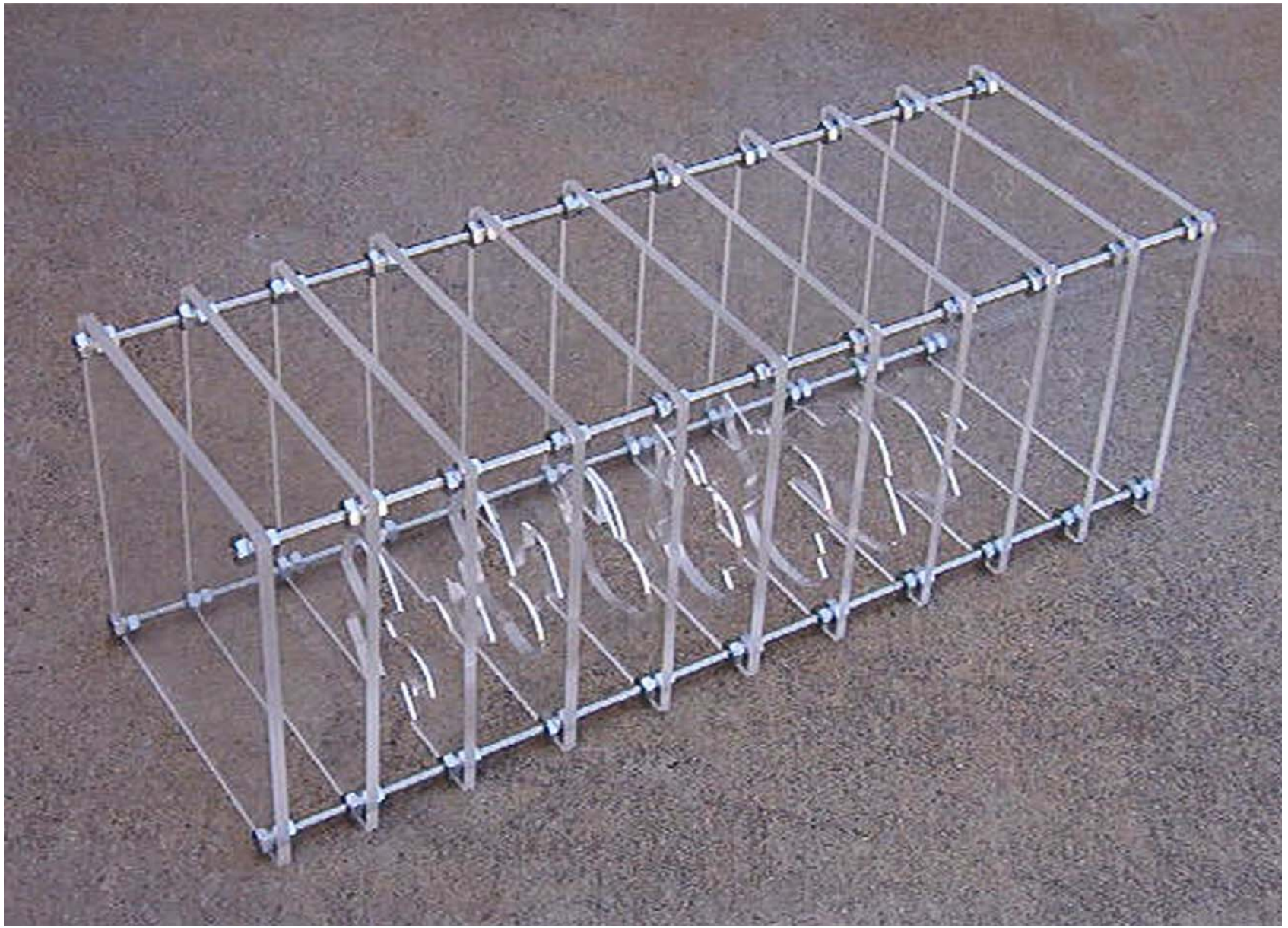

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VLADO VALKOF, RA, LEED AP
4919 INDIAN WOOD RD, #495
CULVER CITY, CA 90230, USA
+ 310.210.8904
VALKOF@DESIGN-INITIATIVES.NET

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Rapid Prototyping:

- **gains popularity** among architects
- **changes** architectural practice as we know it

allows **3D computer models** to be efficiently translated into **physical form** through:

- 3D printing
- stereolithography
- CNC milling
- laser / plasma cutting

- **speeding** the production of **complex shapes**
- currently the main use is as **automated model building**
- will be extended to **automated fabrication**

