# Parallel Tracks: Digital | Analog Dialogue in Toy Development

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Designers and fabricators have long understood their work to be related, but distinct. Boundaries, some intuited, others legally proscribed, dictate that designers establish the intent for a given outcome, while fabricators generate the actual work or product. That understanding is an action-based view, focusing on tasks performed by specific people or entities. We could shift our consideration towards the nature of work itself and state that there have traditionally been two fields, interrelated but distinct: design and craft. How are we to understand the changes to both of these fields necessitated by the ways emerging methods, practices, and technologies are merging the two? This essay will discuss the digital | analog convergence in design and fabrication as illustrated by examples from a line of toys developed through the collaboration of an architect and mechanical engineer.[1] Our work considers questions of craft and fabrication, relying extensively on both digital and tangible techniques in continual iterative dialogue. Also at hand is a parallel consideration of the digital | analog convergence in the realm of toy design, considering toys as objects designed for interaction and play. Our continued engagement in the convergence of technology, material, and culture in the interest of design and fabrication is a catalyst for speculations of what may come next.

## DESIGN AND CRAFT

David Pye, an influential furniture designer and woodworker, developed a clear and insightful theory of the interrelation between design and craft in the late 1960's. Through his texts, *The Nature and Aesthetics of Design* (1964) and *The Nature and Art of Workmanship* (1968), he posits two distinct philosophies — one of design, and one of workmanship — and explains the significance of each field, underscoring their codependence. Pye offers this interpretation: "Design is what, for practical purposes, can be conveyed in words and by drawing: workmanship is what, for practical purposes, can not."[2] His text on workmanship strongly emphasizes a connection between craft and the quality of our environment. Regardless of the quality of design intent, the quality with which craft is executed has a profound effect on how the final outcome will be perceived. He carefully distinguishes craft from workmanship, writing: "Craftsmanship... means simply workmanship using any kind of technique or apparatus, in which the quality of the result is not predetermined, but depends on the judgment, dexterity, and care which the maker exercises as he works. The essential idea is that the quality of the result is continually at risk during the process of making."[3]

Pye goes on to distinguish *workmanship of risk* as any process of making where the worker can potentially affect the quality of the product through will, skill, or chance. It is the opposite condition of *the workmanship of certainty*, which can also be called manufacturing. He describes a nuanced method for discerning workmanship as belonging to one type or the other: "…In principle the distinction between the two different kinds of workmanship is clear and turns on the question: 'Is the result predetermined and unalterable once production begins?'"[4] In his essay entitled "The (Risky) Craft of Digital Making," Branko Kolarevic expertly examines Pye's notion of the workmanship of risk and its implications for parametric design and digital fabrication.[5] We are indebted to Kolarevic's work in this field, and we seek to expand on it by focusing our inquiry on implications for craft and its inherent connections to tools. Craft, for Pye, is understood to have an honorific quality stemming from the dexterity of an uncontrolled hand, a quality which pure manufacturing lacks. Moreover, his work sought to analyze and explain theoretical underpinnings of the craftsmanship of risk specifically so that valuable qualities of such methods could be recognized and preserved as technological and market forces inevitably privilege methods of certainty.[6]

This nuanced reading of differential tiers of workmanship is connected to the tools used to design and produce the work. Specifically, Pye identifies *determining systems* of production as the opposite of *skilled systems*. His definition set is based on the relative consistency of the outcome. It assumes that when using certain kinds of tools (including jigs and fixtures designed to help guide tools in a consistent manner), there is little uncertainty about the outcome. Such work can be described as determined because of constraints inherent to the types of tools being used. Other systems of production, which may still use tools, are considered skilled systems if they include at least one constraint that is "variable at will."[7] The fundamental question, then, is when one uses digital tools to fabricate analog outcomes, is it craftsmanship or manufacturing? Or is it somewhere in between?

