Digital Tools, Distributed Making & Design

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MS ARCH THESIS 2009

DIGITAL TOOLS, DISTRIBUTED MAKING & DESIGN

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MS Arch Thesis
Virginia Polytechnic and State University
Blacksburg, Virginia
December, 2009

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ABSTRACT

Given the current trends with digital fabrication and communication technologies, change in the manner and means of physical object production is clearly on the horizon. Recent peripheral projects show how access to digital fabrication and communication tools pull information for making toward the user, and enable the distribution of information and product outward. They also demonstrate vibrant user innovation in smaller scale projects for both personal and commercial applications. These current trends and peripheral projects are then used to help locate where design and designers may find areas of growth in a potentially less-centralized, and more varied landscape of product development and production in the future.

DIGITAL TOOLS, DISTRIBUTED MAKING & DESIGN

In the past, art became separated from artisans and mass manufacturing turned individuals from creators into consumers. In the future, there will be universal self-reproducing molecular fabricators. In the present, personal fabrication has already arrived.

Neil Gershenfeld *Fab*

CURRENT SITUATION

APPENDIX A
PRELIMINARY EXPERIMENTS

APPENDIX B
PRIMARY PROJECTS

INTRODUCTION

The computer is a machine that meets Marx's definition of an artisan tool: it is an instrument that responds to and extends the productive capacities of the user.

Michael Piore & Charles Sabel *The Second Industrial Divide*

This project developed out of my work with digital fabrication, and from two projects in particular; one with Portland Cement Co. in Portland, Oregon and the other with the Exploratorium in San Francisco, California. Curious about the relevance of these digital fabrication explorations in a broader context of design and production, I began to research other examples of its use. What I encountered was an ever larger and inter-connected array of technologies, disciplines, and motivations driving individuals toward digital fabrication. What I found leads me to believe that we are at the beginning of some profound changes in the ways we create and consider the physical objects around us.

DIGITAL TOOLS AND DISTRIBUTED MAKING – OR, WHAT THE CRACKS IN THE PAVEMENT OF CENTRALIZED PRODUCTION ARE SPELLING OUT FOR US.

With the confluence of digital fabrication, platforms for collaborative communication, and open-access approaches to development and production, real change seems inevitable in both the manner and means of how we design, build, and then propagate ideas about the physical objects in our environment. In this paper, I show that who makes and how they make is shifting away from the sole domain of the professional and the large producer to include multiple layers of interested and productive individuals. By using examples of current peripheral projects as future indicators, I point to possible emerging sites of new activity for design and designers in the future.

Not unlike the commercial and professional changes brought about by the advent of desktop publishing in the 1980s, the combination of digital tools for content creation, output, and communication in the hands of the masses are in the process of helping to redefine the structures behind our culture industries. Current social changes bear this out, whether these industries are text-based (publishing, journalism, graphic design), image-based (photography, video), audio-based (music), or now object-based.

In order to show this, a few things need to be defined, determined, and discussed. Firstly, what are these changes and where are they happening - descriptions of some of the current technologies and trends in making and digital fabrication. To paraphrase one design and research group, what is happening on the periphery is the near future already here. Secondly, how did this happen? The social and technological developments and drivers thought to be enabling this redistribution of making. Finally, what does this reveal for designers interested in this digital and cultural restructuring surrounding the creation of physical objects? Areas of potential growth for design and designers are identified.

THE NEED FOR A BETTER DESIGN DISCOURSE

Design discourse that considers digital fabrication in light of the culture-making and social aspects inherent in the planning and making of things is currently neither particularly well-known, nor well-documented.

Unlike digital fabrication associated specifically with architecture, which for more than a decade has had numerous articles, books, exhibitions, conferences, and university programs devoted to it, a thoughtful and informative discourse of digital fabrication and design that encompasses the scale of objects is scattered across enough disciplines as to be relatively thin in comparison. Texts concerning digital fabrication of this scale and type have instead predominantly focused on the technical and commercial aspects of these tools, while discussions of its development do so largely from the perspectives of engineering or industry interests.

This is not to say that information about digital fabrication and the design of material culture is absent. In fact, it is readily found - albeit often in a cursory manner. There are magazine articles, and online platforms highlighting architects, artists, and craftspeople working within the medium. These forums also include discussion about design exhibitions, and depictions of digitally fabricated art and design objects. There are architecture and design firms documenting their digitally fabricated projects, and design schools outputting a host of digitally designed and fabricated objects while collecting instances of others doing the same.

Digital fabrication and design surfaces as a sub-topic within sustainability issues in professional design discourse, usually as a means of controlling the use of raw materials and energy. While from a sideways perspective, speculative fiction has readily embraced digital fabrication in a culturally considered manner through inspiring notions about the future. However, a more thorough discussion from within the field of design and that extends beyond an immediate documentation, or which is otherwise content-rich, has only recently begun to emerge.

On the whole, designers are poorly represented in the ongoing expansion of digital fabrication into the wider culture. C. Sven Johnson points this out in his recent experiment at kickstarter.com where he attempted to crowd-source financing for an open-source CNC produced toy design.

> If you've wondered why there are so many other creatives on the internet but so few product designers, here's why. We're tied to corporations. We're tied to manufacturing processes... Until manufacturing processes become more fully democratized, the profession will remain largely beholden to the corporations who own the factories and can pay a salary; either directly through employment or indirectly through design firms. (Johnson)

Consequently, it is the makers and engineers, the artists and entrepreneurs who have been most actively engaging with these new technologies. If more designers were to escape from their professional practice long enough, they would likely find a new landscape of digital development and fabrication ripe for experimentation.

CURRENT SITUATION

Meticulous, yes. Methodical. Educated. They were these things. Nothing extreme. Like anyone they varied. There were days of mistakes and laziness and infighting. And there were days - good days - when by anyone's judgment they would have to be considered clever. No one would say that what they were doing was complicated. It wouldn't even be considered new. Except for maybe in the geological sense. They took from their surroundings what was needed and made of it something more.

from the movie *Primer,* 2005

DEFINITION OF THE TERMS DESIGN, MAKER AND DIGITAL FABRICATION

This discussion concentrates on that which is happening along the margins of art, design, industry and craft. Therefore, the terms and tools described favor those commonly adapted for these currently less commercial, non-traditional, or peripheral applications.

Design: The planning and fabricating of things that considers their aesthetic, symbolic or semantic function.

Maker: One who undertakes the planning and fabricating of things generally outside of professional settings or roles.

A narrow definition of professional industrial design would cover the design and production of durable consumer goods, particularly electronics, house wares, furniture, sporting equipment and automobiles. It would also include some rather lucrative industry goods such as medical devices, and interior design products. In some instances industrial design may concern the distribution, display, or marketing processes that are intertwined with a particular product or idea, thus incorporating packaging, exhibition, interior and graphic design as well. As it exists professionally in all these instances, industrial design is often viewed as the value added to those objects that are by virtue of their market, capable of supporting such cost due to their higher social value.

Considering design in a broader sense, however, in his book on the history of design, Thomas Hauffe describes the 1980s as the time when the borders between art, craft, industry and design began to dissolve. Where during the 19th century, "in the process of transition from handwork to industrial production, conceptual work began to separate itself from work by either hand or machine." (Hauffe 20) By the later 20th century, design was understood to include the "drafting and planning of a product or service" (Hauffe 16). Now, with digital tools for both planning and physically producing objects becoming more common, not only is mass-production no longer a determining factor in design, but so too is the separation between conceptual planning and physical making falling away.

In light of the variety of what the term design seeks to include, and the blurring between design-related disciplines in digital fabrication projects, a better definition is needed to describe the changing field of practices and products that make up any current act of design. Consequently, in this paper the term design aims to refer to the planning *and* the fabrication of things, where the function of the object is considered beyond that of the technical or ergonomic, but in its aesthetic, symbolic, or semantic function as well. And in keeping with the popular use of the term 'maker,' this word refers to those who undertake the planning and fabrication of objects generally outside of professional settings or roles.

Digital Fabrication: The making of physical objects through the use of computer-controlled tools.

Digital fabrication requires a relatively complex set of operations to accomplish. First, a digital model is created using specialized software. The geometric information from the digital model is then translated into instructions for tool paths and related tooling information. Any tooling or material setup is readied, and the instructions are communicated to the tool and then run. Each type of computer controlled tool has its own specific approach, but most rely on a robotic head that traverses a spatial grid based on coordinate instructions, and which deposits, cuts, or otherwise manipulates material. (Loukissas 2)

Digital fabrication tools are categorized by the manner in which they are controlled and the way in which they manipulate materials. These categories are not always clearly bounded and there is overlap where tools may work in ways not adequately defined by the category. In general, there are currently two methods of digital fabrication: solid free-form fabrication, and CNC (computer numerically controlled machining tools).

Solid Free-form Fabrication

Solid free-form fabrication refers to what are currently called rapid prototyping and manufacturing (RP&M), or additive, processes. These tools create complex three-dimensional objects by successively layering up (adding) material into a complex physical form. They are comprised of an enclosed build-chamber, robotic head and material feed system, which is attached to, or includes a computer control interface.

Common methods of solid free-form fabrication are 3D Printing (3DP), Selective Laser Sintering (SLS), Stereolithography (SLA), Fused Deposition Modeling (FDM), and Laminated Object Manufacturing (LOM), among others. Each of these methods automatically details a digital 3D model through the tool's associated control software as a series of thin, horizontal cross-sections. These slices are then physically built-up from adhered powders of plaster, cornstarch or other resins in 3D Printing, or as laser-fused powders (polymers, ceramics, metal alloys and composites) for SLS. SLA methods are confined to laser-cured liquid resins, while FDM uses extruded filaments of thermosetting materials (ABS, epoxy). LOM adheres cutout cross-sections of paper, polymers, ceramics, or composites. (Schodek 281-293) In the active open-source maker communities of RP&M machines like RepRap, Fab@Home, and CandyFab, similar processes to FDM and 3DP use materials that users are able to configure themselves, ranging from chocolate to catalyzing plastics.

RP&M are largely hands-off machines in that the processes cannot be modified on the fly while the job is in progress, and are only minimally configurable with the software that controls the machine. Reportedly, only the very costly industrial versions and the relatively cheap DIY open-source varieties encourage user control over the fabrication process. This means the quality of the finished product is largely determined by two factors: the geometry of the digital model before it is sent to the machine and the machine's default capabilities to handle it.

Two main drawbacks users continue to struggle with in free-form fabrication are imperfect surface resolution that results in stair-stepped vertical curvature, and the overall size constraints of the build chamber. There is also an underlying issue that these processes must overcome, namely that today's additive processes primarily build objects from a single, inert material. Though developments are on the horizon, it is beyond most of these machine's current capabilities to create objects, like integrated circuits, from combinations of material properties and behaviors within a single fabrication job. (Gershenfeld 101) Nevertheless, the diminishing costs of these machines, and their increasingly desirable output coupled with ease of use have led them to be adopted into numerous environments whether professional, educational, industrial or residential.

CNC

All other digital fabrication is accomplished with CNC or CNC-like tools. Traditionally, these have been computer-automated machine tools that use coded operations and processes for precise tool control and require the running of a set of programmed commands for each part fabricated. Less formally, CNC is considered as any tool-like process that is a computer-controlled series of operations and movements.

Much more configurable and diverse than RP&M, CNC tools may in fact be materially subtractive, additive or otherwise manipulative. Subtractive CNC tools used in design and making are multi-axis milling, routing, and turning machines, laser cutters, sign cutters, hot-wire foam cutters, plasma cutters, and water jet cutters. Additive and manipulative CNC tools include benders, sewing machines, welding machines, and robotic arms capable of multi-axis movement with various tool attachments.

All types of digital fabrication require that the digital geometry is appropriate to the tool and is adequately communicated to it. For CNC, the creation, manipulation, and conversion of digital information are accomplished with a combination of CAD/CAM software (Computer Aided Design /Computer Aided Manufacturing). For standard machining processes such as milling, turning, drilling, etc., CAM software is used to generate a set of coded operations and processes from CAD-created geometry. These commands are then output to the tool via a programming language, often g-code or related language that precisely describes tool paths, feed rates, and stock material placement. Solid free-form fabrication and the CNC-like tools (e.g. laser cutters) are different, however, in that they usually incorporate the CAM operations directly into their functioning. Acting more like desktop text printers, they automatically convert the sent data into a particular output with little user control over the method.

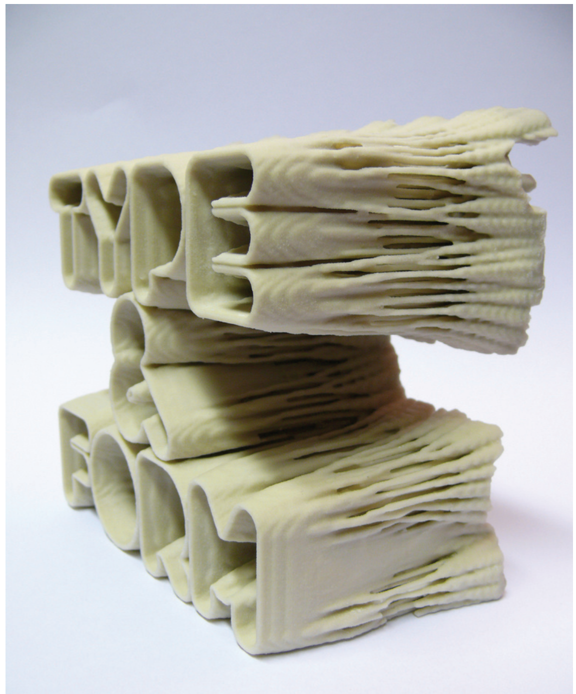
DIGITAL FABRICATION ON THE PERIPHERY

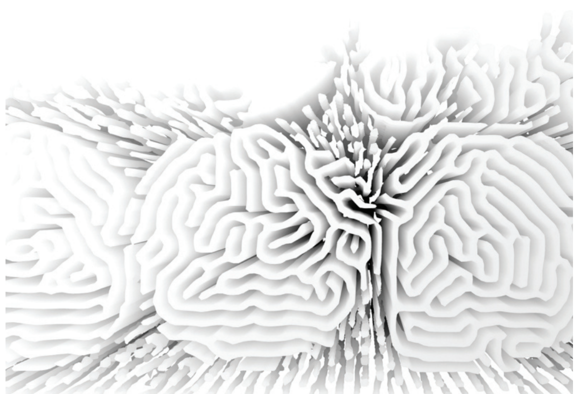
Digital fabrication tools are used in numerous industries and by a wide variety of professionals. These range from machinists using CNC mills to fabricate parts for use in the aerospace industry to industrial designers 3D printing medical equipment prototypes. It is, however, what lies outside of, and along the edges of the generally closed, commercialized and highly professional environments that the energy of innovation can be seen. In the natural overlaps between art, craft, industry, and design, individuals are producing objects that deserve closer scrutiny for the potential variety of output enabled through small-scale production facilitated by digital communication and fabrication technologies. "Personal fabrication is said to be the killer app of the 21st century, and it's not just because people like to make things, it's rather because everybody has a problem these tools can help to solve." (*Digital Fabrication Primer*, P2P Foundation)

The following pages include some examples of the current breadth of innovation with digital fabrication on the periphery in design, business and through the networking of individuals and facilities. These are Karsten Schmidt of PostSpectacular; the design-build furniture company Unto This Last; artist Bathsheba Grossman; jewelry designers Jessica Rosenkrantz and Jesse Louis-Rosenberg of Nervous System; industrial designer Ronen Kadushin; the Fab@Home open-source project; the non-profit network100K Garages; accessible workspace ProtoSpace; and the online fabrication service, Shapeways.

Karsten Schmidt / PostSpectacular

Graphic and interaction designer, Karsten Schmidt collaborated with the fabrication service ThingLab UK to generatively 'grow' physical typographic forms for the award winning August 2008 cover of Print magazine. Schmidt describes the series of coding operations he used to develop the final form on the PostSpectacular blog as beginning with a two-dimensional kinetic image of the type form. Schmidt converted the developing image as a series of frames, translating each from grayscale into a volumetric density that when stacked as slices formed the three-dimensional figure. He mentions this process as similar to MRI imaging. Schmidt worked onsite at ThingLab to physically produce the 3D printed form on a ZCorp printer, with ThingLab helping to overcome fabrication issues with model complexity and material constraints.

