The Unflat Pavilion: Responsive Materialism + Adaptive Fabrication

"As the complexity of our physical and social systems make the world more unpredictable, we have to abandon our focus on predictions and shift into rapid prototyping and experimentation so that we learn quickly about what actually works."[1]

Nick Gelpi
Florida International University

FROM PREDICTION TO EXPERIMENTATION

The statement above comes from The Stanford Social Innovation Review, an online journal dedicated to non-profit business operations. The statement calls for business leaders developing strategic plans to abandon them in favor of rapid prototyping, the underlying message being it isn't enough to come up with a 5-year strategic plan and wait to see how it goes, rather come up with immediate goals and act on them now, the future won't wait. Citing several examples of businesses whose markets quickly changed while they stuck to their long term business models, think Barnes and Noble in relation to Amazon, or Blockbuster video to Netflix, the authors argue for having a mobile strategy capable of rapid response and adaptation.

With this in mind the authors recommend a redefinition of "Strategy" from the age old practice of strategic planning, as fat binders which sit on the shelf, in favor of a new attitude towards a practice of rapid prototyping.

Strategic planning is really just military strategy, "...setting objectives, collecting intelligence, and then using that intelligence to make informed decisions about how to achieve your objectives, take that hill, cut this supply line."[2] Historically, intelligence was difficult to gather and relatively speaking the world wasn't a fast changing place. As a result strategic plans were effective for a great number of years.

Arguing that the future is more unpredictable now than ever before, as a result of technological change, climate change, and social media, the old method of devising a strategic plan based on some concrete notion of the future is dead.[3]

The authors argue that the flaw in this model is that the target is now moving, and just as we didn't plan for climate change 100 years ago, we can't adequately plan for a future unknown with a static plan, the implication being that the past is no longer a good indicator of the future.

The article argues that business leaders shouldn't freeze their strategic thinking in a five-year plan, rather focus on the present with a strategy for being adaptive and directive, that emphasizes learning and control and reclaims the value of strategic thinking for the present world in what's termed an Adaptive Strategy. [4]

Architecture is a historically based discipline based on codes, strategy and intelligence gathering, whose strategies take the shape of plans which typically take several years to implement much like a strategic plan.

If architecture can benefit and more quickly adapt to contingency through prototyping, what are its historical evidence and future directions?

This paper presents a series of curious case studies including a recently constructed pavilion, both as a design process and as a constructed form, which embodies situational design methodologies indicating a shift in design tendencies from something static to something adaptive, or from something ideal to something contingent and reactive to prototyping and re-evaluation. These case studies don't necessarily respond to changes in social media or technological growth, however they re-evaluate the use of familiar materials finding new ways of achieving unexpected results from them. These examples represent shifts in tendencies towards new protocols for design and prototyping, the Personal, the Soft, the Reactive, the Material and the Unflat.

Perhaps in a subtropical environment buildings can look for innovative methods of fabrication using the materials already around us to achieve new results, which better allow us to respond to a changing future and environment through a practice of adaptive fabrication.

ATMOSPHERIC MOCKUPS

The following two projects, while quite similar document 2 promising methods of fabrication in which material is mined for its ability to behave. Instead of detailing which reduces the inherent range of material behaviors, the following two projects place their behaviors on exhibition. Much research has been done into the following topic as of recent, projects allowing for a more active responsiveness between material and environment, something Omar Kahn refers to these as 'reflexive architecture machines.' [5]

This research distinguishes itself, in that it redefines the unresponsiveness of building material, in favor of more flexible, resilient, and modest structures with techniques based on verification and feedback in the field.

Plywood is actually engineered to resist deformation. The laminating of veneers with cross grain orientations engineer plywood to become stabile and resist warping. The following two projects reorganize plywood's constructive formula to encourage the warping and range of positions the plywood was originally intended to resist. Wood is biological material after all; it is a tree, formed in response to environmental stimulus.

These projects support an empirical embrace of prototyping as an agent of design decision-making. One which takes into account the various effects that atmospheric conditions exert on physical prototypes.