furniture piece - CNC milled urethane foam with lacquer finish

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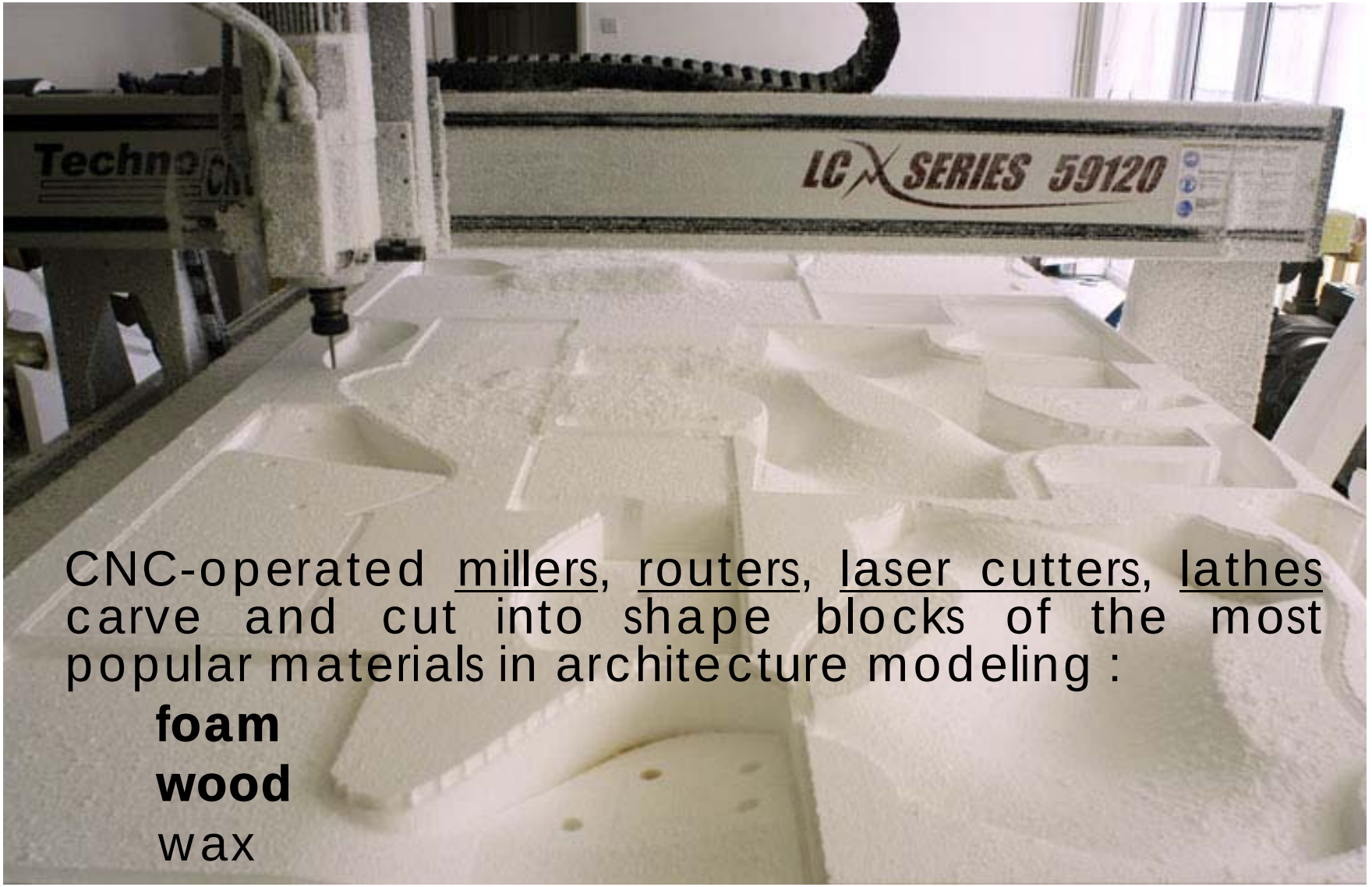

CNC-operated millers, routers, laser cutters, lathes carve and cut into shape blocks of the most popular materials in architecture modeling :

foam

wood

wax

3-axis CNC milling machine

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CNC machines can be as small as **12-inch-by-9-inch** desk-top machines used for model making

FROGMill - the industry's most powerful CNC foam carving router

architectural millwork – shelf out of solid wood

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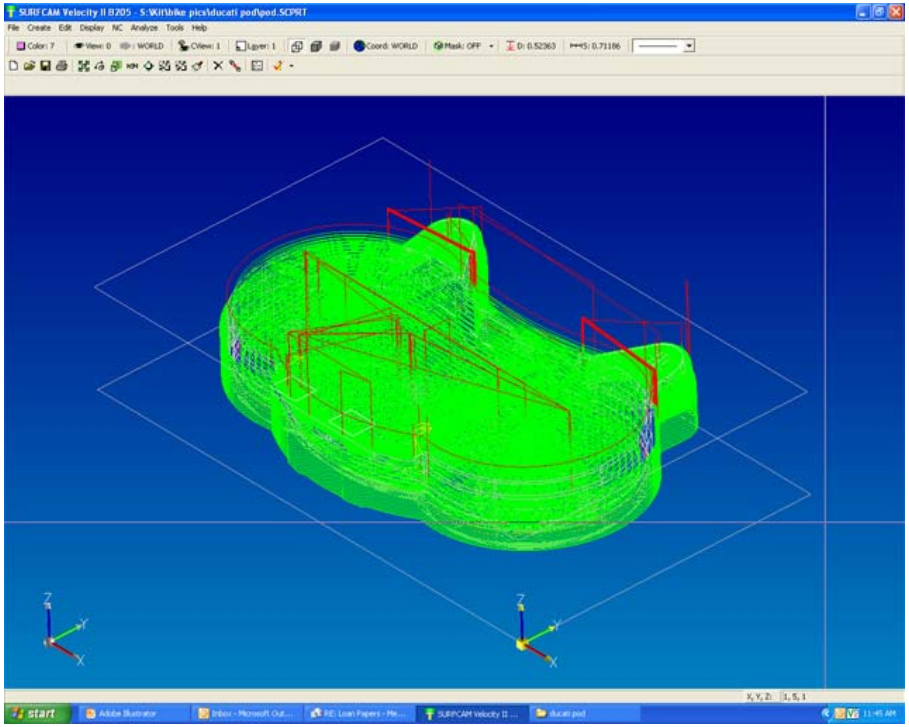
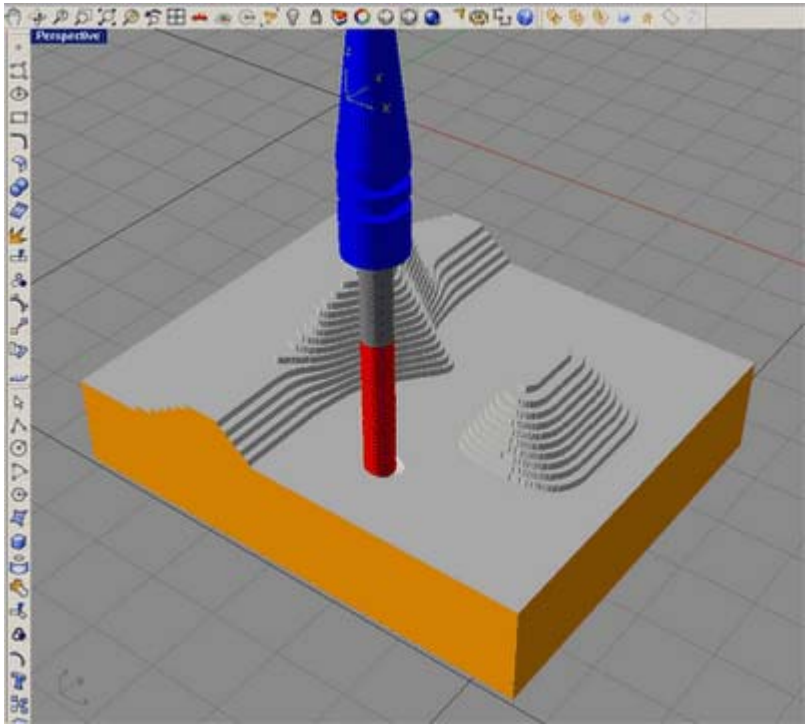
dedicated milling-translation software such as **Surfcam** and **Mastercam** convert 3D computer models into "G-code" which directs the machine moves for the mill



