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Modular Structures and Related Techniques

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I want to very quickly cover the background of light-frame residential construction. A brief look at history, a look at where we are today, and some looks at where we might go and the possible impacts.

The biggest change that we had in this nation in housing was when a guy by the name of Taylor, a carpenter in Chicago, created what we call balloon framing — the first use of two-by-fours in 1833. This was the major departure from the old European system of heavy timbers and heavy masonry construction.

Strange as it looks, that system really turned the United States into a nation of homeowners. One hundred seven years later in 1940 in Lafayette, Indiana, Jim and George Price came up with factory panelization. About twelve years after that in 1952, this man, A. Carroll Sanford, invented what we call the toothed metal connector plate, This created the component industry, which in a sense allowed site builders to compete with what was going on inside factories by panelizers.

About 1973, the next big breakthrough was the flat-chord floor truss, again, metal-plate connected. Simple as it looks, it enabled us to greatly conserve our natural resources by making it unnecessary to use heavy-dimension lumber in our floor systems.

If you think about America's industrialized housing machine and visualize down the center of that picture a big piece of machinery, there are five manufacturing segments. At the far left, we have what we call the production builder, the big-volume site builder; next, the panelized-home manufacturer. Across from that we have the mobile-home manufacturer, the modular-home manufacturer, and the compo nent manufacturer.

As to who builds what in the U.S. housing pie, these figures are based on our research for 1983. The site builders do about 51 percent; the panelized, 26 percent; the mobile, which we probably should more accurately call the HUD-Code home today, builds 19 percent; modulars about 4 percent. Other segments of this industry include the dealers for the factory-built homes, the component manufacturers who build for the production builders, and of course the special-unit manufacturers, who are all factory builders, but they don't build housing. They build everything else except homes and apartments.

The production builder builds single-family homes, low-rise or garden apartments up to mid-rise apartments. We call him a production builder because he usually builds in metro centers, and one house after another. In the metro center, he is served by the component manufacturer who usually sells these units erected. In other words, when the component truck leaves that house, it's weathered in and the builder can take one month to a year to finish the inside, if he wishes.

Turning to the component manufacturer, this industry was created by Sanford; today there are two thousand of these companies across the country, primarily serving production builders. They are among the most sophisticated machine people because they will serve up to one hundred different builders at one time.

Component manufacturers make wall panels, roof trusses, floor trusses, gable ends, plus other components for homes. They use highly sophisticated machinery. This $52,000 component cutter could be compared to a carpenter with a hand saw over his knee at a job site or even a circular saw. There's not much comparison when it comes to the kind of quality you can get into a factory to the lack of quality in our, as someone said, primitive methods at job sites.

Component manufacturers all make roof trusses. Today this roof truss is engineered for the specific house in the specific area where it's going to be used, for span, wind load, snow load, live load, dead load and so on. It's created with metal connector plates. You see the inverted truss there in the background.

Additionally, the industry is becoming more sophisticated. Here they're using what we call machine-stress rated lumber. This is lumber that's run through a nondestructive testing ma-

Figure 1

Hud-Code (Mobile) Home.
When built to the Manufactured Housing Construction and Safety Standards Code, administered by the Department of Housing & Urban Development, and placed on a permanent foundation on land which is sold with the home, this variety of housing becomes virtually indistinguishable from any other type of housing, except that the unit will be more affordable, ranging in price from 5 percent to 30 percent less than other styles of housing in the same area,

Figure 2

Finished Panelized Home.
Panelized home manufacturers, approximately 600 across the U. S., are the most versatile producers of architectural styles. Their homes can range from low-cost vacation cabins to expensive mansions in excess of 10,000 square feet.

chine to actually find out how much it will bear. This puts this industry's products on a part with steel and concrete.

Component manufacturers also machine doors literally by the thousands. Turning next to the panelized-home manufacturer, there are about six hundred of these companies — of which probably twenty-five are large size. They're very versatile in what they build. They can take an architect's blueprint and create the house that the customer wants. One of the largest plants happens to be in Fort Payne, Alabama, the old Kingsbury Home plant, probably half a million square feet under roof.

Today, the important thing to remember regarding all of these phases of housing that we're discussing is that it is a duplicative process. We're all building the same way. Two-by-four studs, usually sixteen inches on center.

In the panelized plant, if a panel such as this would have sheathing on it, windows inserted, siding on the outside, and then it's delivered to the job site in that condition, even though there's insulation between the studs, we call it 'open-panel,' or 'open-panel panelization.' If that wall panel is finished on the inside and the wiring, plumbing, and so on is put inside that wall, then it becomes closed-panel.

Some of our panelizers use cores, mechanical cores. This little self-contained building will contain one or two bathrooms, the furnace, the hot-water heater, and usually the electrical junction box. That structure goes down on the deck first, and then the interior and exterior partitions and the roof system goes up around it.

Also included in this panelized industry, even though they don't build panels, are the two-by-four pre-cutters; and we do include the log-home manufacturers, of which there's about two hundred and fifty. We also include the dome-home manufacturers in the panelized segment, of which there are around sixty, Now, the dome manufacturers actually panelize using five triangles to create a pentagon.

Turning now to the modular home manufacturers, like the panelizers, the log, and the dome, they build to our model building codes; that is, a conventional building code. There are about two hundred modular manufacturers across the nation. Their technique in construction is very similar to what goes on in a mobile-home plant, except they're building to different codes.

This is a typical kind of jig they use for their roof system.

Here's one of the newer plants which happens to be Summey Corp. down in Georgetown, Texas. Their technique is to fabricate their walls on wall-panel machines at the head end of the line and then tip them up onto the floor systems as they go down the production line; and then in the far background, you see the modular boxes, as we call them, getting ready to be shipped out of the plant,

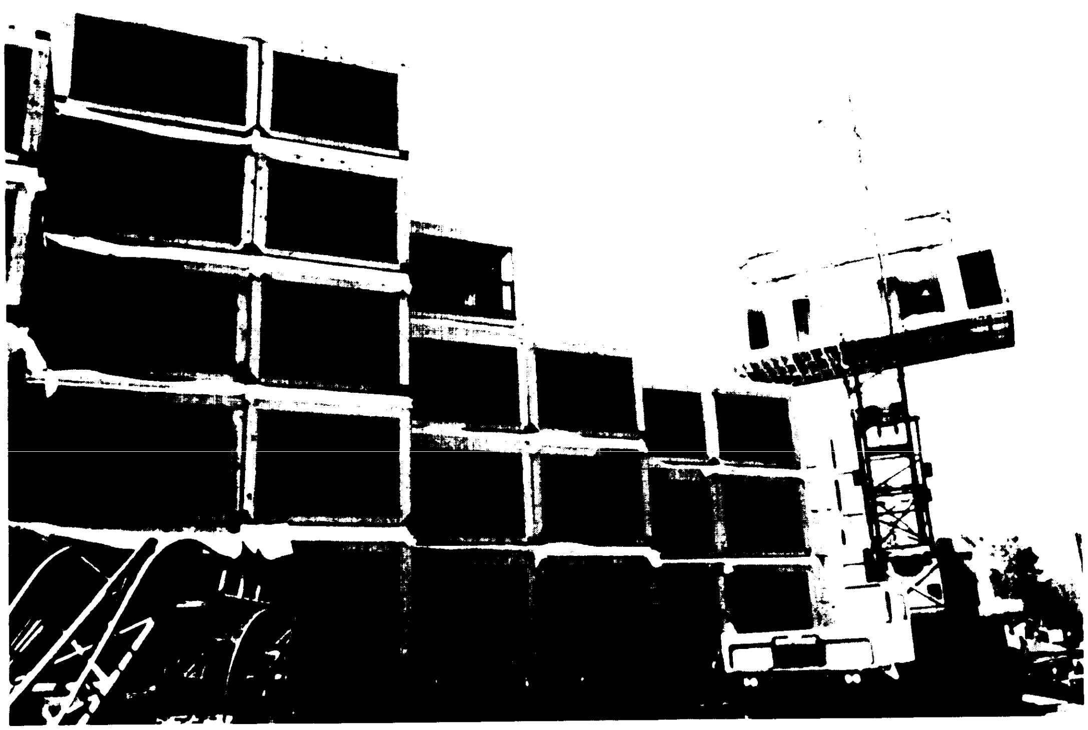
The technique in many plants flows along a production line with fourteen to sixteen stations. The flooring systems are stacked up there at the right. They put down their resilient flooring and their carpeting. They put in their plumbing fixtures, interior partitions, exterior walls and a roof system as the units go down the factory line.

Modulars are about 95 percent complete when they leave the factory if they are going to be a single-family house. We call the modular the strongest of all construction systems used to day simply because it's glue-nailed, plywood construction all the way around. Even the marriage wall has plywood glue-nailed onto the wall studs. This makes each half of the house essentially a self-contained box beam, and the modulars are traditional over-builders. If it takes two two-by-fours to do the job, they'll use three.

At the job site, if the terrain is rough, they'll place them with cranes. Now, that wet wall of a modular will weigh up to twenty-six-thousand pounds, and yet, as you can see, it's being totally supported by cables at just two points.

A major trend along the coast, the East Coast of the US. and the Gulf Coast, is what we call the stacked modular, up to five or six stories tall. These units are sold primarily now as recreational condominiums. They're very, very attractive.

As in all industrialized construction, which covers all of these units, the biggest saving is in your construction loan interest costs. A project of this magnitude, if it's modular, can be finished in about six months compared to about a



Figures 3 and 4

The Use of Stacked Modular housing units is becoming increasingly popular for apartments, resort condominiums, and motels. The modular units (referred to in the industry as 'boxes') are 95 percent completed inside the factory, then shipped to the job site and stacked by crane up to four and five stories tall. The major advantage for the builder is that in a large apartment complex he cuts his construction time by 50 percent with resultant savings in construction interest loan costs which can run as high as $100,000 per month. In a large project, the use of stacked modulars will cut construction time from more than one year to less than six months with resultant interest cost savings.

year if it's site-built; and a project of this size will probably save up to $100,000 per month on construction loan interest costs.

Finally, the HUD code manufactured home, which we used to call the mobile home. Of course, they've not been mobile for many, many years. This industry has two of the greatest advantages going for it ever visited on any segment of housing: one, it has a national preemptive building code; and two, as of about the middle of last summer, you could finance these units just like conventional real estate, providing they were permanently mounted on foundations on their own lot.

