MODULAR AND MOBILE, SUSTAINABLE AND AFFORDABLE

Manufactured Processes

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Introduction

Prefabrication and mass-production techniques since WWII have been predicated on the standardization of building systems. While overall configuration could change, tectonics and components were understood as prototypes: fixed, standardized and identically repeatable. Through the use of Computer Numerically Controlled production processes, new methods of fabrication can create building components from computer data and ultimately allow for differentiation into mass production. Repetitive non-standardized building systems, developed from investigations into materials, serial logics and design software, enable a new paradigm, in which local variations constitute continuous yet differentiated composite structures. Through these processes, it may now be just as easy to make an infinite number of unique houses as identical ones.

This paradigm of mass customization frames the exploration and reconsideration of the building construction industry as a process of production and assembly versus conventional manual building practices. The more instantaneous modeling and construction of a tectonic system— as a set of constraints, with specific limitations of material, fabrication technique and program— allows for immediacy between the designer and the building processes; there is a tightening of the relationship between design and fabrication that reclaims, for the architect, a position in the construction process.

The manufactured housing proposal presented here explores the development of tectonic systems composed of repeatable yet non-standardized building components that allow for multiple configurations and deployments. The design loosens and complicates the relationship between flexible proto-types and tectonic components and reinforces the notion that mass-production is quickly moving away from the paradigm of the standard toward the fluid cast or the multiple. Ultimately, this investigation focuses on the development of repetitious systems of construction that are non-standard— all through a contained and transportable medium, the manufactured house.

History

The design that we propose here follows in the legacy of the origins of manufactured housing. Manufactured housing came from the possibilities of industrial production, but was accepted by a public who had the desire for travel and modernity. As part of our design proposition, we also encourage an examination of the origins of making houses and specifically the reconnection to the automobile industry that has far surpassed the manufactured housing industry in new methods of fabrication through digital production processes and marketing. Americans enthusiastically accept newness and inventive form in their cars and yet still seek traditional and iconic modes of architecture in their homes. We are suggesting that these disciplines merge to encourage a contemporary practice of manufactured housing that reflects consumer customization and allows architecture to actively participate in a currently inaccessible market.

The manufactured housing industry emerged from a convergence of two trends in culture and technology in the beginning of the twentieth century: the American desire for national travel and mobility, manifest in the travel trailer industry, and the desire for cost-effective, efficient modes of construction, evident in new models of factory production.

The American desire for geographic exploration, adventure and family leisure-time activities spawned the design and evolution of the travel trailer. While early adventurers built these trailers in an ad-hoc manner, converting automobile parts and inferior shed-like structures into mobile living units in home garages, eventually, an industry emerged to satisfy an increasing demand. The Airstream, first produced in 1935 by Wally Byam, was an aerodynamic, modern, techno-smooth trailer that was light and strong and could be easily transported hitched to an automobile. It not only touted ease, but desirability: "An Airstream trailer is so well desired that it competes not with other products, but other lifestyles." [1] Initially, these manufacturers built travel trailers like automobiles; in fact, both General Motors and Ford experimented with trailer manufacturing, because they used many of the same components that could be

purchased from automotive part suppliers and the production processes faced similar difficulties. While the industries were closely aligned, inevitably, neither automotive giant engaged the product since it had not yet established its market. By 1936, however, over 250,000 trailers were in use, despite the predictions of Lewis Mumford who claimed that they were too small and would "never amount to anything.[2]"

By the beginning of the Second World War, travel trailers changed in both intended duration and scale, transitioning their purpose from recreation to housing as national nomadicism evolved and technology fostered production at a larger scale. Initially considered, small, immediately moveable structures attached to an automobile, the new requirements for the war era required temporary housing for months at a time that could comfortably sustain a family; in other words, a mobile home could become less "mobile" and more "home." While the war changed the role of mobile housing from travel novelty to domestic necessity, the post war years changed the mobile home into the industrialized house. While consumers used travel trailers as portable vacation homes in the 1930s, after world war II, over 90 percent of mobile homes were built for year-round living, many as dwellings for returning G.I.s and their young families.[3] Simultaneously, as military production diminished, better materials, such as aluminum and steel, and dormant factories became suddenly abundant and both were immediately used for factory production of new, affordable, moveable homes.

