MP3: Manufactured Processes x 3

MAIA SMALL
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Industrialization techniques in architecture since WWII, including prefabrication and mass production, have been predicated on the standardization of building systems. This methodology of the mass production of materials has been through the use of a uniquely designed and built prototype; while overall configuration could change, tectonics and standardized components were understood to be inflexible. At the building scale, architects interfacing with the mainstream construction industry have relied on traditional assembly techniques of standardized components — stud walls, steel framing, etc. — essentially composite systems that predicate the use of planar surfaces. Since this time, however, designers have begun to no longer view form generation as fixed and ideal, but instead as supple and transformable, stemming from a view of contemporary culture as fluid and generated through the use of highly sophisticated surface modeling softwares that encourage complex curvature. Through the use of Computer Numerical Controlled (CNC) production processes, such as three-dimensional printing, laser cutting, and milling, new methods of fabrication arise and ultimately allow for both topographic surfaces and differentiation in mass production. The introduction of specific computational design software has enabled the development of non-standardized building systems through material studies and serial logics. Thus a new paradigm emerges, where local variation formulates continuous, yet differentiated, global structure.

In this paper, we would like to describe how the change from standardized mechanized industrial processes to digitally based fabrication methods affects the possibilities of surface modulation and the reemergence of ornament in architecture through the description of three examples. These projects are really experiments into the possibilities of surface and the material production and techniques of architecture. They seek to propose a system of building that uses seamlessness or a synthetic approach to architecture where the number of systems is reduced by the fusing of surface and structure, space and program. As our interests in design, fostered by digital technology, have shifted from assemblage and ordering (systems of objects) to transformation and deployment (operations of continuity), then our interests in production should shift from constructing and building architecture to fashioning and manufacturing it. Emerging technologies propel us in the way that 19th century building systems compelled Modernism: if Modernism systematized architecture through the processes of the industrial age, how can material possibilities compel architecture in the digital age. Material architecture has become distracted from the veins of emerging physical technologies by the fascinations of the virtual when it is not an argument for either/or, but rather both through their reciprocation and engagement.

ORNAMENT IN ARCHITECTURE

The following historical samples are a series of indulgent highlights in an architectural history of surface ornament and articulation to introduce how digital techniques may facilitate an extension this lineage. What is important in this discussion is not the historical background, but the sensibilities and formal geometry systems active in their production. The geometries form a sort of energy or architectural phenomena.

In the 19th century, the burgeoning Modernists developed both a desire for abstraction and the elimination of ornament while the Arts and Crafts responded with a subsequent fascination against the smooth surface. In some cases, architects looked to recent figures in art and science, such as Louis Sullivan examining V.M.C.

Ruprich-Robert's floral taxonomy sketches from the 1860s, that detailed almost a biological patterning, to investigate the organization of articulation or in Sullivan's case to strip ornament from the bold surface in favor of denser edging. The dissection of science, the analysis of the parts and their relationships encouraged both the patterning of biology but the creation of architectural taxonomies of ornament. John Ruskin, in his *Seven Lamps of Architecture*, made an argument for the surface patterning and geometric repetition in the Venetian gothic and in his sketches demonstrates a series of formal pieces that were arranges into various continuous ornamental facades. (Figure 1) The ordering of the elements provides a sense of sameness or a clear sensibility to the treatment, but at the same time allowed for a richness, complexity and depth.