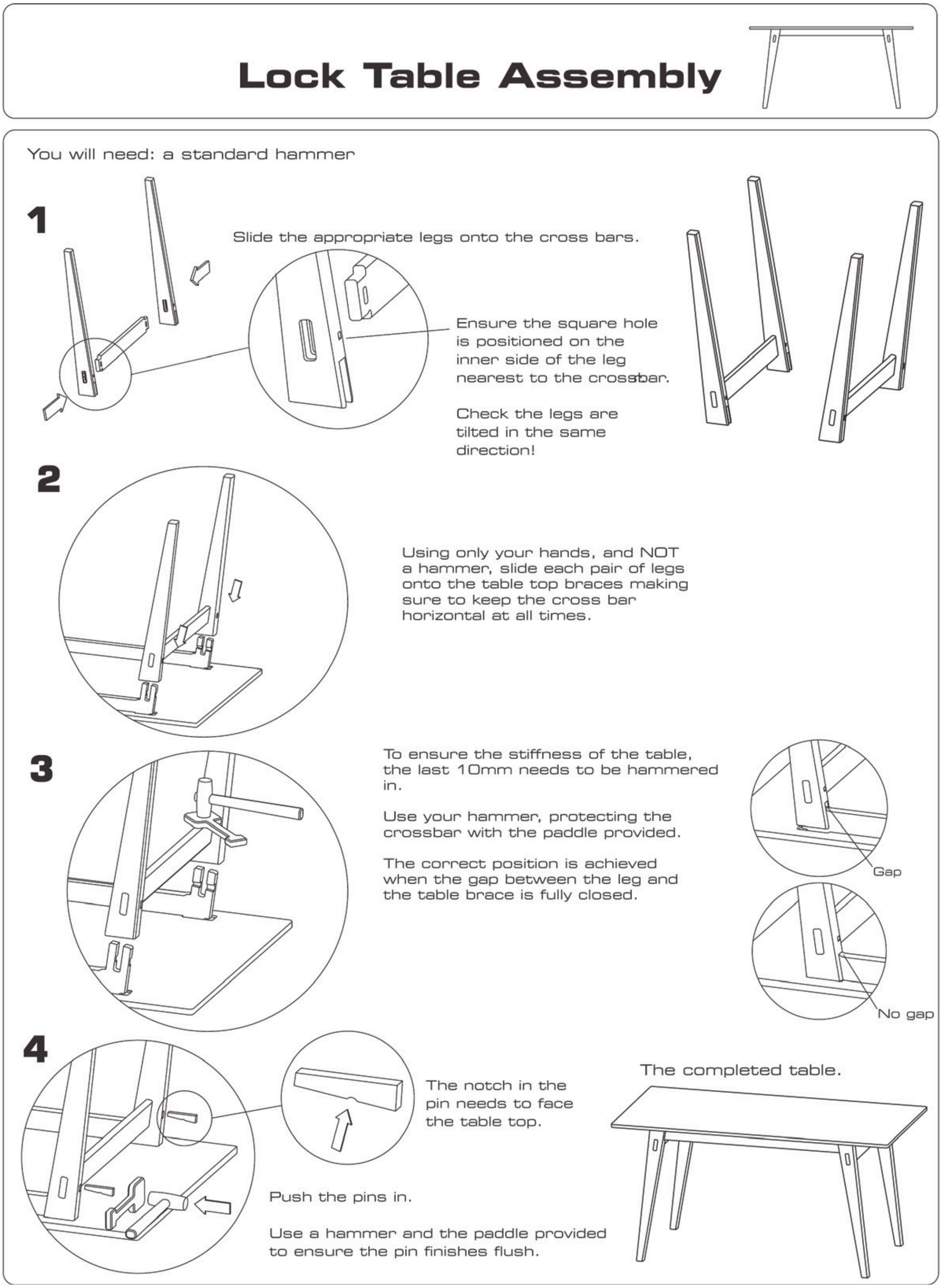




above: figures 1 & 2 Final 3D printed typeform, and view of 3D stacked generative growth. (CC-BY-NC-ND 2.0) toxi [Karsten Schmidt].

opposite: fig. 3 Print magazine cover August 2008 (CC-BY-NC-ND 2.0) toxi [Karsten Schmidt].


print
DESIGN CULTURE TYPE
Kinetic Letters
China's Olympic Symbols
Graffitist Greg Lamarche
TYPE & FORM
$12.95 US
PRINTMAG.COM


Lock Table Assembly
You will need: a standard hammer
1
Slide the appropriate legs onto the cross bars.
Ensure the square hole is positioned on the inner side of the leg nearest to the crossbar.
Check the legs are tilted in the same direction!
2
Using only your hands, and NOT a hammer, slide each pair of legs onto the table top braces making sure to keep the cross bar horizontal at all times.
3
To ensure the stiffness of the table, the last 10mm needs to be hammered in.
Use your hammer, protecting the crossbar with the paddle provided.
The correct position is achieved when the gap between the leg and the table brace is fully closed.
Gap
No gap
4
The notch in the pin needs to face the table top.
Push the pins in.
Use a hammer and the paddle provided to ensure the pin finishes flush.
The completed table.

Unto This Last

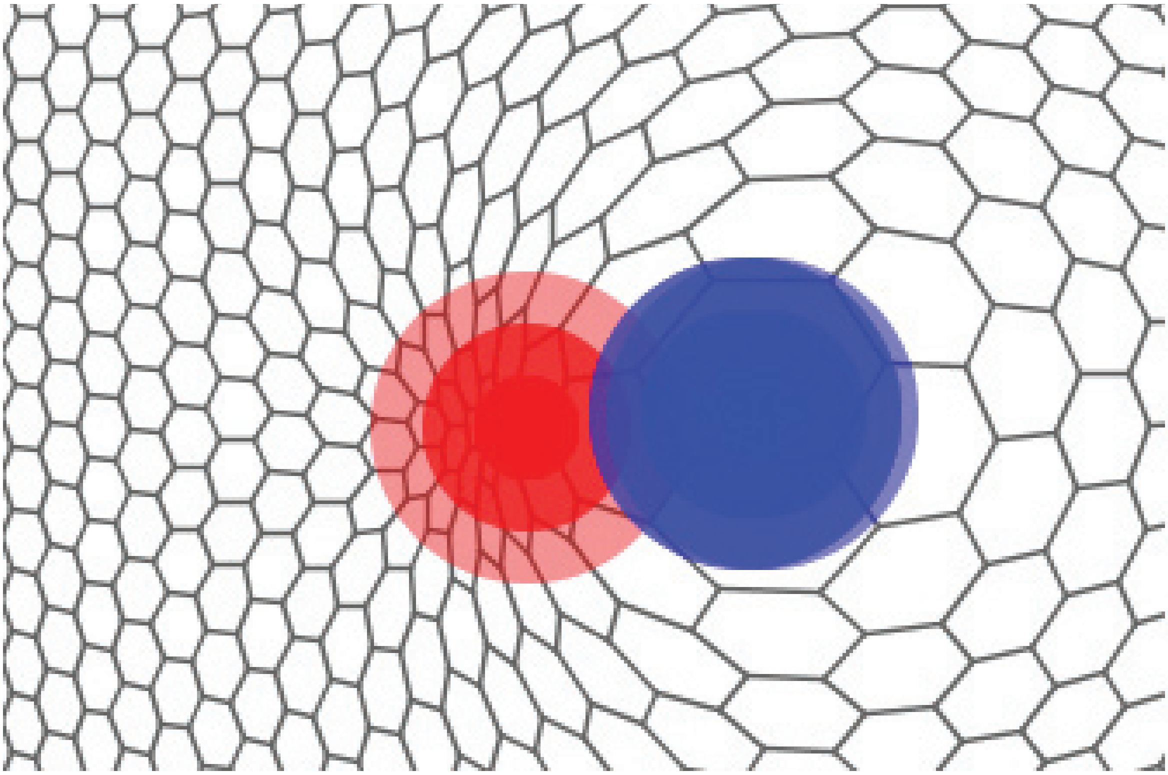
"LESS MASS, MORE DATA"
Quote from the Viridian Manifesto on a corbel of Unto This Last's location at 230 Brick Lane London, UK.

Unto This Last is an urban, micro-manufacturer workshop and design studio that produces made-to order CNC-fabricated plywood furniture. Describing the service as local craftsmanship at mass-production prices, founder Olivier Geoffroy says he is aiming to restore the link between designer and maker.

Since 2000, UTL has developed a digital library of over a hundred products that include furniture, lighting, and other house wares. Many of its products are individually customizable in dimension and finish and they can only be purchased and delivered within London, flat-packed or fully assembled. Lead-times are short, between a few days and few weeks. Moreover, their products generally require no out-sourced fittings or hardware, which is aimed at lowering costs and shortening lead-time, as is their shunning of packaging. Their stock of finished products is limited at any one time to what they wish to have in their showrooms.

opposite: fig. 4 Unto This Last Lock Table downloadable assembly directions from their website untothislast.co.uk.

below: fig. 5 Unto This Last Lock Table, Facet Chair and Cage Bin from their website.



CUSTOM RADIOLARIA

ADD TO CART

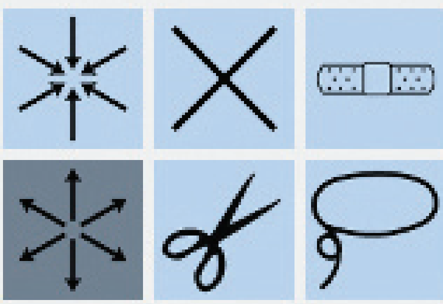
$60.00

pause

clear

hide

save



Create your own custom radiolaria pieces! These pieces will be etched from stainless steel and come with an 18in sterling silver chain. Since these are made to order please allow for 2-3 weeks before shipment.

This program is based off of a physics simulation where each line is simulated as a spring. Add forces to deform the mesh. The patterns recall various cellular formations including those found in the skeletons of radiolarians.

Nervous System

Nervous System is a small design studio begun in 2007 by Jessica Rosenkrantz and Jesse Louis-Rosenberg. Nervous System developed an online interface in the form of open-source java applets for the customization of their generatively designed, and digitally fabricated jewelry. Their pieces are available in materials ranging from felt to stainless steel and can be individually configured and purchased online. In completed form, they are available through various shops in North America, Europe, Asia and Australia. Lamenting the apparent lack of activity in the US with computation and design, Rosenkrantz and Louis-Rosenberg recently began organizing a series of open work sessions in Boston for people interested in collaborating and sharing ideas about computational design.

opposite: fig. 6 User configurable Radiolaria java applet from the Nervous System website. (CC-BY-SA 3.0) Nervous System.

Bathsheba Grossman

Concentrating on mathematical form sculptures, Grossman uses a number of fabrication and retail services to produce and distribute her work, including the online 3D print fabrication and market service provider, Shapeways.

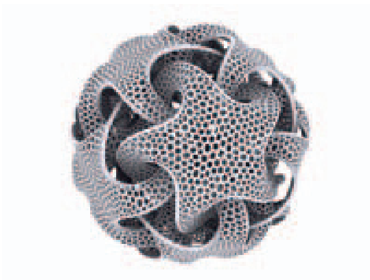
Her collaboration with the Belgian solid free-form manufacturer Materialise and designer Jiri Evenhuis helped to expand her work into functional objects such as interior lighting fixtures, furniture and jewelry. Materialise - one of the largest RP&M manufacturers in the world in turn exhibits and markets her work as part of their .MGX Design Products series.

Though she is arguably one of the earlier, and now better represented independent, peripheral producers, Grossman quietly leveraged the adaptability of digital communication and fabrication technologies to her advantage. The combined profit enabled by small production runs of multiple products through multiple producers has, she says, has now allowed her to support herself through her art. Her own e-commerce site alone reportedly generates up to $500,000 in sales annually. ("Rapid Prototyping Struggles..." RapidToday)

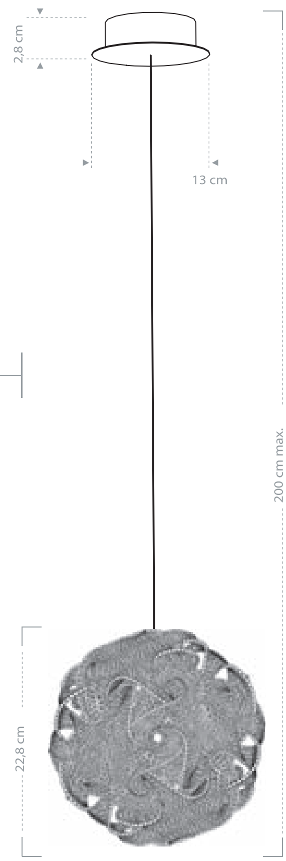
above: fig. 7 Quin.mgx pendant lamp designed by Grossman and produced in nylon via SLS by Materialise. (CC-BY-NC-ND) freckle_m.

opposite: fig. 8 Quin.mgx product data sheet from Materialise nv.

LIGHTING. TECHNICAL INFORMATION



Colour:	shade (SLS): white
Total net weight:	large vers.: 827 g
	small vers.: 529
Dimensions:	large vers.: shade ø 22,8 cm
	small vers.: shade ø 13,9 cm
Package contains:	1 shade, 1 transformer 12V,
	mounting structure, 2m cable,
	50W halogen (Big pendant lamp),
	20W halogen (Small pendant lamp)
	*.MGX data file on CD
Technology:	SLS (Selective Laser Sintering)
Material:	shade (SLS): polyamide (nylon)
	mounting cup: stainless steel cup
	with chrome finish



DESIGNED BY: BATHSHEBA GROSSMAN

TYPE: PENDANT LAMP

QUIN .MGX

CE:

Art. Ref.: Big pendant lamp: QUI.PT50.CE.--- / Small pendant lamp: QUI.PT30.CE.---

CE conformity, licence 13982C decorative portable and fixed luminaries.

EN 60598-1:2000 + A11:2000, NBN EN 60598-1:2000 + A1:2001 + A2:2002

Rating : 240 Vac, 50 Hz, Class II, IP 20 ,12V (incl. transfo)

Lamp type : halogen 12V GY6,35 - 50W halogen (Big pendant lamp), 20W halogen (Small pendant lamp)

UL-cUL:

Art. Ref.: Big pendant lamp: QUI.PT50.UL.--- / Small pendant lamp: QUI.PT30.UL.---

UL conformity license: Listed 102979-001. Use in a dry location.

mounted electric luminaires, susp.: E241112 - UL 1598. CSA C22.2 no 250

portable electric luminaires: E254046 - UL 153. CSA C22.2 no12

Rating : 120V, 60Hz,12V (incl. transfo)

Lamp type : Xelogen T3, 12V G4 - 50W halogen (Big), 20W halogen (Small) (supplier www.thhc.com)

Maintenance: SLS: easily remove stains with water & clear soap

.MGX trademark: 852494

Ronen Kadushin / Open Design

Kadushin freely publishes 2D construction files for his digitally fabricated designs online under a Creative Commons license of Attribution-Non-Commercial-Share-Alike. He refers to open-source software development as the basis for his method of producing, where users are encouraged to download, modify and reproduce the work. Kadushin explains,

> Open Design products flow with an essential cultural wave: towards freer information, web-based collaborations and open-source methods. In Open Design, anyone can download and produce my designs for free. Open Designs encourage modification, redistribution, and direct contact with the designer. I would only ask producers to share with me revenues from commercial uses. (Pillar)

Through his Open Design project, Kadushin became involved with exhibitions, conferences and open-source development communities. This in turn drives the Open Design work further into the mainstream, thus increasing Kadushin's profile for higher-end work, which he sells through exhibitions and auctions.

