CONSTRUCTION CRITICAL: TECHNOLOGY, MILLWORK, AND INTERIOR SPACE

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FORWARD: CRITICALLY ENGAGING CONSTRUCTION

In recent decades, many potentially revolutionary technologies have arrived in the building industry, including the technologies of Building Information Modeling and computer-based manufacturing. Constructors and engineers arguably see the benefit of these technologies to streamline and improve construction; yet architects must be challenged to avoid appropriating these technologies with indifference. Instead, the field of architecture may be challenged to look beyond the efficiency and production-oriented promises of these new technologies to address their potential impact on the rationalization and performance of architecture.

Thus in the case of prefab architecture, a radical change in production *must* have its impact on the final artifact rather than remain as a passive contributor. Architecture and technology are intertwined.

Like the decorative muntins of modern windows, even the pastiche of un-designed buildings exhibit the symbolic residues from a time when production technology fundamentally shaped the thing produced. New technologies in buildings consequently call the architectural field to consider design and construction together.

In their seminal book Refabricating Architecture, Stephen Kieren and James Timberlake explore an emerging paradigm in which new technologies such as BIM have permitted architects to expand beyond appearances and to fundamentally challenge the way in which buildings are built: a critical approach resulting in "more control, higher quality, and improved features" and effecting "how we do things, not merely what they look like".[1] In discussing this issue with students, I use the example of a cheap couch; as architects, we are often using technology (green technology specifically) as applique, covering building systems to which we are indifferent. This is especially true for stick-built buildings, the most common buildings in our building stock. Like the supple textures and soft forms of a cheap couch, beyond the visually opulent veils of these buildings lie cheap, archaic building systems delivering unnecessarily mediocre performance.

The insight in Kieren and Timberlake's new paradigm of building technology is aligning technological opportunities not just to streamline construction, but towards the improvement of architecture. Perhaps their most satisfying anecdote of such a success is a cockpit designed and implemented by Delphi systems that uses a fiber-reinforced plastic tube that both increased structural performance while also eliminating a large number of additional parts by also functioning as the plenum for climate control distribution.[2]

Thus we may deduce that the most critical manner to advance design and fabrication technology is to deploy the building system as a *catalyst for rethinking architecture*. In particular, this paper presents an argument for revisiting interior millwork as a means of engaging space, dwelling, and performance in single-family housing. Historically, millwork has connected production technology and ideology, contributing both character and utility to homes of the recent past through a high-quality, affordable, and innovative mail-order market. Modern millwork, in contrast, is largely relegated to kitchens and bathrooms although technological changes in the industry suggest a possible renaissance in design and integration.

Spending on cabinets and countertops in average builder homes nearly doubled between 2002 and 2007 according to the National Association of Homebuilders, while total construction costs for homes rose only about 45%. In terms of production technology, the modern millwork industry has undergone rapid change as companies adapt to new computer-based production technology geared to more customized, low-volume work. Currently 94% of cabinet making shops use computer-based design software in their work and 47% use computer-controlled equipment in their production.[3] Thus an observation of millwork today is that more resources are being dedicated to a product that is increasingly customized, produced in a made-to-order fashion.

In consequence, it may be argued that a new paradigm of millwork is emerging where millwork can more extensively shape the interior of dwellings. To architects and builders, this suggests design is more than just shaping "the box" of the home. Through an intersection of technology, production, and ideology millwork is an affordable and feasible contributor to space and dwelling. This paper elaborates on this new paradigm while also presenting two design projects in which millwork and fabrication *has* been a catalyst for rethinking space, dwelling, and performance in their respective projects.

