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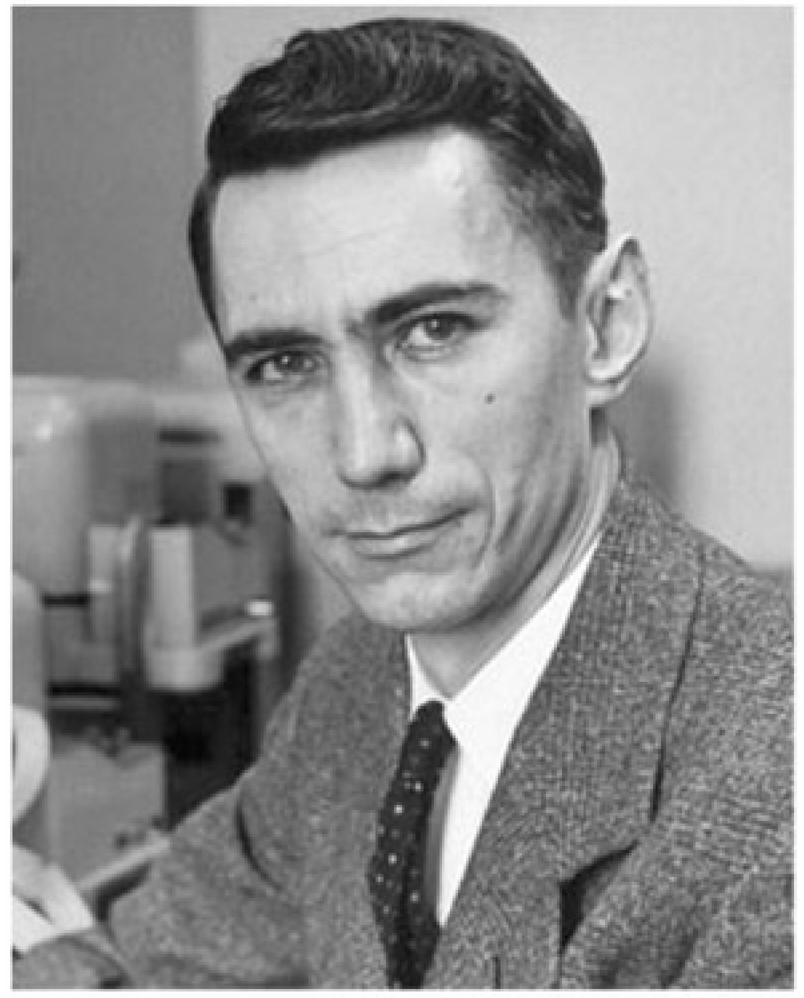
Massachusetts Institute of Technology


**Prof. Neil Gershenfeld**

***Director***

http://ng.cba.mit.edu





A SYMBOLIC ANALYSIS

OF

RELAY AND SWITCHING CIRCUITS

by

Claude Elwood Shannon

B.S., University of Michigan

1936

Submitted in Partial Fulfillment of the

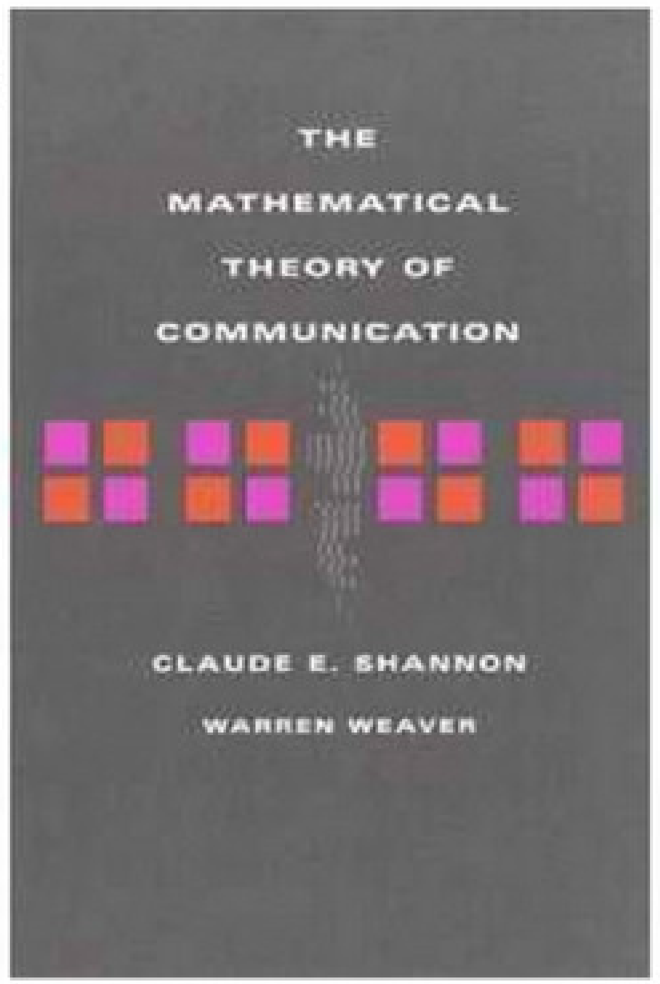
Requirements for the Degree of

MASTER OF SCIENCE

from the

Massachusetts Institute of Technology

1940




Lectures on

PROBABILISTIC LOGICS AND THE SYNTHESIS OF RELIABLE ORGANISMS FROM UNRELIABLE COMPONENTS

delivered by

PROFESSOR J. von NEUMANN

The Institute for Advanced Study
Princeton, N. J.

at the

CALIFORNIA INSTITUTE OF TECHNOLOGY

January 4-15, 1952

Notes by

R. S. PIERCE

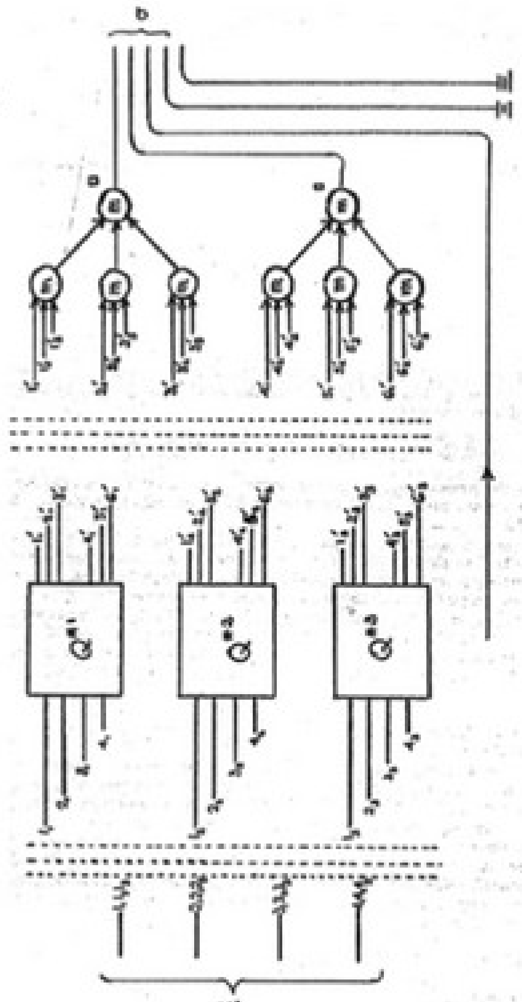
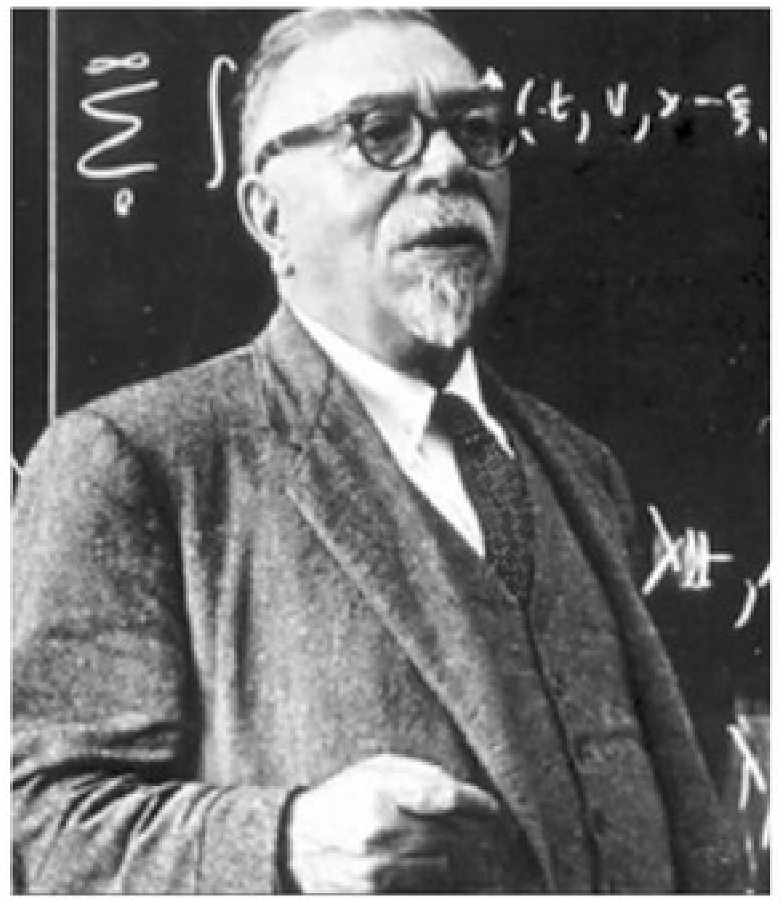


