Component / Assembly: Pragmatism and Precedent in Digital Fabrication Pedagogy

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This paper discusses a series of academic design studios that explore ways to imbue pedagogies of digital fabrication with a critical sensibility rooted in architectural precedent. The work looks to the Case Study House Program spearheaded by John Entenza of Arts & Architecture magazine in Los Angeles (1945-1966) as a model for how architects can re-conceptualize and re-materialize domestic space through an understanding of the limits and possibilities of new manufacturing techniques. Just as the architects of the Case Study House Program crafted new prototypes for domestic living inspired by the postwar (modernist) logics of mass production, this work speculates how contemporary (postmodernist) logics of mass customization can inform new models of domestic space appropriate for today.

The research explores the architectural detail as a locus for reconsidering contemporary domesticity in the context of new technologies of design, fabrication, and assembly. Adapting ideas from research into architectural components from seminal case studies, the work tests ways to employ technologies of mass-customization to reconsider the component's definition, its construction, and its assembly into larger configurations of structure and space. The ambition is to develop new understandings of part/whole relationships that reflect contemporary modes of living at all scales, from the component to the broader architectural organization. By melding computational workflows and advanced fabrication processes with the pragmatics of building and assembly, this work advocates a subtle but nonetheless radical shift in how we design and make architecture. And by grounding the work both conceptually and tectonically in precedent and in architecture's social capacities, the studio pedagogy fosters a critical ethos that sometimes is lacking in academic approaches to design computation and digital fabrication.

> Perhaps we will cling longest to the symbol of 'house' as we have known it, or perhaps we will realize that in accommodating ourselves to a new world the most important step in avoiding retrogression into the old, is a willingness to understand and to accept contemporary ideas in the creation of environment that is responsible for shaping the largest part of our living and thinking.
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> —John Entenza, *Announcement of the Case Study House Program, 1945*[1]

> Severing the architect from the means and methods of construction is somewhat like permitting the writer to use a certain vocabulary, but disassociating it from the very alphabet from which the text emerges.
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> —Nader Tehrani, foreword to *Strange Details* by Michael Cadwell[2]

> A prototype begins as an experiment which may or may not become a building.
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> —Barkow Leibinger, *An Atlas of Fabrication*[3]

The widespread adoption of technologies of customization in architecture has recalibrated paradigms of design, fabrication, and assembly.[4] Although new technologies have dramatically expanded the realm of the possible for architecture, the nature of technological research and innovation can necessitate a narrow focus and rigor, sometimes prioritizing the technical in isolation from broader social questions. Entire academic programs and international organizations have emerged as centers for innovative research in digital fabrication and automated construction, but the risk of pursuing advanced technical work in these areas without grounding in broader disciplinary concerns is that architects will ultimately be unequipped to leverage the technology in effective and productive ways. In academic settings, pedagogies of digital fabrication often perpetuate this conundrum, as coursework and studios in this area typically emphasize technique and rarely engage at a more critical level with the social and political implications of new technologies.

This paper discusses a series of academic design studios that explore ways to imbue pedagogies of digital fabrication with a critical sensibility rooted in architectural precedent. The research focuses on the architectural detail as a locus for re-considering contemporary domesticity in the context of new technologies of design, fabrication, and assembly. It seeks to develop a critical understanding of potential contingencies between tectonics (how the parts of buildings are made) and architecture's capacity to promote social and collective spaces (how buildings are inhabited by people). The work looks to the Case Study House Program spearheaded by John Entenza of Arts & Architecture magazine in Los Angeles (1945-1966) as a model for how architects can re-conceptualize and re-materialize domestic space through an understanding of the limits and possibilities of new manufacturing techniques. Just as the architects of the Case Study House Program crafted new prototypes for domestic living inspired by the postwar (modernist) logics of mass production, this work speculates how contemporary (postmodernist) logics of mass customization can inform new models of domestic space appropriate for today.

THE CASE STUDY PRECEDENT

The Case Study House Program, which produced thirty six projects over twenty years, provided a platform for architects to re-conceive domestic living in the era of postwar, industrial mass production.[5] These projects are notable for their pioneering use of standardized industrial materials, newly available in the postwar pivot from wartime production to domestic production, and their unique adaptation of architectural modernism to the Southern Californian context. Entenza was motivated by a desire to forge a new paradigm of mass housing that would capitalize on industrial materials and technologies to offer low-cost homes for the growing middle class of the Los Angeles area. The program partnered architects with manufacturers, promoting access to and experimentation with materials not typically associated with residential construction, such as steel structural members, aluminum windows, and plate glass.