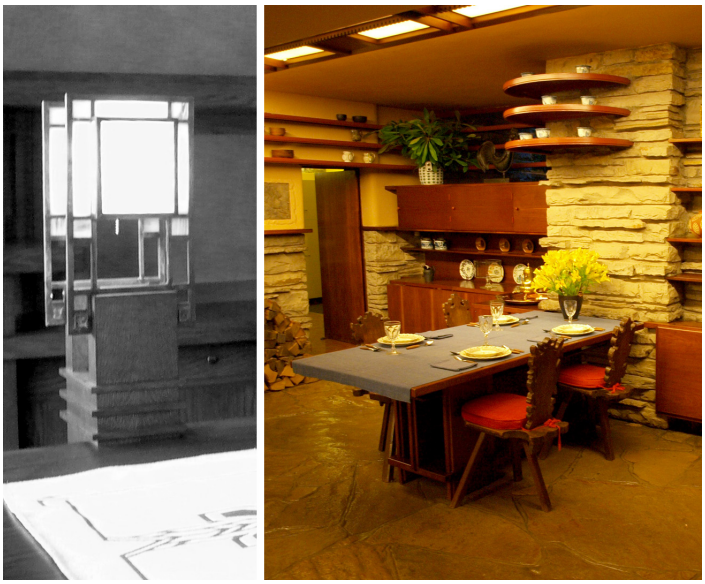

Figure 1. Wright's organic architecture was defined in part by millwork that was made possible by machine fabrication that was cutting edge for its day.

CONSTRUCTION CRITICAL: TECHNOLOGY AND CONTEXT

In early 20th century many architects, swept up in the fever of industrialization and mass production, made unsuccessful and widely discussed efforts to respond critically to construction practice. Kieran and Timberlake attribute these failures to "commodify architecture" to be attributable to "an idiosyncratic agenda about appearance".[4] Such failures often had at their core a failure to connect technological innovation to a tangible context in daily life. Exemplary of this issue is "The Packaged House" of Konrad Wachsmann and Walter Gropius, which was ultimately hampered by the difficulty and cost in executing technical details whose treatment was driven by a technical aesthetic rather than by function, economy, or production. Although Frank Lloyd Wright was unsuccessful in producing a truly mass-produced home in his time, he *was* successful in creating a truly synthetic architecture that emerged in part from rethinking construction technology and its architectural impact; particularly, Wright adopted extensively machine-fabricated woodwork in his homes that, in contrast with his contemporaries, was innovative but also functional and necessary elements to the domestic environment [Figure 1].

At the moment we may recall Peter McCleary's theorization of technology, which articulates that it must be "contextualized" in the "architect's reflection-in-action" rather than merely defined through tools and the way in which they are deployed.[5] Our call today, in the midst of new technologies for design and fabrication, is no different than that of Wright's time: rather than simply appropriate these new technologies with indifference to how and to what end they are applied, architects must seek a *critical approach* that integrates technology with larger intentions in architecture and the environment. In other words, we are not interested in advanced fabrication because it can make novel shapes or assemblies impressive solely for their complexity. Rather, we are interested in technology's link to larger issues of architecture such as environment, space, etc: issues working at the ideological level in architecture. The writing of Diana Agrest, another architectural theorist, is useful to frame technology's relationship to a larger *context*. While her work emerged from the theoretical body of semiotics, her seminal essay on "design and non-design" provides a useful framework for understanding the relationship between the "normative processes" of architecture (design) and the "cultural systems that interrelate and give form to the built world".[6] This framework can be used to expand McCleary's assertion that technology is defined not by its technical instruments and products but by its context; technology should not (or cannot) ignore its context. We can easily see millwork as just another physical component within the physical systems of the house; but we can also understand it's past and future critically through the contexts production and ideology.

MILLWORK: TECHNOLOGY, PRODUCTION, AND IDEOLOGY

The research background of the project emerged from a pair of funded research projects conducted by the author that engaged computer-based design and prefabrication and involved collaboration with local manufacturers; both projects are presented in detail, in papers presented by the author in 2008[7] and 2010 [Figure 2].[8] One of the thrusts of this research was that contemporary prefabrication techniques, despite the new technologies at work, were failing to advance the architecture and environments they were serving Each project used the collaborating manufacturer's prefab system as a starting point, developed a critique of the system based on performance objectives, and the developed an experimental construction system based on this critique that was subsequently tested with a full-scale mock-up. While this research successfully critiqued construction through the framework of structure and envelope, the work left relatively unquestioned the role that technology can play in challenging the building's interior. Thus the current design work (to be introduced shortly) seeks to interrogate the interior wall itself and how new prefabrication technologies and methods be contextualized in its critical reinvention.