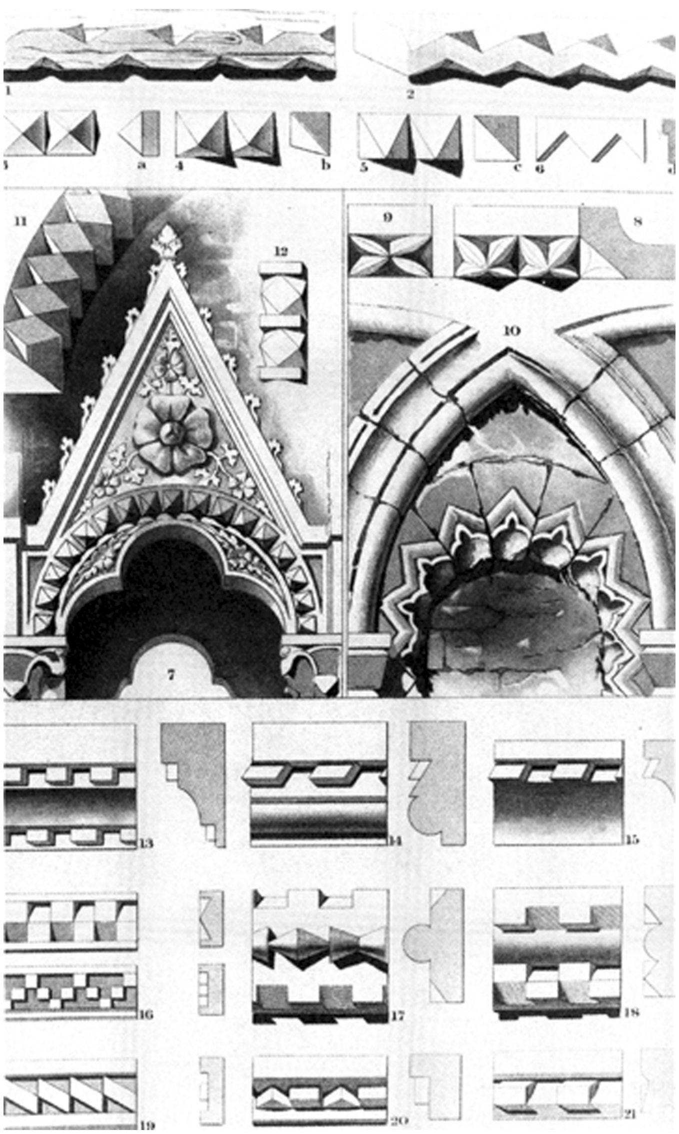

Fig. 1. Ruskin's studies of surface articulation.

Also interested in natural patterning, Gottfreid Semper examined the textile arts as a structure of order and texture. His studies of both human crafted and machined knots not only fascinate architects as studies in formal manipulation, but as patterning and intricacy. Here one could understand the ways in which machinery engaged and changed textiles by providing for the possibility of nearly endless repetition of knots, weaves and stitches. Craft, or the imperfections of handwork, allowed for variation in a way that machining eliminated. The stylize geometries of Margaret Mackintosh in her bead on burlap textiles expressed both the nature of craft and ornament, but at the same time, folded in patterns that shifted, heavily stylized geometrical patterns woven perfectly as if by machine. There evolved a balance between the machine aesthetic and desire for perfection and the intricacies of human error or the ability for humans to modulate a woven system.

While the textile industry and architecture shifted from the one-off (everything custom), to machinic processes (everything standardized), industrial design used the industrial process to formulate entirely different modes of production and entirely new products impossible by hand. From this, new patterns of production began to reflect on architecture, bringing an aesthetic of the machine into decoration — so that it was not only what the machine could do that was abstract or simple, but the articulation of mechanical connections, materials and the pragmatic necessities of construction that were exaggerated to express and emphasize the industrial techniques.

In the 20th century, while Le Corbusier and Mies van der Rohe stripped away ornamental detail in favor of expressing the smoothness of the modern era, Pierre Chareau used components in series, namely the industrially produced glass lenses in the Maison de Verre, to demonstrate a repetitious patterning that created an entire facade. (Figure 2) Here, the standard processes themselves could offer a manipulated surface simply by the arrangement of a linked series. Outside of Europe, colonized architectural systems reacted to the influx of abstraction and reduction by combining new construction techniques with local craft to create a hybrid of layers, for example in Lucia Costa's Bristol Apartment building in Rio de Janeiro where the facade is covered in a grill of brise soleil. It was a colonial compositing of imperial and domestic languages that created a local variation as contextual signage.

Other experiments with Modernist surface articulation employed the machining process directly, for example Jean Prouvé's experiments with manufacturing of panel systems that defined variable surface types. Modulation

Fig. 2. The glass lenses of the Maison de Verre become technologically articulated ornament.

increased the tactility and interlocked form and structure, while allowing for a manipulation or opening of the surfaces themselves. Harrison and Abronowitz expressed this also in their curtain wall system panels clipped into the Alcoa Aluminum building in Pittsburgh, Pennsylvania where the deformation in the aluminum surface structured the surface and, over the entire façade, created a modulated surface.

New Paradigm. Today, as the new building technologies expand, new design and fabrication processes, fostered by software and production technologies, offer the potential of mass individuation and the easy, changeable deformation of surface. 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 and the determine system of manufacturing becomes an indeterminate one of potential.