Then in 1954, Elmer Frey, who established Marshfield Homes in Wisconsin, made a startling change in the industry which would forever separate it from its travel past: he introduced the ten foot wide trailer. The ten-foot wide could not be pulled behind the family automobile; it required commercial transport and to be moved only a few times during its lifetime. As the industry expanded the housing module from ten to twelve and then to fourteen feet, and the mobile homes became factory built houses, other accommodations were made to replace the image of the aerodynamic trailer with the traditional house, or the "shiny box" with the "white picket fence." For example, pre-finished plywood paneling replaced painted surfaces reducing finish time. Designers added extras, such as expandable "cabana" rooms, as well as more plumbing and amenities. Thus the manufactured house was domestic product, meant for immediate installation and operation, and, as inflation increased in the 1960s and traditional housing became more unattainable, a desirable and highly successful one. In 1959, 3 million people lived in mobile homes; by 1969, that number had doubled.

While the culture of travel trailers became the culture of manufactured housing, a simultaneous technological innovation encouraged this transition: the development of prefabrication. At the turn of the century, the technologies of balloon-framing and demountable buildings allowed the house to be thought of as a series of assembled, pre-made components, shipped to a site and reassembled. For example, the Sears catalog in 1919 even included a "mail order" house called the "Simplex Portable Cottage" that could be purchased remotely, shipped as a kit of parts, and assembled—rather than constructed— on site. Capitalizing on the massive increase of assembly production and machine fabrication during the Second World War, architects saw industrialization as the way to supply the massive demand for post war housing. Conceivably, an affordable, residential kit of parts could be fabricated on a large scale then purchased and assembled anywhere.[4] Carl Stranlund began one such experiment in his production of the "Lustron House." As a prefabricated house, it was comprised of vitreous enameled steel panels and came complete with environmental control systems and domestic appliances. It was sold as a car, demonstrated by a franchised sales force in nationwide showrooms, then brought and erected at the site.

What distinguished the manufactured housing industry from the majority of post-war housing experiments was that these houses were not merely assembled prefabricated parts, they were entirely assembled in a factory and shipped to distribution centers nationwide. The factory-built house had three benefits over a site built house: improved construction quality, increased work efficiency and decreased cost of production. Currently, a typical manufacturing facility can produce 8 homes in about 8 hours with a factory of 250 people at an average cost of $35,000. Figure 1 shows the typical current

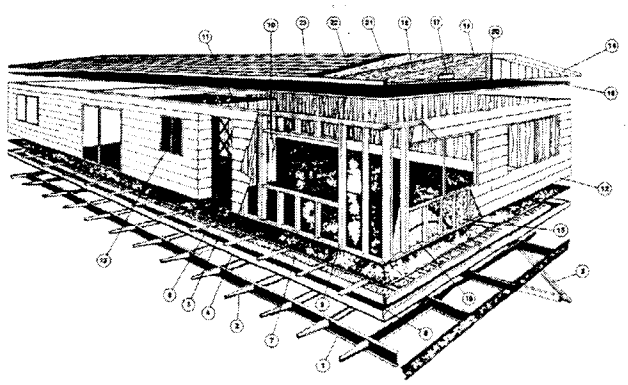

Fig. 1. A typical current configuration of multiple separatized components within a standard manufactured house.

configuration of multiple separatized components within a standard manufactured house. Singles are built in one piece and shipped to a residential property, while double-wides are built in two pieces (usually 14 feet wide each), shipped, and put together on site. Working with pre-cut materials creates less waste and allows for a tighter construction since production time centers around 'assembly procedures' versus the measuring and cutting of materials in a less controllable environment. The mobile home is actually constructed differently than a conventional home, because it must endure the stress of moving and thus mobile homes are built to be flexible, structurally and materially. Also, the construction, financing, transportation, installation and inspection of a manufactured home are handled by one company versus an on-site home where the buyer is responsible for handling the real estate agent, the financing and the inspections.

As living modules, they have become perfect housing products, inexpensive to make, requiring almost no design, endlessly repeatable and movable to any site. This has become such an efficient manufacturing and distribution system, in fact, that it now significantly threatens to further homogenize housing stock nationwide. It also significantly diminishes the already minute role of the architect in affecting the majority of domestic space in mainstream culture.

New Paradigm

Today, as the manufactured housing market expands, new design and fabrication processes, fostered by software and production technologies, offer the potential of mass individuation. The prototype, initially the extent of the design process embedded within a singular object, can now be thought of as the process itself, the set of rules or formulas by which variations emerge, extending the design process much further into the production process. Rather than casting an element by using a specific mold, the mold itself becomes fluid. It opens a determine system of manufacturing into an indeterminate one of potential. This loosens and complicates the relationship between the idea of prototype and the tectonics that emerge; it also significantly tightens the relationship between the designer and the product created.