Surfcam

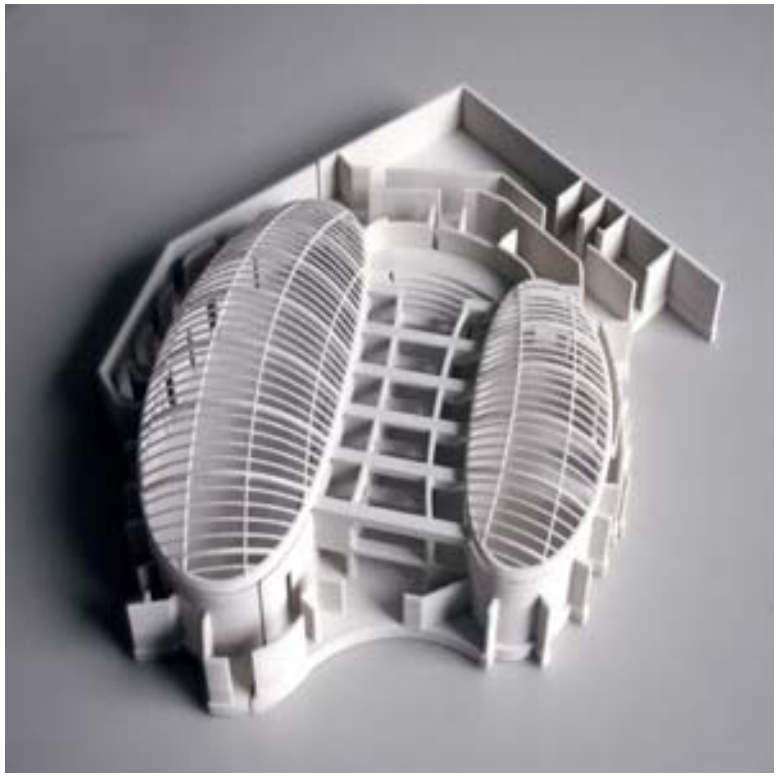


Mastercam

3D printer is ideal for **quick** in-house production of **schematic models** - much faster than subtractive prototyping

as **easy** to output as traditional printing

Z-Corp 3D printer 250



3D printed model

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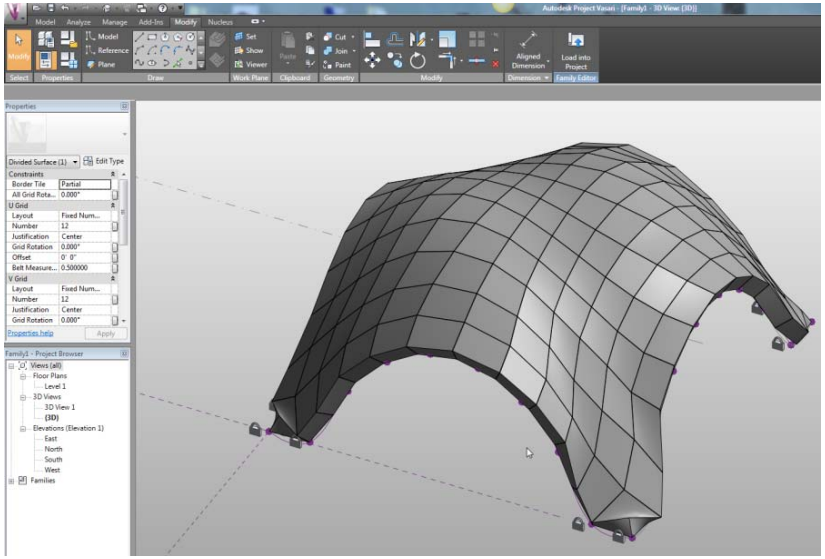
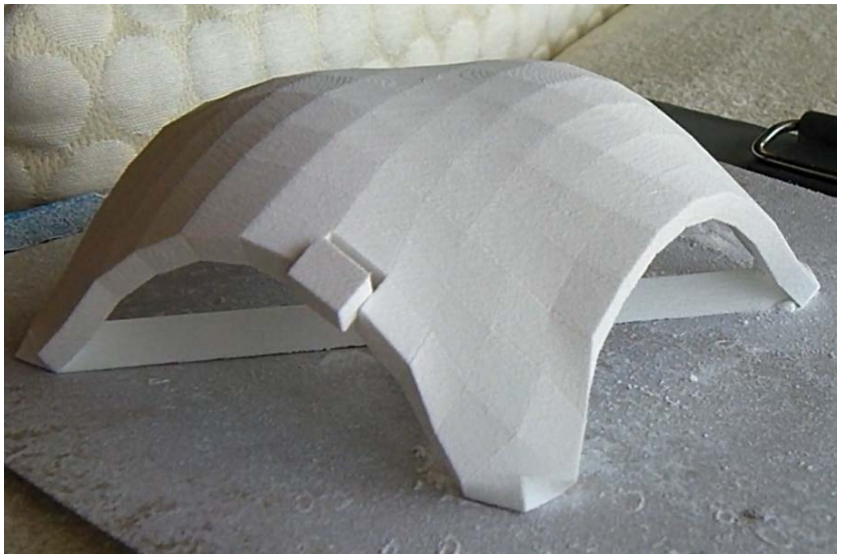
Z Corp's machines use inkjet printing technology: a 3D file is imported into the Zeditpro software which slices it into **thin cross-sections** and feeds them into the 3D printer