An observation of this prior research was that the most common methods of residential building in the U.S. – stick-framed wood construction, wood panelization, and wood modular construction – are constructed quite homogenously inside and out: walls and partitions in particular are wood stud walls with brutally consistent coverings, regardless of their relationship to structure or function [Figure 3]. Even closets are fully framed as if they are rooms, though little structural benefit comes from the untapped capacity of their framing. The lack of differentiation between wall types suggests not just waste and excess, but also a lack of imagination about how these walls can serve the occupants of a home. Renee Chow, in her book Suburban Space, connected this structural homogeneity with critical programmatic and ideological deficiencies; her characterization of the "volumetric" approach to suburban housing was that it has been driven by increasingly solidified exterior walls

Figure 2. Previous research by the author critiquing existing wood prefab systems (panelized building and wood truss manufacturing). Experimental systems were developed from these critiques and through funded research, tested using full scale mockups and BIM software. These projects focused primarily on structural and envelope issues in construction.

that isolate households from their contexts, creating "centripetal" patterns of activity in these volumetric houses that are focused around passive domestic patterns such as television-watching.[9] Chow uses the term "fabric" to describe the "continuous nature of everyday activities and structures";[10] whereas her primary response was an exteriorly connected fabric, we can similarly invert this fabric to address the continuous nature of the interior. Within such a fabric, interior walls might transcend their roles as partitions, engaging programmatic function, activity, and environment in a more continuous, hybridizing manner.

The ability of millwork to project domestic ideology is established historically. The Bourgeois precedents to American homes evolved built-in cabinets, studies, chambers, and libraries to serve both function and culture. In the words of one authority on Victorian villas, this architecture of proto-millwork served as "an innovative medium in which to articulate selfhood in material form, to engage it daily in material practice, and thus to assure its continuity".[11] The intent of these built-in elements was to create a backdrop for informal activity in which the dwelling's family could both be surrounded by their possessions (certainly for show) but could also forgo the freestanding bookcases used in the past, allowing

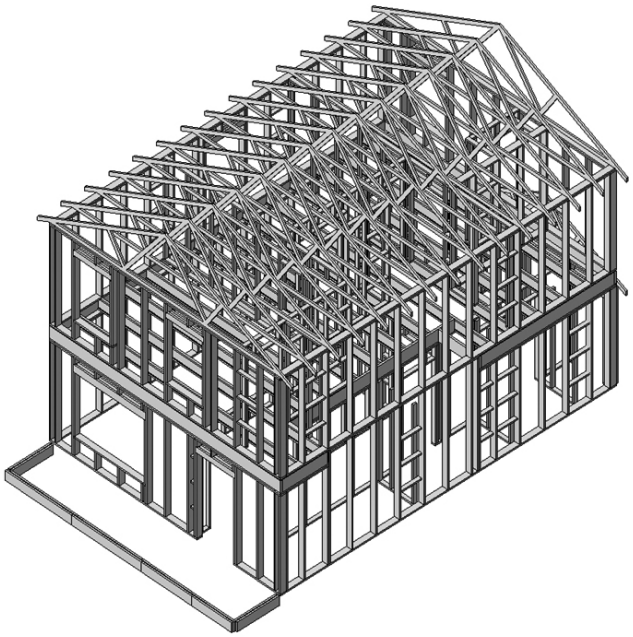

Figure 3. The homogeneity of typical wood construction, in which nearly everything is constructed the same way – even interior partitions. Such practice certainly contributes the shortcomings of volumetric buildings.

seating arrangements and social activity to occupy the central areas of rooms.[12] John Archer writes that "[b]uilding spaces are three dimensional apparatuses that people intentionally lay out for explicit purposes ranging from survival and satisfying basic needs to ordering society, enabling economic activity, producing knowledge, advancing spirituality, affording pleasures, and so on… because built spaces shape what people do and how they live in highly specific ways, they also necessarily shape who those people are".[13] Archer later cites Jefferson's Monticello as an example of an "architectural apparatus" that established Jefferson as a "secluded man of letters";[14] Monticello, coincidentally, is both a museum but also a living apparatus, whose fluid interior chambers are modulated by highly programmed millwork partitions rather than massive plastered walls. Jefferson's ideals, it turns out, were built into the bungalow of the 1920's, which has been asserted to be the ultimate manifestation of the Yeoman ideas of a simple and modest agrarian life, even in postwar suburbia[15] where so many early suburban homes aspired to quaintness and functionalism of a farm house.

