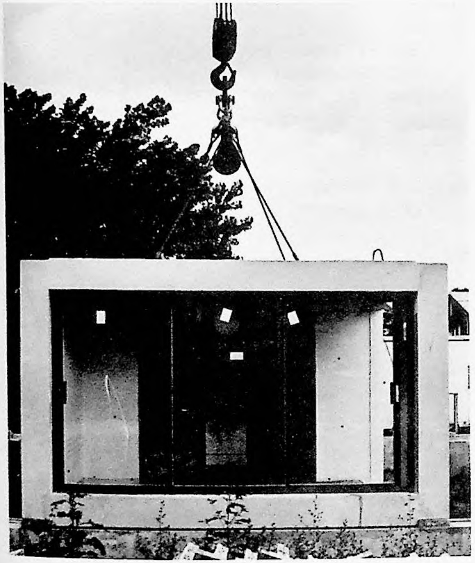
ECONOMICS OF THE SYSTEM

In general, the Shelley system is 10% to 20% less costly than conventional construction. In most areas, modules can be delivered economically up to a distance of 200 miles.

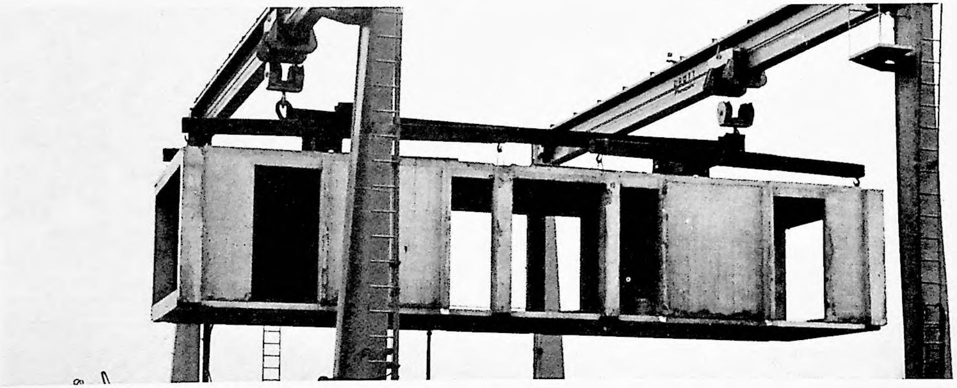
The two principal factors contributing to this cost savings involve labor and reduction of overall construction time. A minimum of highly skilled craftsmen is required. Within the factory, many unskilled union laborers are employed. These include many local and minority workers. The Shelley system drastically reduces the total time for construction. It uses innovative prefabrication, prefinishing, CPM and Fast Track techniques. Cost savings realized include lower interest rates, lower total construction costs through avoiding the 1% construction rise (inflation) per month and earlier occupancy of the buildings.



L. First Concrete Box Modules Erected at Jersey City



K. Totally Prefinished Precast Structural Concrete Box Module Being Placed at the Jersey City Prototype Site.



M. Factory-Cast Structural Concrete Box Module On Specially Designed Crane

MARKETING

Shelley Systems, Inc. can provide a total system concept, or only a part of the work involving the application of a Shelley system. Management and technical services are available from within their staffs or in association with others. Master planning, architecture, engineering, factory production of modules, field construction and installation are all a part of the services offered by Shelley Systems.

Shelley Systems plans to set up national and international distribution rights through special marketing organizations. Shelley will consider joint ventures with any progressive local construction organization having substantial equity anywhere in the world. Such an arrangement would be special licensing or franchise.

For further information about the Shelley system, contact:

Shelley Systems, Inc.
400 Park Avenue
New York, New York 10022

or phone:

S. W. Shelley
(212) 486-9424

N. 152-unit high-rise for Jersey City prototype site

Summary Information

SYSTEM APPLICABILITY	
Location	Urban, suburban, urban renewal, new towns.
Density Range	10-200 dwelling units/acre.
Environmental Adaptability	All climate, topographical and soil conditions.
Non-Residential Functions	Student housing, dormitories, hotels, motels, hospitals, nursing homes.
Site Planning Services	Offers total site planning and management services.
BUILDING SYSTEM DESCRIPTION	
Housing Types	Multi-family, low-rise, high-rise.
Unit Variations	Efficiency to 6 bedrooms.
Structure	Reinforced concrete pre-cast, volumetric modules.
Exterior Elements	Porches, decks, balconies, breezeways.
Foundations	Conventional — design to suit structure.
Comfort System	Uses all conventional energy sources.
Plumbing	Integrated in conventional modules.
Electrical	Integrated in pre-cast modules.
Furnishing	Optional.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Structured system (vertical checkerboard arrangement).
Codes	Meets all national codes—fireproof structure Class IA suitable to seismic zone 3 usage.
Deviations from Original O/B Proposal	None.
PRODUCTION PROGRAM	
Delivery Rate	1,000-2,000 dwelling units/years for each factory.
Off-site Production	Essentially all done in permanent plants.
On-site Installation	Erection of filler panels and interconnection of modules.
On-site Construction	Foundation and utility connections.
Internal Functions	All normal construction activities.
External Functions	Functions performed by others by agreement only.
LABOR REQUIREMENTS/TRAINING PROGRAM	
ECONOMICS OF SYSTEM	
Construction Cost	10%-20% less than conventional construction.
Transportation Limitation	Approximately 200 miles from production plant.
Useful Life	System essentially permanent. Furnishings in accordance with usage and maintenance.
MARKETING FOR PHASE III	Currently marketed in Puerto Rico and the New Jersey/New York City area.

Shelley Phase II units are located at the Jersey City prototype site — 40 MFLR, 152 MFHR.

Stirling Homex

INTRODUCTION AND APPLICABILITY

Through the Operation BREAKTHROUGH Program, Stirling Homex has combined the desirable features of factory produced modular construction, optimum materials and a unique erection technique to design a high-rise system that presents a solution of many of the urban housing problems facing our nation today.

The Stirling Homex Hi-Rise System directly addresses, and promises a practical and economically workable solution to the problems of: inadequate supplies of quality houses, extensive time lags between the beginning and completion of construction, zoning and building code variations from one area to another, the shortage of skilled craftsmen and the high cost of financing a long and drawn-out construction project.

The Stirling Homex Hi-Rise System involves fire resistant modules that are factory produced with 95% of their internal details complete at the factory. In addition, this system uses hydraulic jacks to raise modules, assembled at the ground level, to their proper place within the high-rise structure. This technique results in the roof and top floor of a structure being completed first and the bottom floor last.

The Stirling Homex Hi-Rise System is most effectively applied to medium cost multi-family dwellings in urban or rapidly growing suburban areas where land values and dwelling density dictate multi-family structures. Other applications involve apartments for the elderly, education shelters, hotels-motels, hospitals, dormitories and office space structures. This system is applicable to all climate conditions existing within the United States. Using this system, buildings up to 20 stories are designed to resist building loads imposed by maximum design wind conditions as well as seismic Zone 3 (maximum) earth tremor conditions. (See FHA Structural Engineering Bulletin No. 682.)

Experience over several years of production of "modules" has pointed out the many advantages of this approach. Since production takes place under roof, the process continues as many hours a day as desired—day or night. Expensive delays and damage due to weather no longer plague meeting tight schedules.

Equally important, the ability to schedule repetitive work activities under controlled conditions invites several other benefits. Materials can be procured in larger quantities—a cost advantage. They can be delivered in shapes and sizes that minimize scrap. A key factor is practicality. Quality Control—more than just visual inspection—can be applied. Manufacturing industries have, over the years, developed great skills in quality controls. Random sampling, statistical methods application, emphasis on high cost elements have all been developed to a high degree. The application of these techniques to the construction of housing is new—made possible by factory production of modules in a manufacturing environment. A direct result is better quality and uniformity in housing.

A production line also breaks work-skill requirements into small packages. An individual can, with reasonable on-the-job training time, learn to perform any operation on the production line. Further training expands the worker's capability to other operations and provides incentive growth paths. The result of this approach is to open employment possibilities in the housing industry to many who would not normally become journeymen craftsmen for a variety of reasons. This works directly toward solution of the problems of increasing labor costs and shortages of critical craftsmen.

The advantages inherent to the Stirling Homex Hi-Rise erection system include: (1) Construction proceeds in all weather after top floor and finished roof are completed. (2) Work proceeds at a low, more convenient and safer building height than conventional high rise construction. (3) Rapid completion of building installation makes available uniformly high quality housing at competitive prices a year sooner. (4) A savings of at least a year's interest on the construction loan. (5) If an income property, it is deriving a rent a year sooner, hence earlier return on the investment. (6) The ability to respond readily once a program is accounced since the building is available in months instead of years. (7) And, for those needing housing, quality living is available a year sooner than by conventional construction.

SYSTEM DESCRIPTION

The Stirling Homex Hi-Rise System is composed of factory manufactured modules (approximately 12′ wide x 10′ high x 24′ long) which are complete in decor and detail as they leave the production line. Metal studding, gypsum board, and other fire retardant materials are combined to construct the desired floor plan upon a floor of reinforced concrete. Wall finishes, carpeting, appliances and fixtures complete the module before it is weather-protected for transporting to the building site.

Each Hi-Rise module contains, in addition to its own structural components, heavy structural steel beams, columns and channels. These members, when connected module-to-module by the high tensile strength bolted fasteners, form the structural framework of the building. As the structure is installed in the field, the structural members of each module are joined to the adjacent modules thus forming a unit structure which is fully adequate to withstand the design loads. The only major elements of the Hi-Rise building not produced at the manufacturing facility, are the foundations or pilings and the built-up asphalt roof.

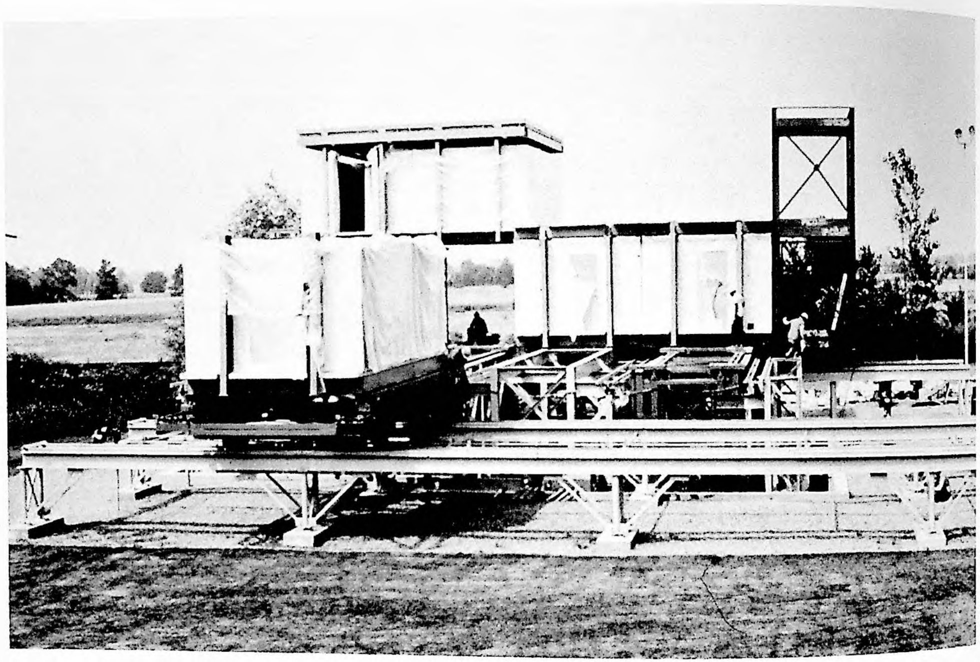
After removal of the jacking system, the ground floor is finished by conventional construction. More dwelling space, community space, commercial units, parking, or basements are all practical with this system.

Plumbing, electrical, and venting systems are designed to permit any variations required to meet local building codes. Selection of materials is made to match requirements. The heating system designed for the Memphis BREAKTHROUGH building is electric on an individual apartment basis. However, the Hi-Rise System flexibility includes the capability for central hot water, electric baseboard, or any other method found acceptable in conventional construction.

Other materials used within the modules, and in completing the Hi-Rise building are those already in use and accepted by the industry and the public. The exterior of the Memphis Hi-Rise design utilizes anodized aluminum facing over the balcony areas and stone aggregate panels on the other external surfaces of the building. Normally the exterior architectural skin, balcony rails and trim, floor covering materials, and wall finish materials can be selected to match the requirements of the purchaser. Also, should it be appropriate, any desired degree of furnishing may be accomplished in the factory as the modules are produced.

INNOVATIVE FEATURES OF SYSTEM

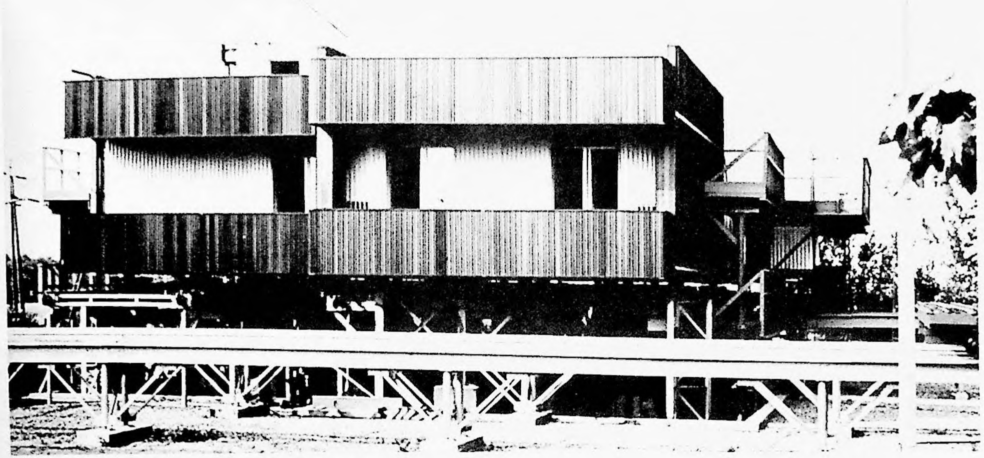
The principal innovative feature of Stirling Homex Hi-Rise System is the field erection technique. A summary of the steps involved, beginning with the top floor of the building, follows:



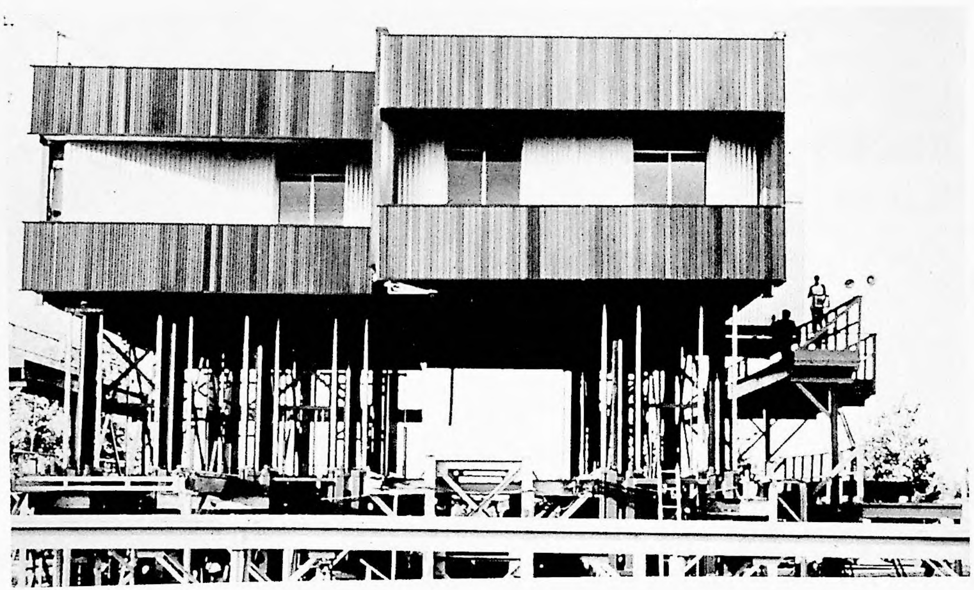
A. Top Floor and Elevator Penthouse Module Installation

Step 1 – (Figure A and B):
The complete top floor of modules is assembled on the supporting foundation steel. They are structurally bolted laterally to each other. Roof slabs are connected in similar manner. External architectural skin is attached and final roofing applied. Internal finishing of module-to-module connections then proceeds—protected from the weather.

Step 2 – (Figure C):
The entire floor is raised 10 feet by use of the coordinated jacking system. Jacks are contained in every other bay. Alternate bays contain final permanent support steel for the building. By design, bridging occurs, with bridging modules being supported by those on either side. 12 feet wide by 10 feet high spaces have now been generated in alternate bays—those containing no jacking assemblies. This opening is shown in Figure C.



B. Top Floor Interior and Exterior Finished—
Roof Complete



C. Top Floor Elevated—Opening Created

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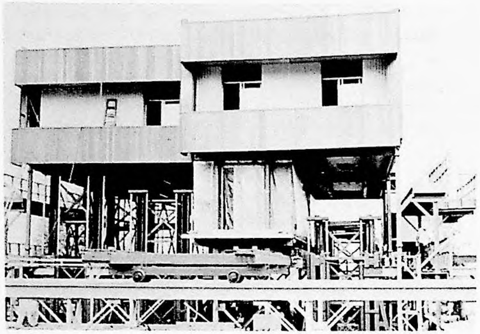
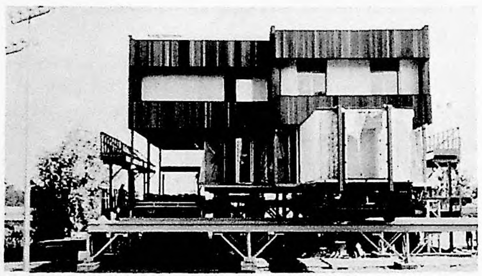
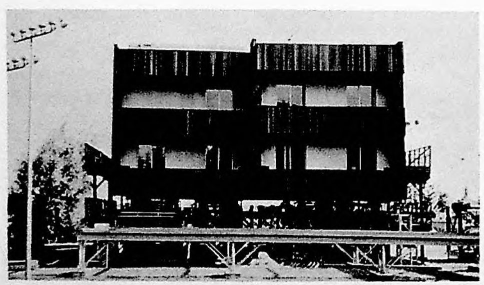


D. Next-To-Top Floor Modules Being Installed. Bridging Occurs As Jacks Are Lowered.



E. Next-To-Top Floor Module Installation



F. Top Two Floors Complete—Being Raised

Step 3 — (Figure D):
"Next floor down" modules are inserted into the open spaces. Vertical structure and utility connections are then made.

Step 4 — (Figure E):
The jacks are lowered, with the building load borne by the newly installed alternate modules. Additional 12 by 10 foot openings have now been generated. Outrigger support posts are provided at the end bays of the building to permit end-of-building modules to bridge.

All vertical building loads are transmitted directly to the foundation steel by the column structure. Module ceilings and walls are not load bearing.

Step 5 — (Figure F):
The alternate spaces are filled with the rest of the module complement for that floor. Both vertical and horizontal structural connections are completed and torqued. Vertical utility runs are connected. Internal joint finishing and external siding are completed.

This completes the top two floors of the Hi-Rise building. The jacking system is then extended again—raising the two top floors of the building 10 feet.