Trends in this industry are to make these units look more and more house-like, to make them more appealing to the consumer/buyer.

Construction technique is the same as we use for anything else, two-by-four studs, sixteen inches on center. In this case, you can see they're getting their shear strength from glue-nail on the interior materials. However, when it comes to insulation, you can order what you want — R-1 1 or R-19 walls.

One of the departures is lighter frame construction than we use in most other housing. Like in this particular mono-roof system, they're using two-by-threes instead of two-by-fours. Well, the question is: What do you want to buy, a Chevrolet or a Cadillac? These homes are in the Chevrolet class.

Going down the production line, they're similar to the modular production lines: the floor system first; then their plumbing, partitions, wall systems and roof systems put on at the end.

By law, the mobile must have a metal chassis beneath it, and you can identify them if you can get down underneath to see that it has a metal chassis. If you see this, you know that it's a HUD-Code unit.

Manufactured-home dealers — there are around fifteen thousand of these dealers (probably nine thousand handle mobiles), and the rest are into panelized, combination mobile-modular, the log, the dome, and so on.

The special-unit manufacturer, as I mentioned earlier, is a factory builder. He builds things like doctors' offices, prisons, motels, everything except private housing per se.

One of the difficulties in marketing today is to tell the difference between a modular unit, which is what we're looking at here. Those units beneath it are not chassis — they're transporters. They'll go back to the job site after this unit is set at the site.

Here's the mobile, or HUD-Code, home. Both mobiles and modulars have house-type siding, roofing, windows, and doors. They've got three and four 12-roof pitches. They look like little houses, but depending on the market you're in, the mobile (HUD-Code) homes are going to run anywhere from 10 to 35 percent less costly than the site-built, comparable unit.

They're striving to make these HUD-Code homes appealing to the consumer. And when these units are placed on permanent foundations, such as this particular project in Rancho Ventura, California, which went on permanent foundations and was sold with the lot, they look good; but the price in that area, even though it might sound high to you, was $71,000 to $91,000. A comparable site-built house started at $130,000. As you might guess, they sold like hotcakes.

The interiors of HUD-Code units are very professionally decorated today. The kitchens use brand-name appliances. If there's a choice, of course, between good, better and best, they probably go for the good because we're talking low-cost housing.

Other Trends in Our Industry: Because of the rise of the component industry, the computer has been used for many, many years (over twenty) because every roof truss we build has to be engineered on a computer. Today we're getting computers into wall panelization. In this case, a girl can look at a builder's blueprint and do the input into this computer. The computer will actually drive this wall-panel machine out in Gardina, California; and that machine will turn out walls for a three-bedroom house in about three-and-a-half hours. However, it's limited. They can't build gable-end walls such as this. So there are many other semi-auto mated systems of wall panelization. This is just one. It happens to be a wall-panel plant in Chino, California.

The high-speed plotter has already replaced draftsmen to a great degree inside our compo-

Figures 5 and 6

Log Homes and Dome Homes
are considered part of the panelized home group There are approximately 250 log home manufacturers in the U.S. and Canada, mostly small firms, and about 60 dome home manufacturers While greatly desired by some consumers, the total number of units of both built each year is less than 150,000

nent plants. That high-speed plotter is computer driven, and it can do the work of about five draftsmen in about an hour.

One of the minor trends through the South (Louisiana, Texas), is what we call metal-plate-connected rough openings. It's one of the toughest jobs at a job site to get a square opening for your windows and doors, and this component solves that problem for most of the apartments being built down in the Texas area.

Another trend that we expect to see more of because it makes so much sense is the permanent wood foundation, sometimes called the all-weather wood foundation. This is made from pressure-treated lumber and plywood; and as you can see by this scene, you can build it anytime, including in a blizzard. You don't have to worry about what the climate is outside.

The permanent wood foundation creates a basement level that is just as livable as the upstairs. And, depending on where you are and what insulation is being done, this unit will range anywhere from 20 to 50 percent less costly to heat in the basement area. Since this was invented by NAHB and a few other groups back in 1969, we've built about one hundred seventy thousand of these. We expect them to proliferate.

Another trend is that the big builders are getting bigger. These figures show the top one hundred home builders. Now, these top one hundred cut across all lines that I've mentioned. In 1982, they built 304,000 units; in 1983, 377,000 units. The percentage of what they built went down, as it always does, during a period of prosperity in housing simply because more small builders come into the marketplace.

Japan — let me just touch on that briefly. I led a study mission to Japan in April of this year. When I left this country, I was very smug about our superiority in housing technique, marketing, manufacturing, and so on. It took about a day and a half for those ideas to get knocked out of my head. My conclusion today is that they're about eight to ten years ahead of us in marketing techniques and manufacturing technology.

This is how they sell their homes. You're looking at an aerial view of a model city wherein sixty to seventy builders bring their homes into one place. Mr. and Mrs. Japanese Home Buyer can go in there. After they pick out the architectural design and their house style, they can sit down with a salesman at a computer, do the final analysis right on that computer, literally draw the house on the computer. Then they can go in a make selections of all of their wall finishes, what color they want the kitchen cabinets and so on.

If the order is finally approved, the salesman can punch a button on the computer, and the order is electronically transmitted to the factory, and the house starts down the production line.

In terms of code, they have a national code set by the Ministry of Construction. They want their homes to not only be energy efficient, but capable of standing up to earthquakes, their typhoons and so on. Of the ten largest Japanese companies, about four have capabilities of completely testing the total house inside their lab oratories.

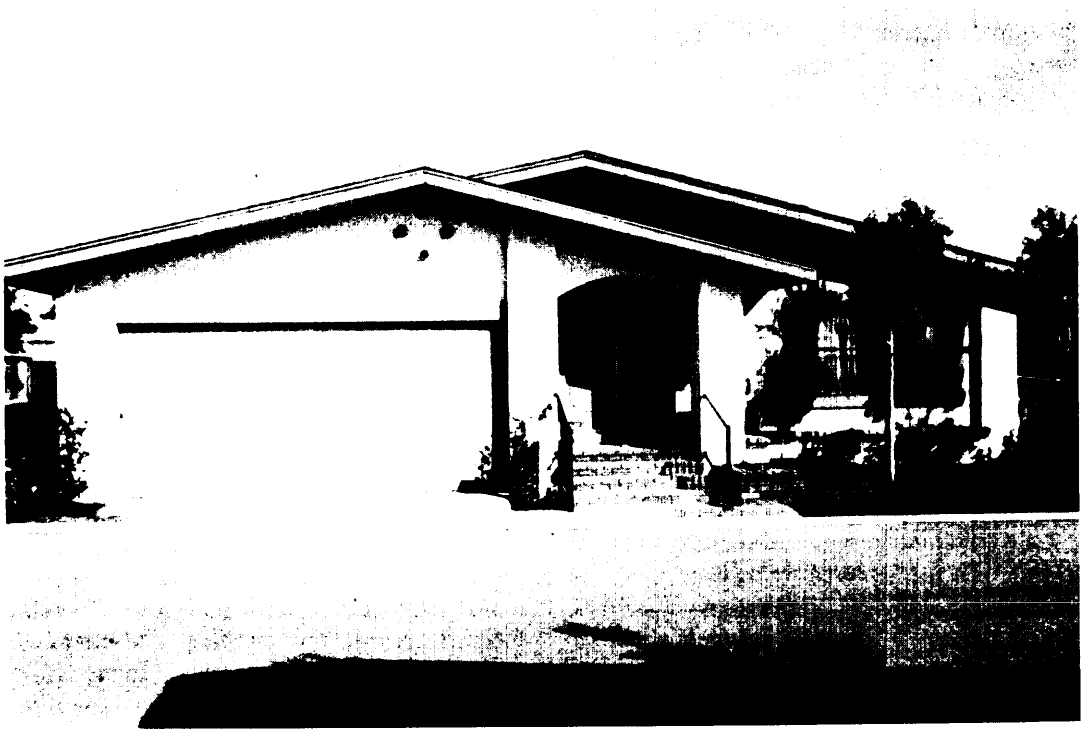
This machine is capable of hitting that full-size house with winds and rains of 140 miles per hour, and those windows don't blow out.

In terms of conveyorization and automation in the factory, they're much further advanced than we are. That happens to be a wood panel, a stressed-skin wood panel plant up in Matsumoto, Japan. That production line went at a steady rate of fourteen feet per minute; it literally never stopped. Every station was controlled by a sidebar computer, which in turn was controlled by a master computer.

They're deeply into robotics for the steel panels they build. This is a robotic unit to create steel trusses. They wouldn't let us photograph the wall-panel system, but it was all robotically welded. The members came down very, very quickly; went into a system where eight robotic welders hit it all at one time and then moved the panel out; and it only took a matter of a few seconds to create a complete steel-wall panel.

The Manager in that plant told me very gleefully, "We're building houses the way we build cars."

This is a new material invented by Misawa Homes. That white panel you see at the end they call precastable autoclave light weight ceramics, or more simply PALC. The PALC



Figures 7 and 8

The Major Trend among HUD-Code (mobile) homes is to make them look more and more like 'conventional site-built dwellings. ' The top photo shows how panelized garages can be placed in front of double-section HUD-Code homes to make them look like typical California tract homes; the lower photo shows that the 'conventional home look' is even being adapted for single-section homes.

panel in one unit there gives you your exterior finish, your interior finish, your structural support, vapor barrier, and insulation.

In talking with all of these Japanese companies, I naturally asked the question: What are you going to do regarding the U. S.? They all said, "We're not going to do what we did to you in automobiles, However, we would like to form partnerships with major U.S. companies and bring our technology to the U. S."

Misawa claims they will have a factory in this country within three years.

Even by Western standards, what they're building is attractive.

Today we already know how to build affordable houses which are also affordable to operate, even with present levels of technology, without going into a sophisticated $20,000 solar system. This is a building we built in Carpinteria, California, to house our office facilities. It has an all-weather wood foundation, a heat pump, an air-to-air heat exchanger; and, to make a long story short, we run thirty-seven items of electrical equipment, twenty-four lights, and the heating, the air conditioning, the furnace fan and the air-to-air heat exchanger fans, and the whole ball of wax, costs us about $2.50 a day to operate.

