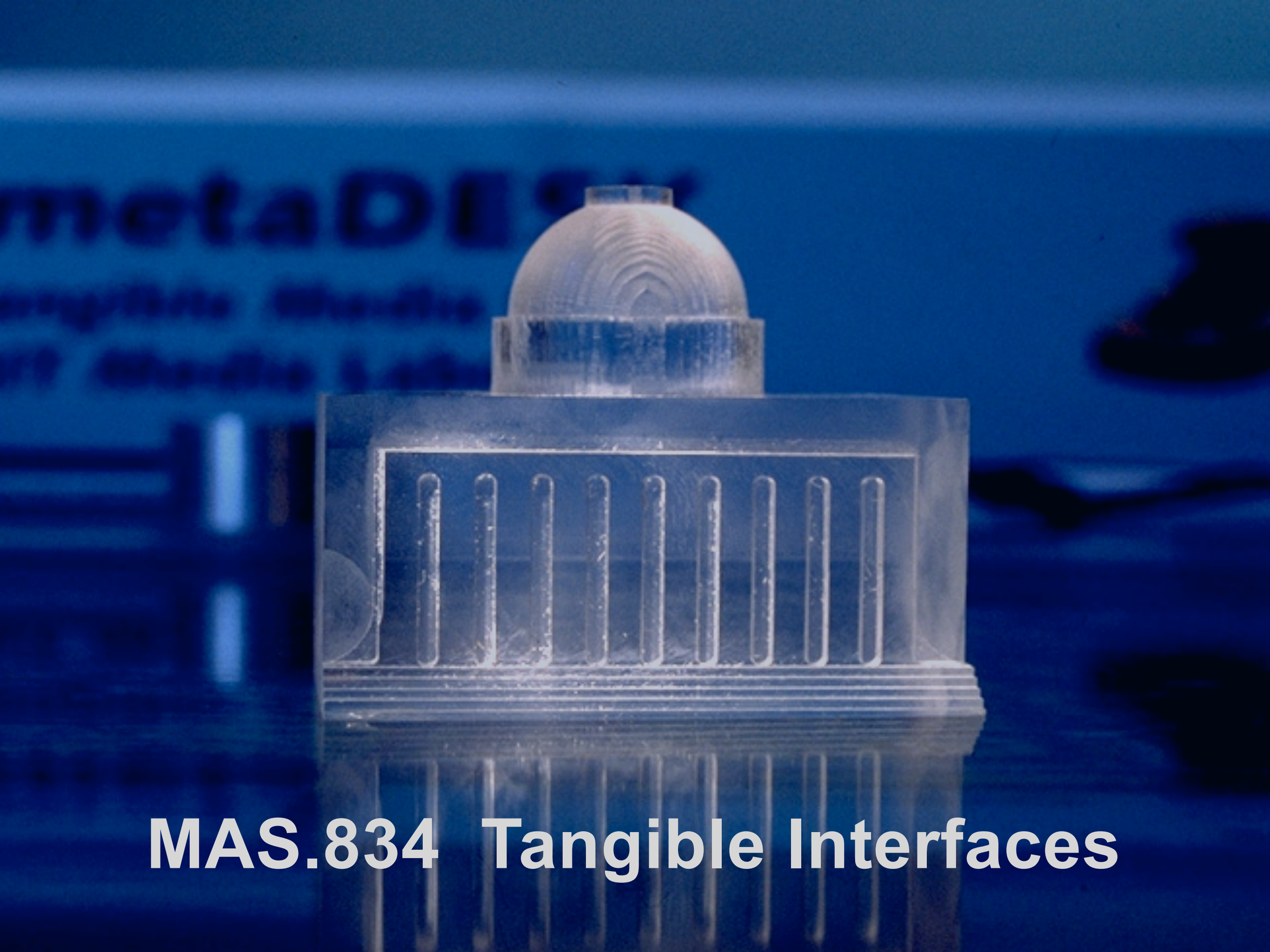
Tangible Bits
Beyond Pixels

MAS.834 Fall 2014
Tangible Interfaces

Hiroshi Ishii
Tangible Media Group
MIT Media Laboratory

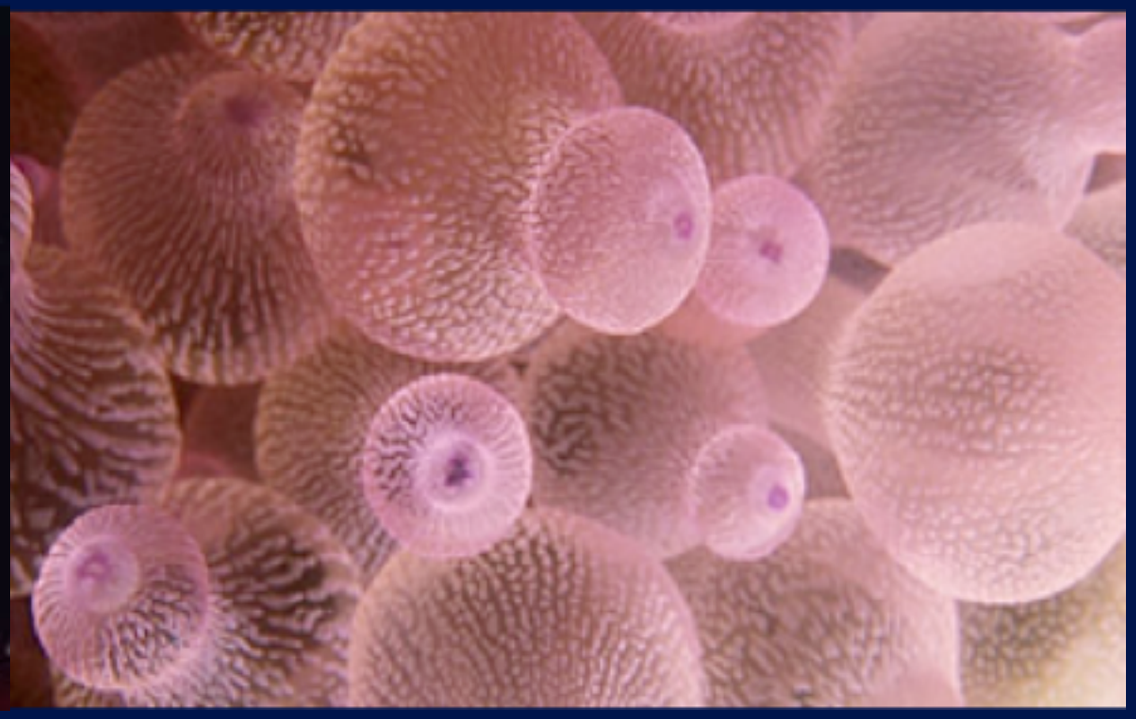


MAS.834 Tangible Interfaces

At the Border

**Where the land meets the sea,
there is a border.**

Living at the Border

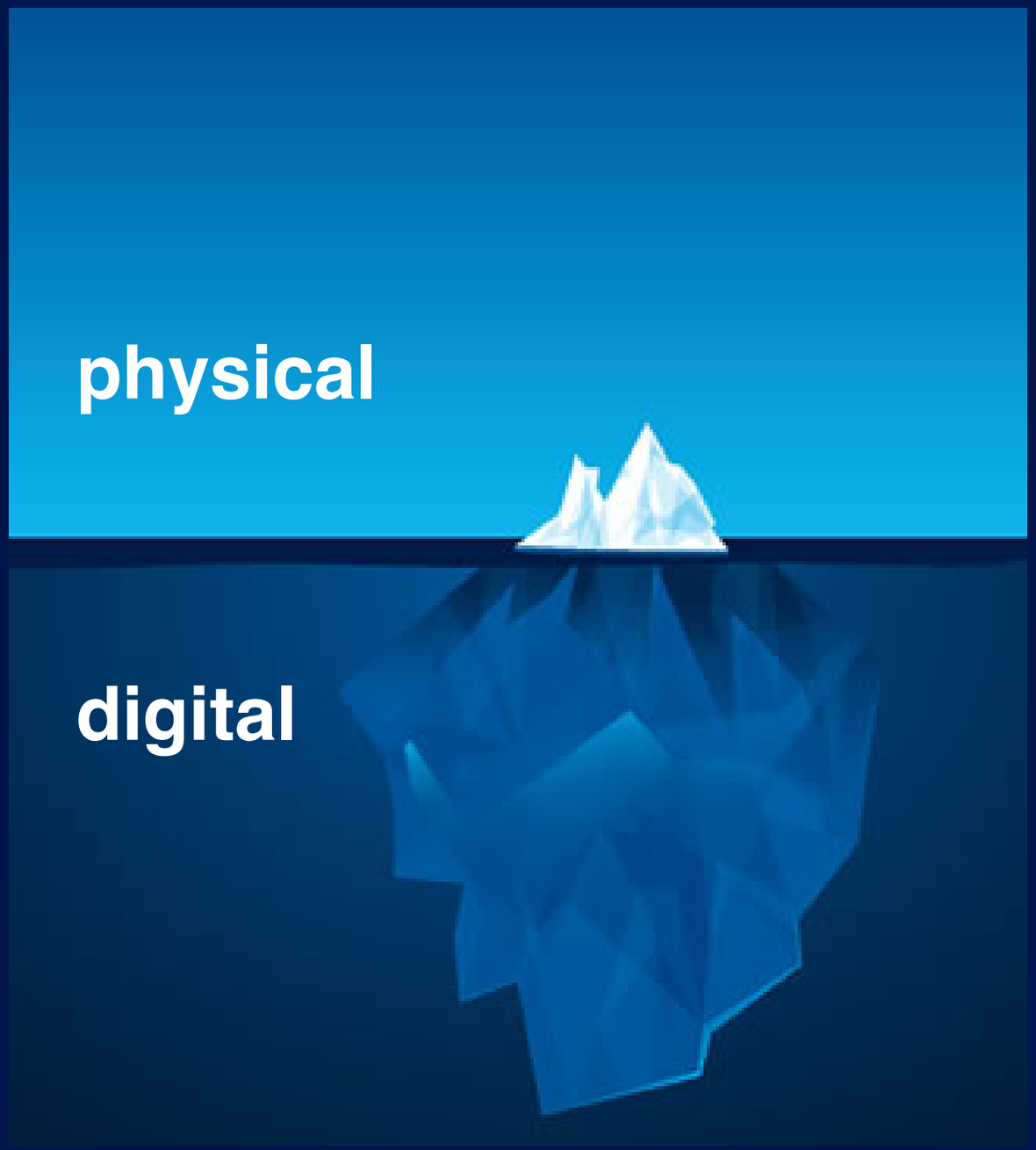


Harsh, but also fertile environment.

At the Border
between Physical and Digital

We live on the border where bits meet atoms. In the flood of pixels from the ubiquitous GUI screens, we are losing our sense of body and places. Pixels impoverish human senses.

