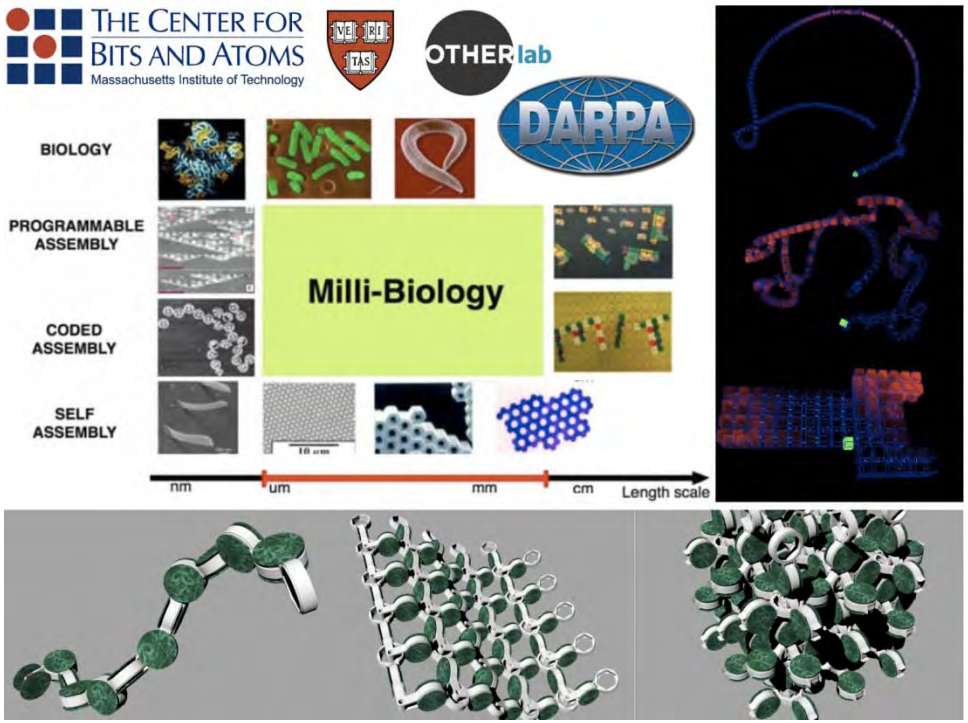
Digital Material Processes

htmstmaa 02Mar2012

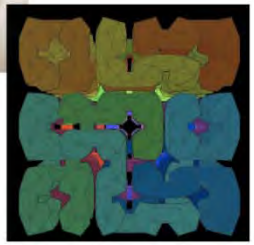


1.0: computers → machines

2.0: machines → machines

3.0: codes → materials

4.0: programs → materials



digital communications

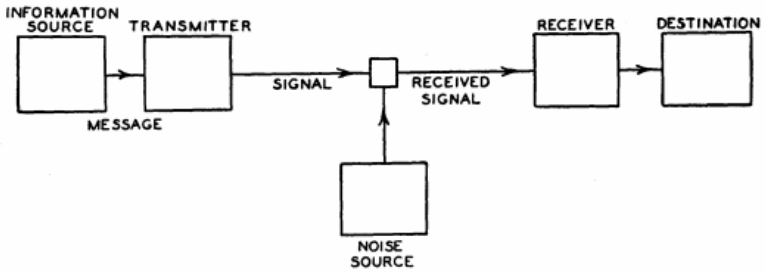
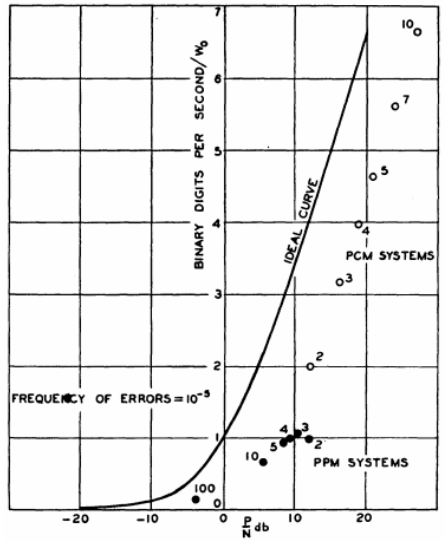


Fig. 1—General communications system.