Fig. 29



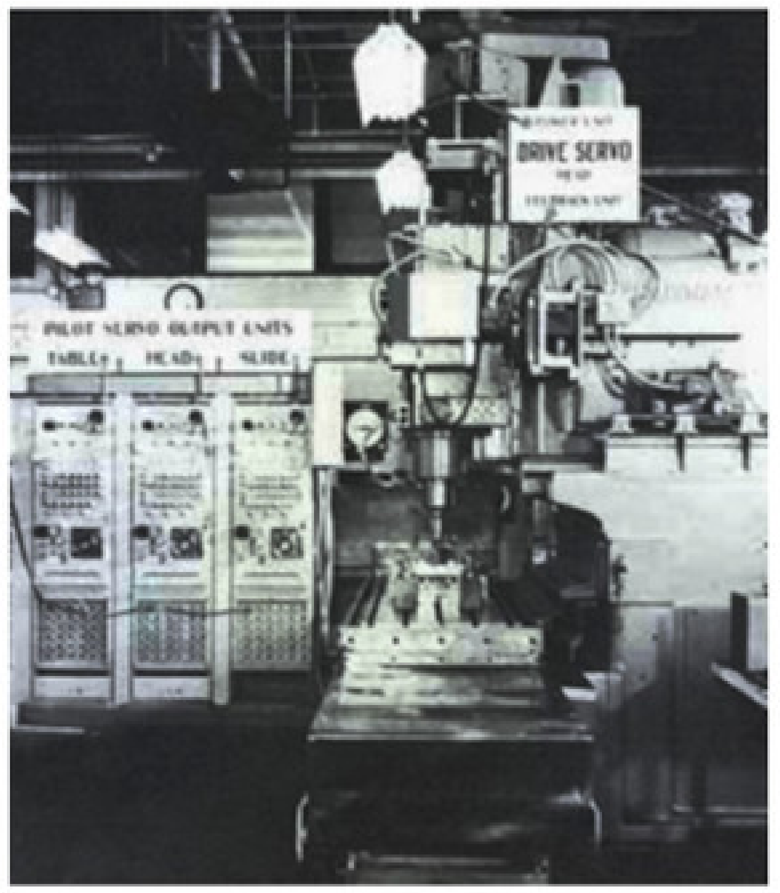
PAPERS ON AUTOMATIC PROGRAMMING
FOR NUMERICALLY CONTROLLED
MACHINE TOOLS

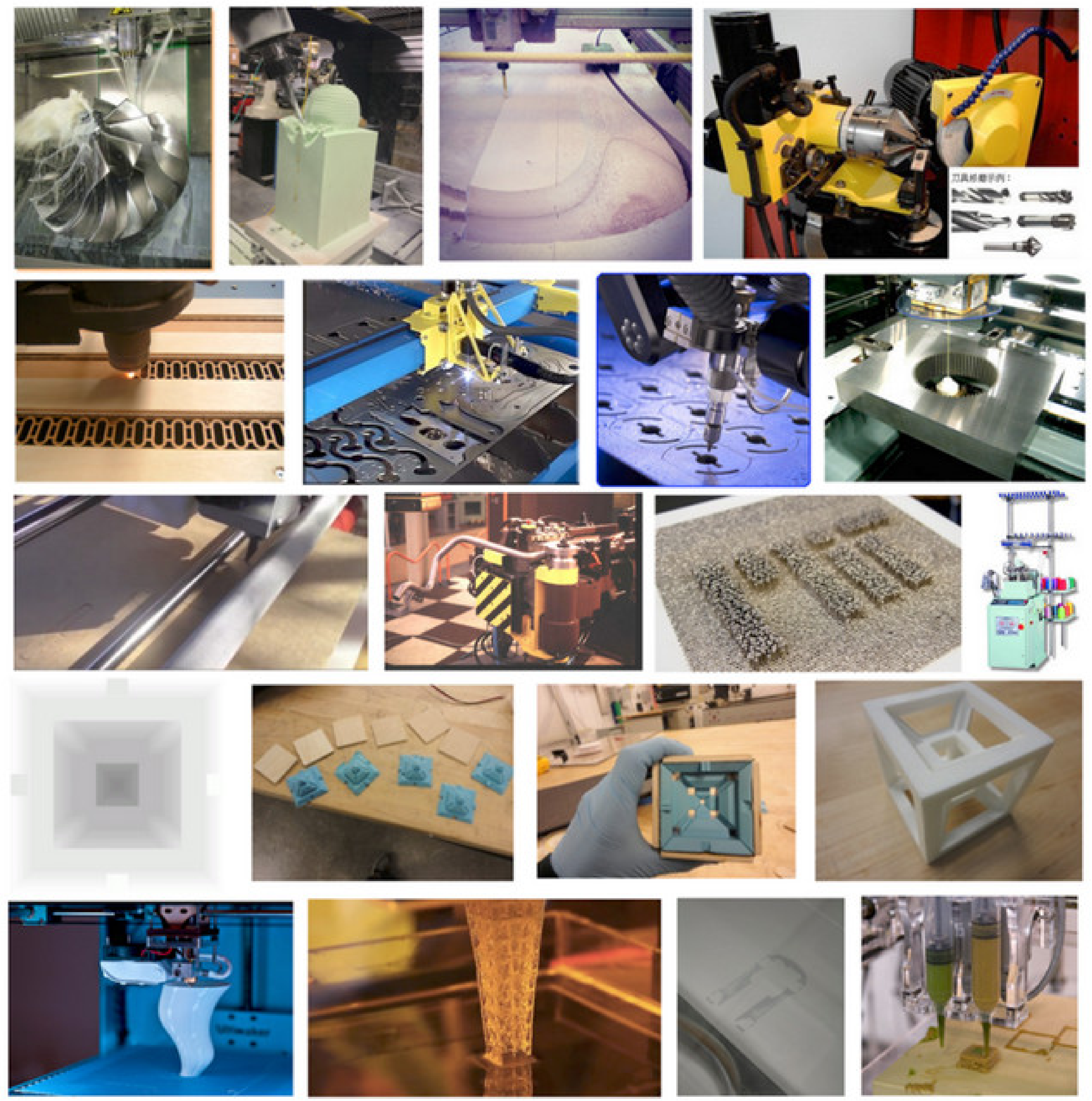
Douglas T. Ross
6873-TM-3
January 7, 1958

This document reports the results of work made possible through the support extended the Massachusetts Institute of Technology, Servomechanisms Laboratory, by the United States Air Force, Air Materiel Command, under Contract No. AF33(038)-24007, M.I.T. Project No. D.I.C. 6873. It is published for technical information only and does not represent recommendations or conclusions of the sponsoring agency. When U. S. Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related U. S. Government procurement operation, the U. S. Government thereby incurs no responsibility or obligation whatsoever; and the fact that the U. S. Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation or conveying any right or permission to manufacture, use, or sell any patented invention that may be in any way related thereto.

Approved by: [signature]
Donald F. Clements

Servomechanisms Laboratory
Department of Electrical Engineering
Massachusetts Institute of Technology





| | | |
|---|---|---|
| continuous | *state* | discrete |
| global | *metrology* | local |
| accumulate | *errors* | correct |
| similar | *materials* | dissimilar |
| irreversible | *reuse* | reversible |

cba.mit.edu/events/13.03.scifab/index.html

THE CENTER FOR BITS AND ATOMS
Massachusetts Institute of Technology

# The Science of Digital Fabrication

*March 7, 2013*
MIT

In 1952 MIT created the first computer-controlled milling machine, based on early work on real-time computing. Since then, a variety of cutting tools have been mounted on moving platforms controlled by computers, including lasers, waterjets, and wires. More recently, additive manufacturing has been widely covered, with tools that can extrude filaments or sinter powders or cure resins. However, even though these processes use digital designs they are all physically analog, continuously depositing or removing material.

In 1948 Claude Shannon created a mathematical theory of communication, showing that by dividing a continuous message into discrete symbols it can be sent reliably through an unreliable communications channel. In 1952 John von Neumann applied this to computing, showing that a digital computer can operate reliably with unreliable devices. The same is now happening for fabrication, with the introduction of fundamentally digital processes that can build reliably with unreliable materials by coding their construction from discrete components. These are being developed on length scales from molecules to buildings, promising unprecedented manufacturing flexibility, functionality, complexity, and reusability.

This workshop will review the research required to turn data into things and things into data, gathering an emerging interdisciplinary community to provide input to guide policy and programs in this area. It is open but requires registration based on available space; to register send your name and any institutional affiliation you'd like to include to <meetings@cba.mit.edu>

pictures

8:00-9:00 *Registration* (E14-638)

9:00-10:30 *Briefings: Materials and Mechanisms* (E14-674)

- Introduction: *Neil Gershenfeld*
- History: *Saul Griffith*
- Fabricational Complexity: *Joe Jacobson*
- Digital Materials: *Kenny Cheung*
- Self-Assembly: *Ned Seeman*
- Nano-assembly: *Peng Yin*
- Micro-assembly: *Will Langford*
- Meso-assembly: *Hod Lipson*
- Macro-assembly: *Skylar Tibbits*
- Mega-assembly: *Larry Sass*

10:30-11:00 *Break* (E14-638)

11:00-12:30 *Briefings: Processes and Workflows* (E14-674)

- Simulation and Optimization: *Wojciech Matusik*
- 3D Scanning: *Philip Withers*
- Design Representations and Interfaces: *Matthew Keeter*
- Path Planning: *Sanjay Sarma*
- Motion Control: *Nadya Peek*
- Printing: *Jennifer Lewis*
- Folding: *Erik Demaine*
- Programmable Matter: *Daniela Rus*
- Little Data: *George Church*
- Self-Reproducing Systems: *John Glass*

12:30-2:00 *Lunch: Demonstrations* (E14-638,648)

12:30-2:00 *Lunch: Demonstrations* (E14-638,648)

2:00-3:30 *Briefings: Policy and Programs* (E14-674)

- OSTP: *Philip Rubin* (video)
- NIST: *John Slotwinski*
- DARPA: *Paul Eremenko*
- NSF: *Richard Voyles*
- NASA: *LaNetra Tate*
- DOE: *Kelly Visconti*
- DHS: *Jose Vazquez*
- Make: *Dale Dougherty*
- MacArthur Foundation: *Connie Yowell*
- Barcelona: *Vicente Guallart*
- Rep. *Bill Foster*

3:30-4:15 *Working Groups* (E14-638,648)

- Policy, Programs: *Tom Kalil* (video)
- Standards, Formats: *Hod Lipson*
- Facilities, Infrastructure: *Jim Newton*
- Communication, Publication: *Joe Jacobson*
- Education, Outreach: *Sherry Lassiter*

4:30-5:00 *Discussion* (E14-674)

5:00-6:30 *Reception: Exhibition* (E14-638,648)

6:30-8:00 *Goldstein Lecture* (10-250)

- The Design of Robotic Fabricated Architecture: *Matthias Kohler*

cba.mit.edu/events/14.05.BB/index.html

THE CENTER FOR BITS AND ATOMS
Massachusetts Institute of Technology

# Bits ↔ Biology

Biology is fundamentally discrete, based on sets of nucleic and amino acids combined into genes and proteins. And computers are fundamentally discrete, based on bits of data processed by logic gates. The latter have long been used to study the former, but a range of emerging technologies are now making it possible to directly convert between these representations. Just as analog/digital and digital/analog converters provide the interface between computers and the physical world of sensors and actuators, "biology/digital" and "digital/biology" converters are allowing computers to create and control biological worlds. This workshop will gather researchers working at the boundary between bits and biology, to explore common themes and identify future opportunities.

The meeting is open but requires registration based on available space. To register send your name and any institutional affiliation you'd like to list to meetings@cba.mit.edu.

## *Agenda*

**May 1, 2014** *E14 6th floor* (pictures)

8:00-9:00 *Registration*

9:00-10:30

- From A/D/A to B/D/B: *Neil Gershenfeld* (video)
- The World's Largest Genomics Organization: *Laurie Goodman, Yang Huanming* (video)
- From Megabytes to Megabases: *Joseph Jacobson* (video)
- Reading and Writing Genomes in 3D: *Erez Lieberman Aiden* (video)
- Principles of Genome Design: *John Glass*, *James Pelletier* (video)
- How To Make Radically New Genomes: *George Church* (video)

10:30-11:00 *Break*

11:00-12:30

- Engineering Materials with Synthetic Biology: *Timothy Lu* (video)
- Synthetic and Natural Analog Computation in Living Cells: *Rahul Sarpeshkar* (video)
- A Single Code For A Hundred Programs: Deciphering The Human Epigenome: *Manolis Kellis* (video)
- Molecular Information Theory: Why is the Genetic Code Degenerate?: *Tom Schneider* (video)
- Biomolecular Recognition: *Andreas Mershin* (video)
- Genetic Rescue of Imperiled and Extinct Species: *Ryan Phelan* (video)

12:30-2:00 *Lunch*

2:00-3:30

- Quantum Life: *Seth Lloyd* (video)
- Photonic Reagents for Probing and Controlling Biological Systems: *Denys Bondar, Alexei Goun* (video)
- Molecular Memory: *Noah Jakimo* (video)
- Unwiring The Brain: *Winfried Denk* (video)
- Digital Encoding For Scalable Brain Mapping: *Adam Marblestone* (video)
- Mapping, Recording, Controlling, and Building Brains: *Daniel Schmidt, Ed Boyden* (video)

3:30-4:00 *Break*

4:00-5:30

- A Comprehensive Understanding Of Simple Cells: *Tom Knight* (video)
- Rapid Prototyping for Biological Design: *Peter Carr* (video)
- Templating Biology for Design: *Steven Keating, Markus Kayser, Neri Oxman* (video)
- Open Data, Open Humans: *Charles Fracchia* (video), *Madeleine Ball* (video)
- Good Bits or Bad Bits? Keeping the New Biology Safe: *David Rejeski*, *Carmine Nigro* (video)
- Living Foundries: *Alicia Jackson* (video)

5:30-7:00 *Reception*


mtm.cba.mit.edu

# Machines that Make

The Machine that make project at the MIT Center for Bits and Atoms seeks to develop low-cost machines that can be made using CNC equipment, like available in fab labs.

**Reconfigurable Stages**

Reconfigurable one-axis stages for multi-purpose motion.

**foldafab**

A deployable medium-format CNC router.

**DIY EDM**

An entry level (under $500) EDM machine for making carbide/HSS tooling and/or lead screws

**5 Axis Timing Belt MTM**

Low cost 5 axis machining.

**POP Fab**

A suitcase milling machine, 3d printer, and vinyl cutter.

**Multi-processes lathe**

The additive lathe is a 3D printer that prints on rotation objects.

**Virtual Machine Network**

Modular control for the MTM project.

**Timing Belt MTM**

A design without lead screws, reducing cost.