There remains a significant element of craft to our work, even though we rely on many kinds of determining tools. Our generation has been given a huge array of tools that, in addition to other qualities, allow us to conflate the act of design and execution of the work. One need only consider the work of the Swiss architectural firm Gramazio and Kohler, including their academic research with the ETH in Zurich, or study the essays collected in Branko Kolarevic and Kevin Klinger's book, *Manufacturing Material Effects*, to see that this integration of design and fabrication has real impact on the changing nature of the role of the architect today.[8] What previously would have been separated into distinct trades and passed back and forth via established communication protocols is now simply done by one design-fab entity out of one messy shop. Fusing design and production has profound implications, deserving critical consideration that should change design discourse at large.

## TOOLS AND MATERIALS

Our work, and the work of many other emerging practices, is characterized by a specific use of tools that simultaneously engage design, representation, and production. This gives immediate feedback between virtual and actual, and trends towards eliminating the separation between any such categories. We fundamentally rely on parametric digital modeling coupled to a CNC milling machine. Designs are developed as models, functionally-mated assemblies of parts, using SolidWorks, a parametric modeling software package. We use PartWorks to translate three-dimensional intent into sequential tool paths: vectors in space which move a cutting tool through stationary material, precisely carving profiles defined by the model. In programming this sequence, vectors are offset from the desired geometry by the tool's actual shape, accounting for constraints of physical reality. Working parametrically also alters the role of tools of representation. Rather than generating representations of an idea or predicted outcome, as drawings perhaps could be described, we directly model intention and generate work from that model.

The complex duality of analog and digital tooling is essential to our process as we also rely on conventional means of design, representation, and production. Initial ideas are always first sketched by hand en route to becoming a quick generative model. Physical prototypes require analog stock preparation. Dried lumber is planed conventionally prior to being worked by CNC mill. Our prototypes inevitably call for hand sanding and finishing. Refining sketches are generated throughout, often in the form of pencil drawings on whatever piece of material is closest at hand in the shop. This duality of physical and virtual isn't novel. Craftspeople have always nimbly combined old and new tools and processes based on suitability.

The ideas presented in *Manufacturing Material Effects* attempt to frame a theory of digital craft. Specifically, Kolarevic discusses ideas of craft in architecture, and the ongoing connection between architecture and the tools that produce it. He observes that digital fabrication has in a very real way enabled designers to be more hands-on with their work, establishing a closer relationship with craft.[9]

Kolarevic reminds us that, historically, there has long been a romanticized notion of the architect as master builder, one who both establishes design direction and literally chisels it into wood or stone. Stephen Kieran and James Timberlake's significant work, *Refabricating Architecture*, presents a similar notion of the master builder.[10] Conveyed with this cultural memory was also a sense of risk that one's chisel might slip — so craftsmanship is both a "noun and verb," as Malcolm McCullough has described it.[11] The care with which the master builder executes his work is inherently connected to outcome and subject to chance.

Recognition of the architect as master builder essentially ended with the establishment of contemporary professional practice. For the past century, the designer's purview has been representational: our product being depictions of ideas about space, fabrication, and occupation. Our professional deliverable has been drawings or specifications telling a contractor how to execute design intent. In this system, the designer has always been at least one step removed from actual outcomes. With digital fabrication, we the designers directly operate the mill. Our models and scripts tell the machine how to execute design intent. This represents a more immediate, and surprisingly more traditional, relationship between designer and product. Yet it also potentially undercuts our role as advocate for ideas, pulling us from the virtual into the actual.

An important revelation came to us in recognizing that using digital technology is inherently hands-on, messy, and variable. The CNC mill is the link between our "actual virtual" model and the physical prototype. The fabrication process is a nearly immediate feedback loop where prototype challenges concept. Mistakes and surprising outcomes are frequent, and ultimately are essential to the evolution of the design. Generative failures often result from under-considered realities, including inadequate toolpath clearance, unintended effects of sequencing, and the need to fasten workpiece to mill in a proper orientation. These concerns would never materialize in a purely digital process. Unexpected outcomes often suggest refinements or reconsideration of the underlying intent, which hold the potential to generate new outcomes richer for having been informed by this loop.

Figure 1. Failure highlights misconceptions, forcing reevaluation and evolution (source: Akerworks inc, 2009).