Within this framework of material innovation, however, the participating architects still conformed to and perpetuated the conventions of domesticity of that time. Hallmarks of Case Study projects include deference to the automobile carport as the primary entrance, organization around a central living and kitchen area, and representations through drawings and photographs that reinforce social and cultural tropes of the postwar era. The occupants of the houses are usually typical American nuclear families, represented with a father in business attire arriving home from work, a mother laboring happily in the kitchen, and a couple of children playing in the family room or outdoor lawn. Although the architecture was radical in its use of standardized, industrial materials, it nonetheless reinforced and helped to cement gender roles and domestic politics in a way that is now codified in the model of the detached, single-family house that has persisted in American cities and suburbs for generations.[6]

This research draws inspiration from Entenza's vision in its desire to test resonances between new ways of making buildings and new forms of living. It recognizes the failures of the Case Study House Program—its role in establishing the single-family house as a viable model for mass housing, despite its detrimental effects on urbanism, ecology, and society. In today's vastly different cultural, social, economic and material landscapes, this work speculates on new architectural and spatial arrangements that are more relevant to contemporary modes of living. Specifically, it proposes a series of questions about tectonics and domesticity, about the parts of buildings, how they are made, and how they might inform alternative approaches to domestic space. How might new approaches to flexible fabrication and mass customization allow architects and builders to rethink domestic architecture? What are possible alignments between emerging modes of production and alternative conventions of ownership, shared living, and collective domesticity? How might questions of fabrication and tectonics relate to the balance between working and living, between labor and leisure? How do the politics of customization condition both the making and inhabitation of domestic architecture? It is in these questions that the work seeks to pick up where the Case Study House Program left off—advocating for innovation and experimentation in material and construction, yet insisting that such research be informed by social realities and demands.

DOMESTIC COMPONENTS

The architectural detail presents a logical opportunity for exploring these questions. The detail—where materials come together to form larger assemblies—is the moment where the architect negotiates design intent with the pragmatics of construction, craft, and labor. As Irene Cheng and Bernard Tschumi have noted, "the detail is a site of excess: the point where something is no longer just about utility or function but begins to carry meaning."[7] It is in the detail that tectonic questions of fabrication and assembly are rendered spatial and architectural.

Rather than accepting the architectural detail as a predetermined assemblage of standardized parts or products, this research speculates on the spatial, programmatic, and social possibilities of customizable, parametric, and bespoke details—and how such a paradigm can relate to emerging forms of domesticity. As a point of departure, work focuses on the *domestic component*: the guardrails, jambs, sills, stairs, moldings, doors, cabinets, coves, reveals, partitions, wall bases, and other parts that, when assembled together, constitute "architecture." These elements become the basis for constructing relationships between the tectonic, the spatial, and the cultural. Integral to the process is critically understanding how tectonics can reflect, promote, and reinforce social, cultural, and political ideas about domestic space.