The foundation was built in a factory in two days or — pardon me — one day by two men who had never seen a wood-foundation blueprint before. The building was built in a factory in eight days. The foundation went in on the ground in one day, and the building was set in about a half a day.

But then as we always say, building at the site is 'building by surprise.' So after the building was set, it took us eight weeks to move in simply because the environmental people in the area wouldn't let us move in until every single blade of grass was planted, and they picked out the blades they wanted planted.

Possible Changes and Impacts: As I mentioned, Japan is eight to ten years ahead of us in CAD/CAM manufacturing, controls, conveyorization, automation, and robotics. They do want to form U.S. partnerships, and I think, if nothing else, we need some sort of a study to cope with what's going to happen in terms of their future intentions in housing in the U.S.

Other Possible Changes and Impacts: We now have one national preemptive building code. That's the HUD Manufactured Housing Construction and Safety Standards. We have three model codes, which are used by the rest of the nation — the basic, the uniform and the standard. Beyond that, there's anywhere from seven to actually fifteen thousand local or regional jurisdictions that decide on what goes into a house. I think what we need is a national preemptive building code, performance-oriented to certain locations, revised to include known methods of cost-cutting (the NAHB has a library on what we already know about cost-cutting), and the new performance code can be merged to include the three model codes and the one HUD Code.

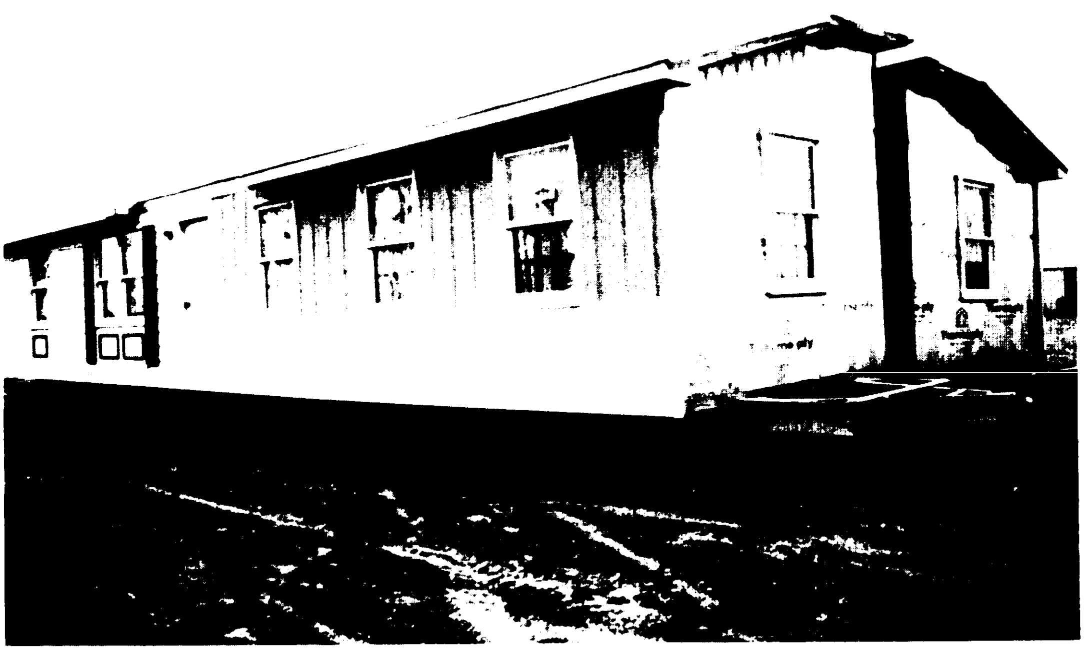
We probably need a similar national preemptive zoning and infrastructure code. Using the known techniques of cutting down costs in sub divisions, this would cover things like streets, sidewalks, sewers and so on; this, I think, would be one of the major methods we could use to reduce costs of housing in the U.S.

Today we have a Department of Housing and Urban Development. It never seemed to me that was a logical marriage, simply because there's not an awful lot in common between the two. When you're talking about urban development, you're talking probably about rehabilitation. You're talking about heavy construction, old infrastructure. Housing deals with things that will go further out in the country. It may make sense, therefore, to divide the two.

Additionally, we have no less than three Government agencies who get their fingers into the housing pie with inspections, mortgage insurance and so on, Perhaps the time has come to merge the FHA, the VA, and the Farmers Home Administration and their separate codes under the Department of Housing and have a separate Department of Urban Development to concentrate on revitalization, primarily through free-enterprise zone systems.

It seems to me the only way we're going to be able to rebuild our cities is the way we built them in the first place. They were built in the first place literally like free-enterprise zones.

Other Possible Changes and Impacts: The Japanese are well along in working toward util-



Figures 9 and 10

A Major Problem facing the housing industry today is the inability of people both within and outside of the industry to discern the difference visibly between double-section HUD-Code (mobile) homes, shown in the above photo, and double-section modular homes, shown in the lower photo Mobile homes are built to the HUD-Code, modular homes are built to any one of the three national 'model' builder codes which in turn have been adopted by states and cities. In general the modular homes are built with a much heavier framing system than is used by the mobile-home industry The major difference is in the fact that, by law, the HUD-Code (mobile) home must have an integral metal chassis beneath each section; the modular section, on the other hand, is simply delivered on a flatbed trailer which is returned to the plant after setting Nevertheless, since both units are beginning to use conventionally-pitched roofs, house-type siding, windows, and doors, it is visually most difficult to discern differences The major difference is in cost where the mobile is built to meet the Chevrolet budget, and the modular is more like the Buick or Chrysler budget ity self-sufficient homes and apartments. If we tap Mother Earth and Father Sun, I don't think it's too far a conclusion to come to that we can eventually, not too many years down the road, have a home or an apartment complex that's totally self-sufficient of utilities.

I think one of the solutions to our energy problem is right under our feet where, you know, if you go down into the earth, regardless of where you are, even three or four feet, you hit an even temperature, which is always warmer in the winter and cooler in the summer. We're tapping this in the building in Carpinteria, and I think that's one of the reasons that our heating and energy costs have been so low.

Also, we've got to mentally reposition our trees to be renewable and harvestable large-corn stalks, and not just museum pieces. The American forests have to be repositioned in our minds to be enclaves of multiple use rather than just a low-use bank vault for two or three people that hike into the wilderness forests every year.

Perhaps we should consider home projects or communities for the homeless. How many homeless are there? You hear figures ranging from three hundred thousand to three million. Who can count the homeless? You can't find them. The point is there are a lot of them out there. Perhaps some of these families should be allowed to involve themselves and build their own experimental low-cost homes; and there's all kinds of experimental systems that we could use, whether adobe, pre-cut logs, dog-bone (profile) lumber, etc. It maybe possible to develop systems that we could export to underdeveloped countries.

Other Changes and Impacts: I think we need a national 10 percent home mortgage plan. It's axiomatic that when housing is going up, the country's prosperity goes up and vice versa. Why should we continue to crucify the American economy on a destructive down cycle of new home construction?

Our present mortgage interest tax deduction system has been historically insufficient to head off recessions in this nation. If we had this 10 percent plan aimed at the first-time buyer, I think we could achieve a steady rate of two million starts every year. This would bolster 330 groups of separate businesses and industries that depend on housing for a large share of their cash income. Literally tens of thousands of individual companies are involved in these 330 groups.

It would obviously increase employment and certainly increase the Government's tax income at all levels, helping to reduce the deficit, and, I think, finally head off recessions and possible social upheavals that could occur if too many people are homeless.

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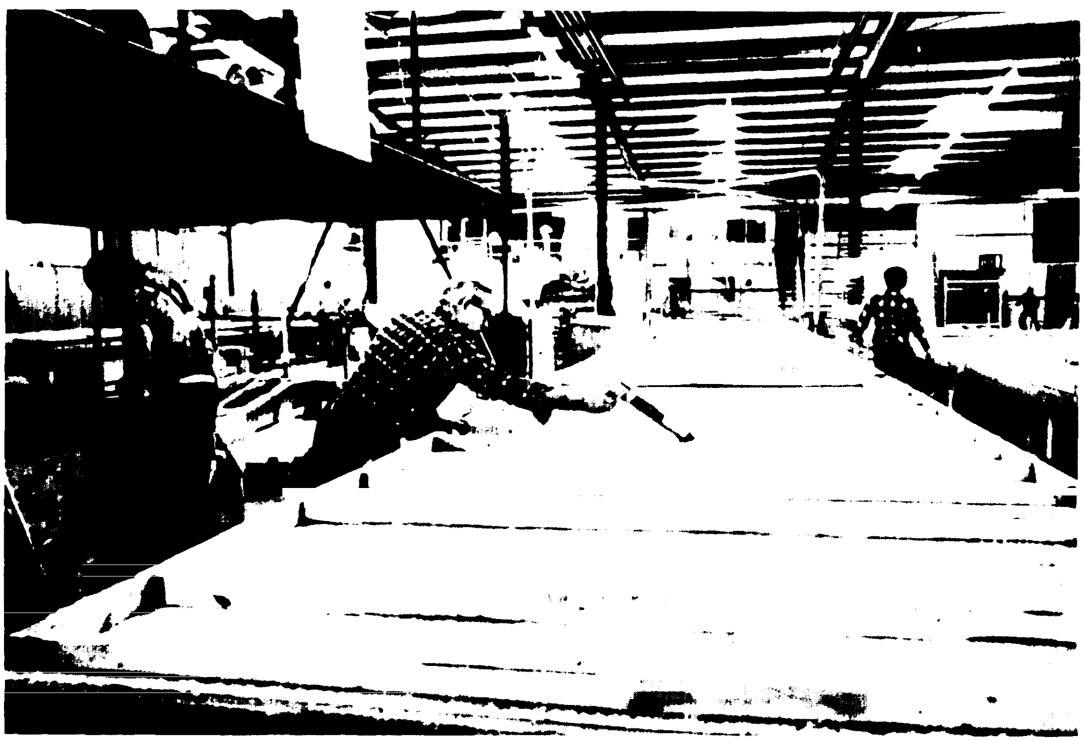


Figures 11 and 12

Construction of all homes in the United States today IS a duplicative process since all types of residential buildings are made with 2x4 stud walls spaced 16" o.c., for all exteriors These photos show typical production scenes in a mobile home plant. In the bottom photo, the worker IS shown spreading glue on studs to which gypsum drywall or wood paneling will be glued and nailed This is how a HUD-Code home wall achieves a major portion of its shear strength from external glue nailed sheathing, which the mobile industry does not use Production steps for mobile and modular homes within their respective factories are quite similar

Figures 13 and 14

Since the Introduction of the Department of Housing & Urban Development Code for the mobile-home industry in 1976, most mobile homes today are insulated (or can be according to the customer's order) just as well as any other type of residential housing. One departure is seen in the lower photo, is that because of its Chevrolet price range, the mobile home will use 2x3 members in its mono roof trusses rather than 2x4's. Nevertheless, the roof system is engineered for that specific home in the specific geographic area where it will be delivered.