**Fab-In-A-Box**

**MtM Snap-Lock**

**MtM A-Z**

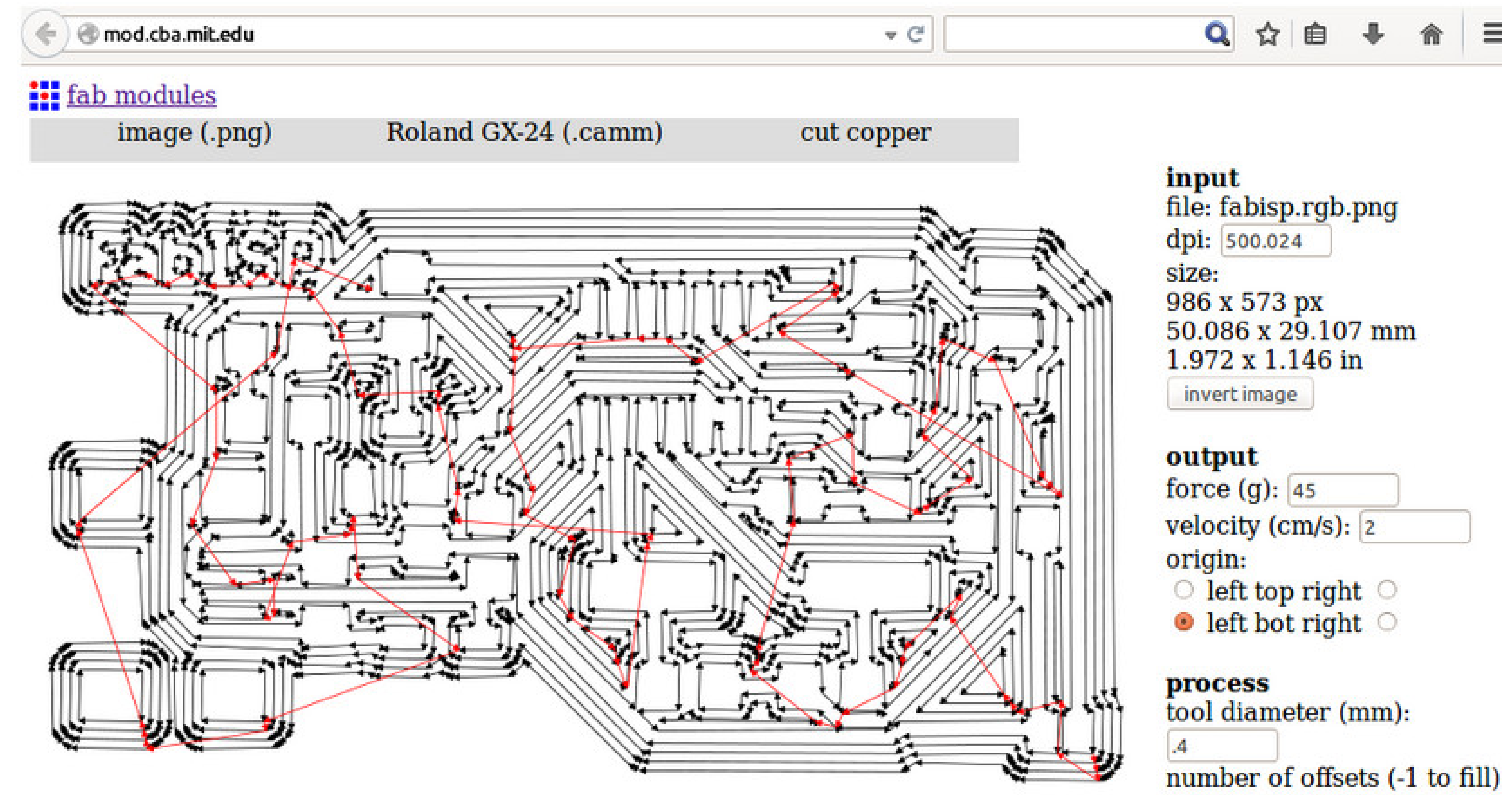
**DIY Vinyl Cutter**

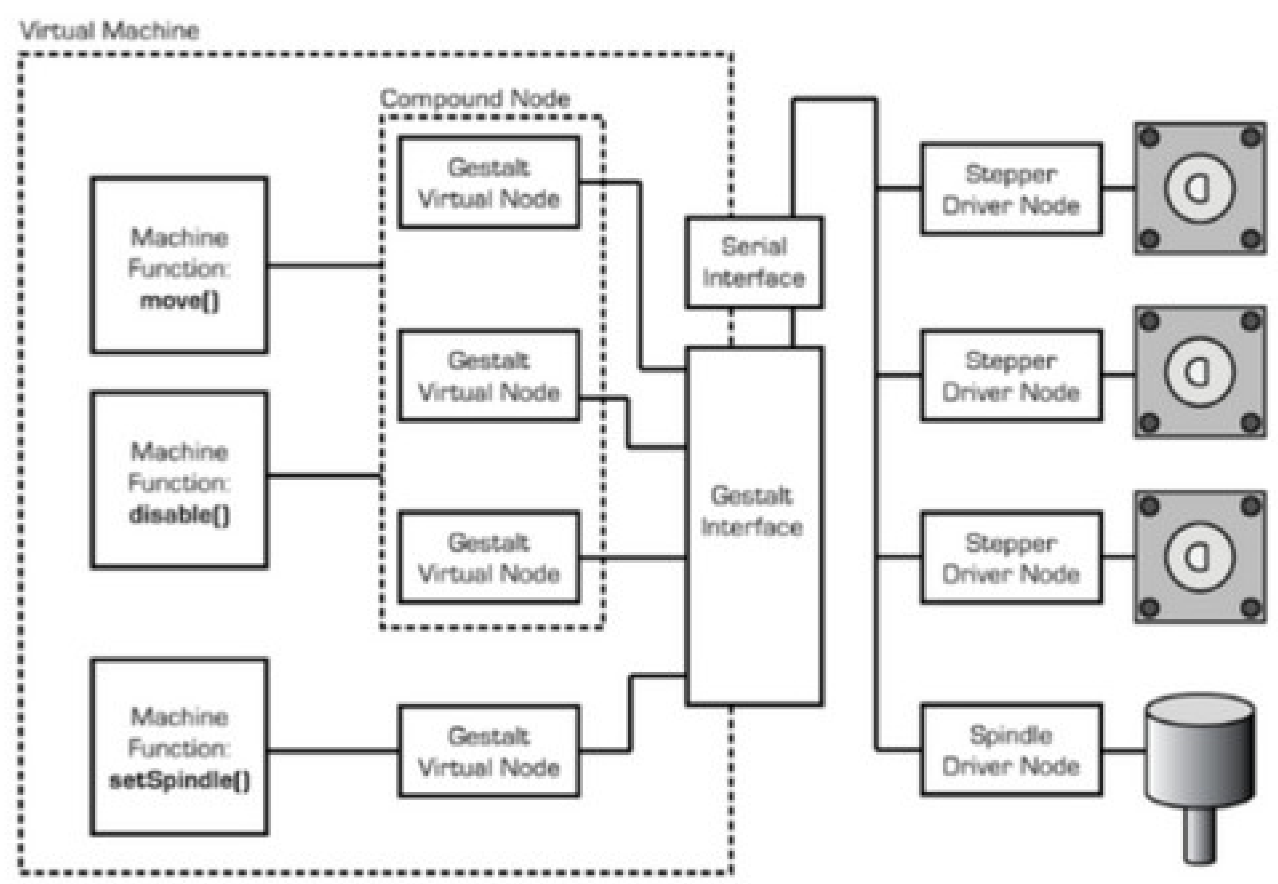
**Mantis CNC Mill**

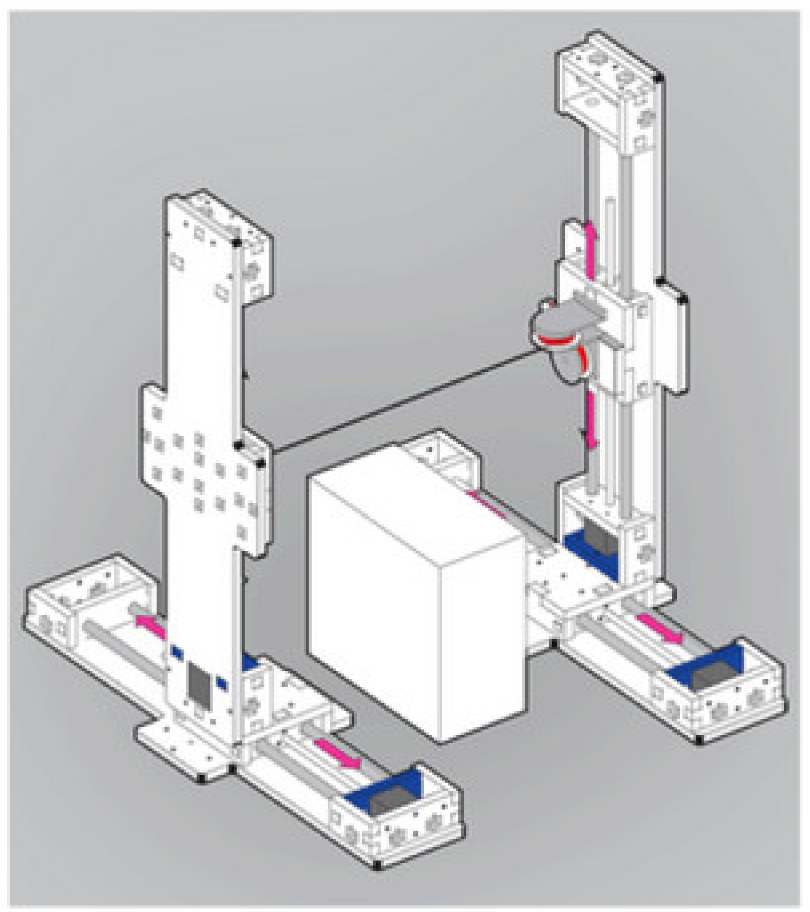
**MTM-LJ**

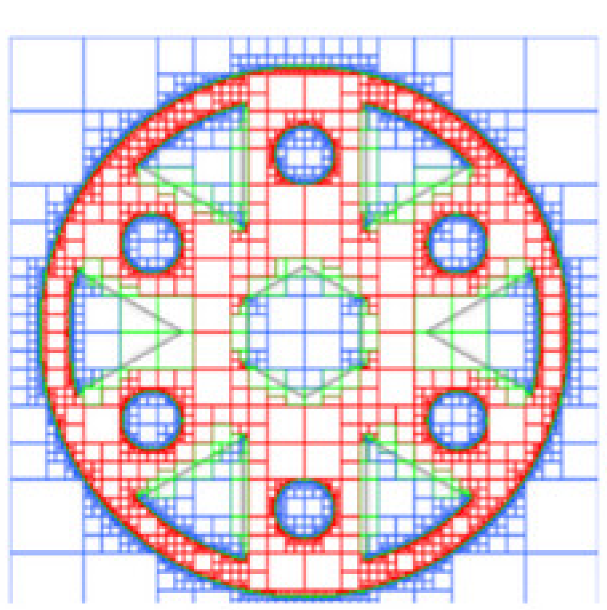
**Cast Cement CNC**

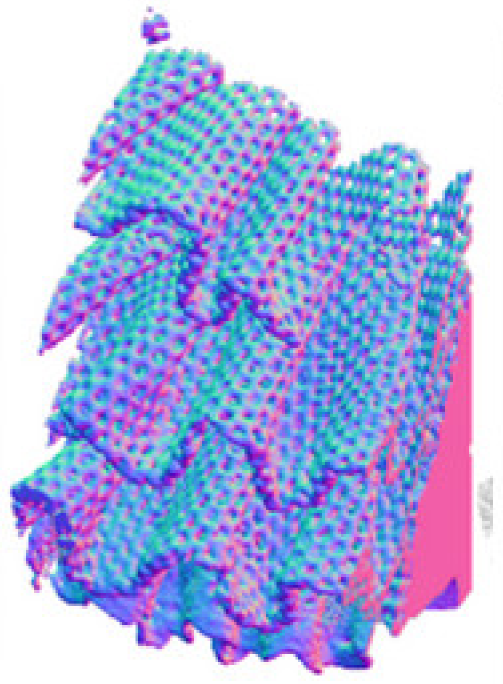
**FabMate**

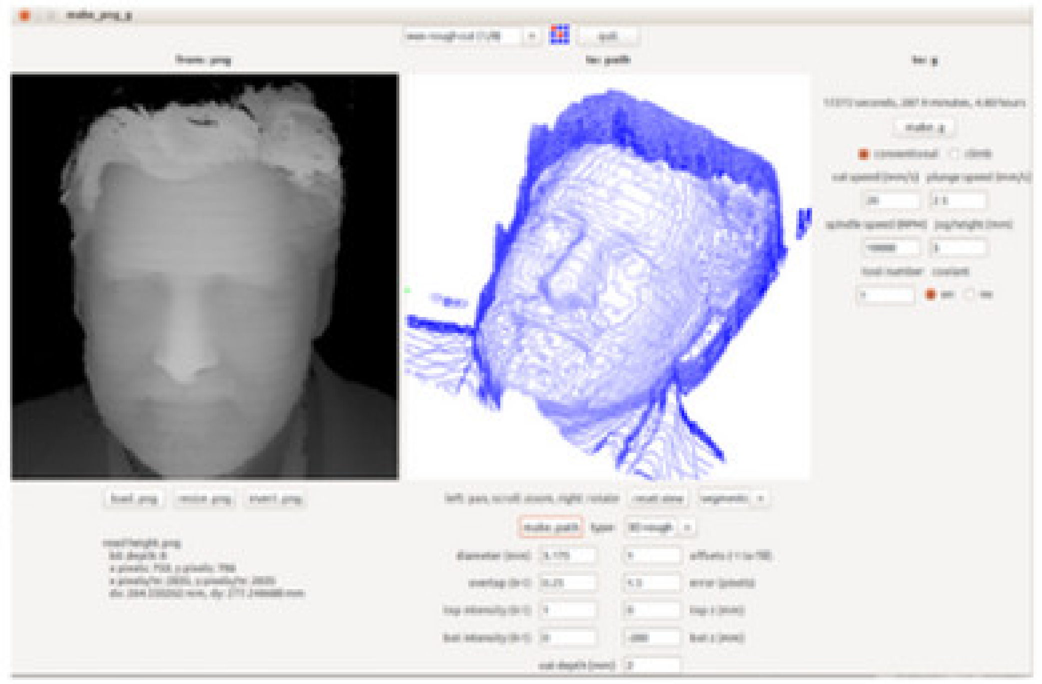


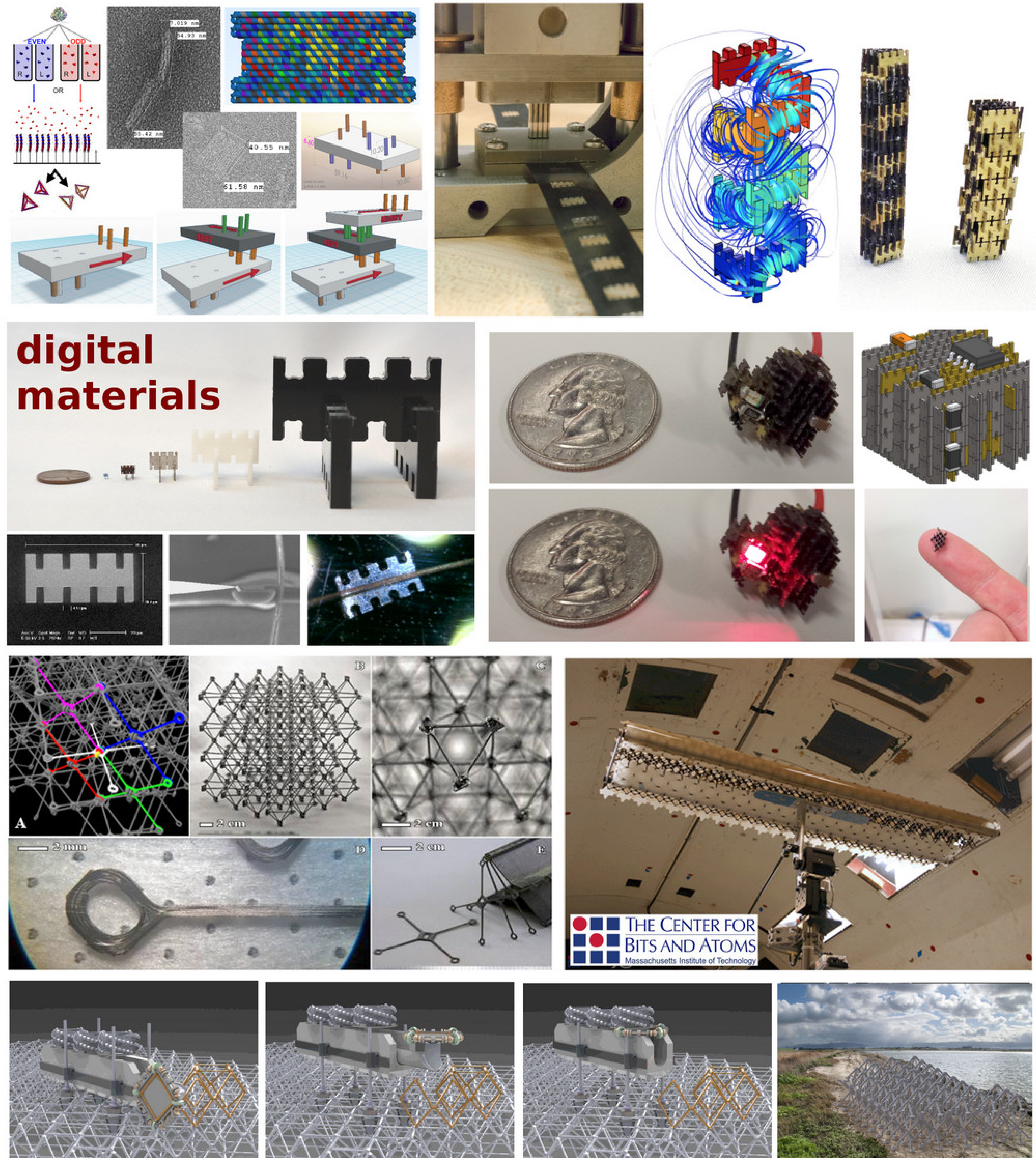










EVEN
ODD
OR
digital
materials
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2 cm
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2 cm
2 mm
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2 cm
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THE CENTER FOR
BITS AND ATOMS
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Co.DESIGN | Co.EXIST | Co.CREATE SUBSCRIBE | DESIGN DAILY FAST COMPANY

INNOVATION ENGINE