Inevitably, using three-dimensional software techniques then fed to a CNC milling machine, as architect Greg Lynn states "it is simply as easy to make 1000 unique objects as 1000 identical ones" and the design process is extended to the moment of physical construction.[5] The translation of three-dimensional information into two-dimensional milling paths where the information can be variable without impacting the cost of production allows for the creation of continuous yet differentiated structures.

The possibility of manufacturing variable elements frames the exploration and reconsideration of the building construction industry as a process of production and assembly versus conventional manual building practices. The more instantaneous modeling and construction of a tectonic system— as a set of constraints, with specific limitations of material, fabrication technique and program— allows for immediacy between the designer and the building processes; there is a tightening of the relationship between the fabrication and the design that reclaims, for the architect, a position in the construction processes and, therefore, construction industry. The design is less organized by the limitation of the fabrication process and can instead explore the almost unlimited extent of what digitally sponsored machining can accomplish.

The potential of mass modulation allows assembly procedures to

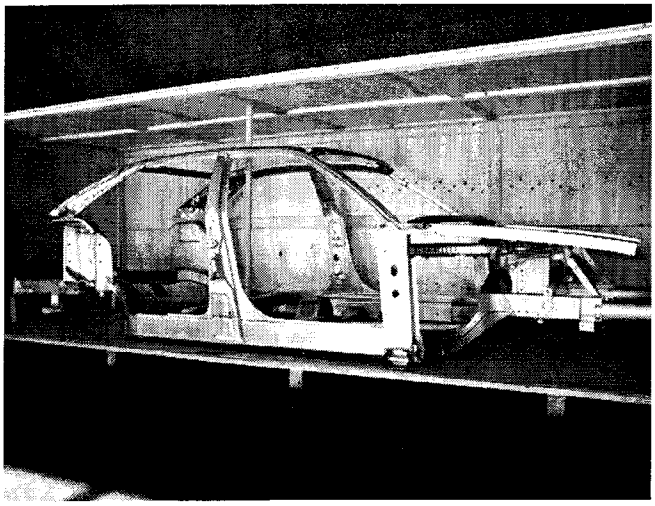

Fig. 2. The Audi A8 frame, showing the relationship between surface and structure.

simplify. The elements themselves are no longer identical copies of the designer's intent, reliant on the complexity of their integration and assemblage, but are instead unique responses to individual desires building complexity and originality into each component. This is occurring already with the automobile industry, which no longer relies on the limits of developing one machine that can only produce one part. Factories can now be organized around a series of reprogrammable machines that can produce multiple parts or components. The machines are designed for a series of constraints or parameters [generic process] rather than a series of specific products [generic objects].[6] Previous methodologies relied on standardized components with variations of assembly; now the components are variable and the assembly immediate.

The potential of these automotive methods can also be linked to a closely aligned industry, the fabrication of mobile homes. Within the mobile home, there is a desire for a seamlessness that can be seen in several of the systems. The first is the relationship between the interior surfaces and furniture elements through the concept of the 'built-in' that allows for an almost indistinguishable relationship between program and enclosure. Architecture at the detail scale perfectly aligns with continuous larger elements. The second is the relationship between vertical and horizontal surface, or between wall and ceiling, much like the continuous surface found in automobiles. This is due to the requirements of how surface and frame are interconnected and economic strategies of internal square footage or volume. In looking at the predecessor to the mobile home, the Airstream fuses both chassis and living area volume or frame; thus surface and structure become inextricably linked. The automobile industry has taken this one step further in the development of the Audio A8 frame, seen in Figure 2, which transitions continuously between the structure and surface of the car allowing the structure to flatten and respond to the nature of the overall performance of the envelope.[7]

Thus, within this proposal, there is a desire to integrate multiple systems into fewer systems— reducing the complexity of assembly, but opening the potential in the complexity of integrated design. A single, intelligent surface can then perform the functions of what used to be a set of assembled, standardized components. This new paradigm, which extends the design process through the development of a more articulated, multi-functional surface, has the potential to radically change the relationship between design and production of manufactured houses. Our design project and theoretical position is to combine multiple systems into singular elements, to create structurally superior, individuated, customized housing which seeks to elevate both the aesthetics and operation through an extended design process completed through new production methods that employ CAD CAM software and CNC milling procedures.

Design Proposal

This ongoing research project involves transformation of three primary elements: structure, surface and space.