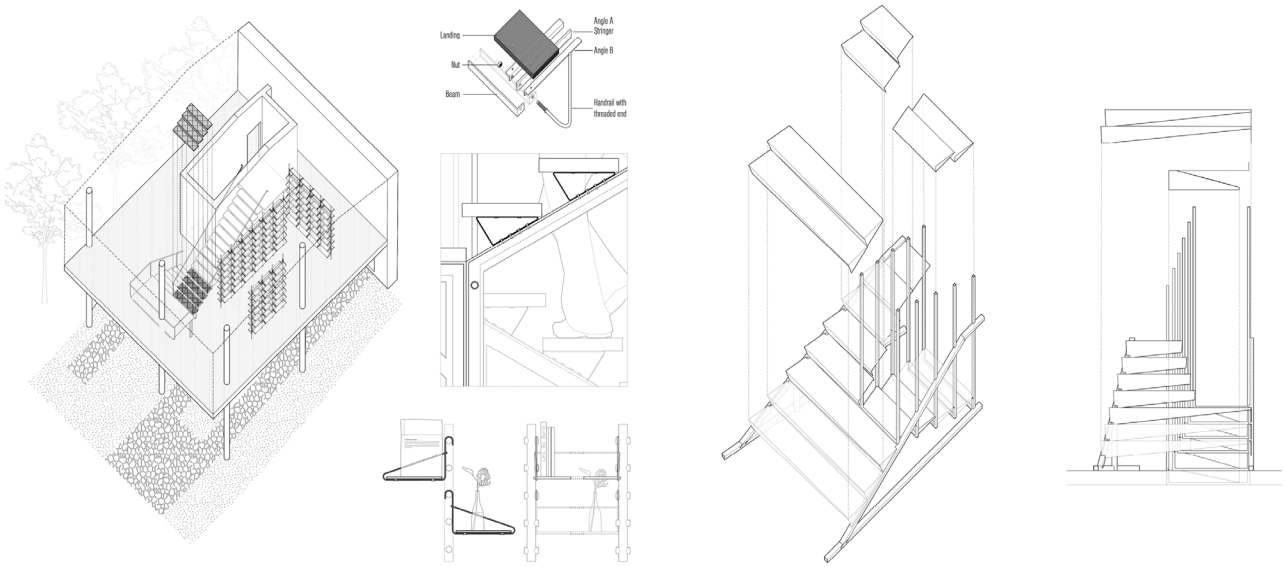

Figure 1. Research into architectural precedents includes analysis of a singular domestic component (left) and reverse engineering of this component using digital fabrication technologies (right). Images of analysis of Lina Bo Bardi's Glass House by J.E. Luo.

In framing their unique approach to fabrication in architecture, Barkow Leibinger ask, "How do tools (now more elaborately defined as emerging technologies or techniques) drive our architecture?"[8] This research takes a similar, bottom-up approach to rethinking the relationship of architectural parts to larger assemblies. If the standardized, mass-produced components that so captivated modernist architects are embedded with ideological bias for repetitive, universal space, what might be the spatial implications of customized tools of fabrication? And how can these qualities be leveraged and deployed towards a more customized, differentiated domestic space? It is in this regard that the research seeks to synthesize ideas about domestic space into the very details of tectonic assembly.

By foregrounding questions of program, meaning, and social performance in constructing the architectural detail, these studios challenge students to interrogate fabrication strategies while simultaneously considering how these techniques relate to alternative notions of domesticity. Use of emerging technologies alone does not give meaning to the design of parts or assemblies; for example, a custom laser-cut and CNC brake-formed stair tread itself offers no advantage over an off-the-shelf, mass-produced tread. However, rethinking the proportions of a stair tread to speculate how certain configurations allow for social gathering areas *does* suggest an opportunity for such thinking, as custom or bespoke configurations that allow for different scales of occupation represent one way to embed new ideas about program, community, and living into these components.

As fluency with the machine tools increases, new opportunities arise for reconsidering the component's definition, its construction, and its assembly into larger configurations of structure and space. The ambition is to develop new understandings of part/whole relationships that reflect contemporary modes of living at all scales, from the component to the broader architectural organization to the context in which the buildings are situated. With each shift in scale, the logic and embedded intent of the initial component should be present, informing the projects in a bottom-up manner.

STUDIO PEDAGOGY, V1

To date, two academic studios have served as venues for testing architectural strategies rooted in rethinking the domestic component. The pedagogical structure of the studio curriculum relies upon focused analysis of precedent as a way to drive both conceptual and material logics. Each student begins by revisiting a domestic component from a seminal architectural case study, typically a stair or other aspect of circulation. The precedents reflect a diversity in architectural style, geography, and time period. After identifying and analyzing the original component, students then reverse engineer it, considering ways to incorporate contemporary manufacturing techniques that can process standardized, off-the-shelf material components in customized and bespoke ways (Figure 1). Students explore these processes through large-scale study models and physical prototypes that emphasize tectonic fidelity and the effects produced by customized components. Particular emphasis is placed on how customization can mediate zones of public and private space at a larger scale, thinking ahead to how these systems might accommodate both individual and collective territory.