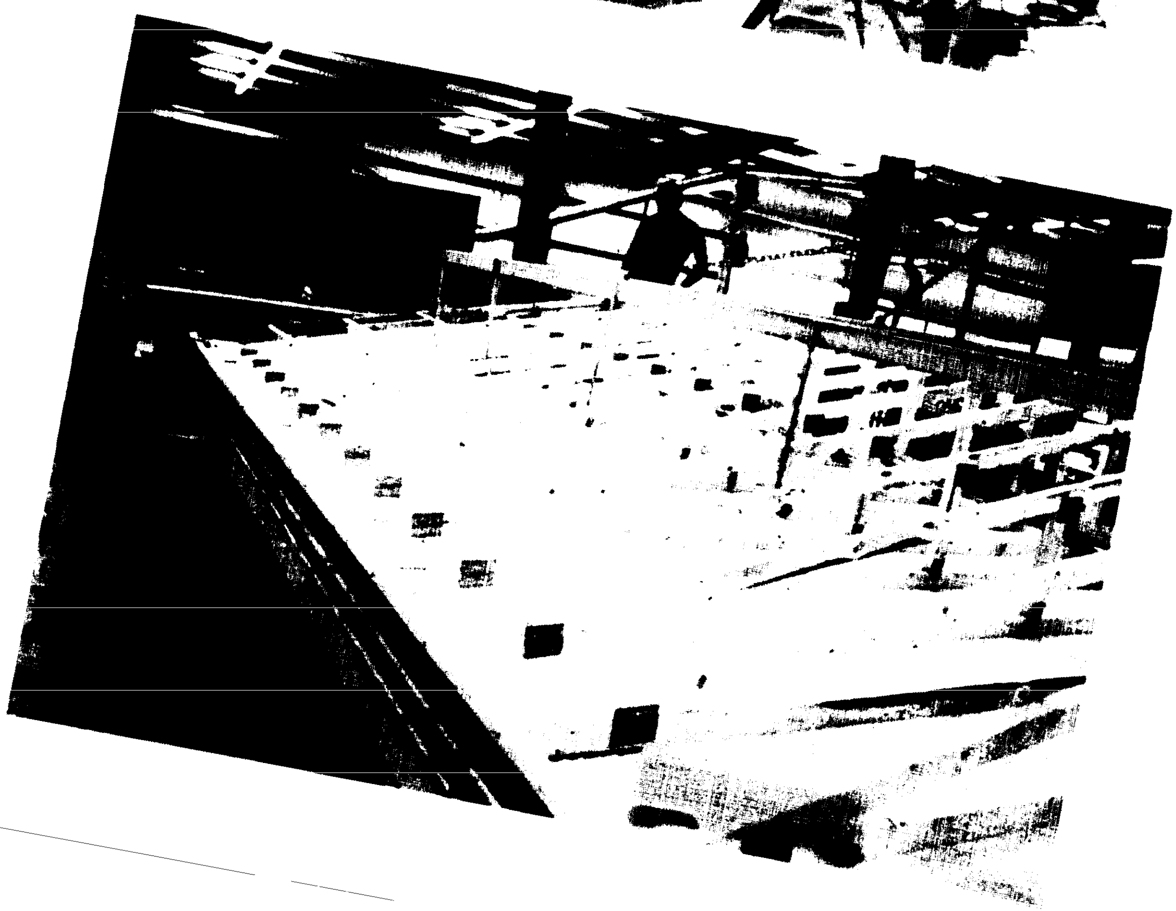


Figure 15

Aerial View of one of the nation's largest panelized home factories, Kingsberry Homes, Fort Wayne, AL, which is in excess of 100,000 square feet. Participants in the nation's panelized home industry number over 600, but range from huge plants of this size down to small retail lumberyards which panelize homes for preferred builders.

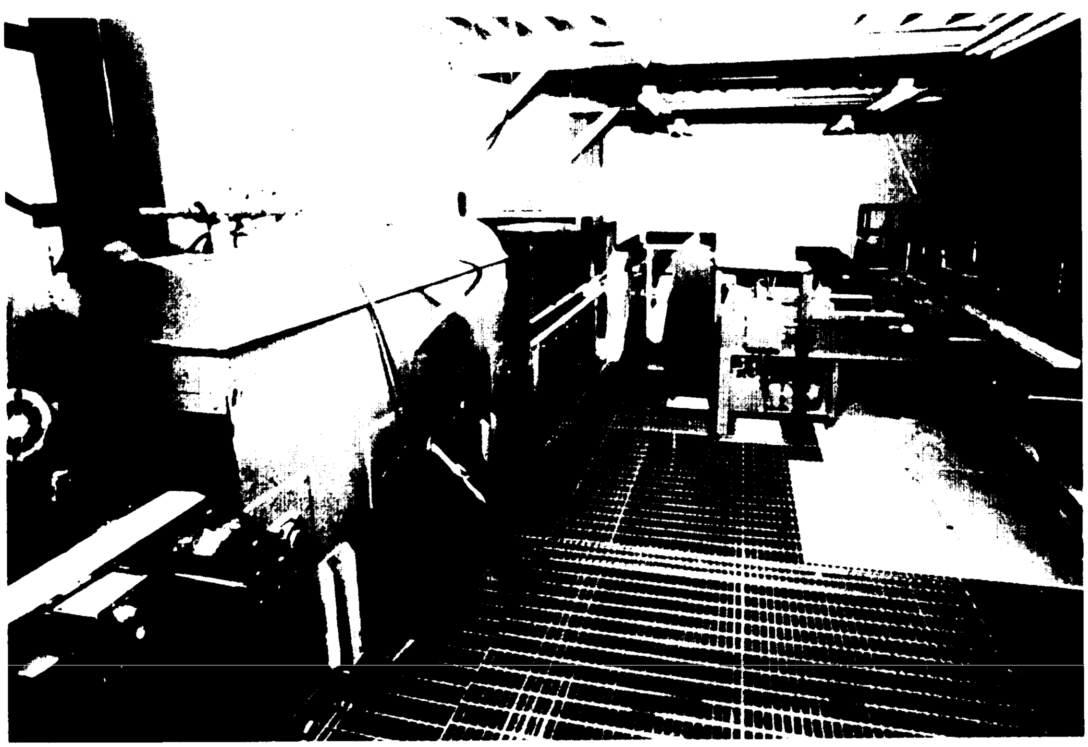


Figure 16

Non-Destructive Testing of lumber for strength qualities now is being performed by a number of lumber producers for the component industry. The independent component manufacturer, which makes major house parts for site builders, needs Machine Stress Rated lumber for critical roof truss projects such as nursing homes, commercial buildings and schools, and homes with unusually large clearspan trusses.

Figure 17

Floor Trusses, made of 2x4's and joined with metal connector plates on both sides of each 2x4 member, are now used in about 80 percent of US. homes and apartments. Floor truss actually is a misnomer because these 'flat-chord' trusses often are used for roof-ceiling systems.