Tangible Bits

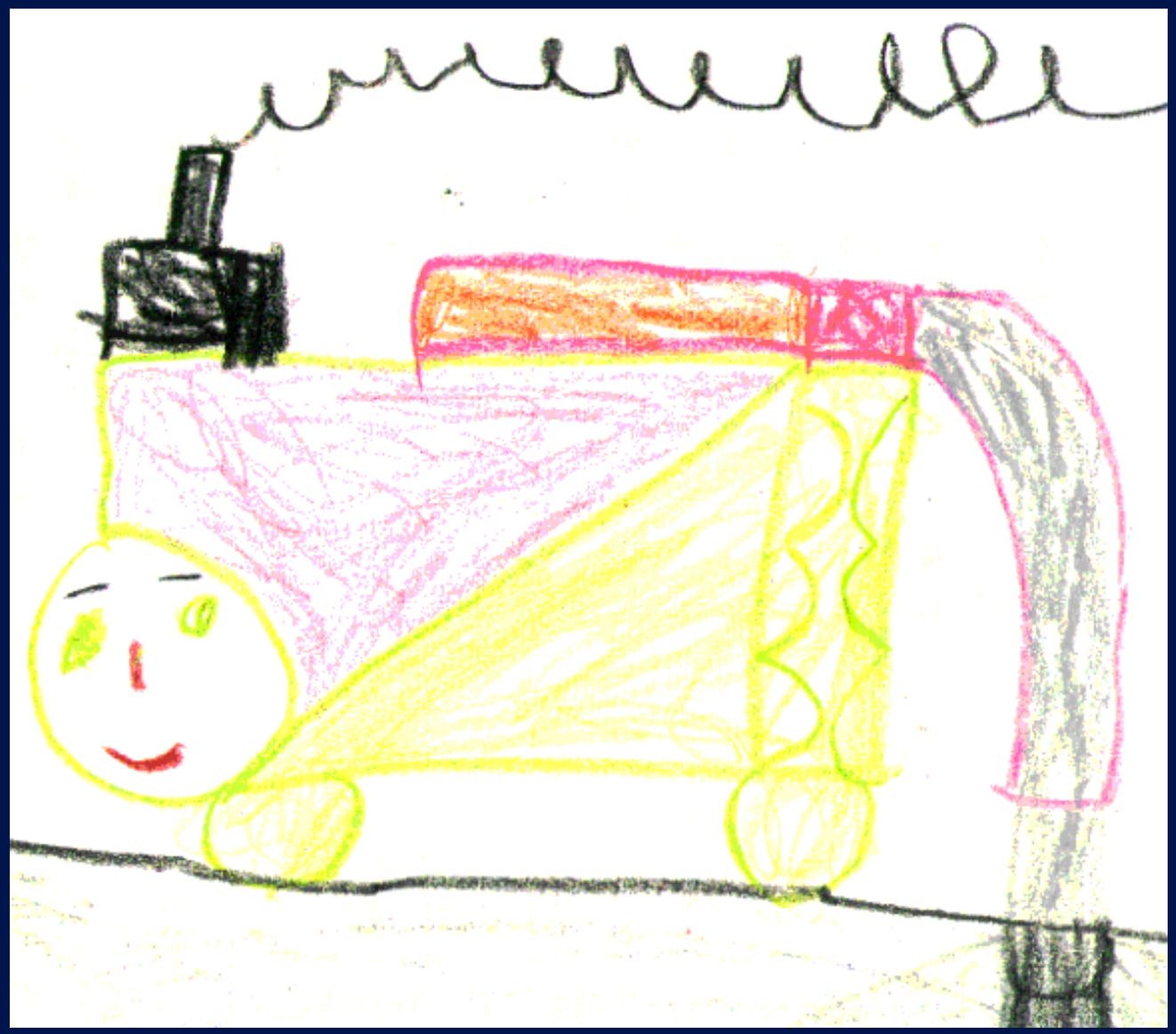



NTT

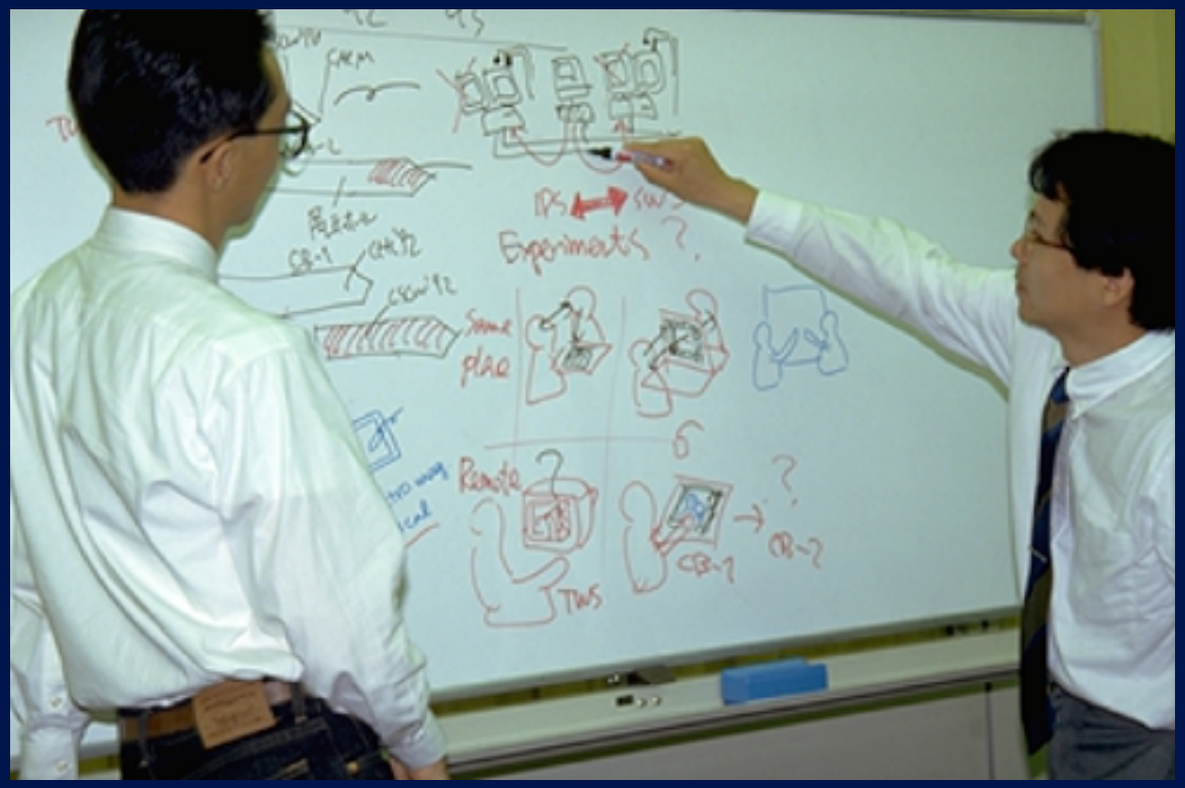
視考

Visual Thinking

My Art Work in 1959



Shared Drawing 1992
Collaborative Visual Thinking



speak
gesture
point
read
write
draw

Ref. Study on Shared Drawing and VideoDraw (PARC)
Prof. Larry Leifer, Dr. John Tang, Dr. Scott Minneman,

ClearBoard

NTT Human Interface Laboratories

Ishii and Kobayashi, 1992

ClearBoard

Seamless integration of interpersonal and shared drawing spaces

Ishii and Kobayashi, 1992

NTT Human Interface Laboratories

2

MIT

1995

NTT → MIT

再起

Reboot

Defy Gravity

GUI		TUI
• Visual	→	Tactile
• General Purpose	→	Special Purpose
• Remote Control	→	Direct and Collaborative Manipulation

1997

March 22-27, 1997

“Tangible Bits” paper presented at CHI ‘97 in Atlanta

Published in the Proceedings of CHI '97, March 22-27, 1997, © 1997 ACM

Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms

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ABSTRACT
This paper presents our vision of Human Computer Interaction (HCI): "Tangible Bits." Tangible Bits allows users to "grasp & manipulate" bits in the center of users' attention by coupling the bits with everyday physical objects and architectural surfaces. Tangible Bits also enables users to be aware of background bits at the periphery of human perception using ambient display media such as light, sound, airflow, and water movement in an augmented space. The goal of Tangible Bits is to bridge the gaps between both cyberspace and the physical environment, as well as the foreground and background of human activities.

This paper describes three key concepts of Tangible Bits: interactive surfaces; the coupling of bits with graspable physical objects; and ambient media for background awareness. We illustrate these concepts with three prototype systems – the metaDESK, transBOARD and ambientROOM – to identify underlying research issues.

Keywords
tangible user interface, ambient media, graspable user interface, augmented reality, ubiquitous computing, center and periphery, foreground and background

INTRODUCTION: FROM THE MUSEUM
Long before the invention of personal computers, our ancestors developed a variety of specialized physical artifacts to measure the passage of time, to predict the movement of planets, to draw geometric shapes, and to compute [10]. We can find these beautiful artifacts made of oak and brass in museums such as the Collection of Historic Scientific Instruments at Harvard University (Fig. 1).

We were inspired by the aesthetics and rich affordances of these historical scientific instruments, most of which have disappeared from schools, laboratories, and design studios and have been replaced with the most general of appliances: personal computers. Through grasping and manipulating these instruments, users of the past must have developed rich languages and cultures which valued haptic interaction with real physical objects. Alas, much of this richness has been lost to the rapid flood of digital technologies.

We began our investigation of "looking to the future of HCI" at this museum by looking for what we have lost with the advent of personal computers. Our intention was to rejoin the richness of the physical world in HCI.

BITS & ATOMS
We live between two realms: our physical environment and cyberspace. Despite our dual citizenship, the absence of seamless couplings between these parallel existences leaves a great divide between the worlds of bits and atoms. At the present, we are torn between these parallel but disjoint spaces.