We have thus far established the functional-ideological significance of millwork; consistent with our earlier discussion of technology, we understand also that millwork is a representative of a larger process of technology, which in turn is interlinked with the functional-ideological role it plays.

Millwork represented a unique intersection between *production means* and cultural developments in housing, particularly in the United States.[16] As it evolved throughout the 20th century, the American millwork industry evolved to set its own standards, fuel the development of new innovative wood products such as plywood, particle boards, and composites, and markedly influence construction based on the availability and affordability of its products.[17]

In the U.S., a millwork boom emerged in the early 20th century when economic prosperity allowed Americans to purchase or build their own inexpensive homes in great numbers. These homes differed from Victorian housing from the previous century in that these new homes were markedly smaller and more affordable, and thus did away with the clutter and fussiness of the Victorian era, and words such as "economic and spare" in fact became important *positive* marketing tools for homebuilders and stock millwork providers.[18] Stock millwork sources became widespread, producing standardized millwork at high quality and affordable price that could be sold from catalogs.[19] One such catalogue, the Roberts Illustrated Millwork Catalog of 1903, offered a range of off-site produced elements ranging from wooden windows, blinds and louvers, closets, parquet floors, hearths, paneling, and entire porches. An important characteristic of these stock providers was their propensity to define and innovate millwork in a synthetic way, where the design could freely break convention, suggesting new hybrid variations of existing millwork products. It may be argued that the commodification of millwork and its emergence as a 'product' actually propelled it to assert ideological authority; scanning through millwork catalogues of the period reveals evidence that millwork at the time was attempting to project a lifestyle and a set of values – an industry, in a sense, constructing and dispersing an ideology.

Thus it has been established that millwork has had a seminal influence in American domestic space, influenced externally by both culture and industry, and that the *technological* basis of millwork has a deeply rooted context in domestic ideology, particularly *American* domestic ideology. When we talk about something like millwork, we are considering simultaneously an artifact, an ideology, and a technology in an expansive sense that includes both the means of creation and production.

Frank Lloyd Wright, it may be argued, understood millwork in this way and in his architecture developed a multifunctioning interior fabric (in the spirit of Renee Chow's fabric). Wright had cultivated a critical approach founded on a knowledge of modern fabrication technology and how and why to use it. Wright's signature interior environment with its custom casework and furnishings emerged quite directly from the flexibility and affordability of finely milled woodwork. What emerged in Wright's work was not just an applique of millwork as ornament. Instead, the harmony of Wright's organic architecture sought to use modern technology to integrate elements such as lighting and mechanical systems with traditional millwork elements like paneling, seating, and storage [Figure 1]. The result is a clear case in which millwork was engaged, at the technological and ideological level, in the establishment of a new paradigm of interior space.

MILLWORK AS FABRIC

The end of millwork's boom in popular domestic architecture was played out, perhaps, in the open floor plans of the mid-century ranch home – which, consequently, was heavily influenced by Wright's Usonian homes and the ranch style adopted modern plywood millwork built-ins extensively for screening, casework, and interior accents.

In recent years, however, with larger homes and presumably tighter operating margins, builders (and even architects) seldom call on millwork to fulfill functional or ideological intent. As discussed earlier, contemporary suburban volumetric houses and their deliberately solid envelopes separate program rather than cultivate it. Interiors are accumulations of isolated spaces, the walls between them static and indifferent to domestic activity, and perhaps new homes are large enough that the hybridization of function is not necessary. Americans may be satisfied with purchasing freestanding furnishings from retail outlets like IKEA (or worse, Walmart) and taking pains to integrate these elements into empty, neutral rooms. Ironically, many homeowners revert to purchasing such freestanding furniture and attempting, through some creative effort, to arrange it so it looks like it has always been there.