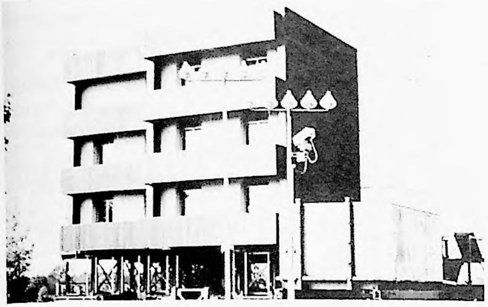
Step 6 — (Figures G and H)
Repeating previous steps, as many additional floors as desired are installed—up to 20 floors with present designs. Figures G and H show 3 and 4 floors completed on a Hi-Rise building. Note the installation system shown beneath the building with the delivery system in the foreground of the picture. At completion, jacks are removed and replaced by the permanent supporting steel—identical to the supporting steel in the open (non-jack) bays.

This installation method permits installation of the roof and side skins as soon as the top floor modules are in place. External scaffolding and material handling are kept near ground level. This is a significant safety advantage, especially when one considers that Hi-Rise buildings are normally constructed in reasonably congested locales.

Internal installation work is also completed at the same time external work is progressing. This proper balancing of work crews will result in completion of internal work on a given floor of the building while that floor is still near the level at which modules were installed.

Following installation, floors above can be locked and personnel access restricted until final punch and clean-up. This results in concentration of the applied labor to the lower floors with the resulting potential for better supervision and quality control techniques. In addition, the transporting of finishing materials and fire-proofing is limited to the lower floors rather than throughout the height of the finished building. Likewise, the removal of trash, packing material, and other debris is simplified.

Cost of the installation system equipment—jacks, transfer rails and controls—is logically spread across many building installations. That prorated cost plus the expense of set-up and removal on a specific project is recovered in the achievement of shorter installation time at the site and in the benefits this provides to the project owner.



G. Top Three Floors Complete—Building Being Raised for Installation of Next Floor

H. Top Floors Complete

OPTIONS

As previously mentioned, the Stirling Homex Hi-Rise System is a variation of a basic modular system used to build townhouses during the past several years. In addition to townhouses and high-rises, Stirling Homex has developed a low-rise system that is applicable for apartment buildings up to four stories high. The principal difference between the low-rise and high-rise system is that the low-rise system may more effectively be stacked by crane with construction beginning on the first floor and ending with the roof.

Material changes in the module construction from low-rise to high-rise design introduce additional work steps and quality control check points. Dimensional tolerances become tighter because of the more extensive stack-up conditions. Provision must be made for building type elements as well to apartment-oriented elements. Fire proofing and structural integrity receive high priority emphasis. Module lifting and weatherproof wrapping methods are modified appropriately.

The Stirling Homex Hi-Rise System is applicable to a variety of floor plans ranging from efficiency to five bedroom apartment units. Apartment square footage, amenity level, parking facilities, playground areas, swimming pools and land density are controlled variables subject to the desires of the developer of a specific project.

The Stirling Homex Hi-Rise building designed for the Memphis, Tennessee site was planned as a home for the elderly. The ground floor design includes the activities center and contains the many service rooms (crafts, auditorium, concessionary, kitchen, lavatory, etc.) for accommodating these functions. Additionally, building management areas, workshops and storage areas are provided. There are twelve dwelling floors above the ground floor level. A typical floor contains ten efficiency and seven one-bedroom apartments.

ECONOMICS OF THE SYSTEM

In order to realize the full economic potential of the Stirling Homex Hi-Rise System, certain conditions are required: (1) Land value and demand justify a high-rise system, (2) Job site labor costs are considerably higher than normal production plant cost, (3) Project schedule requires minimum elapsed time from beginning to end of construction, (4) Project site to be within reasonable proximity to production plant and/or (5) Project to be sufficiently large to justify production facilities expansion or work-around.

After examining the Memphis Site in depth, it was determined that construction of the BREAKTHROUGH prototype units at this time was not economically feasible. This decision was based upon economic factors only and had no reference to the technical feasibility of the system.

DEVIATIONS FROM ORIGINAL PROPOSAL

At the time Stirling Homex Corporation entered into an Operation BREAKTHROUGH contract, a Hi-Rise building had been designed and was being erected at Homex's Plant No. 2. During the Fall of 1970, the building erection was completed. The Hi-Rise model has been utilized in the training of supervisory crews, in working out techniques and installation procedures and in proving the technical feasibility of the system.

Although this was not a part of Stirling Homex Corporation's Phase I contract, it is a milestone of significance which should be mentioned and represents a point of departure for Operation BREAKTHROUGH participation.

The Phase I Contract required, in addition to various plans and studies, preparation of plans applying the Stirling Homex Hi-Rise System to the Memphis and Kalamazoo Prototype Site. As originally processed, the Hi-Rise building was pointed toward apartments for the elderly. The building for the Memphis Site, in fact, evolved without consequential variation from that market objective. Addition of a covered parking area with promenade deck required a second entrance to the building at the floor above the community floor, but other site constraints were not encountered.

Design for the Kalamazoo Site, on the other hand, underwent considerable change in the early months of Phase I. The proposed "elderly" configuration was deemed inappropriate by the site planner in view of the absence of an elderly market in that area.

Early neighborhood questionnaire surveys and meetings by the site planner resulted in agreements with the community that no high-rise buildings would be built on the Kalamazoo Site. Several preliminary designs were prepared and considered before agreement was finally reached in November 1970 on a design satisfactory to the site planner. The number of apartments had changed from 72 to 44. The apartments were to be primarily the one-bedroom design, aimed at the "young professional" market near the site. The roof line of the building was depressed to 3 story, 4 story, 2 story, as may be seen in Figure I. These variations, while well within the capa-

I. Apartment Building Proposed For Kalamazoo Prototype Site bility of the Hi-Rise System, represented a demand for additional design, effort and time.

Available soil analyses of the Memphis and Kalamazoo sites predicted the probable need for a deep foundation beneath the Stirling Homex Hi-Rise. A contract supplement was requested in December 1970 and appeared in February 1971 for additional soil boring. These tests have been completed, and the data used for foundation design.

Phase II Prototype Site Building Cost Estimates were prepared and submitted. Later, cost negotiations resulted in the mutual decision not to further pursue the Kalamazoo Site building. The Memphis building design remained active, however, a later economic decision was made not to proceed with the Phase II Prototype Development.

Phase I Contract was initially for a five-month period. The Kalamazoo design changes brought about a "no additional cost" time extension to the contract, to allow preparation of revised plans.

Phase I Contract products required, with a few exceptions, were produced on, or near, the original planned date and within budget cost. A supplementary change to permit additional soil boring was authorized.

CODES

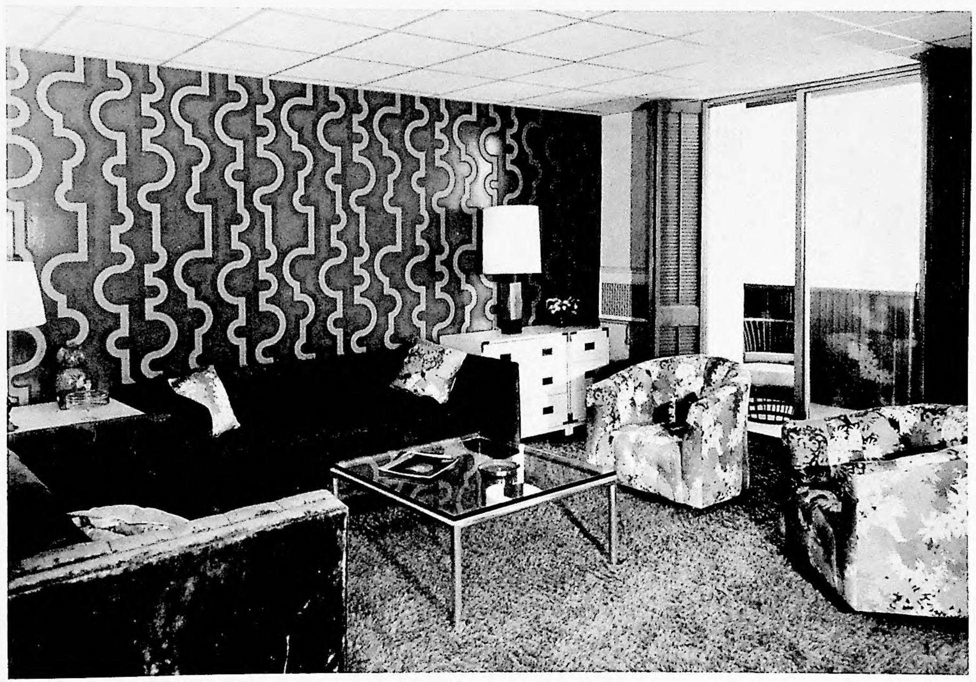
The Stirling Homex production of modules permits code compliance by producing modules for pre-identified location. Designs are reviewed and appropriate changes introduced on the manufacturing line as the modules are produced. Housing authorities and building inspectors are invited to visit the plant when the modules for their project are being produced. In this manner, they can satisfy themselves that detail which is later hidden, is, in fact, being installed per print, and complies with local codes.

LABOR

The Stirling Homex production line is manned by members of the Carpenters Union. All operations are performed by union members. Similarly, activities at the site are subcontracted only to those holding union contracts and to the particular crafts required. Prevailing union wages are paid at the site. This arrangement had been in effect for several years and has demonstrated its workability in many states. The Hi-Rise System will take advantage of continuing use of such arrangements.

TRAINING

Stirling Homex is convinced that proper employee training results in significant long term benefits. They have worked closely with the New York Department of Labor in establishing a 20-week training program oriented to the unemployed. Training of the key personnel of a prospective agent or subcontractor is on a case-by-case basis.



J. Hi-Rise Unit Living Room

MARKETING

The long range marketing plan for the Stirling Homex Hi-Rise System is for nationwide distribution. The near term target is for Eastern United States distribution.

Production Line No. 1 at the Avon, New York plant, can readily be used for the production of Hi-Rise modules. Plans have been made to open a second and larger production facility at Gulfport, Mississippi, when conditions warrant.

K. Hi-Rise Efficiency Apartment Interior

The date that Stirling Homex will market their Hi-Rise System will be determined by: (1) The economic factors mentioned in the previous section, (2) timing in relation to other Stirling Homex commitments so that their entry into the high-rise market would provide a smooth progression, (3) long term market demand, and (4) the economic factors of a proposed project. Stirling Homex will continue to monitor the first three factors while examining various specific projects to determine the proper time to enter the high-rise market.

Stirling Homex considers that subcontracting the complete installation sequence and authorizing the production of modules by others is within the realm of possibility. Both circumstances, however, would require quite firm arrangements with regard to quality control, uniformity, follow-up responsibility and responsibility for maintenance of the reputation of the product. Specific requirements will, of course, depend in part on the circumstances of a specific authorization. For example, a license to an organization beyond the borders of the United States might vary considerably from an arrangement within the country. Patent applications have been pursued on an international basis in anticipation of such a variety of possibilities.

The degree of delegation of responsibility will logically be expected to increase with time and favorable experience. Delegation by license or by subcontract, however, will be accomplished only when product reputation is established. Other considerations will include: conforming to BREAKTHROUGH criteria, minimum property standards, quality control standards and pricing.

Working with the project developer, be it private enterprise or housing authority, the marketing function assesses the feasibility of the project and examines—perhaps helps to set-up—the financial arrangement. In some cases, a preliminary proposal is prepared which presents conceptually the site plan and type of dwelling unit being proposed. If the approach receives a favorable response, additional details are worked into a complete proposal with costs and presented with prints and specifications. Close liaison is maintained between the marketing and technical service people so that all questions may be examined and answered.

In working with a project developer, the degree of required assistance emerges. In some cases, it is obvious that a potential developer is capable of producing a successful project with little, if any, outside assistance. On the other hand, there are potential sponsors who require a broad range of assistance. Stirling Homex Corporation is prepared to assist potential developers on an as required basis in the disciplines of site planning, technical assistance, site assembly, land and customer relations throughout the life of a project. As appropriate, the corporate cadre is supplemented by utilizing local professional services and labor as required to ensure a successful project.

Inquiries involving the Stirling Homex System should be addressed to:

Stirling Homex Corporation
1150 East River Road
Avon, New York 14414

or call:

Mr. Charles Eastwood
Phone (716) 926-2481

Summary Information

SYSTEM APPLICABILITY

Density Range	Applicable for high-rise construction up to 20 stories.
Environmental Adaptability	Applicable to all climate, soil and seismic conditions.
Non-Residential Functions	Hotels, motels, dormitories, hospitals and office structures.
Site Planning Services	Will provide total system or work as consultant or producer only.

BUILDING SYSTEM DESCRIPTION

Housing Type	High-Rise System utilizing fire resistant modules.
Unit Variations	Efficiency to 5 bedrooms. Flexible open planning.
Structure	Modules with reinforced concrete floors and lightweight steel framing bolted together in the field to form composite structure. Auxiliary strucutral steel provides framework of building to support floors above.
Exterior Elements	Balconies, decks, patios optional.
Foundations	Conventional or designed to fit site conditions.
Comfort System	Heating or unit cooling use all normal energy sources.
Plumbing	Service lines integrated into modules.
Electrical	Electrical distribution system integrated in modules.
Furnishing	Includes closet and storage spaces. Built in appliances optional.

DEPARTURES FROM CONVENTIONAL SYSTEMS

Innovative Features	Construction of modules and erection technique that permits the roof and top floor to be erected first.
Codes	Adaptable to all national model codes.
Deviations from Original O/B Proposal	No technical deviations involving high-rise system. Low-rise system developed using crane.

PRODUCTION PROGRAM

Delivery Rate	Projected to be approximately 5000 dwelling units/year within six months after start up.
Off-site Production	Essentially all done in factory.
On-site Installation	Bolting modules together and jacking assembly into place.
On-site Construction	Foundations and first floor only.
Internal Functions	Stirling Homex insist on providing management "know how" until buyer of their system has proved capability with system.

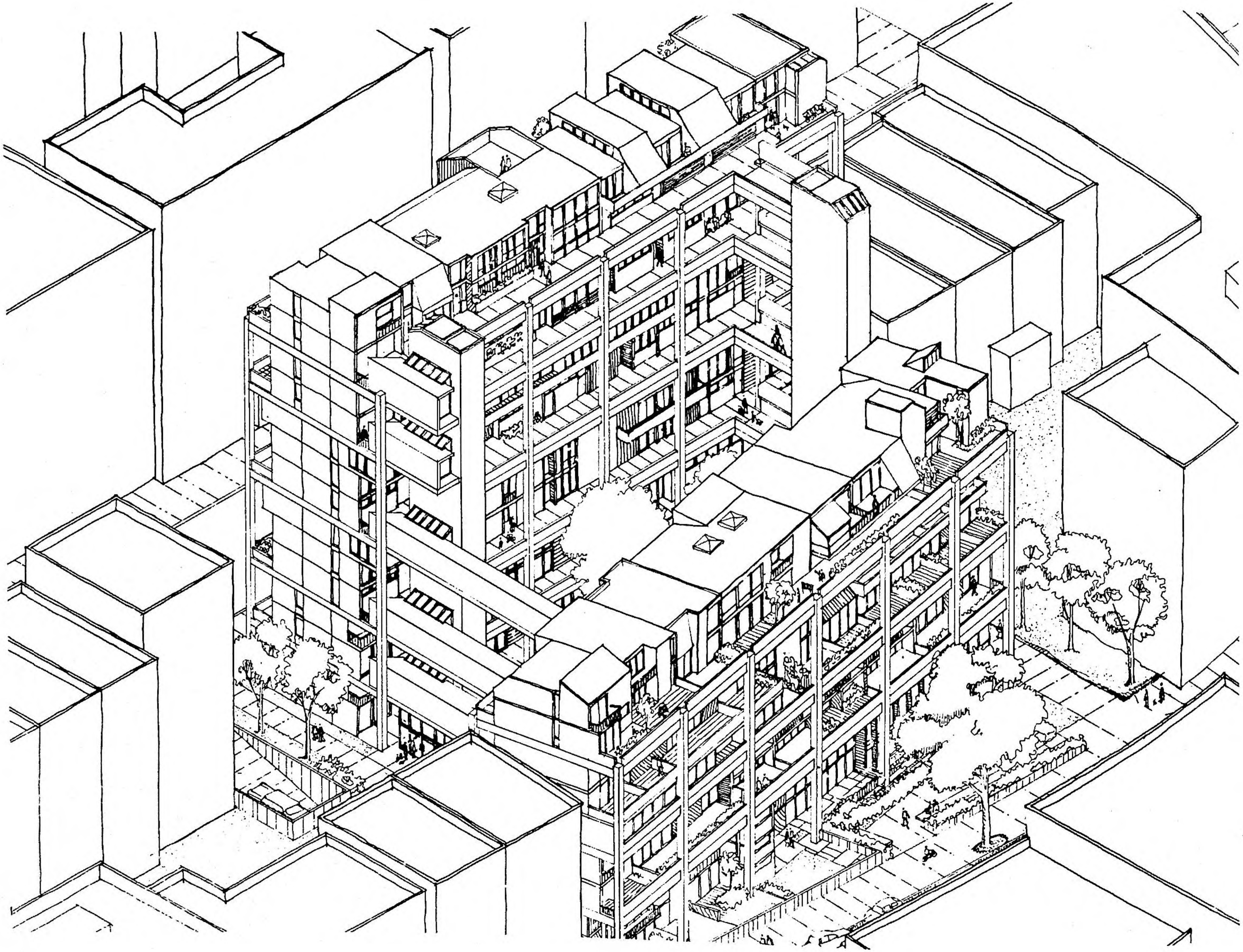
LABOR REQUIREMENTS/TRAINING PROGRAM

ECONOMICS OF SYSTEM

Construction Cost	Medium cost compared with conventional high-rise systems.
Transportation Limitation	Approximately 500 miles under normal conditions.
Useful Life	Structural system essentially permanent. Finishes, fixtures and appliances in accordance with usage and maintenance.

MARKETING FOR PHASE III

Eastern USA — See marketing text.



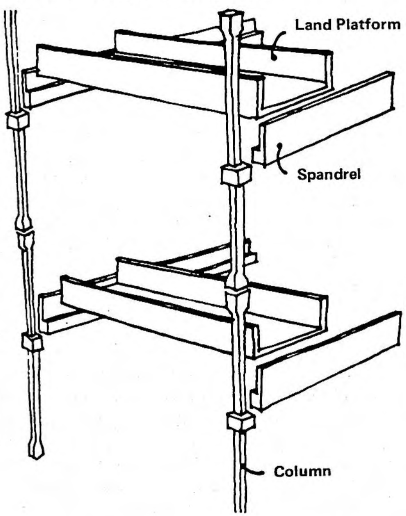
Townland

INTRODUCTION AND APPLICABILITY

Sophisticated—even radical—structures have been proposed for the urban environment. Like Fuller's containers and Soleri's megastructures, Townland is an imaginative solution. But, with the opportunity afforded by Operation BREAKTHROUGH, Townland is an immediate rather than futuristic application.

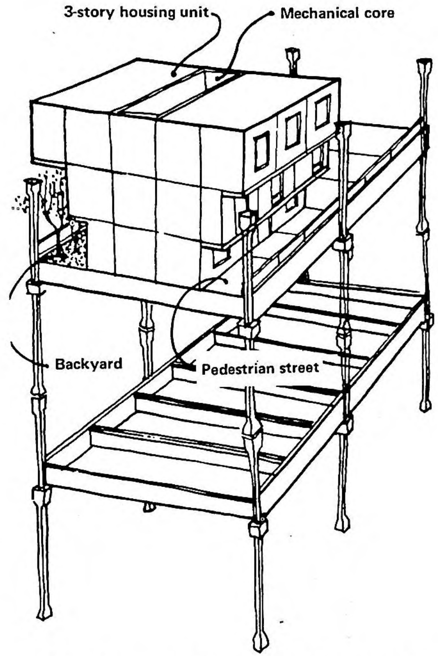
The Townland Marketing and Development Corporation was a consortium formed by the Keene Corp. to participate in BREAKTHROUGH. This consortium having been reorganized, the Townland system is now managed by Warner, Burns, Toan, Lunde of New York City. Responsibility for erecting the 58 units of BREAKTHROUGH housing, at the Seattle City site, is The Boeing Company's.