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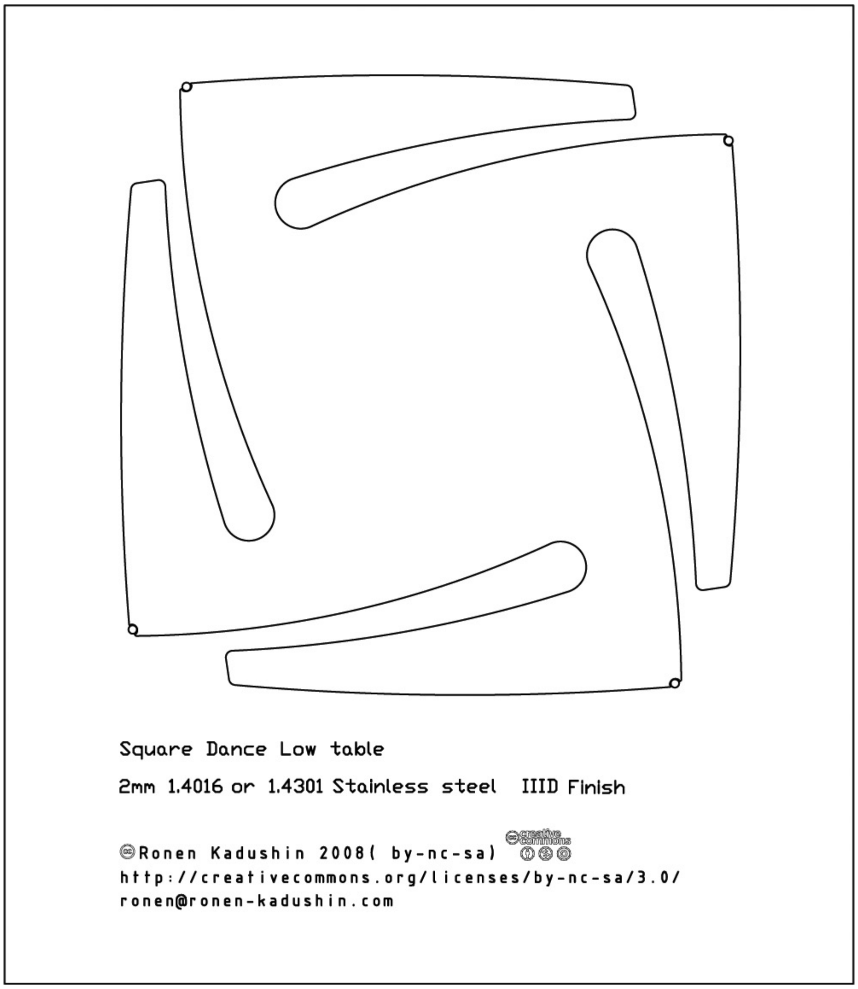
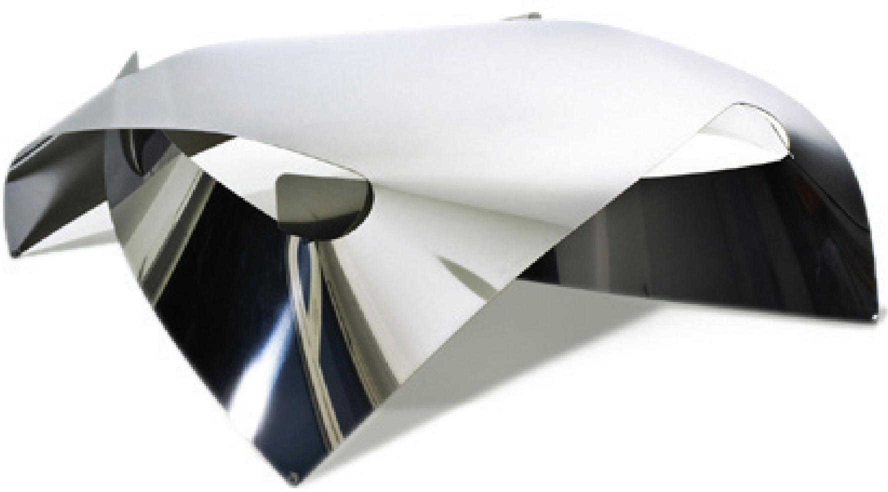
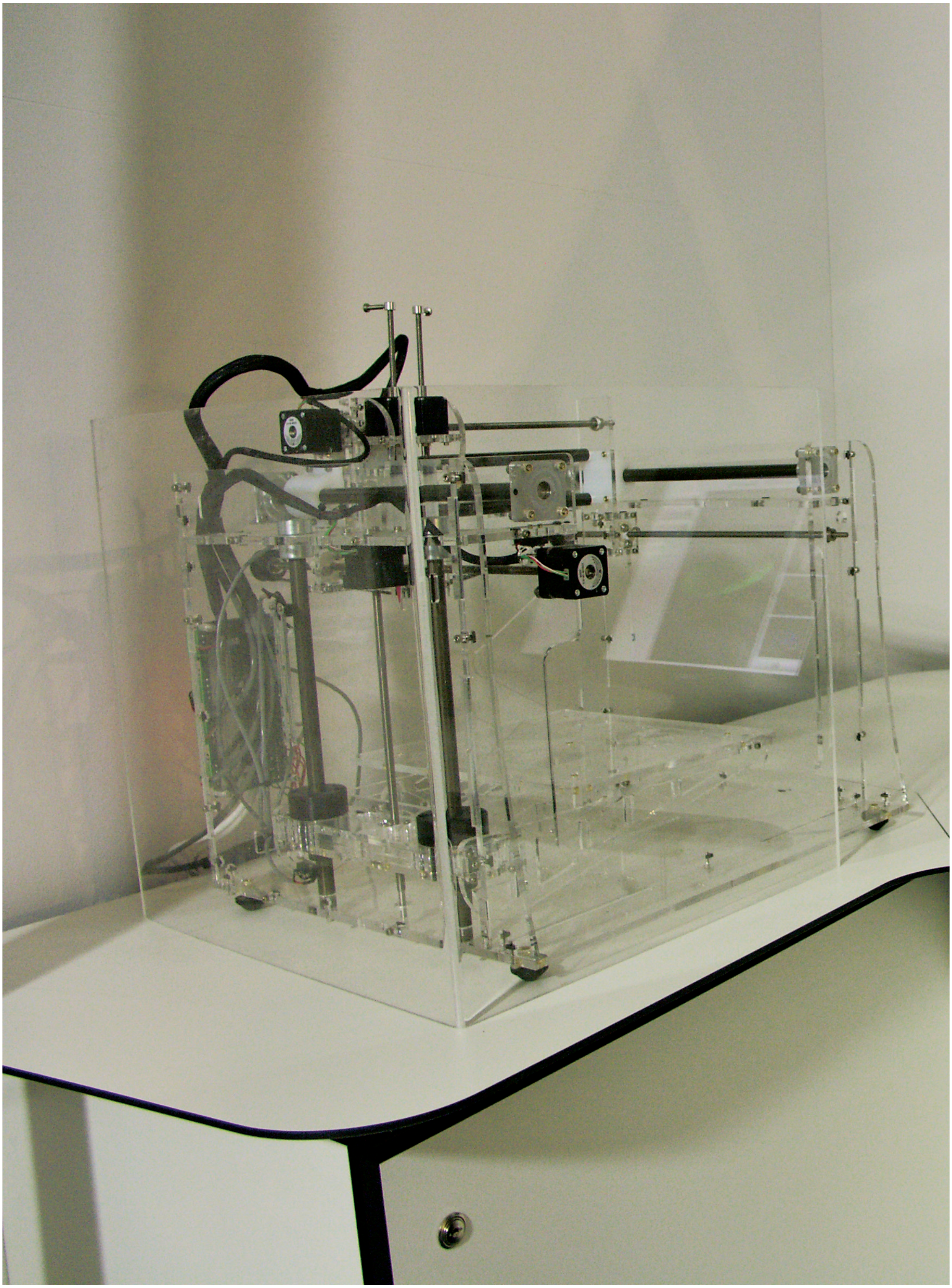
opposite: figures 9 & 10 From the Open Design series, Square Dance Low Table 2D construction file and assembled table. (CC-BY-NC-SA 3.0) Ronen Kadushin.


Square Dance Low table
2mm 1.4016 or 1.4301 Stainless steel IIID Finish
©Ronen Kadushin 2008(by-nc-sa)
creative commons
http://creativecommons.org/licenses/by-nc-sa/3.0/
ronen@ronen-kadushin.com





Fab@Home

Fab@Home is one example of a number of ongoing open-source projects for the development of physical products, and in particular digital fabrication tools themselves. These projects include homebrew versions of laser cutters, 3D printers, and CNC machines. Open source projects such as these often operate through a combination of dedicated core-members with a distributed network of developers and users working outside of, or alongside, a commercial business. Information for building these tools is generally freely shared in online forums and face-to-face collaboration.

Other open-source projects for digital fabrication tool development include RepRap, CupCake, and CandyFab among others. There are also open-source machining software projects such as LinuxCNC and CNC Toolkit that provide for more creative end uses of CAM software than is normally available.

100K Garages

100k Garages is a newly formed open-access collaborative project between CNC fabricators and individuals with a project to build. As an innovative approach to harness the potential of networked fabrication facilities, it connects tools to designers, and projects to interested fabricators in numerous countries. Organized by the online digital fabrication service Ponoko and CNC router manufacturer, Shopbot, 100K Garages is a non-profit endeavor aimed at the social benefit of small-scale innovation and business development.

opposite: fig. 11 Fab@Home 3D printer, an ongoing open-source development project. (CC-BY) fluidforms [Hannes, Walter, Stephen Williams and Andreas Jaritz].

ProtoSpace

An open access prototyping lab located in Utrecht, Netherlands. ProtoSpace is founded on Gershenfeld's concept of a Fab Lab that offers hands-on access to digital fabrication tools, workspace and collectivized knowledge for producing. They offer daily and free open hours to individuals. While start-ups and businesses younger than 2 years old are charged a subsidized rate, established businesses choosing to use the facilities pay full price: €150 per day.

From an American perspective, it is interesting to see that this facility is sponsored through a joint initiative of eleven organizations, many of them non-profit or governmental that support established business interests, but favor access for new commercial entities and unaffiliated individuals. While there are approximately twelve Fab Labs in the US, most are not this well funded. Instead, in the US numerous small, local maker clubs are emerging alongside occasional for-profit (and not Fab Lab) enterprises such as TechShop in Palo Alto, CA.

Shapeways

Spun-off from the Philips corporation in 2008, Shapeways is a Dutch-based online service bureau specializing in solid free-form fabrication. It is an example of an online factory as described by Donal Reddington in the following section. Shapeways' fabrication methods include SLS, FDM and 3DP in a variety of materials. Their site offers an online marketplace for users to sell their products, user information forums, and a 3D parts database. Like other user customization businesses, Shapeways also offers its own 3D creator software for the personalization of small stock objects.

As one of the larger, and well-supported online digital fabrication services, Shapeways emphasizes user-generated and community driven object fabrication. It shares a similar business model with the laser cutting service, Ponoko. Other online services geared more toward traditionally professional prototyping and manufacturing-scale product development are also emerging with sites such as eMachineShop, QuickParts and ProtoMold.

opposite top to bottom: fig. 12 ProtoSpace located in Utrecht, Netherlands. (CC-BY-NC-SA 2.0) tonz [Ton Zijlstra]. fig. 13 3D prints produced by Shapeways and created by a Norwegian 3D illustrator. (CC-BY-NC 2.0) superrune [Rune Spaans].

LET THE MACHINES DO THE WORK - DAVE TURTLE'S ADVENTURE'S IN DIGITAL CRAFT

http://daveturtle.blogspot.com

Thu, Dec 4, 2008 5:22
Isn't About Time I Made Something?

Enough pictures for awhile it's about time I made something. I have various bits of digital kit I can get my hands on through my teaching job at the Royal College of Art in London. These include CNC milling, laser cutting and rapid prototyping, if you want to use them too why not try the guys at Rapid Form at the RCA.

On the whole my problem is this ... I like the way that hand formed objects look, and I want to retain some of those characteristics when using digital production methods. I don't like the way digital production tools dictate the kinds of materials I have to use, and software to some extent dictates the kinds of forms I can create.

I love the idea of variation. With digital production every object can be unique, there is no hard tooling to invest in and so no cost implication with customization.

Technology manufacturers make it very hard to customize software and machinery. The hardware is made from proprietary parts, the software drivers do what they do and there is no way to edit functions or hack into the system. From this standpoint I love what the Fab at Home project represents, a home brew rapid prototyping system. It's not the most sophisticated technology but it fosters experimentation and collaboration between individuals keen to get their hands dirty. As a tool it is potentially a far more creative environment to create unique objects than an off the shelf package.

Anyway I had better get on with making some machines do something they never thought they would end up doing...

ACCESS TO DIGITAL FABRICATION TOOLS

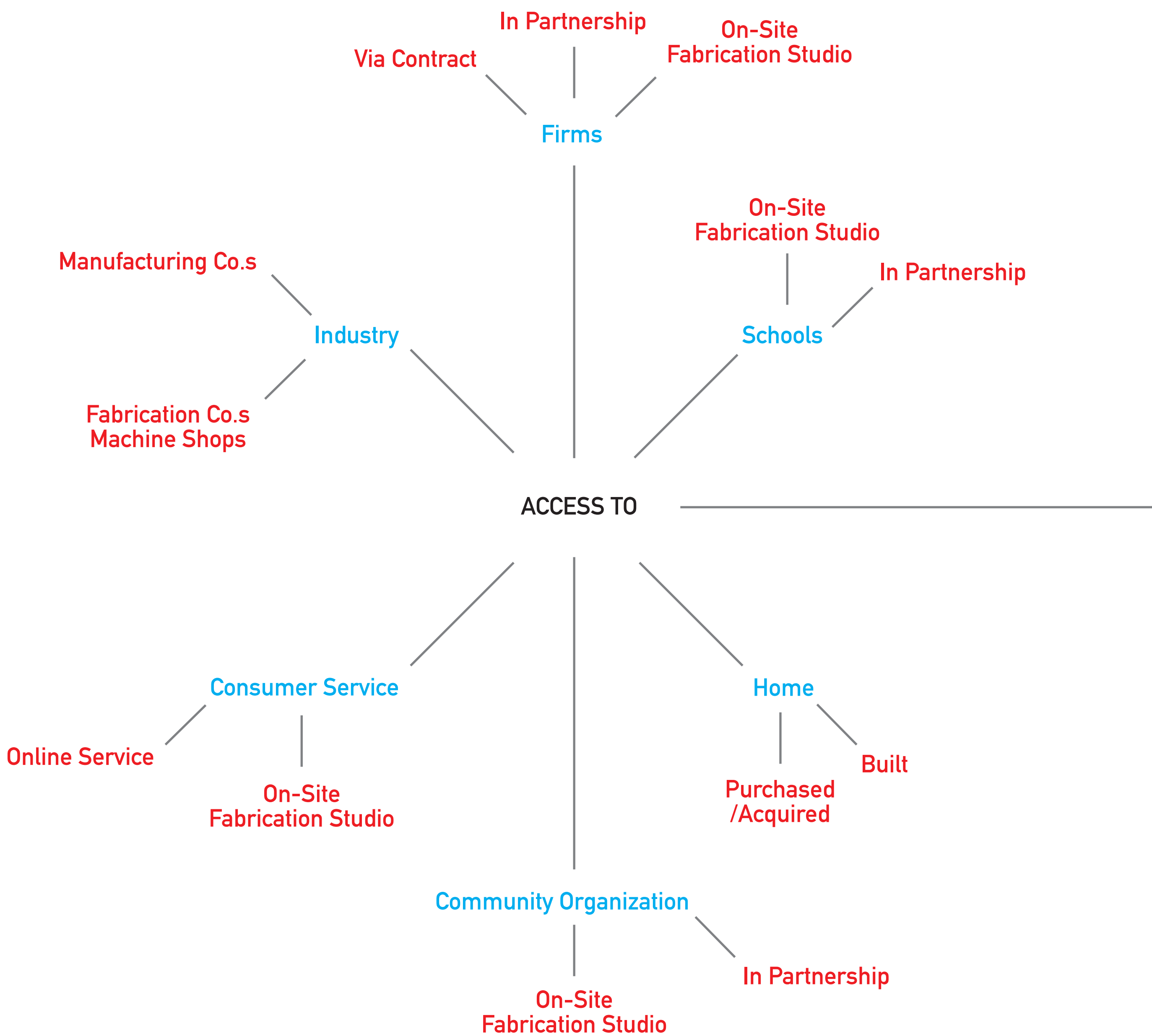
Because CNC tools are expensive, often dangerous, and complex to operate, hands-on access for interested individuals can be difficult to locate outside of fabrication studios in educational institutions or well-appointed design firms. Second-hand access as a contract service is much more readily available through fabricators and manufacturers, either locally or online. Digital fabrication of most types also have dynamic open-source communities of DIY and pro-am users making and configuring their own tools. To give a better perspective of the current situation, if the development of digital fabrication is compared to that of home computing thirty years ago, these current projects, and maker communities would correspond to the homebrew clubs, swap meets and BBS networks of the late 1970s.