channel capacity

error reduction, tolerance, and correction codes

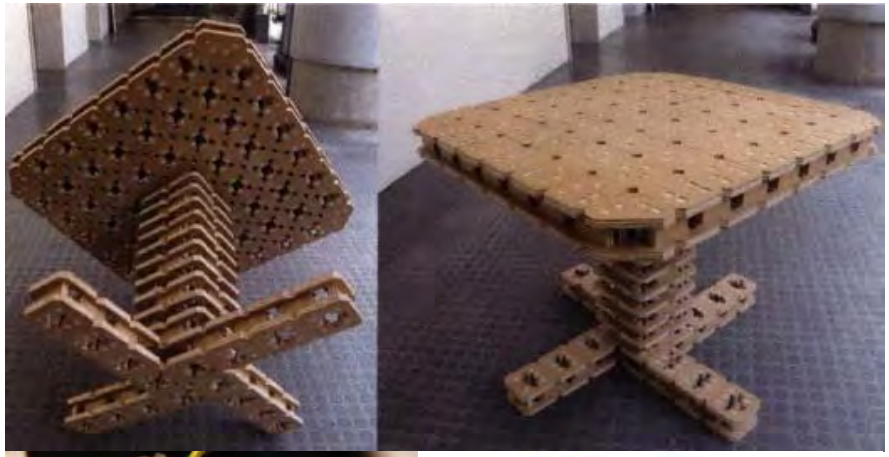
bits – discrete units in feature space

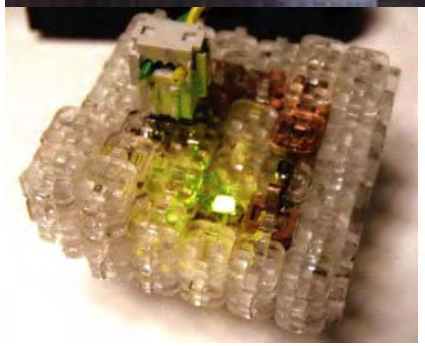
scalability

$$C = W \log_2 \frac{P+N}{N}$$

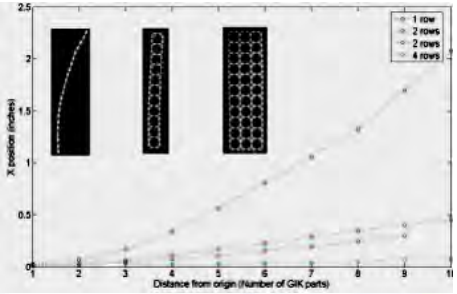
Shannon 1947

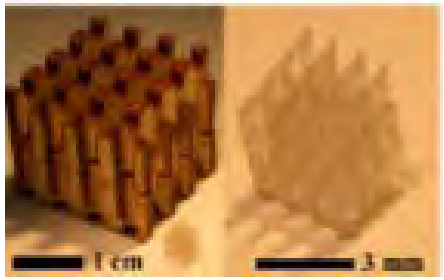
digital materials



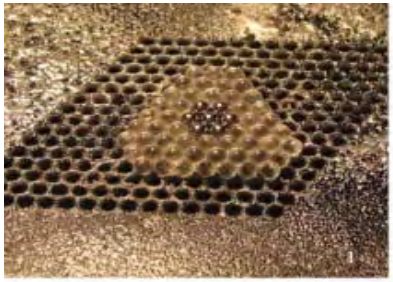


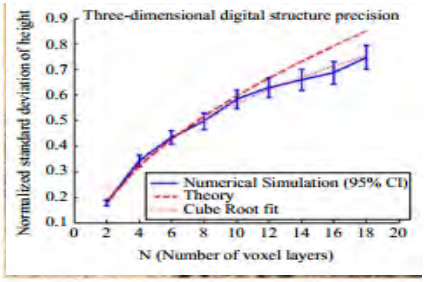
Ward 2010





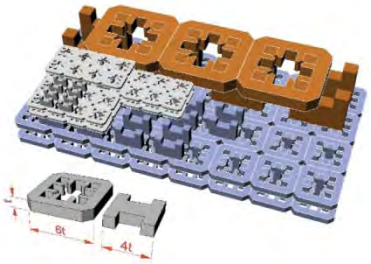
Popescu, Mahale, Gershenfeld 2006

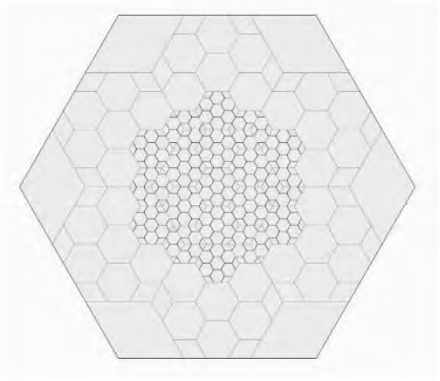




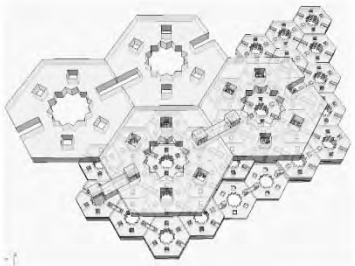
Hiller, Lipson 2006

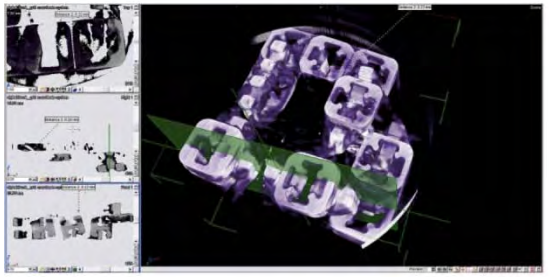
scalability, versatility

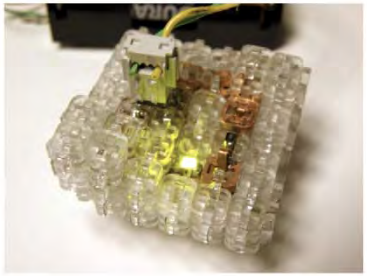

6t
4t

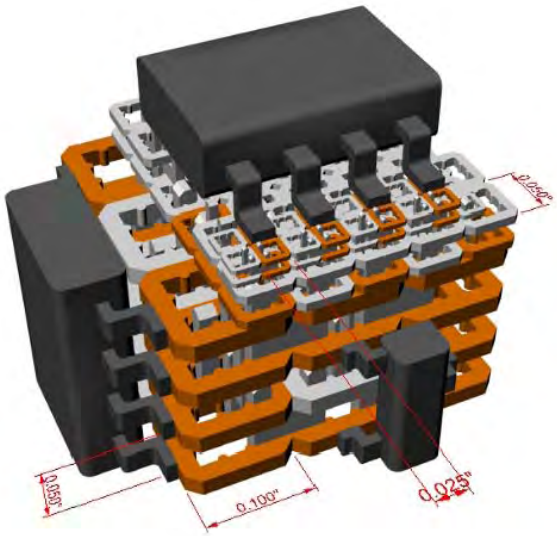


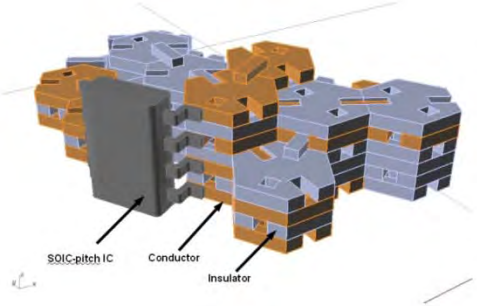

T = 0.5"
T= 0.25"
T = 0.125"

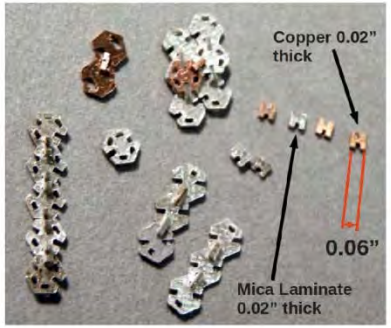


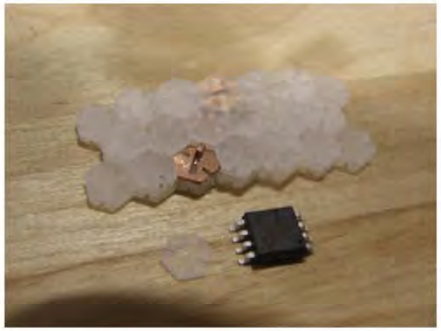





0.050"
0.100"
0.025"
0.050"


SOIC-pitch IC
Conductor
Insulator

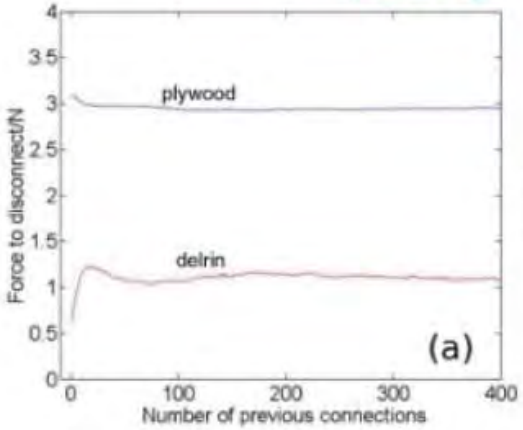

Copper 0.02" thick
0.06"
Mica Laminate 0.02" thick

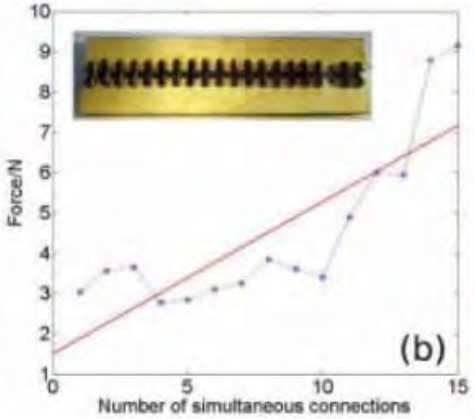


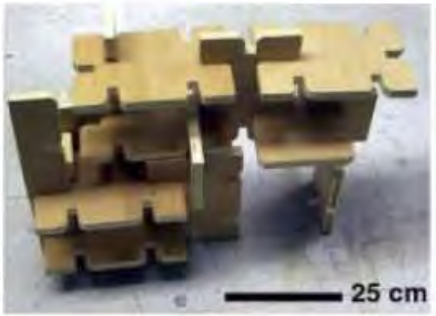
Ward 2010

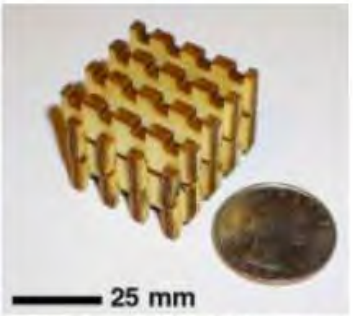
digital materials

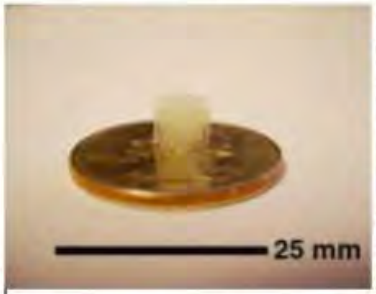
(George Popescu)