WARPED EXHIBITION

Warped was an exhibition of research by Matthew Hume from the university of Buffalo in 2008. Hume noticed the effects of reorienting the grains of the

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various veneers of plywood construction, which made it less rigid and more prone to warping in specific ways, particularly as the weather changed. Hume developed a panel which can connect to other panels in series to construct structural sectionsand as they are exposed to varying degrees of humidity, or atmospheric moisture they slowly twist independently and collectively deform as a whole. What's explicit here is that materials are not inert, rather they will move and in fact Hume encourages them to move, designing with this observed behavior as an ambition. This effect was accomplished by re-examining plywood manufacturing methods.[6]

Steffan Reichert's Responsive Surface structure project focuses on the reactive natures of materials as design applications. The project is specifically about the material system's reactivity as proof of concept, but it is easy to imagine various architectural applications for such a system. Reichert investigates how varying thicknesses and fiber direction effect the shape of materials as varying degrees of humidity are encountered. The project is described by its author as 'containing a high level of integration of form, structure and material performance thus enabling it to respond to environmental influences without the need for additional electronics of mechanical controls.'[7]

Allowing material prototypes to adapt to environment could become quite useful in a post disaster scenario when a power grid is often disrupted. Perhaps designing for the implicit behavior of material and fine tuning for specific environments allows a system to remain functioning even when there is damage to regional infrastructure.

Figure 1: Unflat Pavilion during the day

Bothof the previous projects are based on some empirical observation about the behavior of materials and their interactions with environment.Both projects take into account predictability and planning, but with a deference to the rapid feedback of the physical prototype. These projects demonstrate a new type of prototypical thinking, in which they wouldn't be possible without the physical mockup. In fact there is a requirement in these examples that something be made or manufactured to physically observe its performance. These mockups demonstrate new insight into design, mapping the feedback between representation and specific material.

FABRICATION

Digital fabrication allows for design customization in the tradition of DIY, and provides a more flexible means and methods for working with non-standard construction and assemblies allowing a more extensive understanding of the way materials behave, whereas off the shelf components and systems approach materials from a perspective of standards, averages and mass-markets, not allowing for subtle nuances or adaptations to environment.

Fabrication is a big word and has many contexts, whose instrumentality isn't a solution to any problem on its own, however methods of doing research using digital fabrication may suggest potential shifts in approach towards prototyping from a rapid perspective.

Two graduate level university seminars, offered at the Massachusetts Institute of Technology, demonstrate two complimentary approaches towards utilizing digital fabrication as design research. These complimentary modes of fabrication each situate prototypes within a pedagogical context suggesting how Digital Fabrication functions as a model for research by combining new tools and techniques with a more nuanced approach for understanding and mediating materials and their behaviors.

PERSONALIZED FABRICATION

The first is a class titled How To Make Almost Anything, offered at MIT's Media Lab by Professor Neil Gershenfeld. Gershenfeld's class teaches students how to use an existing suite of fabrication tools for the purpose of making things. This pedagogy engages students with direct and hands on experimentation with materials and technologies that leads to developing a different type of knowledge and judiciousness. In this class it isn't enough to simply have an idea for a design, rather the design must be fully operational in order to be successful. According to Gershenfeld, the humanist distinction between the "liberal arts" and "illiberal arts" separated making ideas, from the making of things.[8]

Students are led through a series of weekly demos and exercises, for example the laser cutter is weekly topic number 1. Students are taught how the laser cutter works in two ways, first how to use it to make something each student designs, but then also how it works and how one could make their own laser cutter from scratch if desired. Final projects in Gershenfeld's class require students to use a combination of tools learned in the class to make something which they couldn't otherwise purchase on the market. A democratization of technology, Gershenfeld believes rather than relying on large market manufacturers for the masses, individuals should have access to the tools necessary to invent their own technologies and applications for a market of 1. A customized product or


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technology developed from scratch. Gershenfeld discusses his fascination when observing students using computation and advanced fabrication tools to make products for a market of one, instead of one-million, a practice he refers to as "Personalized Fabrication." (pp21)

For Gershenfeld if libraries are historically the places for communities to access information and knowledge for the purposes of personal education, fab-labs are the new places for learning the new knowledge of fabrication for personal innovation.[9]