the printer creates the model **one layer at a time** by spreading a layer of **gypsum-based powder** and inkjet printing **binder** into the cross-sections of the model



self-supporting masonry 3D computer model



self-supporting masonry 3D printed model

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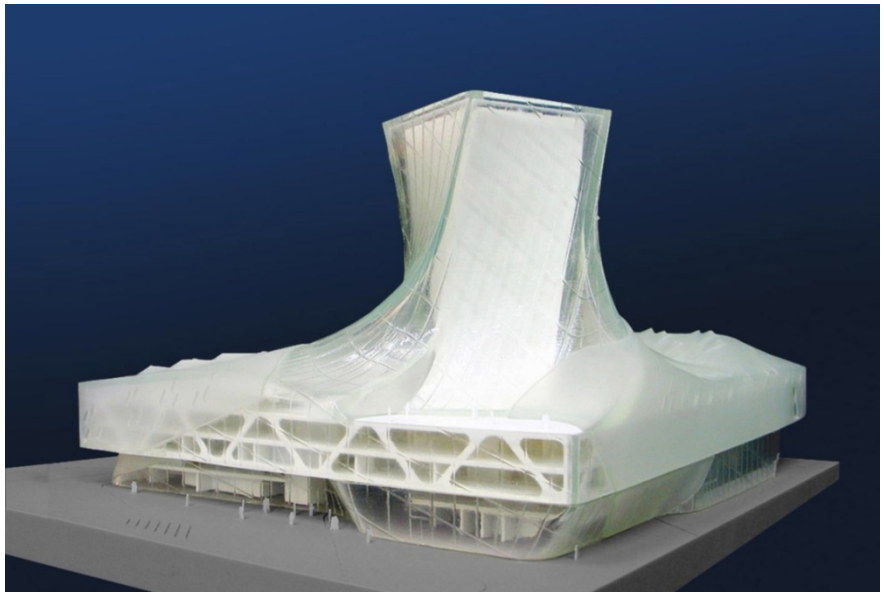
stereolithography: a computer-controlled **UV laser** etches models out of **liquid synthetic materials / resins**

a thin layer of the liquid synthetic is poured into a chamber

the laser etches the shape of the model into the layer by **hardening the liquid** on contact

3-D Systems stereolithography machine



Czech National Library stereolithography model

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3D printing produces a **less stable model out of powder** than stereolithography does out of resin but the **cost of equipment and materials is less**

composite models - to take advantage of the most cost-effective process :

stereolithography (more precise process) - for delicate and complex components

+

3D printer (concept modelers) – for not delicate or complex components

other more costly 3D printing technologies :

- Selective Laser Sintering (SLS) - similar to stereolithography, but uses heat to **fuse metal or plastic powder** instead of resin

EOS SLS machine

SLS polyamide (nylon) lighting

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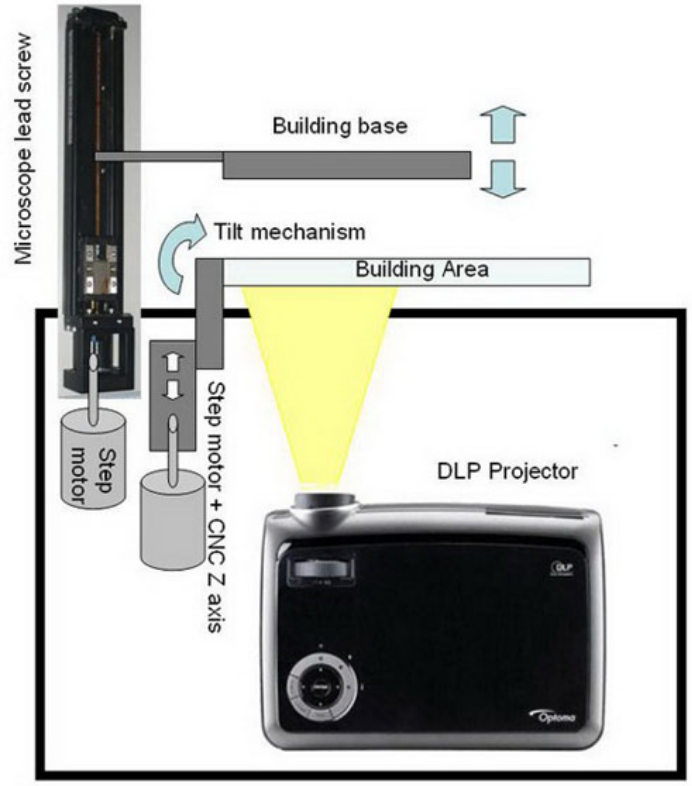
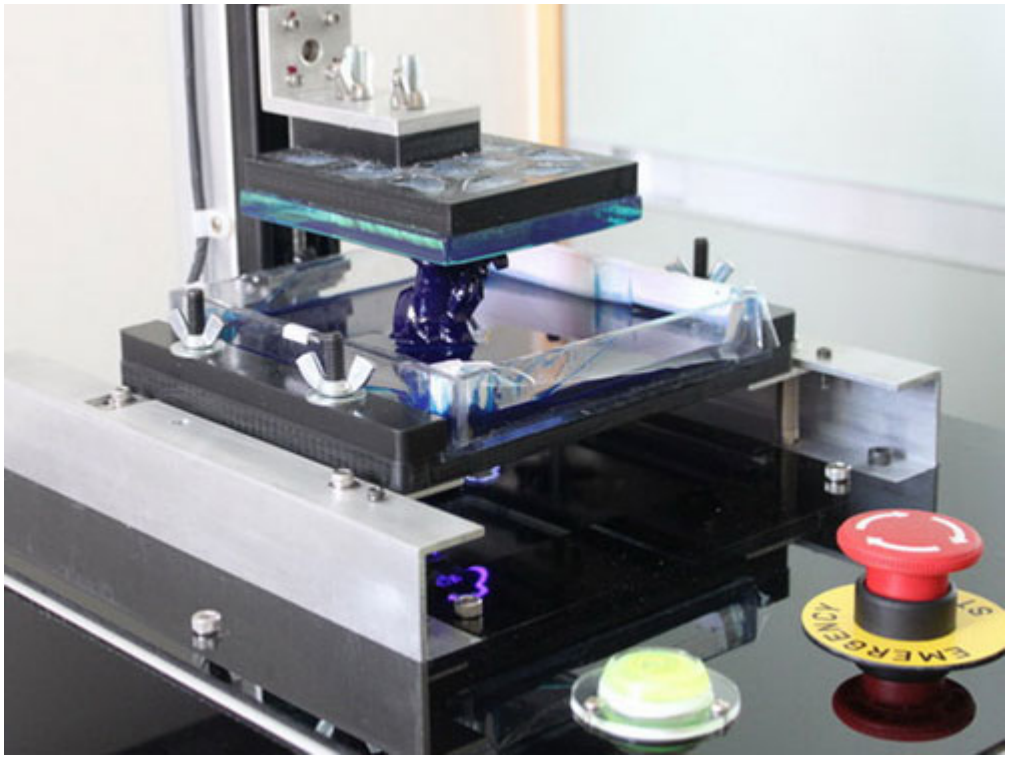
other more costly 3D printing technologies :