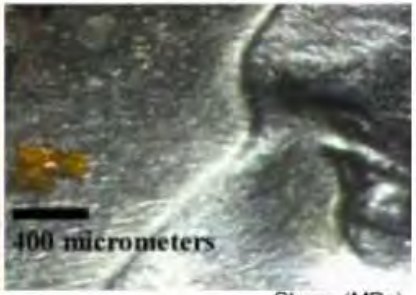


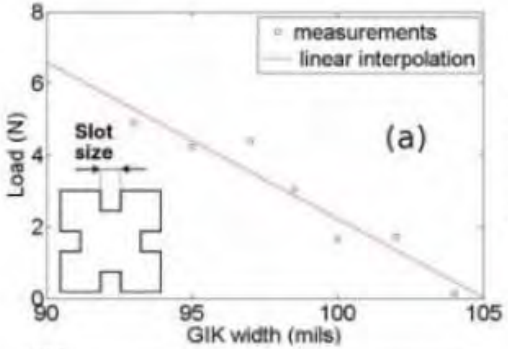


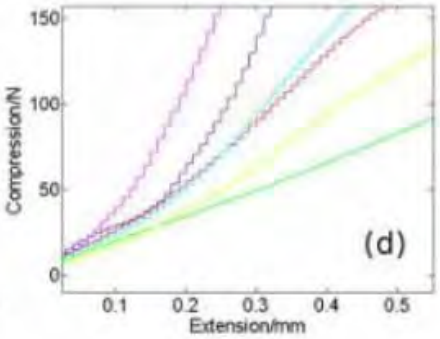


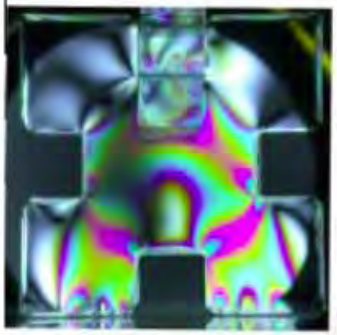


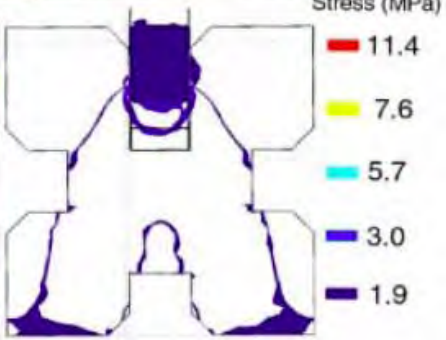


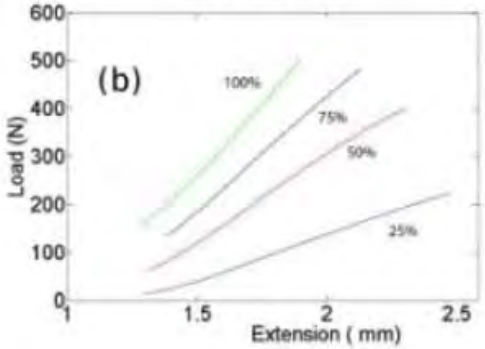


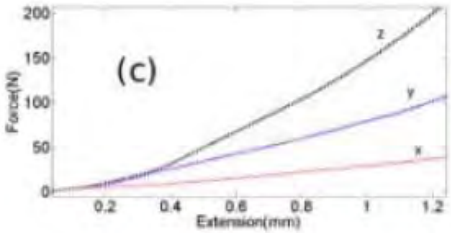


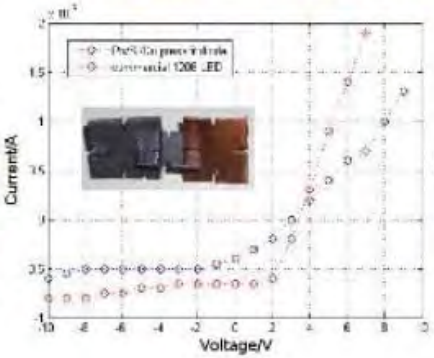


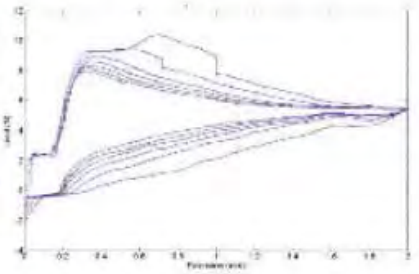












digital materials

low cost and reversible systems (low precision assembly)

error reduction, tolerance, and correction

small and discrete set of parts

“synthetic biodegradability”

natural digital fabrication

tuned, adaptive, reconfigurable structures

small and discrete set of building blocks (…biodegradability)

industrial fabrication

complexity and size ←→ design and qualification

manufacturing systems much more complex than product

scalability

exponential design space

parts contain information

But, what about the bulk material properties?

Full Size Lego House, James May, 2011

3.3e6 bricks

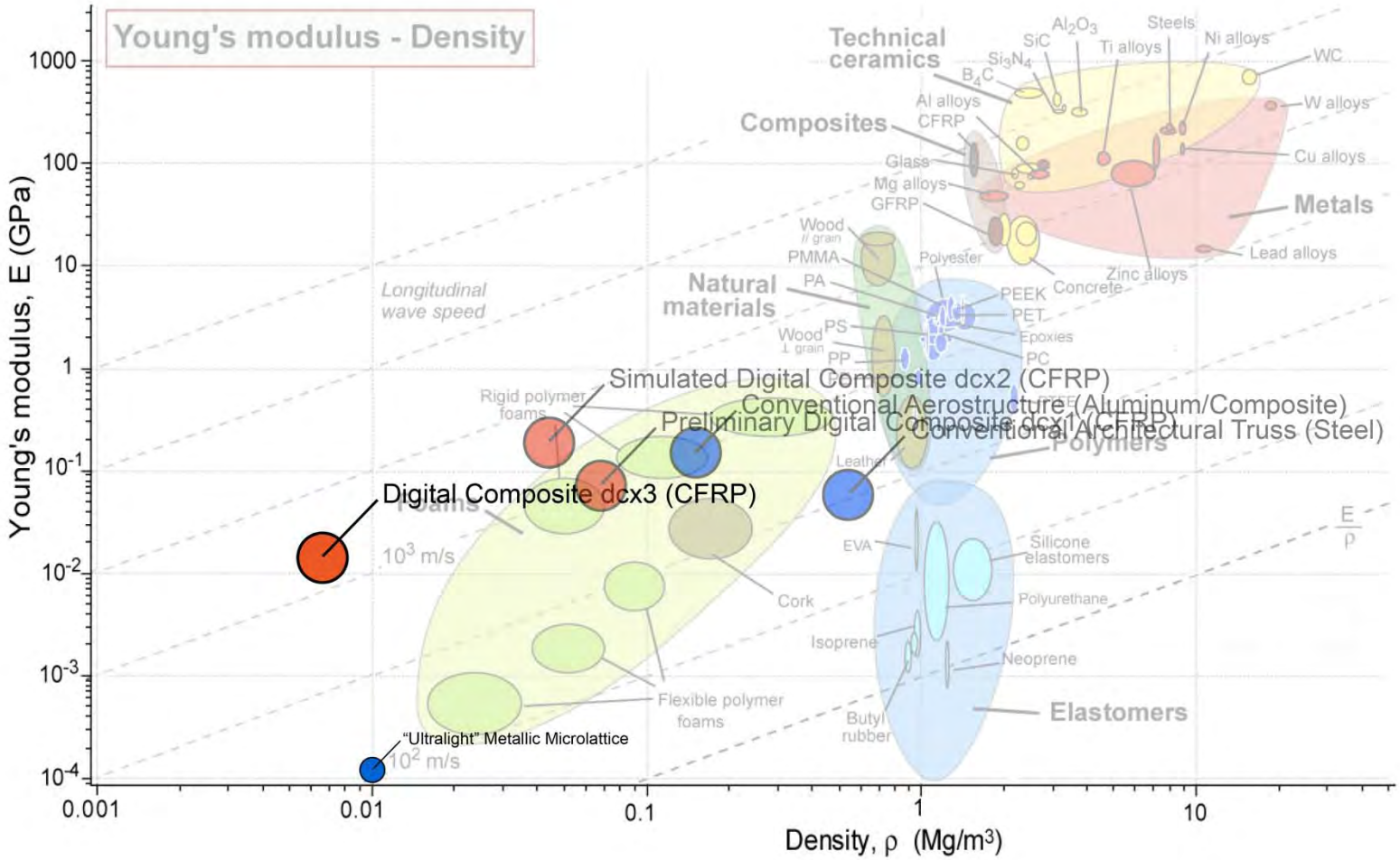
industrial fabrication

Eiffel Tower 1889

Vickers Wellesley/Wellington 1935

24 hour assembly time

Continuum Analysis of Reconfigurable Structural Assemblies
Elastic Modulus



*underlay: Ashby Material Property Chart (http://www.grantadesign.com/download/charts/new_modulus_density.pdf)

cellular solids

Gibson, Ashby, 1983

$\delta \propto F l^3 / E_s I$

simplified beam bending model: natural cell formation constrains geometry

stochastic foams $E/E_s \propto (\rho/\rho_s)^2$

E = modulus of structure, ρ = mass density of structure

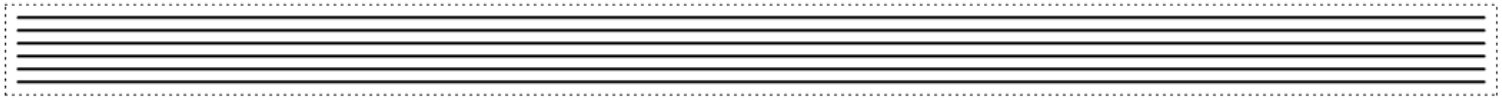
E_s = modulus of constituent solid material, ρ_s = mass density of constituent solid material