Yet we must keep in mind the unique situation of *dwelling* and the importance of our homes in enabling it. Renee Chow writes about the diversity of the interior environment:

> "Our settings need to suggest and remind us of ways we have lived, or would like to live, and should allow us to revisit our associations without having to completely change the form of the house…
>
> An alcove of a room holds a desk, then a sofa, then a table. The fireplace hearth not only delimits an area around the fire but also can be a seat, a display area, a structural support, a definition of spatial direction, and a shared element among neighbors…In this way the forms of our residential settings support dwelling."[20]

In the passage above, Chow refers to the aspiration of an interior fabric: a way of making interior space that is both functionally and ideologically rich. It is doubtful that a palette of gypsum wall board bathed in white paint, with a smattering of cheaply-produced furniture is enough to really achieve such a sense of place. Architects and builders invest significant effort in organizing the location of walls within the whole of a particular building; yet the scale of human interaction is often limited to banal elements such as light switches.

Achieving an interior fabric requires a different scale of design thinking, a scale that acknowledges domestic activity in a functional and experiential sense. Chow later asserts that "[b]y weaving a fabric of dwelling, we not only can sustain living in the suburbs but transform it to support dwelling in ways as yet unforeseen".[21]

TWO CONSTRUCTION CRITICAL CASE STUDIES: TECHNOLOGY IN CONTEXT

The following two projects intend to create just such an *interior fabric* using digitally prefabricated millwork. The footnote to this argument is that a large number of cabinet shops are already producing affordable 'made-to-order' millwork using highly customizable, efficient computer-based processes; one need to look no further than their dentist's office to spot the fabrication means underpinning these projects. Rather than an afterthought, each project has engaged millwork as part of a larger strategy considering the building at both the structural and the ideological level. As part of each design, the millwork transcends the gyp-board partitions it replaces conceptually to work as part of an *interior fabric*.

Through cultivating this interior fabric, it may be possible to truly transform *dwelling.* Environmental design encourages the designer to consider the relationship among things in an environment; a window is not just a hole in a wall, but a conveyor of light that establishes a micro-environment perfect for a reading chair, a brightly hued carpet that reflects the light and warms the room, a place for a house plant, and so on. An interior *fabric* should have this quality: the elements should be covalent and interconnected, designed to relate to activity at multiple levels. Thus the fabric should be by its nature a hybrid of sorts, bringing together multiple systems at work in the interior into a functional harmony to support dwelling. In this sense we have returned to the Yeoman bungalow, where imperatives of technology, functionality, economy, and identity converged.

THE AUBURN HOUSE

The first project to be examined is the Auburn House [Figure 4], a new home (currently in the schematic design phase) designed for clients whose primary intent was to construct a house of a prefabricated, moment-resisting steel frame – a similar system used for many steel commercial and industrial buildings. The introduction of this system immediately required a rethinking of the manner in which the house was constructed and detailed, with a litany of adaptations required to deal with finishing the wall packages, insulation, the conveyance of mechanical systems, and the approach to interior partitioning. What was immediately recognized is that the structure would open the interior and the envelope to very large spans; interior partitions would not be needed for structural purposes, and for many of the interior functions, it was questionable if a partitions was even needed at all. On the other hand, it would be foolish to build a large amount of redundant partitions to create storage closets and other things. A second issue was that the steel structure required thick insulation on the exterior of the structure, and design is proceeding with assumption that structural insulated panels will be used for the envelope, installed exterior to the steel structural. Consequently, the structure will be exposed in the interior and some sort of provision was requested by the clients to cover the structure, which will be steel shapes of a depth much greater than light wood or steel framing. In summary of these issues, a strategy emerged in which a large amount of partitioning in the interior will actually be prefabricated casework that will function both as wall, gallery shelving, storage, an armature for sliding panels and other dividers, and a conveying method for building systems such as power, lighting, and HVAC. In summary, the steel structural system created the scenario for rethinking the