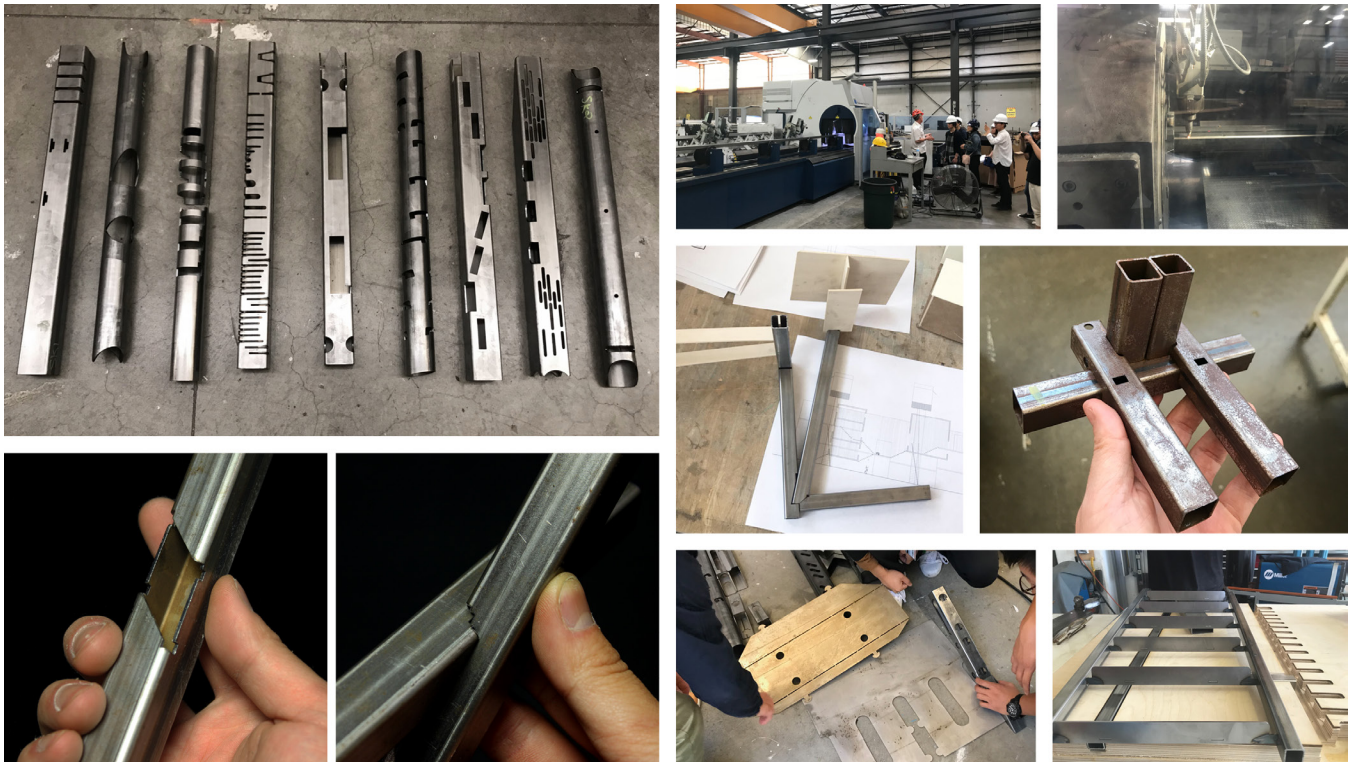

Figure 2. The studio partnered with local manufacturers to integrate the production of full-scale laser-cut steel sheet and tube. The iterative process allowed students to refine and optimize tolerance, joinery, and assembly as they worked toward the final proof-of-concept mockup.

As students develop a thorough understanding of how to calibrate joint, detail, and spatial effect, they scale the domestic component up to a *spatial component*, a proto-architectural interior condition not yet at the scale of a building, but large enough to understand ideas of public/private relationships within the space. This process is conducted in collaborative teams, a challenge for students as they must negotiate their individual research and tectonic strategies, testing ways to hybridize ideas into a compelling synthesis. The spatial components are developed through iterative physical models that allow the students to experiment and refine how tectonic decisions can condition spatial effects and boundaries.

It is only after the student teams are able to confidently calibrate tectonic, space, and effect that the ideas scale up to a sited architectural proposal. The first iteration of the studio did not assign a specific site, instead allowing the students to develop their own approach and attitude in siting their work. Students began to adapt their spatial components into an architectural proposal informed by research into a specific *domestic culture*. Research topics included different approaches to communal living, from co-living cooperatives, to artist communes, to youth hostels. These scenarios provide a basis for students to consider how their tectonic and spatial components might mediate more private and more collective zones of the building.

STUDIO PEDAGOGY, V2

The second iteration of the studio consisted of a similar process but was more specific in both site and programmatic requirements. The intent was to build upon the successes of the first studio but more directly foreground questions of collective living in an urban context. Using Los Angeles as a site for the research, an obvious choice given the legacy of the Case Study House Program, provided a rich landscape for studying domestic space in the contemporary city. After a century of rapid growth and proliferation of predominantly low-density detached houses across the Los Angeles basin, the city is grappling with a housing crisis: how to densify, and how to provide affordable housing in an extreme market. There is an increasing desire and willingness to challenge the notion of single-family home as panacea, and to test new models that accommodate both density and affordability, such as accessory dwelling units, microunits, and co-living.[9] Although the social and political parameters of domestic life today are entirely different from those of the 1950s, this demand for new prototypes for living echoes the conditions that prompted the Case Study House Program.