E/E_s = relative modulus ($0 < E/E_s < 1$)

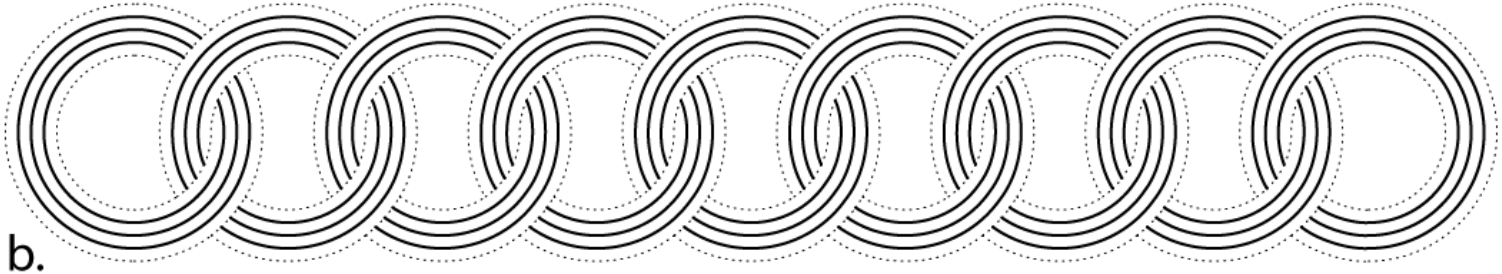
ρ/ρ_s = relative mass density ($0 < \rho/\rho_s < 1$)

ultralight stochastic materials $E/E_s \propto (\rho/\rho_s)^3$

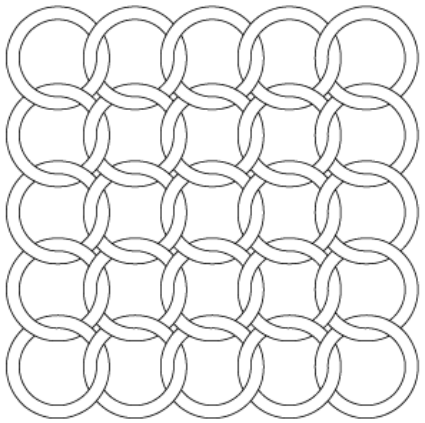
discretized cfrp parts



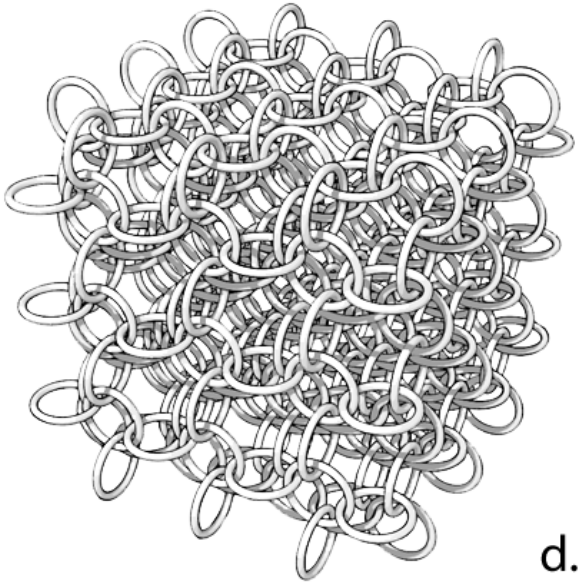
a.



b.



c.



d.

2 component system

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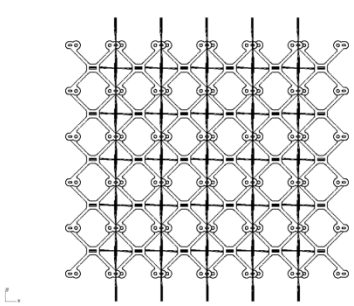
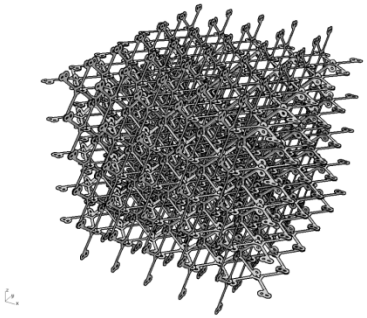
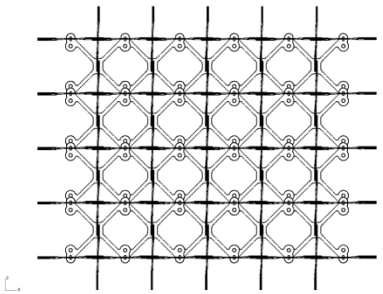
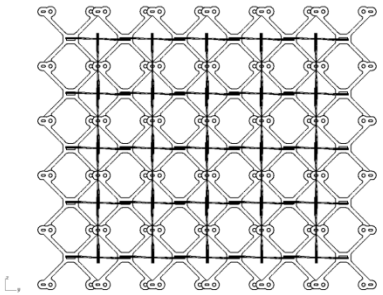
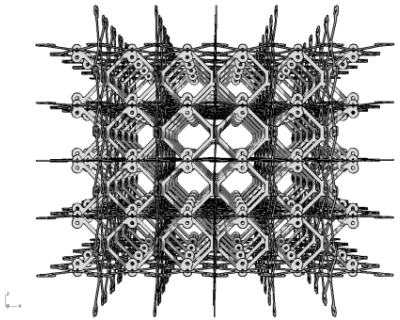
geometry