Our strategy for structuring a manufactured house involves fusing structure and surface. Current practices like the Audi A8 in automobile manufacturing allow structure to become planar, in essence merging enclosure and stability while the current structuring model for a manufactured house involves the assembly of framing and chassis. In our proposal, these two components are combined

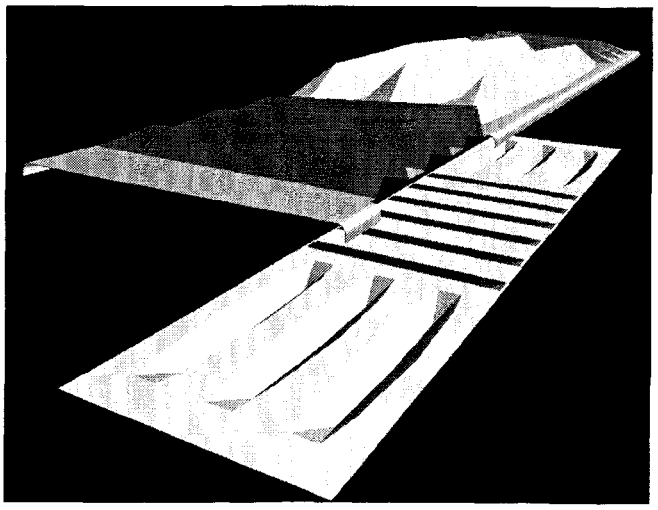

Fig. 3. Design proposal surface steel chassis.

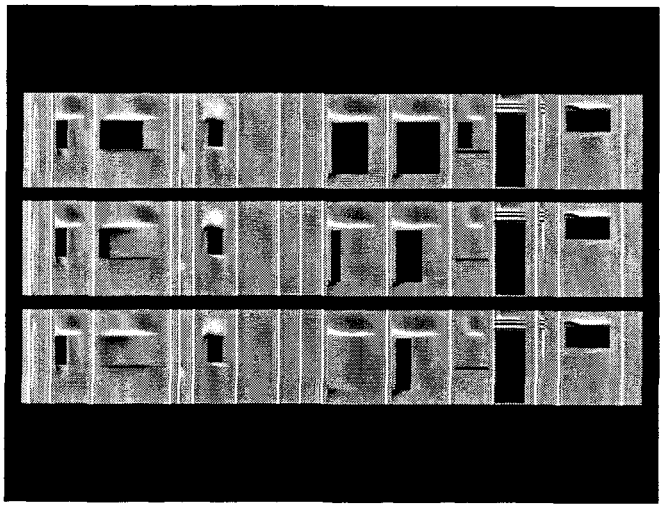

Fig. 4. A panel assembly showing surface modulations.

into one structural surface through the creation of wells that act as stiffeners, as seen in Figure 3. What would typically be thought of as a frame and panel system can now be modeled on the shipping or freight container system: the inflection of the surface provides structural stability and stiffening to reduce components. This also solves other problems; for example, manufactured housing owners often replace the cheap quality flooring located above the chassis because it is not as durable at the structure itself. Here we alleviate this problem by fusing the two systems; instead of providing a steel multiple w-section chassis, we offer a stamped steel, single surface chassis. The roof also acts as a surface structure that potentially provides storage space as well.

The transformation of surface, in relationship to structure, came in the development of a panel system that posits and responds to many interior and exterior considerations. The panels are actually *two surfaces, a wall sandwich, that thicken and thin in response to* structural and interior program considerations. This was inspired by the Winnebago that utilizes 'hollows' or 'cavities' for storage purposes while simultaneously creating a seamlessness between both multiple materials and embedded programs. Some possible programs that are afforded through this thickening and thinning sandwich are: casework, shelving, working surfaces, storage, seating, stairs or even inhabitable spaces. From the exterior, however, the panels exhibit the specificities of the interior conditions, but also align to form a larger composition at the scale of the entire wall. Since the panels would be created through digitally controlled processes, they do not need to be the same width and can thus exhibit more specific architectural qualities to form a varied elevation. The elevation would also exhibit the qualities of the local environmental conditions since the space in between the panels can be used for infrastructure, such as electrical wiring, but also for insulation. A house made for a colder climate would thus have more thicker panel conditions to allow for greater insulation which be inevitably be expressed in the modulation of the elevation. When combined, the individual panels create a single landscape or elevation of the variant surface modulations, based on both interior content, or program, and exterior protective strategies, such as rainshields, or awnings over openings.

The second exterior consideration in developing the panel system was for adaptations in fenestration. We wanted to establish a quantifiable relationship between the specificities of the client and the number and size of the windows in a house. For this, we used the Expressions tool in Alias | Wavefront software to create this relationship so that by inputting various data, for example cost, climate, and desires, we could easily update the scale of the individual openings

as well as the specific profiles of both doors and windows. The fenestration originally began as cut outs in a modulated skin, but can now be seen as a set of tears or shreds allowing for a more continuous surface development. The windows do not upset the changing surface, but instead allow the seamless introduction of a new material, glass. Figure 4 shows this modulation.