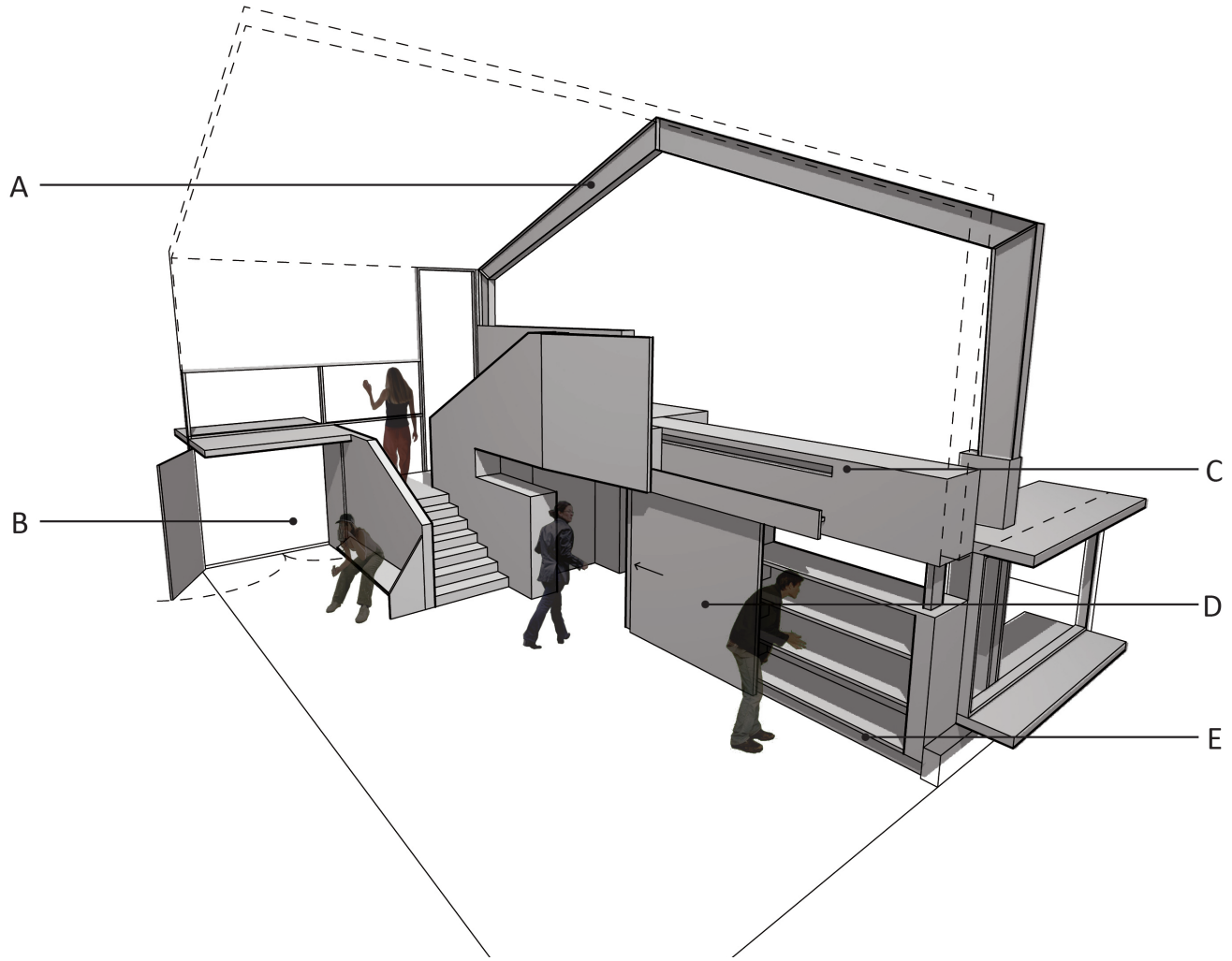

Figure 4. The Auburn House and its use of prefabricated millwork to create an *interior* fabric. A) The prefabricated moment-resisting steel frame. B) Entry area with seating, light shelf, storage, and stair as a continuous element. C) The home will be heated by radiant floor heating, while cooling is delivered to the main zone laterally through the upper area of the casework. D) Face-mounted sliding door can close off the dining room and/or kitchen areas. E) Electrical systems are introduced through the casework from the basement below and routed directly to A/V junctions and integrated lighting.

integration and purposing of the partitioning systems, to where they are now envisioned to be multifunctional elements that go far beyond bounding the interior space.