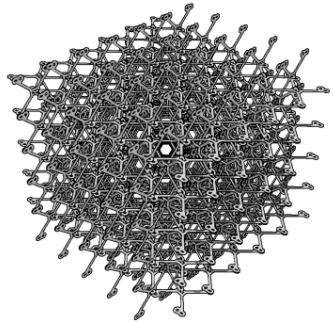


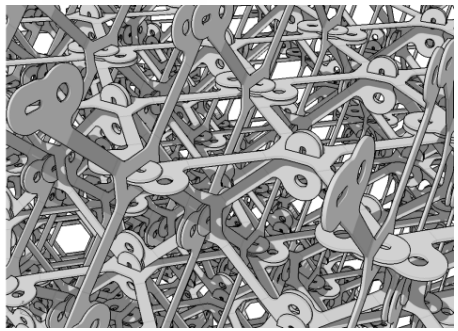


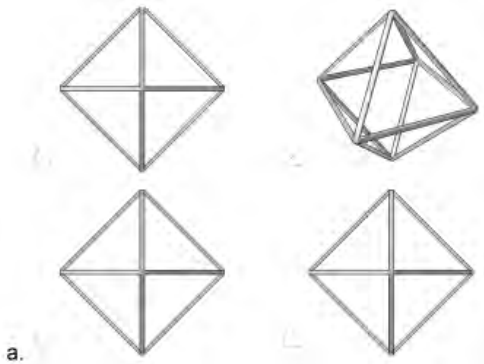


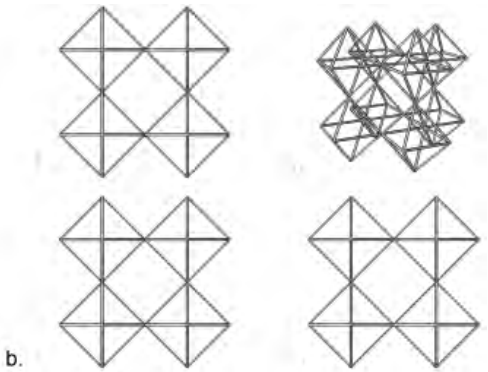


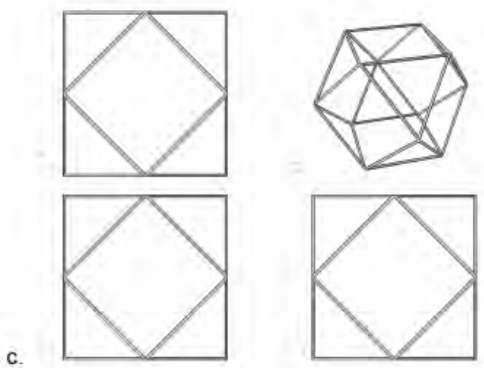


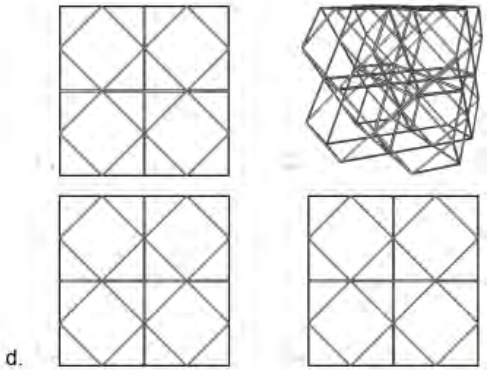


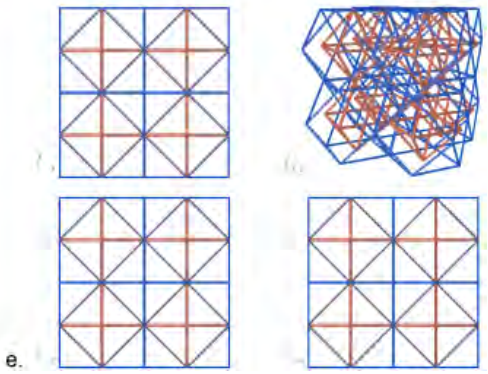












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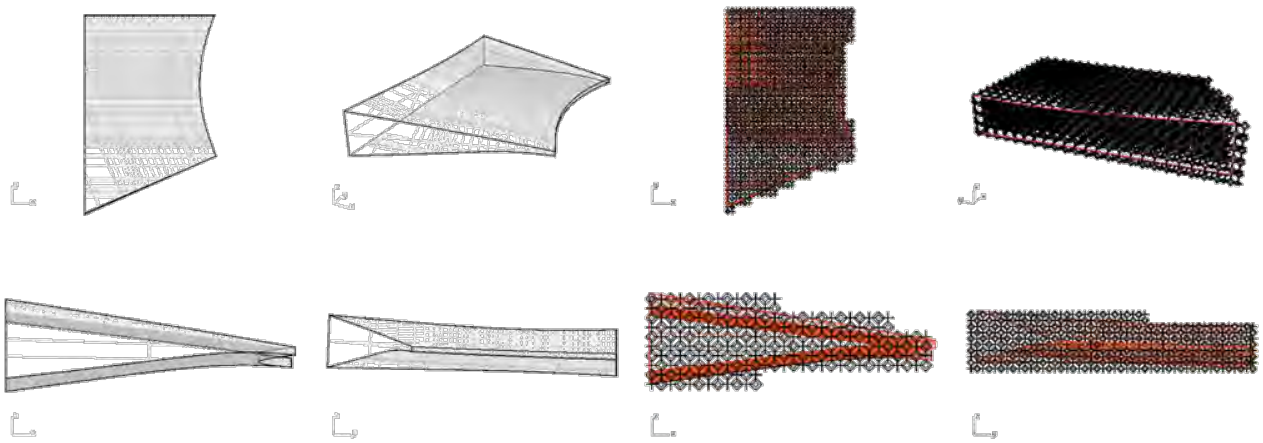
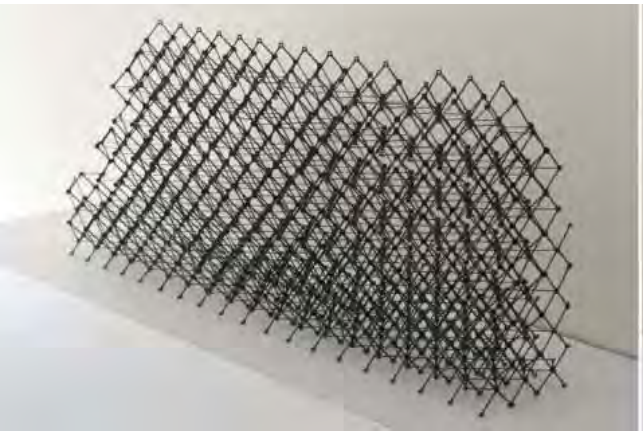
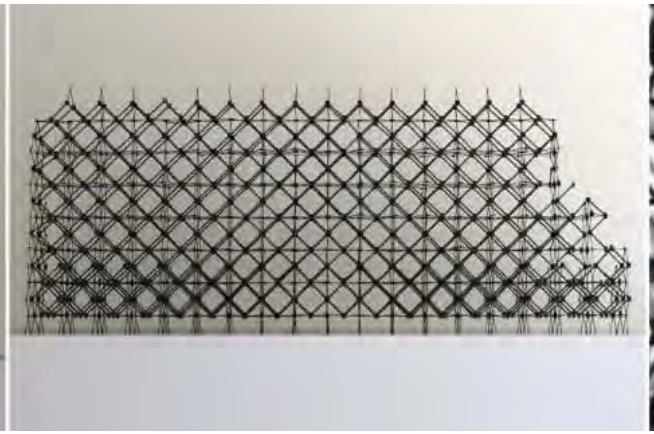
digital composite aerostructure prototype







An example substructure is shown – a part on a commercial aircraft in current production. The part is approximately 1.0m x 0.4m x 0.1m, and incorporates ~700 of a single part type.

relative strength

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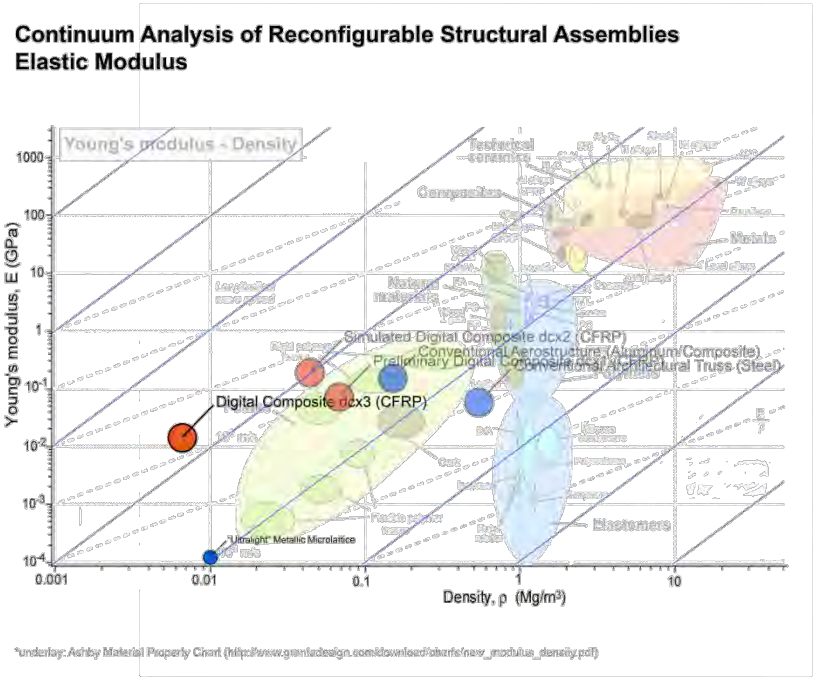
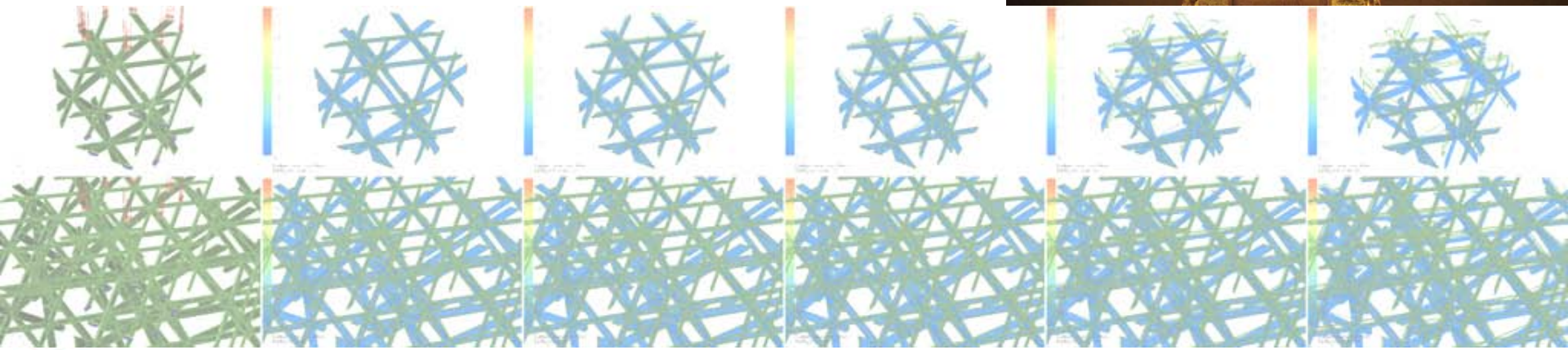
relative modulus