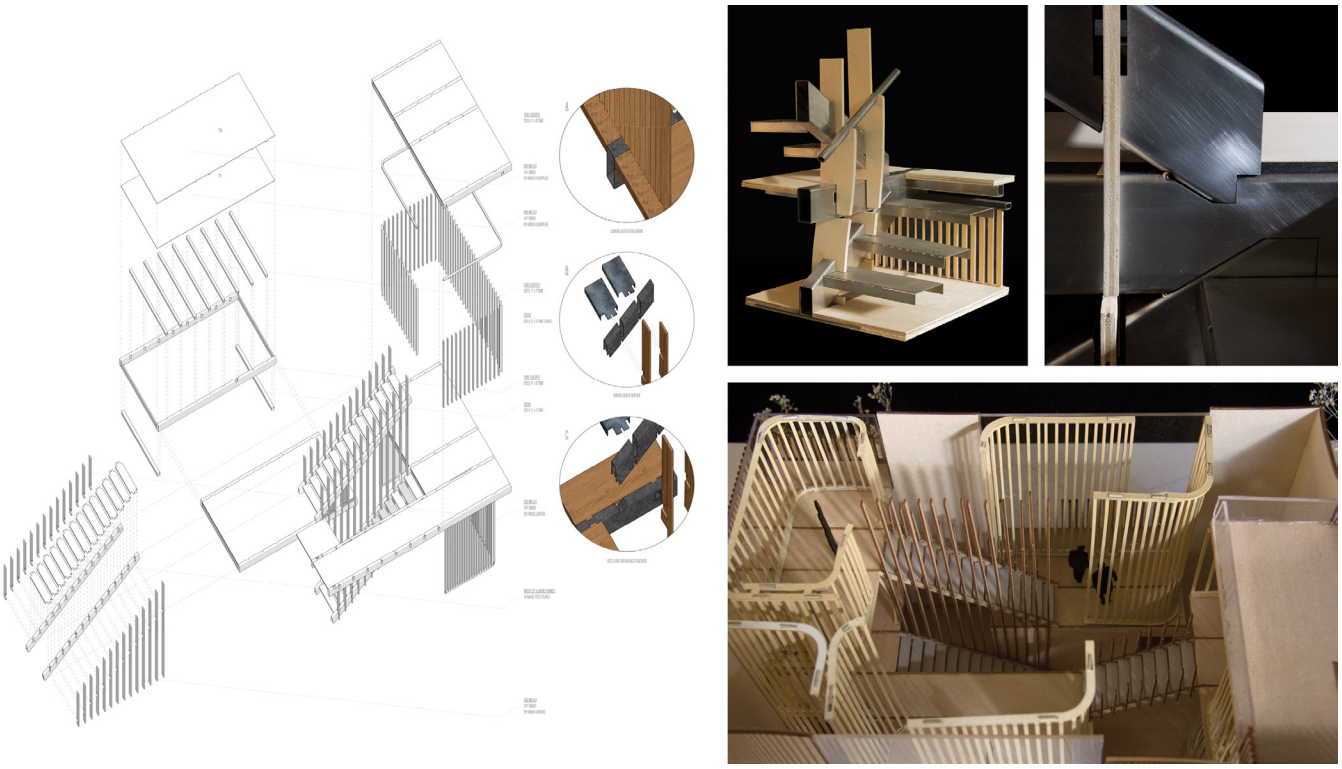

Figure 3. Bimble Inn, by A. Burlinska and S. Moriuchi.

The students were asked to design a building to house twenty people, in a typical mid-block lot in West Hollywood. This context positions the work somewhere between the legacy of the Case Study House Program and the ubiquitous Los Angeles vernacular of the "dingbat" stucco boxes that represent one of the city's primary types of collective housing.[10] Celebrated by critic John Chase as "glamorously packaged consumer objects" that "[reflect] at once the pragmatic and hedonistic character of Southern California," dingbats represent an earlier era's negotiation of the utopian ideal of the low-cost, single-family home projected by the Case Study House Program with a more realistic understanding of multi-unit density and "ruthlessly expedient" economies of construction.[11] Reyner Banham recognized the importance of this typology in his seminal *Los Angeles: The Architecture of Four Ecologies*, which identified the dingbat as the "true symptom of Los Angeles' Urban Id trying to cope with the unprecedented appearance of residential densities too high to be subsumed within the illusions of homestead living."[12] Learning from the precedent of the dingbat as reconciling the need for density with constraints of mass production, the studio's work sought to explore how new technologies of fabrication and approaches to customized tectonics could inform alternative notions of domestic space in the contemporary city.

In adapting the domestic component and spatial component research to the site, students focused on ways in which these tectonic systems could produce scales of individual and collective space. Projects developed different attitudes towards the definition of private living space and shared or communal space, and in many cases these positions emerged from the material and tectonic research—understanding how systems of repetitive and customized components could adapt to produce variable degrees of privacy and scales of occupation.