SOFTWOOD

A second course was a class called Softwood offered at MIT's Department of Architecture in the spring of 2011 co-taught by myself and Sheila Kennedy. Softwood was a workshop/seminar conceived of to rethink wood and its soft processes. Wood is increasingly something viewed as a rigid material to be used in rigid applications with a disregard for the variety of soft attributes that wood possesses. 3 Soft objectives laid the foundation for the course. First the distinction between the families of Soft woods and hard woods encouraged students to look at the deep structures of wood, as not all woods are created equally. Softwoods are usually the non-decorative species coming from the Conifer family, most often used in the back-of-house applications. Typically softwoods are not exposed, but rather used as subflooring or sheathing for their performative values, as opposed to their decorative cosmetic potentials. While Softwoods are Low-cost and more quickly regenerative, the course also investigated the Soft Energy Path, a discourse articulated by Sheila Kennedy referencing Amory Lovins' text advocating a soft approach to energy consumption favoring renewable sustainable options as opposed to the Hard paths which rely on fossil fuels and ultimately nuclear power.[10]   The last of the 3 Softs is the use of Software to interact with wood material articulating a shift from the hard tools and industrial equipment used to manufacture wood products towards computation and the processes of digital fabrication asking what new potentials existed across these three conceptual territories. Students examined a range of furniture projects from the 1940s-60s which began bending and deforming wood on an industrial scale, and looked to at how to isolate and redeploy various woodworking processes as softly as possible.

Figure 2: Molded plywood profiles testing the material to find its failure point.

Digital fabrication allows for design customization in the tradition of DIY, and provides a more flexible means and methods for working with non-standard construction and assemblies based on a more extensive understanding of the way materials behave, whereas off the shelf components and systems approach materials from a perspective of standards and averages, not allowing for subtle nuances or adaptations to environment.

These courses each situate rapid prototyping in a complimentary pedagogical context suggesting how Digital Fabrication functions as a specific model for research by combining new tools and techniques with a more nuanced approach towards understanding and mediating materials and their behaviors in specific ways.

UNFLAT PAVILION

The Unflat-Pavilion is a large scale inhabitable pavilion designed and constructed based on the observation of a certain materials ability to behave, in this case plywood's ability to flex.

A small size / full scale mockup was conducted to demonstrate a range of positions for a thin plywood membrane digitally perforated and then flexed to allow flaps to open up in relation to bending. This sketch of performance suggests a material property and the range of geometries it is capable of. Great effort was taken to scale up this range of behaviors, first as small sized objects, and then again at the scale of building form. Careful observations and iterative studies led to a relative definition translated into digital form which was able to link the tangential strain relief pattern with the bent position of the membrane as something reactive. As the bent section was redefined the flaps would respond to different positions based on a relative tangent angle to the curvature of the section. As the plywood flexed the pattern would expand and allow greater transparency.

The physical flexing of material became the generator of the pavilions shape. Present from the beginning the ambition was to construct a pavilion utilizing the physical range of behaviors of a given material, privileging physics over optics.

Careful study of flexing occurred at a small scale, after which the design development phase increased the scale of this behavior to the size of an inhabitable pavilion where it is merged with a building's form. Various advanced modeling and analytic software were utilized in support of the design, with an anticipation of material behavior present from the beginning.

The design and fabrication of the pavilion combines characteristics of both personalized fabrication as well as an understanding of material potential energies and techniques for capturing these behaviors.

The design of the pavilion is a large scale generic house section mediated through the behavior of its materiality. The house section was revised several times based on the physical ability to bend plywood into its shape. What results is a mediated shape, a negotiated condition blended from the specific geometry, and the plywood's ability to define that shape based on the physical behavior of material. Several times the section needed to be redrawn based on the observed bending radius of materials at various scales, and then finally at full scale based on the specific wood-species of tree used.

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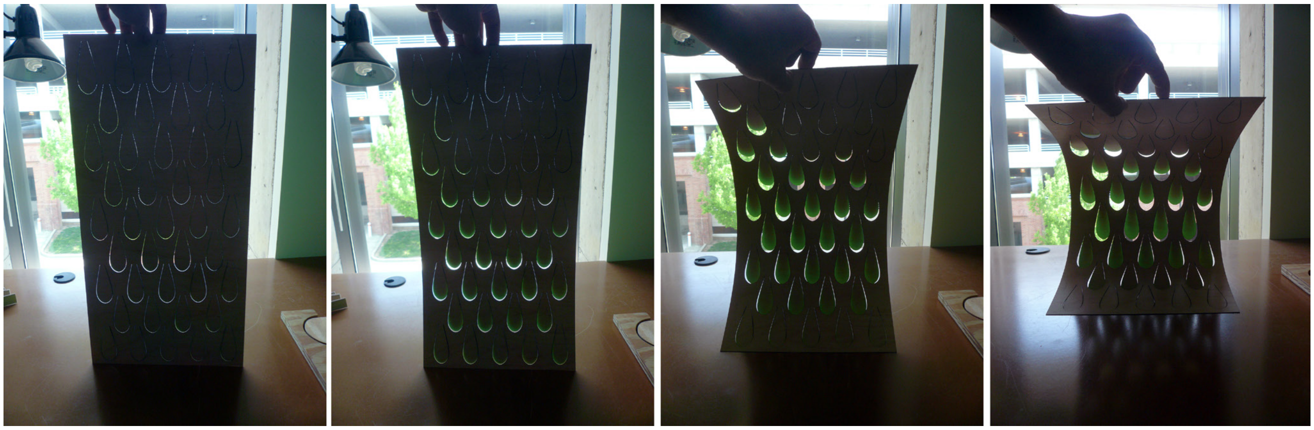