The Townland concept combines the amenities and architectural variety of private dwellings with the land economy of high-rise structures. This is possible because of "created land": platforms above ground level, complete with pedestrian streets and backyards as well as room for dwellings or other uses.



A. Subsystem 1 - Supported Land System.

There are two basic subsystems, usually called the "superframe" and the "infill." The superframe, or "Supported Land System" (SLS), consists of pre-cast concrete components making up the elevated platforms (Figure A). Infill, for purposes of the BREAKTHROUGH demonstration, is two- and three-story dwelling units that use a number of factory-built parts (Figure B). Since, in theory, infill is not limited to housing alone, the modest Seattle trial only hints at possible future applications.



B. Subsystem 2—Prefabricated housing units.

When base column lengths are varied, the SLS can be adapted easily to hillside, shore or other sites. Different foundation supports accommodate particular local soil conditions.

The Townland System is especially suitable for crowded core cities. Heights up to 17 stories are feasible with the present design. In urban renewal projects, for example, SLS could allow air-rights housing, even commercial and institutional needs, with a minimum disruption of the existing neighborhood life.

Such an urban renewal demonstration was planned for the BREAKTHROUGH Jersey City site. Design advanced to the 95% point, but the Townland assignment then was cancelled. Cost aspects at Jersey City were significant, including the economic paradox of large dwelling units for low-income tenants. Also, the Townland System gains its advantages at the price of certain structural redundancies. Townland, in the townhouse configuration, is not yet competitive in cost with center-corridor high-rise buildings, but it fills a need that cannot otherwise be met.

The usual dense housing is a dubious solution in the urban core. Low-rise and mid-rise structures are not practical because real estate is too expensive. But the Townland concept offers attractive in-city living with minimum land cost per unit.

When all the intangibles are given due consideration, the potential of the Townland System appears to be very good.

SYSTEM DESCRIPTION

The system as developed for Phase II (Figure C) may be deployed in a wide range of configurations. These are low-rise, medium-rise, or high-rise (nominally to 17 stories, depending upon local site conditions).

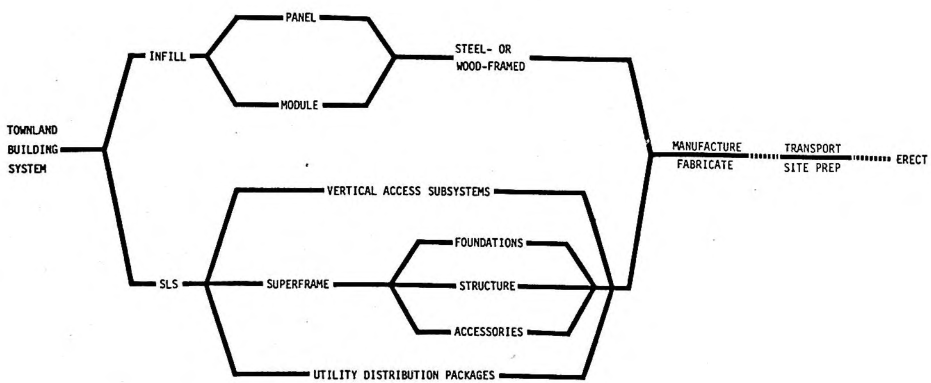
Infill

Designs for the housing units, or residential infill, accommodate wind and seismic loadings imposed should the units be placed in the maximum height structure.

The infill is specifically matched to the load-carrying capabilities of the superframe (10 x 12 foot loading grid and a live load of 250 psf for three-story infill).

When used as low-rise units, infill can be three stories high with a modular roof system. At maximum height, with peak loads, infill is two stories with roof.

The infill, then, is the same basic design irrespective of its use as low-rise, medium-rise or high-rise. When the economies of volume production allow, slight changes toward more specialized designs will result in cost savings.



C. The Townland system as developed for Phase II.

Infill designs are available in different structural and material "families." Both modular (volumetric or three-dimensional) and panel (two-dimensional) units may be built of either wood or steel. The development of wood-framed families resulted from extensive discussions with HUD and the National Bureau of Standards (NBS). An existing body of experience and expertise within the Townland Consortium (Wickes and 3H) was drawn upon.

The Townland System does not preclude site-built design solutions. Indeed, such solutions are to be expected in the case of nonresidential uses. This will be particularly true the first time commercial and institutional facilities are provided. In theory, residential spaces too could be "stick-built" should community or labor conditions at a particular site dictate. (These conditions are accommodated in different ways in the Seattle and Jersey City designs.)

The decision at Jersey City was that the 14 SFA units at stories 3 through 5 would be wood-framed modules provided by Wickes; the 28 MFLR units at stories 6 through 8 would be "Steelshell" metal-framed modules of a columnar side-frame design, as developed by the Consortium.

All 58 units at Seattle are of steel panel design, an adaptation of the Rusco Building System. This system, now made by Bucoa, Inc., has been proven in various commercial and residential applications. As used for BREAKTHROUGH, it actually is a framing system, replacing the usual studs, headers, etc., with load-bearing steel panels. The panels may be finished as exterior walls (although in Seattle they are overlaid with cedar siding). Precut at the factory. The panels are assembled on site and attached mainly with sheet metal screws.

Superframe/SLS

The Townland System uses a patented concrete superframe in medium-rise and high-rise situations. This subsystem has been given several names, such as megastructure, superframe, high-rise grid, synthetic land structure or Supported Land System (SLS). The technology essentially is that of a parking garage with longer spans. An important difference, however, is that the SLS has long spans in both horizontal and vertical directions, the latter properly known as long column design.

Nominal bay spacing is 30 by 60 feet. Levels are separated two or three stories. The frame may be either precast or cast in place. There are three basic elements—columns, spandrels and channels—plus wind-bracing members.

For Jersey City, a precast SLS was designed. The columns and spandrels would be constructed of plain (stone) reinforced concrete, while the channels and wind braces would be 6000 psi lightweight concrete and are prestressed. Columns, spandrels and wind braces would be cast with protruding reinforcements to be caged and laced together prior to the making of the wet joint. Column bases and capitals (tops) are typical throughout any given building's SLS.

At Seattle, the bulk of the work—cast in place—is concentrated on site; its selection was based on economies of scale, market development timing and logistics. Dimensions of the cast-in-place members vary slightly from those of the precast. Columns and spandrels were cast in place, while channels were precast off site.

The SLS results in point loading of foundations at the 30 by 60 foot bay spacing. Caissons, spread footings, or other conventional foundation supports may be used. As with any other large structure, extreme care has to be taken with initial line and plumb of the columns on the foundation caps.

To complete the description of the SLS, certain additional elements should be discussed. The pedestrian street (adjoining the front entries to the dwellings) is built up of precast concrete planks. They span the channel troughs, and a concrete wearing surface is then cast in place over a waterproof membrane. Street drains are included in specified planks to collect all surface runoff. The runoff is funneled into the storm sewer drainage pipe within the under-street utility package.

Backyards, at the rear of the dwelling units, may be filled with earth. A 6 inch layer of porous granular material is overlaid first with fiberglass board, then with approximately 2-1/2 feet of soil. The channel is fitted with a yard drain to carry off percolated water.

Backyards also can be decked in wood or paved similar to the pedestrian streets.

Utility Distribution Module

Another subsystem has been developed to mate with the SLS, a subsystem that is important to the concept of "created land." This is the Utility Distribution Module (UDM). There are five distinct elements:

1. A vertical riser kit, for street ends and intermediate points
2. An under-pedestrian-street horizontal chase
3. An in-channel lateral chase to the housing unit
4. Channel crossover connection kits
5. Vertical riser manifolds for the vertical access shafts within the dwellings

The chases and manifolds are preinsulated with polyurethane foam and sheathed in galvanized metal. Pressure and quick-couple connections were selected, with extensive use of flexible devices. (UDM's are not being used at Seattle because all but six units there are built on grade.)

Typically, the following services will be contained in the UDM:

Electrical distribution	Telephone
Television	Domestic cold water
Gas/oil	Storm drain
Sanitary drain and vent	Spare for special service or future use

Within the housing units themselves, plumbing and wiring are conventionally provided on site for the panel family. The module family would generally be wired and plumbed at the factory. A copper, single-stack Sovent installation was designed for each unit, but not used at Seattle.

Vertical access methods were not fully explored by the conclusion of Phase I.

Prototype designs employed conventional techniques for fabrication and installation on site of stairs, elevators and utility risers. The SLS is a good work platform for this purpose.

FLOOR PLANS AND OPTIONS

Residences in the Townland System may be SFA or MFLR. They are designed as pairs of units: 30 and 40 feet wide for Seattle, and 30 feet wide for Jersey City. This is consistent with initially proposed Townland floor plans, which showed 15 or 20 foot wide units.

In all cases, present SLS loading constraints require infill load transfer within the basic 10 by 12 foot grid spacing. Widths, across the front elevation, are in multiples of 10 feet for either modules or panels. When vertically superimposed, joints, lot lines, etc., are in line. Unit depths are in multiples of 12 feet.

To illustrate, in the Jersey City module design, SFA's are 36 feet deep, and MFLR's are 48 (one-bedroom) and 36 (two-bedroom). Modules are arranged transversely, each containing elements of two or more dwellings. All living units in Seattle, panel-built, are 36 feet deep.

Even though the infill design must satisfy the special requirements for use on SLS, it is also well suited for stand-alone, low-rise applications.

A wide variety of consumer needs can be met by different arrangements of the Rusco System. Five configurations cover six floor plans at Seattle (Figure F):

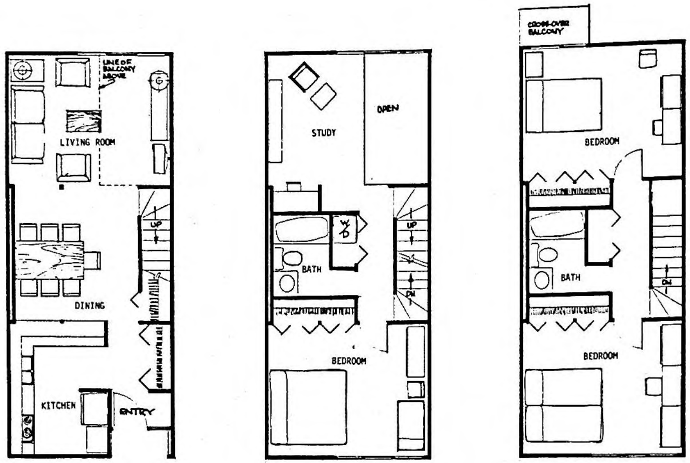
MFLR "piggyback," two-bedroom over three-bedroom

SFA four-bedroom

SFA three-bedroom

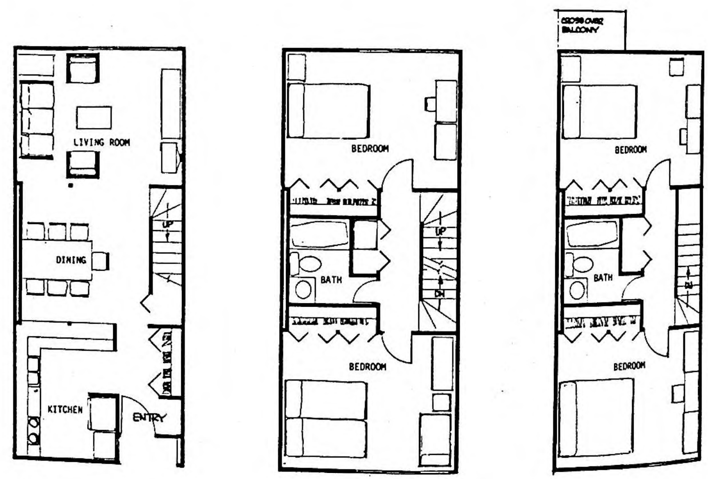
SFA two-bedroom with cathedral ceiling

SFA two-bedroom with flat ceiling



LEVEL 1 LEVEL 2 LEVEL 3

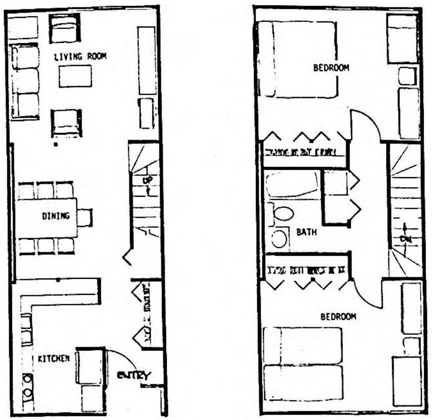
THREE–BEDROOM TOWNHOUSE



LEVEL 1 LEVEL 2 LEVEL 3

FOUR–BEDROOM TOWNHOUSE

D. Plans of Seattle prototype units.



LEVEL 1 LEVEL 2

TWO–BEDROOM TOWNHOUSE

LEVEL 1 LEVEL 2 LEVEL 3

TWO–BEDROOM OVER THREE–BEDROOM MFLR

DEPARTURE FROM CONVENTIONAL SYSTEMS

Innovations

Townland is the unique combination of a structure that can reach high-rise dimensions with individual dwellings that are typically townhouses. Since the whole concept is a distinct departure, the system description has covered many innovations.

The SLS superframe enjoys certain advantages of simplicity and flexibility in its foundation requirements. Load transfer of the structure dead load and imposed live loads from the frame to the foundations takes place within the frame and is transmitted axially through the base columns. No additional members or uniquely-designed load transfer beams need be developed for any given site.

The UDM also represents a significant innovation in the industrialization of utilities main runs. It is not limited to housing, but is applicable to many developments and building types.

Deviations from Proposal

The Keene consortium proposed for Operation BREAKTHROUGH a steel-framed core-and-panel infill design. It was mistakenly assumed that this solution was within easy reach of contemporary U.S. housing technology, and could be purchased from existing producers.

However, investigation of systems suppliers nationwide showed that the desired product was not likely to be economically obtainable. Complete development was impractical within the time and budget limitations of Phase I. Design thinking thus turned to three more basic approaches: modular (three-dimensional), panel and stick-built.

This was the first significant departure from the proposal.

At the 25% design completion stage, five infill solutions were under consideration. These included two panel systems, framed with wood and steel, for Seattle. For Jersey City, one wood-framed and two steel-framed modular systems were in work. One steel-framed modular design used a side frame with slender columns spaced 10 feet apart. Rolled or brake-formed steel members were employed instead of structural shapes. These five systems were subsequently reduced to the three described elsewhere.

The original superframe concept envisioned a dry connection of precast members. This design actually was carried out in the full-scale mockup built at Berlin, New Jersey. The mockup is 30 by 60 feet in plan and has two deck levels, at the second story and the fifth. Seismic loadings on the dry connections, however, exceeded the allowances of the HUD/NBS Guide Criteria for MFHR, and connections proved cumbersome. Therefore the superframe design was changed and a wet knuckle replaced the dry joint.

Also, wind bracing members were added to the design. These are horizontal cross-braces between column-spandrel joints. They provide what is essentially a post-and-beam frame before the channels are placed.

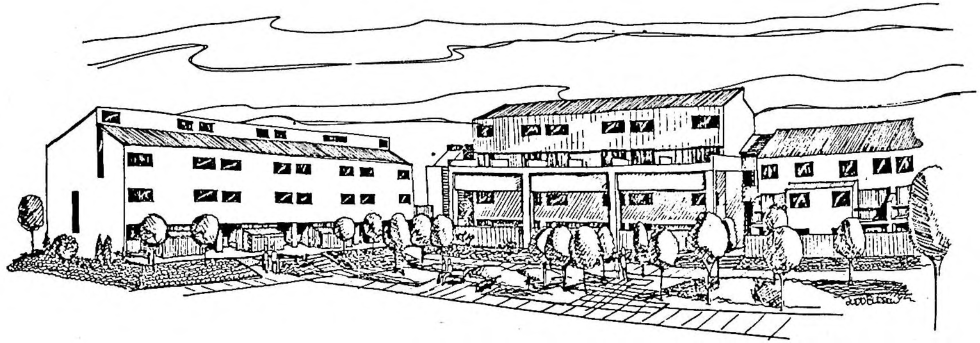
With this design change, criteria for drift under wind or seismic loading were met. Important production advantages were gained too. Taken together with the wet knuckle, the additional member made it possible to reduce the number of channel variations from three to one. The column design was simplified to a constant shape.

During Phase I, firmer cost estimates emerged as the design developed. To stay within fund limitations it was necessary to change the site plans. Then the housing design was modified in turn. This iterative cycle was a problem, but it had a positive aspect. There evolved within the Townland team a facility for adapting the system to many different site requirements. At one time or another, the complete range of configurations – SFD, SFA, MFLR, MFMR and MFHR – was being designed.

Townland was the only housing system producer assigned to the Seattle City site. Program budget constraints caused the reduction of the number of units successively from 80 to 72 to 58. The amount of SLS was drastically curtailed. Seattle became largely a low-rise development, with SFAs and MFLRs (Figure E).

By the 95% design completion stage, the Townland assignment at Jersey City had been reduced from 150 units to 42, and the SFDs were deleted. Jersey City redesign was complicated by HUD plans to test a central energy plant and a pneumatic trash collection system.

Although the underlying needs for design changes were compelling, these exercises proved costly both in real dollars and from the standpoint of thwarted development progress. They also contributed to a major reorganization of the Townland company.



E. Seattle site is largely a low-rise development.

PRODUCTION

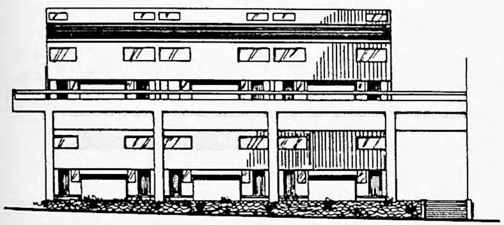
Operation BREAKTHROUGH prototype units are being built only at the Seattle, Washington site. The Jersey City assignment was cancelled late in 1971.

A 12-unit SLS is included in the prototype demonstration (Figure F). Six townhouses are on the "created land" level and six underneath. The upper dwellings are SFAs, functionally, but have been classified MFMR by the fire department and others with specific concerns.

Infill for all 58 Seattle units uses the Rusco framing system, assembled on site by semiskilled local labor (Figure I). The components are standard items made in the Bucoa, Inc., factory at Fullerton, Calif. A 16 inch wide channel, 2 or 4 inches deep, cold rolled of 18-gage galvanized steel, is the basic element of floors, walls and ceilings. All parts are cut to length at the plant and tagged and coded for location.

A Rusco technical representative was in Seattle for 6 weeks preparing journeyman workers for the semiskilled erection tasks and supervising their work. The Rusco system is designed for assembly by carpenters; however ironworkers and carpenters share the Seattle work equally by union agreement. Most of the connections are made with sheet metal screws, but some welding is required for upper stories.