Peripheral projects are achieved through diverse methods, but one of the most crucial factors is access to tools. The diagram on the following pages charts the current means of access for the majority of people engaging with digital fabrication tools.

The chart, if split north / south, describes the professional realm in the upper section and the pro-am, and personal fabrication side in the lower section. Industry, firms, and educational institutions comprise the professional, while consumer services, community organizations and the home are those more commonly utilized by non-professionals. There is, of course, overlap with, for example, personal use of work or school resources.

There is roughly an equal split between hands-on access and secondary or contracted access through a service provider. Where, for example, an individual or firm may contract a local fabricator to produce an object, or a designer may negotiate a collaborative partnership with a fabricator in a manner that provides hands-on access or similar knowledge to some degree. Additionally, a small company may locate a community organization with digital fabrication tools available for one-off projects.

Once access has been secured, the output of these tools is categorized on the right as either additive or CNC. This is to better describe the capabilities of the tools and how they promote certain types of output versus others. These differences are generally in scale and material constraints, and extend into time, cost and production volume capabilities. Consequently, CNC is more often used in commercial applications, while solid free-form fabrication, or additive, methods are used for low-volume and one-off objects.


In Partnership
Via Contract
On-Site
Fabrication Studio
Firms
On-Site
Fabrication Studio
Manufacturing Co.s
In Partnership
Industry
Schools
Fabrication Co.s
Machine Shops
ACCESS TO
Consumer Service
Home
Online Service
Built
On-Site
Fabrication Studio
Purchased
/Acquired
Community Organization
In Partnership
On-Site
Fabrication Studio

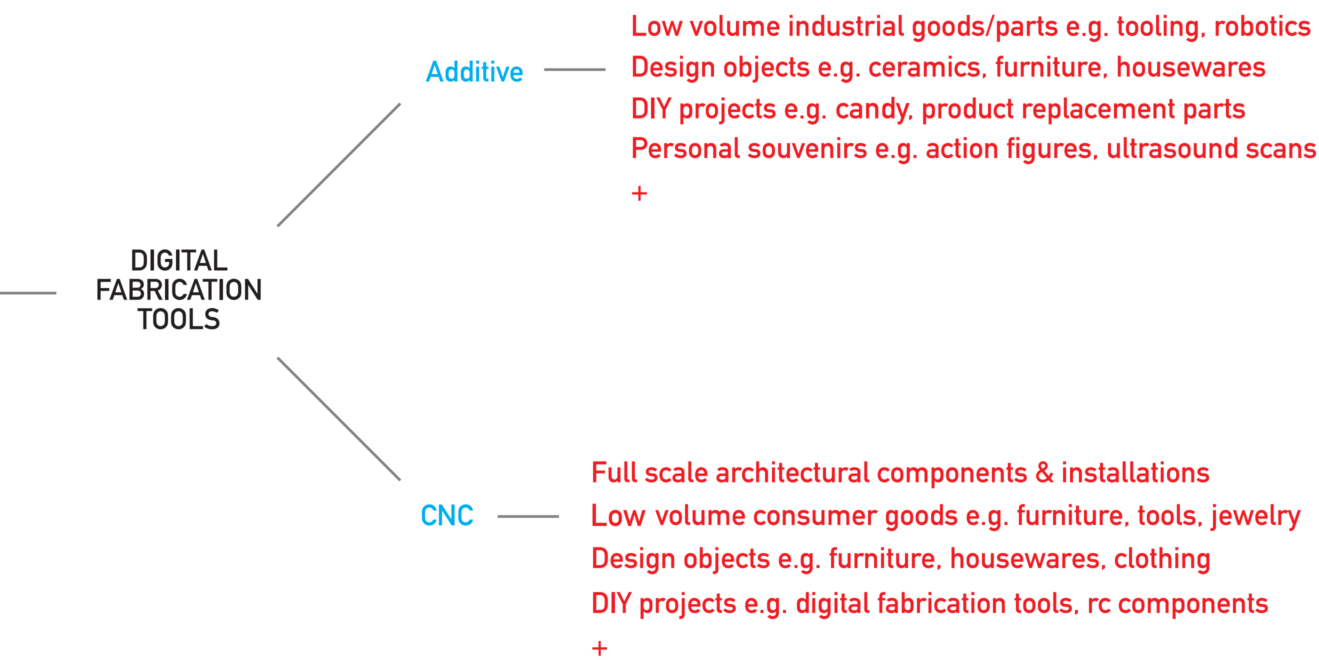


fig. 14 Means of access to digital fabrication tools and the range of peripheral project output. Based on a survey of various online sources.

TRENDS TOWARD THE DEVELOPMENT OF DISTRIBUTED MAKING

If the practice of personal fabrication expresses a deep-seated human desire to create, a driving inspiration for that creation is communication. Around the world, one of the first things people do when they get access to tools for technological development is to apply them to accessing and exchanging information.

Neil Gershenfeld *Fab*

THE FUTURE

Looking at what may come next, research on trends in technology, business, and society are useful to relate. Sources including the non-profit think tank, Institute For The Future, MIT researcher Eric von Hippel and engineer Neil Gershenfeld, plus numerous books and essays by designers, critics, and writers, each support in various measure the notion that digital technologies are in the process of changing, if not revolutionizing the way we produce everyday objects.

Social Trends

In 2008, the RAND spin-off think tank Institute for the Future (IFTF), located in Palo Alto, California published the results of their research into the future of making. Their report, written by David Pescowitz, gathered ideas from many individuals and projects. These include those of Eric von Hippel who coined the terms 'lead user' and 'user innovation' in the late 80s, and the work of Charles Leadbeater of the UK think tank Demos on the role of 'ProAms', professional amateurs and open-source innovation. Projecting out 10 years, IFTF identified six drivers of change in the ways objects are produced plus six areas of activity that they believe will continue to grow in the future. This resulted in the definition of two major trends that the IFTF points to as shaping the future of fabrication: maker culture and the de-centralization of manufacturing technologies.

Access to Tools

A few years prior to this in 2005, Neil Gershenfeld, the director of Massachusetts Institute of Technology Center for Bits and Atoms published the book *Fab: The Coming Revolution on Your Desktop–From Personal Computers to Personal Fabrication*. In this book, Gershenfeld concentrates on the approaching technological revolution of 'invention tools' that make physical fabrication as accessible as ideas are today. In it, he describes his own experiences with the creative potential of individuals through the development of 'Fab Labs,' studios supplied with basic digital fabrication, electronic and computing tools. These hands-on facilities are created in partnership with institutions, organizations, and governments around the world. Open to potential artists, inventors, engineers, and designers, Fab Labs enable individuals to make objects that meet their own personal needs.

Business Model Innovation

Business model innovations based on the use of digital communication and fabrication technologies are rapidly evolving. In 2006, the Irish business writer, Donal Reddington, constructed a map of the social and technological developments that have been leading toward mass-customization as a viable business model and for which he used the term 'Customerism,' to better describe the attributes it contained. Reddington summarized the threads in this map as "Mass Customization + Custom Marketplaces + Online Factories + Co-creation + User Innovation + Outside Innovation + Creative Commons = Customerism."

Forecasting from Trends

As part of their 2007 Ten-Year Forecast The independent non-profit research group Institute for the Future released a summary research report on the possible influence of 3D printing on manufacturing titled *Manufacturing - Do it Yourself?* This was followed up with a more in depth explication of the trends and drivers for their projections in a report written by David Pescowitz titled *The Future of Making*.

In this second report, IFTF identified what they felt would be continuing drivers of change in the ways objects are produced in the next ten years. Of these, the most significant seem to be: platforms for sociability (such as online user forums), the rise of the professional amateur, open-source everything, and access to tools. The trends they noted as deriving from these, and that are interesting for a discussion aimed toward future niches of design are: grassroots economics (user-created online marketplaces like Etsy.com), networked artisans, personal design and fabrication, and lightweight manufacturing.

> Tomorrow's factory may look very different from the massive, rigid machines familiar to us since the advent of the Industrial Revolution. Flexible manufacturing technologies on the horizon will shift fabrication from massive and centralized to lightweight and ad hoc... in the near future, rapid manufacturing technologies, personal fabrication, and the networking of supply chains into flexible "supply webs" will transform the way goods are made. These technological developments, combined with global job shops, enable fast, customized, and often greener production. Moreover, general-purpose manufacturing technologies and desktop factories could trigger the rise of micro niche production. Diverse communities could forego many mass-produced goods for custom-produced items that meet their specific needs. (Pescowitz 6)

However, in Pescowitz' 2007 interview with science fiction and technology writer, Bruce Sterling, Sterling made the following comments regarding a future of more distributed digital fabrication capabilities as a social phenomenon:

> Bruce: ... It reminds me very much of the sort of classic American technological sublime in the early 1980s when writers like myself first got word processors. We immediately concluded that we were going to disintermediate and distribute the publishing industry.
>
> What really happened with electronic text had very little to do with publishing, per se. Most of the text that is on the net is net-texted. It would have been hard to say at the time, say if you were doing Boing Boing Magazine and you suddenly got a laser printer, that the upshot of this would be boingboing.net.
>
> ... I don't think it will democratize design exactly, but I think it will digg.com and reddit.com it. In other words, in these peer-to-peer methods of distribution of plans, you don't actually get everybody going out, running the recipe, and making one of their own. You

> get power-law distributions with someone who was formerly an amateur. They discover how to put the Mentos into the Coke bottle and have a massive viral hit. (Cascio)

Bruce Sterling's example of digitally delivered text points out that this content, these products, will probably serve a different function than what is currently available, and that the technological capabilities will grow alongside more traditional means of production, rather than displacing the status quo from the beginning. Extrapolating from Sterling's overall position may also be useful for designers to note. Specifically, that designers are in a very good position - should they choose to step outside of their professional enclaves, to help provide this new content.

Professional Amateurs

In 2004, the UK think tank Demos released *The Pro-Am Revolution* in which it argued that an historic shift is occurring in society. "Pro-Ams - people pursuing amateur activities to professional standards - are an increasingly important part of our society and economy."

Demos describes the twentieth century as being shaped by the rise of professionals in most occupations.

> From education, science and medicine, to banking, business and sports, formerly amateur activities became more organized, and knowledge and procedures were codified and regulated. As professionalism grew, often with hierarchical organizations and formal systems for accrediting knowledge, so amateurs came to be seen as second-rate. (Leadbeater and Miller 12)

Since the 1980s, however, Demos suggests that Pro-Ams have emerged in industrialized society as knowledgeable, educated, committed and networked, by new technology. In a 2007 TED conference talk, Charles Leadbeater of Demos described some of the ramifications of such a proposal. With an enormous increase in the number and capabilities of productive resources such as networked communication, open-access collaboration, and technological advances in available tools, the users then become producers. This is in effect "an explosion of creative endeavor" that Leadbeater feels will initially lead to a struggle between open and closed methods of producing, between professionals and professional amateurs.

> ...Because the professionals over here in these closed organizations - they might be academics, they might be programmers, they might be doctors, they might be journalists - say No, no - you can't trust these people over here. (Leadbeater)

But that ultimately, many closed organizations will become more open largely because of the strength of innovation through Pro-Am methods of producing.

> What I think you will see is the intelligent, closed organizations moving increasingly in the open direction. So, it's not going to be a contest between two camps, but in between them you'll find all sorts of

> interesting places that people will occupy. New organizational models coming about mixing closed and open in tricky ways. It won't be so clear cut, there won't be Microsoft versus Linux - there'll be all sorts of things in between. (Leadbeater)

Demos' research did not specifically address design and making in their publication. Rather when they surveyed the general population in the UK, Demos used categories that would contain these activities: 'DIY' and 'Arts and Crafts'. Yet these categories were two areas respondents cited as being most frequently involved, and in which they reported having a higher percentage of good skills. Demos extrapolated that 15% of the population are DIY Pro-Ams and 8% of the population are amateurs working at the professional level in the areas of arts and crafts. If nothing else, these numbers point to both the potential interest, and the capabilities of non-traditional 'makers' within the larger population. More specifically, as digital technologies become more readily available and configurable, professional amateurs pursuing design-related activities are also likely to become more common.

User Innovation

Eric von Hippel, a professor at MIT in business management, has been researching distributed and open innovation for over twenty years. His research has been influential for many involved in thinking about how business and users are changing in relationship to each other as technology develops.

In his 2005 book titled *Democratizing Innovation*, Von Hippel gives the example of Saul Griffith, a prolific graduate student at MIT also cited in Gershenfeld's book *Fab*, who as an avid kitesurfer created a website for fellow kitesurfers in 2001. On the site, zeroprestige.com, Griffith posted plans for designs of kites he had designed as well as some information about kite construction and use. What makes this example different is that other users of the site - other kitesurfing aficionados, were encouraged to download the information and also upload their own. It was this active sharing of ideas, which over time created a dynamic and evolving locus for a globally distributed community of kitesurfers. Eventually, this community developed into one that shared CAD files for kite designs as well as the sourcing of manufacturers and fabricators in order to produce their custom designs at a fraction of the time and cost of a manufacturer-produced product. (von Hippel 102)

Some of von Hippel's findings as they relate to innovation and digital fabrication follow below. These are the role of free-revealing in product innovation by users; the ability of, and reasons for users to innovate; and the role user innovation may play in future manufacture.

> The empirical finding that users often freely reveal their innovations has been a major surprise to innovation researchers... Innovators often freely reveal because it is often the best or only practical option available to them. Studies find that ... free revealing can provide innovators with significant private benefits... (such that) users find others improve or suggest improvements to the innovation, to

> mutual benefit. ...(and they) may also benefit from enhancement of reputation, from positive network effects due to increased diffusion of their innovation. Being the first to freely reveal a particular innovation can also enhance the benefits received... (von Hippel 9-10)
>
> Users' ability to innovate is improving radically and rapidly as a result of steadily improving quality of computer software and hardware, improved access to easy-to-use tools and components for innovation, and access to a steadily richer innovation commons. (von Hippel 13)
>
> On a level playing field, users will be an increasingly important source of innovation and will increasingly substitute for, or compliment, manufacturers' innovation-related activities... In physical product fields, product development by users can evolve to the point of largely or totally supplanting product development - but not manufacturing - by manufacturers. (The economies of scale associated with manufacturing and distributing physical products give manufacturers an advantage over 'do-it-yourself' users in those activities). (von Hippel 13)

In this last context, it would be interesting to explore if whether manufacturing on a different scale, e.g. numerous smaller manufacturing facilities served by the networked communication of digital information for digital fabrication tools, might tip the economy of manufacture further in favor of user innovators as viable producers.

Access to Tools

The driving concept behind the creation of Fab Labs was to provide ordinary people access to a small scale workshop with a number of flexible digital fabrication and computing tools in order to explore "the implications and applications of personal fabrication..." (Gershenfeld 11)

Initiated by Neil Gershenfeld, director of the Center for Bits and Atoms at MIT, Fab Labs are neither run nor maintained by MIT (all except for the Mobile Fab Lab), rather the idea for their setup, and in part the means for enabling supporting partnerships is the core of MIT's involvement with Fab Labs today. As of this writing, there are approximately 34 Fab Labs globally, a number of which are located in developing countries.

These small-scale workshops are organized on a charter system, where one of the key factors in their success is their method for creating and distributing collectivized knowledge for making. Gershenfeld described this as also being a component of his MIT course 'How to Make (Almost) Anything.' In effect, necessary information is pulled in by the student as needed, rather than pushed from the instructor. The Fab Lab charter refers to this as: "you can use the Fab Lab to make almost anything (that doesn't hurt anyone); you must learn to do it yourself, and you must share use of the lab with other uses and users. Training in the Fab Lab is based on doing projects and learning from peers; you're expected to contribute to documentation and instruction." (ProtoSpace)

The basic Fab Lab setup usually includes a laser cutter, a sign cutter, a small, precision CNC milling machine, sometimes a larger CNC router, and always the tools for programming processors and micro-controllers. Some of the first Fab Labs around 2002 were put together with tools costing a total of between $20,000 and $50,000. The Center for a Stateless Society has put the cost of outfitting a Fab Lab using open-source tools such as the Fab@Home 3D printer, between $2,000 and $5,000 total. (Carson 18) Other tools a Fab Lab might include, and which significantly increase its cost, are a 3D scanner, 3D printer, plasma cutter, water jet cutter, and CNC lathe or multi-machine.