Figure 1 Sketches made at Collection of Historical Scientific Instruments at Harvard University

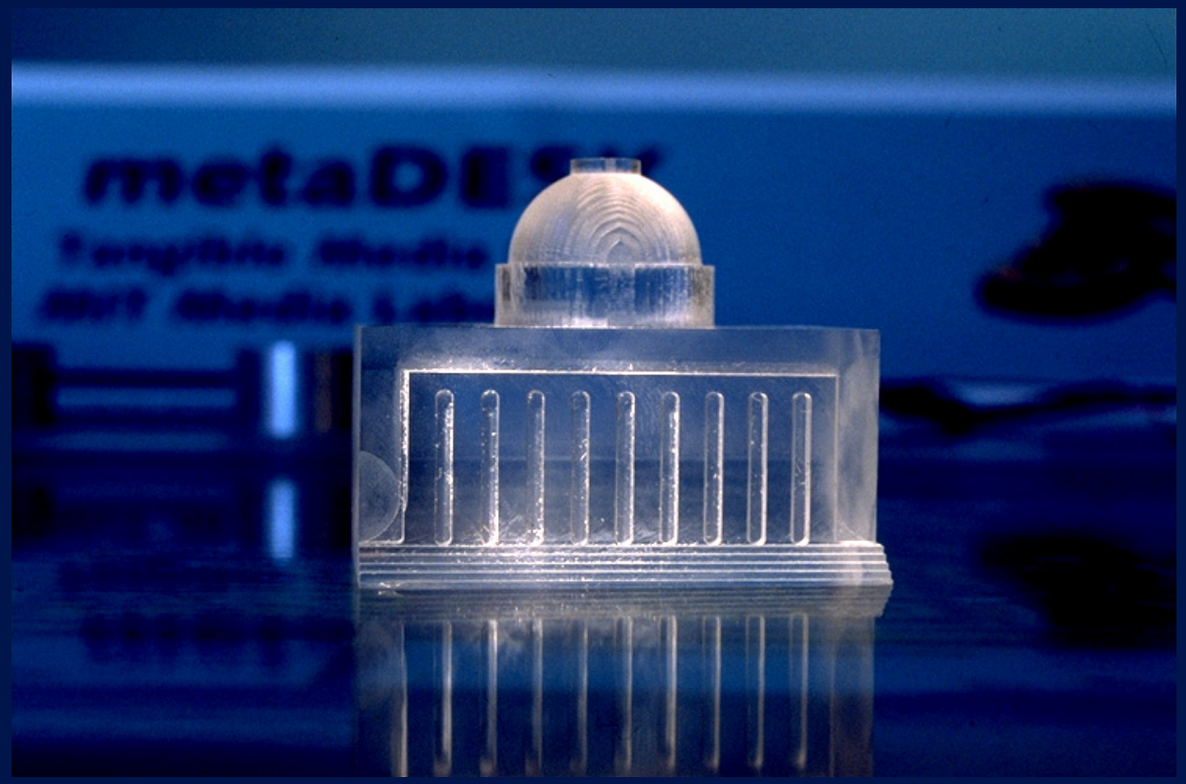
We are now almost constantly "wired" so that we can be here (physical space) and there (cyberspace) simultaneously [14]. Streams of bits leak out of cyberspace through a myriad of rectangular screens into the physical world as photon beams. However, the interactions between people and cyberspace are now largely confined to traditional GUI (Graphical User Interface)-based boxes sitting on desktops or laptops. The interactions with these GUIs are separated from the ordinary physical environment within which we live and interact.

Although we have developed various skills and work practices for processing information through haptic interactions with physical objects (e.g., scribbling messages on Post-It™ notes and spatially manipulating them on a wall) as well as peripheral senses (e.g., being aware of a change in weather through ambient light), most of these practices are neglected in current HCI design because of the lack of diversity of input/output media, and too much bias towards graphical output at the expense of input from the real world [3].

Outline of This Paper
To look towards the future of HCI, this paper will present our vision of Tangible Bits and introduce design projects including the metaDESK, transBOARD and ambientROOM systems to illustrate our key concepts. This paper is not intended to propose a solution to any one single problem. Rather, we will propose a new view of interface and raise a set of new research questions to go beyond GUI.

FROM DESKTOP TO PHYSICAL ENVIRONMENT
In 1981, the Xerox Star workstation set the stage for the first generation of GUI [16], establishing a "desktop metaphor" which simulates a desktop on a bit-mapped

Tangible Bits



Physical embodiment of digital information and computation

Tangible Bits

Physical embodiment of digital information and computation

3

vision

理念

What drives creation?

What drives Creation?

Vision

Concepts, principles

Users' need

Applications

Technologies

What drives Creation?

Vision

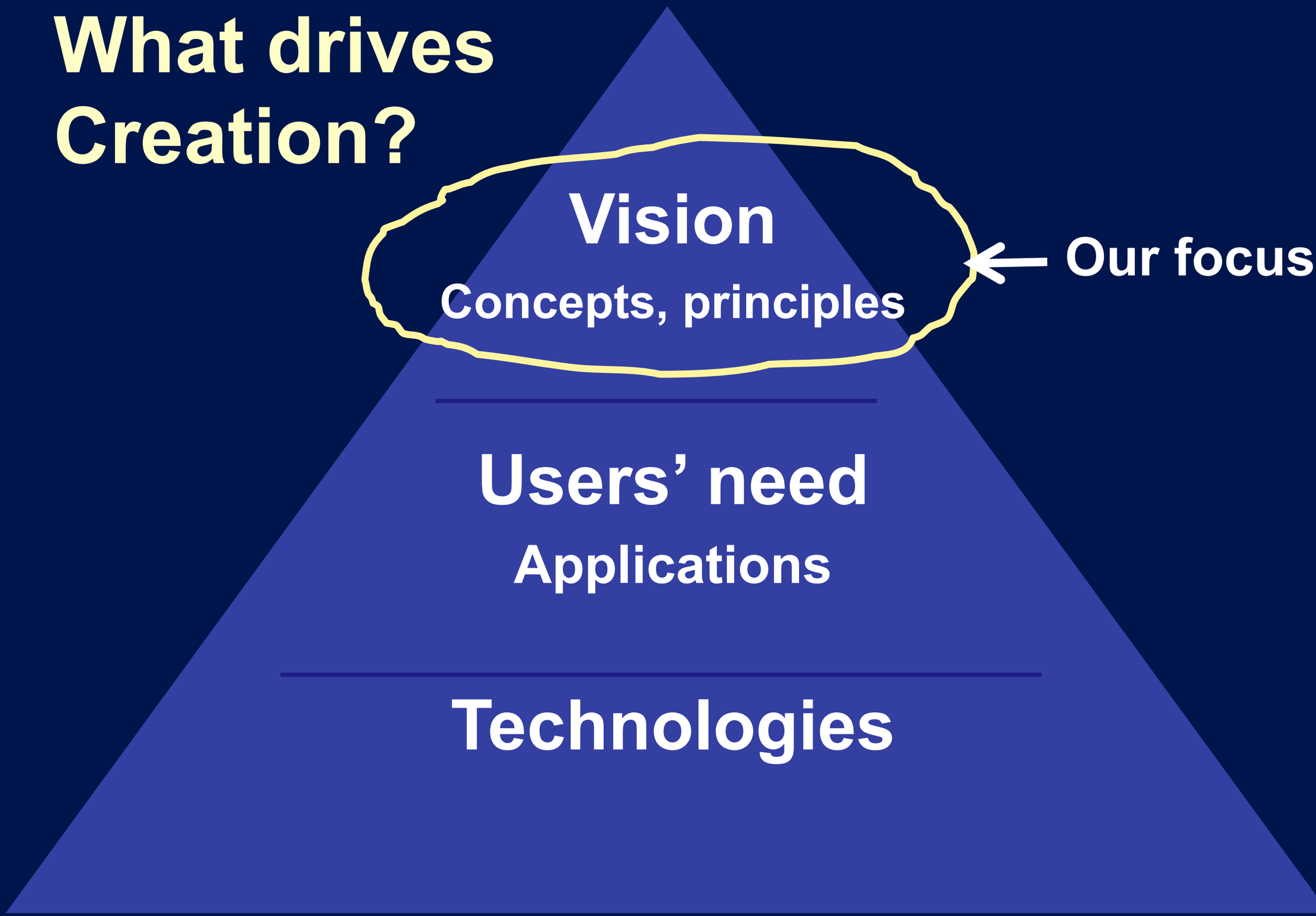
Concepts, principles

Business
HCI/usability

Users' need
Applications

Technologies

What drives Creation?



What drives Creation?

art!