This example of window variation helps to explain how software and manufacturing processes allow for new ways of creating mass customization. The Expressions tool essentially allows for a series of basic mathematical 'if/then' propositions to be written and keyframed, or tied into, the 3-dimensional panel surface and its variant modulating systems. We developed a series of algorithms to fuse both the economic and material datasets resulting in a change of formal panel characteristics. If you have x amount of money, then, y is the exact size and position of the opening (or window) for that panel. The 'swelling wall systems' are easily manufactured in different configurations without changing the cost of the panel; ideally, there could be endless variation via this mass customization technique. The overall shape and the amount of window area opening could be reconfigured from client to client, and their budgets and/or programmatic desires, without either adding or subtracting elements to the design or continually reworking the design. This process explores a shift from an exact panel module repeated identically to one of potentially infinite variation to affect elevation, section, space and program.

It is the switch from industrial processes to digitally controlled ones that would allow us to make a differentiated, yet repeated set of panels. The process involves first gathering information from the client and establishing a final customized three-dimensional model for the desired number of panels. The three-dimensional information, created in Alias | Wavefront software, is then translated into a two-dimensional path in CAD/CAM software which is then fed to and used by a CNC milling machine to make the desired formwork. Milling is a removal process— the machine removes mass from a block of material to leave a sculpted surface. Once the formwork is complete, finish material is cast over the formwork to create the final panels. Currently we are experimenting with this process at multiple scales. Figures 5 and 6 show both a digital version of the panels and the 1/4" scaled analog, or milled, versions. The casting process is essentially a vacuum forming process which forces a finish material to the contours of the mold (Figure 7). The formed panels are then cut at the edges of the formwork, slipped together

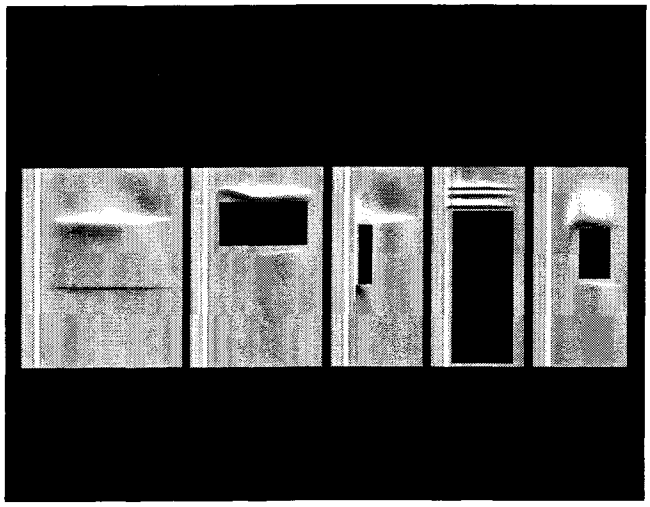

Fig. 5. Digital panel assembly.

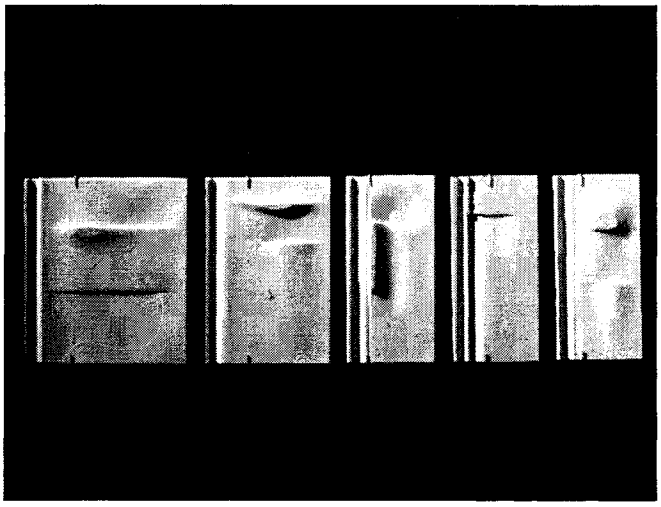

Fig. 6. Milled panel formwork at 1/4" scale.

at the spine edge and tack welded together, creating a structural bond through interlock. This seaming technique was also adapted from the methods used to make large-scale containers. Computer controlled machinery processes thus allow us to avoid designing a specific set of panels and instead create something that can be easily affected and directly changed by the client and context: a panel system that is influenced by a series of interior and exterior variables.