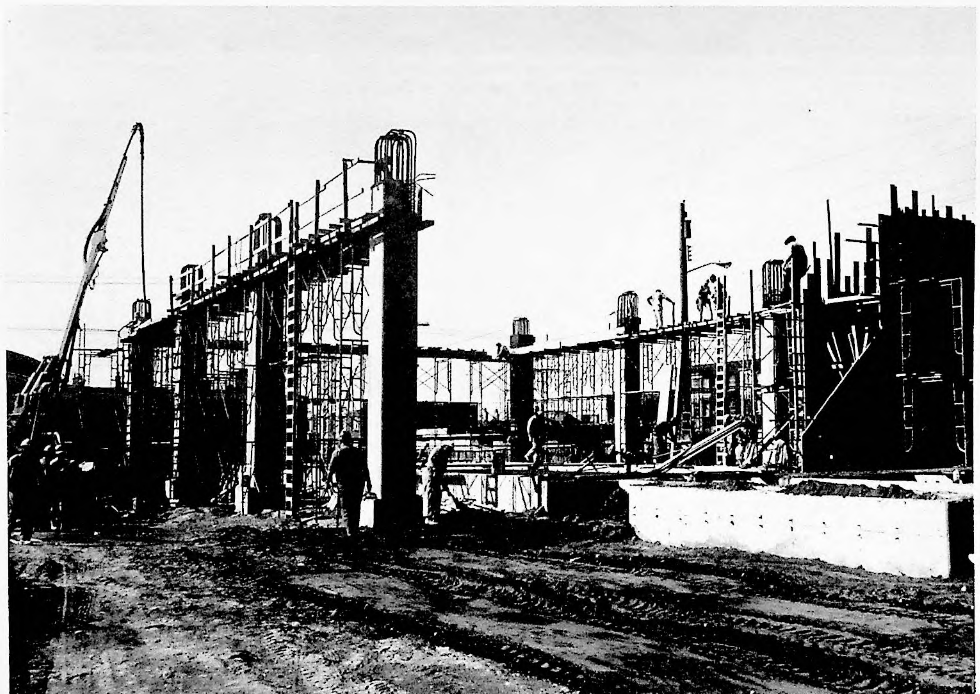
Gypsum board is used on interior walls; vertical tongue-in-groove cedar siding over plywood in the outside finish. (The Rusco panels can be finished directly with an exterior surfacing, however, usually with a stucco-like material.) One and five-eights inches of lightweight concrete placed over the floor paneling adds stiffness and sound insulation to the system; carpeting is laid normally on top of this.



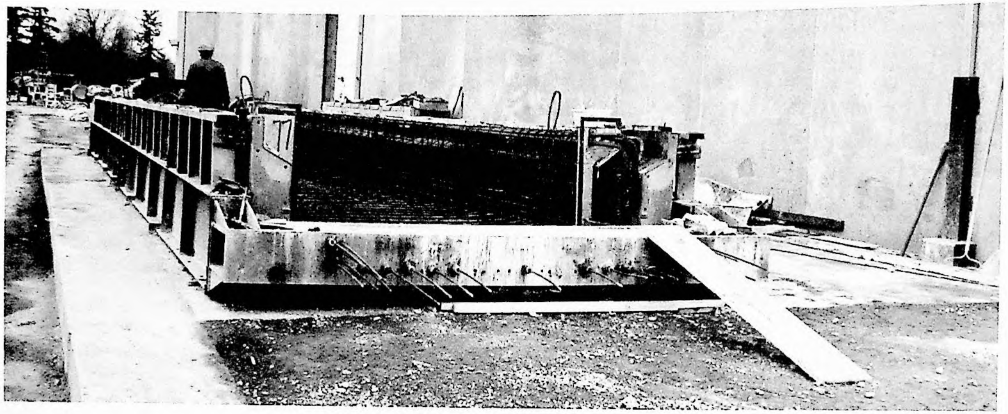
F. Seattle site Supported Land System

The SLS is cast in place (Figure G) except for the precast channels. These members were made of lightweight concrete at Olympian Stone Co.'s Redmond, Washington, plant, 18 miles from the site (Figure H). The same self-stressing steel form was used for this job as for the original New Jersey mockup. This channel design has a sectional depth of 3 feet, but the future design standard will be 3 feet 6 inches.

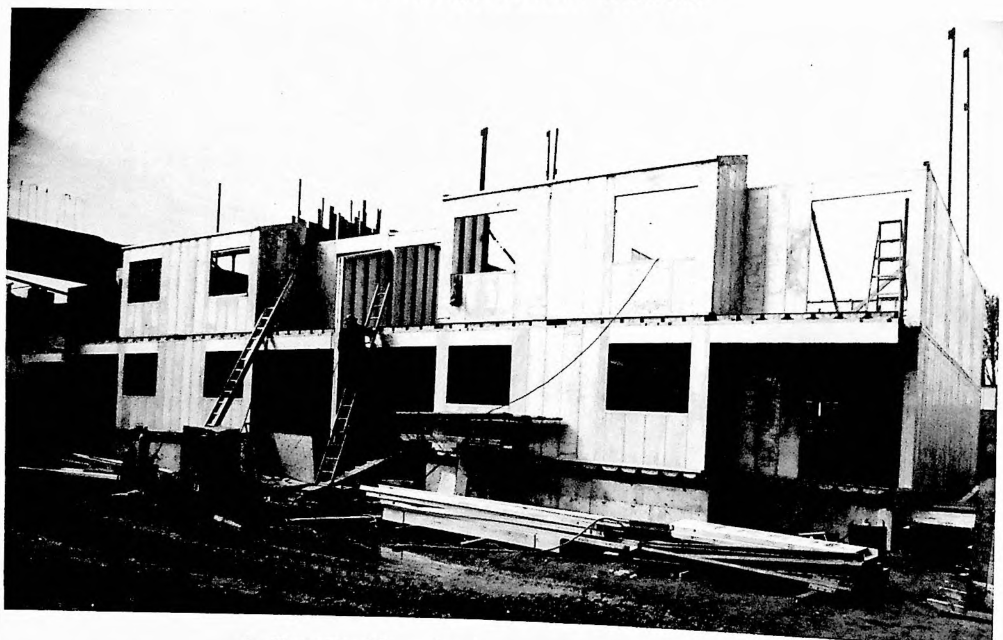
Channels were placed in the partially complete post-and-beam frame, then the final casting was completed on site. The result is three bays of SLS ready to accept two-story housing units below the deck and two-story units, with roof, on the frame itself.



G. Cast-in-place SLS at Seattle prototype site.



H. Casting of channels for Seattle SLS.



I. Elements of Rusco framing system being erected at Seattle.

ECONOMICS OF SYSTEM

Infill presently available is cost-competitive with other factory-built forms of housing. Its advantages are those expected from industrialization: shorter erection time, simplified labor requirements, and rigid quality control.

The SLS has not yet reached full development. Applications in the near future must give consideration to functional and people-oriented factors that are not cost-definable, for a strict cost comparison with conventional high-rise structures (with no credit for outdoor area on the SLS) will probably be somewhat unfavorable. Certain structural redundancies are inevitable in the SLS design, although these will eventually be refined to a minimum. The basic simplicity of the standardized shapes and ancillary subsystems clearly indicates a potential for optimum economies.

It is likely that mid-rise configurations, if housing is deployed at grade below the SLS, can be fully cost-competitive in the future.

MARKETING OUTLOOK

Program slippage and the foreseeable lag in reaching Phase III production created a serious financial situation for Townland. However, additional capital could not be obtained in the recession economy of 1970-71. In the circumstances, Consortium members were not willing to support the company further.

With the cooperation of the shareholders and HUD, Townland management was taken over late in 1971 by Warner, Burns, Toan, Lunde (WBTL), the system designer. Although Townland activities were necessarily retrenched, the firm continues to work toward the deployment of the Townland Building System.

The Seattle prototype site will be the first valid demonstration that the idealistic Townland concept has become a practical system. It is also a laboratory for probing various aspects of the design. At the conclusion of Phase II, WBTL will be in a position to exploit the promotional value inherent in BREAKTHROUGH participation.

Townland offers one qualitatively superior answer to a broad class of inner-city urban design problems. As a system, it has the flexibility to instigate and accommodate shifts in housing legislation, in such areas as urban renewal, new towns in-town, vertical zoning, and other mixed-use community housing applications. This capability will allow attitudinal preferences, reflected in local politics, zoning and community action groups, to be met.

There is also an increasing number of air-rights situations for which developed, economical solutions are sought. In this product area, the Townland System has important advantages unshared by any other system or by conventional building techniques.

For additional information, contact:

Townland Marketing & Development Corp.
724 Fifth Avenue
New York, New York 10019
[212] 757-8909

Townland Phase II units are located at the Seattle prototype site – 38 SFA, 20 MFLR.

Summary Information

SYSTEM APPLICABILITY	
Location	Urban in-city, periphery.
Density Range	50 to 100+ units/acre. 10 to 50 for low-rise w/o SLS.
Environmental Adaptability	Can be used on slopes or flat terrain. SLS can be erected over existing land-users with little disruption (air-rights). Continental U.S. climate range and most commonly encountered soil conditions can be accommodated.
Non-Residential Functions	Variety of functions possible on and under "created land"—light commercial, public, recreational, even vacant or play lots.
Site Planning Services	Available from Townland and associated companies.
BUILDING SYSTEM DESCRIPTION	
Housing Types	SFA, MFLR to MFHR.
Unit Variations	One- to five-bedroom.
Structure	Superframe of concrete, infill (housing units) of wood or metal.
Exterior Elements	Add-on subassemblies for balconies, bay windows, room extensions. Modular roof system. Outside storage shelters.
Foundations	Conventional, designed for point loading at 30' x 60' SLS bay spacing.
Comfort System	Housing units have individual HVAC. Electric heating optional, air conditioning optional.
Plumbing	"Utility Distribution Modules" (packages). Standard plumbing installation optional.
Electrical	Utility Distribution Modules.
Furnishing	Choice of floor covering.
DEPARTURES FROM CONVENTIONAL SYSTEM	
Innovative Features	"Created land" (Supported Land System) with pedestrian streets, backyards, etc. on elevated platforms. Ready acceptance of factory-built or custom-built "infill" for living units or other functions. Seattle site uses Rusco metal-framing system. Prefabricated Utility Distribution Modules; single stack waste system (not used at Seattle).
Codes	Can be adapted to typical codes including UBC. Since concept is a departure from the commonplace, experience is needed for wide acceptance.
Deviations from Original O/B Proposal	Original infill not available from commercial sources; replaced by new designs. SLS knuckle and wind bracing added. UDM not used.
PRODUCTION PROGRAM	
Delivery Rate	No firm plans.
Off-site Production	Superframe members precast, infill components preformed and cut to length.
On-site Installation	Assembly of superframe, erection of infill.
On-site Construction	Foundations, wet jointing of superframe, finish interiors of infill.
Internal Functions	Design. Site planning (optional).
External Functions	Factory production of subsystems by qualified contractors. Site development. Erection.
LABOR REQUIREMENTS TRAINING PROGRAM	Local labor can be trained for many semi-skilled erection/assembly tasks.
ECONOMICS OF SYSTEM	
Construction Cost	Data are preliminary but indicate cost-competitive.
Transportation Limitations	None that are not common to precast construction.
Useful Life	Normal; structure 100 years.
MARKETING FOR PHASE III	Plans for 236 project in Northeastern U.S. accepted by HUD; others under discussion.

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TRW Systems

INTRODUCTION AND APPLICABILITY

TRW Systems, Inc., has developed a new, factory-produced building system called Fiber-Shell. It combines conventional and unconventional materials. The major component is a sandwich panel fabricated from gypsum or plywood, GRP (glass-reinforced polyester resin) and a cellulose honeycomb core of phenolic-impregnated kraft paper.

The housing units designed for Operation BREAK-THROUGH during Phase I consist of modules, assembled in the factory from panels and structural shapes. Fourteen townhouses and six single-family detached units will be demonstrated at the Sacramento prototype site .

Fiber-Shell is one of the truly innovative results of BREAKTHROUGH. The modules are a good solution for Phase II prototype requirements, but an improved system is the goal for Phase III. Easier transportation and a wider variety of functional and architectural choices are forthcoming refinements. Developmental work is being carried on by TRW's subsidiary, Community Technology Corp. (CTC).

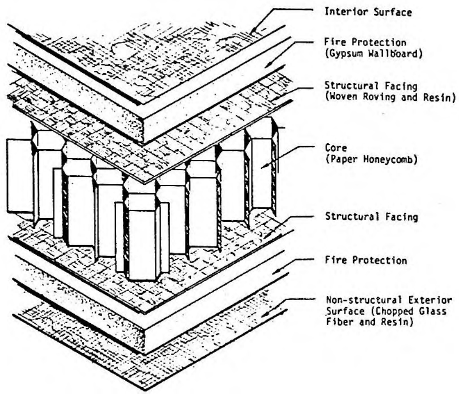
CTC plans to enter both the conventional and low-income housing markets with this industrialized system. All normal site conditions can be accommodated. Modules can be set at various positions on almost any grade, because of their unusual structural properties. The same inherent strength allows extreme cantilever over-hangs, which add esthetic interest. Fiber-Shell is appli-cable to most low-rise situations, particularly the advanced cluster concepts such as planned unit developments.

SYSTEM DESCRIPTION

The basic Fiber-Shell panel is a lightweight, glass-reinforced plastic sandwich (Figure A). A 3-inch-thick core is used for wall panels and 6-inch for floor/ceiling/roof panels.

End walls have most of the openings, so these panels are built differently for greater strength. Kiln-dried Douglas fir is used as framing, with plywood laminated on both sides. Insulation is rock wool. The preassembled end walls are attached to the open shell by adhesive and lag screws.

Completed modules have unusual strength, and can provide 20 feet of clear span.



A. Components of Fiber-shell panel

For BREAKTHROUGH two-story townhouses, double-wall construction was designed at the interfaces. Modules thus can be completed independently. Upper and lower modules are separated vertically by an 8-1/2-inch support structure or "horsecollar." The resulting space between the lower-story ceiling panel and the upper-story floor panel is used for HVAC duct runs, electrical cables and so on (Figure B).

Side-by-side separation of adjacent townhouses is 3 inches. To meet fire rating requirements, two layers of 5/8-inch gypsum board are used on all inner surfaces of party walls and roof panels. The second layer is secured by staples in addition to adhesive.

Bathrooms and kitchens are service cores; they are purchased in completed condition and installed at the housing factory. The wood-framed volumetric modules, obtained from a supplier, are stock commercial items with standard fixtures.

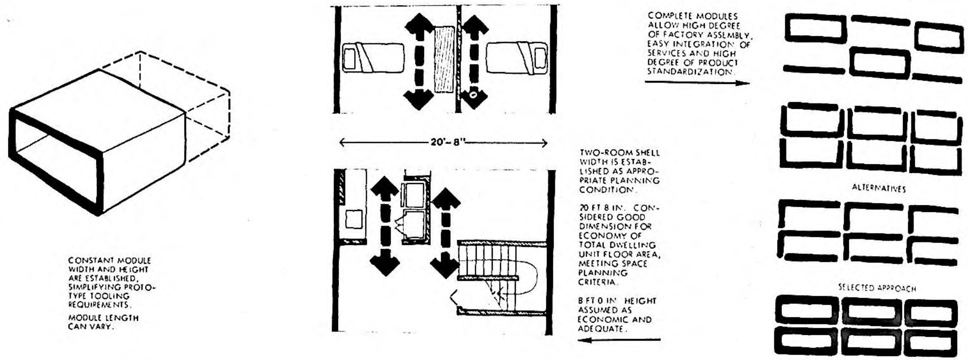
B. Ducting in place between two-story townhouse shells.

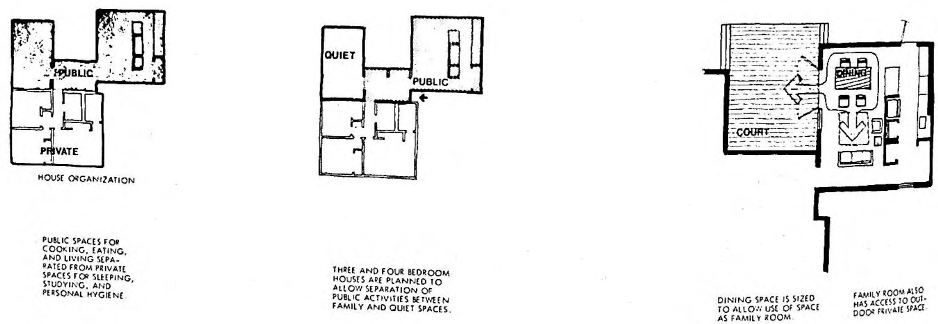
Interior partitions are 2 x 3 stud subassemblies, and preframed doors are used throughout. Inside finishes are conventional, with water-based paints over gypsumboard.

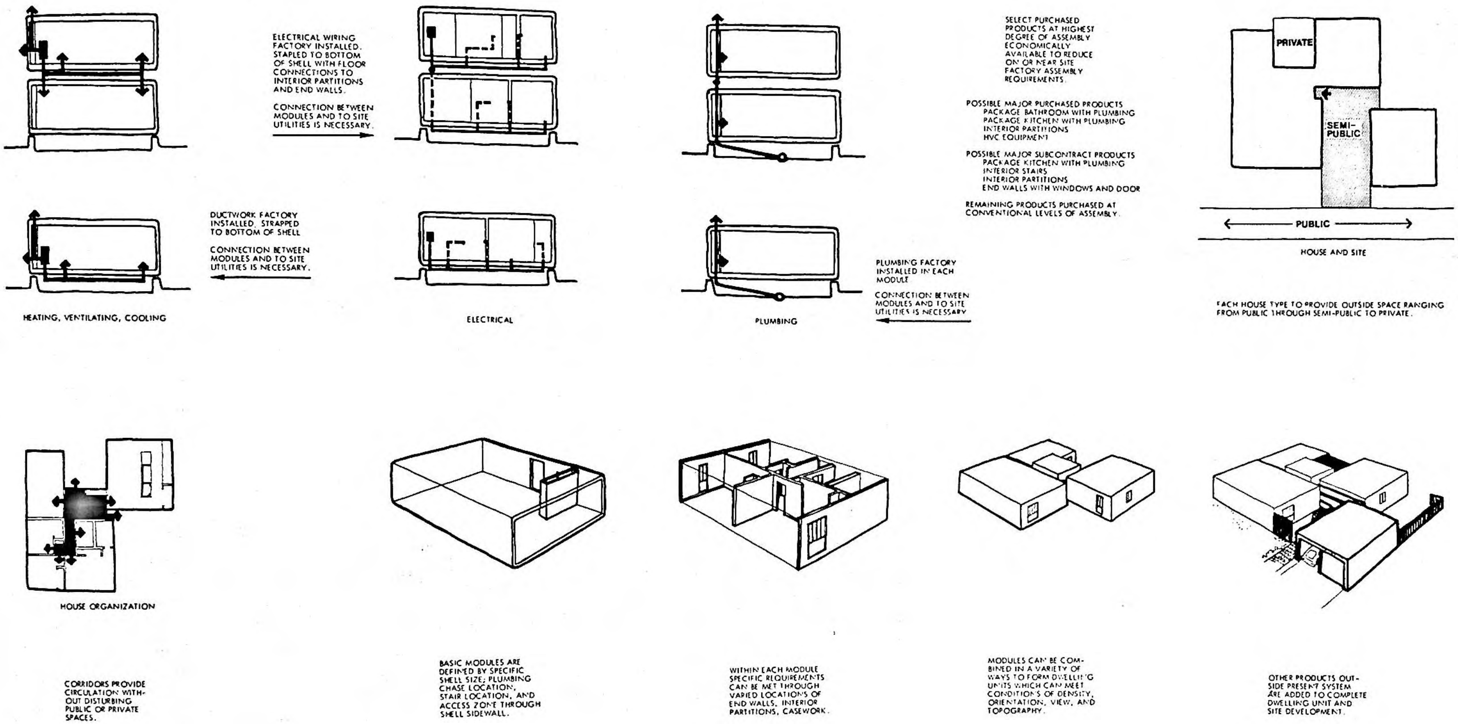
A novel exterior finish that closely resembles stucco has been developed by TRW. It is a modified polyester resin (similar to that used on boats) fortified with chopped glass, and with aggregate included for texture. Any color pigment may be added to the resin, contributing to an attractive, durable finish. It can be applied to all outside surfaces, including interfaces between modules. On those unexposed areas, aggregate and pigment are not used.