Vision

Concepts, principles

Users' need

Applications

Technologies

Why? **Life Span**

Vision **>100 y**

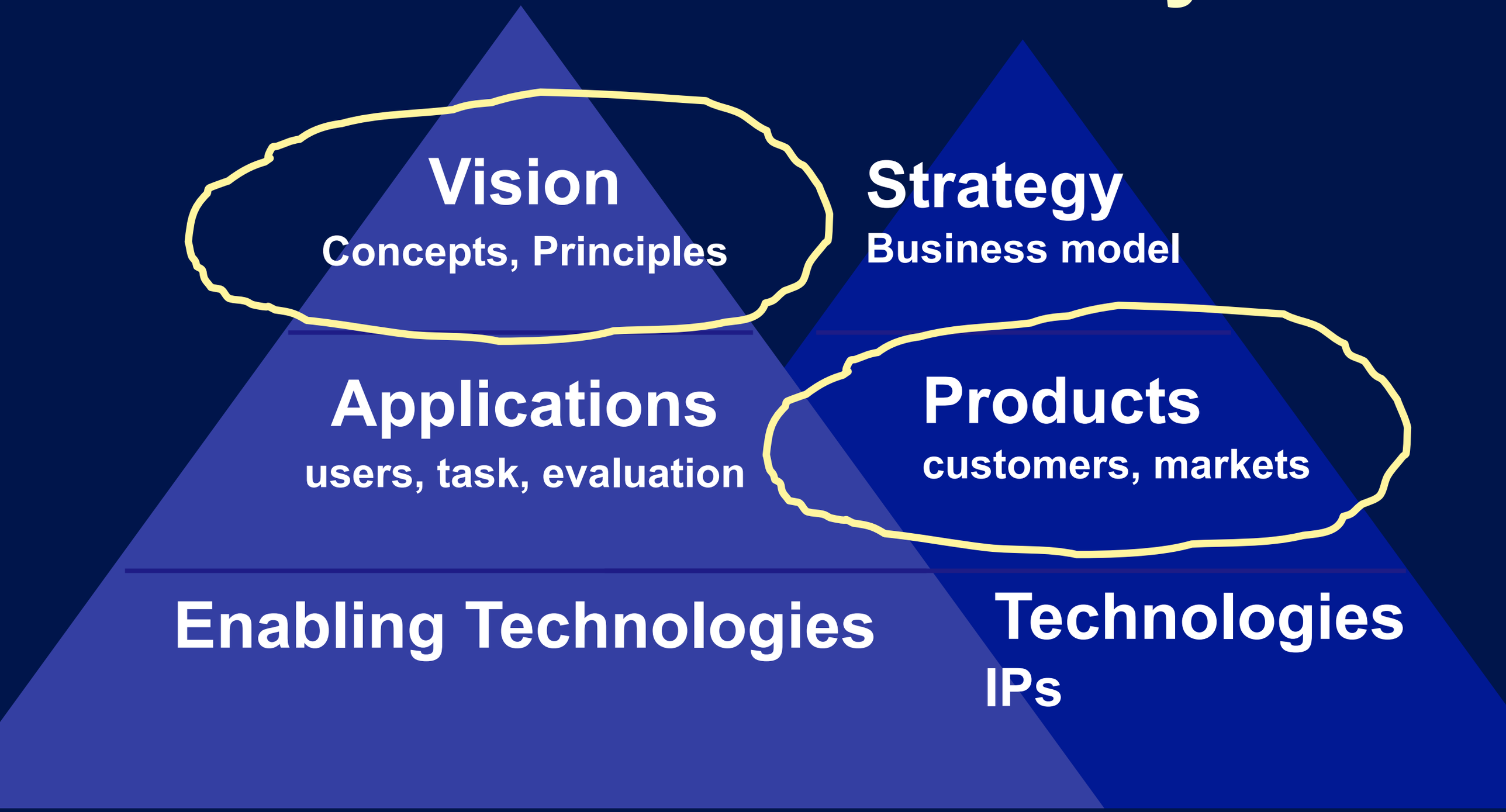
Concepts, principles

Applications **~10 y**

Need, users, task, evaluation

Technologies **~1 y**

Research & Business
Academia - Industry



1

tangible

physical

p

painted bits

d

digital

tangible bits

Materialize

digital information to interact with directly

painted bits

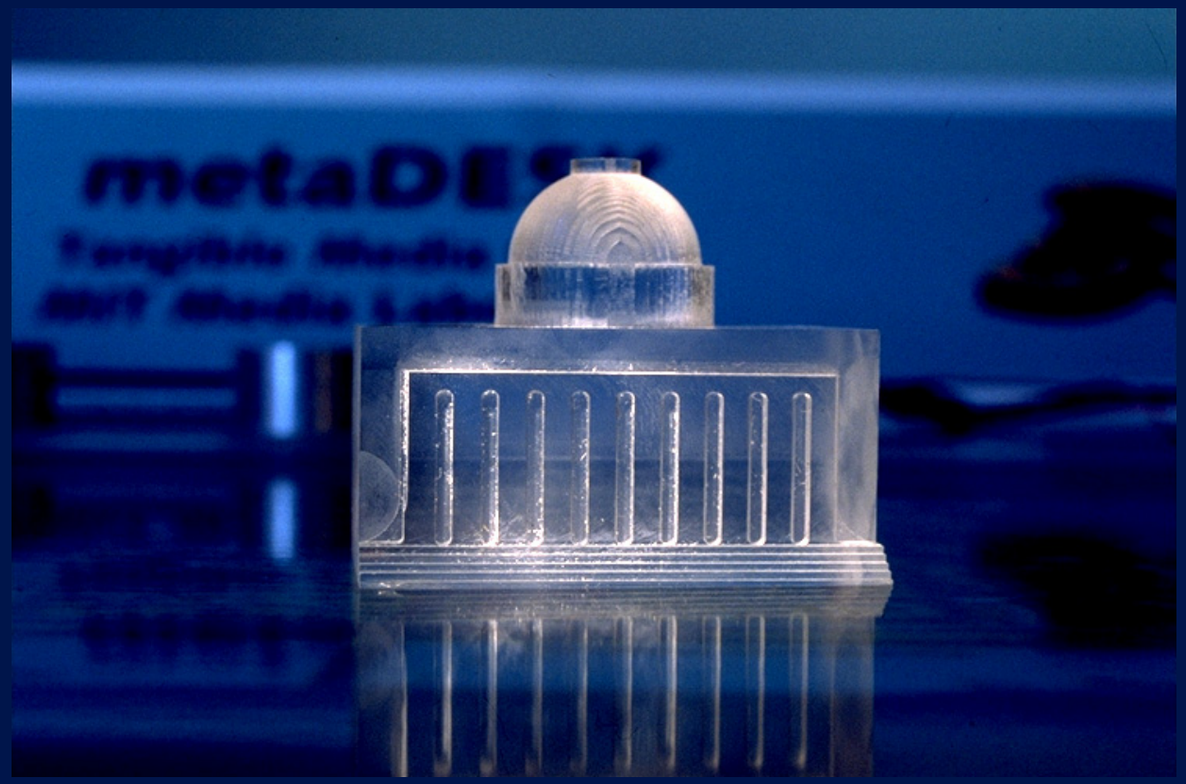
GUI

tangible bits

1997

TUI

Tangible Bits



Physical embodiment of digital information and computation

Eyes are in charge,
but hands are underemployed.

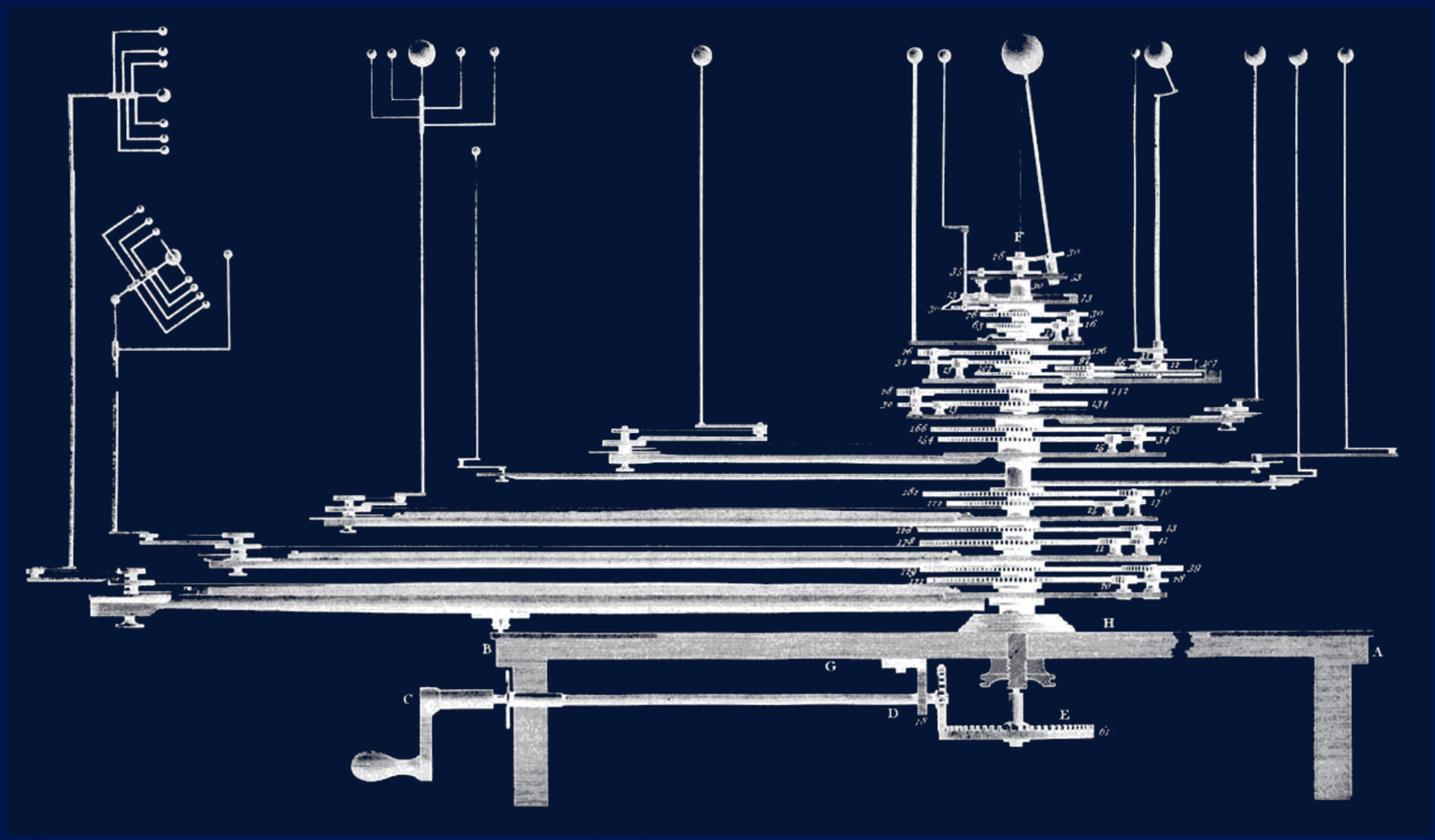
Eyes are in charge, but hands are underemployed.

By pointing, by pushing and pulling, by picking up tools, hands act as conduits through which we extend our will to the world.

They serve also as conduits in the other direction: hands bring us knowledge of the world. Hands feel. They probe. They practice.

Malcolm McCullough
“Abstracting Craft: The Practiced Digital Hand ” 1996

Orrery:
Tangible Representation of Knowledge



Aesthetics which value haptic interaction with specialized physical objects ... but much richness has been lost.

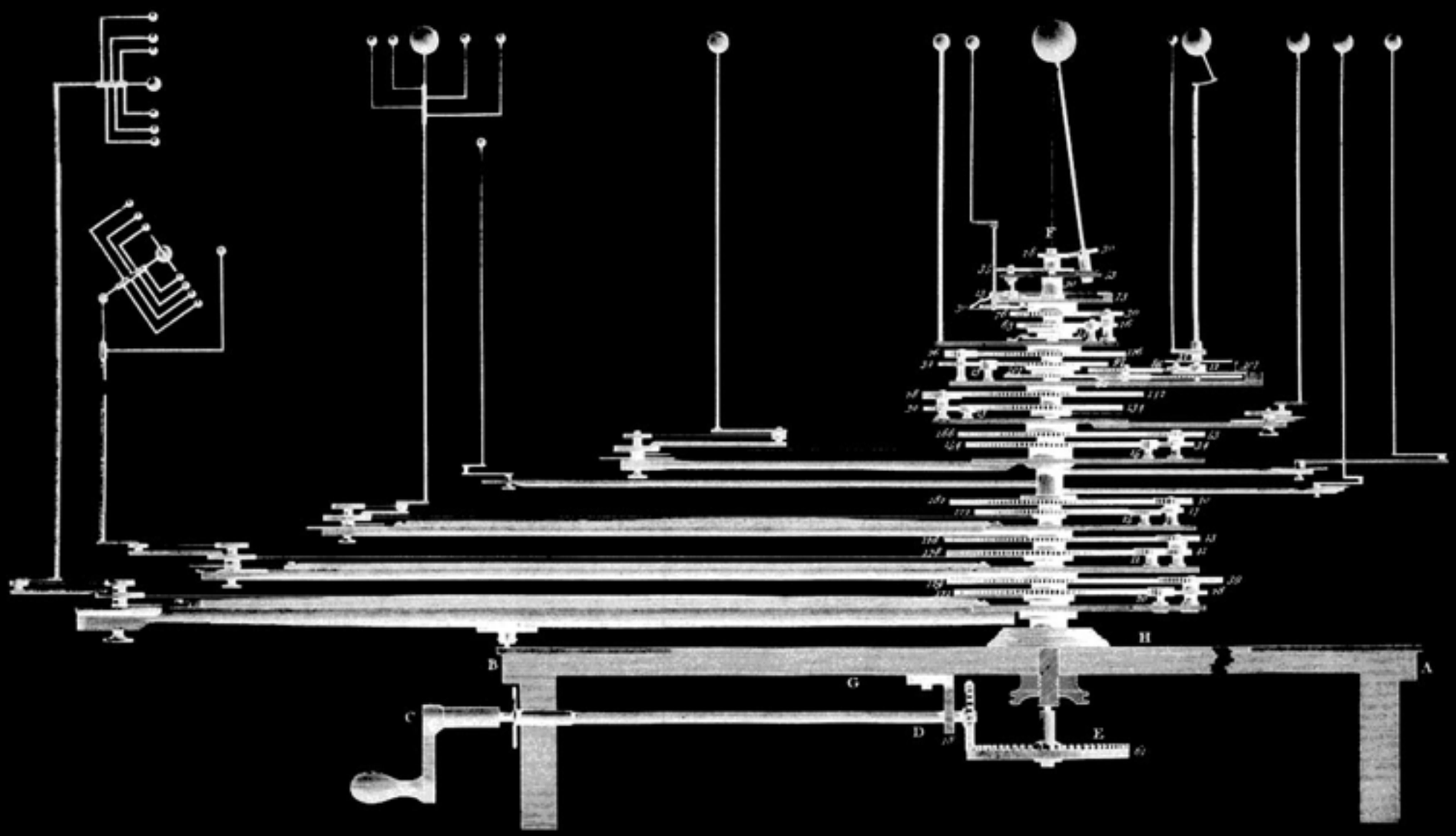
http://en.wikipedia.org/wiki/File:Grand_orrery_in_Putnam_Gallery,_2009-11-24.jpg