# MIT Reveals Wondrous Modular Robots Inspired By Proteins

AN INCREDIBLE RESEARCH PROTOTYPE MAY CHANGE THE WAY ALL OBJECTS ARE BUILT AND WORK IN THE FUTURE.

166 124

The computer--or more accurately, the Turing Machine--changed the world with a groundbreaking idea: Any piece of information could be coded in 0s and 1s. And so theoretically, any question could be answered by sorting these numbers through an automated process. Even today, in the era of microprocessors and 4G Internet, it's a rendition of these 0s and 1s that apply Instagram filters, power Google's predictive search, or render headshots in *Call of Duty*.

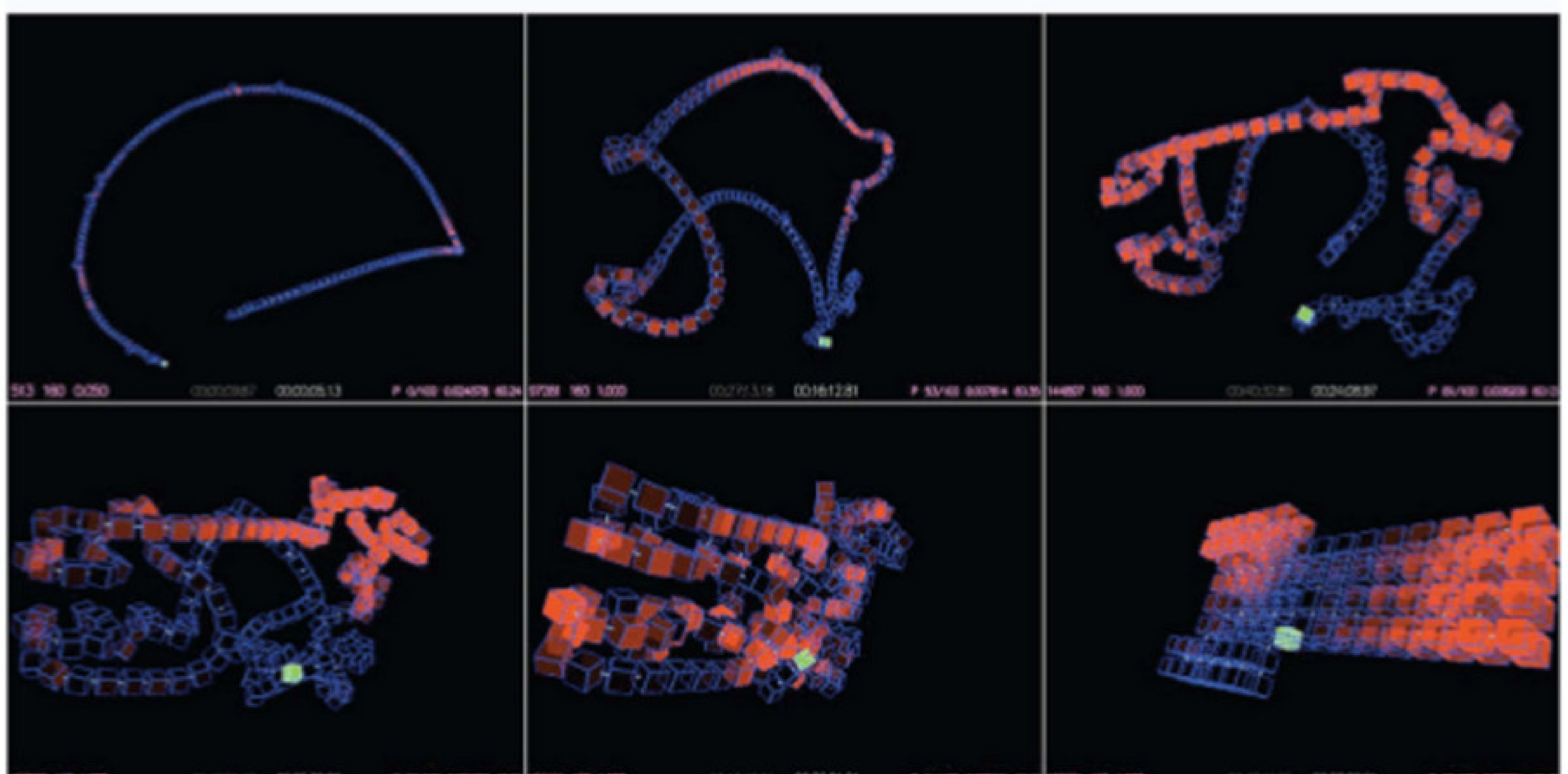
Working under a grant from DARPA, Neil Gershenfeld, head of MIT's Center for Bits and Atoms, along with graduate students Ara Knaian and Kenneth Cheun, have flipped this idea on its head. Rather than turning real ideas into binary code, they're turning binary code into real ideas.