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.[1] 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 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).[2] Previous methodologies relied on standardized components with variations of assembly; now the components are variable and the assembly immediate.

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 architecture and can encourage the reintroduction of ornament as both functional and aesthetically desirable.

CASE STUDIES

The following describes three projects that are examples of the way in which both surface articulation and digital processes combine to form an architectural process and product. Two specific technologies are

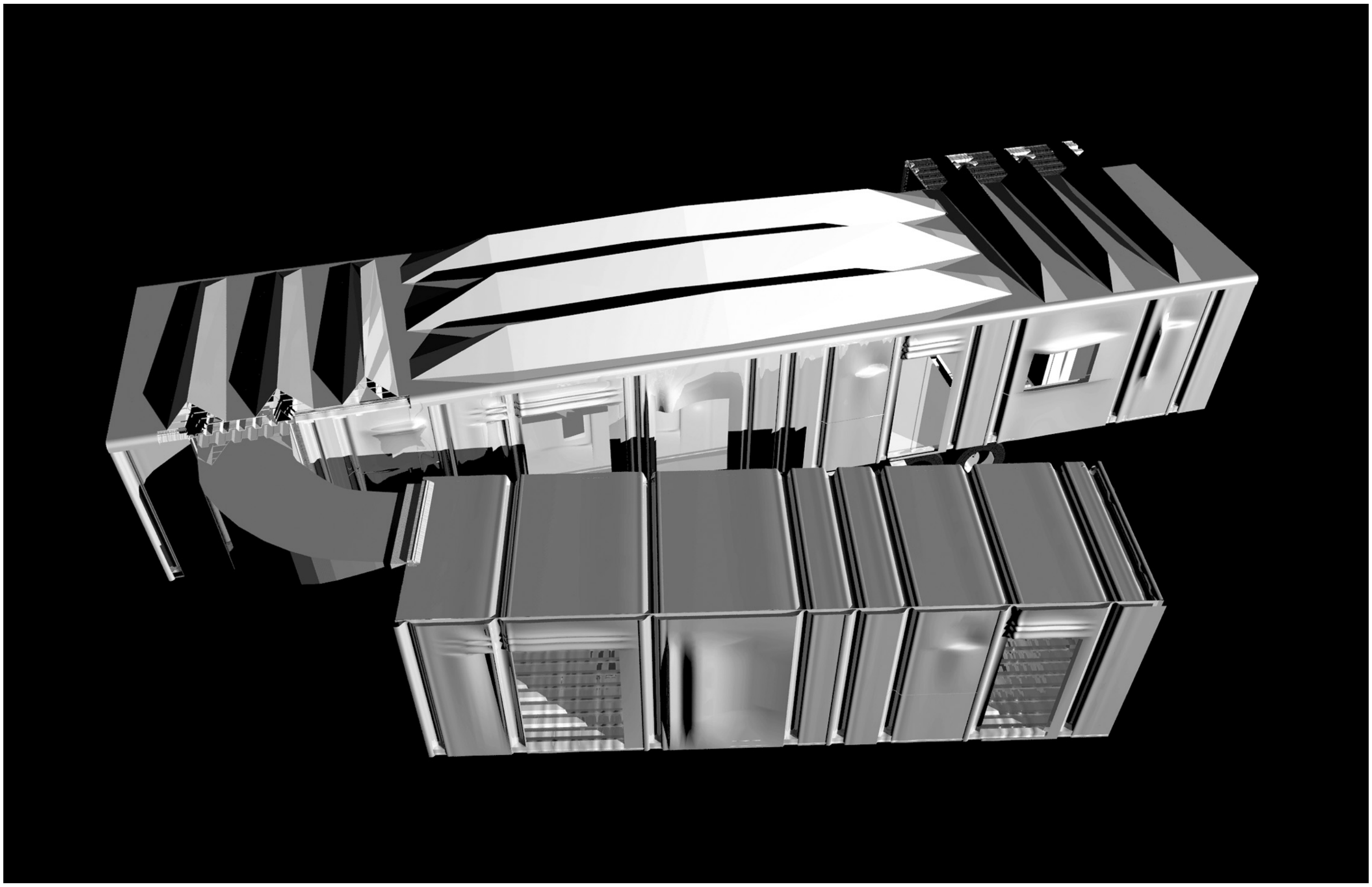

Fig. 3. The manufactured housing design proposal showing the modulated surface elevations.