Housing Designs

The evolution of the dwelling unit designs for Operation BREAKTHROUGH was relatively conventional. After site selection and layout, the architectural design was initiated (Figure C), followed by electrical, mechanical and structural.





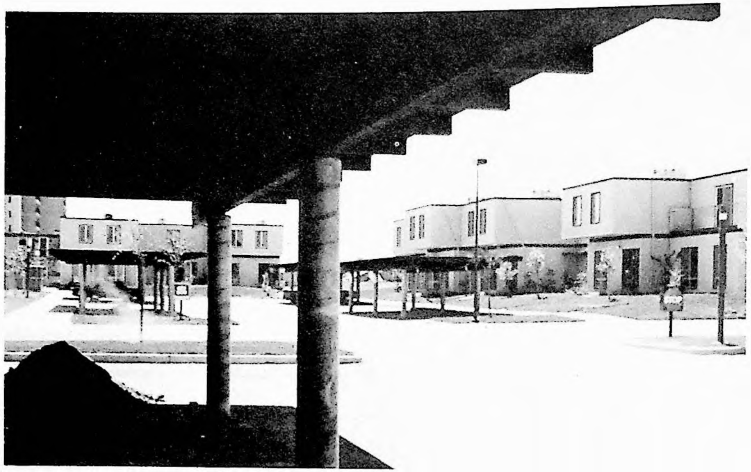


C. Architectural evolution of the Phase II system.

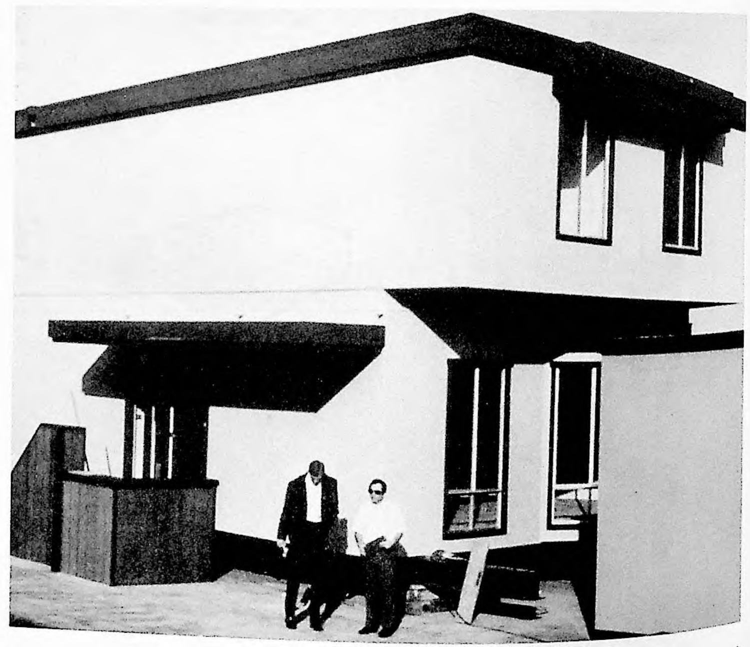
Exterior appearances of the Sacramento units (Figures D and E) do not represent accurately the wide variety possible with the system. The primary purpose of the prototypes is to validate the Fiber-Shell approach to practical and economical housing. However, variety is inherent in the system concept.

Specifically for Sacramento, three shell lengths and a constant shell width were chosen. The 20-foot 8-inch width is optimum for economic floor areas, various bedroom furnishing possibilities, and good circulation.

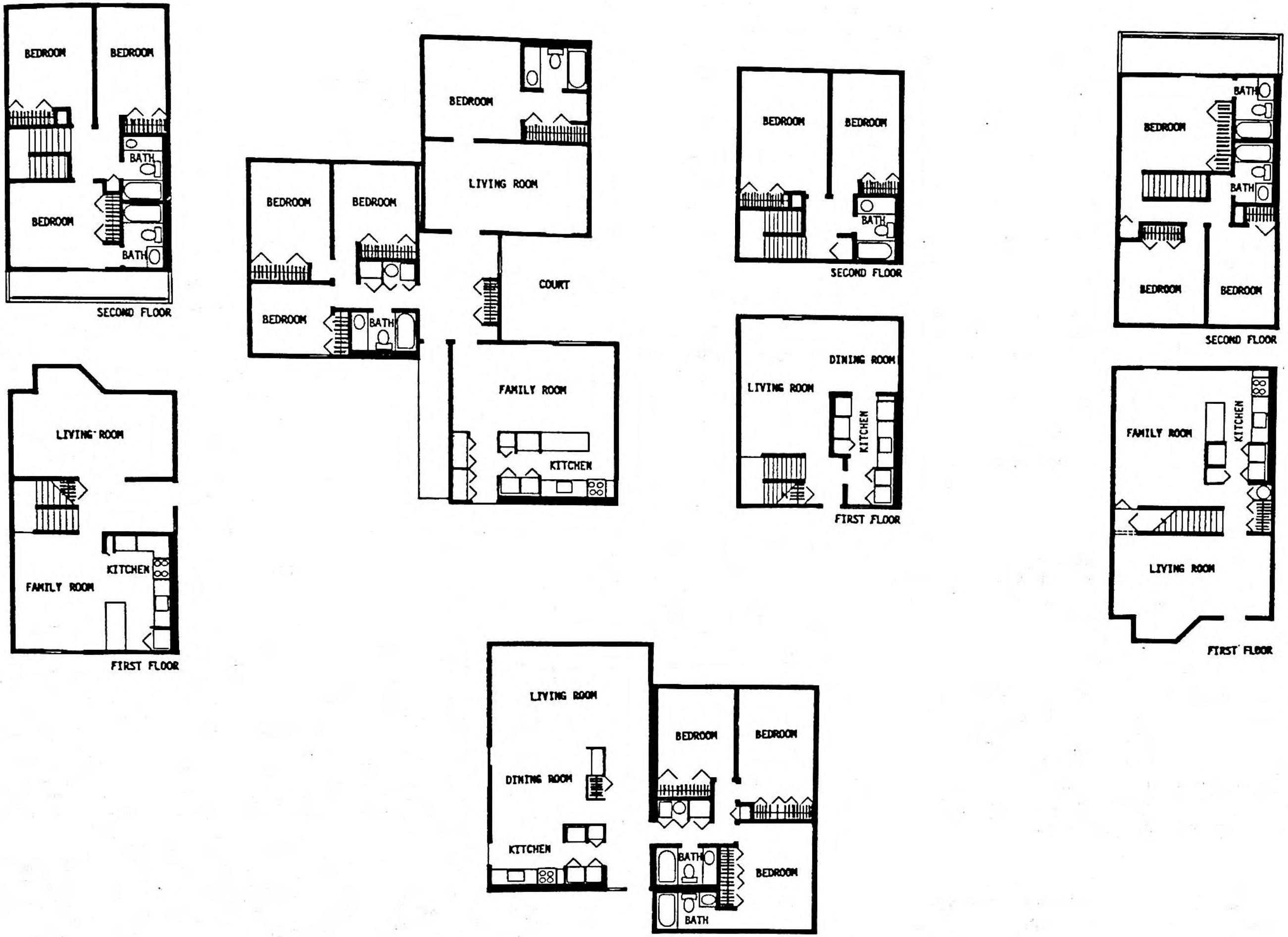
Layouts provide private outdoor space adjacent to family and dining rooms. Interior arrangements reflect basic system objectives for separation of public and private spaces, and circulation that is convenient and avoids through-room flow (Figure F).



D. TRW Fiber-Shell units at Sacramento site.



E. Sacramento prototypes demonstrate the TRW approach to practical and economical housing.



F. Floor plans reflect system objectives of separation of public and private spaces.

DEPARTURE FROM CONVENTIONAL SYSTEMS

Innovations

TRW's Fiber-Shell system offers many unique and innovative features:

- Adaptability to automated production techniques
- Potentially lower costs
- Architectural flexibility of interior and exterior arrangement
- Simplified module or dwelling unit handling and transportation
- Simplified foundation designs
- The use of nonconventional materials without losing conventional appearance

Some of these features are evident at the BREAKTHROUGH Sacramento site. However, the full potential of Fiber-Shell remains to be demonstrated in future projects.

The modular concept used for BREAKTHROUGH has some material redundancy, but many offsetting benefits. Among the advantages of modules are a high degree of factory fabrication, regular production rates independent of the weather, more control of final quality, and dimensional regularity that favors the installation of large purchased components within the shell.

Fiber-Shell does not present an unconventional appearance, despite the use of novel materials. This is important, because customer resistance to change in the appearance of the living environment is well known. The uniqueness of Fiber-Shell is hidden within its walls, floors and ceilings.

Deviations from Proposal

Production of dwelling unit shells on a mandrel was originally proposed by TRW for Operation BREAKTHROUGH. This basically was an application of a highly developed and refined aerospace industry technology. Bodies of revolution, such as large pressure vessels for missiles or spacecraft, are commonly filament or tape wound.

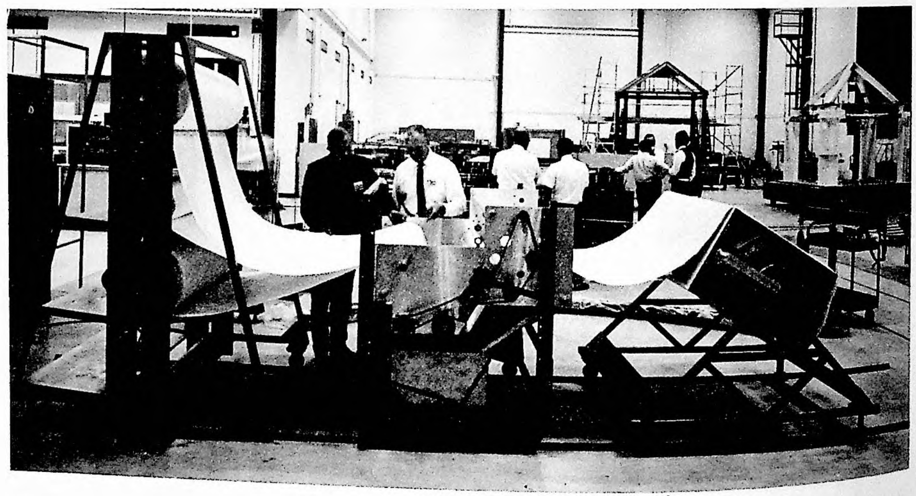
Early in 1970, a functioning sub-scale prototype operation was put in service (Figure G). This pilot plant simulated a number of the proposed production techniques. In the course of nearly a year, many modifications were made. The unit provided guidelines for design of a full-scale "stub" mandrel.

The stub mandrel has a full-size cross section through the shell (8-foot ceiling height by 20-foot 8-inch floor span), but it is only 4 feet long. On its surface (the width of typical material: gypsum board, plywood, honeycomb), Fiber-Shell fabrication can be demonstrated effectively. A major capital investment for a full-length mandrel was unnecessary.

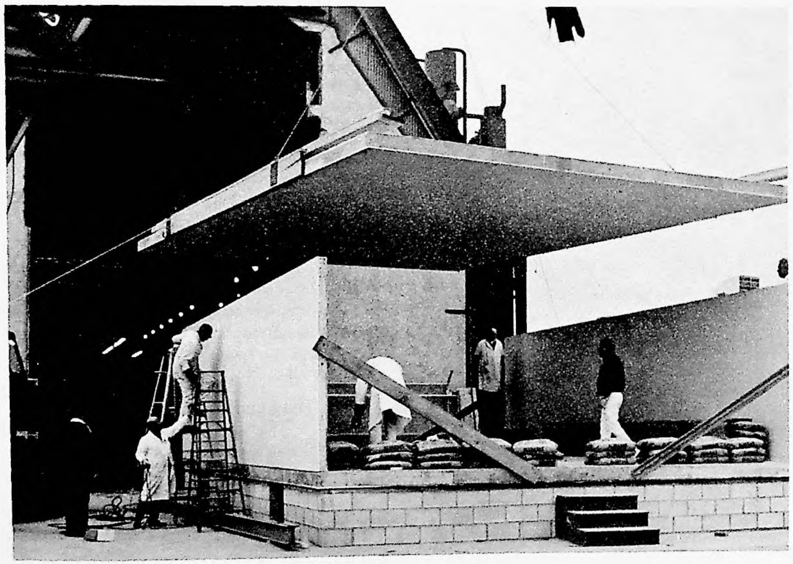
The mandrel was designed, built and operated in late 1970 at the TRW Inglewood, California, Test Facility. Fiber-Shell bents were successfully produced, and a number of improvements and refinements were made to the system. Some other problems were raised by the limited stub mandrel operation and by the concurrent design studies of a production system. These problems were soluble, but time for starting the Sacramento prototype units was running short.

Meanwhile, an alternative approach was being used to prepare flat panels for required TRW and NBS tests. These panels were fabricated readily on simple, flat, bench lay-up surfaces.

But the Fiber-Shell system was intended to be based on modules, not panels. A major change in concept had to be avoided at this point. Therefore, the panel experiment was extended to the assembly, in the factory, of a module from panels produced in the flat (Figure H). The result compared favorably with that of the mandrel, and HUD therefore accepted the change to a panel-module method.



G. Subscale pilot plant with 20 by 30-inch by 4-foot long mandrel.



H. First full size shell assembled from flat panels.

Actually, the end product is the same in either case. But the limited production run of 20 dwellings for BREAKTHROUGH did not justify the design, fabrication and development of a complete mandrel system. The primary objective was to prove out Fiber-Shell as a viable building system, demonstrating its factory producibility at minimum cost. This could be accomplished more easily and quickly by the panel approach, which permits sequential resolution of each technical problem.

Another change, a relatively minor one, was made in the transportation plan. It was originally proposed to stack the shells for townhouses on site, using a crane and a specially made spreader bar. Instead, stacking was done at the factory.

Trade-off studies showed that the cost of raising telephone and electric lines along the travel route was under $1000. This very reasonable amount was more than justified by potential savings from less site work.

The initial roof system proved inadequate and was replaced by a new design. One stairway design was also changed.

TESTING

Before Operation BREAKTHROUGH, there was scant experience with man-made materials for house building. The performance of a composite sandwich could not be predicted entirely. Therefore TRW had to make many tests during 1970 and early 1971 to evaluate the properties of Fiber-Shell.

The first group of tests aided in the development of Fiber-Shell as a structural material. Later, techniques of fabrication and the quality of different materials (paper honeycomb cores, gypsum board, etc.) from various sources were evaluated. Other tests were made to verify material structural properties and analysis methods.

Firm direction for BREAKTHROUGH housing design is given in the HUD Guide Criteria. Compliance with the criteria was demonstrated by a series of tests, planned and conducted both by TRW and NBS. Results were fully documented. Of particular interest was the successful completion of the life-safety test program, a summary of which is shown in Figure I.

CHARACTERISTICS	TEST LABORATORY	FIBER-SHELL PERFORMANCE
Structure		
Wall compression	TRW	5620 lb/ft–(T/3–moist ult.)
Wall/floor joint compression	TRW	4870 lb/ft–(T/3–moist ult.)
Floor bending strength	NBS	18,700 psi bottom lam tensile ult.
Roof/ceiling strength	NBS	6180 psi top skin ult. comp.
Floor creep	TRW	$<$l/240
Floor damping	TRW	0.36 sec to 20% ampl.
Fatigue	TRW	10,000 cycles at DL+LL
Special		
Water saturation of paper core	TRW	6.5 psi for 30 days
Fire Safety		
Rating (time to failure):		
Wall	National Gypsum Co.	1 hour, 42 minutes
Ceiling	National Gypsum Co.	1 hour, 4 minutes
Flame spread	NBS	16 units
Smoke	NBS	60 units
Comfort		
Acoustical	Kaiser Gypsum Co.	STC-53
Thermal	Johns-Manville Co.	0.15 BTU/hr/ft^2/^{o}F.

Figure I. Summary of Key Life-Safety Test Results

PRODUCTION PROGRAM

The basic process techniques evolved from experience in several areas: the pilot plant, stub mandrel, structural tests, panel equipment design and other development activities. Phase II production flow is as follows:

1. Place lower vacuum bag on lay-up bench.
2. Place lower layer of gypsum board. For townhouse wall and roof panels, two layers of gypsum are needed on the inner surfaces. 3M1897 adhesive is used between double layers.
3. The lower layer of woven roving is dispensed onto the lower layer of gypsum. Two cloth widths (roll lengths) of woven roving are used, 8-foot widths for walls and 11-foot widths for floors and ceilings. They overlap about 6 or 7 inches to produce 21-foot 4-1/2-inch-wide floor and ceiling panels.
4. Spray shields are placed on the bench around panel perimeters to protect the clamps and bench from over-spray.
5. Resin is applied to the cloth by hand, using an airless spray from a movable full-span catwalk.
6. Spray shields are removed or retracted.
7. The completed subassembly of headers with honeycomb is hoisted into position and placed on the lower laminate.
8. The upper lay of woven roving is dispensed.
9. Spray shields are repositioned around the panel perimeter.
10. The upper laminate resin is applied by spray and the spray shields are then removed.
11. The upper layer of gypsum or plywood (floors only) is positioned.

12. The upper vacuum bag is installed and the lower vacuum bag is overlapped onto the upper bag. Bunk-bed corner folds are made and taped. Bagging of panels is for pressure during cure.

13. Perimeter pressure beams are installed. Mechanical clamps are secured. This procedure ensures a good bond with the headers and prevents the headers from being pulled inward by the vacuum.

14. The vacuum system is connected and activated to obtain a partial vacuum. Pressure monitors are connected.

15. The loaded bench is rolled into the 170°F oven. Cure, accomplished by circulating heated air around all surfaces of the panel while it is held under vacuum, takes 1 to 1-1/2 hours.

Three lay-ups per day—a floor panel, two walls, and a ceiling panel—can be made on the prototype tooling. After oven cure, panels are stripped (unbagged and trimmed) and drilled and dowels are inserted. The panels are assembled into shells, using a thixotropic modified polyester resin on the joints with clamping across the floor and roof panels. Adhesive is cured overnight.

End walls are built conventionally and secured to the shell with adhesive and lag screws. One end wall is installed before adhesive cure to ensure shell squareness. The remaining end wall is not attached until after the completed stairwells, partitions and bath or kitchen cores are in place.

Bathrooms and kitchens are received at the factory as completed products. A minimum of assembly is required, mainly installation and connection.

Interiors are finished in the conventional manner. The exterior finish is applied to the completed module. Roofing is applied before the modules are moved out to the factory yard, where townhouses are stacked and exterior trim is put on.

Townhouse stacking enables plumbing and electrical intershell connections, stairwell trim, etc., to be done under factory conditions. There are obvious resulting efficiencies (as well as cost savings from lower factory labor rates) in these activities. Townhouse stacking at the factory also minimizes the danger of water damage to lower stories through ceiling register cutouts and other openings.

Fully outfitted modules are transported 5 miles to the Sacramento site by regular house-moving equipment and techniques (Figure J). The erection procedure consists of backing the trailer in through an open end of the concrete foundation, blocking the unit and removing the trailer, completing the foundation and lowering the unit into position after the concrete has cured. Then the final on-site connections (gas, electric, water, waste, phone) are made.

Every step in production is monitored for quality assurance. The quality assurance plan was based on aerospace practices and, although modified many times, it has been followed in principle.

Because of the developmental nature of the job, quality monitoring was a problem. Clear-cut criteria for workmanship were difficult to establish on prototypes alone. However, there is little question that factory operations lend themselves to efficient quality control more readily than traditional field construction.