**Co.Design**
business + innovation + design

EDITOR: Cliff Kuang

12 / 03



# Aligning the representation and reality of computation with asynchronous logic automata


**Neil Gershenfeld**

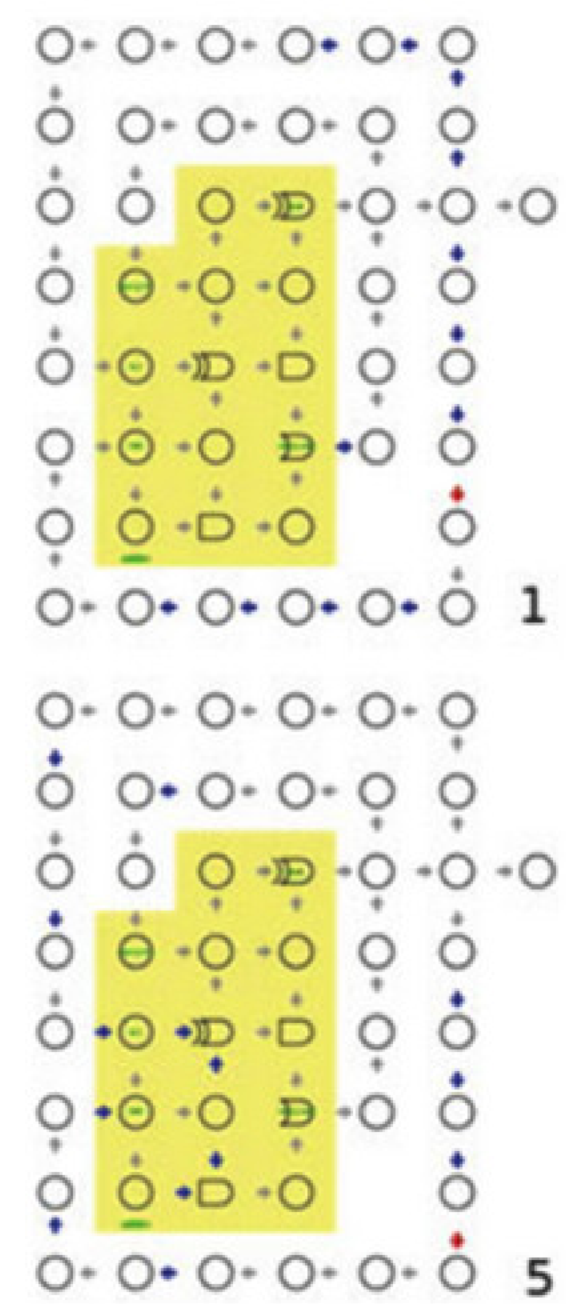


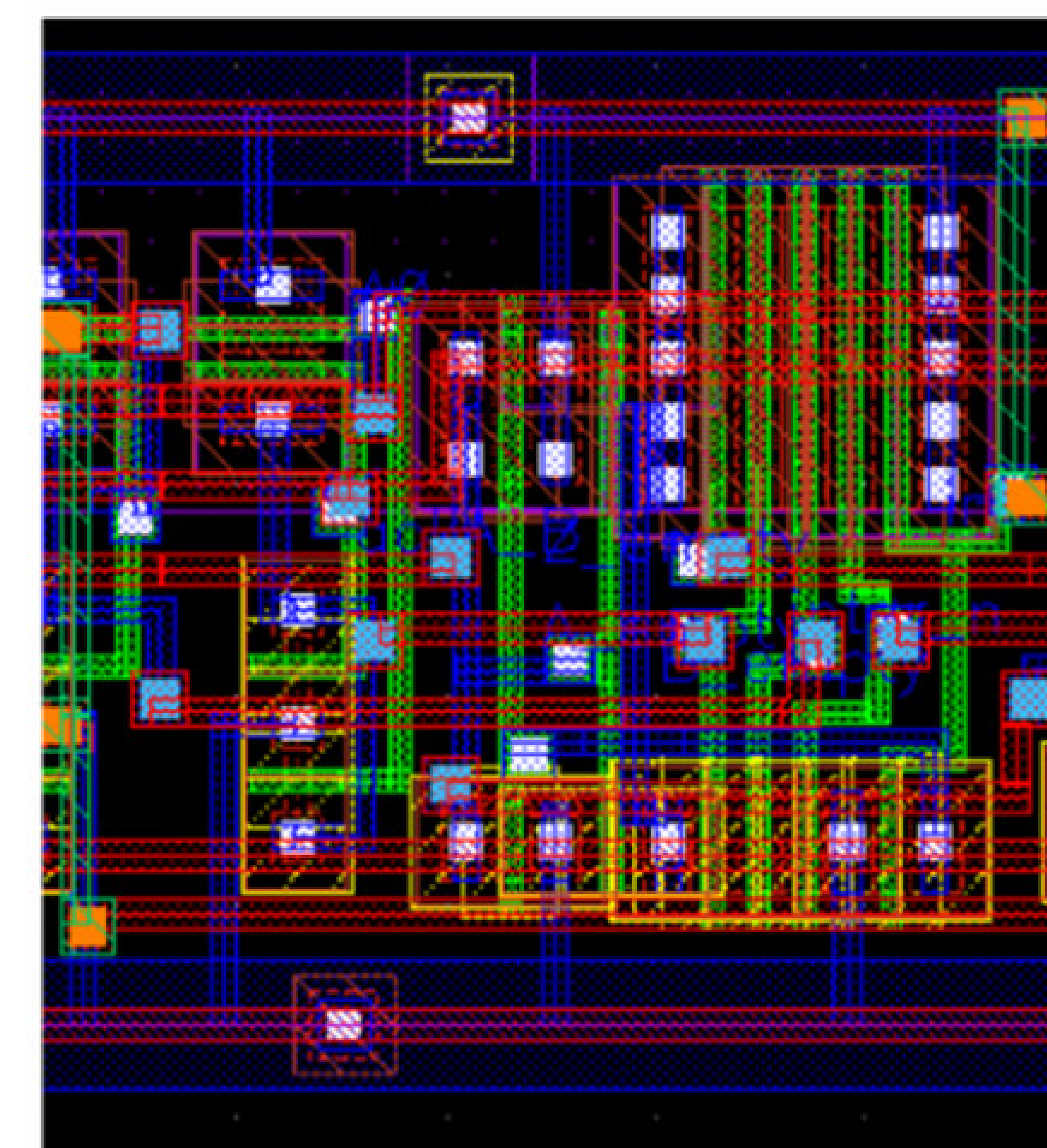
Received: 15 October 2011 / Accepted: 24 October 2011 / Published online: 16 November 2011





**Abstract** There are many models of computation, but they all share the same underlying laws of physics. Software can represent physical quantities, but is not itself written with physical units. This division in representations, dating back to the origins of computer science, imposes increasingly heroic measures to maintain the fiction that software is executed in a virtual world. I consider instead an alternative approach, representing computation so that hardware and software are aligned at all levels of description. By abstracting physics with asynchronous logic automata I show that this alignment can not only improve scalability, portability, and performance, but also simplify programming and expand applications.