Cheung 2011

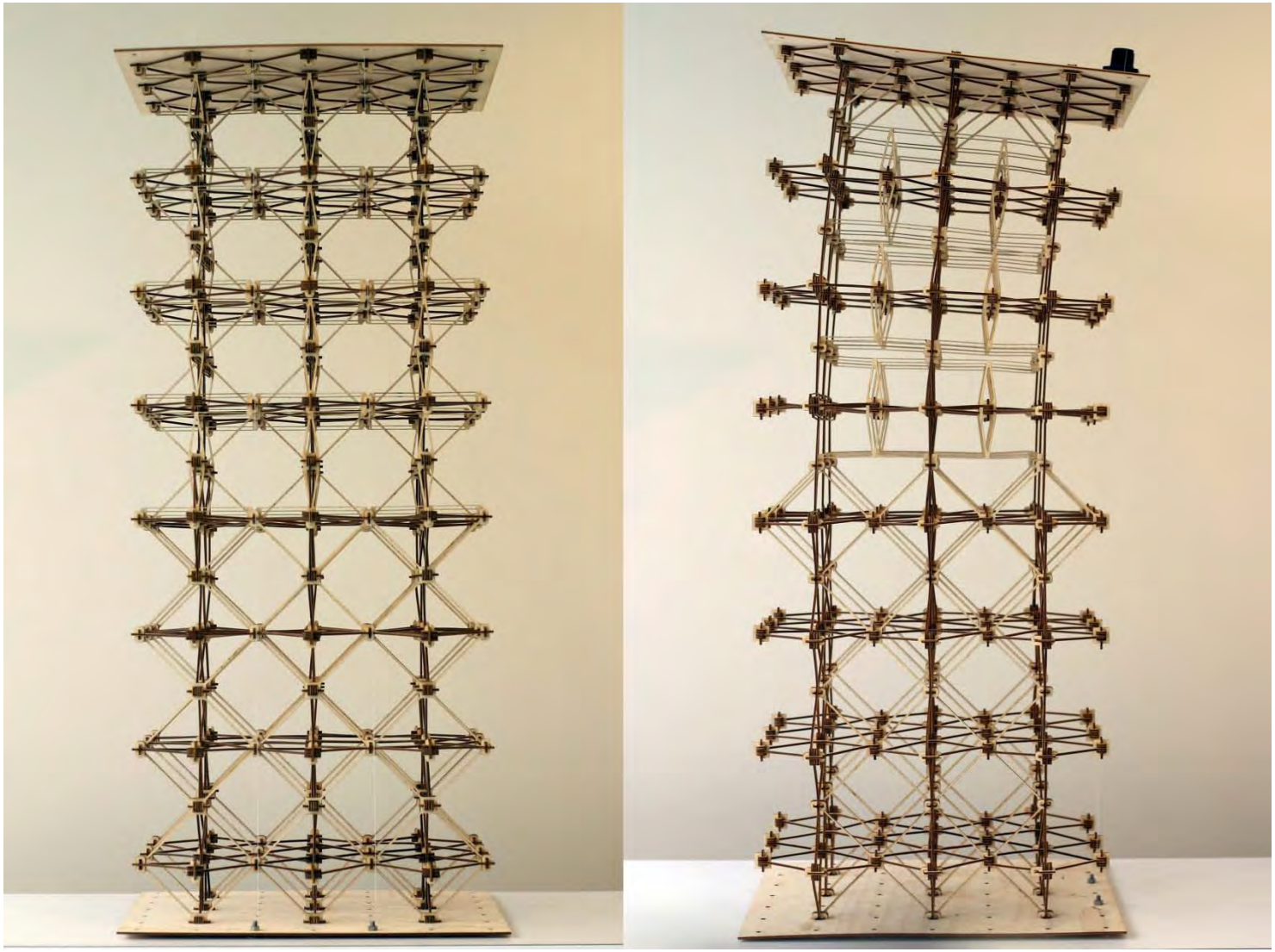
simulation & testing



(As expected, testing is showing favorable scaling properties)



tuning



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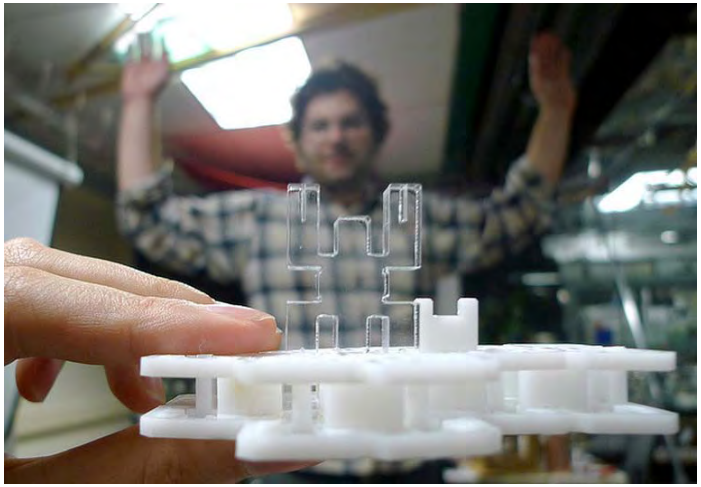
rigid position based systems → compliant force based systems

the assemblers

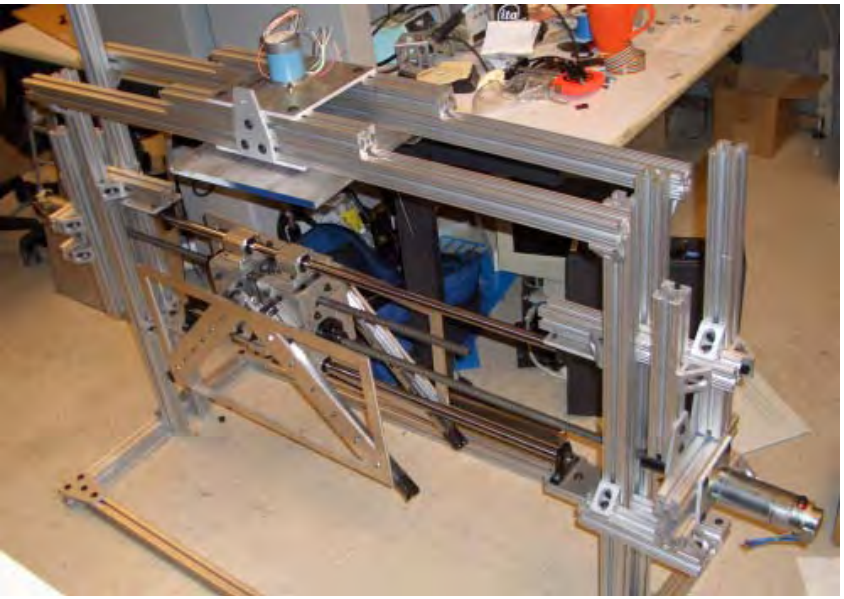


(Ward 2011 photo: Nadya)