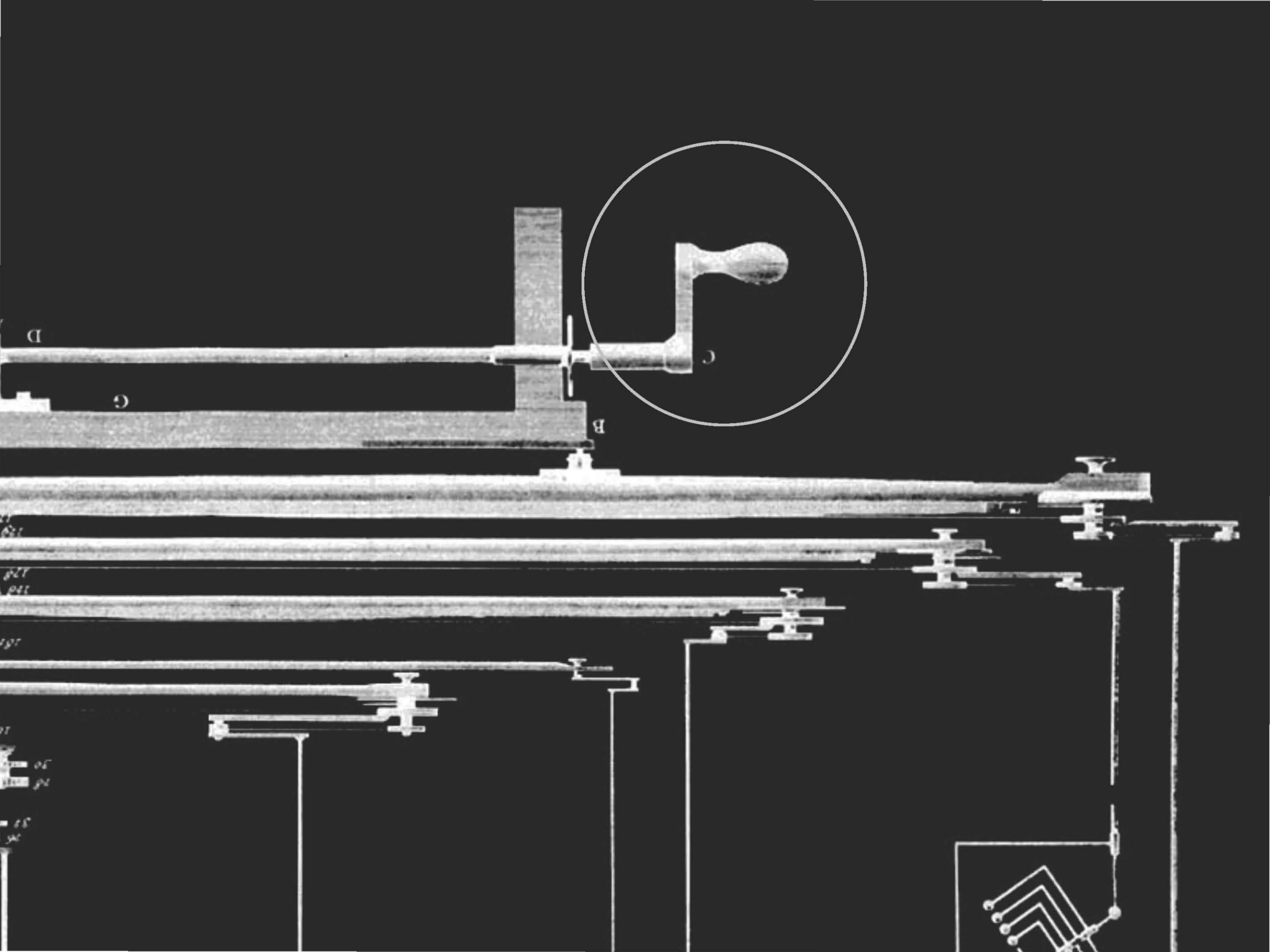
representation

http://en.wikipedia.org/wiki/File:Grand_orrery_in_Putnam_Gallery,_2009-11-24.jpg

Orrery

Tangible Representation of Knowledge

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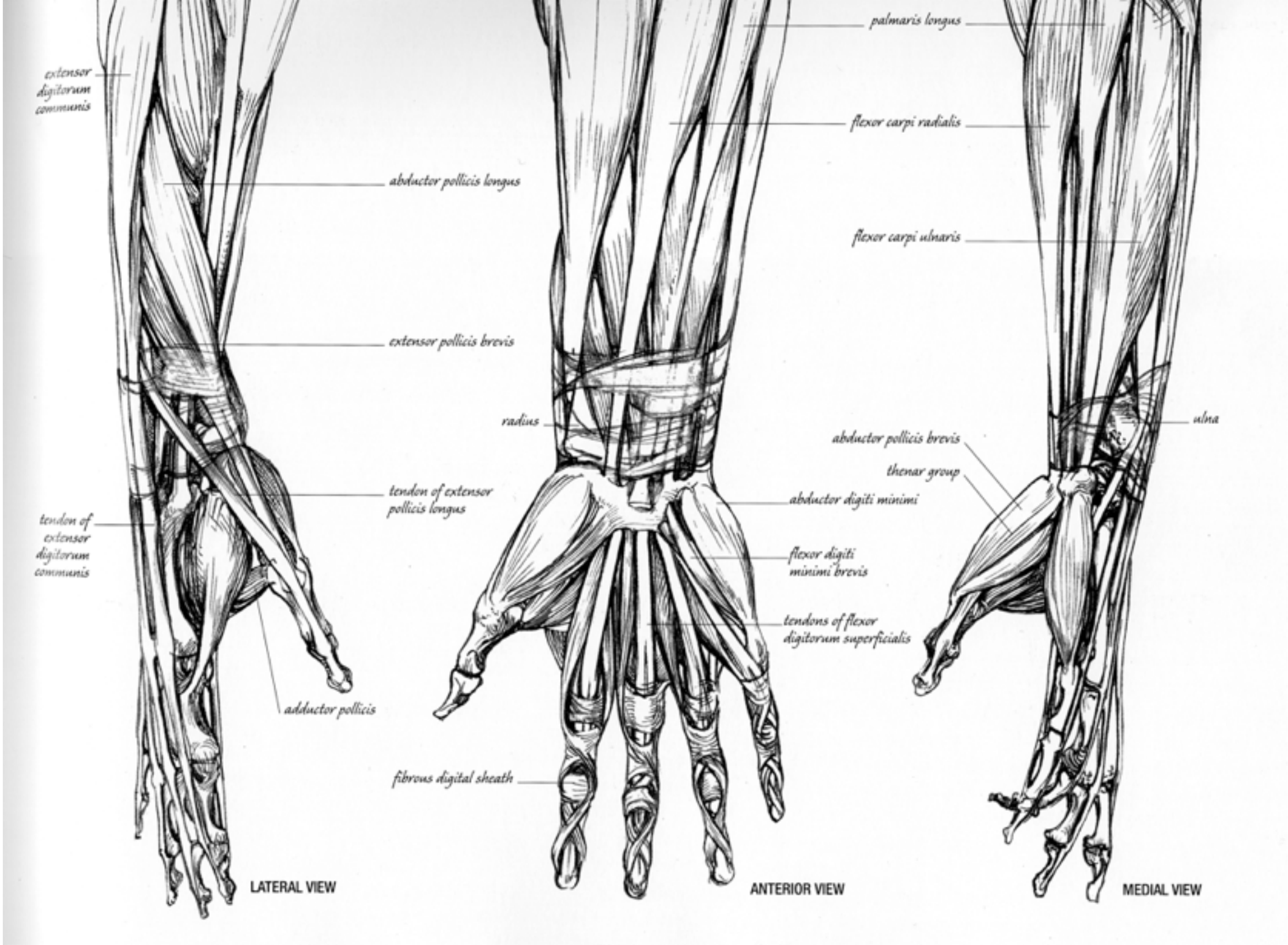

extensor digitorum communis
abductor pollicis longus
extensor pollicis brevis
tendon of extensor pollicis longus
tendon of extensor digitorum communis
adductor pollicis
LATERAL VIEW
palmaris longus
flexor carpi radialis
flexor carpi ulnaris
radius
abductor digiti minimi
flexor digiti minimi brevis
tendons of flexor digitorum superficialis
fibrous digital sheath
ANTERIOR VIEW
ulna
abductor pollicis brevis
thenar group
MEDIAL VIEW

hands

collaboration

http://en.wikipedia.org/wiki/File:Wright_of_Derby,_The_Orrery.jpg

計算

Compute

Abacus: Origin of Tangible Bits

Hiroshi ISHII, born February 4th, 1956

起源

origins

metaDESK and Tangible Geospace

Ullmer and Ishii, 1997

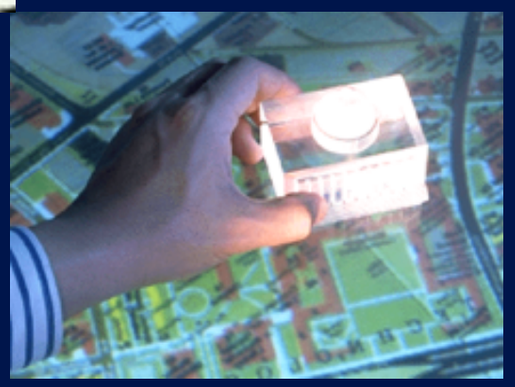
passiveLENS

activeLENS

phicons
(physical icons)

metaDESK and Tangible Geospace

Ullmer and Ishii, 1997



ambientROOM

Architectural Space as Interface

Ripple shadows on ceiling

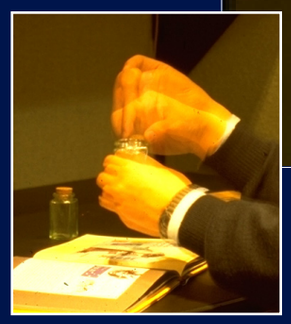
Ambient sound of rain drops

Light projection on side wall

Clock to navigate time

Bottles as containers of bits

Open a bottle to release bits into air



ambientROOM

Architectural Space as Interface

Tangible Bits

- Giving physical forms to digital information and computation, making bits
  - –directly manipulable with two hands
- Supporting multi-user collaboration and “tangible thinking”