J. Three-bedroom two-story townhouse in transit.

K. Fiber-Shell panel house, Belen, New Mexico.

PRODUCT DEVELOPMENT

When TRW became involved with Operation BREAKTHROUGH, its objective was to apply aerospace technology and refined systems engineering capability to the housing industry. TRW is committed, through CTC, to continue research and development in this field.

A specific example is the manufacture and site assembly of two panel houses. One is in Belen, New Mexico, and the other is the twentieth BREAKTHROUGH unit on the Sacramento prototype site. Panels were manufactured in the Sacramento plant and trucked to the sites. Field joining techniques were developed as well as special field handling and erection equipment. Both units were set up quickly and with no significant problems. They clearly demonstrate the feasibility of a Fiber-Shell panel system (Figure K). This would be a practical application for distant or inaccessible sites.

The Fiber-Shell concept offers great latitude for variety. At the present time costs are the only restraint. More production processes must be verified and second-generation plants established with the capability for many different panel sizes, shapes, and finishes. In the future, when high-volume production is ensured, the mandrel method may well prove competitive.

ECONOMICS OF SYSTEM

Material costs of Fiber-Shell are, at present, slightly higher than comparable stick-built structures. A relative cost differential in favor of Fiber-Shell is anticipated in the near future, based on predicted dwelling unit requirements and timber price trends influenced by lumber supply and demand. In addition, refinement of the basic materials used in the BREAKTHROUGH houses is currently under study and test. Those houses have extremely high structural margins, and a more optimized and balanced Fiber-Shell design will reduce material costs.

Production techniques used for the BREAKTHROUGH units were austere. Major refinements in tooling and manufacturing methods are currently under way. These improvements, with modest equipment investments, will lead to automated mass production of the Fiber-Shell system.

Labor expenditures of less than 0.3 to 0.4 man-hours per square foot (of living unit floor space) are considered readily achievable in a second-generation plant.

MARKETING FOR PHASE III

CTC plans to enter both the low-income market, via Section 236 set aside for Phase III, and the conventional housing markets.

Essentially, CTC will develop projects to ensure demand for factory output. Joint-venture entities with qualified developers will be formed in specific regions. CTC has entered the market in northern California by means of a joint-venture corporation based in Sacramento. It is planned to enter the southeastern United States market also, through a joint venture in New Mexico.

Each region will have its own factory. Housing designs will be tailored for the regional markets. Modular width will be determined by the required shipping radius. The 16-foot-wide modules produced in the initial commercial run at Sacramento can be shipped within 50 miles. In the Southwest, because of longer shipping distances, 12 or 14 foot modules will be built.

CTC central offices will provide the regions with marketing, engineering, manufacturing, quality assurance, personnel and financial support. However, each region will operate either as a separate company or as a division and separate profit center.

The future of the Fiber-Shell system will depend to a large extent on the success of this business concept and performance in the initial regions.

For additional information, contact:

Norman J. Priest, Director of Marketing
Community Technology Corporation
One Space Park
Redondo Beach, California 90278

(213) 536-1703

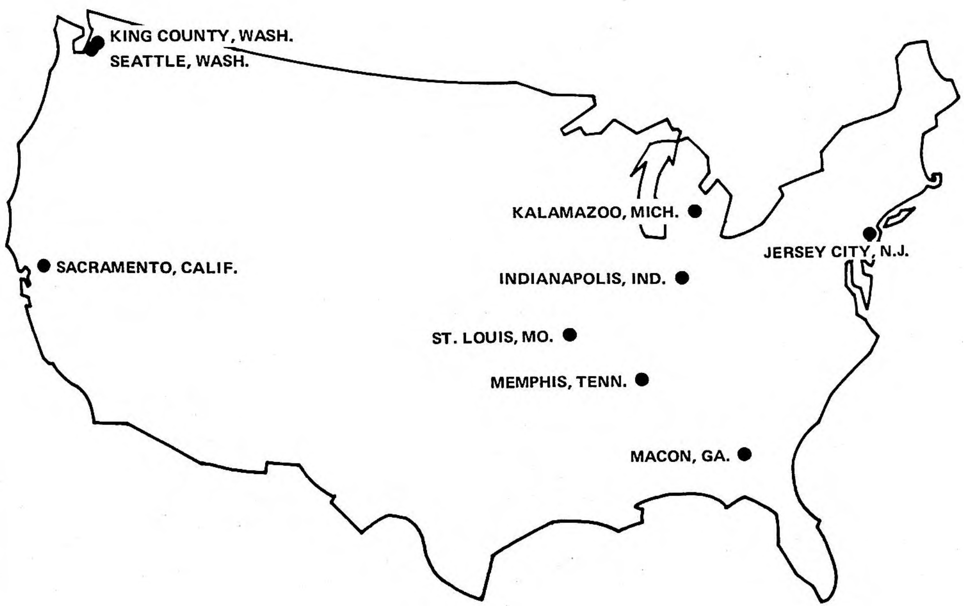
TRW (CTC) Phase II units are located at the Sacramento prototype site — 6 SFD, 14 SFA.

Summary Information

SYSTEM APPLICABILITY	
Location	Urban, urban renewal, suburban, new town.
Density Range	13 to 25 dwelling units per acre; adaptable to low, medium, and high density.
Environmental Adaptability	Adaptable to all normal topography and soils and to all national climates.
Non-Residential Functions	Social, commercial and service facilities.
Site Planning Services	Internal reference only.
BUILDING SYSTEM DESCRIPTION	
Housing Types	Single family detached and attached; multi-family low-rise.
Unit Variations	Up to 4 bedrooms.
Structure	Self-supported module (gypsum, fiberglass and paper honeycomb core); floor, wall, and roof panels.
Exterior Elements	Simulated conventional finishes, balconies, trim.
Foundations	Alternatives; prefabricated box rail, post and beam, direct placement, wooden piles.
Comfort System	Radiant panel, hydronic, or forced air heating-cooling; integrated with module.
Plumbing	Factory-installed, subassembly, prefabricated for site assembly, or conventional.
Electrical	Conduits in structural shell or dropped ceilings, surface mounted raceways.
Furnishings	Conventional.
DEPARTURES FROM CONVENTIONAL SYSTEMS	
Innovative Features	Plastic module assembled from gypsum-fiberglass-paper honeycomb panels.
Codes	Adaptable to national model codes.
Deviations from Original O/B Proposal	Module assembled from panels instead of being mandrel-wound.
PRODUCTION PROGRAM	
Delivery Rate	1,000 units per year for one factory near site.
Off-site Production	Modules or panels, components, plumbing and electrical cores.
On-site Installation	Assembly of panels or modules and mechanical connections.
On-site Construction	Foundations and utility lead-ins.
Internal Functions	Management, factory production.
External Functions	Service modules.
LABOR REQUIREMENTS/TRAINING PROGRAM	Semi-skilled and unskilled factory work; training program for production and construction.
ECONOMICS OF SYSTEM	
Construction Cost	\$11.55 to \$11.97 per sq. ft.
Transportation Limitation	16-foot wide module is restricted but optional design for narrower module is feasible within 100 to 400 miles from plant.
Useful Life	Expected to surpass normal wood-frame life.
MARKETING FOR PHASE III	Northern California and New Mexico.

4
The Prototype Sites

The Prototype Sites



Essential to the BREAKTHROUGH program was the demonstration of innovative housing units on prototype sites. Eleven of these sites were selected, representing a wide range of geographic, climatic, and marketing conditions. Fund limitations caused the deletion of two sites (New Castle County, Delaware, and Harris County, Texas) during the planning stage, and the nine sites that were developed are briefly described in this chapter.

Of the 22 Housing System Producers (HSP) chosen to begin Phase I, most were expected to erect units in Phase II on at least two sites, every site to have a variety of housing types and price levels. The total number of units envisioned was in the order of 2000 to 3000. This amount would allow a significant quantity of each prototype to be built, and make the test valid in many aspects: production and erection techniques, cost experience, consumer reaction, etc.

Assignment of producers and systems to particular sites was a task that had to be completed early in Phase I. HUD and the site planners (and, later, the developers) worked with the HSP's to arrange optimum matches of sites with systems. Obviously these were complex decisions, and an important influence on the housing system designs subsequently prepared.

Factors such as site character, density, topography, and climate had major effects on housing designs and are included in the site summary descriptions that follow.

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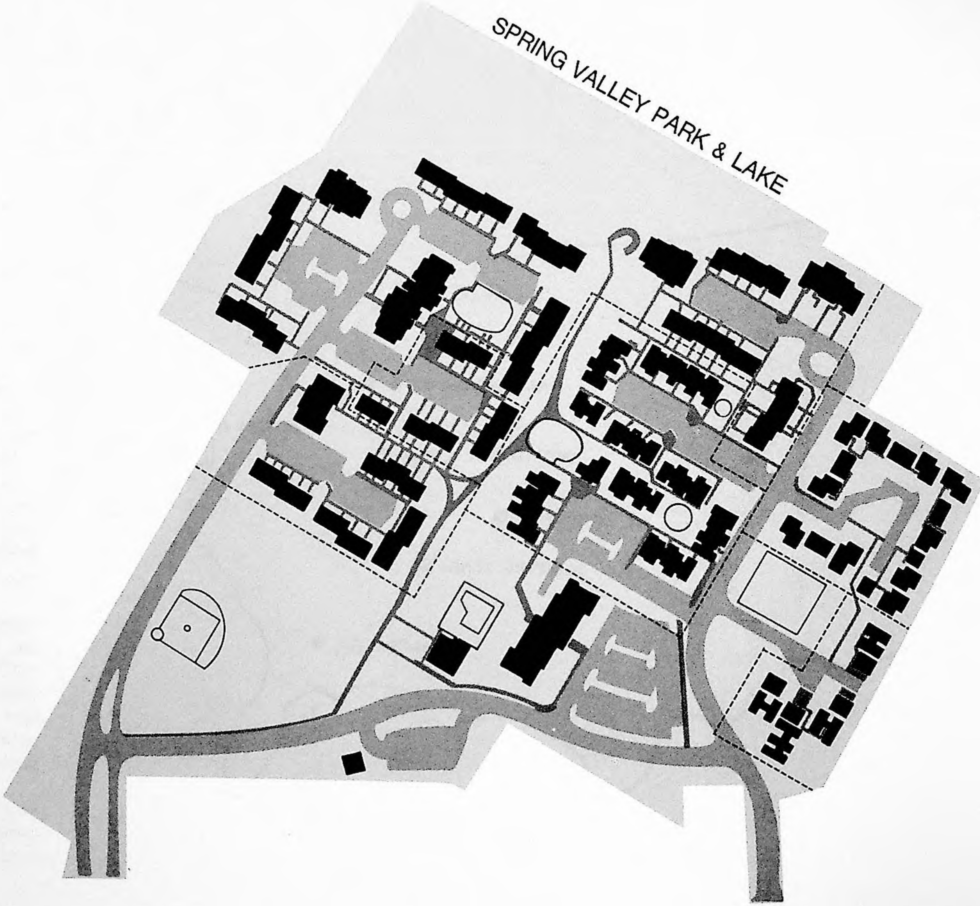

SPRING VALLEY PARK & LAKE

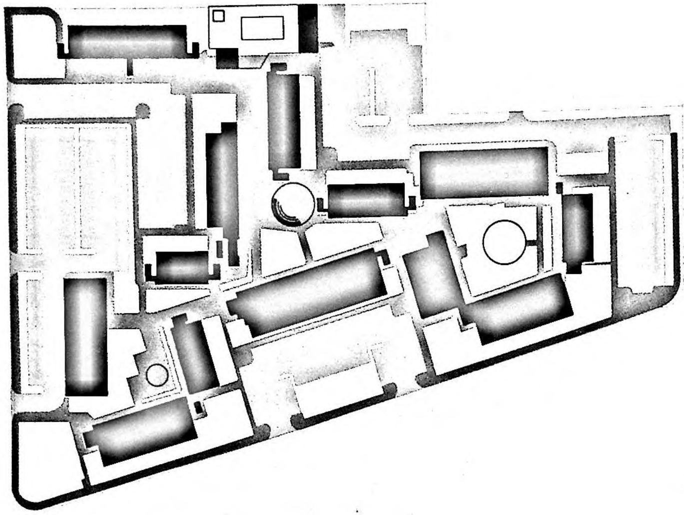
Kalamazoo, Michigan

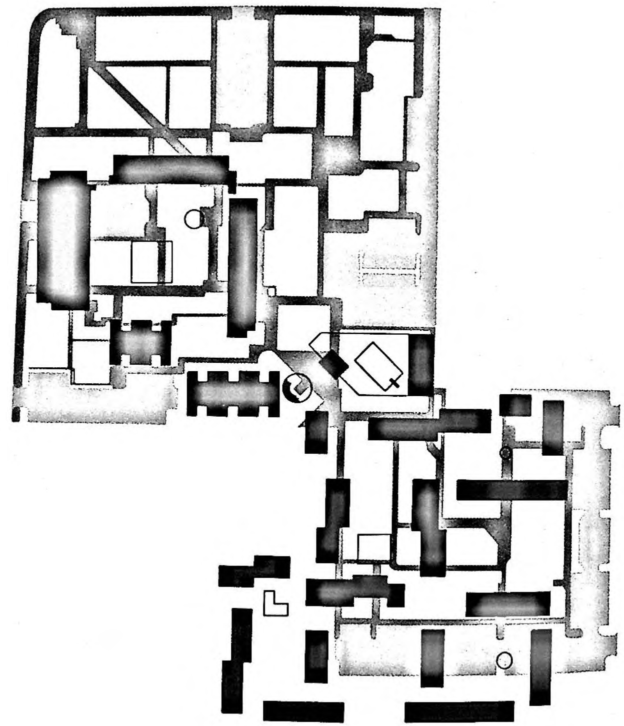
Type:	Suburban
Location:	2307 Gull Road, northeastern Kalamazoo
Size:	33.8 acres
Total Units:	245
Density:	7.25 per acre
HSP's:	FCE-Dillon – MFMR (52 units) Hercoform – MFLR (12), SFA (39) Levitt – MFLR (32), SFA (51) Material Systems Corp. – SFD (10) National Homes – SFA (15) Republic Steel – SFD (4) Scholz – MFLR (8), SFA (22)
Site Planner:	Perkins & Will of Chicago
Site Developer:	Bert L. Smokler/National Corp. for Housing Partnerships
Market:	Co-op, eligible for FHA Section 236, with representative mix at market rate. Medium-rise for elderly

From the north side of the Kalamazoo site, the ground falls away abruptly to a surprising view of neighboring Spring Valley Lake. The site itself is an open and level plateau, on the outskirts of this town of some 80,000. Community needs for housing are in a wide range, from production workers to college professors.

While BREAKTHROUGH Kalamazoo has a valuable asset in the lake, with its surrounding park, it posed a problem, too. Careful planning and development prevented any pollution by drainage from the higher elevations of the site.

The only Republic Steel units in the BREAKTHROUGH program are being demonstrated at Kalamazoo. Levitt has a large number of units here because of HSP assignment changes made to replace Pemtom. National Homes was added and FCE-Dillon replaced Stirling Homex.





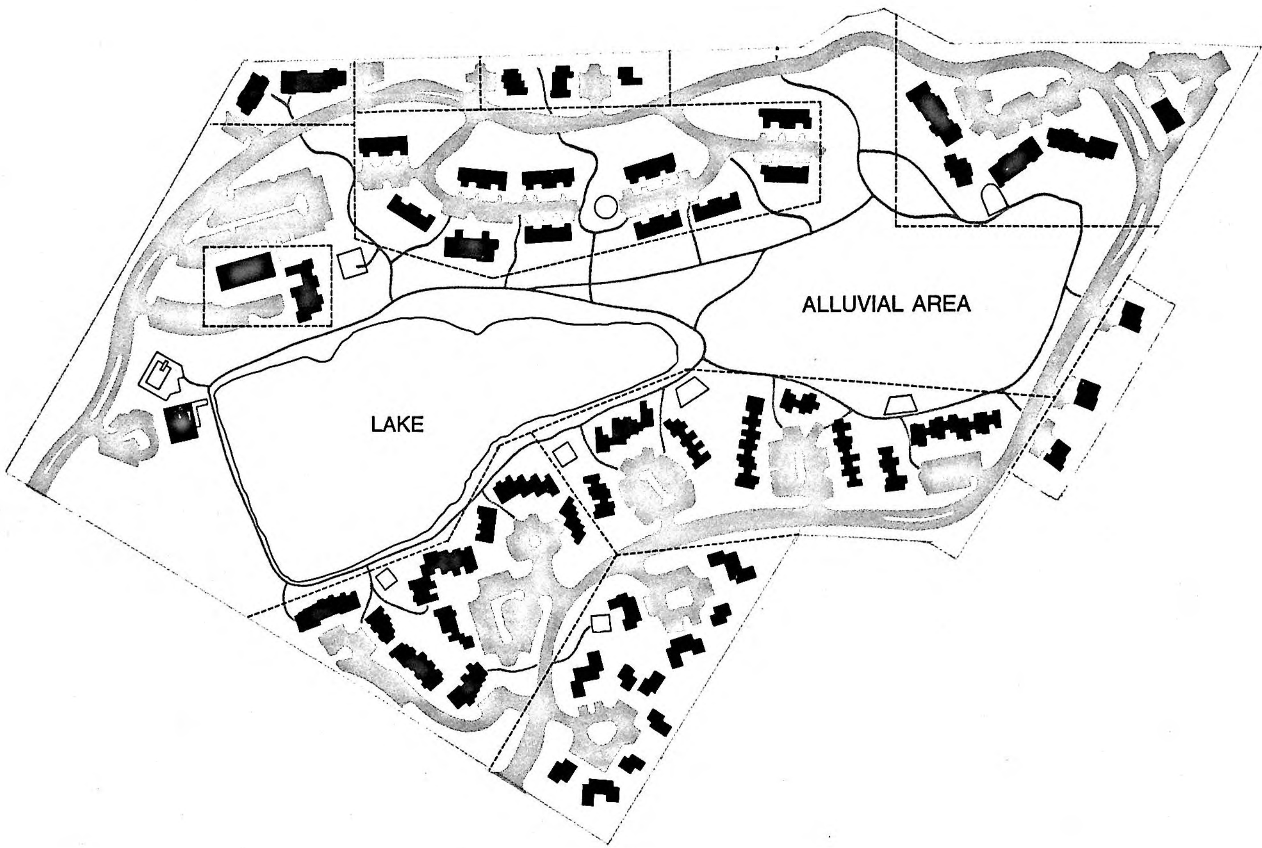
St. Louis, Missouri

Type:	Urban renewal in-city
Location:	Market & Ewing (east site); Compton & Laclede (west site)
Size:	7.6 acres (east); 7.9 acres (west)
Total Units:	464
Density:	30 per acre
HSP's:	Descon/Concordia – MFHR (90 units), MFMR (24), MFLR (14) Home Building Corp. – SFA (75) Material Systems Corp. – MFLR (20) Rouse-Wates – MFHR (84), MFMR (27), MFLR (130)
Site Planner:	Hellmuth, Obata and Kassabaum of St. Louis
Site Developer:	Millstone
Market:	Rental to wide mix of tenants, 90% of whom are expected to be eligible for rent supplement or FHA Section 236

BREAKTHROUGH St. Louis is in two parts, separated by about three city blocks. The area between the east and west sites is an established neighborhood, Laclede Town, that is a model of effective urban renewal. In planning for the medium-density BREAKTHROUGH development, the community character and spirit of Laclede Town were preserved.

Both sites are in the existing Mill Creek Valley renewal area, where very old and deteriorated buildings are being removed. The land is flat, directly adjacent to transportation, shopping, business, schools and recreation. It is 1 mile from downtown St. Louis.