- Digital Light Projection (DLP) - **liquid polymer** is exposed to **light from a DLP projector** under safelight conditions to **harden it into a plastic layer by layer**



DLP diagram



DLP printer

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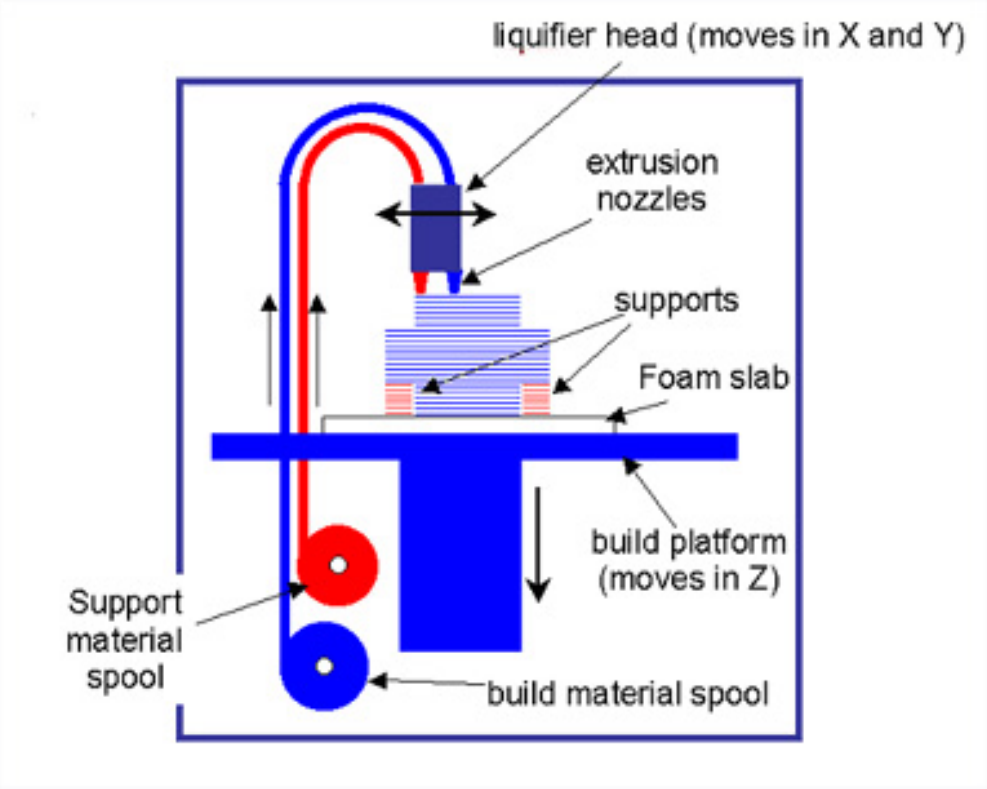
other more costly 3D printing technologies :

- Fused Deposition Modeling (FDM) - **fuses material** (even sugar) as its **deposition head passes over the model bed**



FDM diagram

FDM model

FDM machine

FDM printed coffee table

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- software obstacle:

automated model building needs a consistent 3D computer model with a continuous exterior surface / water-tight digital “wrap”

the capacity of conventional architectural CAD programs to accommodate complex geometry and to generate STL files was very limited

additional programs (such as IronCAD, ProEngineer, Studio Tools) had to resurface the 3D computer model and make it consistent = two-thirds of the time required to print a physical 3D model for architects – to get the computer model properly configured

architects tended to produce 2D drawings – not 3D models

today this trend is rapidly changing and more architects are switching to BIM software and Rhino, 3D Studio Max, MAYA, Form Z which easily create water-tight “wraps” and transfer 3D geometry to 3D printers

- cost obstacle:

lowering prices of the latest 3D printers and their associated production materials

powder, sealant, and consumables for a Z Corp inkjet-style 3D printer would cost about $3-$5 per cubic inch

a finished product can run up to $30 per cubic inch

APLICATION I

quantity of quality study/massing models in-house:
enable creativity by making **quick tests of design ideas** for considering many conceptual design iterations than would otherwise be unreasonable