In some ways, the degree of risk or uncertainty is heightened because we work primarily in wood. There is an insistent but variable relationship between medium, production tools, and design process. The density, grain, inherent cell orientation, unexpected blemishes, and other characteristics yield unpredictable results. A piece of wood on the mill does not respond to a set of tool paths in the same way as MDF, plastic, or foam. Wood is an organic material, susceptible to diurnal and seasonal changes tied to temperature and humidity. We get demonstrably different outcomes working with different species, or working at different times of the day, of the year. Certain tool paths will rip a piece of wood in two, necessitating redesign. This relationship is not new by any means. There has always been a necessary connection between what we design — be it architecture or industrial objects — and the tools that produce them.

Wood is our preferred medium in part because we are interested in the ambiguity between using digital and analog tools and methods of production on an organic, previously living, biological form of matter. There is a quality of the uncanny in using digital fabrication on an organic material, similar to underlying dialogs between "nature" and "artifice." But, using wood also makes direct allusion to the history of craftsmanship, insisting on considerations of craft and tradition as we pursue digital | analog technologies. We also simply like working in wood for issues of responsible material sourcing and sustainability at large.

Figure 2. A child's rattle evokes tactile and acoustic responses (source: Akerworks inc., 2009)

Digital fabrication has enabled production of forms and shapes that otherwise simply would not be practical. The mill cuts curving surfaces as easily as straight ones, opening a multitude of formal and tactile possibilities we wouldn't have considered using traditional tools alone. What if we carved wood to fit the shape of your hand? We made a series of baby rattles exploring complex curves, constantly testing and iterating the form. The result is an organically shaped object, comforting in form, but familiar in its wooden materiality. It's a safe material. It's warm to the touch. It sounds nice. The outcome is an object that is inherently grounded. You are compelled to touch it. The sound provides auditory feedback, immediately linking sound, movement, and touch.

Digital fabrication technology also enables mass customization. So far we've primarily explored this through custom engraving. But long-term, there is the possibility of developing our processes such that each item can be unique, incorporating customer-driven ideas and preferences. For the robot, a hundred unique parts are as simply made as a hundred identical ones. Perhaps specific curve profiles or proportional relationships could be defined by an individual placing an order. This poses serious questions about authorship and the role of the designer. In this possible scenario, who is responsible for establishing design intent? Which parameters would we be able or willing to relinquish to the customer? More importantly, what is the benefit? The possibility suggests that the designer's role is to enable a multitude of outcomes rather than advocating for a singular ideal conclusion. This shift in responsibility towards facilitating others to materialize their own design objectives underscores the need for education and cultivation of a design ethos in culture at large.

## TOYS

> I have always wondered whether good educational toys made of wood still have a place in a society overrun with electronics. Of course, all children are thrilled by the latest electronic gimmick, but, as a result, they lack toys that they can grasp with all their senses and that encourage them to experience the world directly. This is a serious shortcoming, since to guide and support is the purpose of education. Toys that children can touch go back to time immemorial and continue to open up new experiences. They will never disappear. --Kurt Naef, "Toys You Can Touch" [12]

Our product development company was established specifically to design and fabricate wooden toys. There has always been a sincere resonance for us about toys as designed objects that have an inherently interactive quality to them. They're not meant to be purely beautiful objects, or even functional ones. There's a sense of discovery and a kind of narrative that develops as a person engages a toy and learns what it's about. The notable Swiss cabinetmaker and furniture designer Kurt Naef began focusing on toy and game design in the 1950's, with a keen interest in geometry, order, and tactile engagement. His design philosophy underscores the