PROTOTYPING AND FABRICATION

Parallel to the programmatic and tectonic research, students engaged in an iterative process of prototyping at full-scale as a way to further develop an understanding of joinery, tolerance, and assembly (Figure 2). Both iterations of the studio partnered with local manufacturers to integrate the production of laser-cut steel sheet and rotary laser-cut tube components. The workflow required an ability to operate between softwares, scales, and dimensions to translate geometry from a design model to fabrication toolpaths. The rotary laser process in particular demanded a comprehensive grasp of solid modeling and the unique constraints of the machine, a challenge not typically faced by architecture students at this level.

Figure 4. *Continuous Ambiguity*, by J. Guo and H. Jia.

In the last part of the term, as students continue to refine their architectural proposal at the site and building scale, each team also produced a final proof-of-concept mockup. Each prototype, typically at full- or half-scale, focused on one architectural moment that demonstrates the impact of customized componentry on the project's spatial organization. As a complement to the architectural drawings and representations, the mockup allowed critics and guests to experience the range of potential spatial effects, reinforcing the students' arguments relating tectonics to different programmatic conditions.

COMPONENT/ASSEMBLY CASE STUDIES

One project from the first studio, *Bimble Inn*, proposes a travelers hostel in the countryside. The project employs a stair and screen system to create spaces of varying privacy that capture the traveler's sense of wanderlust and exploration (Figure 3). As one moves through the hostel, the screens begin to reveal and conceal spaces and moments, drawing the visitor in. The stairs define upward movement, but by merging with the screen system they maintain the visual intrigue of the spaces beyond. Highly specific manufacturing techniques are leveraged to create customized components that in turn create customizable spaces which enhance the experience of the traveler by creating space for exploration.

Another project, *Continuous Ambiguity*, demonstrates how a single tectonic system can accommodate a range of functions and programmatic zones. This project is a house on a lake designed for two couples: designers and filmmakers. The house consists of a series of small spaces that merge into larger figures to produce qualities of spatial continuity and spatial ambiguity. Overlap of domestic programs is achieved using a customized steel fabrication system of modular components that adapts ideas from Ryue Nishizawa's House & Garden and Lina Bo Bardi's Glass House. This system comprises floors, walls, ceilings, and furnishings, producing ambiguous boundaries and continuous zones throughout the building; everything is a part of everything else (Figure 4). These qualities give the residents more flexibility to customize and redefine the space, therefore expanding the functionality and apparent size of the house.

Treebat, a project from the second iteration of the studio sited in Los Angeles, proposes a series of communal living spaces organized around exterior terraces that meander through the building and the site. Autonomous territories for children and adults are linked through a series of stair and ladder circulation routes, with wood screen walls creating an interface between the two zones. The project learns from Pierre Chareau's Maison de Verre and Juan O'Gorman's Casa Estudio Rivera Kahlo to construct discrete territorial zones that are connected in complex and variable ways.

Spatial Offset reimagines the Los Angeles typology of the "dingbat" apartment building as a self-contained neighborhood of variously sized and aligned volumes that provide a range of domestic programs. The building merges standard stucco