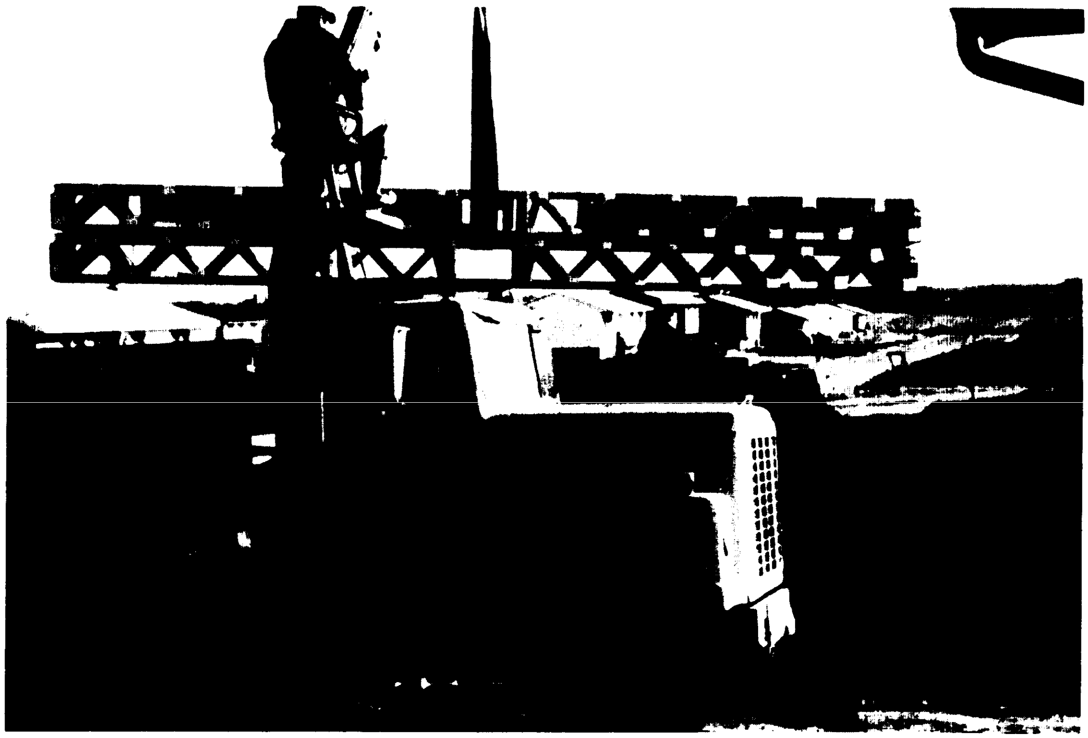
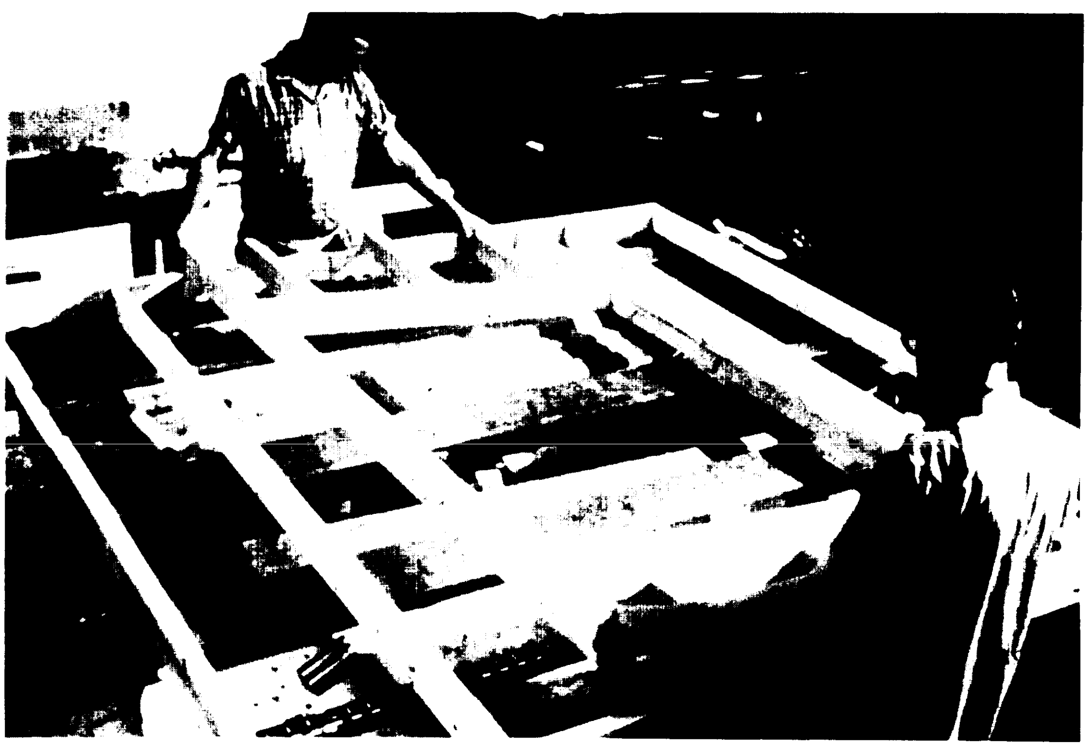


Figure 18

Component Manufacturers often assemble wall panels in the factory for use by site builders. Approximately 30 percent of the site-built homes and apartments utilize wall panels made by the nation's 1,800 component fabricators.



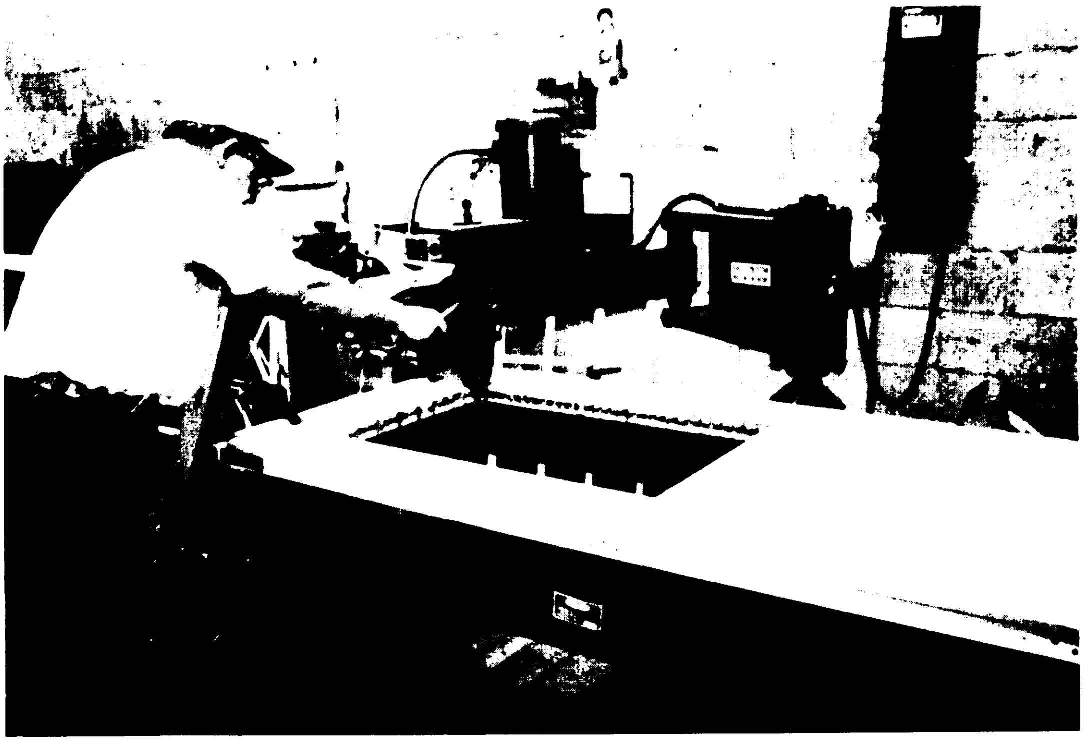


Figure 19

Component Fabricators also machine door blanks to order for production builders. They install the windows to order, put in the hinges, put in the lock sets, and pre-hang the door in its frame before delivery to the site builder.

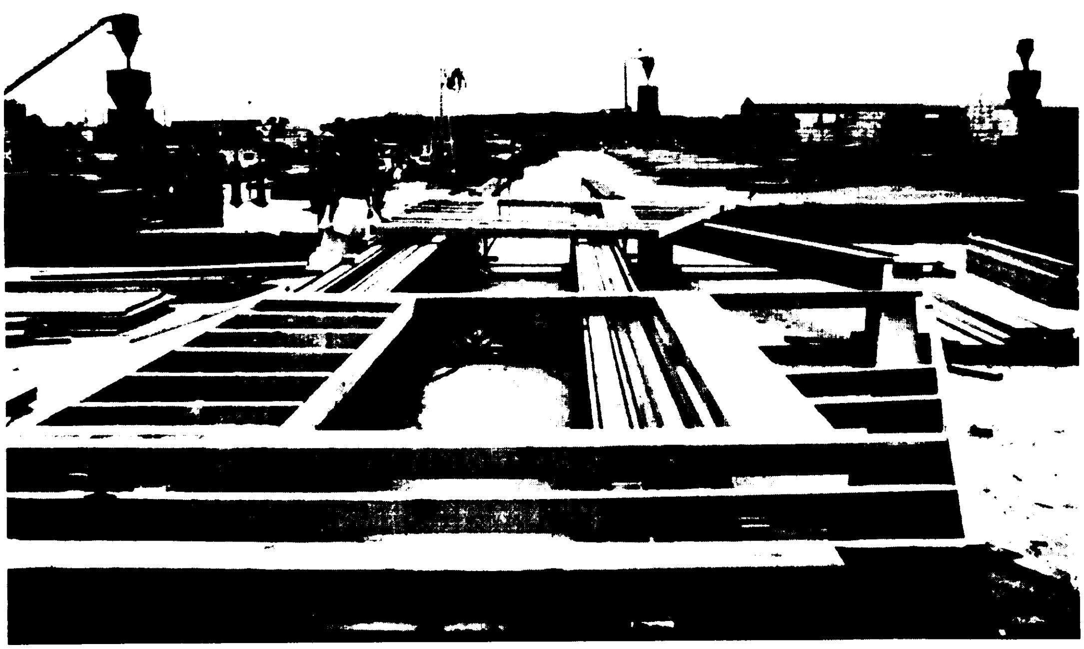


Figure 20

Wall Panel Machines used by component fabricators today are capable of making straight walls or gable end walls.

Figure 21

Component Fabricators are among the most sophisticated in terms of machining, and many use high-speed component cutters (saws) as seen in this photo which are capable of five angle cuts on the ends of 2x4 members at the rate of 60 pieces per minute. In-plant quality today far exceeds quality at the job site,

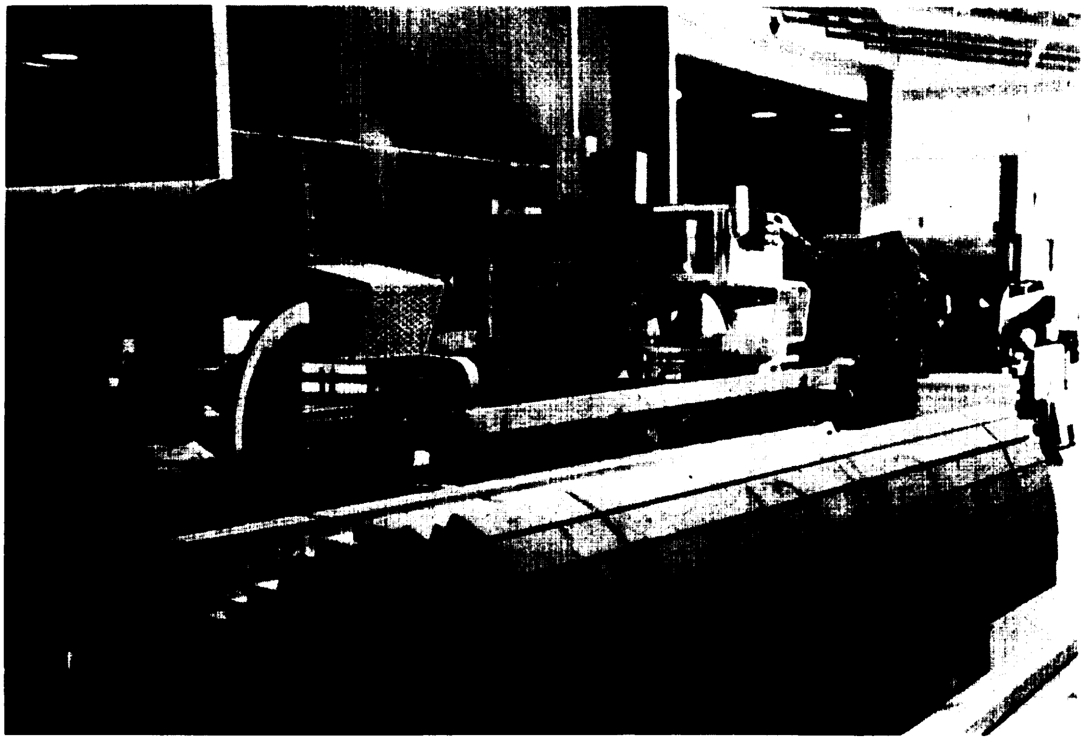


Figure 22

About 95 Percent of all component fabricators make roof trusses, and this is a mirror of the roof systems for single family homes and apartments in the U.S. today, These triangular trusses all are engineered for the specific in a specific geographic area by computer.