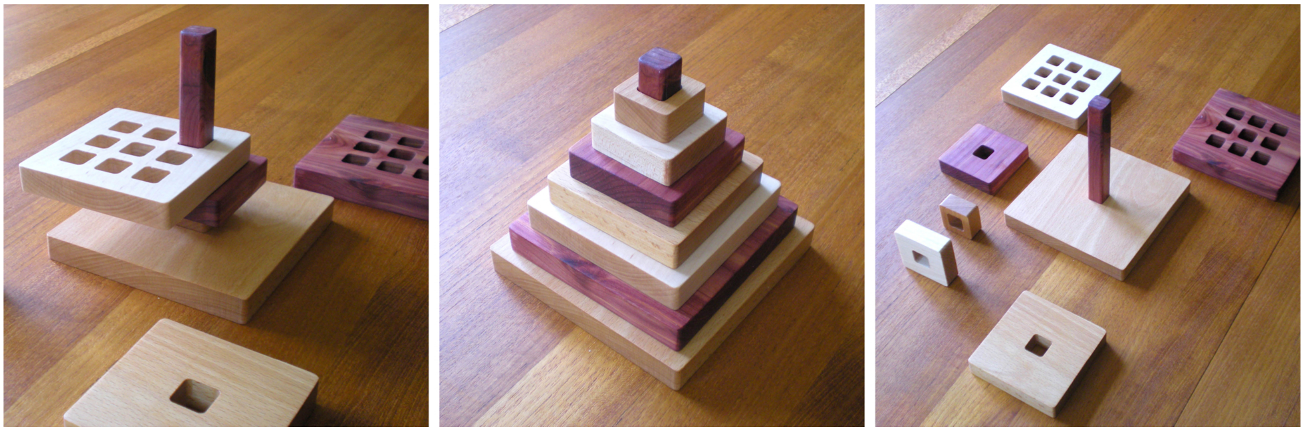

Figure 3. Stacker block system explores how toys might grow with a child's developmental progress (source: Akerworks inc., 2010)

importance of interactivity associated with "toys one can touch" in facilitating mental acuity and direct engagement with the world through experience. This holds merit, and also raises questions of how one might extend this philosophy into a digital | analog experience. Rather than succumbing to the seduction of screen-based games and toys, or retreating to purely inert objects, is there a middle ground rooted in both and resulting with heightened engagement of a sensory and physical experience?

In thinking about toys, we were also struck by the nostalgia or sentiment that surrounds general consideration of the subject. This was disconcerting, as sentimentality can be a warning of misguided intent. But perhaps it's something more. As Baudelaire describes it, the toy takes on a deeper meaning as a child's "first concrete example of art." In his essay "A Philosophy of Toys," first published in 1853, he states: "The toy is the child's earliest initiation to art, or rather for him it is the first concrete example of art; and when mature age comes, the perfected examples will not give his mind the same feelings of warmth, nor the same enthusiasms, nor the same sense of conviction."[13] Children don't seem to express a sense of ownership of their possessions, with the exception of specifically chosen toys. It's a special relationship, much deeper than the ways they relate to most other objects. Comparatively, the rest of us are continually bombarded with things that need to be bought, consumed, and thrown away. There is a human desire to reclaim that state when you cared so sincerely about a few special things. Perhaps this is why toys, for all of us, hold such resonance.

Our focus has expanded to include objects beyond toys, including puzzles, games, and musical instruments, but we recognize that all such work incorporates designing objects of interaction, or things that are animated by how you engage them. One potential definition for "toy" could be: an object that is meaningless without the interaction of its user. Such interaction is not passive; rather it is engaged and can follow a precise choreography, one that implicates object and user in a partnership that melds artificial, cultural, and biological.

Heightening one's engagement with the object can be reconsidered and used productively by designers and makers in the context of consumer culture, an issue that is both massive and disconcerting. We seek to make things that people won't throw away. We develop objects that can grow with a child, possessing latent qualities they begin to recognize differently as they mature over time. In this way, a rattle grows from pacifier, to teething ring, to rhythmical instrument. A stacking block system can be rediscovered to have multiple solutions or can evolve into building blocks as new skills develop. Moreover, by carefully sourcing wood, we use benign materials which can become nutrients for other organisms when their useful life is done.[14] The closer tie between design and fabrication brings these concerns more sharply into focus and illuminates more options for their resolution.