While clients could affect both form and openings within the system we have created, they can also pick colors and textures of their house. Our studies of structural capacities and surface modulation resulted in something rather unexpectedly, particularly as a result of the milling process, they resulted in new models of ornamentation and decoration. As can be clearly seen in Figure 8, the machinic process of milling offers different surface qualities. In this 1-1/2" scale formwork made from roofing insulation, we tested various bit sizes and spacings to achieve an exaggerated corrugative texture. Rather than attaching trim or iconic elements to an existing structure, ornament is embedded within as a result of the manufacturing process itself. Along with affecting the surface characteristics, clients could choose the skins themselves from a multitude of materials and coatings available through a customization process. Interior surfaces could respond to interior desires creating a two-sided sandwich. The finishes could also be selected from a predetermined palette as a series of yearly updated swatches.

Along with developing the potential of surface modulations, the same ideas could be applied to transform the space and form of the house. We considered the deformation of the housing through two methods. The first method, at the smaller scale, was the invention of a deployable and retractable the bedroom wing or area. To do this, we used the Alias|Wavefront Inverse Kinematics tool, as attached to a roof structure membrane, in order to deploy the surface (see Figure 9). This could be an armadillo shell or armor plating sheathing, in order to pack and unpack program conditions. The second spatial transformation was a much larger scale and included the development of deployable units that could vastly expand the interior space of the project and even sculpt the exterior into a protected open space. As with the Winnebago, we wanted to have multiple volumes push out from the main shell or container, into the site. In our proposal, we show this as a deployable living unit that would move across the site not only creating additional programmatic space, but leaving a more

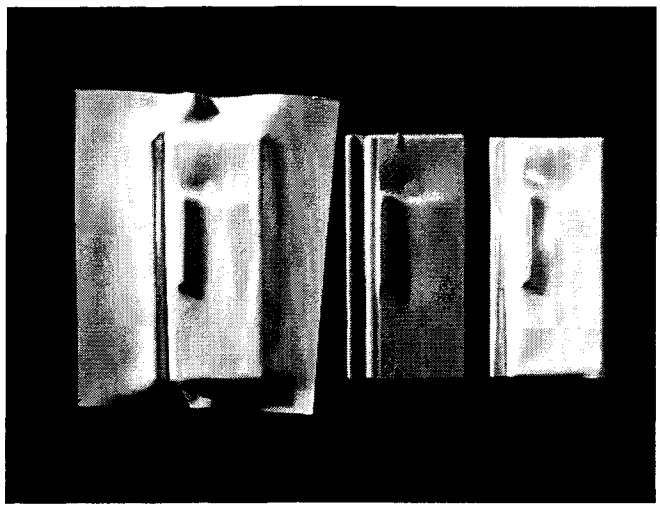

Fig. 7. Example of milled panel formwork, vacuum formed panel, and cut final panel.

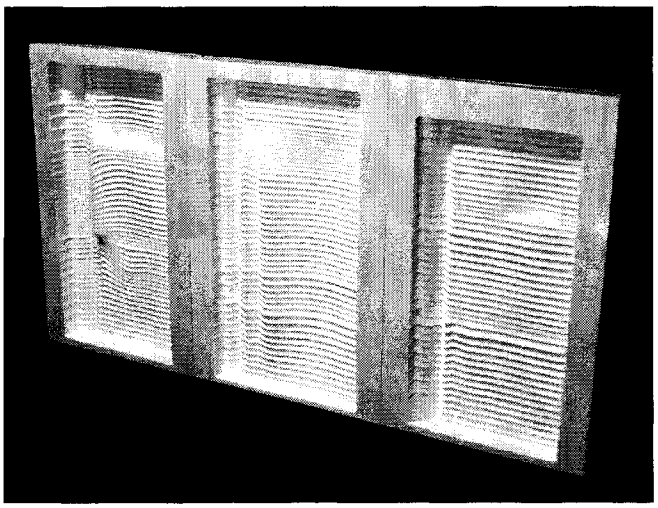

Fig. 8. Milled formwork from foam, 1-1/2" scale.