When Gershenfeld was actively engaged developing the early Fab Labs, he described how he looked at what the Fab Labs were doing:

> Possession of the means for industrial production has long been the dividing line between workers and owners. But if those means are easily acquired, and designs freely shared, then hardware is likely to follow the evolution of software. Like its software counterpart, open-source hardware is starting with simple fabrication functions, while nipping at the heels of complacent companies that don't believe that personal fabrication 'toys' can do the work of 'real' machines. That boundary will recede until today's marketplace evolves into a continuum from creators to consumers, servicing markets from one to one billion. (Gershenfeld 15)

It is this continuum of producers coupled with varied means of distribution that will likely influence the role of designers in the future by offering new avenues for their evolving practice. As Gershenfeld has helped to establish with Fab Labs, in order for this type of change to occur, these tools not only need to be accessible to a wide range of individuals, but in a manner in which they may play, experiment and explore without immediate commercial constraints on their activities.

Business Model Innovation

In the essay and map, *One Word for Many Trends*, Donal Reddington describes the confluence of events he sees as affecting the rise of customer control in business. For this discussion, it is probably sufficient to highlight the time frame and some of the connections he made for their relevance to distributed making.

Reddington points to influential books regarding these kinds of business strategies, the ideas of which were largely theory at the time of their publication. For example, with Alvin Toffler's 1970 *Future Shock* and Toffler's concept of a 'pro-sumer,' - someone actively working in concert with a producer for more appropriate goods and services. And the 1993 publication of Joseph Pine's *Mass-Customization - the New Frontier in Business Competition*, a book that sets out strategy for the implementation of mass-customization in a business enterprise.

Reddington principally covers important technology-related developments. Where for example, after the first web browser in 1991, and the first built-to-order products via the web in 1996, other changes quickly build upon these advancements. These include the introduction of Creative Commons licensing for online content in 2001, and the development of the social internet in the early 2000s, which combine to encourage peer review and use of product designs in tandem with online custom marketplaces. Add the growth of digital manufacturing to these prior examples, and they give rise to the creation of online factories. In Reddington's assessment, these are all steps leading to the maturation, and soon the mainstreaming of user involvement in the design and production of goods and services.

All of these trends show the growing interest and potential for individuals outside the conventional systems of production to physically create objects of their own design. They also describe how access to digital fabrication tools provides for individual creativity and problem solving on a much greater scale than has been available to most at any time previous. Taken as a whole, these activities appear to be on the cusp of redefining the roles of large producers while they actively generate new types of activities and businesses that will lead to further, and even greater changes in a not so distant future.

HISTORY

The technology has advanced dramatically over the past twenty years and is talked about as the Second Industrial Revolution, yet the present stage of its development is the first Industrial Revolution equivalent to the year 1800.

Michael Eden ***The Wedgwoodn't Project***

Given that some feel we are now entering a new industrial revolution, it's helpful to recall that the industrial revolution of the 19th century led to the creation of industrial design as a profession in the early 20th century. And that then, as now, designers were motivated to use new industrial manufacturing techniques to create better living situations. (Lippert and Wipperman 10) It's also relevant to note that the Arts and Crafts movement arose as a direct reaction against the industrial methods of production of the late 19th century.

More importantly, however, the industrial revolution served to alter the relationship of maker to user and vice versa. Simply put, it created the overwhelming centralization of production during the 20th century, which in turn led to the mass-production of most all material goods. This had the effect, especially in the United States, of removing many smaller producers from the community and replacing them with points of distribution for the finished goods. Today, where goods and services combine with digital technologies there are some very interesting developments in the reverse. If what we are seeing now is the beginning of a pulling away from mass-production toward more customized and distributed methods of production by virtue of digital technologies, looking at a related situation may be helpful.

THE RELATED EXAMPLE OF DESKTOP PUBLISHING

Arguably, the first digital shift occurred in the mid-1980s when four key elements emerged and were quickly embraced by many as a new method of producing printed matter. And as a result, the printing industry was dramatically altered. These were the Apple Macintosh computer, the LaserWriter desktop printer, Adobe PostScript page description language, and Aldus PageMaker, page layout software. Together, the activity these technologies first enabled came to be known as desktop publishing.

Traditional print operations in the United States in the 1980s existed as numerous small, local businesses or as large printing houses operated by or for publishers and newspapers. The smaller businesses supplied the needs of other local businesses and individuals in the form of books, advertisements, packaging, and business documents with reprographics (copies of documents) and original print production. This was accomplished through processes such as offset lithography, rotary letterpress, and screen printing, among others. (Spring 26)

Beginning in 1984 with the introduction of the Apple Macintosh computer, those with enough money ($2495 US), or access were able to create, modify, and (with the $495 Apple ImageWriter) output their text and image documents without additional cost. What Apple provided, was for its time, a novel graphical user interface, high screen resolution, and bundled graphic and word processing software in an easy-to-use product package. (Webster) What it revealed - to many for the first time - was the potential that digital tools offered. The following year, in 1985, Apple released the much more expensive LaserWriter. At $6,995 and 300dpi print resolution, the LaserWriter's output rivaled that of professionally typeset documents. This was accomplished with Adobe's PostScript language, which allowed for a faithful reproduction onto paper of the graphics and type as they appeared on-screen. At roughly the same time, Aldus released its type and page layout software, PageMaker, that took advantage of Macintosh's graphical interface for the layout of multi-page text and image documents. (Spring 125-126)

Up to this point, the print industry had relied on graphic artists, and an array of skilled tradesmen operating a combination of machine and photographic processes. The role of graphic designers was more of specifier than producer, communicating their design intent to the typesetters, photo-retouchers, graphic artists and reproduction specialists. With the transition to digital technologies, not only were many of these skilled trades unnecessary for production, but graphic designers, by virtue of their place in this process, were given direct control over much of these production-oriented, but now digital tasks. (Wildbur and Burke 2)

Alongside these changes within the industry of printing, the adoption of desktop publishing tools by a variety of individuals and businesses quickly affected the small business print trade. By the early 1990s small, local printers were either pushed toward more niche print production for which digital production was not yet adequately capable, pushed out of business entirely, or, by virtue of their clientele, encouraged to take up the rapidly digitizing reprographics side of printing. In effect, they become streamlined service facilities for quick and relatively unskilled digital output. (Romano 5-13) As a result, and in less than a decade, the digital adaptation of its tools for individual use had almost completely reconfigured the small business print industry.

Theodore Roszak has noted that the culture Apple grew out of - the California counter-culture of the 1960s and 70s appears to have significantly influenced the company's early development. Roszak described this in his 1985 essay *From Satori to Silicon Valley* as a place and time where people were intensely interested in making and doing in order to step outside of the prescribed culture of mainstream consumerism. This drive found particular voice in the publication of The Whole Earth Catalog in 1968. Both high- and low-tech devices were listed in the catalog side by side as a kind of revelatory how-to manual for modern day survivalism. What The Whole Earth Catalog tapped into was that the ability to produce was something the counter-culture wanted - access to the knowledge and the tools in order to create as they saw fit.

Steve Wozniak, soon to become Apple's first engineer, was in the 1970s an active member in one of the San Francisco Bay Area's electronics and computing clubs. These clubs were largely an outgrowth of this same do-it-yourself energy of the California counter-culture.

> ... In its early days, home computer invention and manufacturing did

> resemble a sort of primitive cottage industry. The work could be done out of attics and garages with simple means and lots of brains. The people pioneering the enterprise were cut from the mold of the Bucky Fuller maverick: talented drop-outs going their own way and clearly outflanking the lumbering giants of the industry, beating them to the punch with a people's computer. (Roszak)

What is interesting is that it took an unconventional business with a similarly unconventional approach toward the desires of the middle class to realize this concretely, and to realize it in a manner that the middle class was able to recognize, i.e. in the form of a cozy appliance to be purchased for home use. More significant, is that these tools (computer, software, printer, page description language) needed to be aggregated by a single, dynamic business in order for them to be accessible and useful to a much larger segment of the population. As of yet, there is still no Apple of digital fabrication. (Carson 36)

The evolution of desktop publishing is not dissimilar to that of digital fabrication. The shared connection through design is, however, likely limited. The commercial and professional settings that desktop publishing upended twenty years ago are different from the situation of manufacturers and industrial designers now. This is in part because the commercial print environment of the 1980s supported tens of thousands of small, local printing businesses in the US. The same cannot be said of small, local manufacturers and product design and production - in the US at least.

At the beginning of the twenty-first century, industrial design is almost exclusively controlled by large producers and their tight network of smaller providers. So though the rise of desktop publishing in the 1980s and 90s can certainly be seen as one of the first incidences of users wielding digital technologies to their own ends, the commercial situations do not correlate exactly. Rather, it is the potential reconfiguration of centralized production that will lead to changes for professional designers in the future. The social trends behind a shift in who produces and how products are distributed do seem to share much in common with desktop publishing, and are worth keeping in mind as digital fabrication is adopted into a wider field of applications.

AREAS OF POTENTIAL GROWTH

I'm trying to do for products what has already happened to music and digital photography, money, literature - to store them as information and be able to send the data files around the world to be produced. By doing this, you can reduce the waste of the planet, the labor cost, transportation …it's going to have a huge impact in the next couple of decades for the manufacturing of goods; we believe it's a new industrial revolution. We will be able to produce products without using the old mass-production infrastructure that's been around for two hundred years and is fully out of date.

Janne Kyttänen ***Freedom Of Creation***

ACCESS TO TOOLS AND COMMUNICATION OF INFORMATION

After reviewing numerous projects that involve digital fabrication of the last few years, two principal aspects of their success became apparent. These are the access to tools, and the communication of information. Each of the projects highlighted in the prior sections revolve around both access and communication to a greater or lesser extent, and it can be said that it is only in the detail of organization of these aspects, that the projects truly differ.

Access and communication can also be conceived as variants of the traditional dimensions of capital, namely production and distribution. With one main difference - in these digital fabrication projects distribution is not necessarily of a finished physical product, but is rather the information for its production. This allows distribution to occur either before or after production. Consequently, production as seen in the previous sections, can occur through increasingly decentralized means, whether online service bureaus, local production facilities, or a network of like-minded participants. Since the product is not a fixed entity, but the data that defines it, it can also be modified and manipulated with relative ease. The result, I believe, is distributed making becoming ever more possible as the access to tools in turn pulls the information for making to itself.

Peripheral projects show experimentation with how individual and customized methods may work toward a larger system or holistic role of design. Current smaller projects show the variety of innovation just beginning to emerge online and in local communities in the form of local design and production shops such as Unto This Last and 100K Garages. These act along with the distributed niche or long-tail services enabled by digital communications that bring networked business to small producers on a global scale not unlike Nervous System and Grossman. This, in addition to the rise of grass-roots economics in the form of customized marketplaces similar to those provided by Shapeways, have much to offer peripheral producers in future incarnations of distributed making through their connection to niche markets.

Modification of Software Tools

Extrapolating from examples like Nervous System and Karsten Schmidt, the ability to individually configure software toward a desired output will likely be a continued mode of design investigation, as software is one of the primary tools used in design. Today, it is algorithms for modeling form that designers are configuring, which suggests that software manipulations in the future may extend much further into the process of design and the tools used for fabrication. Moreover, there are early examples of creative CAM software that show this. More importantly, however, it is the ease and the extent to which the designer can reach down in and truly manipulate the software as a medium that will affect the degree to which they will be able to create with it.

Craft Production and Cottage Industries

In their much discussed book, *The Second Industrial Divide*, Michael Piore and Charles Sabel argue that... craft production, the suppressed alternative to mass production... is once more showing itself to be a real possibility. Its return in more propitious circumstances could mean not just economic but social and political gains. (Kumar 45)

It could be said that on the scale of cottage-industries, craft production and individual use, the digital tool is much more readily subverted to the needs and the desires of the individual than anything the traditional industries of mass-production are capable of producing. Where now in the early twenty first century, unlike the 1980s when Piore and Sabel wrote, the technical, if not the economic circumstances, are much more promising for a return of craft production. It is not so difficult to see the rapidly multiplying use of digital fabrication in small scale projects as the beginning of a shift away from the centralization of production, and instead toward the development of varied means of developing and producing material goods.

With digital fabrication tools, tooling requirements for differing products can be minimized, if not eliminated. Where mass-production is not the aim, but rather customized, design-build, or craft production is, then the ability for designers to produce context-specific physical objects is greatly enhanced with access to these tools. This points toward a return for some to craft-based design and making on a local scale, but one with a potentially global reach. This is not unlike UTL, that produces locally designed and fabricated furniture. It also means greater access for others too, where customized products are much closer, more easily understood and appropriately configured for each individual when access to the producer is made available.

Accessible Tools & Collaborative Work

Where designers and makers currently access digital fabrication tools is piecemeal and limited. To some extent, this is driving the development of homebrew CNC and solid freeform fabrication tools along with the growth of community groups and community workspaces that include digital tools. It is probable these will continue to grow in popularity until the tool cost comes down, and independent fabricators are better able to produce for, and with their local communities.

Access to digital tools, especially direct and hands-on access is a crucial aspect for designers, and others to realize its potential. When access to CNC tools is less focused on the bottom line, innovative projects often result. These frequently rely on negotiated relationships between manufacturers and designers, or community organizations and schools. On larger scales, they include projects such as the proliferation of Fab Labs and 100k Garages, which aim to bring individuals together with tools in an on-going fashion. While small-scale collaborations arise for specific projects like that between Karsten Schmidt and ThingLab UK.

Traditionally, this kind of individual collaboration between designer and fabricator are common. With a shift to digitalization for both specifying and fabricating, design seems to be naturally including physical production as well. If the example of desktop publishing suggests anything concrete about the production of objects, it is that digitalization offers greater control over physical production for designers. Thus the designer-as-producer will plausibly become more common as digital tools facilitate the making of objects, and designers are more readily able to physically produce their ideas. How skilled fabricators might be impacted by such a scenario, remains to be seen, but for now, it appears to favor greater collaboration between skilled fabrication trades and designers.

Through the research undertaken for this paper, peripheral projects are apt to spin-off additional commercial projects and non-commercial projects in similar frequency. Making or designing at this level is thus self-propagating to a degree, potentially self-supporting, and as discussed above, often collaborative.

Distribution of Design as Media & Culture

The digitization of design places an emphasis on two-way communication for the distribution of design intent and the products of design. In this sense, digital design data is conceived as a kind of media, not unlike music, or video content capable of being variously packaged and modified as necessary. Current digital media use for other types of content indicate a preference for searchable databases. In the case of design, this takes the form of downloadable geometries for fabrication, and algorithms for creating design alternatives within a set field of constraints. Indeed, these are beginning to surface at sites such as Shapeways, and exhibition and conference blogs like Generator.x. In the future, digital design content would ideally take the form of readily accessible open-commons content created by the users, and where the organization and access to this data is one of many possible services that grow up and around it.

What can be done with design content, whether for product innovation, or as an easily accessed source of information for production and distribution are possible avenues for designers to explore. Ronen Kadushin's Open Design project is an early example. It involves designed objects for 2D sheet fabrication with digital tools based on the open-source philosophy of promoting access to the product's source materials.

His work, however, is largely self-contained. Even though the designs are freely available for download, the activity around them online is relatively flat. By providing an incentive to participation on the other hand - tapping into an already engaged group as Griffith did with kitesurfing, further energy could be spurred by the sharing. Kadushin's existing Open Design site shares almost exclusively one-way and it is centered on Kadushin. If instead, it included an active area for uploads of similar designs, and user-varied designs also for download, the emphasis would be less on the designer, and more on the creation of objects and its innovation centered on the idea of creating designs for open distribution.

Modular Design

As of this writing, open-source design projects of physical objects are beginning to appear. In current practice, this is similar to the framework used in open-source software development, but for hardware. The methodology often relies on the creation of modular components that can be mixed and matched together as users require. These modules are developed as building blocks for more complex objects Though the projects described earlier only hint at the possibility of modular design, design critics such as Paola Antonelli and Werner Lippert have noted its likelihood as a future direction for professional design.