explored here as well: CNC milling, employed at the architectural scale, and three-dimensional printing, used to study architecture at the model scale. The first project is a study in manufactured housing where a house would be made from a highly articulated, modulated panel system that could be customized on a massive scale. The second project, the design of a mobile medical HIV/AIDs clinic for sub-Saharan Africa, articulates the surface as a pattern aesthetic, programmatic indicator and structural stiffening device. The last project, a small art pavilion for downtown Calgary, takes surface articulation to a larger scale allowing the manipulations to become more spatial and ultimately fully inhabitable.

MAN: MANUFACTURED HOUSING PANEL SYSTEM

This manufactured housing study examines how an articulated set of interlocked surfaces can provide for a variable elevation and a system of customization on a mass scale. 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. When combined, the individual panels create a single landscape or elevation of the surface modulations, based on both interior content, or program, and exterior protective strategies, such as rainshields over openings. (Figure 3)

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 employed the Expressions tool in Alias/Wavefront software 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 and introduction of a new material: glass.

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 into, the 3-dimensional panel surface and its 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 in that panel.* 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.

The panel development 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. (Figure 4) Once the formwork is complete, finish material is cast over the formwork to create the final panels through a vacuum forming process that forces a finish material to the contours of the mold. The formed panels are then cut at the edges of the formwork, slipped together at the spine edge and tack welded together, creating a structural bond through interlock. CNC machinery processes thus allow us to avoid designing a specific set of panels and instead create an easily affected system changed by the client and context to respond to both interior and exterior conditions.

In engaging the milling process, the toolpath software terminology has proved to be both useful and critical to understanding how topological surface and digital information is translated into physical form; these include notions of spindle speed, feed rate, plunge depth, step size and surface tolerances. The animations created by SurfCAM show the literal excavation of material that results in the final complex surface. What is interesting for us here is the introduction of controllable surface detail that has incorporated pronounced

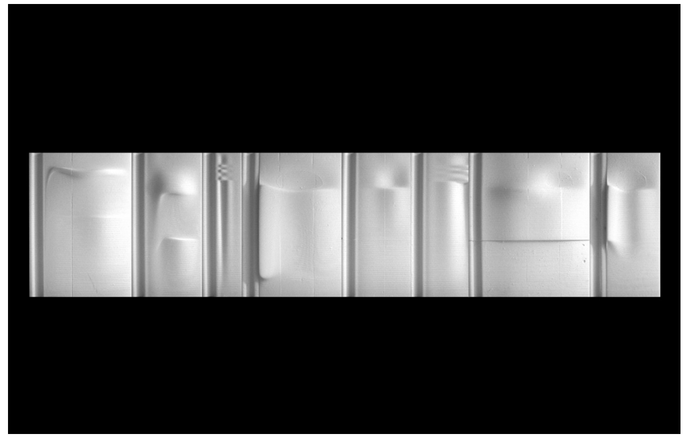

Fig. 4. The manufactured housing design quarter full scale milled elevations.

ornament into the panel surfaces. The result is a graining of the surface that is both suggested and easily controlled by the technology itself. After milling, we then tried a series of different materials over this formwork including resin pours that resulted in translucent, colored panels. Along with the experimentation in a new material, we found the mirroring procedure necessary for the casting and formwork intriguing.

These analog fabrication processes reflexively inspired subsequent digital studies. Initially, we began with a series of colorizations and enamels. Therefore, any panel type could be selected from a multitude of materials and coatings available through a customization process, not unlike the auto vehicular industry when you choose the color of your car. 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, 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.