## MECHANICAL IMPERATIVE

It was important to us from the outset to work in wood, for reasons that are philosophical, historical,

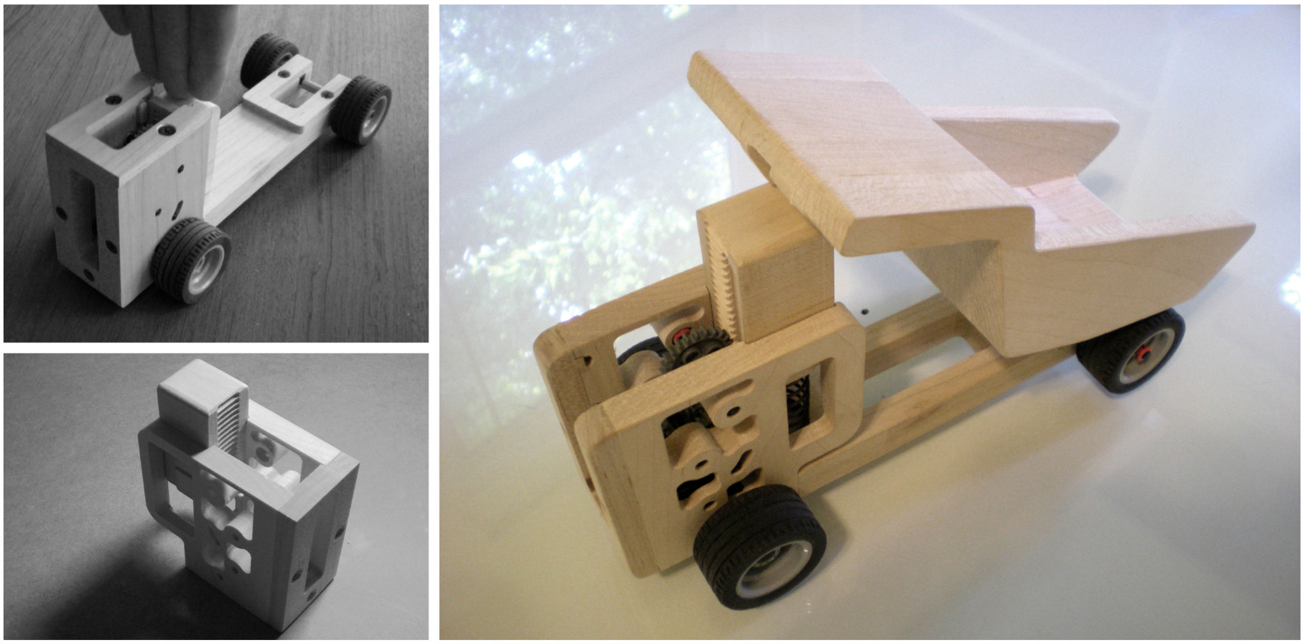

Figure 4. Prototype studies incorporating mechanical systems into actuated toy dump truck (source: Akerworks inc., 2008)

cultural, and ecological. We purposefully engage underlying relationship between material and the resultant object. We continually investigate what kinds of unexpected, mechanically inventive objects might be crafted out of wood. We explicitly look to precedents in the history of simple transfer mechanisms, seeking opportunities to apply them in wood. Herbert Herkimer's *Engineer's Illustrated Thesaurus* (1952) has been an invaluable resource for this inquiry.[15] We are interested in the potential for the mechanical to impact the type of interaction one will have with an object. Incorporating mechanical qualities animates the object and establishes rules of engagement. In the context of a game or toy, this enables the designer to choreograph a precise type of interaction between user and object. One application illustrating this idea is the development of a push-down-and-go toy dump truck actuated by a clutched gearing mechanism fabricated out of wood. Depressing a hinged rear bed loads a spring mechanism that propels the truck forward on release. It also raises the bed up in the process, playfully scattering the truck's payload across the floor in the act of pushing the vehicle forward. The game involves anticipation, projectile acceleration, noise, and a willful progression from order to disorder.

**PLAY**

In this discussion there are two readings of play we should consider. The first involves thinking of toys more broadly as interactive objects that are willfully whimsical. As we have continued developing objects that are interactive, we've found that an iterative process is fundamental to getting the product right. So perhaps another way of thinking about play is to consider this ongoing design process, which is highly iterative, as a type of play.