> The product as starting point was yesterday. Tomorrow the consumer will be the focal point for enhancing value. The emerging knowledge economy relies on digital self-determination in real time. The individual linking of what consumers want with the solutions offered by the databases, from music downloads all the way to personal medication, will shape the economy of the 21st century.
>
> In future, both designers and their clients will have to dissociate themselves from the task of styling isolated products and adopt a holistic approach to their work. (Lippert and Wipperman 10)

A good example of this is Bug Labs, the New York-based company behind BUG, a modular open-source hardware development platform. They have designed and developed components of different electronic functions as freestanding elements with both physical and software joints that allow connection to other BUG hardware components. Users purchase the low-cost open-source components and combine them to make their own programmable electronic devices like GPS triggered MP3 players, or motion-detecting recording devices.

As MoMA's leading design curator, Paola Antonelli points out,

> Rapid Manufacturing Technology gives us amazing possibilities for 'open-source design.' In the future, designers will be able to give their clients a complete framework for creating their own products, serving as consultants regarding form and structure. This has happened in every medium from desktop publishing, music, and video, to

> fashion and user-generated web content. Really, three-dimensional products are the last area that this digital revolution can put into the hands of the public. (Deenaro-Bickerstaffe 31)

Within the design of open-source modular product systems, the more useful a component, the more likely it is to be absorbed into other products. The very nature of open-source, however, flies in the face of traditional corporate product design, where it has been in the commercial interest of the producer to discourage crossovers with other products for fear of losing market share. Yet in an environment of potentially user-modifiable products, proprietary may in fact turn out to be a hindrance to the growth of a producer's market share.

APPENDIX A

These four creatures were the only animals that had survived a great massacre perpetrated during the previous year by Mac, one of Mom's boyfriends, who in a fit of rage had gathered up all of the dolls and stuffed animals in Nell's room and stuffed them into the Knacking hatch.

When Harv had opened it up a few hours later, he had found all of the toys vanished except for these four. He had explained that the deke bin would only work on things that had come from the M.C. [matter compiler] originally, and that anything that had been made "by hand" (a troublesome concept to explain) was rejected. Dinosaur, Duck, Peter and Purple were old ragged things that had been made "by hand."

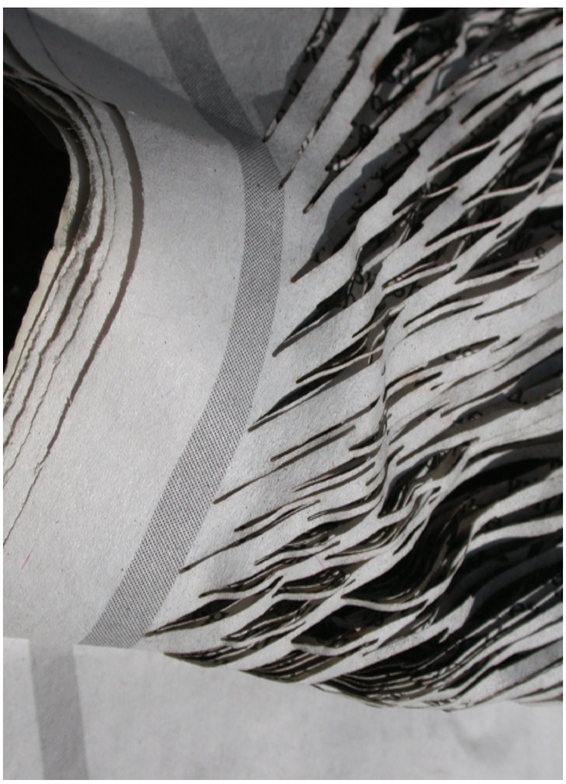
Neal Stephenson *The Diamond Age: Or, a Young Lady's Illustrated Primer*

PRELIMINARY EXPERIMENTS

1. Lasercut News
2. Digital Color Studies
& Pixilated Images
3. Lasercut Screen
4. Lasercut Bracelets


TAXPAYER BATTLE
ENDS WITH SALE
OF BIG LANDLORD


LOSS OF 'COPTERS
SUGGESTS CHANGE
IN IRAQI TACTICS



Lasercut News

Lasercut News is a tool and material study. In this brief experiment I was interested in learning how far a low wattage laser (45W) would be able cut into multiple layers of newspaper, and how the cuts might fade as they penetrated into subsequent pages. I was also interested in seeing what the repetition of cuts through multiple layers would produce visually, where for example, as the pages opened they might offer a fading and repeating pattern. What I hadn't anticipated –and what connected this to other experiments, was the tangled growth that ensued once the pages were opened and then folded back together. The alteration of the material, and the specific ways the digital tool left remnants of itself was a thread I pursued elsewhere.

clockwise from top left: figures 15-18 Laser cut newspaper unopened & damp (In certain circumstances, I found wetting combustible materials was preferable for reducing the likelihood of fire during lasing); Refolded newspaper; Detail of 'faded' interior cuts; Detail of outer layer cuts.

Digital Color Studies & Pixilated Images

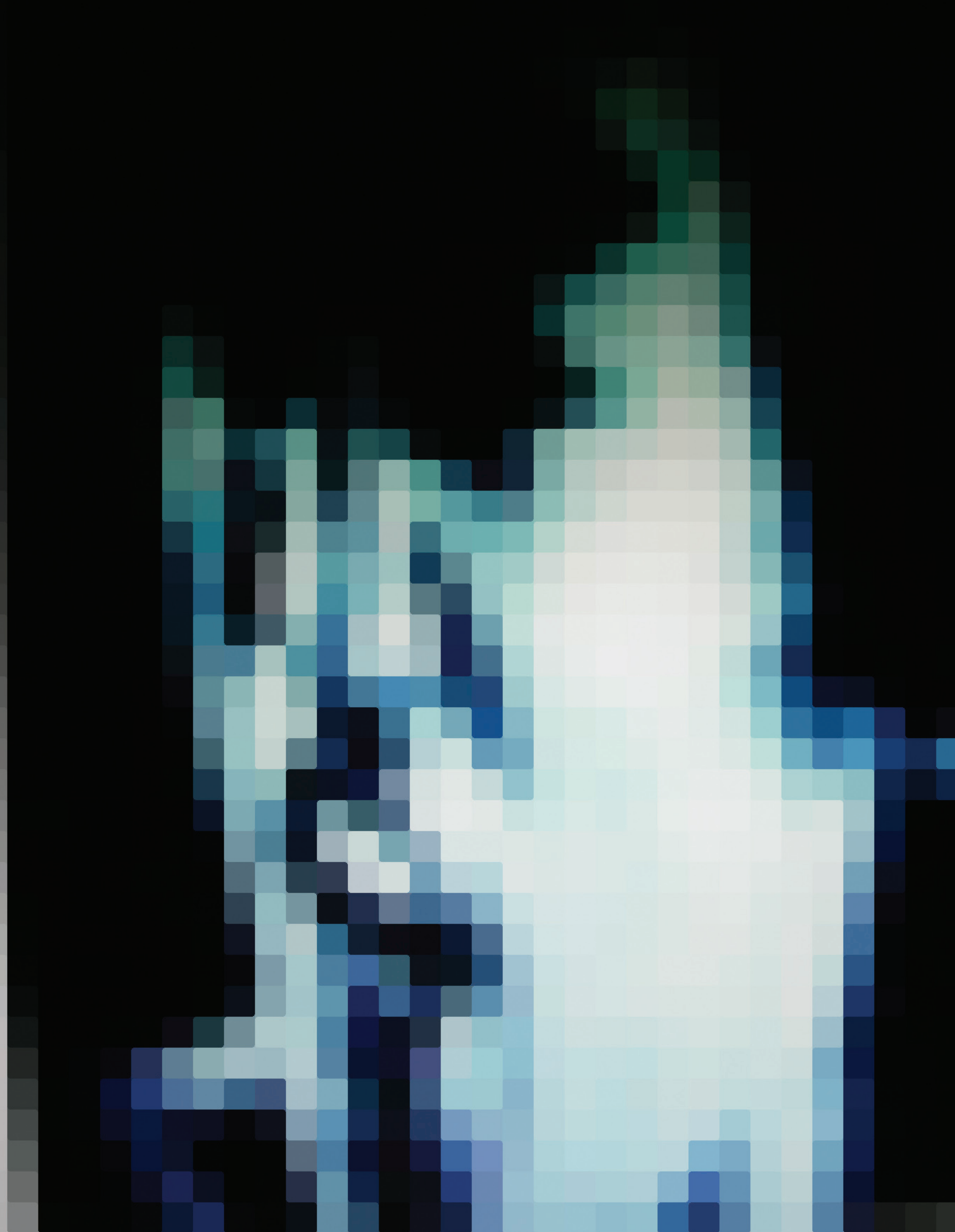
Thinking about how color may be interpreted through a digital process, a series of pixilated color studies were taken from portions of larger images.

With this project I was particularly interested in digital deterioration, and the visual manner in which the decay takes shape. How could a digital tool erode something that it ostensibly deals with as ones and zeros? Using a linear process of re-creating the original in another form multiple times seemed one approach.

In this example, a photograph was taken of a video, of what was originally a photograph. This photograph was then reduced further with a standard Photoshop filter into exaggerated pixels of single colors. The result is a deterioration of visual information through translation.

In hindsight, the clarity of this process was lost with the addition of the software pixilation. Instead, the pixilation could have been a separate, but related series, while the visual media process ought to have been taken further to a final resolution of its own. In this way, the tools employed would perhaps also leave a more discernable remnant of their use, something akin to chisel marks on wood.

top: fig. 19 Page from digital color studies booklet.
bottom: fig. 20 Original image.
opposite: fig. 21 Deteriorated image.



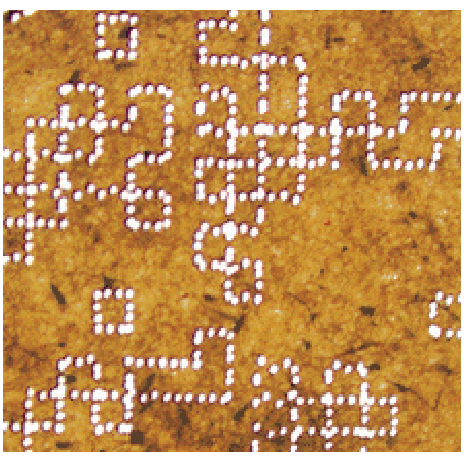
Lasercut Screen

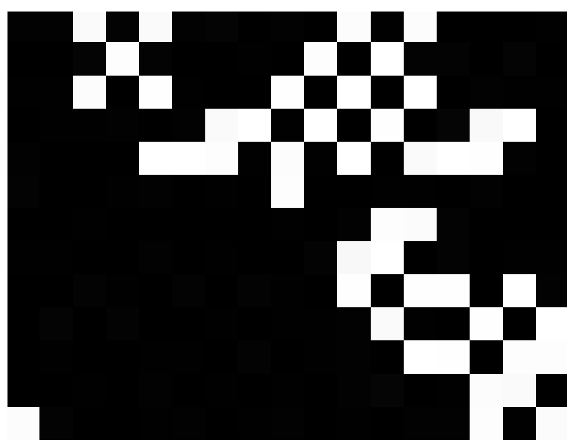
Using a similar conceptual approach to the digital color studies, the lasercut screen is a better realization of accentuating the processes of the tools employed. The paper screen is the result of taking a pattern, simplifying it digitally, and using a laser cutter in a manner that seeks to emphasize its own tool-processes. In this case, I was thinking of disintegration and immateriality.

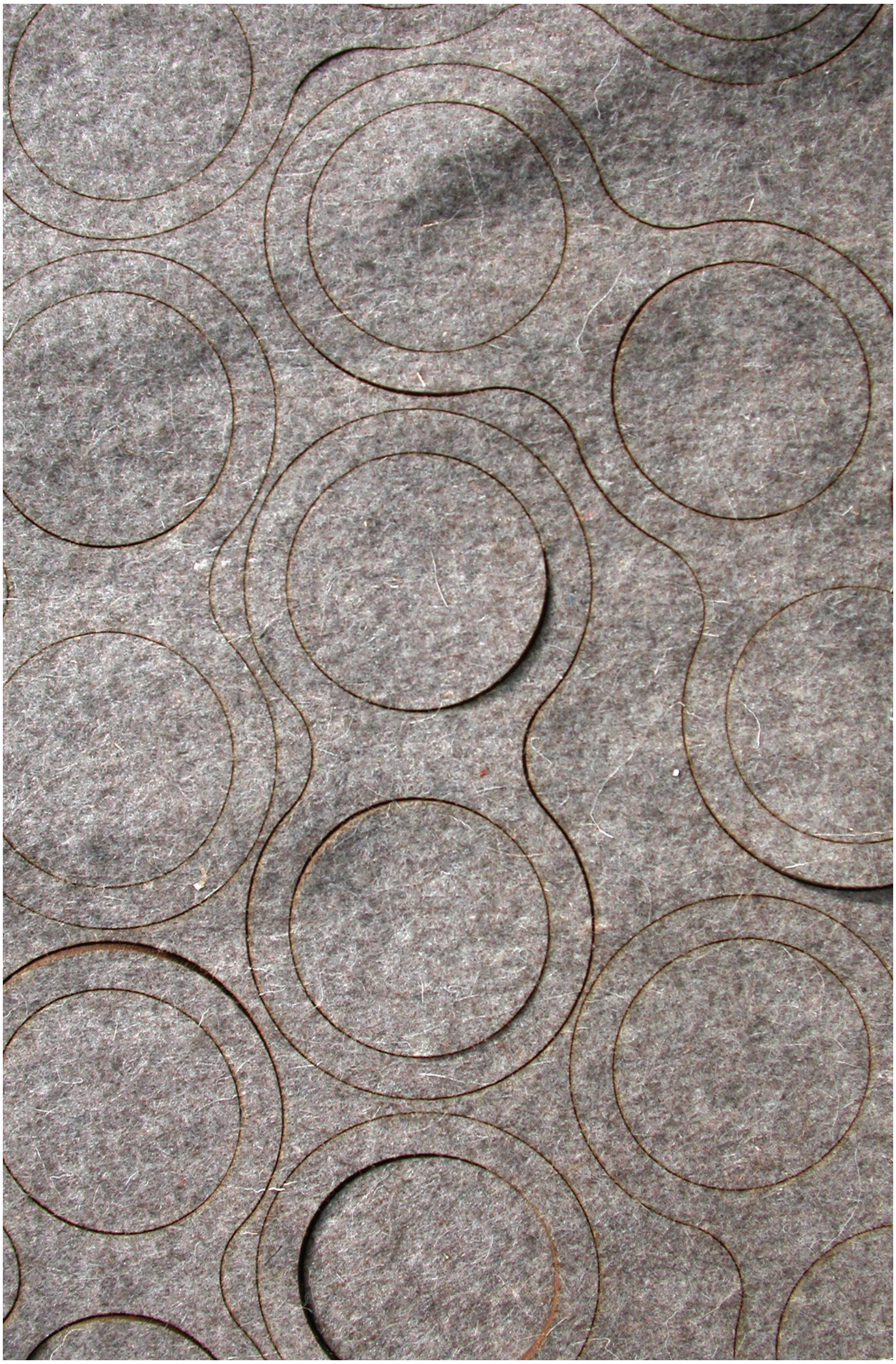
The pattern is a portion of a wallpaper design from the 19th century. By converting the pattern into a bitmap, the smooth curves are reduced to black and white orthogonal interpolations of the original. Generating tool paths that trace these rectilinear forms, the laser cutter can recreate the smooth curves in an emphasized x-y grid. The manner in which the laser cutter beam pulses to create a continuous stream is likewise articulated. Whereby lowering the pulses per inch (ppi), the laser cutter, instead of cutting the paper only perforates it.

fig. 25 Portion of bitmap image.

opposite: fig 22 Laser cut screen installed on door.
below: figures 23 & 24 Closeup of laser cut screen and closeup of bitmap image.







Lasercut Bracelets

By this point, I had realized that at the scale of projects I was working on, once I had access to digital fabrication tools, the difference between making one of something and making many was minimal in terms of time and effort. This is also true in the case of variation. If the important aspects of the form are understood, multiplying it, and even varying it can be negligible. In this case, the form is dead simple. So making one bracelet is only slightly faster than making 20 similar bracelets. If the shapes were algorithmic variations, i.e. varied by programmed rules in software along the lines of Nervous System's work, then the time per varied piece would be even less.

As a test, I took these felt bracelets to a local shop to sell. By doing this I was able to recoup about twice the cost of the material used. This is not evidence for the viability of mass-production through digital fabrication, nor is it in itself particularly supportive of viable profit margins. Rather by looking at it from the perspective of cottage industries related to design, it is the flexibility engendered by digital tools that I find tremendous.

opposite: fig. 26 Laser cut felt sheet.
above: fig. 27 Finished bracelet.
below: fig. 28 Single-fold and double-fold bracelets.