THE KAW HOUSE

The second project is the Kaw House, an addition to the author's residence. The addition, planned for construction in summer 2013, was originally conceived as a means of expanding the living space on the southern edge of the house and, in elevating the roof line, capturing passive solar heat during Kansas' sunny winters. The second intent of the addition was to correct the foundation condition of a previous addition that was constructed over questionable concrete porch footings. In developing the design for the addition, it became apparent that the southern and eastern wall could integrate several functions into a continuous package. Below grade, a double wall against the cast-in-place foundation will conceal a labyrinth of modular masonry units; the labyrinth will serve as an intake plenum for a passive cooling system that will provide secondary cooling for the living space above. In the living space, a stretch of prefabricated casework will house the distribution systems for both the passive cooling system and the conventional heating and cooling system for the home. The structure of the addition will be composed of a conventional dimensional lumber floor deck with a 'trussed' wall and roof structure that will be built off-site in structural modules. Above the casework, an expansive multiwall thermal plastic clerestory will permit solar heating. Between the solar clerestory and the labyrinth below, the interface of the casework will serve to conceal the addition's structure, to integrate distribution systems for heating and cooling, provide concealed and gallery-style storage in the living area, house electrical receptacles and audio-visual equipment. In summary, a large amount of program has been engaged through this single intersection between structure, envelope, and casework altogether enabled by prefabrication technology.