Figure 23

Some Component manufacturers use computer-driven, high-speed Kellner wall panel machines which are capable of turning out walls for a 1,800 square feet, 3-bedroom house in less than three hours.

Figure 24

All Styles of in-plant home builders today use simple or elaborate cutting departments to prepare members for wall panels, roof trusses and floor trusses

Figure 25

A Typical
wall panel production line for either a component plant or a panelized home manufacturer may consist of a steel-topped or wood-topped production table with roller conveyors on both sides. Some wall panel machines are totally fabricated of steel, and contain lugs to hold 2x4 members in position while they are pneumatically nailed. When a wail is finished on one side it is said to be built by an 'open-panel panelizer; when a wall is finished on both sides (and has plumbing and electrical inside) it is said to be a 'closed-panel' panelizer

Figure 26

Mechanical Core Structures
are made by both panelizers and component plants. The self-contained structures have a completely finished bathroom, the hot-water heater, the furnace, electrical junction box, and sometimes the wet wall for the adjoining kitchen. By doing all of this electrical and plumbing work inside a plant, the in-plant producer can save from $300 to $1,500 over the cost of plumbing and electrical work done at the site. In construction, the mechanical core structure is placed on the deck of the home or the concrete slab first, then the panelized home is erected around it.

Figure 27

More and More Plants today are multiple purpose plants. This factory in Austin (Georgetown), TX, produces both modular units and panelized units.

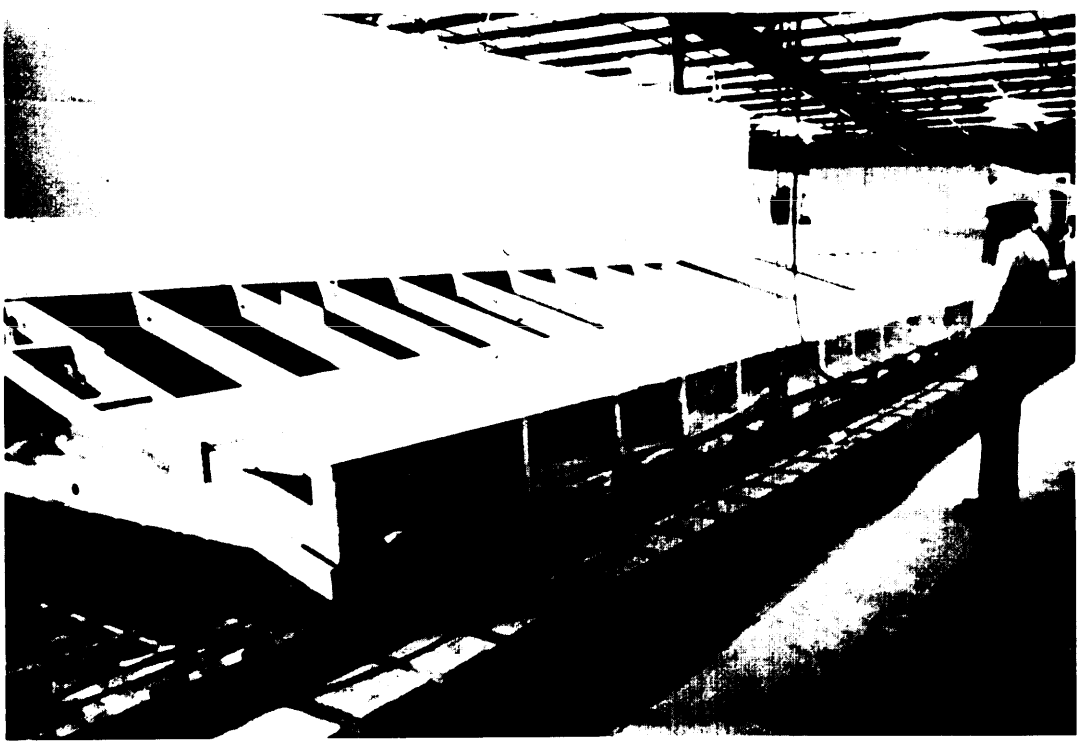
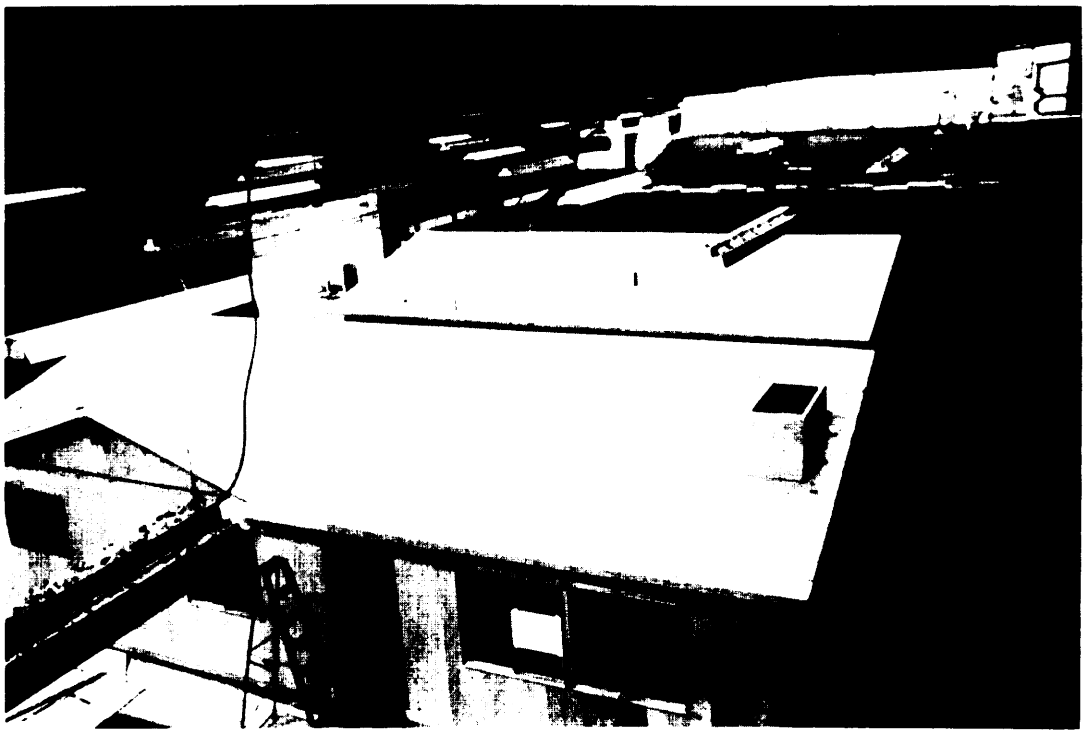


Figure 28

Jigs Are Used in both mobile and modular plants for fabrication of complete 'half-house' ceiling systems, which when complete, are transported by crane to the house production line and set in place on top of the half-house box.

Figure 29



Some **Modular Plants** build their homes with both sections joined together to insure perfect fits. At the end of the production line, the two halves of the house are split apart for transport to the job site. All modular homes are heavily sheathed with plywood, and they usually are built with unusually heavy floor decking and roof sheathing.

Figure 30

A Small Office Building, built to resemble a home but partitioned like an **office, was** built in a mobile home plant in San Bernardino, CA, in eight days. Its wood foundation was placed in the ground in one day, and the building was set on the foundation in one day. This structure could have been occupied in less than three days after delivery to the site.

Figure 31

Many of the Nation% component manufacturers located near metropolitan centers sell their major house parts 'erected. ' Thus, by the time the last component truck leaves a job site for a site builder, the floor trusses are in place, the walls are in place, the roof trusses have been added, and the home has been completely sheathed, or weathered in. The builder at the site then can take as long as he wishes to finish the house at the site using site subcontractors,