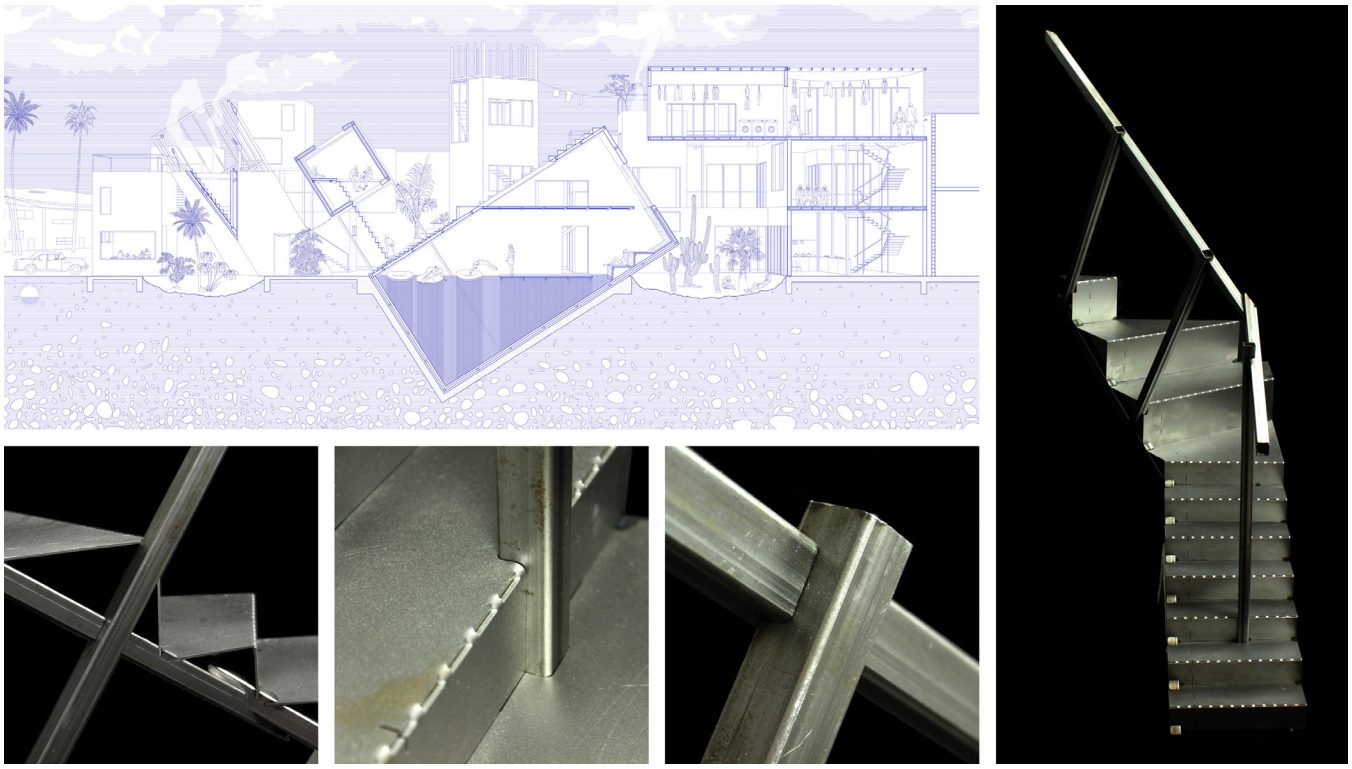

Figure 5. *Spatial Offset*, by S. Kilpatrick and J.J. Tan

box construction with a bespoke, custom laser-cut steel tube frame that produces calculated shifts, offsets, misalignments at multiple scales (Figure 5). It adapts ideas and geometries from Robert Venturi's Mother's House and Paul Rudolph's Modulightor Apartment to explore how strategic misalignments can produce various scales of communal and social spaces.

As with other projects in the studio, the authors of this project developed a distinctive representational approach that reinforces the overall concept and critical sensibility. Stylistically, the work echoes the representational techniques of Case Study House architects like A. Quincy Jones and Craig Ellwood in its graphic qualities and the manner of drawing the occupants of the architecture—the people, vegetation, and things that explore how the might come to life. The intent is not only to speculate about the qualities of the space, but to project the social aspirations of the project in a critical way.

REFLECTIONS ON THE WORK

As Scott Marble notes, endeavors such as the Case Study House Program "were atypical and short lived exercises, because industry and manufacturing remained primarily driven by purely economic imperatives. In the meantime, architecture drifted toward design that defined itself as distinct from the goals of industry."[13] Even though the Case Study House Program sought out industry partnerships to build from the best available materials in order to reimagine what a house could be, the lack of "mediation between design and production"[14] ultimately contributed to the program's failure to gain traction at the scale its proponents had imagined.

The Component / Assembly studios look to introduce such mediation in critical and contingent ways: not only via digital workflows, but also in cultural and social aspects of design. The partnership with industry is mutually beneficial, linking the resources of industry (tools and materials) with the imaginative and speculative capacities of academia (intellectual resources and freedom from constraints like clients and contractors and budgets). For students, the access to tools such as a 3 kilowatt fiber laser or a multi-axis tube laser allows for experimentation with technology typically beyond the reach of the typical academic studio. Students also acquire a proficiency in terminology, standards, and protocols in learning to communicate with fabricators to develop custom design solutions. For the fabricators, these partnerships introduce them to potential future customers and specifiers, as the graduating students will already be familiar with their workflows and processes. For industries at the periphery of architecture or the construction industry, this could offer entry into a new market as they see their services and technologies used in novel ways. As witnessed in these studios, students unburdened with prior knowledge of predetermined solutions can offer alternative approaches that, while often lacking the rigor of more informed veterans, are nonetheless full of potential.

The studio pedagogy, which inverts the structure of a typical academic design exercise, offers several benefits. In prioritizing proof-of-concept through tangible physical construction of large-scale models and near full-scale mockups, the students gain a number of skills in executing custom components that reinforce ideas about difference and variation in their building proposals. Rather than simply selecting or specifying products, students think through the limitations and potentials of process and materials, communicate with potential collaborators and fabricators, and problem solve through detail iteration and prototype production in a critical and informed way. This is augmented by embracing Barkow Leibinger's "reversal of the normative design process,"[15] which increases the confidence of students to grasp an understanding of material, detail, and assembly that will then inform larger architectural design decisions. Design studios typically begin with site analysis, then broad, perhaps even abstract concepts at the scale of the building, and develop detail incrementally throughout the course of a project. The architectural detail therefore becomes the byproduct of a top-down or sometimes preconceived idea about tectonics. By leveraging the detail as a generative design tool, students not only gain insight into material properties and connections early in the process, but they have a chance to refine and explore their details through iteration and various permutations as the projects grow.