2

ambient

Tangible Bits

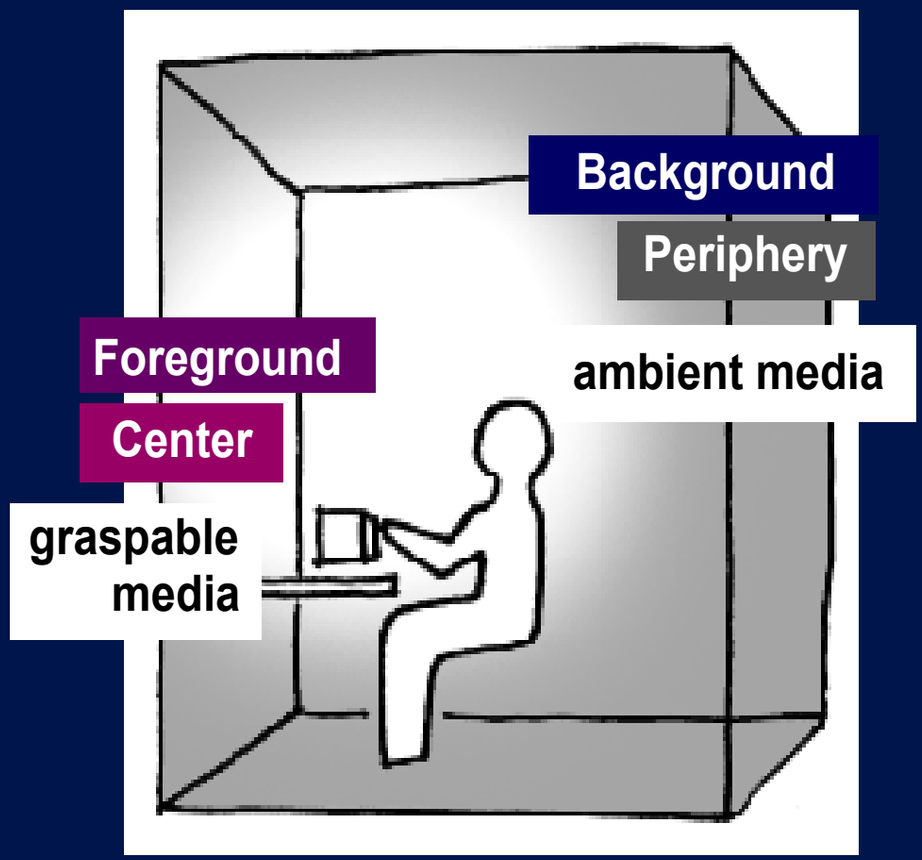
Physical embodiment of digital information and computation

周縁

peripheral awareness

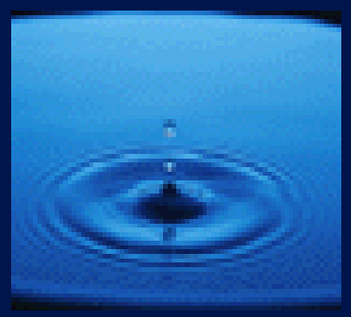
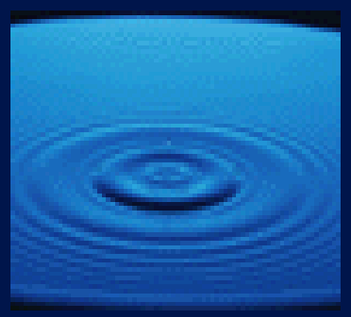
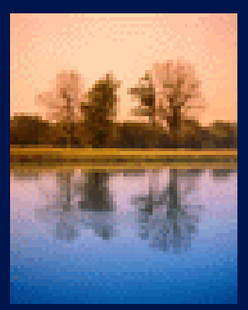
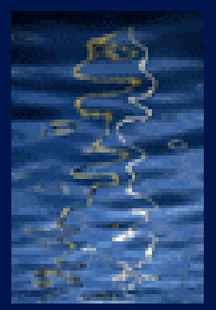
Center and Periphery
Architectural Space as Interface

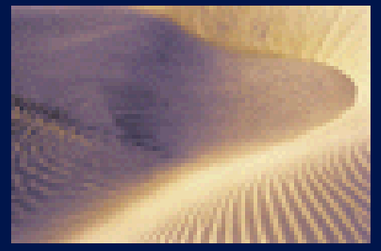
- **to grasp & manipulate bits**
  in the center of user's focus by coupling bits with physical objects and surfaces, and
- **to be aware of bits at the periphery**
  using ambient display media such as light, sound, airflow, and water movement.



Ambient Media in Nature

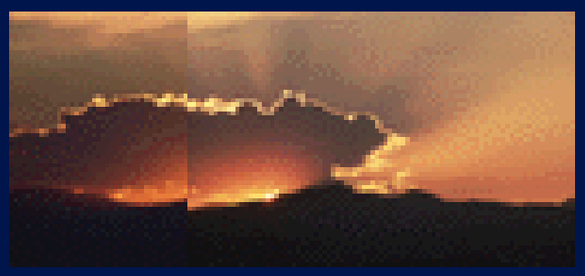
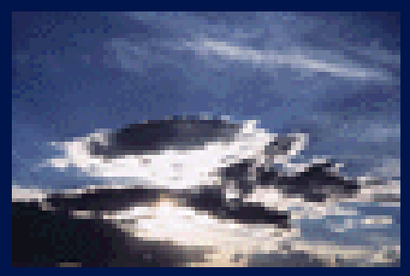
water, sand, wind, light, shadow, cloud







wind

Pinwheels: wind of bits

Ren, Frei, Dahley, Wisneski, and Ishii, 1997-2000

Ambient information display spinning in a "wind of bits."

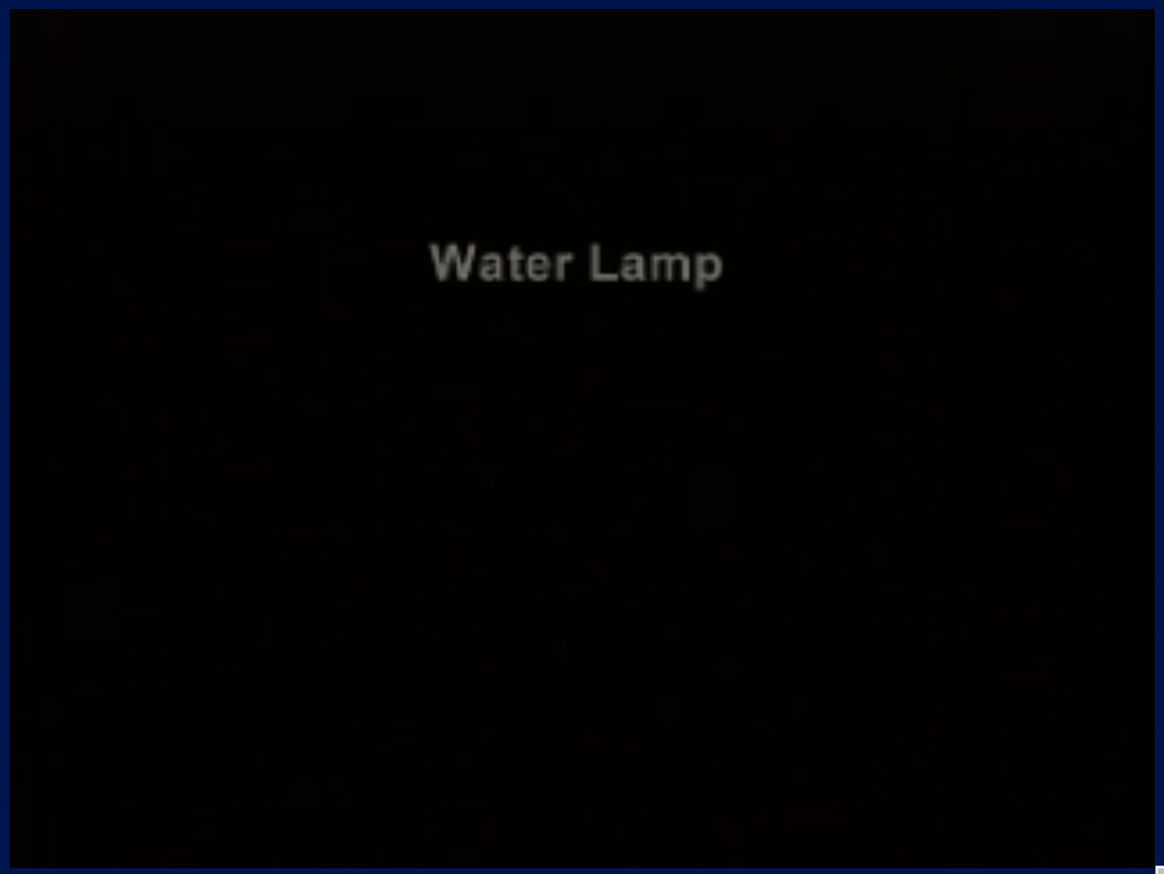
Architectural space will be an ambient interface.

雨

rain

Water Lamp: rain of bits

Dahley and Ishii, 1997



Water ripple shadow created by a "rain of bits."