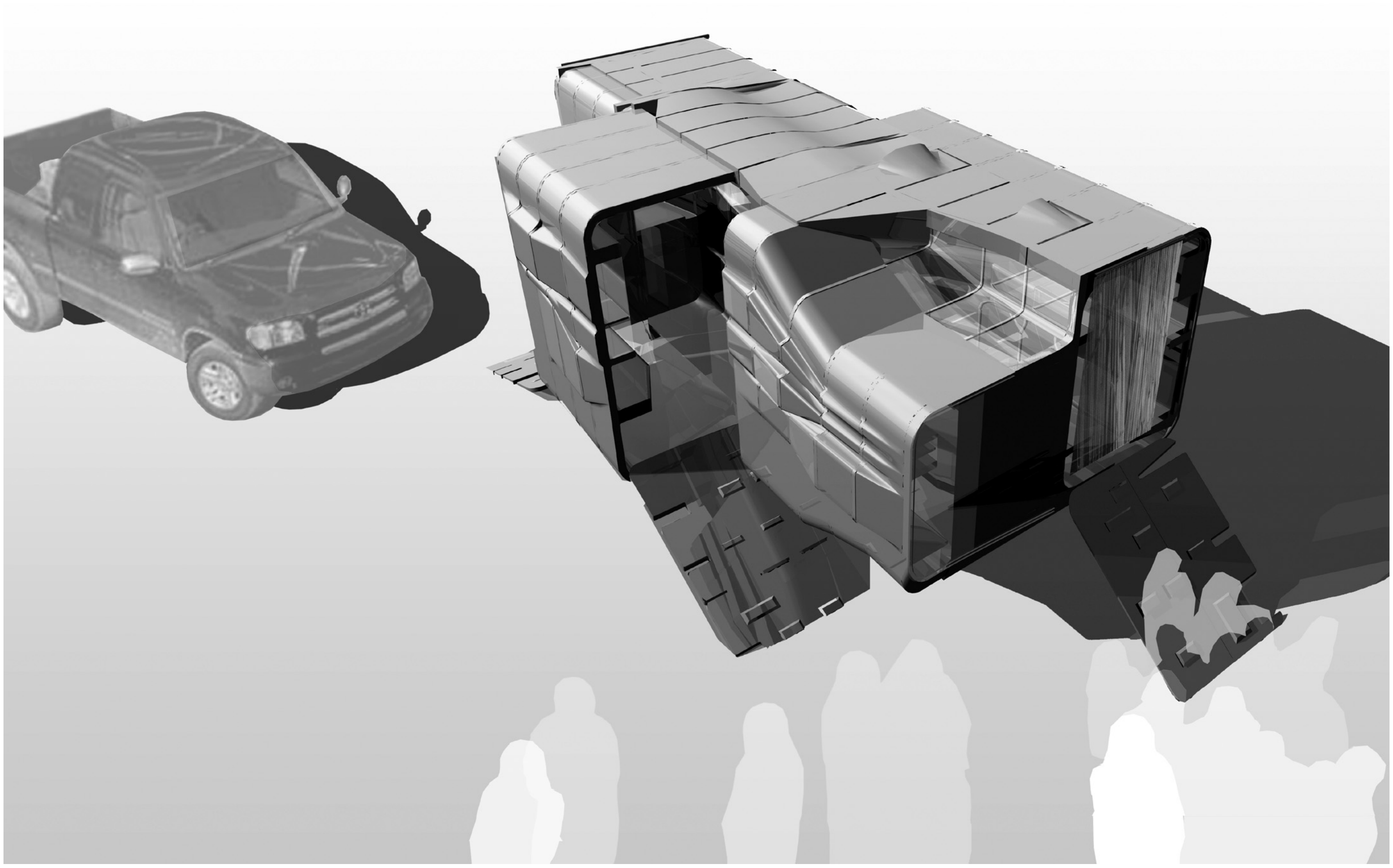

Fig. 5. The programmatically affected elevation of the mobile unit.

AID: HIV/AID MOBILE CLINIC

The second project that employs surface modulation as ornament is a design for a mobile HIV/AID medical clinic located in Sub-Saharan Africa as part of the recent Architecture for Humanity competition. (Figure 5) Here the unit is made up of a series of exterior and interior layers or surface strips that combine to not only to provide a variably articulated surface, but an elevation that is broken down and manipulated to respond to program. The formal attributes comprising the interior elevations were designed using anthropomorphic logics to respond to programmatic needs, namely seats, counters storage units, and beds as necessary for a mobile medical unit. The exterior panel forms also respond and react to the interior programmatic activities, providing for exterior ornament. It also allows the program to pattern the exterior and reduce the scale of the elevations.

The unfolded interior panel elevation as pictured on the left profiles the spatial continuities. Each two foot width panel form is manufactured through both rotational molding or roto cast processes and vacuum form plastic processes, similar to the previously explained manufactured housing formwork and molding techniques. A panel lamination process would then occur between interior and exterior panel for the sidewalls, roof and backwalls included within that assembly is block foam insulation and metal plating. This marriage of interior and exterior modulated panel surfaces act as stiffeners for the unit as a whole and as programmatic devices.