Furthermore, gaining familiarity with the tools of fabrication and the production processes associated with both standardized and highly customized componentry empowers the student to delve more deeply into the potential social, cultural and political implications of the technologies at hand. Analyzing, rethinking and designing components that one might initially assume to be neutral or static reveals embedded meanings, biases, and values. What are the implications of using off-the-shelf stock parts or components versus designing completely custom solutions? Each has a completely different set of associated attributes, such as embodied energy, waste, cost, labor for production, and labor for assembly. Students therefore become acutely aware of the cost implications of design decisions and by extension, efficiencies (or inefficiencies) in production and fabrication, such as reducing material waste or reductive detailing that will require fewer parts, and potentially less labor. As opposed to traditional modes of fabrication, digital fabrication—and, by extension, automation—shifts the balance of labor and skill from maker to designer, or from builder to architect. This raises questions about craft in design and architecture, where it resides, and who has access to it.

Through the Component / Assembly studios, students discover that it is important and necessary to understand the social, cultural and political implications of the technologies at hand, who benefits from their use, and ultimately how we as architects can design more completely and responsibly. By melding computational workflows and advanced fabrication processes with the pragmatics of building and assembly, this work advocates a subtle but nonetheless radical shift in how we design and make architecture. And by grounding the work both conceptually and tectonically in precedent and in architecture's social capacities, the studio pedagogy fosters a critical ethos that sometimes is lacking in academic approaches to design computation and digital fabrication.

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ENDNOTES

1. John Entenza, "Announcement: The Case Study House Program," *Arts and Architecture* 62, no. 1 (January 1945): 37–39.
2. Nader Tehrani, foreword to *Strange Details*, by Michael Cadwell (Cambridge, MA: MIT Press, 2007), ix.
3. Barkow Leibinger, *An Atlas of Fabrication* (London: Architecture Association, 2009), ii.
4. For a thorough overview of how digital technologies have transformed architecture over the past twenty years, see this trio of books documenting these changes: Branko Kolarevic, ed., *Architecture in the Digital Age: Design and Manufacturing* (New York: Spon Press, 2003); Branko Kolarevic and Ali M. Malkawi, eds., *Performative Architecture: Beyond Instrumentality* (New York: Spon Press, 2005); and Branko Kolarevic and Kevin Klinger, eds., *Manufacturing Material Effects: Rethinking Design and Making in Architecture* (New York: Routledge, 2008).
5. Elizabeth A. T. Smith, "Icons of Mid-Century Modernism: The Case Study Houses," in *Case Study Houses* (Cologne: Taschen, 2013), 8–9; Elizabeth A. T. Smith, ed., *Blueprints for Modern Living: History and Legacy of the Case Study Houses* (Los Angeles: Museum of Contemporary Art, 1989).
6. Dolores Hayden, "Model Houses for the Millions: Architects' Dreams, Builders' Boasts, Residents' Dilemmas," in Smith, *Blueprints for Modern Living*, 197–211.
7. Bernard Tschumi and Irene Cheng, eds., *The State of Architecture at the Beginning of the 21st Century* (New York: Monacelli Press, 2003), 37.
8. Leibinger, *Atlas of Fabriciation*, i.
9. Frances Anderton, "This Is Home in LA: From the Tent to the Gigamansion (and Everything In Between)," December 25, 2018, in *DnA: Design and Architecture*, produced by Frances Anderton and Avishay Artsy, podcast, https://www.kcrw.com/culture/shows/design-and-architecture/home-in-la-from-the-tent-to-the-gigamansion.
10. Thurman Grant and Joshua Stein, eds., *Dingbat 2.0: The Iconic Los Angeles Apartment as Projection of a Metropolis* (Los Angeles: DoppelHouse Press, 2016).
11. John Chase and John Beach, "The Stucco Box," in *Glitter Stucco and Dumpster Diving: Reflections on Building Production in the Vernacular City*, by John Chase (London: Verso, 2000), 3.
12. Reyner Banham, *Los Angeles: The Architecture of Four Ecologies* (Berkeley, CA: University of California Press, 1971), 159.
13. Scott Marble, "Imagining Risk," in *Building (in) the Future: Recasting Labor in Architecture*, ed. Peggy Deamer and Phillip G. Bernstein (New York: Princeton Architectural Press, 2010), 40.
14. Marble, 40.
15. Leibinger, *Atlas of Fabrication*, i.