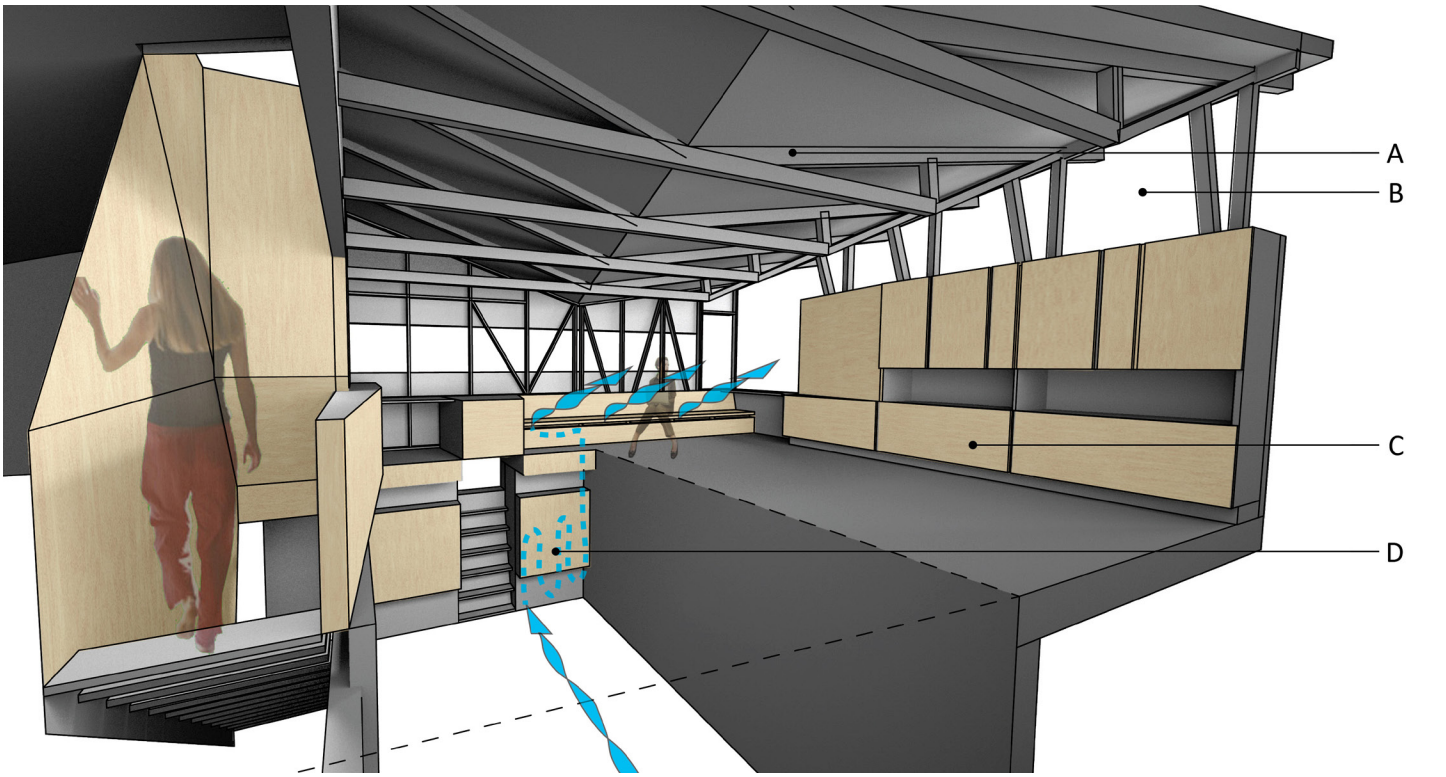

Figure 5. The Kaw House and one of its main banks of built-ins, integrated with a passive cooling system below. A) The prefabricated wood trusses in the roof/wall system; B) translucent south-facing thermal glazing; C) casework integrating primary HVAC system, electrical systems, and concealed uplighting; D) double wall at the foundation contains a passive cooling labyrinth that draws from the finished basement, discharging air at low velocity from a plenum in the casework.

CONCLUSION: MILLWORK AND TECHNOLOGY'S POSSIBLE CONTEXT IN DWELLING

Technologies for fabrication and construction *must* challenge architecture critically, at the ideological level. Like the bungalows of the last century, a new approach to interior fabric can be similarly realized through emerging computer-based technologies in fabrication, construction, and design. In this case, the means of fabrication is no longer the critical end of this technology: instead, we are looking beyond to understand technology's context, what it does, and how it can contribute to and improve our domestic environments.

In the author's prior research regarding experimental construction systems, the critical shifts brought about by computer-based design and fabrication were identified among three themes: production and assembly, prototyping, and performance [22]. Without revisiting a discussion of these themes in detail, we may summarize them briefly.

- Technologies in production and assembly can permit modern millwork to expand design intent and better respond to specific programmatic, functional, and spatial concepts while controlling expense.
- In terms of prototyping, with parametric design tools (such as BIM) and digital fabrication, there is little penalty in using variation or invention in either the design process or among the final products; in the case of the two examples presented, the millwork systems are *entirely* prototypical, aspiring to do more to ideologically 'fit' the project while at the same time having no prior precedents, all at a relatively neutral cost compared to standardized components.
- As a result of computer-based design (more so than computer-based fabrication), designs are much more readily aligned with performance intent in the design process, activating and optimizing building components to specific activities and functions that would previously be unvalued; designing millwork to respond to performance, whether visual or technical, can legitimate its essential role in designs.

While the author's prior research in experimental prefab systems was directed at structural and envelope innovations, revisiting architectural millwork has presented a more experientially-rich opportunity for the application of technology. Millwork, from its historical development to its use by Wright and later contemporary architects, has a way of interfacing with daily life and domestic space that structural or envelope focused prefabrication systems cannot provide. In a sense, millwork is more ideologically dense, at the transition between traditional room-scaled architecture and the intimate-scaled space of interior fabric.

Moreover, technologies for design and fabrication can become part of a *construction critical* architecture, finding a critical context in designing and fabricating an interior fabric that extends past traditions of millwork that were both rich in ideological significance and technical integration. Here, their status as "technology" in McCleary's definition can be gained, as these technologies are critically deployed in rethinking space and performance in architecture.

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