We also 3D printed this project from a stereolithography digital model. (Figure 6) In order to do this, we had to translate the Alias Wavefront Maya surface model into a solid model in Form•Z that significantly changed its sensibility and format. Again, it was the translation between softwares that allowed a negotiation between form and materiality. While as a surface model it was easy to manipulate its shell and see it as an accumulation of surfaces that definied the edge between inside and outside, as a solid model, it operated as a solid from while programmatic regions had been carved. We were intrigued by how the views of the digital models themselves provoked the way in which we considered the interior space and exterior surface. The wireframe side view allowed us to see changes in density which could be read as a program mapping, as well as the

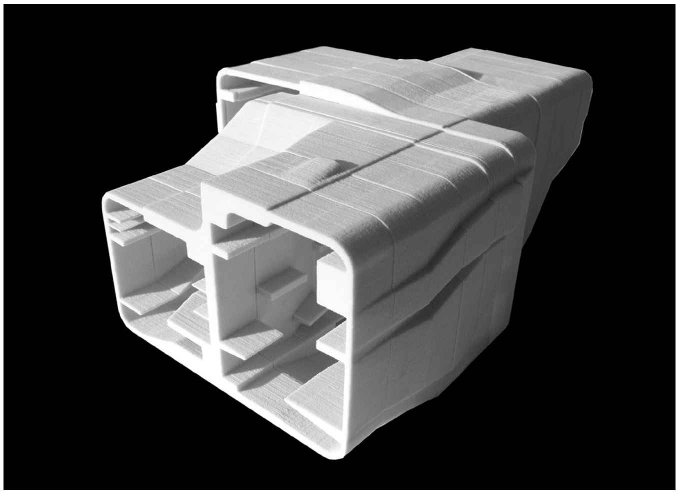

Fig. 6. A 3D printed model of the mobile unit.

crenellations, again returning to ornament and surface articulation shown through modulated contours.

ART: OUTDOOR ART PAVILION

The final project was a design entry for an art pavilion as part of the ArtCity 2002 Peepshow Design competition located in Calgary. Our first investigations began with a study of expandable packing materials, since these contractive and expansive two-dimensional surfaces are specifically designed to act as fill and therefore to wrap into three-dimensional volumes. We began to study the idea at a much larger scale and particularly how the movement of the surface could connect two sides or foster an engagement between the horizontal and vertical. (Figure 7)