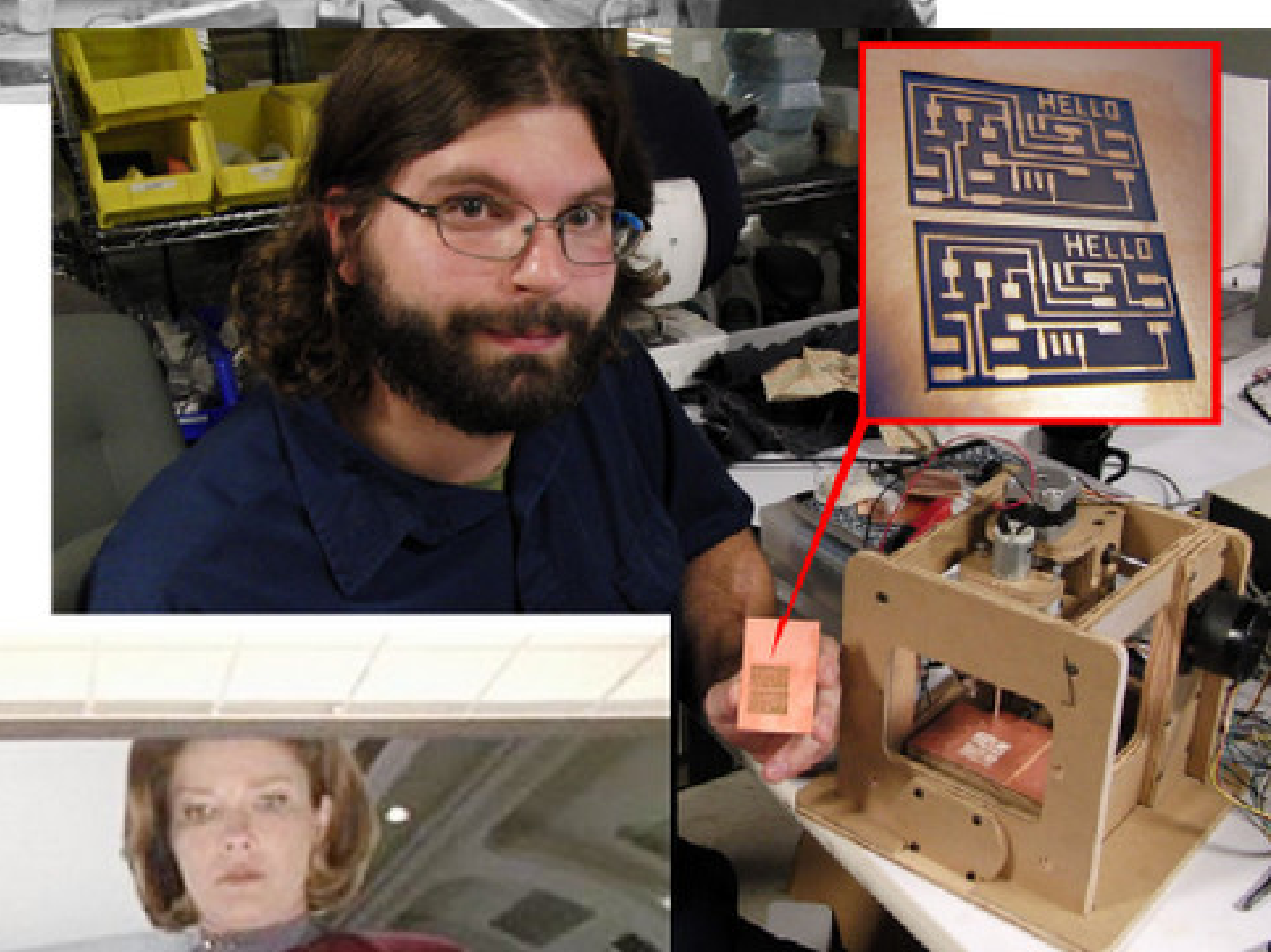




ALTAIR 8800 COMPUTER


DRIVE SERVO
PILOT SERVO OUTPUT UNITS
TABLE
HEAD
SLIDE


laser cutter
sign cutter
milling machine
electronics assembly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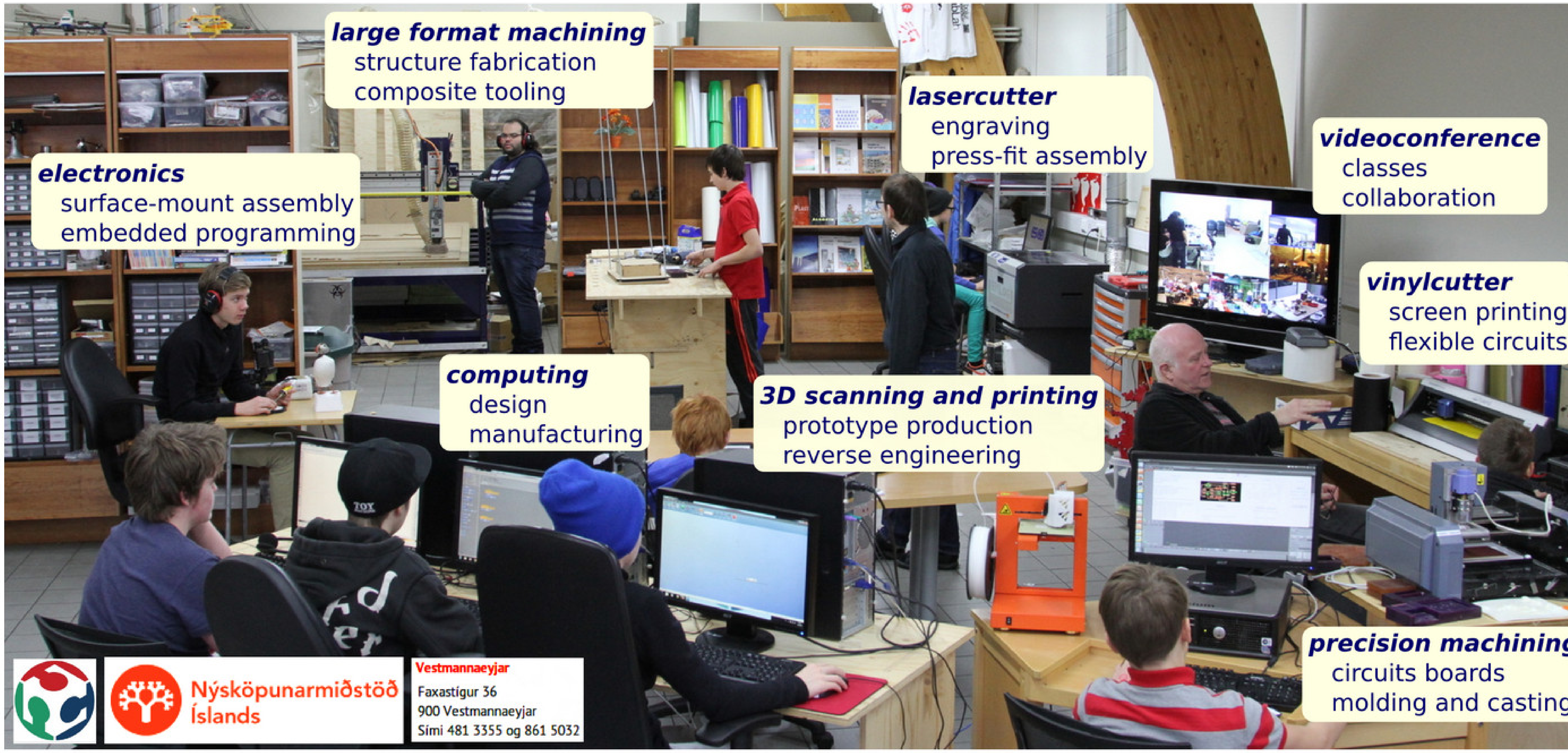
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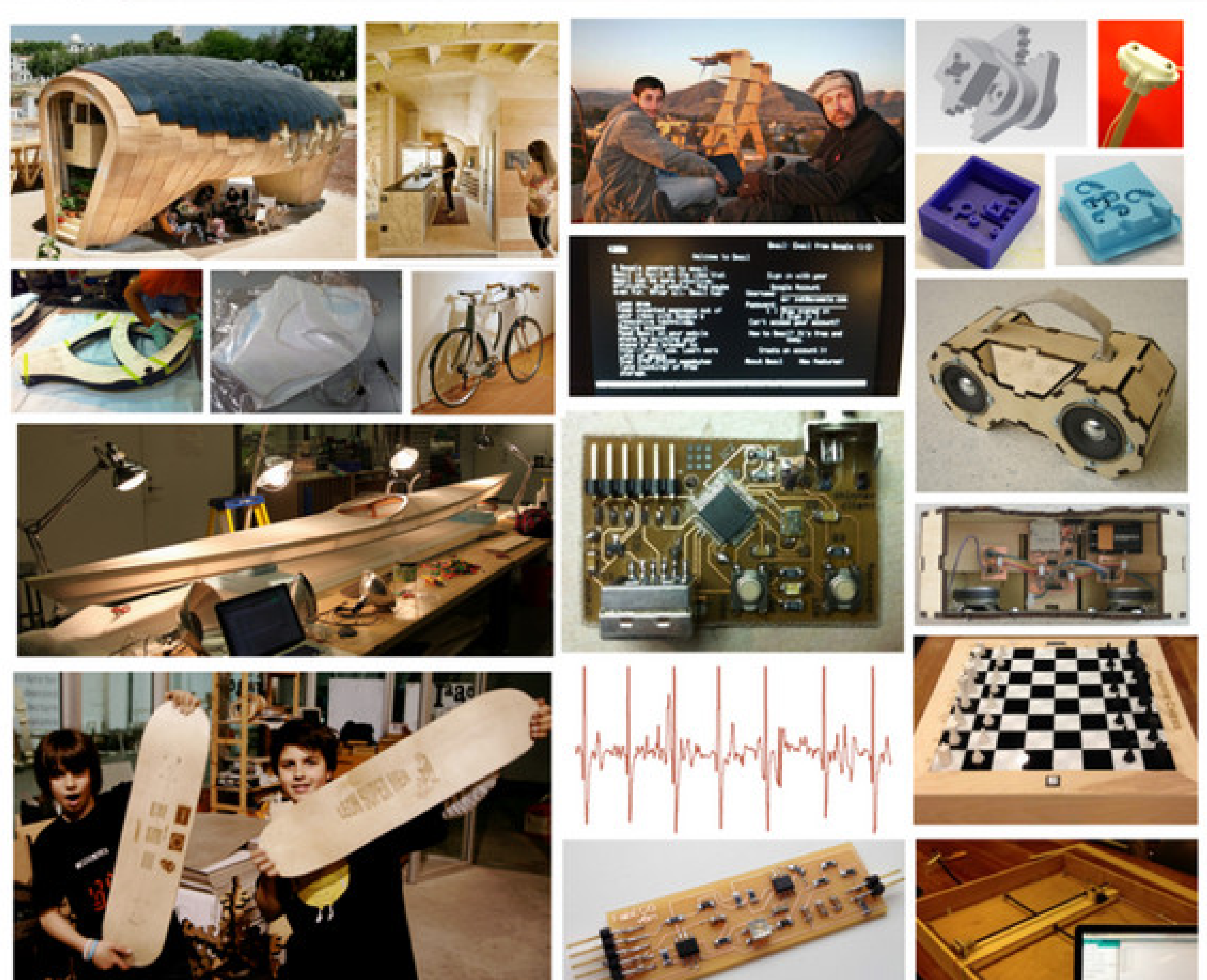

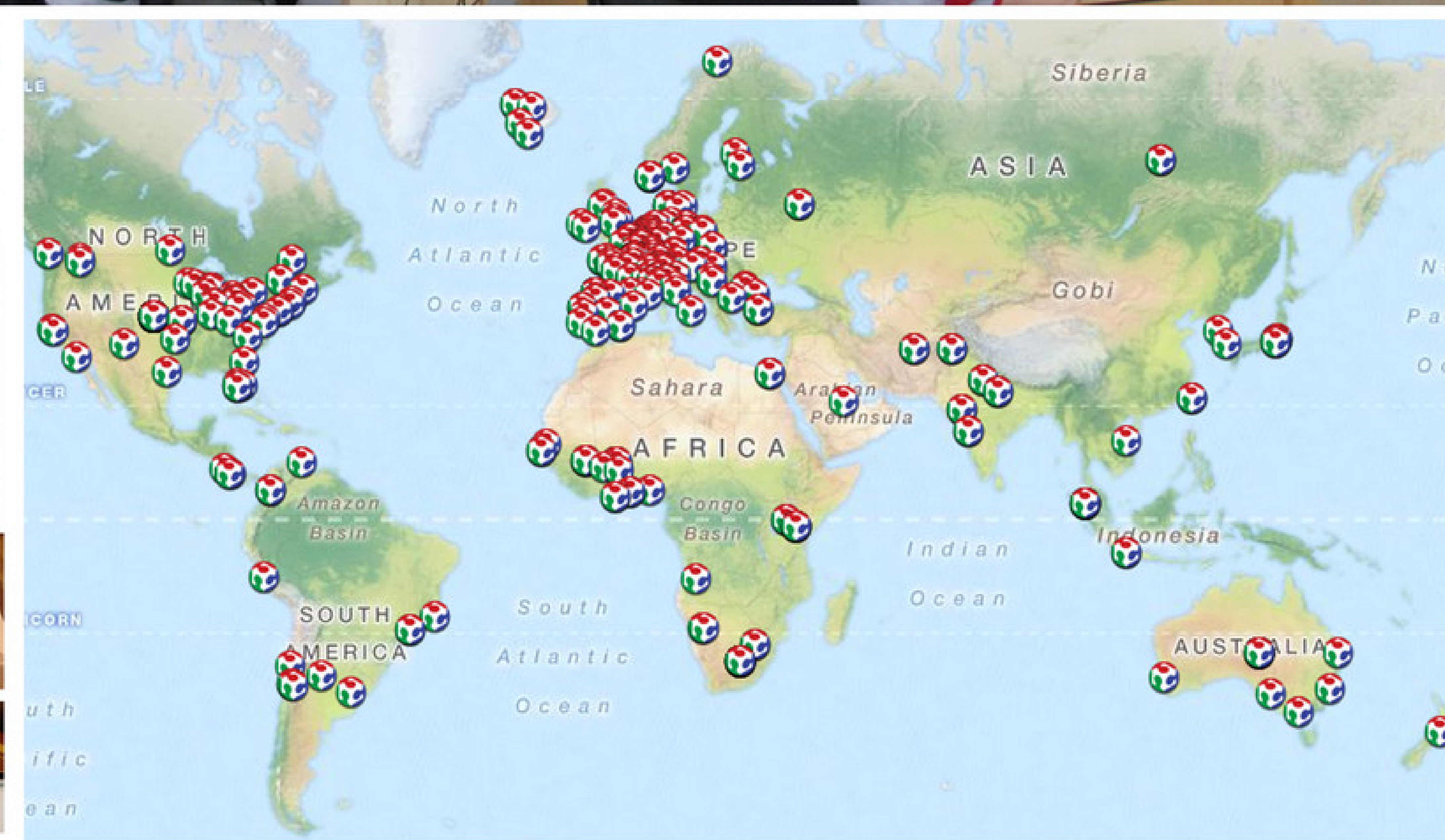
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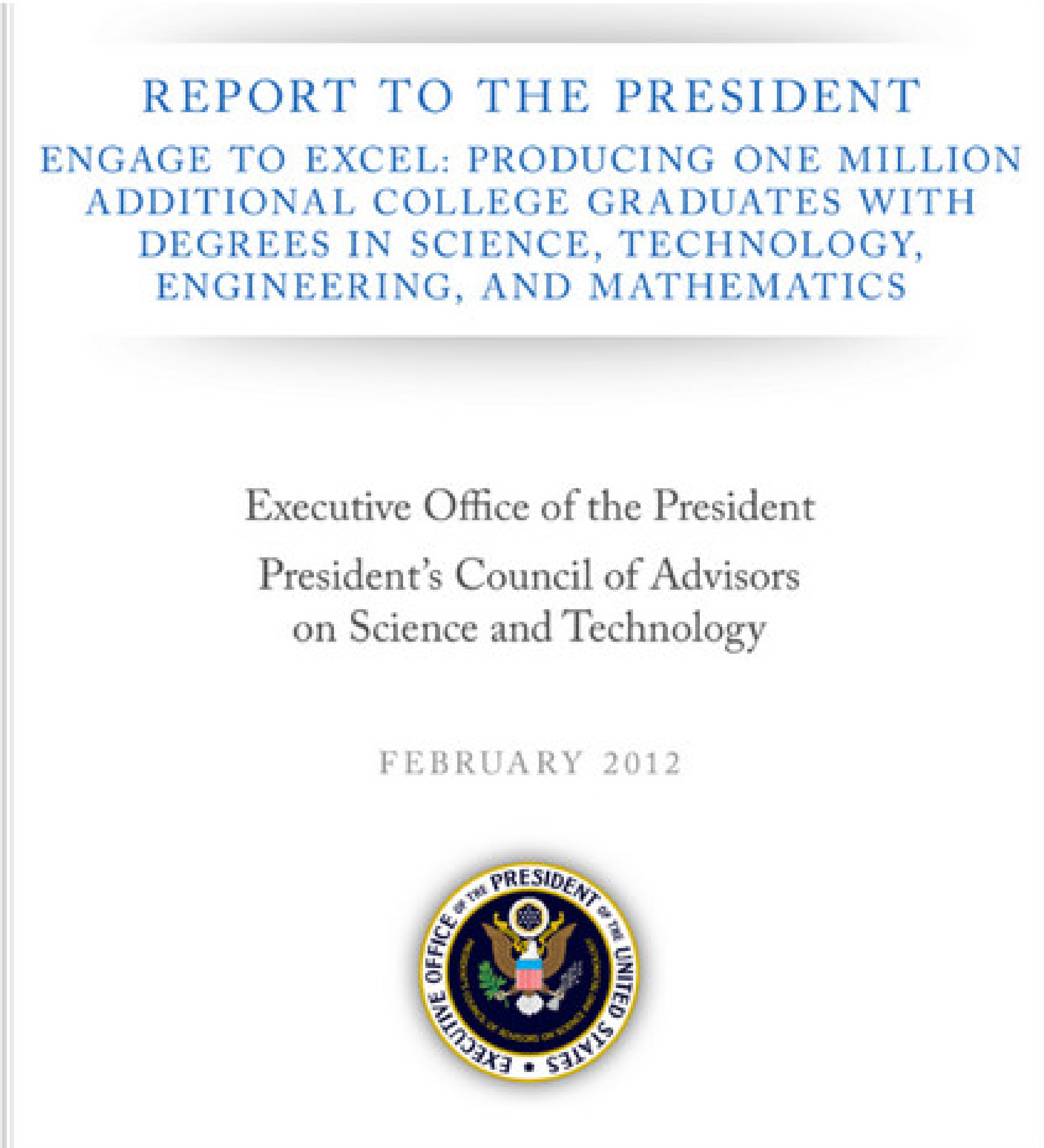
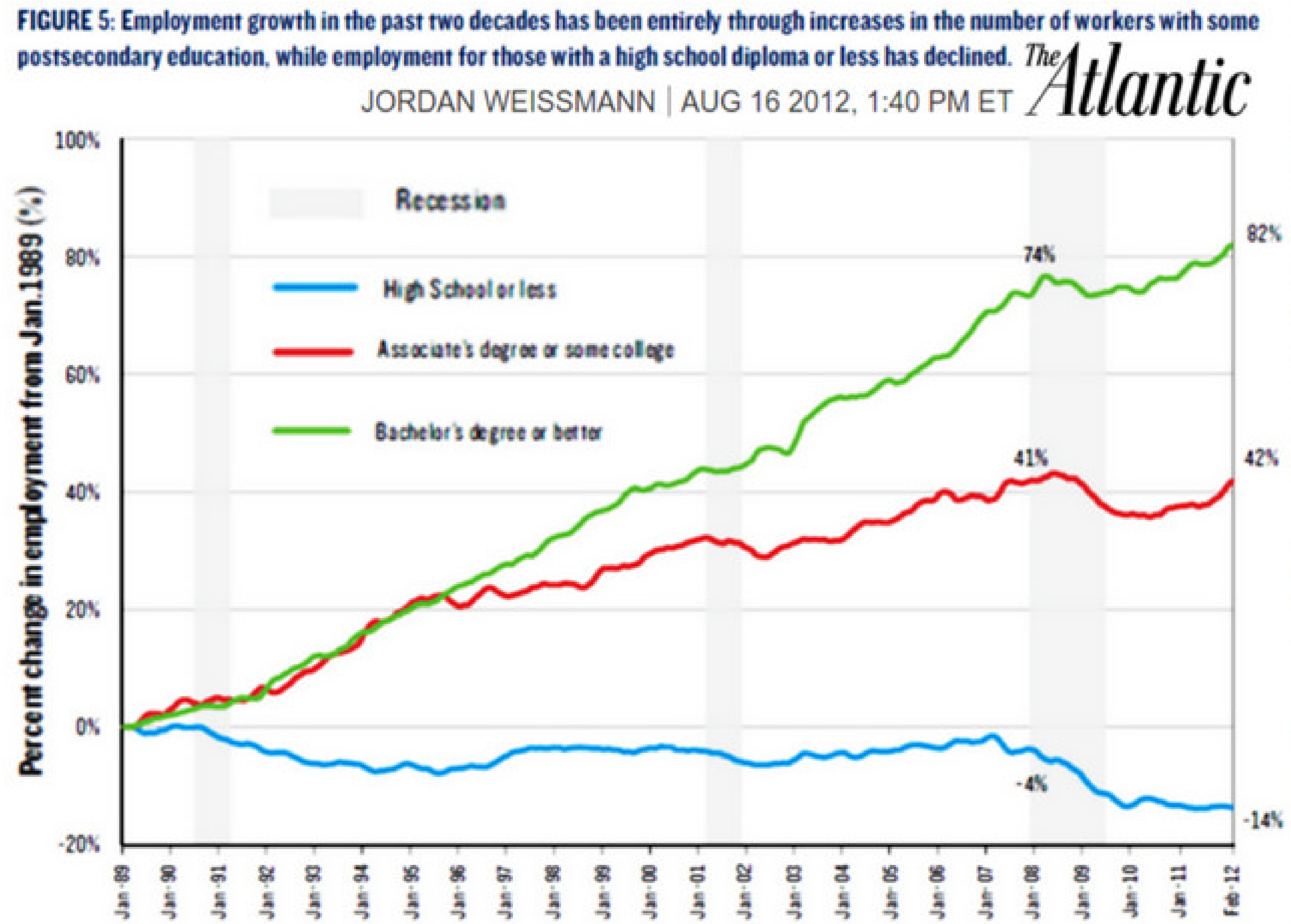