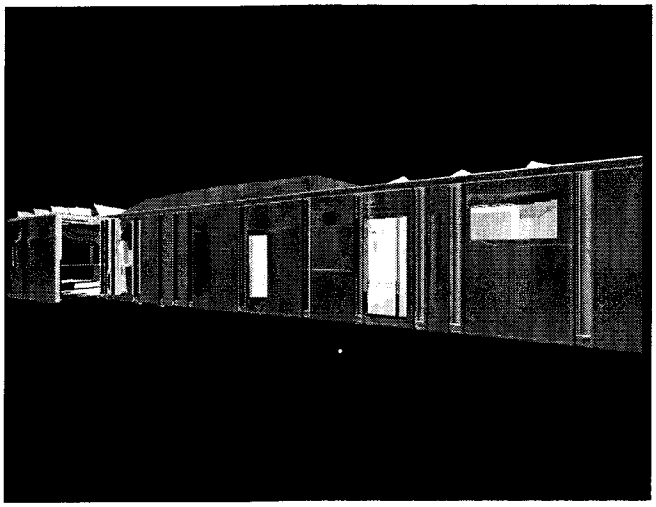

Fig. 9. Projected bedroom expander unit.

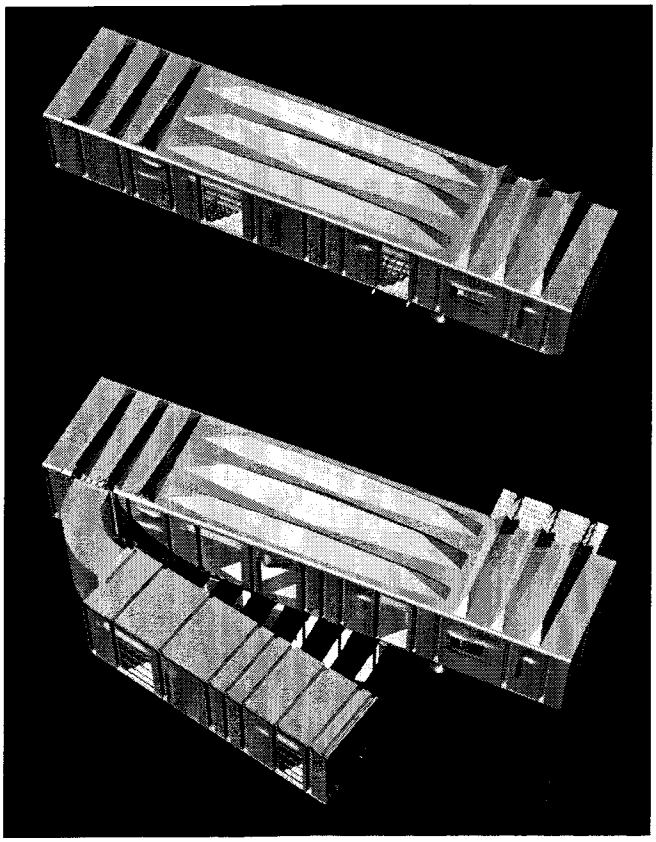

Fig. 10. Expander spatial unit deployed on site.

open internal plan structure as well (see Figure 10).

Thus the house, upon reaching a site, can deploy an entire volume of program, such as the living room, out away from the main volume. This expands the usable floor area and provides, perhaps, for a more dynamic exterior elevation. Therefore, in terms of extending this deployable program logic, we created a courtyard condition (or patio space) by unpacking the interior living room volume to the exterior; we accomplished this by using telescoping triangulated beams as nested in the roof and floor assemblies. This additional volume could be programmed as a library, a studio space or an additional bedroom or living space. Once the interior living space is pushed out and becomes the additional volume, it opens the interior of the main body of the project to become an open programmable space—a "free" plan (Figure 11). As shown in Figures 12 and 13, the original interior surface becomes an exterior surface and the house is expanded across its site.

Consumer Culture

"I could already see then that if everyone was to get high quality shelter, houses must be mass-produced industrially, in large quantities, like automobiles." Buckminster Fuller

This proposal, along with expanding the influence of the designer and restructuring the relationship between design and production, seeks to further affect the interface between designer/producer and the consumer. Again looking to a closely aligned automobile industry, the manufactured housing industry can more closely relate the intentions of the designer with the desires of the consumer thus providing an impressive increase in both the power of the consumer as well as the influence of the designer on culture at large.