This is the only BREAKTHROUGH location in which Rouse-Wates is building. The original assignment of National Homes to St. Louis was replaced by Material Systems Corp.


ALLUVIAL AREA
LAKE

Macon, Georgia

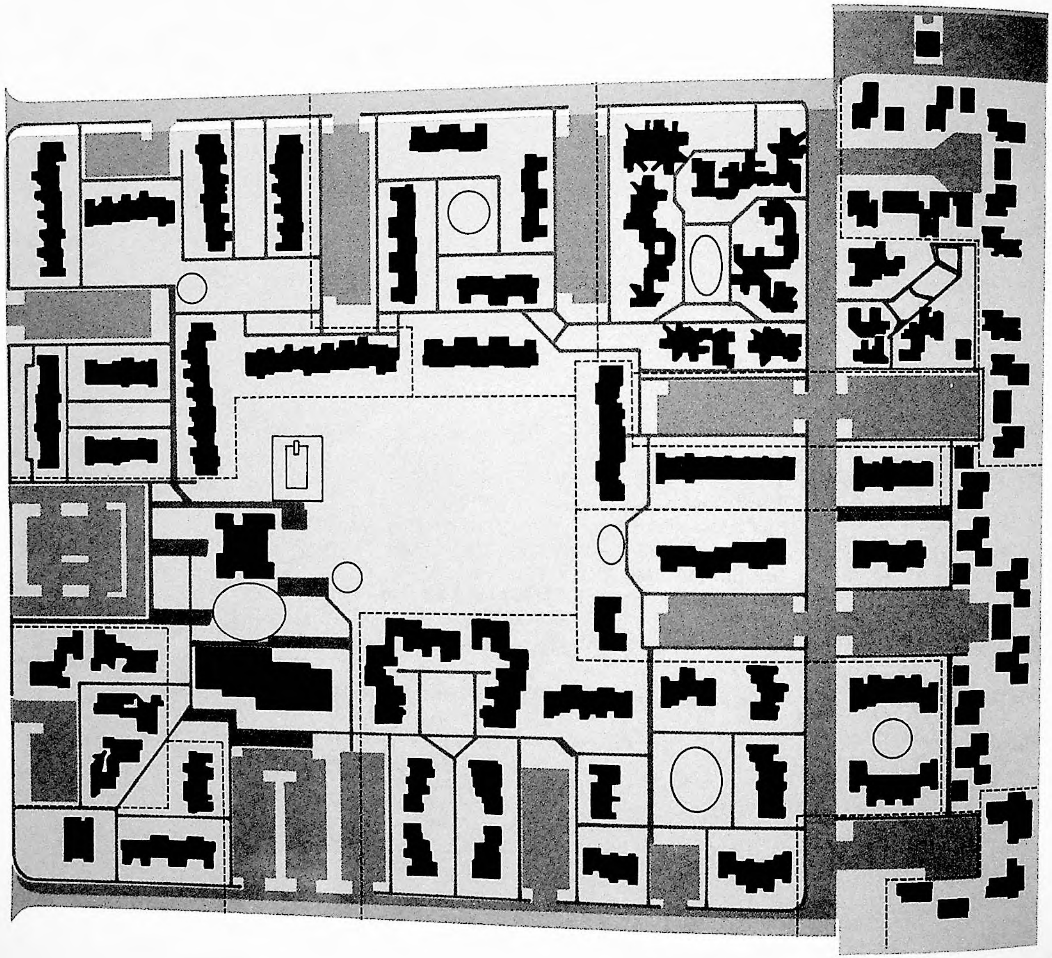
Type:	Suburban
Location:	4215 Chambers Road, within Macon city limits
Size:	50 acres
Total Units:	287
Density:	5.7 per acre
HSP's:	Alcoa – MFLR (12 units), SFA (40 units) Boise Cascade – MFLR (18), SFA (31) Building Systems International – MFHR (56), MFMR (24) Christiana Western – SFA (26) Hercoform – MFLR (12), SFA (38) Material Systems Corp. – SFA (14), SFD (16)
Site Planner:	Reynolds, Smith & Hills of Jacksonville, Florida
Site Developer:	Fickling & Walker/National Corp. for Housing Partnerships
Market:	Cooperative, eligible for FHA Section 236. Some at market rate

The rustic setting of BREAKTHROUGH Macon is regarded by many as the prettiest of all the prototype sites. Wooded slopes rise around tranquil Crystal Lake, a six-acre, spring-fed pond. The site previously was a private sportsman's retreat, and the development plan favors the same natural advantages.

On the southwestern edge of Macon, 4.5 miles from downtown, the neighborhood is partly settled with modest residences. However, there are major new highways nearby, and a growth pattern is evident. Macon itself has a present population estimated at 135,000.

A change in HSP's at Macon was the replacement of FCE-Dillon by Christiana Western. Home Building Corp. also was deleted in early planning.

This is the only site on which Building Systems International is represented.



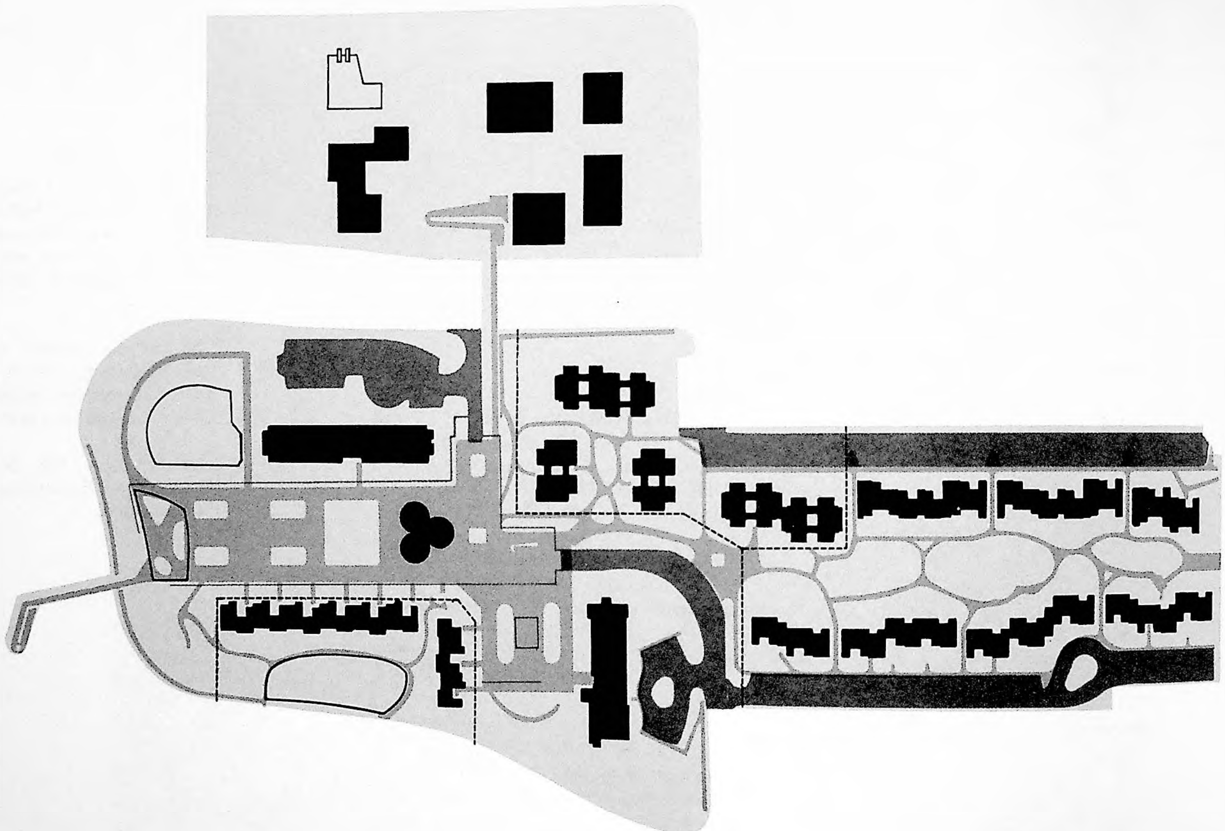
Sacramento, California

Type:	Periphery
Location:	Broadway and 57th in southeastern Sacramento
Size:	30.4 acres
Total Units:	407
Density:	13 per acre
HSP's:	Alcoa – MFLR (24 units), SFA (24), SFD (4) Boise Cascade – MFLR (28), SFA (47) Chirstiana Western – MFLR (28), SFA (45) FCE-Dillon – MFHR (112) Material Systems Corp. – SFA (20), SFD (10) Pantek – MFLR (16), SFA (29) TRW/CTC – SFA (14), SFD (6)
Site Planner:	Wurster, Bernardi & Emmons of San Francisco
Site Developer:	Campbell Construction Company/National Corporation for Housing Partnerships
Market:	Single-family units to be sold in a price range consistent with that of adjacent neighborhoods ($16,000 to $25,000 per unit). Garden apartments to be rented out by private owner; high-rise for elderly by nonprofit sponsor

Part of the former State Fairgrounds, the Sacramento site was flat and featureless. The development plan creates a well-landscaped community with nearly 10 acres of play areas and lawns. Over 2000 trees and shrubs will provide pleasant relief from the California summer sun.

The location is within 10 or 15 minutes of downtown and the State Capitol. It is convenient to transportation and most services. Access generally is from perimeter roads, reserving the site interior for pedestrians.

Sacramento is the only place where the TRW/ Community Technology Corp. units are being demonstrated.



Memphis, Tennessee

Type:	Urban renewal in-city
Location:	Madison Avenue at Neely Street in downtown Memphis
Size:	16 acres
Total Units:	518*
Density:	32 per acre
HSP's:	Boise Cascade – MFLR (51 units), SFA (69 units) FCE-Dillon – MFHR (206) General Electric – MFLR (48) Adult Student Housing – MFHR (144*)
Site Planner:	Miller, Wihry & Brooks of Louisville, Kentucky
Site Developer:	Alodex
Market:	Memphis Housing Authority to rent 206 units to elderly; balance to be rented out by Adult Student Housing Agency as College Housing or Section 236

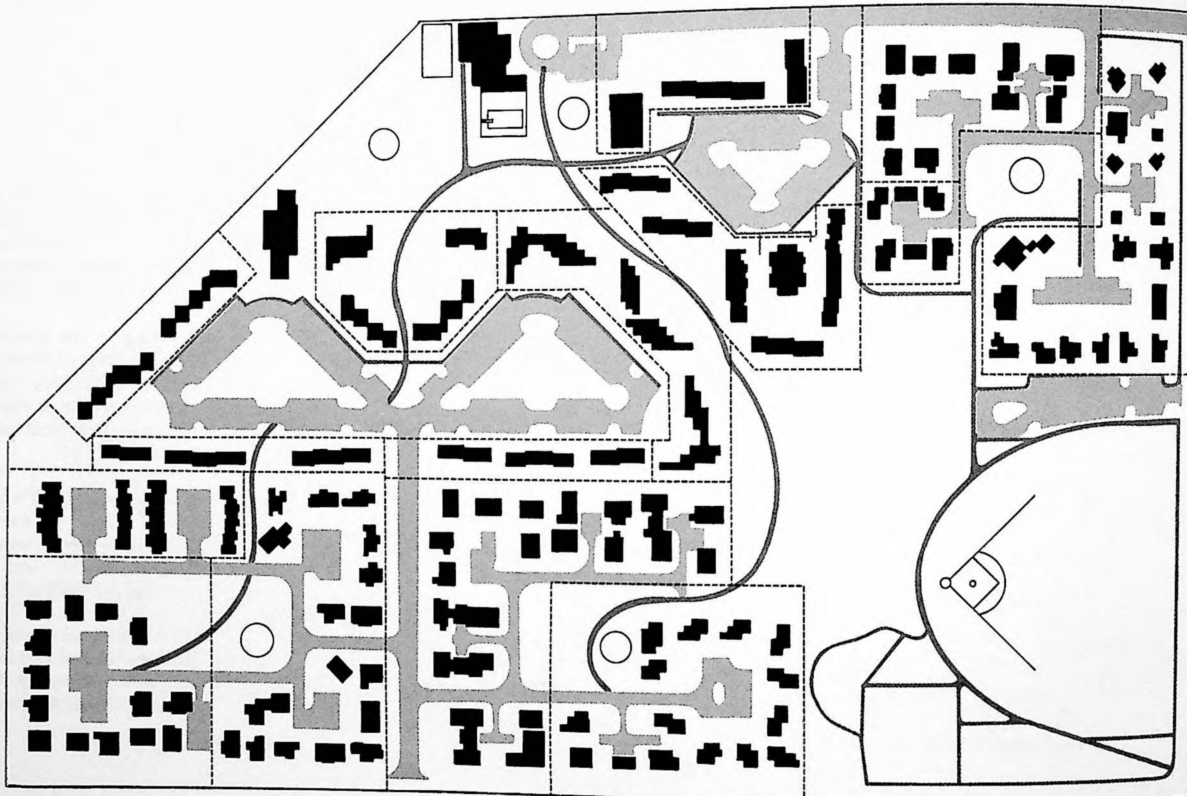
*144 units non-BREAKTHROUGH

Located in the Court Avenue Urban Renewal area, the BREAKTHROUGH site adjoins the downtown business district. Just to the east are the many facilities of the South's largest medical center, including the University of Tennessee Medical Units.

Planning for the prototype site had to take into account the high level of nearby activity. One concern was noise and other hazards from busy streets that bound the property on three sides. Another strong influence was the immediate local need for housing for students and the elderly.

Assignments of HSP's to the Memphis site were changed several times. In the process, CAMCI, Shelley, and Material Systems were deleted, FCE-Dillon replaced Stirling Homex, and one high-rise was built by a non-BREAKTHROUGH producer.

At some future date, development by the City of a recreational and commercial complex just north of the site would complete the master plan for the BREAKTHROUGH neighborhood.



Indianapolis, Indiana

Type:	Periphery
Location:	2300 N. Tibbs Avenue, in northwestern Indianapolis
Size:	42.9 acres
Total Units:	295
Density:	6.9 per acre
HSP's:	FCE-Dillon – MFMR (36 units) General Electric – MFLR (8), SFA (48) Home Building Corp. – SFD (45) Material Systems Corp. – SFA (32), SFD (18) National Homes – SFA (14) Pantek – SFA (40) Pemtom – SFA (20) Scholz – MFLR (8), SFA (26)
Site Planner:	Skidmore, Owings & Merrill of Washington, D.C.
Site Developer:	Urban Systems Development Corp.
Market:	Units to be sold at prices ranging from $11,000 to $30,000 each. Some Section 234 or 235 for apartments

Extensive landscaping has created gentle knolls and shade trees in what once was an open field. This is BREAKTHROUGH Indianapolis, one of the largest sites. To increase the amount of green space, the zero lot-line concept is used in many SFD areas.

Indianapolis has the greatest number of HSP's of any site. It is the only place where the Pemtom system is being demonstrated. During the planning stage, GE was added and two other HSP's, TRW and Republic Steel, were dropped. Also, the FCE-Dillon high-rise structure was reduced to four stories.

Neighborhood needs were important to the design; in fact the overall master plan covers 120 acres in and around the BREAKTHROUGH site. The "500" Motor Speedway property adjoins the west boundary, but the neighborhood generally is residential. Many local stores and services are available on nearby 16th Street, a major arterial. Downtown Indianapolis is less than 5 miles away.

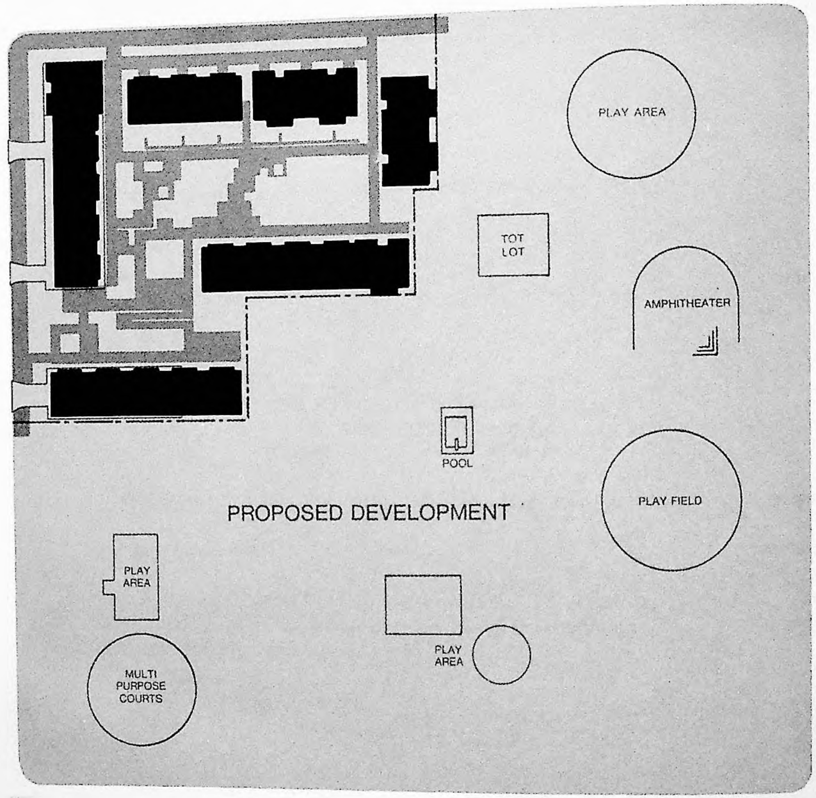
King County, Washington

Type:	Suburban
Location:	East of Lake Washington at 124th Ave. NE and NE 149th Street
Size:	35.9 acres
Total Units:	178
Density:	5 per acre
HSP's:	Alcoa – SFA (24 units), SFD (62 units) Christiana Western – MFLR (16), SFA (34), SFD (4) Levitt – MFLR (8), SFA (20) Material Systems Corp. – SFA (10)
Site Planner:	Eckbo, Dean, Austin & Williams/George S. Nolte of San Francisco
Site Developer:	The Boeing Company
Market:	Will be sold at prices from $18,000 to $36,000, compatible with neighborhood values. Apartments rented out by private owner, possibly FHA Section 236

Located 20 miles from Seattle, near the rural village of Woodinville, is the beautiful King County site. Deep forests, native berry vines and bushes, small hills and meadows, and a tiny stream have been preserved in the site design. Another challenge was the newness, in the Pacific Northwest, of planned unit development and townhouse concepts.

At the start, the site was somewhat isolated except for a high-priced residential subdivision to the south and west. However, neighborhood growth has kept pace with BREAKTHROUGH; a shopping center and some public buildings are included. A County Park is planned on East Norway Hill next to the north boundary of the site.

Important HSP assignment changes were made in the Alcoa and Christiana Western areas to replace Boise Cascade. An earlier addition was MSC with 10 units.


PLAY AREA
TOT LOT
AMPHITHEATER
POOL
PROPOSED DEVELOPMENT
PLAY FIELD
PLAY AREA
PLAY AREA
MULTI PURPOSE COURTS

Seattle, Washington

Type:	Urban renewal in-city
Location:	E. Yesler Way and 18th Avenue, Seattle
Size:	1.7 acres
Total Units:	58
Density:	33 per acre
HSP:	Townland – MFLR (20 units), SFA (38 units*)
Site Planner:	Building Systems Development of San Francisco
Site Developer:	The Boeing Company
Market:	Nonprofit sponsor will rent out units, eligible for FHA Section 236

*Classifications assume created land is equivalent to ground level.

The Seattle City site was originally considered a subsite of King County BREAKTHROUGH. As the only urban-rural combination in the program, they do present an interesting and informative contrast.