APPENDIX B

Several years ago, Fredric Jameson said that the computer would be capable of giving us a new nature; not an unnatural nature but a nature derived directly from computerized algorithms and processes. Such a thought means it would no longer be necessary to look at nature with the same eyes through which Le Corbusier observed the natural shapes of D'Arcy Thompson.

Peter Eisenman *A Matrix in the Jungle*

PRINCIPAL PROJECTS

Distorted Chair and Asperatus Tile

These two projects were driven in part by a curiosity of the possibilities of digital fabrication. They were also well-suited to production with the available digital tools, as each concentrated on an exploration of physical geometries with the aim of creating repeatable one-off forms, but not volume production via the digital fabrication process.

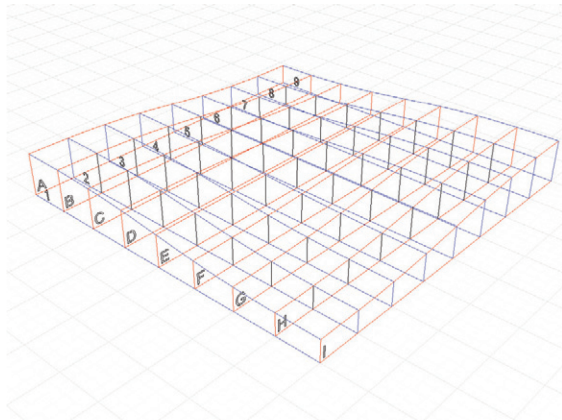


fig. 29

figures 29 & 30 Digital construction geometries for the Asperatus Tile and the Distorted Chair.

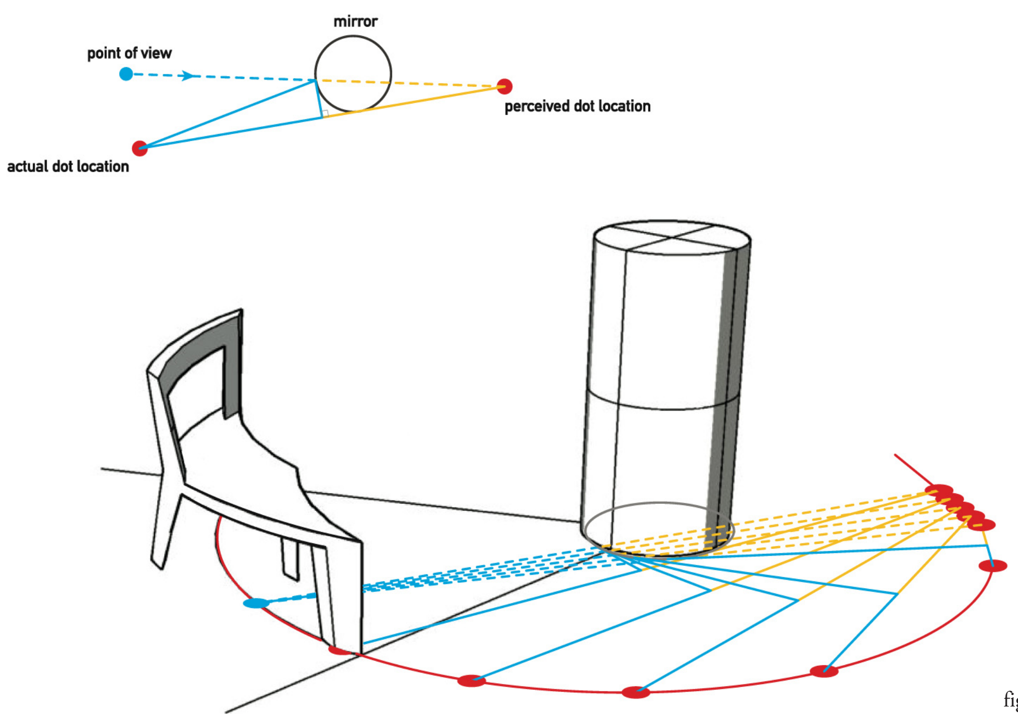


fig. 30

Distorted Chair

Anamorphosis - a drawing presenting a distorted image that appears in natural form under certain conditions, as when viewed in a specified manner or through a special device.

The Distorted Chair was developed as one of approximately twenty exhibits for a traveling geometry exhibition for the Exploratorium, a hands-on science museum in San Francisco. Conceived and produced by myself and Mary Elizabeth Yarbrough, with help from Thomas Humphries, Jesse Marsh, Toni Dancu and others at the Exploratorium. The idea for the Distorted Chair grew out of related two-dimensional anamorphic exhibits. It was specifically devised to help bring the phenomenon of reflection and the geometries of distortion into a physical form in which visitors could interact using their whole bodies.

The final prototype was first exhibited at the Exploratorium in early 2009 and included a distorted background wall that followed the same anamorphic geometry as the chair. Both objects are placed in relation to a 2 foot diameter cylindrical mirror in which an undistorted reflection may be seen. The exhibit can be encountered at any viewing angle and visitors need not sit on the chair to see an accurate reflection of the undistorted chair in the mirror. The visitors' reflections, however, will become distorted in the mirror, so that assimilating the reflections of distorted self with the undistorted chair becomes a playfully disorienting experience.

Because of the relative complexity in deriving the appropriate distortion in three-dimensional form and physically producing the result, digital tools were used for the majority of work. This process included the following: 2D anamorphic geometry defined and tested with a 3D digital model (Geometer's Sketchpad, Rhinoceros); paper scale models made to physically test the distorted form (Rhinoceros, Pepakura, 100W laser cutter); full scale prototypes constructed to evaluate with users, and for overall size and build technique (1/4" masonite, 3/4" plywood, 3-axis CNC router, hand fabrication); fabrication of final prototype (1/2" plywood, 3-axis CNC router, hand fabrication).

opposite: fig. 31 2D grid and 2D grid with anamorphic distortion. fig. 32 Distorted Chair geometry tested with 3D digital model.

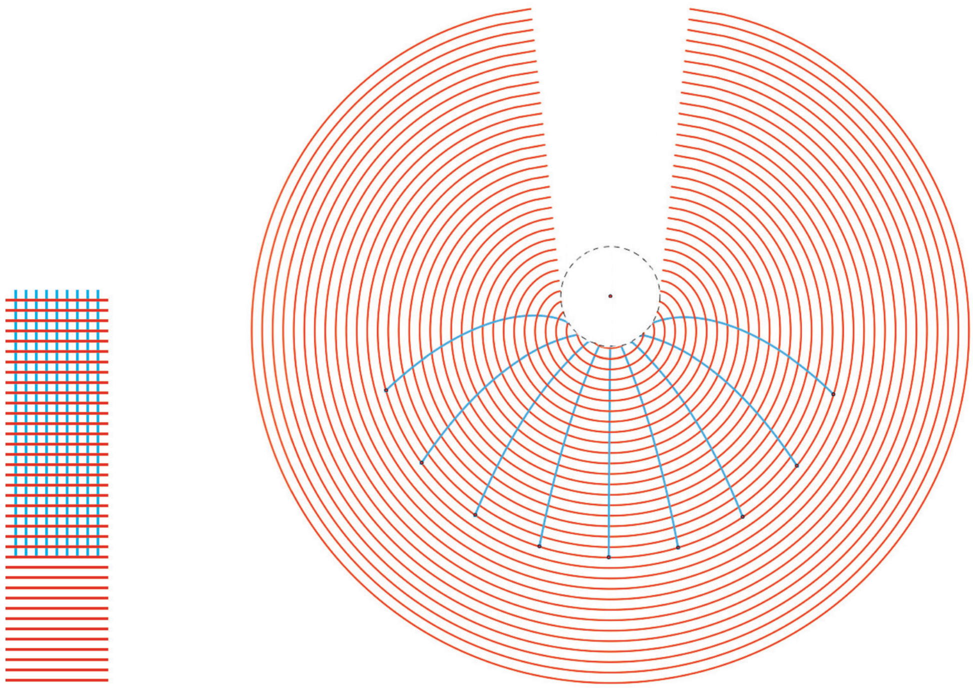


fig. 31

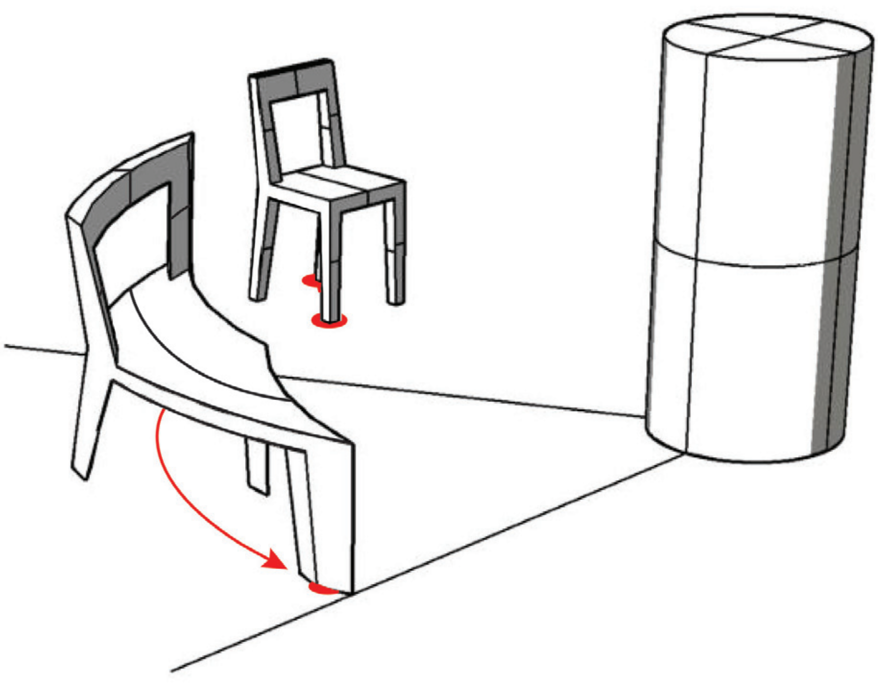


fig. 32

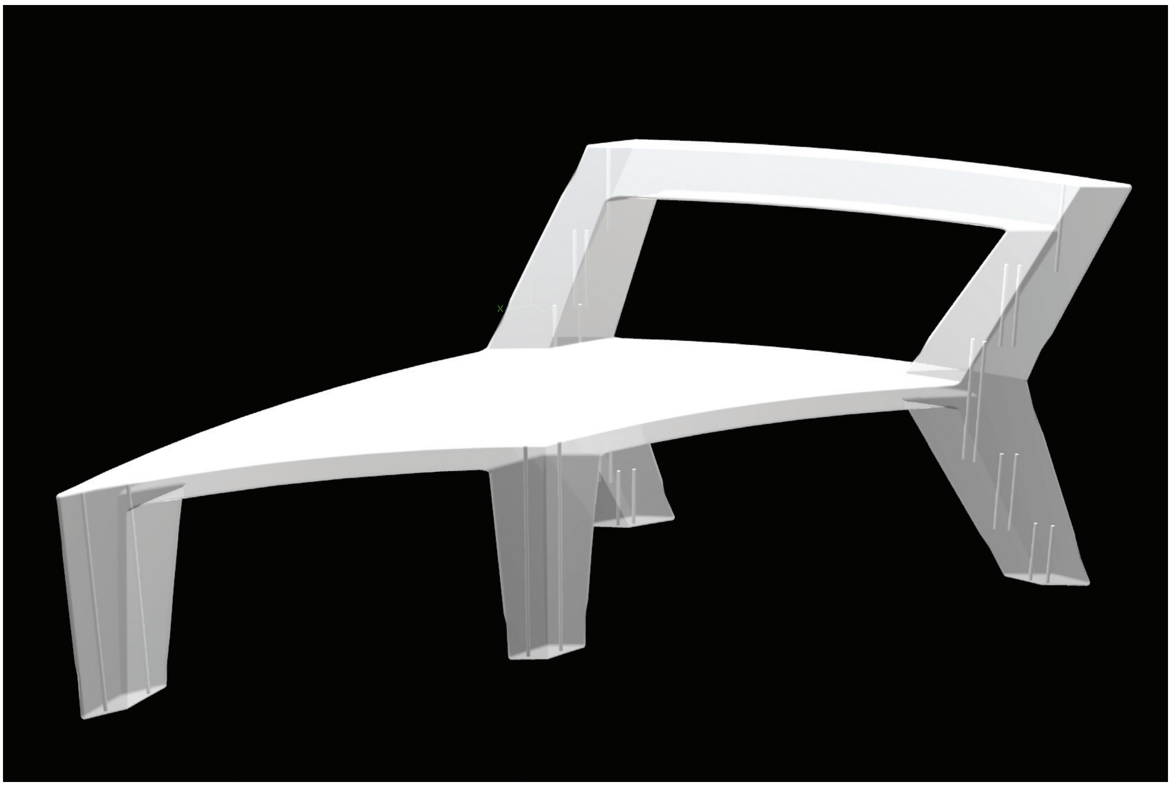
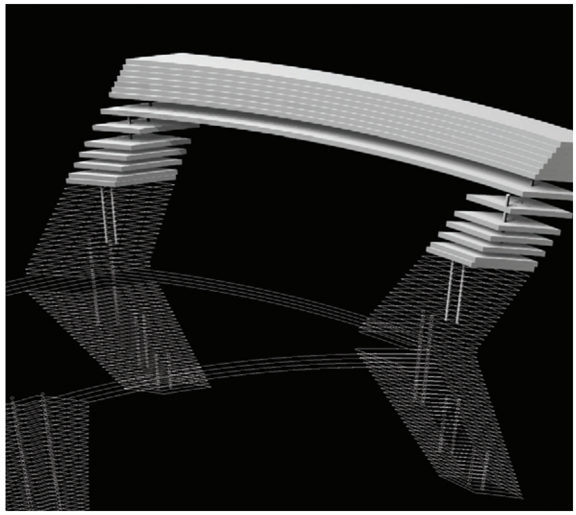
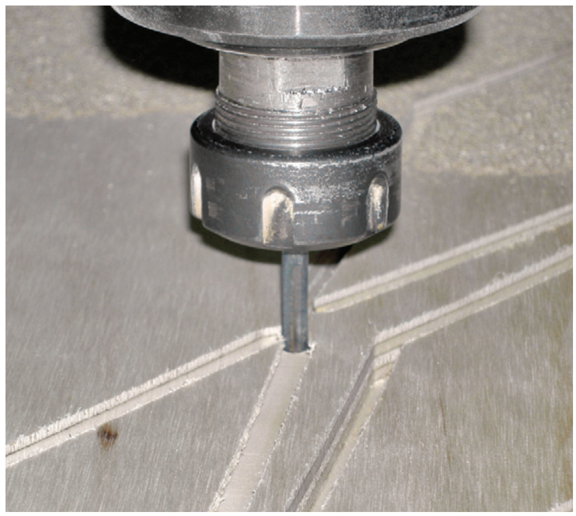
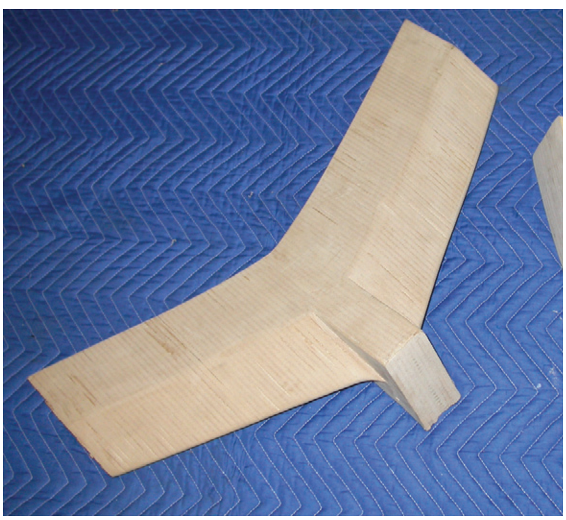