Product development of this sort allows for a much faster and more direct iterative feedback process than we experience working as architects or engineers. An idea can be quickly modeled, modified, and used to generate a prototype which is then tested, prompting model revisions and fabrication of an improved prototype. Our relationship to the object is 1:1, both in scale and in substance. You find out very quickly what the actual proposed object feels like, how heavy it is, what it looks like in sunlight, what it tastes like, what it sounds like, how it fits your hands. There is an immediacy allowing for a different kind of iteration. It also enables direct feedback from users. Such feedback is fundamentally experiential, rather than being rooted in aesthetic or speculative concerns. In the example of a rattle, the prototype becomes a tool for investigating many questions. What happens when you hand this rattle to an infant? He's not going to read the user's manual. Is it intuitive? Can a small child produce an optimized sound? Does it rely on developing a skill? The feedback from such inquiry quickly generates design evolution rooted in the experiential.

Our iterative process is strongly shaped by the multidisciplinary collaboration between an architect and a mechanical engineer. The significance of this relationship is difficult to address without indulging generalizations, which is not the intent of this discussion. However, the approaches of the architect and the engineer differ, and bringing them together is constructive. We have seen a tendency for the architect to contextualize problems, focusing on technology as a means to address a cultural issue, whereas the engineer tends to optimize solutions, using culture as an opportunity to develop technology. The balance between these two interests in technology and culture is fundamental to our research, but also applicable to broader contexts suggested by themes intrinsic to digital | analog convergence.

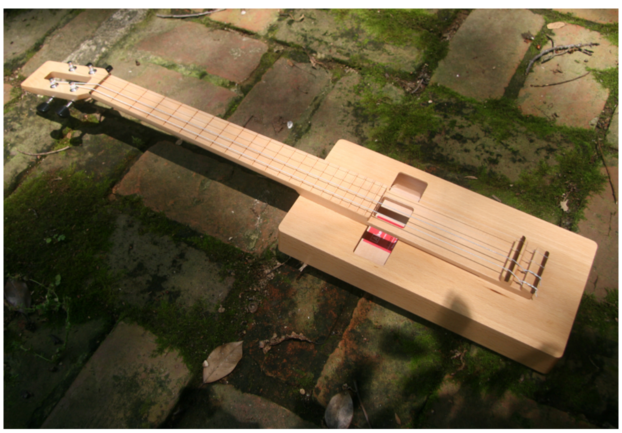

Figure 5. Simple stringed instrument (source: Akerworks inc., baritone ukulele, 2009)

The development of a series of simple stringed instruments illustrates aspects of the iterative design process and potential benefits of multidisciplinary collaboration. Our investigations into children's toys raised the possibility of developing simple stringed instruments which could be open-tuned. Strumming would produce harmonious noise without special knowledge of chord positions or musical theory. This idea evolved into the design of a simple baritone ukulele, a four-stringed instrument with the same fret spacing and tuning of the smallest four strings of a guitar. Proficiency with simplified chord progressions can produce surprisingly rich music. Architecturally, it was important to develop an underlying proportional order and rigor to the object, to engage material decisions, and to challenge assumptions that acoustic stringed instruments need to be round. Mechanically and acoustically, through many iterative prototypes, tuning mechanisms were refined, integral frets evolved, and internal structures were reshaped to better amplify sound. One such prototype incorporates electrification such that this toy-like instrument can be directly connected to professional amplifiers or recording devices.

## DIGITAL | ANALOG CONVERGENCE

Swiss architects Fabio Gramazio and Matthias Kohler use the term *digital materiality* to describe the interplay between digital and material realms in the context of their work. They write: "The synthesis of two seemingly distinct worlds — the digital and the material — generates new, self-evident realities."[16] They resist establishing confrontational attitudes between the digital and the material, opting instead to embrace possibilities of a hybrid condition where process design and digital methodologies create a potentially heightened state of "informed" materiality. An illustration of this idea can be found in their investigation of "super wood" at the Monte Rosa Alpine hut in collaboration with the ETH. Their design of a restaurant interior consists of space frames made of lumber whose surfaces have been CNC routed with stepped ridges, physically superimposing a digital wood grain pattern to actual wood.[17] The resulting heightened condition fuses analog and digital while also playfully challenging traditions of craft and ornament.