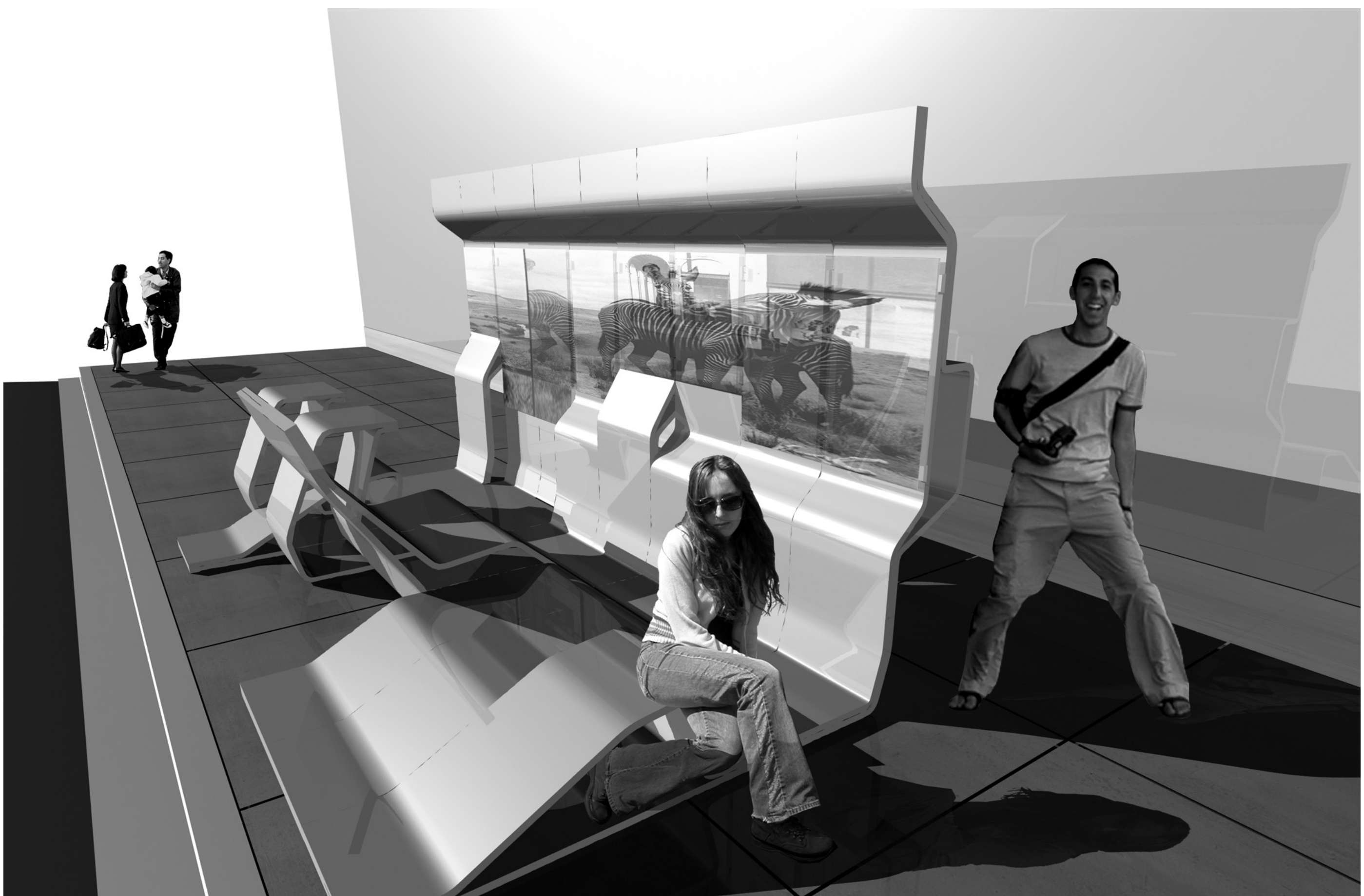

Fig. 7. The art pavilion design proposal.

To fix specific geometries, we diagrammed anthropomorphic relationships or series of viewing positions, in terms of modified relationships between the art and its subject. Like with the packing material, the expansion or contraction of the surface formed to relate to their positions. Also, the manipulations on one side could affect the condition of the other. We charted a series of various specific heights to see what spatial configurations would be afforded and inevitably these could affect the urban realm once on the site: the lounge-type booth not only offers art, but a place to recline; the seat-type booth, a short rest; the bar-type booth, a place to write or set your coffee. On the outer side, ledges provide places to lean, set down packages, or sit down, perhaps doubling as a bus stop. The final profiles and their configurations would allow for both the display of art and people — promoting urban acts of lounging. Like the peep show, where eroticism stems from the intimate relationship between the voyeur and the desired object, each booth profile stems from an organized physical relationship between the spectator and the work on display. Here the booths operate at a glance to entice various patrons — passers-by, tourists, and urban opportunists. Their specific profiles organize a relationship between an individual viewer and piece of art through a shared surface, a go-between, which fosters a quick peek or perhaps a lingering gaze.

In the original design, each booth is made of two layers of a simple honeycomb panel system, composed of an aluminum coating over an expanded aluminum honeycomb core. The honeycomb can be bent into the required curvature and then locked into place by the lamination of an aluminum skin. All inter-piece connections, to connect booths, mount art or secure it to the site, are made with clip types that are inserted into the small sections of removable panel edge. The laminated system also allows the base of the booth to be weighted to stabilize the configuration and discourage theft. This system allows for the flexibility to modify the configuration of the booths relative to one another and the specific chosen site.

We converted the surface models into a solid model in order to print a 3D model. Also as an experiment in surface and material relationships, we fabricated less expensive versions than the honeycomb panels proposition in order to experiment with how the material process could inform the product. Our first attempt was with aluminum sheet which we then bent over a break which meant that our radii had to be flexible since it provided much more tight dimensions than the original design. Our final material test involved vacuum forming as a process with laminated bent plywood as a material and a series of formwork modules that could be stacked or reconfigured in order to provide for the construction of two more art booth components. (Figure 8) We also discovered an interesting nesting process as we allowed the wood laminar surfaces to wrap around the formwork so that they could synch together.