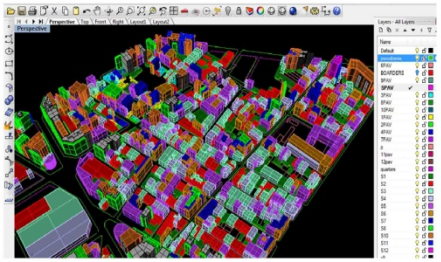
- the **size limitations** (of the 3D printing bed and the stereolithography chamber) limit the size of the models

software can divide the building into interlocking segments – glue, paste together, sand and paint the pieces to appear as a seamless whole

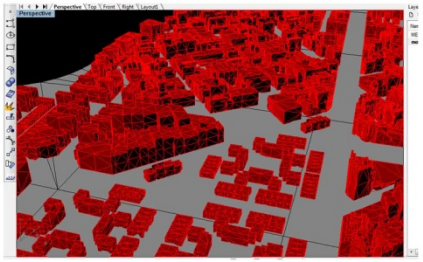
- printed models are **not as adaptable** as traditional paper models – for each option now we need to create a different RP model

+ the monochromatic color of the claylike compound is good for **observing** schematic designs

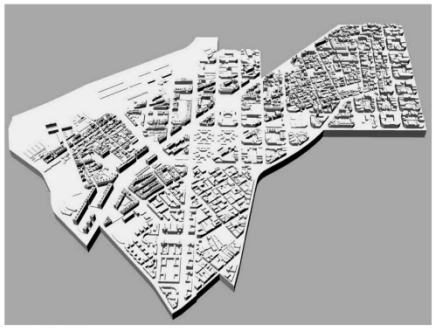
+ one highly effective use of the machine - to create a **context base model** with a space prepared for **plugging various alterations** of the schematic building model

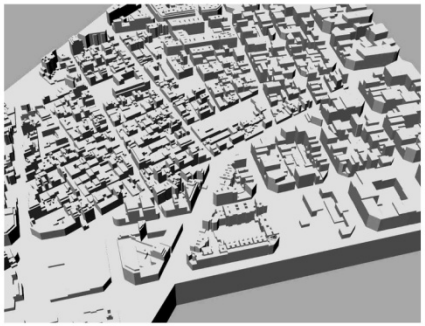


The digital file using different layers

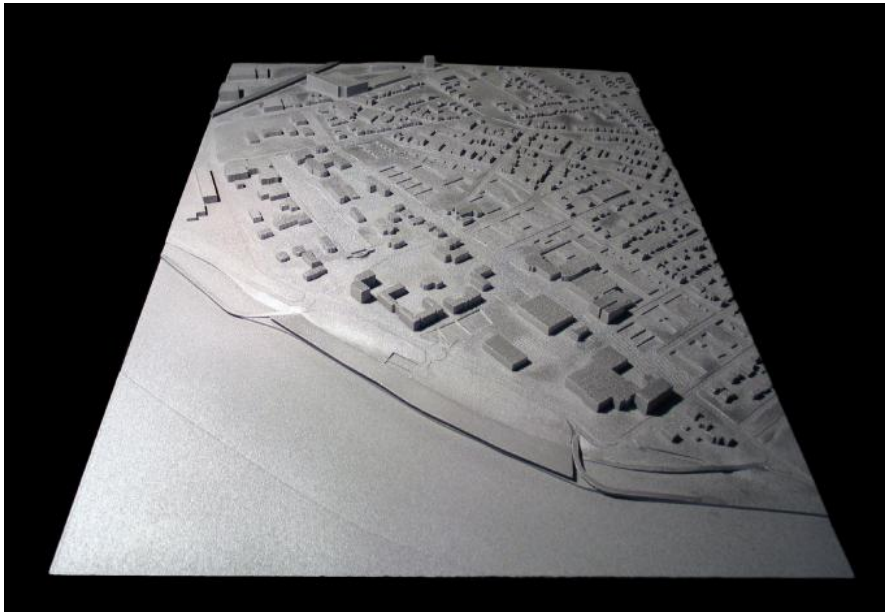


Surfaces converted into meshes_Printed file





Render of the whole area



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a complex curtain wall system was made buildable with stereolithography modeling - going through **design iterations** and **understanding** the elaborate connection details, how components come together, and allow subcontractors to **submit accurate bids**

505 Union Station, Seattle, WA, NBBJ

the stereolithography model was send to the curtain-wall manufacturers to serve **as a reference** during the fabrication of a full scale sample section used for wind and water penetration testing

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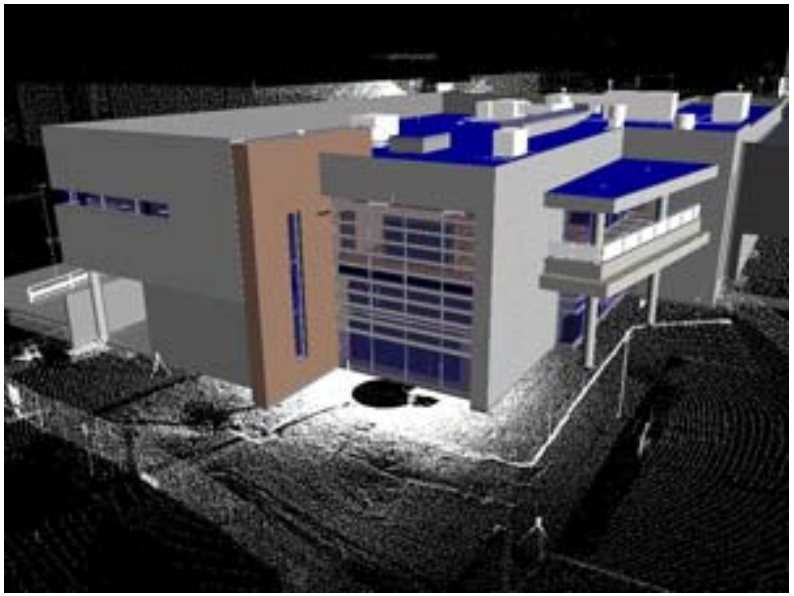
APLICATION II

architects need physical models to:

- exhibit at **planning hearings** for jurisdiction authorities
- **show to prospective clients** various detailed schematic designs in model form and convey schematic design information to the client and to the rest of the team