Figure 3: Plywood Flexure demonstration.

WOOD IS A TREE

Materials were tested for their ability to simultaneously be flexible enough to bend yet be rigid enough to support load. Indeed multiple species of woods were tested, Marine Grad Merranti, Rotary Cut Lauan, Verticle Grain-Douglas Fir, Flat Sawn-Ash, Italian Poplar, Rotary Cut-Okoume, and finally settling on Baltic Birch. Different species demonstrated differing capabilities. Several of the discarded species were able to bend to the shape of the pavilion, but were too flimsy to prop it up. Several other species were too rigid to accommodate the bending radii of the sections, so they had to be revised. Baltic birch was the most resilient, able to be bent, although requiring greater force, but also able to support load on its edge condition. All of these wood specimens look approximately the same with slight variations in grain and tone, but while they look more or less the same, they perform with radical difference. Some buckled, some sagged, and some shattered into pieces, all symptoms of specific performance unrelated to the image of the building.

In the introduction to Mike Cadwell's Book Strange Detail, Nader Tehrani discusses the scenario in architecture where the architect has significantly been disempowered by a divorced relationship between the means and methods of construction and the image of a building. Tehrani states, "

> *"The architect is charged with the design; the builder is responsible for the means and methods of its construction-as long as it remains faithful to its 'design intent'. While this legal provision may seem a guarantor of design implementation in general, it significantly disempowers the architect and presents several theoretical predicaments....First, the law effectively severs the architect from the "specific" relationship she or he can construct between the technical specification of an artifact and its corollary effect-the assumption being that the architects investment is in the image and its rhetoric, not in its constructive makeup. Second, it further problematizes the relationship between design intent and material construction... as if to suggest that any detail or any material will suffice, so long as the general effect is delivered."*[11]

There is a strong argument here for forging stronger relationships between design as the production of images and actively engaging the means and method of construction by which that image is translated into reality.   This pavilion takes the deformations of specific materials as its generator of shape. The flexing becomes not the representation of shape, rather a posture or a position selected from a range of possible positions which aren't flat.

For another example of this effect, see Frank Gehry's I.A.C. Headquarters in New York City, in which full story sheets of glass are evaluated for their flexibility and deployed across the envelope of a building. Having premeasured the flexibility of the sheets, to a set of behavioral bending radii, the angles can be implemented and arranged in space. The glazing panels are actually clipped into place on site and two benefits are achieved, first the typical backup structure necessary prevent the material from deflecting is minimized resulting in a more efficient framing system, second the thin material gains additional rigidity by being placed into a bent position.

Observed in the small scale mockup of flexing and bending, strain relief flaps unflattened at tangent angles to the surface, this unflattening of components occurred in relation to the flexing of the plywood. Likewise at the scale of the pavilion, there is reciprocity, where the shape of the house effects the position of the flaps as they unflatten.   The plywood flaps act as structure, column, buttress, windows and vents, gaining their independent roles only as they unflatten and find their position in space.

Compositionally and structurally the plywood skin demonstrates a role reversal across its elevation, on one end being hung on a structural frame, and on the other actually lifting the weight of the frame with its precise tangent angles to the ground, inverting the normal relationship between curtain wall and frame. The skin which is normally hung like a curtain, actually lifts and suspends the frame, rendering the support as an excess of the system. While the appearance remains consistent there is a radical difference of force occurring within the skin of the pavilion, shifting from tension to compression. Several key details were developed to reinforce this moment of Force inversion.