REPORT TO THE PRESIDENT

ENGAGE TO EXCEL: PRODUCING ONE MILLION ADDITIONAL COLLEGE GRADUATES WITH DEGREES IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

Executive Office of the President

President's Council of Advisors on Science and Technology

FEBRUARY 2012





## BOTTOM LINE /2000-2009

**370 MILLION EUR TURNOVER 1000 FULLTIME JOBS**

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Since 1972 we have run the public advisory service for inventors in Denmark. Each year we advise more than 5000 inventors and screen 1000 unique inventions. The advisory service helps inventors mature and commercialize their ideas through licensing and start-ups. We create 8-10 license agreements per year.

### INVENTORS SCHOOL SERVICE

Since 2010 we have run an educational programme aimed at inspiring and training students in hands-on innovation. More than 2000 students a year enjoy our human-centered, idea-generating, practical, fail-fast, live prototyping and involving approach to innovation.

### FABLAB TI

Opened in 2013, based on a long tradition of running a prototype workshop for inventors. FABLAB TI is now open to the public and is an integral part of the development of inventors ideas, commercialization of these ideas and the hands-on, design thinking-inspired training in our school service.

### FOR FURTHER INFO PLEASE CONTACT

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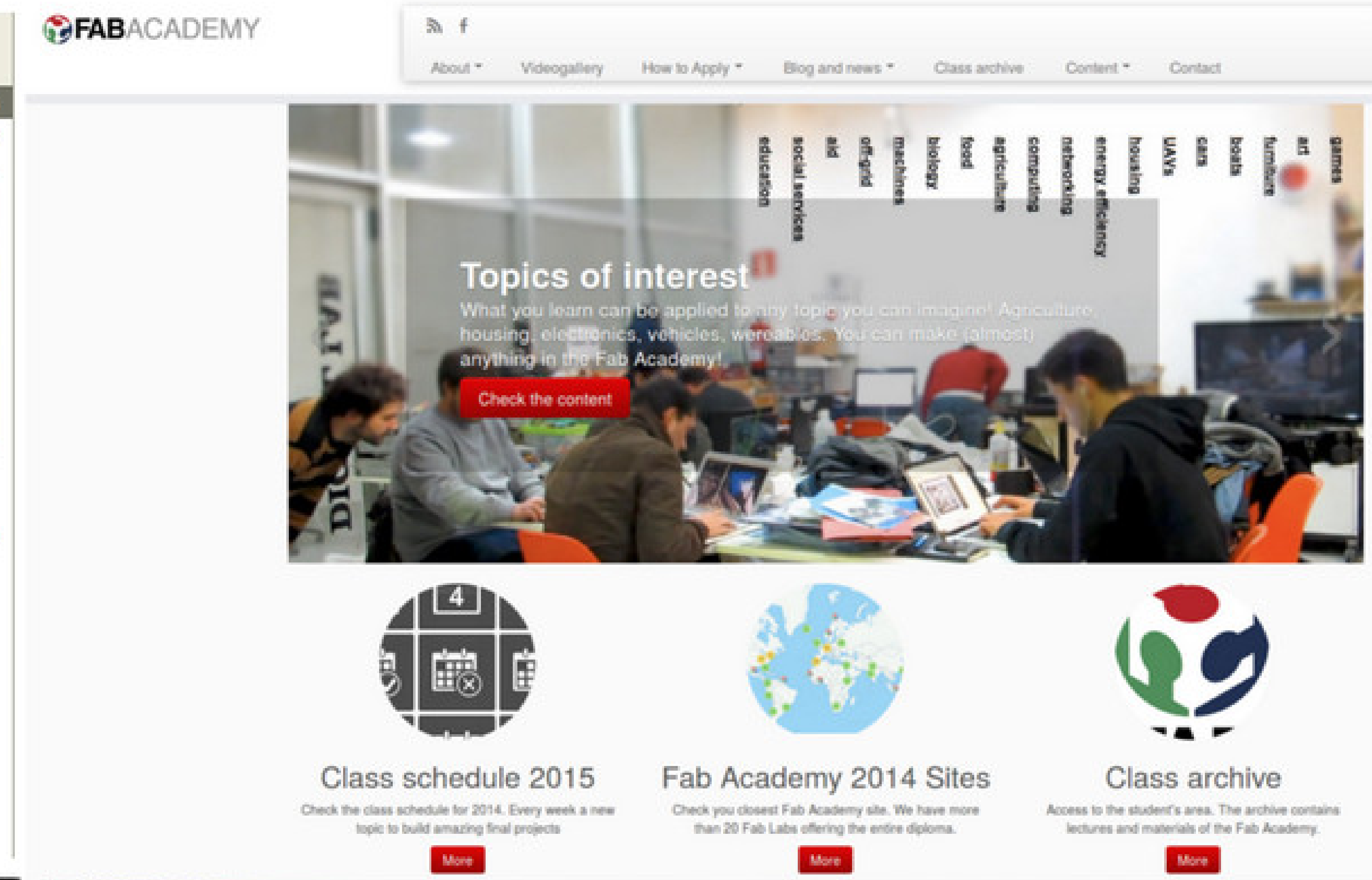