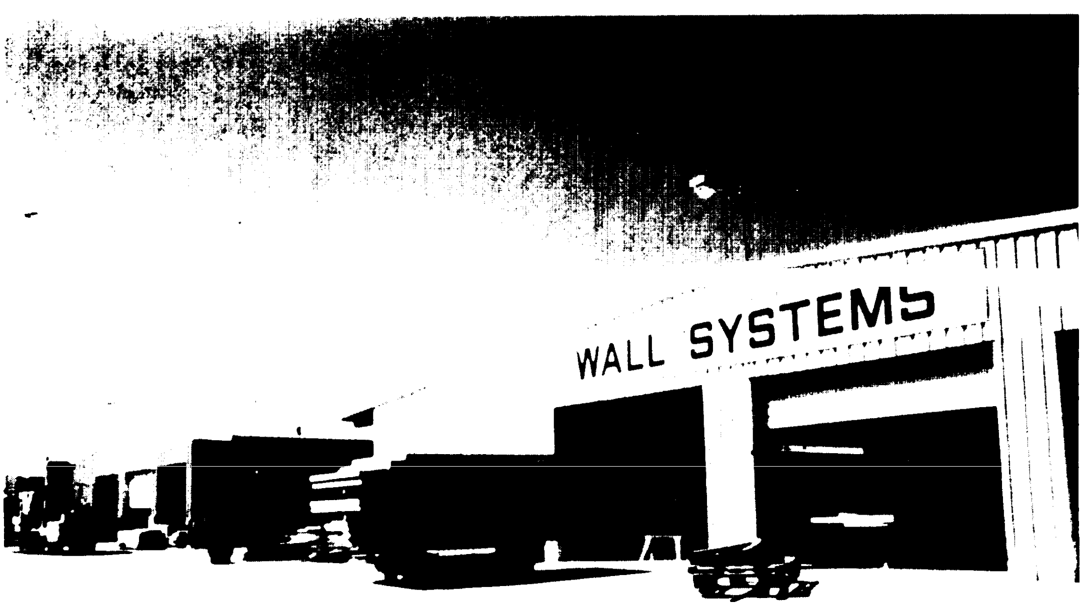


Figure 32

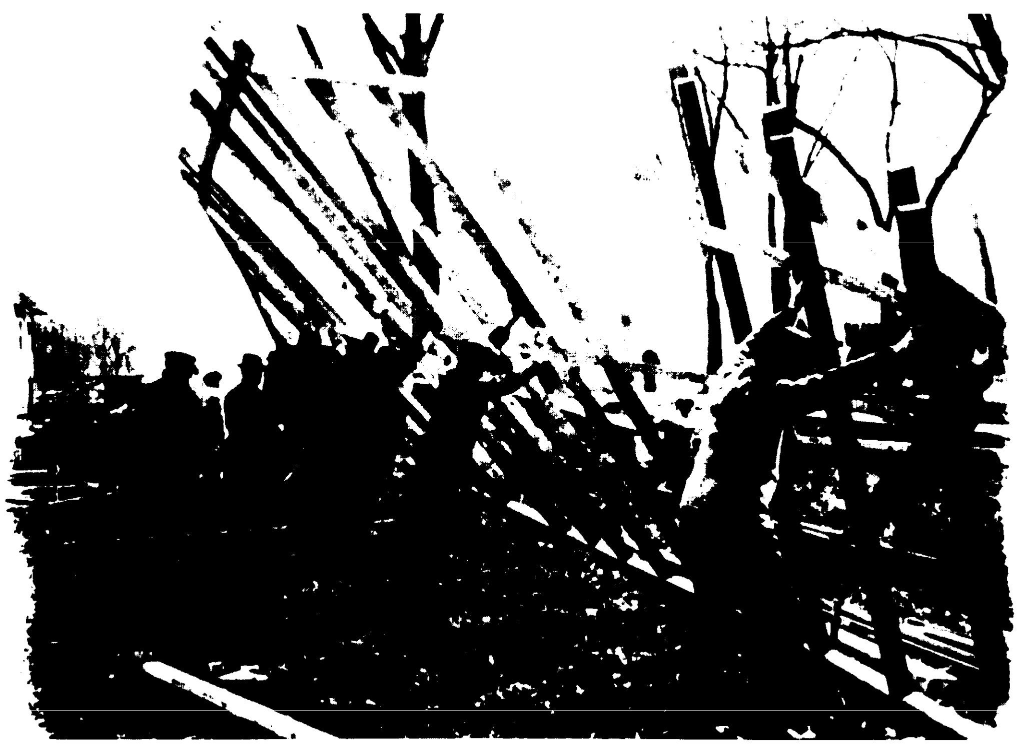
Many Component Fabricators, such as this one in Ogden, UT, have separate buildings for the production of wall panels, floor trusses and roof trusses.

Figure 33

The **Setting**
of modular homes frequently is done by crane. It is also fairly routine to set mobile homes by crane, providing space is available. By having these half-house sections completely finished inside a factory, the 'cosmetic and stitching up work' to be done at the job site usually can be handled in less than one week, and the family can move in quickly. The speed saves considerably on construction interest loan costs because of the much faster occupancy time at the site.

Figure 34

This Is Where
the modern U.S. housing industry got its start. The invention of the 2x4 or 'balloon' framing system in Chicago in 1833 made America a nation of homeowners.



Eric Dluhosch

It is encouraging that the impact of technological change on the building industry is receiving national recognition and Congressional attention. The question is: Why now, and why the focus on building technology?

Clearly, there must be a feeling of uncertainty about the future performance of this important sector of the American economy, called the building construction industry, which according to the *Report of the President's Committee on Urban Housing* was expected to produce enough new homes between 1968 and 1978 to 'provide a decent home for every American family' during that decade. The dream of an *affordable* decent home seems to be receding, rather than becoming reality. For this reason alone, it is good to meet here and look at the problems of change and innovation again. For, in the meantime, we had Operation Breakthrough, the energy crisis, and the effects of technological change on the steel and automobile industries. If one adds to all this the many changes in American life styles, and continuing demographic age and geographic redistribution of the U.S. population, and the incipient entry of Japanese and European home manufacturers in the U.S. market, uneasiness may easily turn into alarm,

The fact that we are meeting here, and the fact that the problem has been recognized as worthy of national attention, brings hope that a state of alarm can be avoided, and that lessons have been learned from past mistakes, and that another 'crisis' situation can be avoided.

If there is indeed an uneasiness about the future of the building industry, the first question to be addressed is whether we are, in fact and as a matter of perception, dealing with a *bona-fide* manufacturing industry, or whether it may not be more useful to regard the home-building industry as a *service industry,* since it is the home-building industry which I wish to discuss. In many respects it is indeed similar to many other service industries, such as health, education, recreation, and communications, for the home building industry delivers much more than just a short-term consumer product. Beyond building houses, it is inextricably involved in providing a host of other services, from financing to financial security, from status to ostentation, and from despair to pride. For the remainder of this discussion, and in order to provide a better conceptual frame for the following suggestions to be made, I will proceed on the assumption that home building is indeed as much of a service than a product, and that it acts as such in an *integrated* and highly coordinated manner in providing a host of specialized services, regardless of the fact that it may be regarded as highly fragmented as a production industry. This makes it also possible to neutralize the perennial controversy of fragmentation vs. integration, and also makes it much easier to look at technological change as a subservient aspect of service, rather than as the purely technical calculus of production efficiency. Technological change per se may thus be viewed as secondary to the achievement of desirable and/or feasible human goals, rather than as a quasi-autonomous end product. Beyond that, the assessment of change, if related to service, allows a more inclusive definition of technology, i.e., the inclusion of 'soft' technologies as an equivalent partner to past overemphasis on 'hard' technologies.

Thus, if the operations of the home building sector are viewed as a continuum of multi-faceted but integrated services, it is not only possible, but necessary, to include such 'soft' technologies as planning, programming, design, management, scheduling, procurement, and general goal setting and decision-making in our considerations. Institutional constraints can be legitimately factored in as part of the service mission of the housing sector, and questions such as the environmental impact of housing and quality of various life-style options can be linked to qualitative as well as quantitative strategies for the deployment of concrete 'hard' technologies (products, materials, systems, and assemblies). Based on the imperatives of service, technology assessment of hardware avoids limited definitions of what may or may not be assigned to a narrowly defined construction sector, thus allowing for the transfer of both techniques and products from the 'outside.' The intention is to break out of existing conceptual cages, and to broaden the scope of the discussion to include experiences and opportunities offered by all emerging and new technologies, regardless of their origin, while keeping in mind the ultimate goal of a quality environment for all citizens, with least damage to be inflicted on our already strained natural resources.

Keeping the above in mind, what then are the major technological changes which have had an impact on housing? Is there a new and different way in which we plan, design, procure, and assemble our houses today that is different from that of a few decades ago?

I submit that indeed changes in home building techniques and materials have been extensive and significant, even though, on the surface, the actual appearance of the average American home has changed very little. There are two reasons for this: the first is the nature of the product, the house, as a symbol of social stability and financial equity; and the second has to do with its long-term life as an investment asset tied to land and location. Real change has occurred, however, in the way the house is being put together, or, to use the proper technical term, *assembled.* Here major changes have affected the selection of substitute materials, the introduction of mechanized equipment and hand-held power tools, the delivery to the site of prefabricated components and assemblies, and the substitution of traditional fasteners, such as nails, staples, nail-plates, glues and zippers.

In that sense, the industry has learned its lesson well as an aftermath of the failed expectations of Operation Breakthrough to create a viable mass market for fully-prefabricated modular units by large quantity producers on large sites. In general, the trend has been away from so-called ‘proprietary’ or ‘closed’ systems, towards a more evolutionary (and more orderly) emphasis on highly-rationalized subsystems, components, and elements, produced under controlled factory conditions, and supplied at controlled cost and quality.

In addition, the disappearance of large tract developments in the seventies has forced producers to serve a more diversified market of scattered sites distributed over larger geographic areas. This has led to more careful considerations of ease of transportation, handling, and product customization in assembly.

Let me list some of the more dramatic changes which have occurred along these lines:

Planning and Design

- More compact site planning, with savings achieved by providing better planned and less wasteful infrastructure services (i.e., sewers, water, power, and communications).
- Introduction of new dwelling types for new life-styles such as cluster housing, zero lot line zoning, ‘theme’ villages, garden apartments, condos, and other ‘specialty’ types.
- Better space utilization by more compact plan layouts, and the combining of functional spaces into lofts and galleries, including the provision of unfinished spaces for future expansion.
- Better understanding of energy saving systems as part of integrated design packages, using design as a means to minimize energy consumption. This includes both active and passive systems, such as solar heating, tromb walls, insulation sandwiches, atriums, solar greenhouses, and many more.

All of the above-listed developments have generated new markets for new products, such as ‘life-style’ supermarkets for do-it-yourselfers, TV home-improvement programs, and new magazines for yuppies and other new life-style groups. New home owners have become more sophisticated in their understanding of the way their homes are constructed, and thus may be expected to demand better quality and higher performance from their houses in the future as well.

In terms of new techniques, the gradual introduction of low- and medium-cost microcomputer systems in the design of housing has led to the establishment of national as well as local data bases, readily accessible to professional and layman alike, thus allowing both access to a wide range of services, product catalogs, and other related life-style information.

The linking of computer-aided design programs with compatible software, with the capability of almost instant energy calculations, cost estimating, inventory checking and designoriginated production control of automated machines, has made it possible for the first time to control the entire process by means of fully integrated design-decision programs. Thus, decisions made in the design office can be electronically linked with inventory and cost control, procurement, as well as controlling production in the factory, scheduling assembly on the site, and delivering a customized house, as per specifications, at a guaranteed cost to the home buyer. In addition, the increased memory capacity of the new generation of microcomputers allows for simulated or real-time testing of alternative designs in terms of cost, production ease, and customer acceptance. Given this capacity to manipulate and combine, standardization by repetition becomes redundant, since it is now possible to program the computer to take cognizance of complex and/or sophisticated compatibility rules for dimensional and/or positional coordination, without necessarily repeating the end product. This promises more, not less, design freedom in less time at equal, if not lower, cost to the end user.