The City site is one square block in the Central Area of Seattle, and a part of the Model City. According to citizen-formulated urban renewal plans for the Yesler-Atlantic Neighborhood Improvement Project, the site and three adjoining blocks will be a superblock. Streets will be closed off and housing will be incorporated with parks and recreation facilities. It is hoped thus to arrest declining neighborhood conditions; already BREAKTHROUGH has helped and has strong backing from the black community.

This is the only site upon which the Townland system is being tried. The original plan had 80 units, most of which were in the Supported Land System, but the number was reduced to 58 units (only 12 units of them in the SLS) when final cost estimates were examined. All tenant parking is underground.

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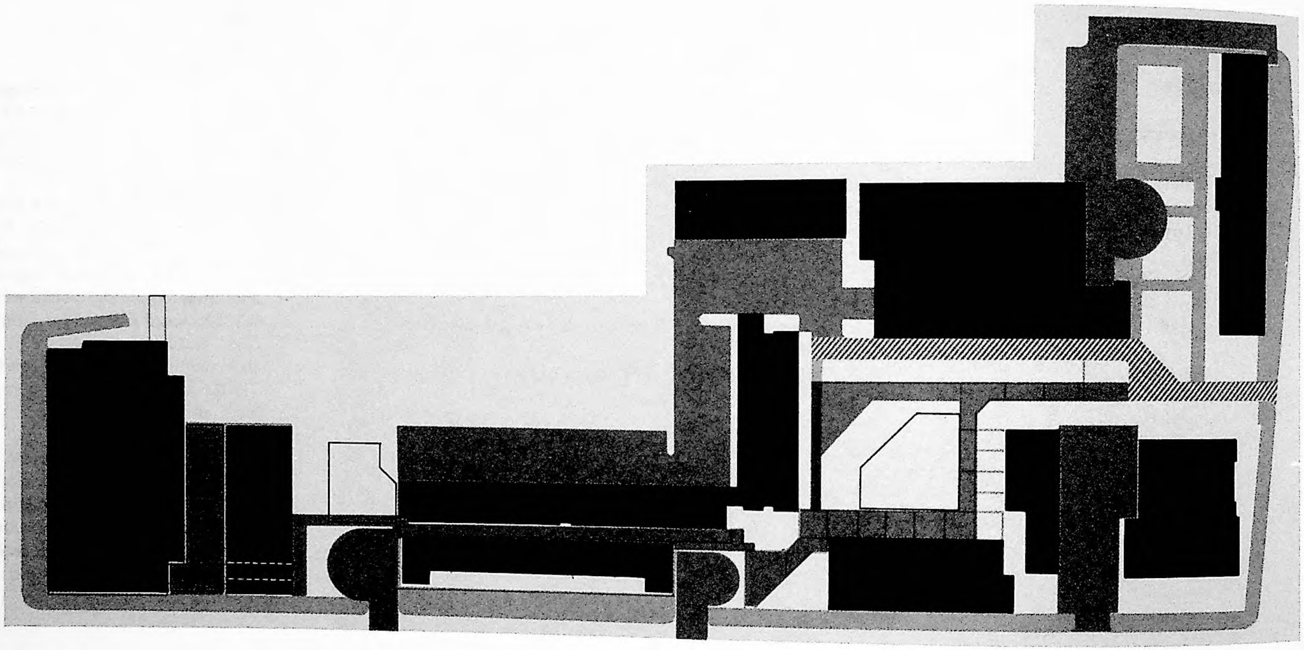

Jersey City, New Jersey

Type:	Urban renewal in-city
Location:	Newark Avenue and John F. Kennedy Boulevard
Size:	6.35 acres
Total Units:	486
Density:	77 per acre
HSP's:	CAMCI – MFHR (153 units) Descon/Concordia – MFHR (111), MFMR (18), MFLR (12) Shelley – MFHR (152), MFLR (40)
Site Planner:	David A. Crane of Philadelphia
Site Developer:	Volt Information Sciences
Market:	Nonprofit sponsor to rent out units, some eligible for FHA Section 236

One block from Journal Square, in the center of Jersey City, is the BREAKTHROUGH site. Accessibility to mass transit makes it a strategic location (for example, downtown Manhattan is 20 minutes away). However, the dense urban conditions pose many problems for site design and development. The site is part of the St. John's Renewal Area.

Grouping of the high-rise structures was a design concern, and the solution avoided a regimented look. Incorporation of commercial and public activities along with the housing, and continuing reevaluation of HSP assignments had serious impact upon the progress of the Jersey City plan. Shelley was an early addition. Perhaps most significant was the deletion of Townland late in 1971. Two of the HSP's, Shelley and CAMCI, are building their BREAKTHROUGH systems only at this site.

Appendix and Acknowledgements

Appendix

A comparison, based on their important characteristics, has been made of the 22 Operation BREAKTHROUGH housing systems. The separate HSP reports are the primary sources of information. However, the material had to be interpreted so as to fit the summary format. Many HSP descriptions cover systems that have been developed beyond BREAKTHROUGH designs. Wherever a question arose concerning system capabilities, weight was given to the evidence offered by the prototype.

Nomenclature has been standardized for the sake of consistency. Some terms may not agree with those used by individual HSP's, but the changes are self-explanatory. Most of the BREAKTHROUGH locational usage has been adopted; although arbitrary it is simple and familiar:

Urban ...... an in-city site, marked by dense settlement, intensive mixed land use and general reliance upon mass transportation. Includes urban renewal projects in similar areas. Examples are the St. Louis, Jersey City, Memphis and Seattle prototype sites.

Periphery ... a neighborhood toward the corporate limits of a major city. Examples are the Indianapolis and Sacramento prototype sites. Housing appropriate to these circumstances would also fit equivalent conditions close in to smaller cities. Typical features are residences dating back to the street car era, some vacant lots and a transition to smaller shopping centers and apartment houses.

Suburban ... a development outside the central city, usually in smaller towns or semi-rural areas. Typified by low density, residential subdivisions and automobile orientation. Examples are the King County, Macon and Kalamazoo prototype sites.

Rural ...... Usually individual single-family lots beyond the settled areas. Distinguished by minimum density, small and isolated developments and a preponderance of natural countryside, farmland, etc.

Classification of dwelling types, used throughout this document, is by the following accepted notation:

SFD .... Single family detached. A single dwelling on an individual lot, self-contained and physically separated from other buildings by open area. May be one or more stories high.

SFA .... Single family attached. A single dwelling on an individual lot, self-contained but with at least one wall commonly shared and subdividing a larger building complex. May be one or more stories high; the dwelling unit occupies the space from the lowest level to the roof. Popularly called a townhouse or row house.

MFLR ..... Multi-family low rise. A multiple dwelling on a common lot, composed of two or more single living units (apartments or flats) in a building that is one to three stories high. The units typically share the use or ownership of some facilities; the building may or may not have elevator service. A "garden apartment," in Operation BREAKTHROUGH usage, is an MFLR unit accessible to outside landscaping on at least one side, in a walk-up (no elevator) building, but not necessarily occupying all space from lowest level to roof. "Duplex," "four-plex," etc., usually are MFLR terms, with the prefix indicating the number of dwelling units in a single structure.

MFMR ..... Multi-family medium rise. A multiple dwelling on a common lot, composed of a number of single living units (apartments or flats) in a building more than three stories high but less than eight. The units typically share the use or ownership of some facilities; the building has elevator service. This category resulted from the practical limits of various elevator types in apartment buildings.

MFHR ..... Multi-family high rise. A multiple dwelling on a common lot, composed of a number of single living units (apartments or flats) in a building more than seven stories high. The units typically share the use, or ownership, of some facilities; the building has elevator service. Strictly speaking, MFHR originally covered all multiple dwellings over three stories high, but MFMR as an intermediate category has since become common usage.

SYSTEM CHARACTERISTICS

SYSTEM APPLICABILITY	Alcoa Construction Systems Inc.	Boise Cascade Housing Development	Building Systems International	CAMCI, Inc.	Christiana Western Structures	Descon/Concordia Systems Ltd.	FCE-Dillon Inc.	General Electric Company	Hercules Inc.	Home Building Corporation	Levitt Technology Corp.	Material Systems Corporation	National Homes Corp.	Pantek Corp.	Pemtom, Inc.	Republic Steel Corp.	The Rouse-Wates Co.	Scholz Homes Inc.	Shelley Systems Inc.	Stirling Homex Corp.	Townland Mktg. & Develop. Corp.	TRW Systems Group
Use																						
Urban	●	●	●	●	●	●	●	●	●	●	●	●	●		●		●	●	●	●	●	●
Periphery	●	●	●		●		●	●	●	●	●	●	●	●	●		●	●	●			●
Suburban	●	●	●		●		●	●	●	●	●	●	●	●	●	●	●	●	●			●
Rural	●	●			●			●		●	●	●			●	●						
Optimum Density Per Acre																						
1-14	●	●	●		●		●	●	●	●	●	●	●	●	●	●		●	●		●	●
15-40		●			●	●		●		●	●	●	●	●	●		●	●				●
Over 40	●		●	●		●	●										●		●	●	●	
Environmental Adaptability																						
All systems are adaptable to all climates, soils and topography.																						
Code Adaptability																						
All	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●		●
Other														(1)							(2)	
Non-Residential																						
Recreational		●			●			●	●	●	●	●	●		●	●					●	
Office			●	●						●						●			●	●	●	
Commercial			●	●			●				●	●		●			●		●	●	●	●
Educational											●		●	●			●			●	●	
Social and Service		●	●	●	●		●	●	●	●	●	●	●		●		●		●	●	●	●

Notes: (1) Complies with HUD/NBS Guide Criteria
(2) Adaptable to Uniform Building Code

SYSTEM CHARACTERISTICS

SYSTEM DESCRIPTION	Alcoa Construction Systems Inc.	Boise Cascade Housing Development	Building Systems International	CAMCI, Inc.	Christiana Western Structures	Descon/Concordia Systems Ltd.	FCE-Dillon Inc.	General Electric Company	Hercules Inc.	Home Building Corporation	Levitt Technology Corp.	Material Systems Corporation	National Homes Corp.	Pantek Corp.	Pemtom, Inc.	Republic Steel Corp.	The Rouse-Wates Co.	Scholz Homes Inc.	Shelley Systems Inc.	Stirling Homex Corp.	Townland Mktg. & Develop. Corp.	TRW Systems Group
Housing Type																						
SFD	●	●			●					●		●	●	●	●	●						●
SFA	●	●	●		●		●	●	●	●	●	●	●	●	●	●		●			●	●
MFLR	●	●	●		●	●	●	●	●	●	●	●	●	●		●	●	●	●		●	●
MFMR	●		●	●		●	●										●		●		●	
MFHR	●		●	●		●	●										●		●	●	●	
Unit Variations																						
Efficiency to 5 Bedroom		●	●																	●		
Efficiency to 6 Bedroom				●													●		●			
1 to 4 Bedroom					●	●		●	●	●	●	●		●				●				●
1 to 5 Bedroom	●												●			●					●	
1 to 6 Bedroom							●															
2 to 3 Bedroom															●							
Structure																						
Self-Supporting Volumetric Module		●						●	●	●	●	●	●		●			●	●	●	●	●
Wood Frame	●	●			●				●	●	●		●		●			●				
Metal Frame	●	●						●					●			●				●	●	
Reinforced Concrete			●	●		●	●										●		●		●	
Composite												●		●								●
Exterior Elements																						
Special Trim or Finished	●	●	●					●		●	●			●								●
Garage, Storage					●					●	●	●	●			●					●	
Porches, Deck, Patios, Balconies, Etc.		●	●	●	●	●	●		●	●	●	●			●		●	●	●	●	●	●
Interior Elements																						
Separate Service Units	●	●	●			●	●							●			●					●
Foundation																						
Conventional	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Design for Site		●	●		●	●			●	●		●		●	●		●			●		
Comfort (HVAC)																						
Factory Installed	●	●	●	●		●	●	●	●	●	●	●	(1)	●	●			●	●	●		●
Site Installed					●								(2)			●	●				●	
Plumbing																						
Factory Installed	●	●	●	●		●	●	●	●	●	●	●	(1)	●	●	●	●	●	●	●		●
Site Installed					●								(2)								●	
Electrical																						
Factory Installed	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●
Site Installed					●																●	

Notes: (1) Modules—Factory Installed
(2) Panels—Site Installed

SYSTEM CHARACTERISTICS

	Alcoa Construction Systems Inc.	Boise Cascade Housing Development	Building Systems International	CAMCI, Inc.	Christiana Western Structures	Descon/Concordia Systems Ltd.	FCE-Dillon Inc.	General Electric Company	Hercules Inc.	Home Building Corporation	Levitt Technology Corp.	Material Systems Corporation	National Homes Corp.	Pantek Corp.	Pemtom, Inc.	Republic Steel Corp.	The Rouse-Wates Co.	Scholz Homes Inc.	Shelley Systems Inc.	Stirling Homex Corp.	Townland Mktg. & Develop. Corp.	TRW Systems Group
INNOVATIONS																						
Factory-Built Framing Subassemblies					●																	
Factory-Built Panels												●	●	●		●						●
Factory-Built Modules		●						●	●	●	●	●	●		●			●	●	●		●
Panel and Service Module Assembly	●		●	●		●	●										●					
Construction and Erection Techniques				●				●												●		
Structural Concept			●													●	●				●	
Box-Module Arrangement		●							●						●				●			
Layout Flexibility	●													●		●						
Man-Made Material												●										●
Custom Design and Construction	●																					
Owner-Built Home														●								
"Created Land" in Air																					●	
Subcontract to Produce in Existing Facilities						●																
OFF-SITE CONSTRUCTION																						
Finished Box-Modules																						
Service Modules																						
Panels	●		●	●		●	●					●	●	●		●	●					●
Frame System					●																●	
Floor Slabs/Panels			●	●													●					
Mechanical/Utility Packages																●					●	
Precast Super-Frame																					●	

SYSTEM CHARACTERISTICS

PRODUCTION EFFORT

	Alcoa Construction Systems Inc.	Boise Cascade Housing Development	Building Systems International	CAMCI, Inc.	Christiana Western Structures	Descon/Concordia Systems Ltd.	FCE-Dillon Inc.	General Electric Company	Hercules Inc.	Home Building Corporation	Levitt Technology Corp.	Material Systems Corporation	National Homes Corp.	Pantek Corp.	Pemtom, Inc.	Republic Steel Corp.	The Rouse-Wates Co.	Scholz Homes Inc.	Shelley Systems Inc.	Stirling Homex Corp.	Townland Mktg. & Develop. Corp.	TRW Systems Group
Unit Comp./Year																						
0 - 1,000		●		●					●			●										
1,001 - 3,000	●					●				●						●		●				●
Over 3,000			●				●	●			●		●						●	●		
Estimated Off-Site Work																						
0 - 33%					●																●	
34 - 67%	●			●		●	●					●	●	●		●	●		●			
68 - 100%		●	●					●	●	●	●				●			●		●		●
Estimated On-Site Work																						
0 - 33%		●	●					●	●	●	●	●			●			●	●	●		●
34 - 67%	●			●		●	●						●	●		●	●					
68 - 100%					●																●	
Factory Labor																						
Primarily Skilled																						
Primarily Semi-skilled	●	●				●	●	●	●	●	●	●	●	●	●			●		●	●	●
Primarily Unskilled			●	●	●											●	●		●			
Site-Work Labor																						
Primarily Skilled				●	●								●					●			●	
Primarily Semi-skilled							●	●		●		●			●				●			
Primarily Unskilled	●	●	●			●			●		●			●		●	●			●		●

SYSTEM CHARACTERISTICS

ECONOMICS OF SYSTEM

ECONOMICS OF SYSTEM	Alcoa Construction Systems Inc.	Boise Cascade Housing Development	Building Systems International	CAMCI, Inc.	Christiana Western Structures	Descon/Concordia Systems Ltd.	FCE-Dillon Inc.	General Electric Company	Hercules Inc.	Home Building Corporation	Levitt Technology Corp.	Material Systems Corporation	National Homes Corp.	Pantek Corp.	Pemtom, Inc.	Republic Steel Corp.	The Rouse-Wates Co.	Scholz Homes Inc.	Shelley Systems Inc.	Stirling Homex Corp.	Townland Mktg. & Develop. Corp.	TRW Systems Group
Comparison of Cost																						
Less than Conventional	●			●										●			●		●			
Comparable to Conventional					●	●					●				●					●		
More than Conventional																						●
Varies with Requirement									●													
Construction Cost																						
Low									(1)			(1)										
Medium		●						(1)				(1)								●		
High															●							
Cost Estimate																						
$10 – $16/Sq. Ft.	●						●			●								●				
$17 and Up/Sq. Ft.	●						●															
$20,000 – $25,000/Housing Unit																●						
Useful Life																						
40 – 49 Years								●	●	●		●										●
50 – 100 Years	●	●									●					●						
Essentially Permanent			●	●		●	●										●		●	●	●	
Comparable to Conventional					●								●		●							

Note: (1) Applicable to HUD Section 235-236 Programs

SYSTEM CHARACTERISTICS

AVAILABILITY OF SYSTEM

	Alcoa Construction Systems Inc.	Boise Cascade Housing Development	Building Systems International	CAMCI, Inc.	Christiana Western Structures	Descon/Concordia Systems Ltd.	FCE-Dillon Inc.	General Electric Company	Hercules Inc.	Home Building Corporation	Levitt Technology Corp.	Material Systems Corporation	National Homes Corp.	Pantek Corp.	Pemtom, Inc.	Republic Steel Corp.	The Rouse-Wates Co.	Scholz Homes Inc.	Shelley Systems Inc.	Stirling Homex Corp.	Townland Mktg. & Develop. Corp.	TRW Systems Group
Transportation Limitation																						
50 - 299 Miles from Factory			●	●		●	●			●			(1)	●			●		●		●	
300 - 499 Miles from Factory								●			●	●	(2)					●				●
500 & Up Miles from Factory									●											●		

Notes: (1) Module Delivery
(2) Panel Delivery

	Alcoa Construction Systems Inc.	Boise Cascade Housing Development	Building Systems International	CAMCI, Inc.	Christiana Western Structures	Descon/Concordia Systems Ltd.	FCE-Dillon Inc.	General Electric Company	Hercules Inc.	Home Building Corporation	Levitt Technology Corp.	Material Systems Corporation	National Homes Corp.	Pantek Corp.	Pemtom, Inc.	Republic Steel Corp.	The Rouse-Wates Co.	Scholz Homes Inc.	Shelley Systems Inc.	Stirling Homex Corp.	Townland Mktg. & Develop. Corp.	TRW Systems Group
HUD Region																						
All Regions		●	●	●									●	●								
Region 1. Maine, Vermont, New Hamp., Mass., Conn., R.I.						●		●	●								(1)			●		
Region 2. N.Y., N.J., Puerto Rico	●																		●	●		
Region 3. Penn., W. Va., Maryland, Wash. D.C., Dela.	●								●	(2)							(3)			●		
Region 4. Ky., Tenn., N.C., S.C., Miss., Ala., Ga., Fla.	●						(4)													●		
Region 5. Minn., Wisc., Mich., Ill., Ind., Ohio							(5)				●	(6)						●				
Region 6. Texas, Okla., N. Mex., Ark., La.	●																					
Region 7. Nebr., Kan., Iowa, Mo.									●	(7)								●				
Region 8. Colo., Utah, Wyo., Mont., N.D., S.D.										(8)												
Region 9. Calif., Ariz., Nev., Hawaii	●					(9)	(9)					(9)										(9)
Region 10. Wash., Oreg., Ida., Alaska	●																					

Notes:
(1) Connecticut only
(2) Pennsylvania only
(3) Maryland only
(4) Florida only
(5) Ohio only
(6) Indiana only
(7) Missouri only
(8) Colorado only
(9) California only

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EQUAL HOUSING OPPORTUNITY

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