The automobile industry has brilliantly strategized through advertising to create not only the functional demand for automobiles but impassioned the desire for lifestyle. Buying a car no longer merely satisfies a consumer need for transportation, it fulfills a consumer self-image and implies status beyond the capacity of even of architecture in contemporary culture. Unlike the manufactured housing industry that has long suffered from a poor image in the media, the auto industry has propagated a sense of the car as a fetishized object,

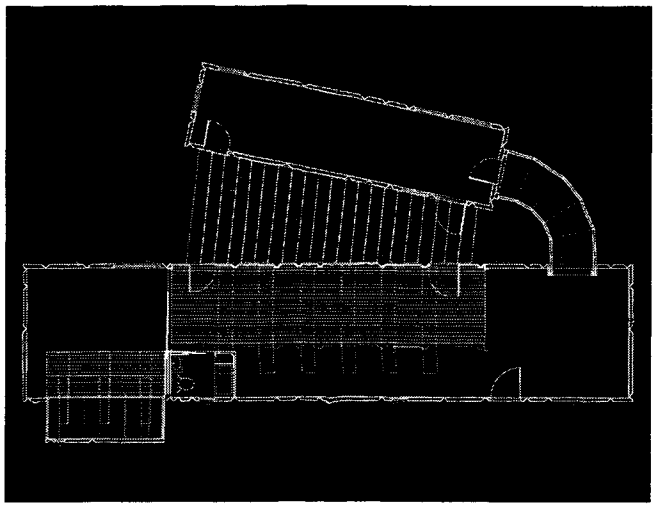

Fig. 11. Manufactured Housing Proposal Plan.

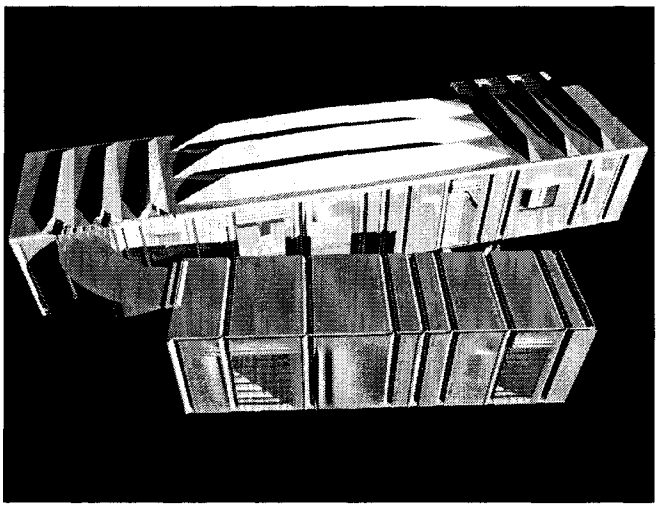

Fig. 12. Manufactured Housing Proposal Rendered view.

easily identifiable and telling of social and financial status through the implication of performance, style and power.

Based on the model of the automobile industry, we propose a revised interface with the consumer that encourages the perception of architecture as more than comfortable, but instead performative and desirable. Along with the new possibilities of customization, it could posit architecture as also a purveyor of lifestyle through the development of aesthetics, spatial and programmatic effects manifest in a base model amplified through a range of options. Individuals could therefore customize the options of the house to adapt it to site, climate, materials, function, and wants. These options, listed here, could be selected and prioritized based on individual purchases and affordability: storage space, deployable awnings, improved insulation, expandable living units, increased fenestration, cathedral ceilings, fireplace, built-in fixtures, kitchen islands, subzero appliances, carport, garage, built-in terraces, climate control systems, built-in entertainment systems, power sunroofs, and high-end interior finishes. A customer could therefore select an already composed set of features, for example a "luxury package," or individual options to complete a unique combination. These options assist traditional models for consumer purchasing by allaying fears about structural strength and material durability, as well as improve the quality of finishes, connection to site, and offer name brand inclusion into the domestic space.[8] Figure 14 is one possible way to promote options, based on common automobile advertising techniques. Figures 15 and 16 show the house being shipped to a site and deployed in a land-lease community.

The auto industry has capitalized on the desire for novelty and innovation that keeps the consumer returning and the industry quickly evolving. The average duration of house ownership in the U.S. is three years and, as the economy continues to encourage the mobile family, families could improve their living "performance" with each successive purchase— either through refinement, adaptation or packaged options.[9]

From it origins in the industrial process and mobile home manufacturing, manufactured housing has bloomed from the development as a response from the housing shortages as the Second World War, into an vastly expanding influential, architectural industry. In this growth, however, it is critical that it respond to the changes in culture and possibilities of technology that offer the potential of customization, contextualization and affect. CAD-CAM and CNC processes have the potential to change supple digital models into the realities of the everyday, translating complex algorithmic processes

into surface formations, programmatic evolutions and new material experiences for the population at large. The use of non-standardization in the building techniques of this design proposal posit it as an example of a new paradigm which offers individuality and specificity at a mass scale encouraging the existing shift in both building industries and the image of manufactured housing.

Notes

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