As an extension of the above, it is now technically feasible, both in the US. and to an even larger extent in Japan, to combine computer-aided design directly with the sales office, where the customer can actively participate in the design of his or her future home plan and at the same time get instant feedback on cost and delivery.

Many of these innovations have been introduced piecemeal and, more often than not, were developed independently of each other and on a limited application basis. It is now becoming evident, especially in view of the Japanese example, that a fully-integrated, computer-aided system which covers all aspects of decision making from design to erection is not only feasible, but virtually inevitable. This, in turn, will significantly affect the entire practice of design. An opportunity will be provided for the designer to again become a true 'master builder,' since he or she will be able to assess the consequences of each design decision on every aspect and phase of the total design-delivery process, rather than having to depend on time-consuming and indeterminate processes of delegated control. The impact on design-office organization, professional decision-making roles, and education is yet to be assessed, but surely will be dramatic.

Beyond that, the capability of computer-aided design-delivery systems to communicate with each other may be expected to have an equally dramatic effect on all other aspects of decision-making in the construction industry, both in terms of horizontal and vertical communication flow, to wit:

Horizontal:

- Quick access to powerful local as well as national data-bases on a fee-for-service basis (e.g., Specwriter, AEPIC, etc.)
- Nationally coordinated and periodically updated catalogs of products, assemblies and entire home packages, including performance and cost data (e.g., a Sears catalog of building)
- Linkage between electronic-specification data bases, testing, and code administration. For example, a given design can be matched by entering its specification 'profile' into a code-checking program, to give the designer instant feedback on code violations or alternative code-compliance rules
- Electronic control of inventories, linked to cost and availability
- Customized, as well as automated, production control
- Robots for productivity and quality control
- Positive cost control and accurate quantity estimates, linked to design
- Testing and comparison of alternative design solutions against all or some of the above.

Vertical:

- Elimination of 'back-f-the-envelope' bidding
- Bidding based on combination of best or least expensive modular packages, rather than lowest overall estimate
- Direct end-user input into design process, allowing simulated as well as real customization of plan, linked to instant cost estimate of desired solution
- Time-lapse monitoring of energy consumption as part of budgeting home-maintenance expenses
- Scheduled operation and maintenance routines as part of electronic home-control systems

- Full-service professional services that are integrated both horizontally and vertically and are multidisciplinary. Elimination of division between design and production.

Product/Process

- Substitution of cheaper and/or better performance products, with better characteristics in terms of handling, connections, interface and maintenance ease
- Substitution of hand tools by power tools, and eventual transfer of most conventional site operations into the factory
- Introduction of computer-controlled machines in production process. Increased diversification of end product
- Introduction of robots, both in production and in the home
- Gradual shift from ‘constructing’ a house by means of semi-processed and extensively site-modified materials to fully-processed and pre-coordinated elements, assemblies or entire modules. Elimination of waste in cutting and other manipulations on-site.

Some examples of products or processes now on the market:

Materials:

- Annular ring- and spiral-shank nails
- Single-layer siding/sheathing
- Improved paints
- High-pressure, melamine-laminated, counter-surfacing materials
- Prefinished siding
- Stress-rated lumber
- Self-sealing shingles
- Epoxy coatings for plywood
- Polyethylene vapor barriers
- Rubberized/plastic, single-sheet roof membranes
- Hardboard roofing panels
- Fiberglass insulation blankets/sheets
- Prefinished large ceiling panels
- Prefinished tapeless, vinyl-covered, gypsum drywall
- Resilient tension flooring, applied without adhesives and stapled only at edges
- Solar-film window glass
- Vinyl-extruded window sash.

Assemblies:

- Split-ring trusses
- Component wall panels (stapled or glued)
- Wall-hung closets
- Prehung doors and windows
- Pre-fab stairs
- Wood foundations
- Fiberglass modular bathrooms/showers
- Raised bathtub assembly with above-floor trap
- Washerless faucets
- Single-vent bathroom plumbing
- Snap-on pipe connections
- Water-saving faucets, toilets, and shower heads
- Compressed-air-assisted toilet flush
- New air-to-air heat exchangers
- Self-diagnosing appliances.

The above list is far from complete, but is offered here as a sample of the rich variety of new products and assemblies which have entered the market since Operation Breakthrough. The impact of these innovations on all aspects of construction practice is both subtle and all-pervasive. There is a clear shift from traditional ‘craft’ skills to industrial-type ‘assembly’ skills, even on-site. In general, no work that can be handled mechanically (with some rare exceptions, such as brick laying), is done manually. There is a parallel tendency to reduce the number of joints by larger basic elements, and to manage jointing operations as much as possible from the factory. Joints constructed on-site are more accurate and tighter due to power hand tools, better joint compounds, joint fillers, and cover strips, all of which promise easier maintenance (as well as better performance) and mean less or minimal maintenance. Diaphragm construction permits the use of thinner wood sections and wider spacing of framing members. The list goes on. As a consequence, homes are put up much faster and require less labor input per unit. Quality control has shifted, to a large extent, from the site to the factory. This has serious implications on inspection and code enforcement. In fact, the whole system of code administration and enforcement is due for extensive revision and will rely more and more on computerized data banks and mixed material/performance specifications.

Training of construction labor will require a new approach to specialized skill development, as well as periodic retraining in mid-career.

Unions will have to cooperate in negotiating new trade responsibilities, options for trade integration, and a certain degree of skill reorientation on a continuing basis.

Current distinctions between designer, developer, contractor, and producer will become blurred, with integrated 'full-service' organizations — teams providing comprehensive design-to-delivery services, possibly including financing and periodic upgrading options.

As a service sector, construction will rely on materials from both traditional construction supply sources, but also from formerly non-construction-oriented industries, such as electronics, plastics, fabrics, etc.

New specialities, such as geodesic domes, space-frame structures, inflatables, and fabric/tension structures are already entering the market as mature industries and are expected to invade the leisure and recreation segment of the home-building market. Different skills in both engineering/design and production/assembly will develop as demand for these 'exotic' structures increases.

With the exception of the mobile home, the trend will be in the direction of 'open' or catalog component systems.

Emphasis will be on the development of 'foolproof' and easily maintained joints and connections, allowing easy installation and maintenance-free operation.

Factory production will continue to rely even more on computer-controlled machines and robets, and will compete with conventional construction for a diversified and customized market.

Craft skills will become part of a lucrative, but limited, market for retrofit, conversion, rehabilitation and historical preservation.

Houses will be sold with component warranties by manufacturers and may be financed by component mix rather than as a finished product.

The development of plug-in, zip-in, and hook-up connections for telephone equipment, and the use of plastics in plumbing, heating, and electrical equipment will ease maintenance problems, both in terms of currently outrageous service fees for even minor repairs, and as an integral part of self-monitoring devices, combined with home security, climate control and computer-controlled communication centers.

Much of routine maintenance will be performed on a do-it-yourself basis, with the possibility of linking computer-controlled monitoring systems with pre-recorded or locally broadcast TV do-it-yourself instructional messages. This will help the home owner to diagnose, as well as correct, minor failures or communicate for help with warranty service centers.

Impact on Policy

Historical experience has shown that innovation responds to change, and change to innovation, in most unexpected ways, and that it usually manifests itself first at the interface of the frontiers which appear on the horizon of our expectations. If we fail to search for signs of change on the horizon of our hopes and expectations, crisis usually forces change and imposes innovation. Much of our past reaction has been a response to crises of various origins, rather than the expansion of our freedom to act. Operation Breakthrough has been mentioned before and may be seen as a reaction to the housing 'crisis' of the sixties. The energy embargo of 1973 precipitated another 'crisis.' Few of us who have devoted years of our professional lives to the 'solution' of these crises have continued to receive support for continuing our efforts, even though the 'crisis' may have lapsed. Indeed, we are asked to respond to new emergencies, to study new problems, to re-tool for new research. The tragedy is not that these projects have failed, for they have not — at least not entirely — but the cost at which their limited success was purchased.

Thus, after having responded every five years to a new 'crisis,' it is my humble opinion that we do not need or deserve another 'breakthrough' or another heroic 'if we can put a man on the moon' effort.

What we need most is genuine continuity and the removal of unnecessary institutional barriers and restrictions, which have stunted sustained efforts to take the long view of things, and which impede the ability to carry experiments to their full maturation, including the chance of failure.

Since innovation by its very nature is impossible to predict — for then it would cease to be perceived as true innovation — it may be more useful to remove existing constraints which prevent us from breaking out of present conceptual cages and to develop a climate of confidence for long-term institutional as well as private centers of excellence, which may or may not invent new gadgets, but which will act as powerful intellectual and technical brain trusts, and whose members will act as a vital source of basic knowledge and understanding for both government and industry. The former to act as a facilitator, the latter as producer. In concrete terms this implies:

- Agreement on long-term national goals, beyond party or factional concerns;
- Assurance of long-term support for so-called centers of excellence in universities and not-for-profit think tanks;
- Removal of institutional barriers, restrictive rules, and bureaucratic interference with long-term research and development;
- A clear mandate for short-term initiatives and research, without false promise of long-term and sustained support, if not expected or likely to be forthcoming;
- Clear allocation of responsibilities and commitments to research and development between government, industry and the universities;
- Monitoring of objective assessment of new technology as to its side effects, and in relation to long-term goals
- Removal of conflicting jurisdictional rules between local and national levels of government
- Non-adversary partnership between government, industry and universities
- Review of all restrictive zoning, based on new technical and life-style conditions
- Operation and maintenance of urban infrastructure systems made independent of discontinuous political mandates. Establishment of minimum quality standards and technical performance criteria for capital investment in the public sector
- Short-term policy cycles to be coordinated with long-range national goals
- Appointment of ‘technology watchers’ both domestically and abroad (based on Japanese precedent). Regular reporting to Office of Technology Assessment
- Establishment of national data base and information exchange for construction technology advancement and dissemination of research results and reports by technology watchers
- Establishment of regional construction technology centers, say on the model of Dutch Bowcentrum, including affiliated continued training and education programs
- Set up bonded warranties for new products and processes to be introduced in market for testing purposes
- Upgrading of equipment in trade schools and universities.

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