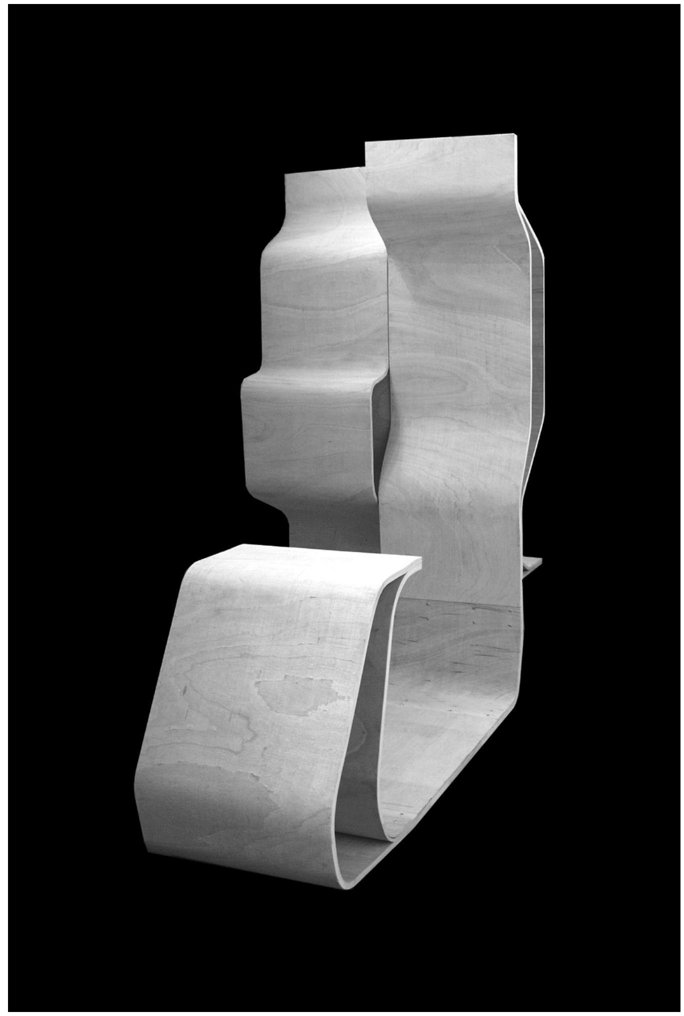

Fig. 8 Two full scale laminated wood booths.

These two different materials became case studies for us in the back and forth process between the analog and the digital or the design and the material. We allowed the system to give to the needs required by the manufacturing process and in turn found new architectural conditions — the thinness of the metal verses the solidity of the wood — the aluminum tight corners and the generally relaxed corners of the wood. The final architectures were an inherent reaction to functional needs, material desirability and inevitably cost.

These studies of surface and technique were intended to explore the reciprocal effects between digital information and material production — essentially the way in which the digital and the analog inform one another. Through this exploration, we have found that the most useful relationship is the organized series of natural feedback loops that informed both the design and the material end. The loops involved the interrelationships between hand drawing and digital modeling, the transformation between softwares — particularly solid and surface modelers — and finally the techniques of production fostered their own needs and variations. We build the ART project in two materials to see how they would require us modify our expectations and inevitably the design. As most contemporary practices involve such a struggle between innovative designer and conventional builder, the battle becomes one of refinement and forcing unyielding processes to conform to atypical conditions or altering the design so dramatically that it seems to lose its formal integrity. CNC and rapid prototyping processes hope to avoid this by shortening the relationship between design and fabrication; however, it is through the feedback in which the design and fabrication needs can marry — materials have their own implications and design systems need to be tactical enough to reformulated specificities without systematic compromise to achieve a result that uses the specificities of material to foster a formal, spatial and hopefully programmatic result. It is a back and forth process, a process of experimentation and variability within itself. Each time the design is represented or digitally converted is it reformatted and transformed in terms of a new logic system. It is the transfer between states — analog, digital, surface, thickness, triangulated, 2D, 3D, and inevitably material — that inform and create architecture.

NOTES

[1] Cramer, Ned and Guiney, Anne. ''The Computer School'' *Architecture Magazine* 89 (2000): pg. 99.

[2] Lynn, Greg. ''Bio Time'' *Anytime*, Cynthia Davidson, editor. MIT Press, 1999, pg. 266.

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