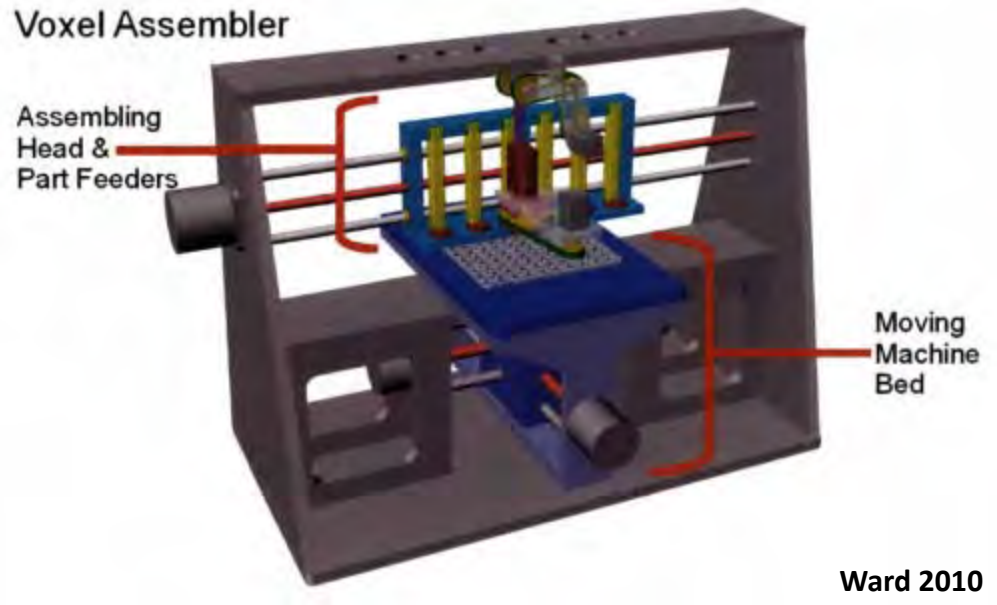
Hovsepian 2011

Cheung 2008 fablab.no

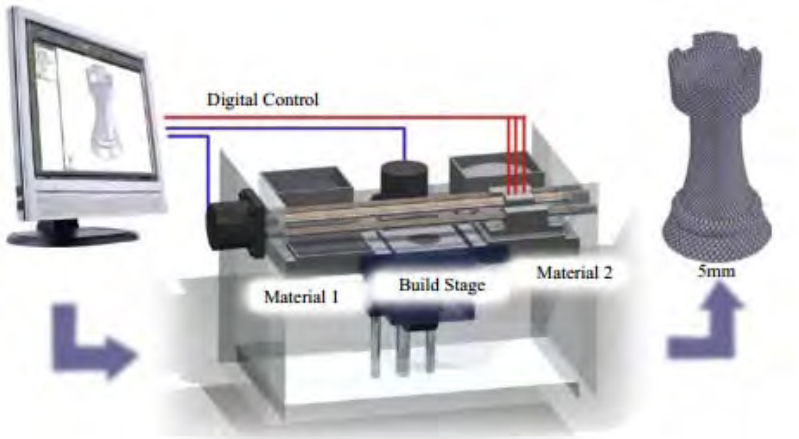
the assemblers



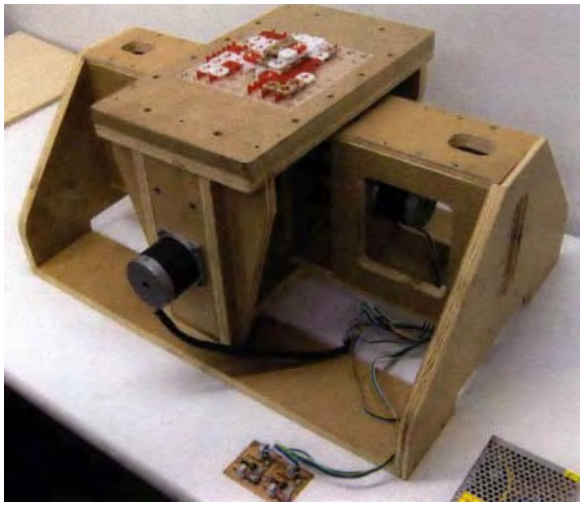
Popescu 2007

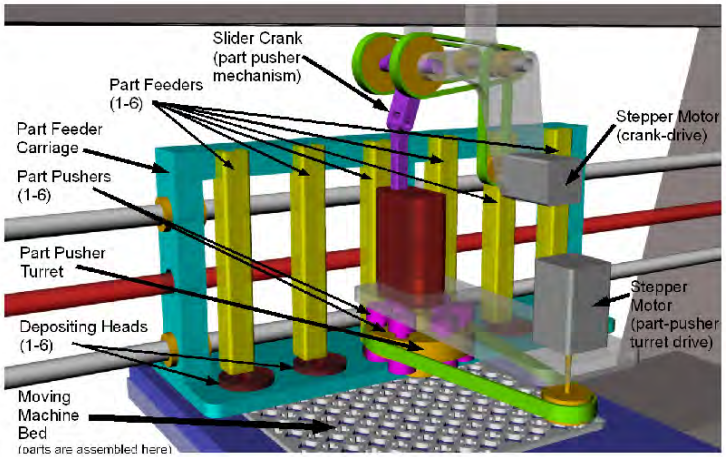


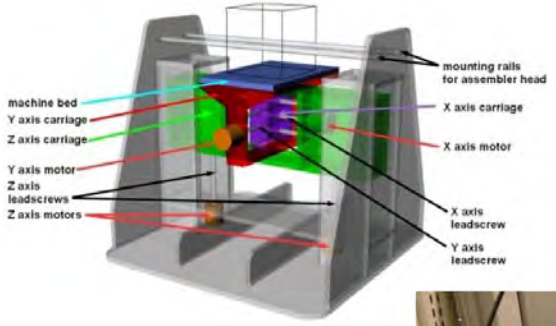
Ward 2010

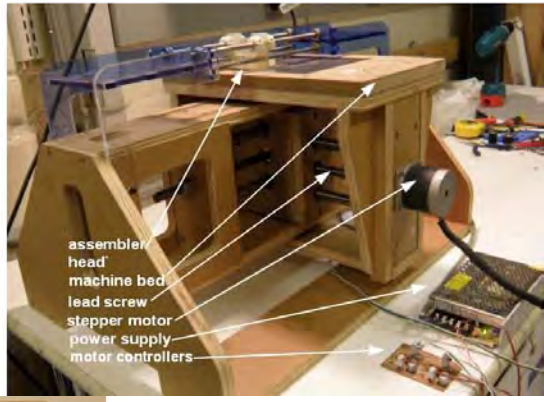


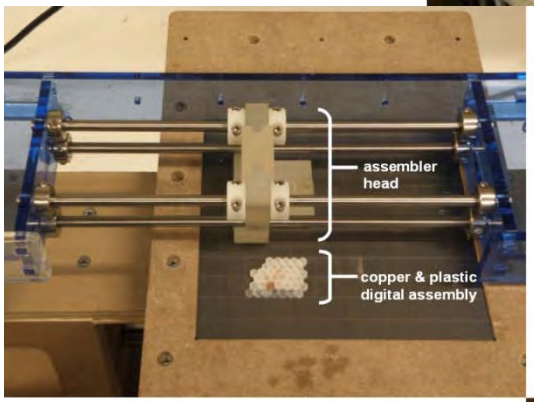
Hiller & Lipson 2009

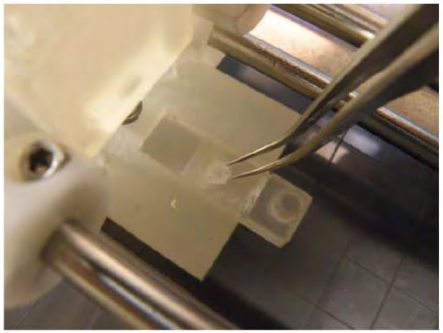


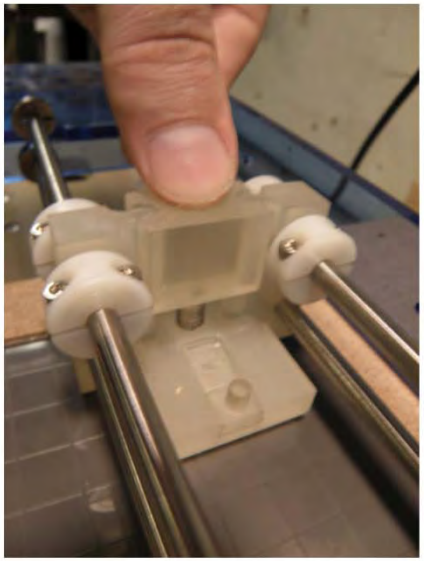

Slider Crank
(part pusher
mechanism)
Part Feeders
(1-6)
Part Feeder
Carriage
Part Pushers
(1-6)
Part Pusher
Turret
Depositing Heads
(1-6)
Moving
Machine
Bed
(parts are assembled here)
Stepper Motor
(crank-drive)
Stepper
Motor
(part-pusher
turret drive)