Crate & Barrel Store, Annapolis, MD - 3D printed model was taken to the construction site as a reference

+ far more **sophisticated** and **accurate** than the handmade models

- the printed models do not have the color or detail refinement for use as marketing tools

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APLICATION III

to fabricate PRECISE architectural components, products, and buildings directly from 3D computer model

architects become more **directly** involved with the **physical output of their designs** and with moving their projects **straight** from design development to a built form

Big Belt House, White Sulfur Spring, Montana, William Massie

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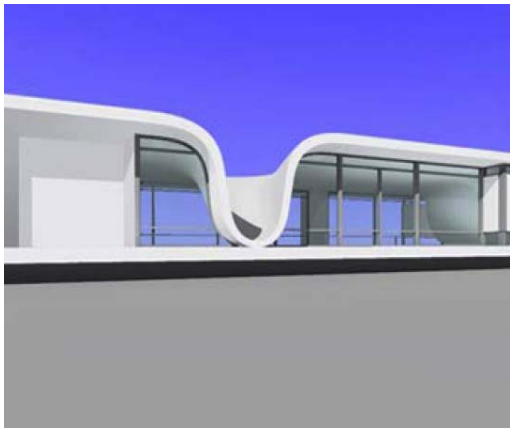
+ economical and **rational** design-to-build process :

- the computer file produced by an architect becomes the actual code for the fabrication process
- eliminates the need of **construction drawings**
- eliminates the need of **middle man** who interprets architect's vision

+ reduces limitations of creating **COMPLEX structures** and makes them **easier** to achieve



American House 2008, Pontiac, MI, William Massie – 3D computer model

American House 2008, Pontiac, MI, William Massie

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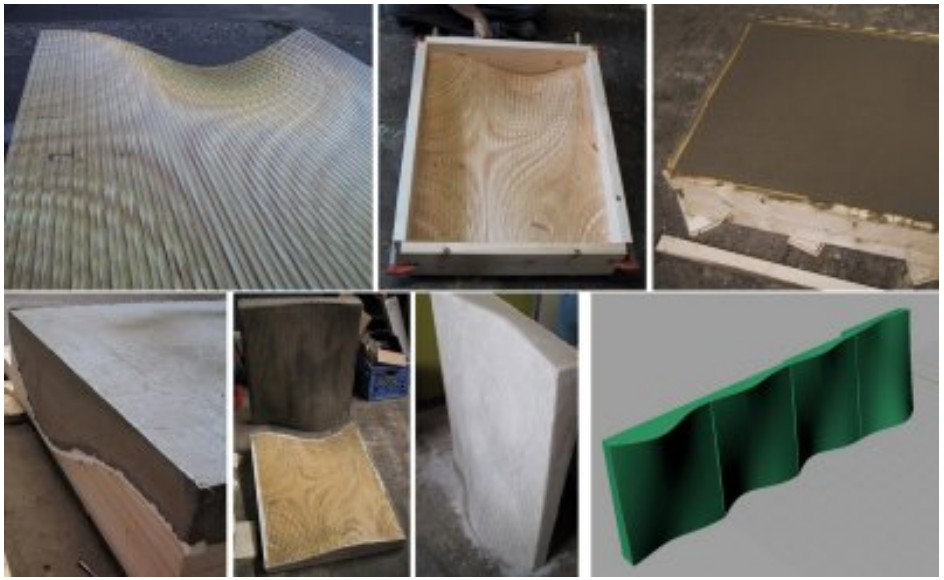
architects use large scale milled foam molds to:

- curve heated glass
- cast metal
- cast concrete

CNC machining allows for easy production of computer-generated formwork / concrete coffers



CNC milled mould - used as a formwork for concrete panels, Ply Architects

Big Belt House White Sulfur Spring MT 2002, sink, William Massie

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customized foam formwork sections are carved using the CNC mill, then bound together and poured

once the concrete had set, the forms were removed, allowing for interior or exterior articulation of the curving concrete forms

Seat Slug bench - more than 250 3D printed ceramic-concrete polymer sections fit together

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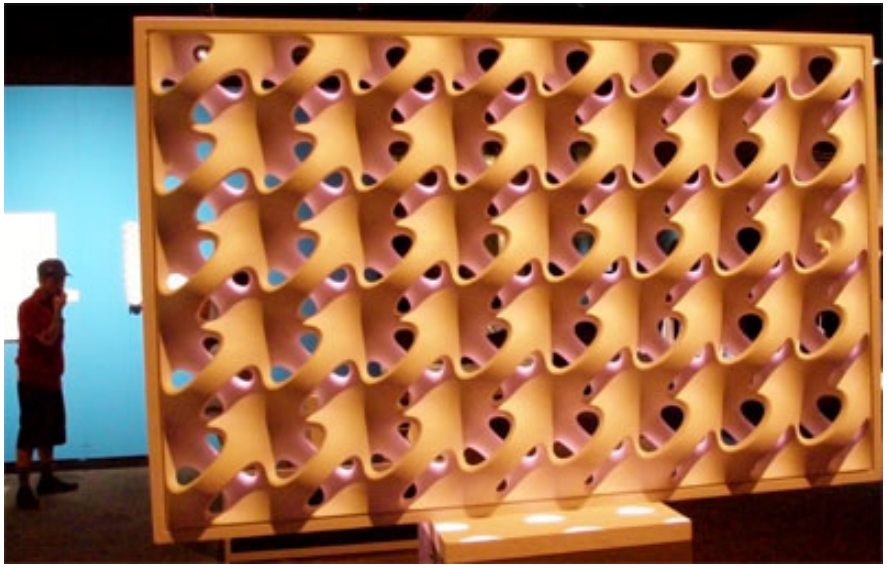
- CNC technology is not widely embraced by architects for "do-it-yourself" actual large-scale building production because is:
  - still **expensive** - larger machines are costly, noxious, and take up a lot of space
  - requires a high level of **expertise of physical properties of materials**