Foreground --> Background

Peripheral Awareness using Ambient Media

PCs

Time-consuming

Requires navigation

Complex

phone

Interruptive

Intrusive

ambient

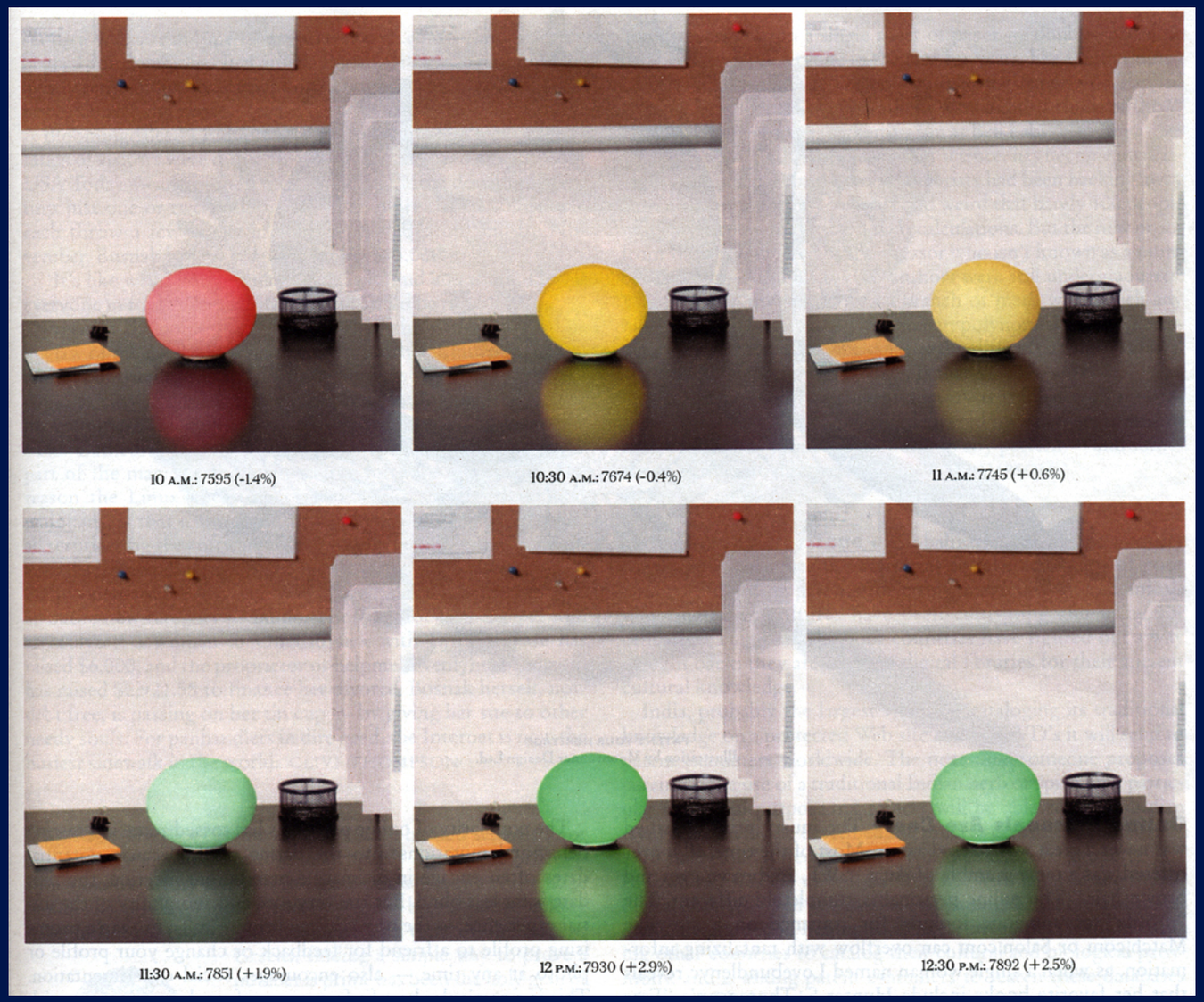
Always on, real-time

Peripheral awareness

Seamless with environment

Orb by Ambient Devices (Media Lab Spinoff)

www.ambientdevices.com



New York Times Magazine, Dec. 2002

- **This light glows different colors to help you monitor your portfolio, traffic on your commute, new snow in the mountains, pollen index, etc.**
- **The behavior can be remapped to summarize whatever information you'd like in your periphery.**

Ambient Devices

http://www.ambientdevices.com/

Ambient Devices

http://www.ambientdevices.com/

Ambient Displays
Design Principles

- **Browser-less interface**
  – Glance-able, requires no navigation and no analysis, simple.
- **Calm**
  – Non-intrusive, seamless with environment
- **Persistent connection**
  – Information is continuously updated.
- **Decision-driven data**
  – Personalized and summarized data feeds to make a decision.
- **Private**
  – Encoded data

Flowers in Digital Vase
Ambient Display designed by BT exact

- Goal: manage and maintain personal relationships.

  目的:人間関係の維持管理

- Flower stems and buds represent selected individuals from users' social networks and, the straightness of the stem indicates the health of the relationship.
  - 花の茎とつぼみが人間関係の健康度を表現

http://www.businessweekly.co.uk/news/view_article.asp?article_id=7055

3

touch

inTouch:
Haptic Interpersonal Communication Medium
Brave, Dahley, Frei, Su, and Ishii, 1998

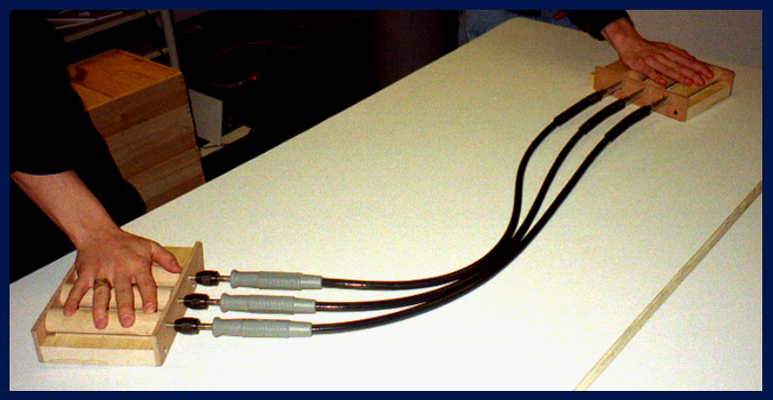
"Reach out and touch someone."

"Synchronized Distributed Physical Objects" create an illusion of touching the same object using force-feedback technology.

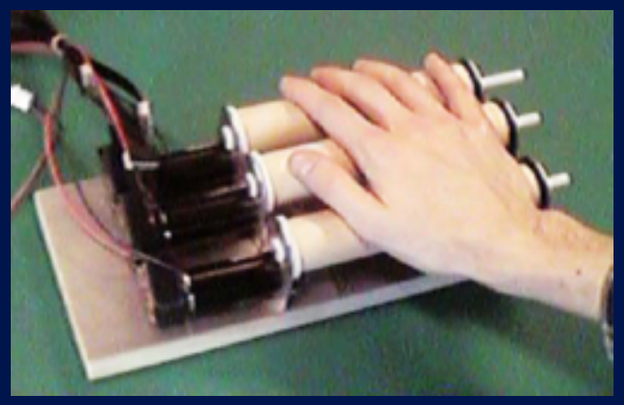
inTouch: Tangible Telepresence

Brave, Dahley, Frei, Su, and Ishii, 1998

"Synchronized Distributed Physical Objects" create an illusion of touching the same object using force-feedback technology.



inTouch-0:
mechanical mockup



inTouch-1:
early electronic prototype

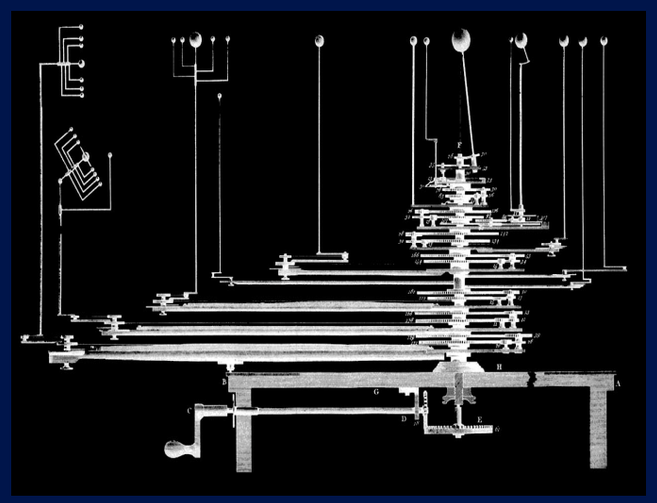
inTouch-2:
distributed prototype

inTouch:
Haptic Interpersonal Communication Medium

illusion of touching the same object using force-feedback technology.

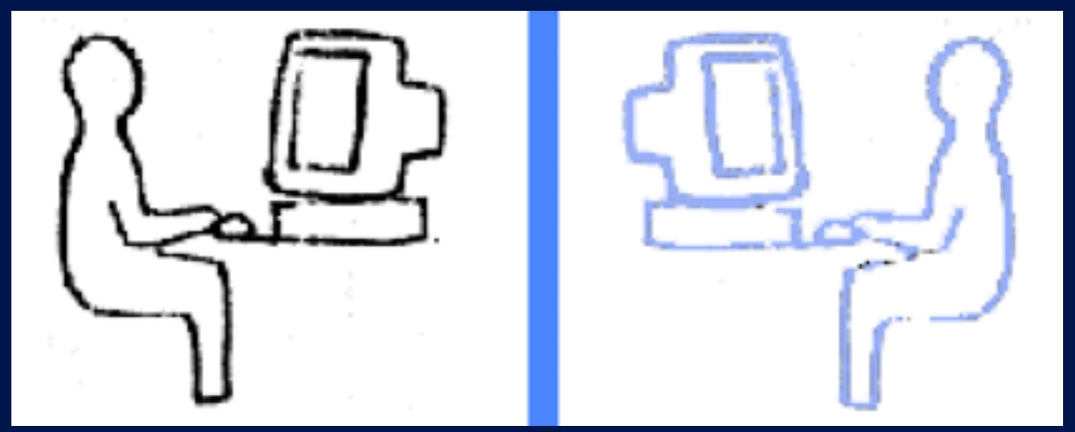
“Ghostly Presence”

tangible telepresence



shared physical work space

traditional remote collaboration systems



user A’s physical space

user B’s physical space

Movement of local objects suggests the *physical presence* of remote users.

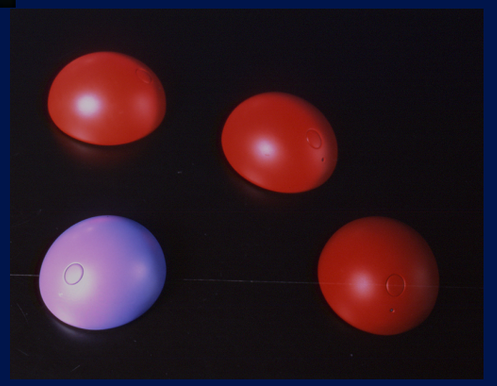
Remote users remain isolated behind computer screen.