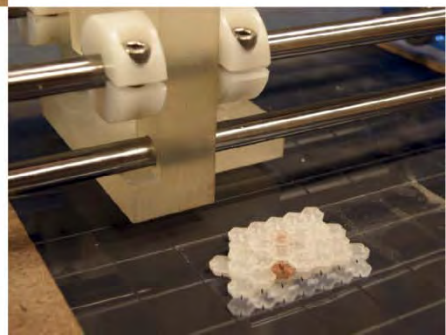

machine bed
Y axis carriage
Z axis carriage
Y axis motor
Z axis
leadscrews
Z axis motors
mounting rails
for assembler head
X axis carriage
X axis motor
X axis
leadscrew
Y axis
leadscrew


assembler
head
machine bed
lead screw
stepper motor
power supply
motor controllers


assembler
head
copper & plastic
digital assembly

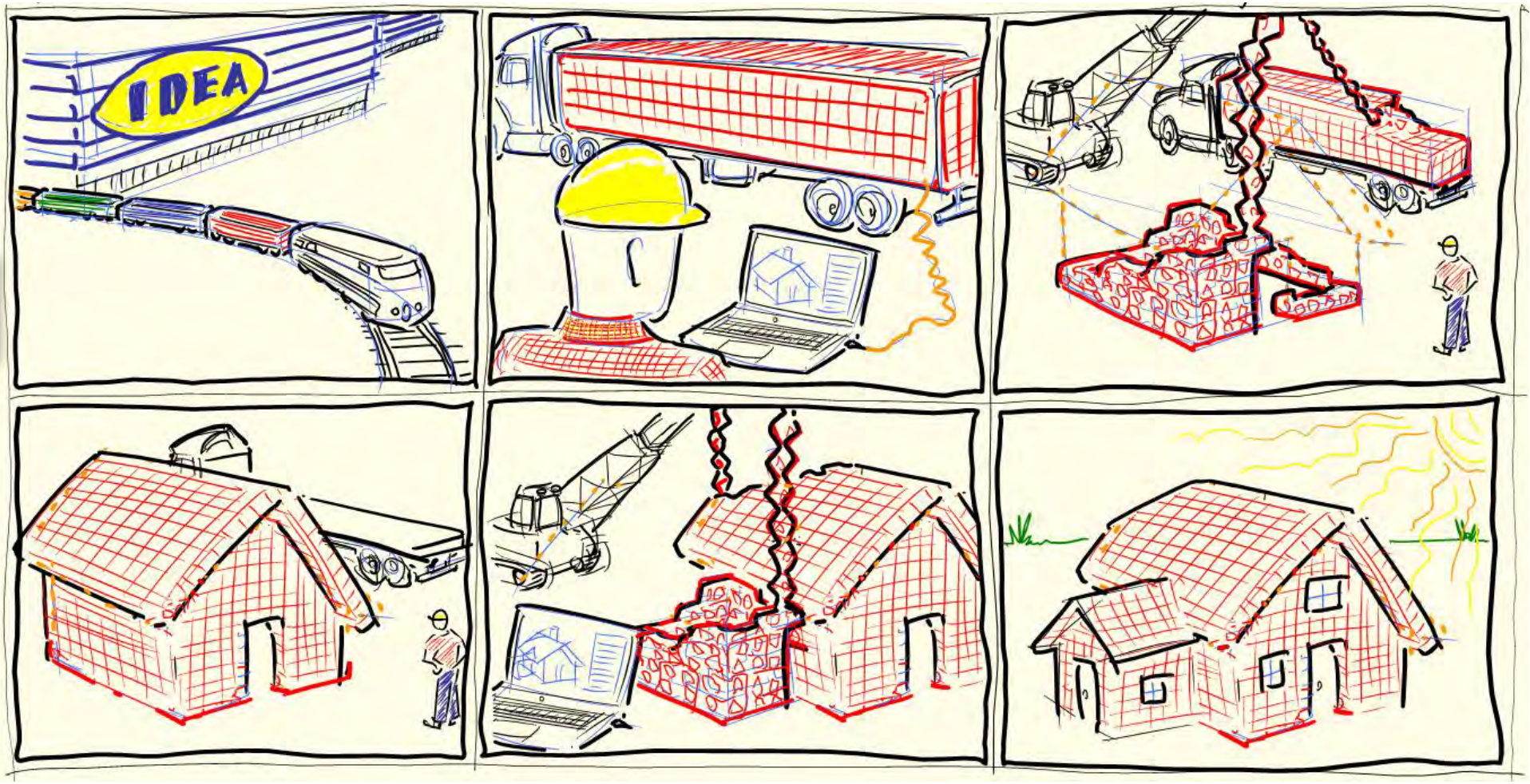




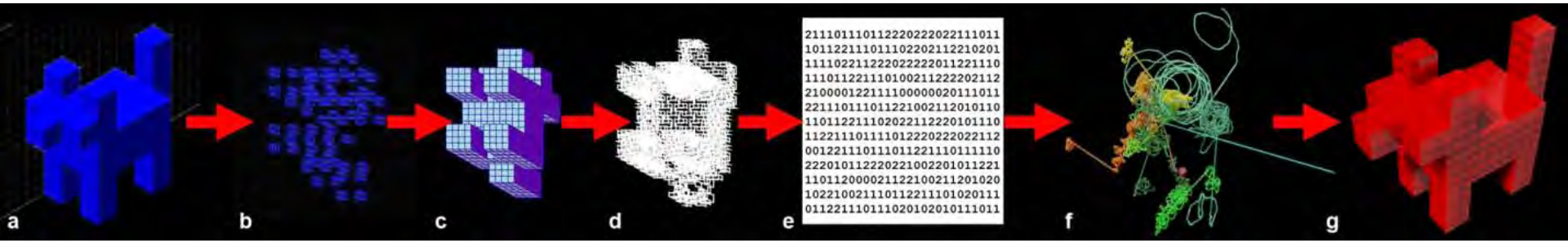


Ward 2010

the assembler?



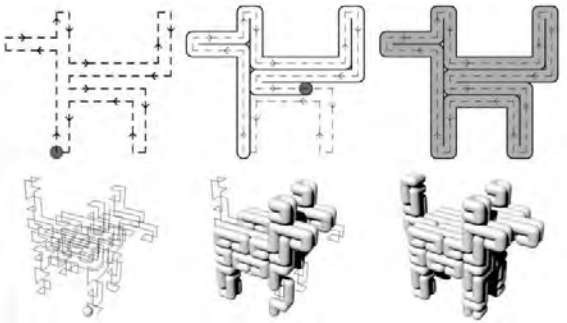
the assembler?

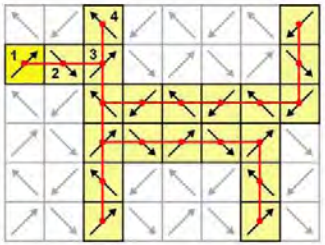


Cheung, Demaine, Bachrach, Griffith, 2011 “moteins,” IEEE Trans. On Robotics

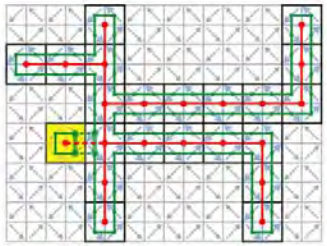
Programmable Assembly With Universally Foldable Strings (Moteins)

Kenneth C. Cheung, Erik D. Demaine, Jonathan R. Bachrach, and Saul Griffith

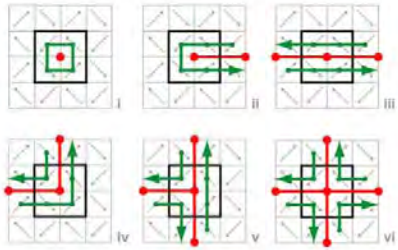




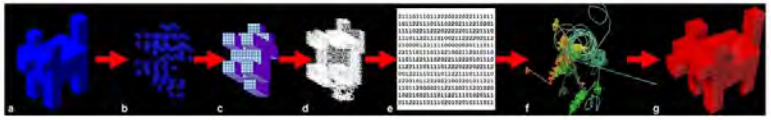
(a)

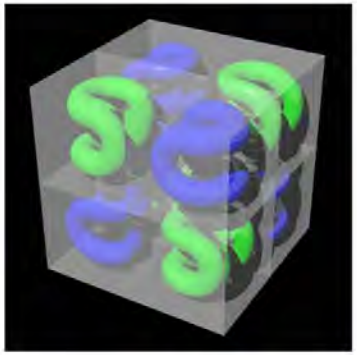


(b)



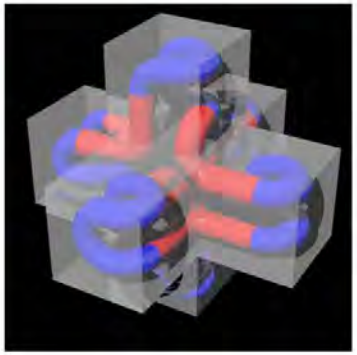
(c)





(d)

(e)



(f)