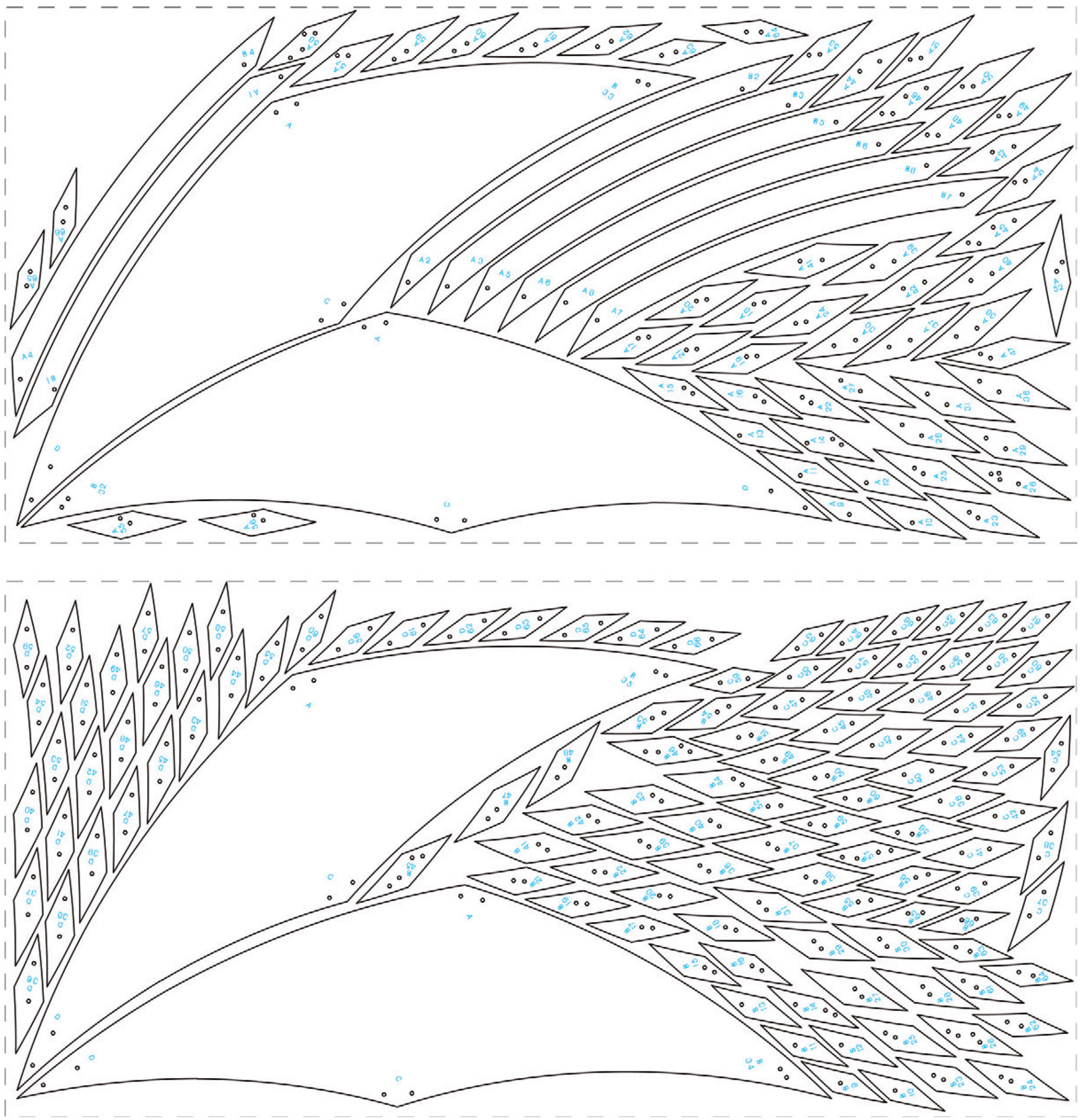
fig. 33 Digital 3D model of distorted chair.

fig. 34 Completed prototype.









opposite clockwise from upper left: figures 35-40 Paper model; Digital model of final construction method; CNC routing parts from 1/2” plywood; Final prototype on museum floor; Full scale test sections in 1/4” masonite; Full scale rough usability prototype.

above: fig. 41 4’ x 8’ Cut files for final prototype.
overleaf: fig. 42 The Distorted Chair final prototype reflected in a cylindrical mirror.

Asperatus Tile

The Asperatus tile is the result of a design and fabrication collaboration between myself and Rude Graves of Portland Cement Co. This company designs and produces small-batch concrete tiles in Portland, Oregon. Asperatus is one of half a dozen forms we developed as an experiment to investigate the viability of using digital tools in the design phase of their tile making process. The three-dimensional saddle-shaped Asperatus is produced as 4 inch and 8 inch tiles in a variety of colors.

The process of creating the Asperatus into mold masters and then cast concrete tiles for installation evolved as follows:

Beginning with concept sketches, digital forms were created and then refined in Rhinoceros for draft, material thickness, overall size and some minimal tool-specific output requirements. Originally, we explored SLA printing in an ABS-like polymer through a digital fabrication service, but the surface was too crude and required too much handwork to correct that it altered the regular geometry. At this point we turned to the open-access workshop, TechShop in Palo Alto, Ca., which enabled us to work with some basic digital fabrication tools ourselves. After experimenting briefly with laser cut cardboard profiles, we turned to 3-axis CNC routing the 3D forms. First from 16lb polyurethane tooling foam, and finally Medium Density Fiberboard (MDF). When tooled at a high speed and a small step over, the MDF presented a good surface finish that required only minimal preparation to make ready for casting.

The mold-making process that Portland Cement Co. uses varies somewhat with the type and details of the tile being made. In the case of the 4 inch Asperatus tile, a urethane rubber cast was made of the CNC routed master form. A small number of plaster positives were then poured from this one rubber mold. The plaster positives were grouped together and vacuum formed with ABS. This then provided the production molds used for creating the final concrete tiles.

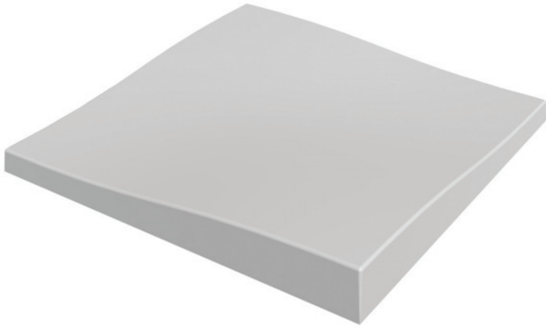


fig. 43 3D digital model of the Asperatus tile.

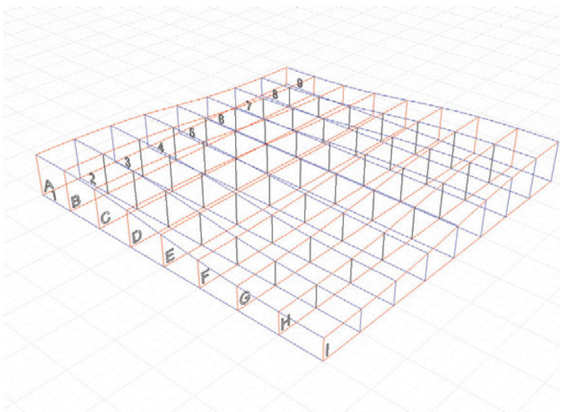


fig. 44 Cross-section profiles for laser cutting.

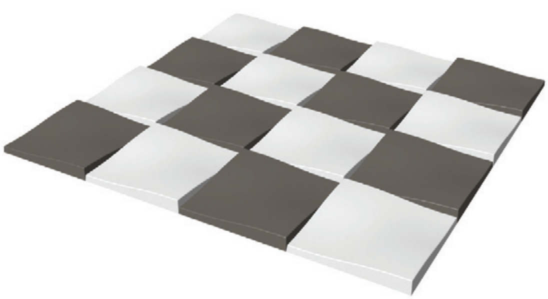
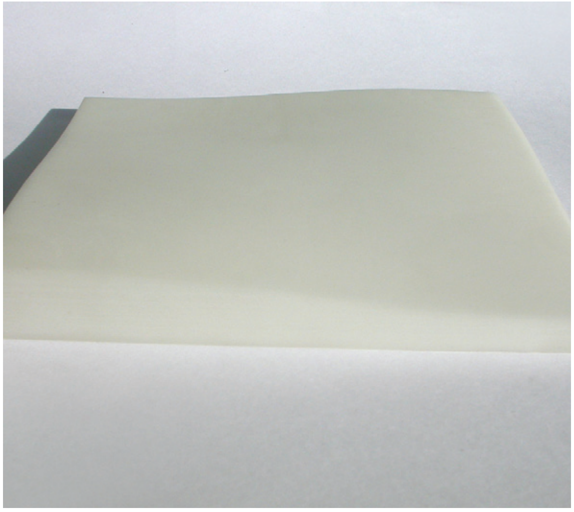
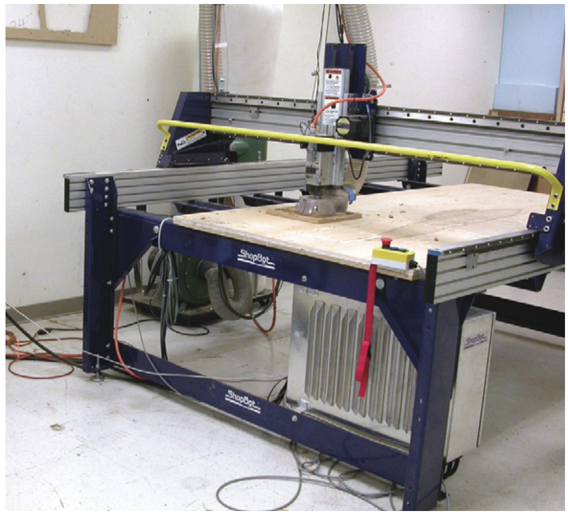
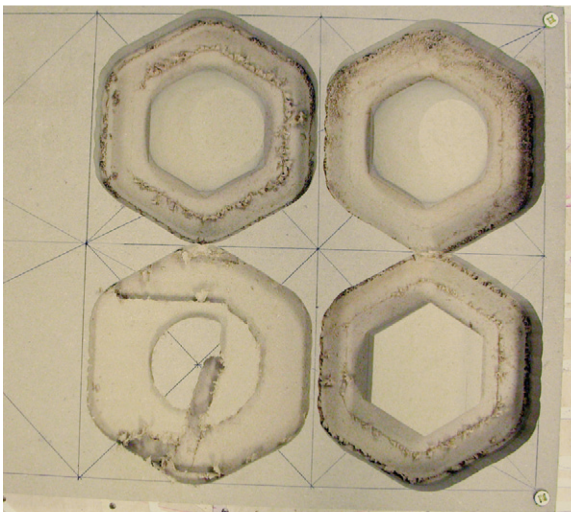


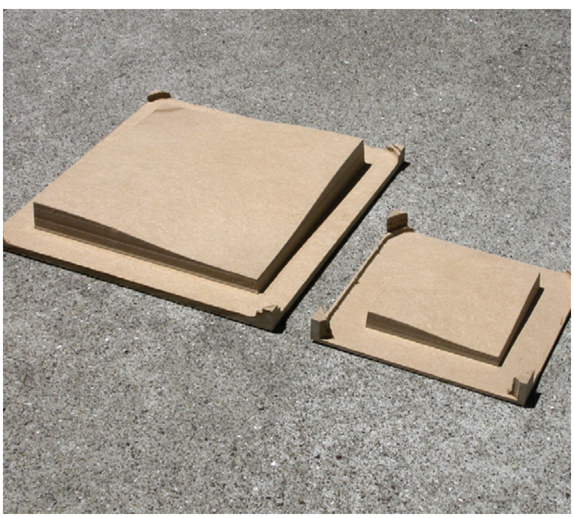
fig. 45 Digital model of one of the two possible tiling configurations with the Asperatus tile.

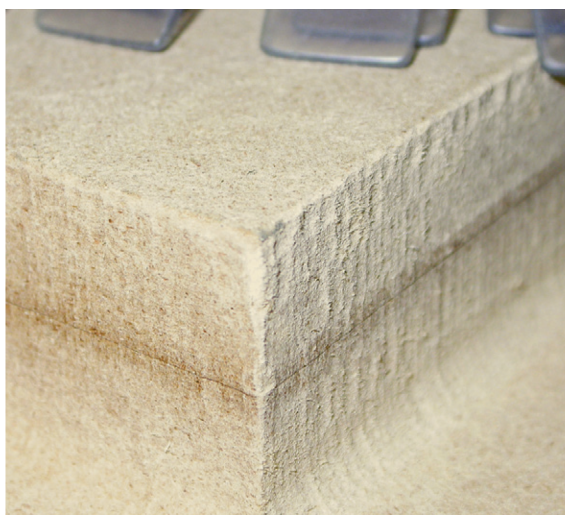
opposite clockwise from upper left: figures 46-51 Unusable SLA print; CNC routing at TechShop Palo Alto, CA.; Making the finishing tooling pass with the CNC router; Tooled surface; 4" and 8" master forms; Other CNC tile form experiments.

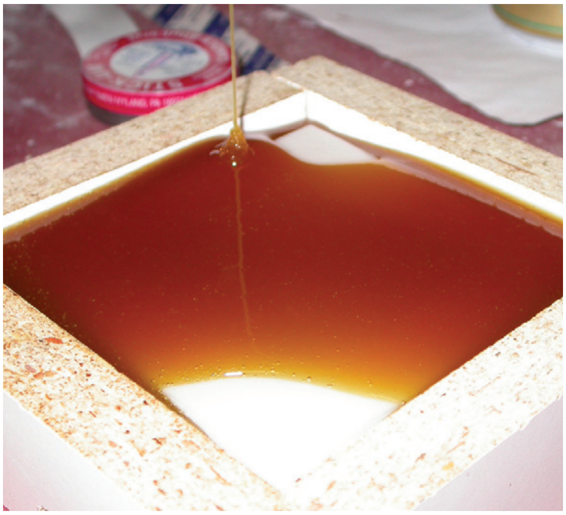


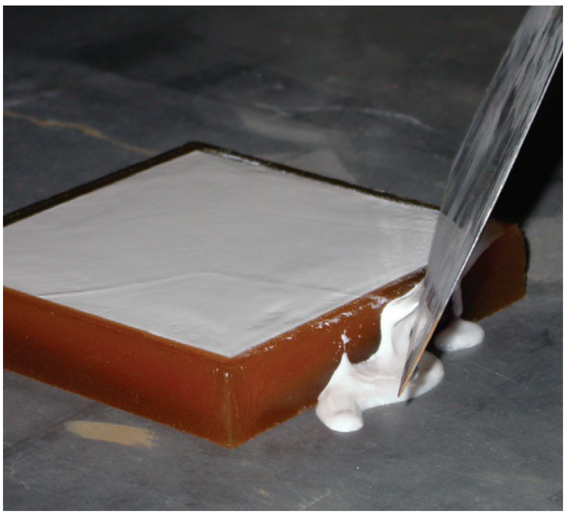


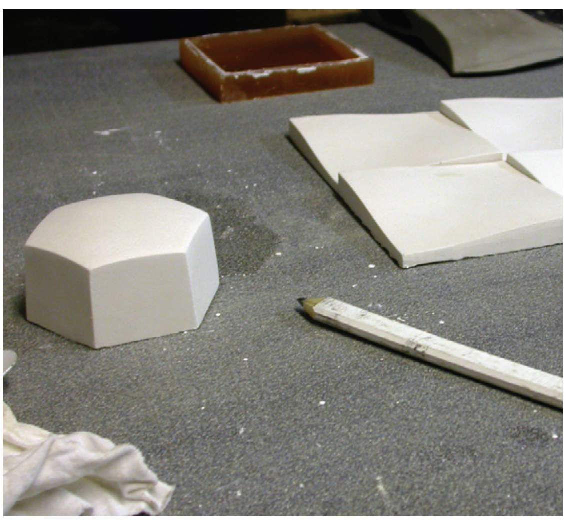












opposite clockwise from upper left: figures 52-57 Pouring the rubber mold; Portland Cement Co. workspace; Making cement tiles; curing tiles; Plaster masters; Making the plaster masters.

above: fig. 58 Asperatus display board with alternate tiling configuration.

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IMAGE CREDITS

All images and illustrations are by the author except those noted here.

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fig. 13 superrune [Rune Spaans]. "Brooches 3D Print, Shapeways" (CC-BY-NC 2.0) 10 Sept. 2008. Flickr. Web. 8 Nov. 2009.

fig. 31 2D anamorphic distortion grid originally conceived by Thomas Humphries, recreated by the author.

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