Similarly, our work affirms that conflating design intent and methods of production requires a reconsideration of design and craft that no longer needs to separate these fundamentally interconnected realms. The toys we have developed could never have materialized without digital fabrication or absent the tangible feedback of iteratively developing successive prototypes. Virtual informs tangible; tangible reforms virtual. Bringing the discussion back to David Pye's elegant categories, our work is deeply indebted to both the workmanship of risk and the workmanship of skill. There is no need to hold one over the other as being a more pure or more ethical embodiment of craft. As Pye intended, the importance is in seeking to find value in either, sustaining or building upon traditions, rather than letting them be lost or discarded out of a pursuit of blind efficiency or progress. Designers and craftspeople embrace the most appropriate tools available to them, and at times tools themselves are the catalyst for heuristic evolution.

## ENDNOTES

1 For more information on the product development firm and lines of product design discussed, see: www.akerworks.com. All work developed by collaborators Adan Akerman, Jennifer Akerman, Ian Stiefel, and Dori Stiefel.

2 David Pye, *The Nature and Art of Workmanship (*London: Cambridge University Press, 1968. Reprint, London: Herbert Press, 2010), 17. See also: David Pye, *The Nature of Design* (London: Cambridge University Press, 1964. Reprint, London: Herbert Press, as *The Nature and Aesthetics of Design*, 2007).

3 Pye, *Nature and Art of Workmanship,* 20.

4 Pye, *Nature and Art of Workmanship,* 22. In this consideration, there is little that could be accurately classified as hand-made, a point Pye develops further later in the text.

5 Branko Kolarevic, "The (Risky) Craft of Digital Making," in Branko Kolarevic and Kevin Klinger, eds., *Manufacturing Material Effects: Rethinking Design and Making in Architecture*, (New York: Routledge, 2008), 120.

6 Pye, *Nature and Art of Workmanship*, 23.

7 Pye*, Nature and Aesthetics of Design*, 51.

8 See: Fabio Gramazio and Matthias Kohler, *Digital Materiality in Architecture: Gramazio & Kohler* (Baden: Lars Müller Publishers, 2008). The work of Gramazio & Kohler and the architectural research they conduct with students of the ETH continually explores the intersection of design intent and fabrication methodology. See also: Branko Kolarevic and Kevin Klinger, eds., *Manufacturing Material Effects: Rethinking Design and Making in Architecture*, (New York: Routledge, 2008), This text is notable in breadth and variety as it presents many significant examples of ways in which technology is reshaping design and fabrication in both theory and application.

9 Branko Kolarevic, 120.

10 Stephen Kieran and James Timberlake, *Refabricating Architecture: How Manufacturing Methodologies are Poised to Transform Building Construction* (New York: McGraw-Hill, 2004), 25–31.

11 Malcolm McCullough, *Abstracting Craft: The Practiced Digital Hand*. (Cambridge, MA: MIT Press, 1996). Referenced in Branko Kolarevic, 120.

12 Kurt Naef, "Toys You Can Touch," in Charles von Büren, ed., *Kurt Naef: Der Spielzeugmacher: The Toymaker* (Basel: Birkhäuser, 2006), 9.

13 Charles Baudelaire, "A Philosophy of Toys," in *The Painter of Modern Life and Other Essays*, Jonathan Mayne, trans. (London and New York: Phaidon, 1964), 199.

14 Our approach of considering wood as a biological nutrient derives from William McDonough and Michael Braungart's categorization of materials as either biological or technical nutrients which ought to be designed as part of a continual nutrient flow. William McDonough and Michael Braungart, "Waste Equals Food," in *Cradle to Cradle: Remaking the Way we Make Things* (New York: North Point Press, 2002), 92–117.

15 Harold Herkimer, *Engineer's Illustrated Thesaurus* (New York: Chemical Publishing Co., 1952).

16 Fabio Gramazio and Matthias Kohler, *Digital Materiality in Architecture: Gramazio & Kohler* (Baden: Lars Müller Publishers, 2008), 7.

17 Fabio Gramazio and Matthias Kohler, *Digital Materiality in Architecture: Gramazio & Kohler* (Baden: Lars Müller Publishers, 2008), 22–23.