FABRICATION

The pavilion pioneers a flat to form fabrication methodology, which links the unflattening of parts to the demands of structure and shape. Individual panels were unflattened, as part of an automated process of designing between 2d and 3d, and prepped for readiness to be milled on a computer numerically controlled (CNC) milling machine. Custom tabs and slots were designed to allow the frames to be able to capture the bending skin at various positions. These details were coordinated to be able to slip-fit together secured with minimal set screws. Of course most projects utilize details which allow for materials to cycle through their various phase states, think of expansion joints, control joints, gaskets...etc, however in these cases details are deployed to mitigate the deformative effects that the material properties may have on the ideal image or shape of the project. In this application, considerations of panel length, curvature, flap location and fastener coordination were combined into the process of design and the automation of fabrication output, with full scale behavior anticipated from the beginning by sketching with material performance. Individual sheets are fastened to the inside or outside of a frame with each side creating a double layer sandwich, connected at the edges and at the flaps. Individual sandwich panels are stacked horizontally and vertically essentially constructing a vault.

UNFLAT

This pavilion project is different from many other projects in that it doesn't' go through the standard flattening procedure of manufacturing. Typically

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even complex shapes and forms are rationalized into flat planes...a process called penalization. These planes are then arranged on site to build up complex geometries, but at the scale of the panel, everything is flat. The Unflat pavilion never goes through the flattening process, in fact it takes flat material stock and pre cuts it using a combination of computer modeling and projection in space. A 3Dimensional model is built in the computer simultaneously as a flat sheet and an unflattened form. These panels come out of the fabrication lab and go directly into the field where they are literally unflattened into shape.

The pavilion is titled "UNFLAT" because it refers to the process of taking the design off the flat page of representation. Without waiting for the years of construction to see how it will perform, this design is quickly mocked up from the beginning instrumentalizing behavior and performance from the beginning. The drawings are also uniquely unflat here, similar to a Hologram, where 3Dimensional information is embedded in a 2dimensional plane. Each of the buildings features, columns, buttresses, windows and vents are embedded on the flat sheet, finding their position as the wooden skins are unflattened on site.

Figure 4: Full scale flexing of roof peak sandwich panel for the pavilion.

The pavilion embodies 5 design-shifts away from an unresponsive project, as the combination of these various shifts contribute to a discourse based more broadly on adaptation: the Personal, the Soft, the Reactive, the Material and the Unflat.

Perhaps in a subtropical environment buildings can look for innovative methods of fabrication using the materials already around us to achieve new results, which better allow us to respond to a changing future and environment through a practice of adaptive fabrication.

ENDNOTES

1. O'Donovan, Dana + Flowers, Noah, "The Strategic Plan is Dead. Long Live Strategy." Stanford Social Innovation Review Online, http://www.ssireview.org/blog/entry/the_strategic_plan_is_dead._long_live_strategy (accessed 8/6/13).

2. ibid

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Prototyping provides us with a model for rapid collaboration with materials and performance. Collectively these various innovations constitute a shift towards a new design practice which allows for feedback of environment and material. As contemporary practice evolves technologically and climates continue to change, the very nature by which we test and materialize our designs also shift. These projects demonstrate how being acutely aware of the behavior of different material species and their properties, can be advantageous economically and suggestive of new forms. Certainly observing the mechanical and physical properties of matter aren't all that's required to adapt to an uncertain future, but perhaps these insights into the nature of materials and the behavior of the world can help assure new collaborations between objects and the environments we inhabit. This suggests that the environment plays as large a role as our discursive sensibilities, and as one changes so too must the other. This evolving collaboration with prototyping does the work of fine tuning form for environment and material, and this work is the focus for understanding the new possibilities for adapting to a climate which isn't ideal rather contingent and always changing.

Figure 5: Unflat Pavilion wall section suspending the frame above the ground.

3. ibid
4. ibid
5. Kahn, Omar, "Reflexive Architecture Machines," University of Buffalo, Lulu, 2008;
6. Hume, Matthew, "Warped; Experiments in Ply Construction," University of Buffalo, 2008, Lulu, 2011;
7. http://www.achimmenges.net/?p=4638, (accessed 8/6/13).
8. Gershenfeld, Neil A."Fab: The Coming Revolution On Your Desktop-From Personal Computers To Personal Fabrication;" New York, Basic Books, 2005; (pp7, 33-42).
9. Gershenfeld, Neil A."Fab: The Coming Revolution On Your Desktop-From Personal Computers To Personal Fabrication;" New York, Basic Books, 2005; (21).
10. Amory Lovins, "Soft Energy Paths: Towards a Durable Peace;" Harper Collins (1977).
11. Tehrani, Nader, "A Murder in the Court," in Cadwell, Mike; "Strange Details;" Cambridge, The MIT Press, 2007; (ix).