CNC wall, Norwegian Wild Reindeer Centre Pavilion, Snoheta



Siggraph CNC panel, Hauer

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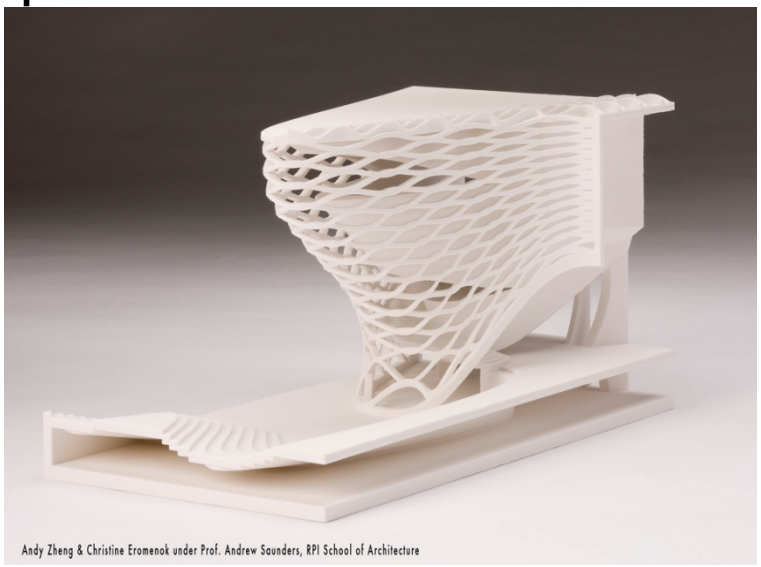
10 or so of the 126 schools of architecture in North America formally teach the subject and have the equipment

in order for rapid prototyping to **reach its full potential** in architecture, **universities will have to play a large role**

penetrating the architectural market **from the ground up** via higher education will be the primary path by which rapid prototyping will be widely introduced to the profession



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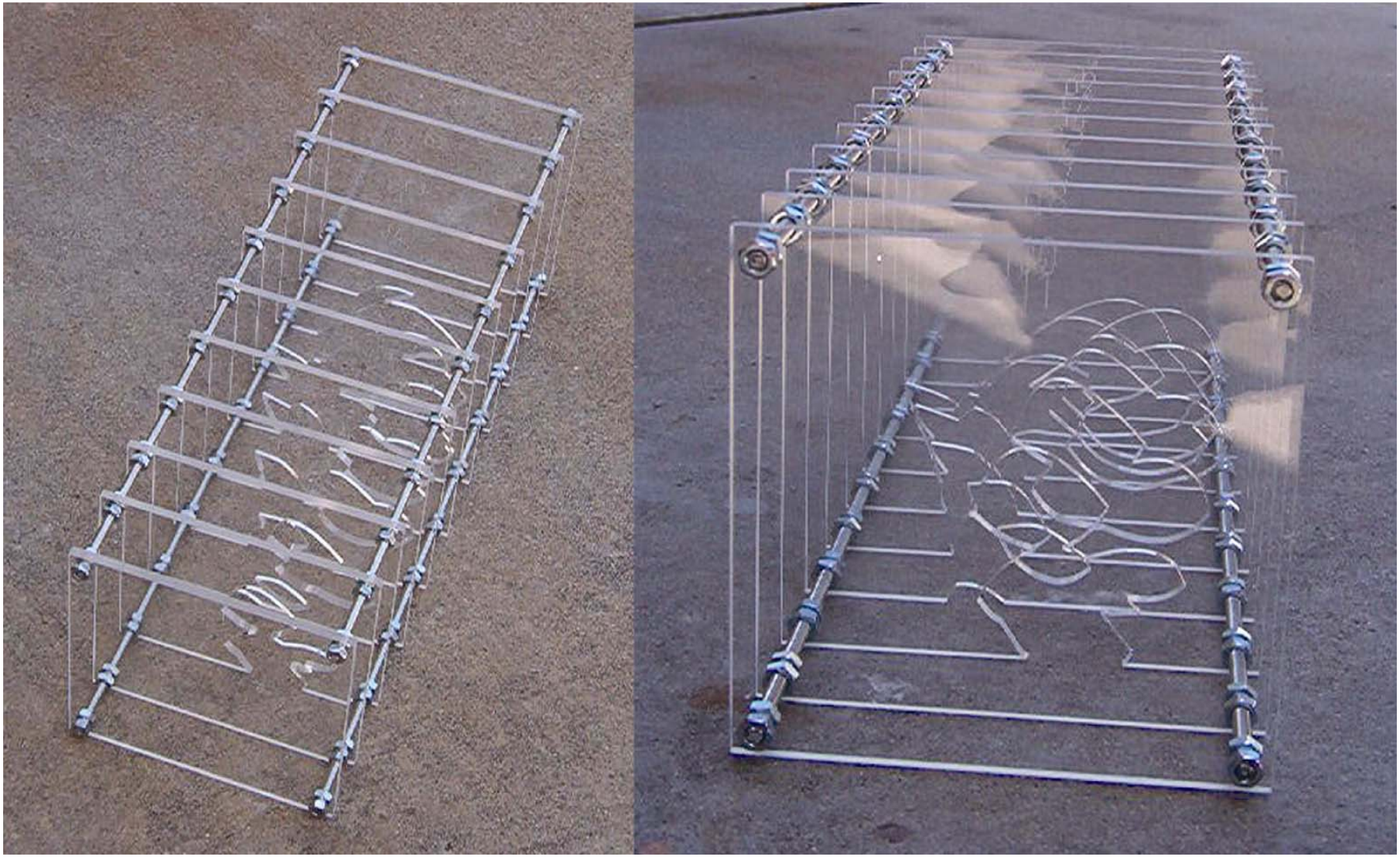
let's finish in a good mood and exhibit the **gelatin mold** of St. Paul's Cathedral in London served by London-based duo Bompas – Parr at one of their unique parties



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VLADO VALKOF, RA, LEED AP
4919 INDIAN WOOD RD, #495
CULVER CITY, CA 90230, USA
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