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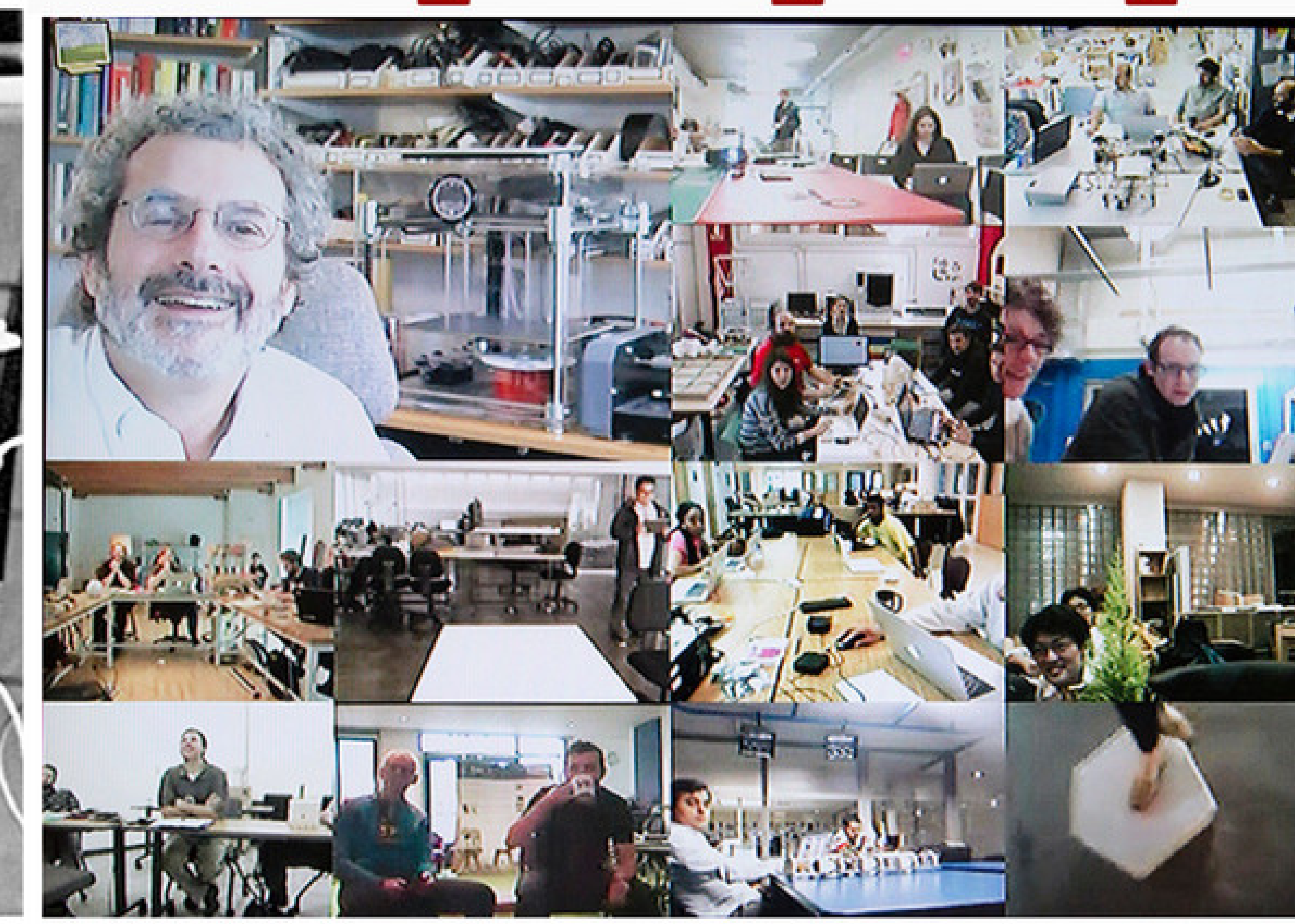
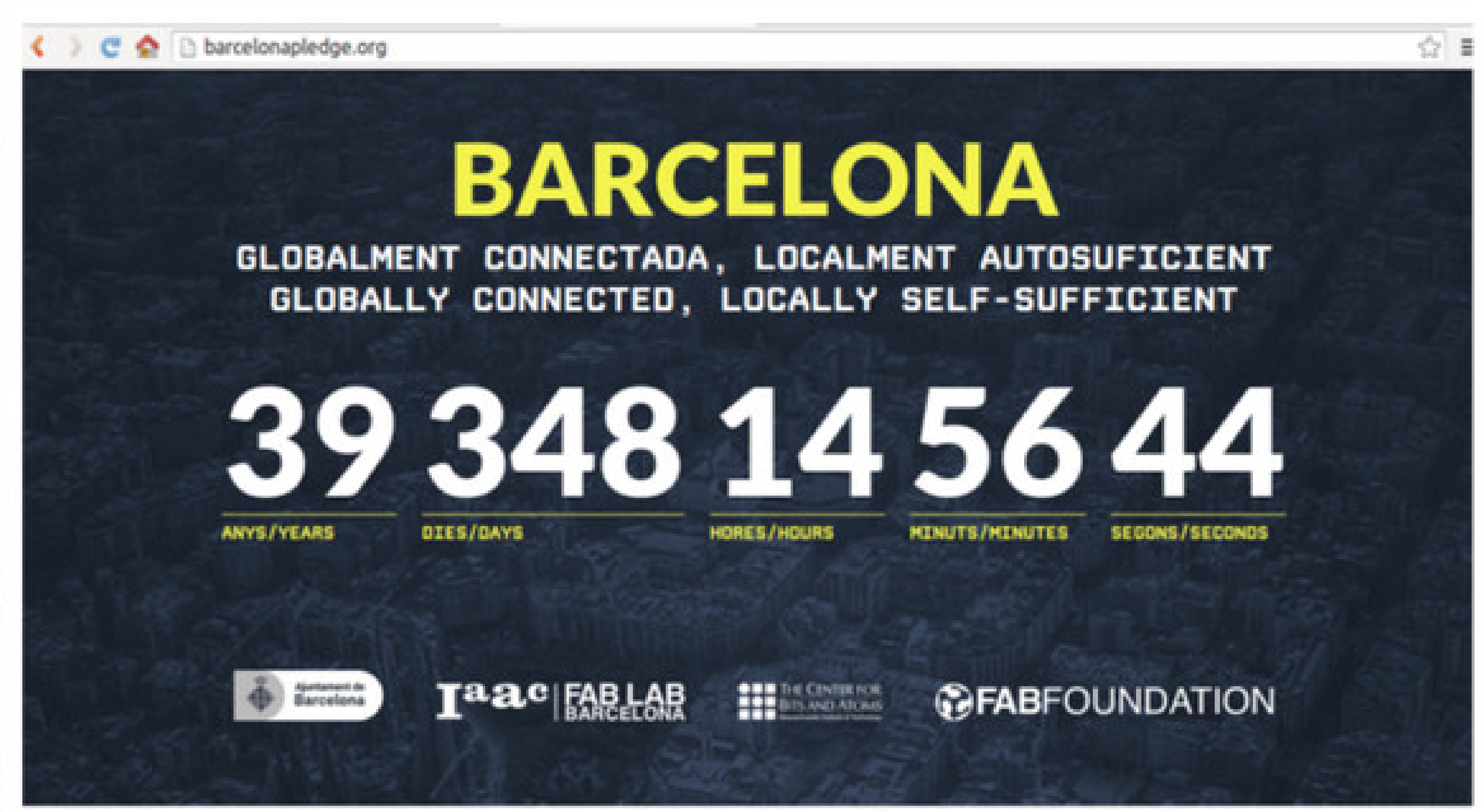



113TH CONGRESS
1ST SESSION

## H. R. 1289

IN THE HOUSE OF REPRESENTATIVES

March 20, 2013

**Mr. Foster** (for himself, **Mr. Hultgren, Mr. Massie, Mr. Van Hollen, Mr. Capuano, Mr. Carney, Mr. Cicilline, Mr. Connolly, Mr. Danny K. Davis of Illinois, Mr. Loebsack, Ms. McCollum, Mr. Peters of Michigan, Mr. Pocan, Mr. Rush, Ms. Schakowsky**, and **Ms. Shea-Porter**) introduced the following bill; which was referred to the Committee on the Judiciary

## A BILL

To provide a Federal charter to the Fab Foundation for the National Fab Lab Network, a national network of local digital fabrication facilities providing community access to advanced manufacturing tools for learning skills, developing inventions, creating businesses, and producing personalized products.

**Section 1. Short title**

This Act may be cited as the " National Fab Lab Network Act of 2013 ".

**Sec. 2. Findings**

Congress finds the following:

(1) Scientific discoveries and technical innovations are critical to the economic and national security of the United States.

(2) Maintaining the leadership of the United States in science, technology, engineering, and mathematics will require a diverse population with the skills, interest, and access to tools required to advance these fields.

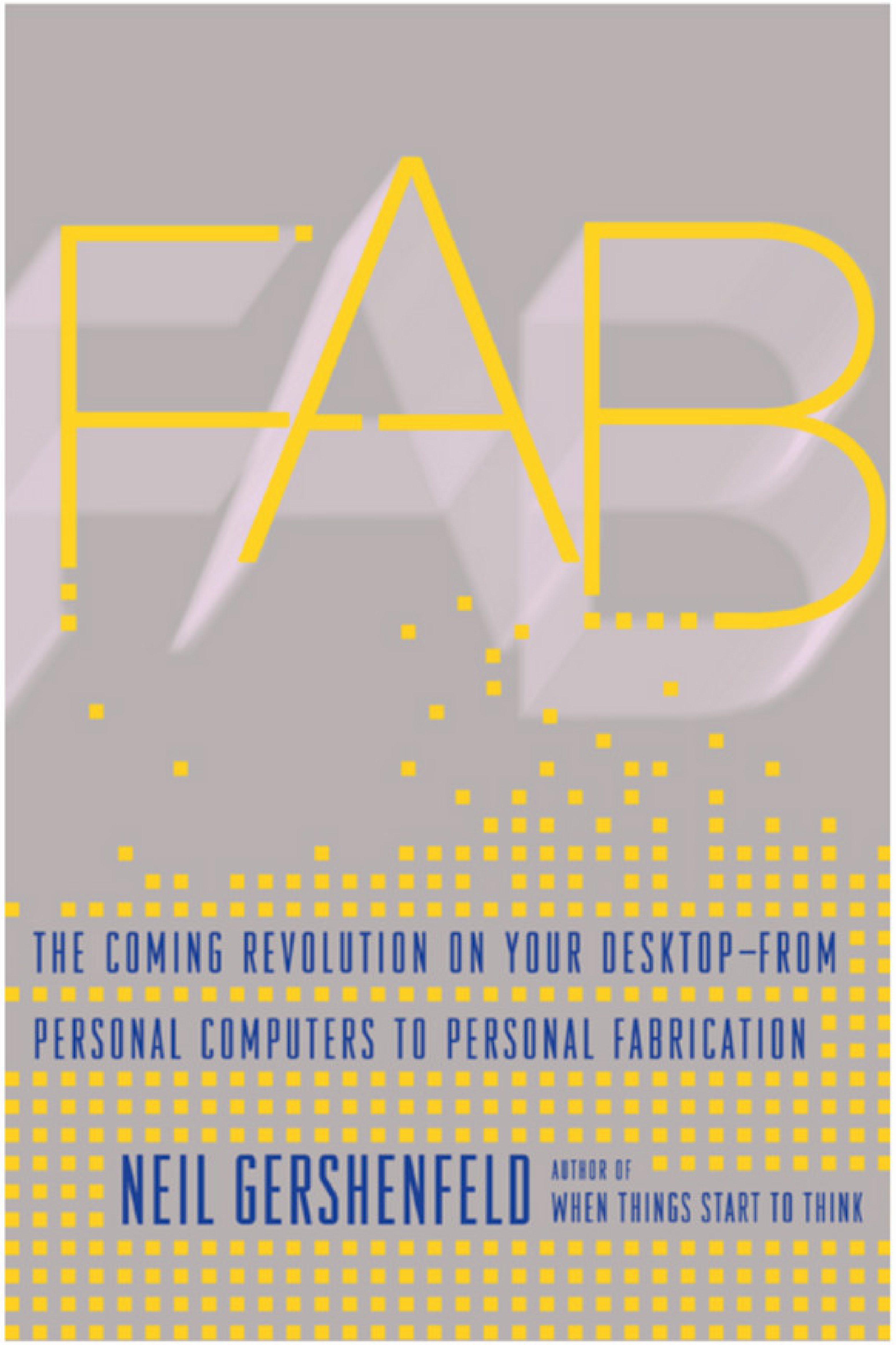
(3) Just as earlier digital revolutions in communications and computation provided individuals with the Internet and personal computers, a digital revolution in fabrication will allow anyone to make almost anything, anywhere.

(4) The Center for Bits and Atoms of the Massachusetts Institute of Technology (CBA) has contributed significantly to the advancement of these goals through its work in creating and advancing digital fab labs in the United States and abroad.

(5) CBA's fab labs provide a model for a new kind of national laboratory that links local facilities for advanced manufacturing to expand access and empower communities.

(6) A coordinated national public-private partnership will be the most effective way to accelerate the provision of this infrastructure for learning skills, developing inventions, creating businesses, and producing personalized products.

**Sec. 3. Establishment of national fab lab network**




FOREIGN AFFAIRS
NOVEMBER/DECEMBER 2012

# How to Make Almost Anything

## The Digital Fabrication Revolution

*Neil Gershenfeld*

Volume 91 • Number 6

# As Objects Go Online

## The Promise (and Pitfalls) of the Internet of Things

*Neil Gershenfeld and JP Vasseur*

Since 1969, when the first bit of data was transmitted over what would come to be known as the Internet, that global network has evolved from linking mainframe computers to connecting personal computers and now mobile devices. By 2010, the number of computers on the Internet had surpassed the number of people on earth.

Yet that impressive growth is about to be overshadowed as the things around us start going online as well, part of what is called "the Internet of Things." Thanks to advances in circuits and software, it is now possible to make a Web server that fits on (or in) a fingertip for $1. When embedded in everyday objects, these small computers can send and receive information via the Internet so that a coffeemaker can turn on when a person gets out of bed and turn off when a cup is loaded into a dishwasher, a stoplight can communicate with roads to route cars around traffic, a building can operate more efficiently by knowing where people are and what they're doing, and even the health of the whole planet can be monitored in real time by aggregating the data from all such devices.

Linking the digital and physical worlds in these ways will have profound implications for both. But this future won't be realized unless the Internet of Things learns from the history of the Internet. The open standards and decentralized design of the Internet won out over competing proprietary systems and centralized control by offering fewer obstacles to innovation and growth. This battle has resurfaced with the proliferation of conflicting visions of how devices should communicate. The challenge is primarily organizational, rather then technological, a contest between command-and-control technology

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