Curlybot

Frei, Su, ishii, 2000

A toy that can record and playback physical motion.

Children establish an affective and body syntonic connection with curlybot, and develop intuitions for concepts such as differential geometry.



Curlybot

Frei, Su, ishii, 2000

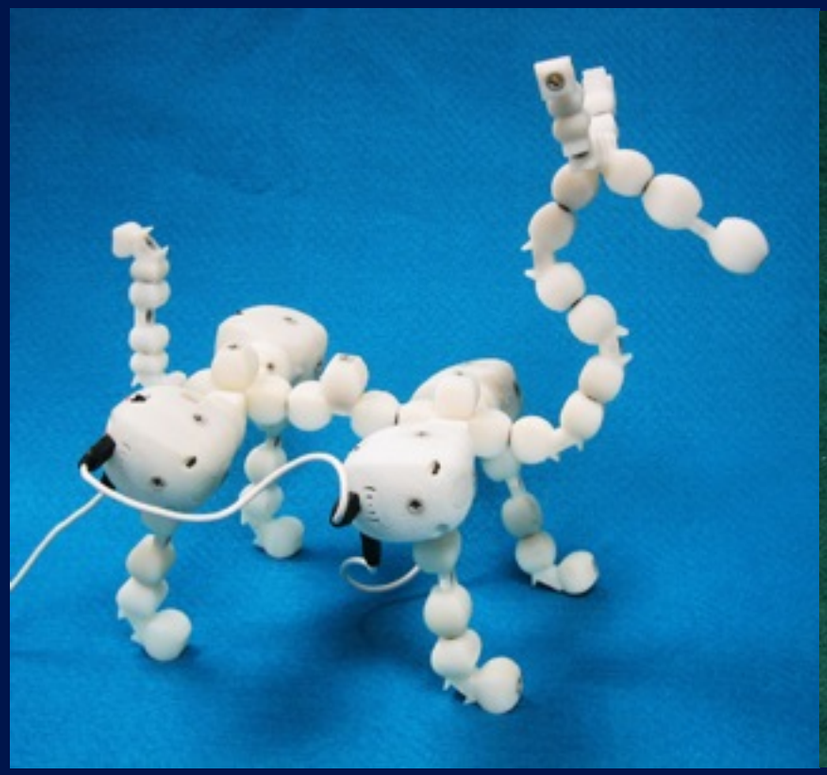
- Children readily establish an affective and body syntonic connection with curlybot.
- They can develop intuitions for concepts such as differential geometry, through play away from a traditional computer.

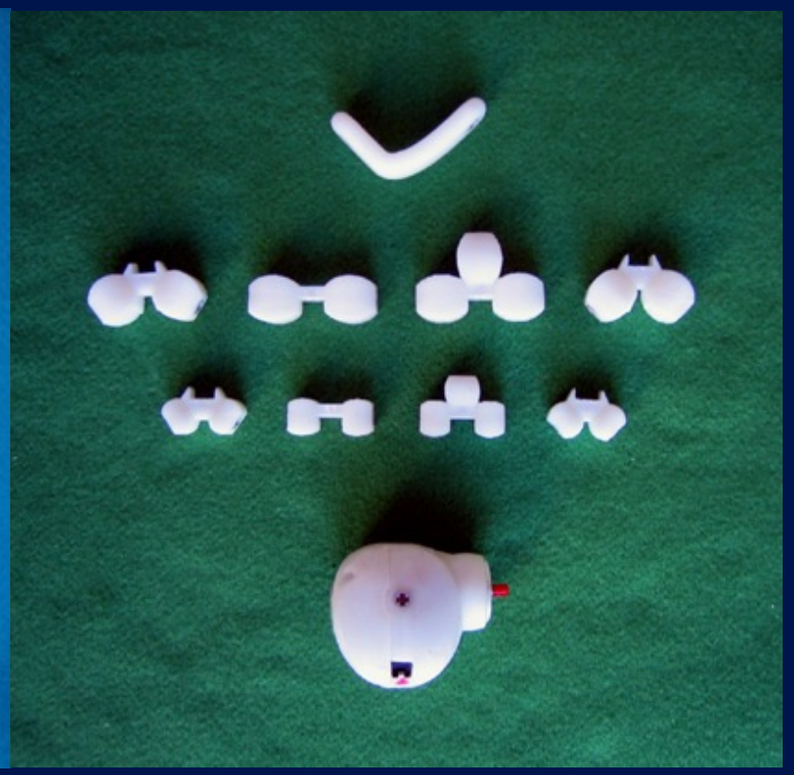
topobo

Building Blocks with kinetic memory

Hayes Raffle, Amanda Parkes, and Hiroshi Ishii

- made of active (motorized) & passive (static) components
- passives geometry based on cubic & tetrahedral crystals
- coincident input & output space
- actives “programmed” by moving, pushing, twisting units
- recorded sequence automatically plays back repeatedly
- distributed computation and networking





topobo

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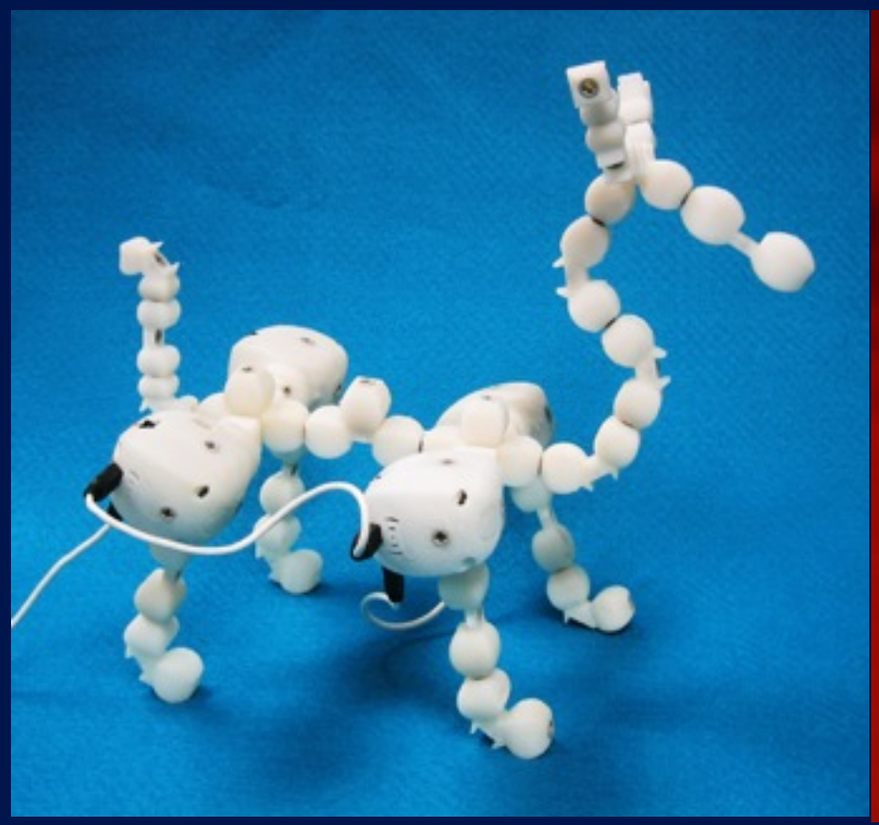
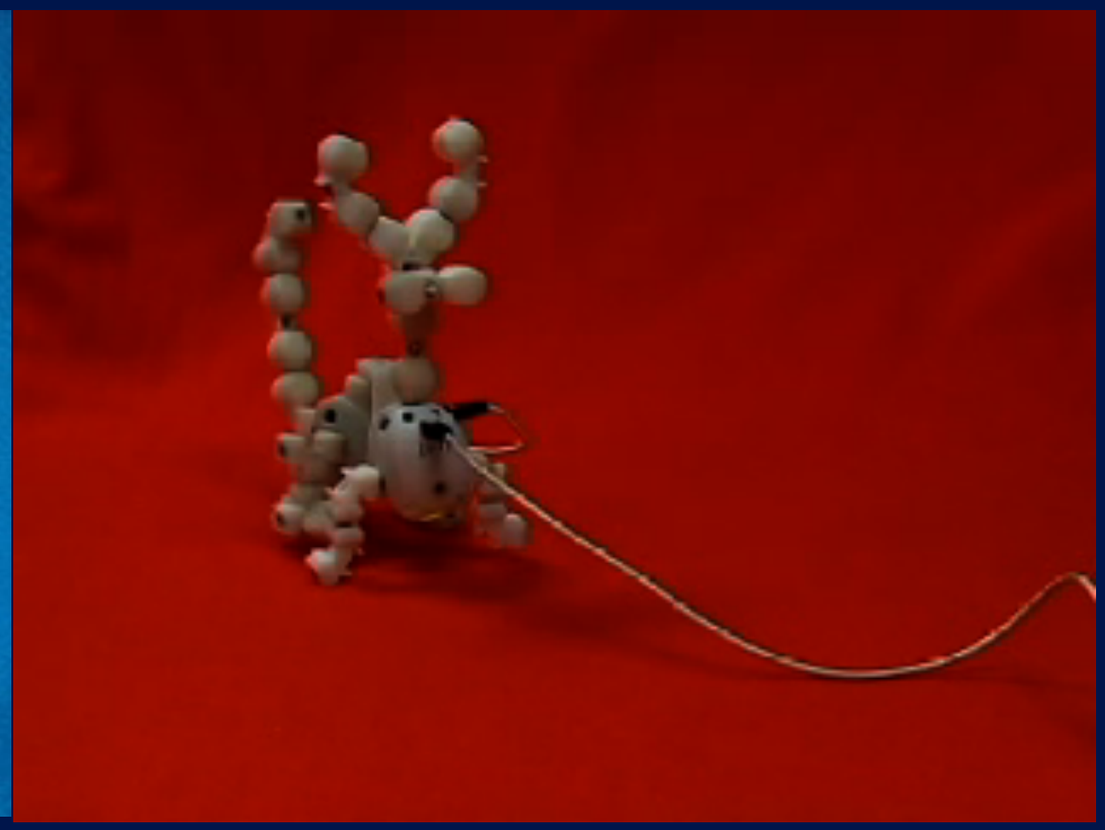




topobo

3D constructive assembly with kinetic memory

- educational digital manipulative for teaching physics & system concepts
- made of active (motorized) & passive (static) components
- passives geometry based on cubic & tetrahedral crystals
- coincident input & output space
- actives “programmed” by moving, pushing, twisting units
- recorded sequence automatically plays back repeatedly
- distributed computation and networking




Coincidence of input and output spaces

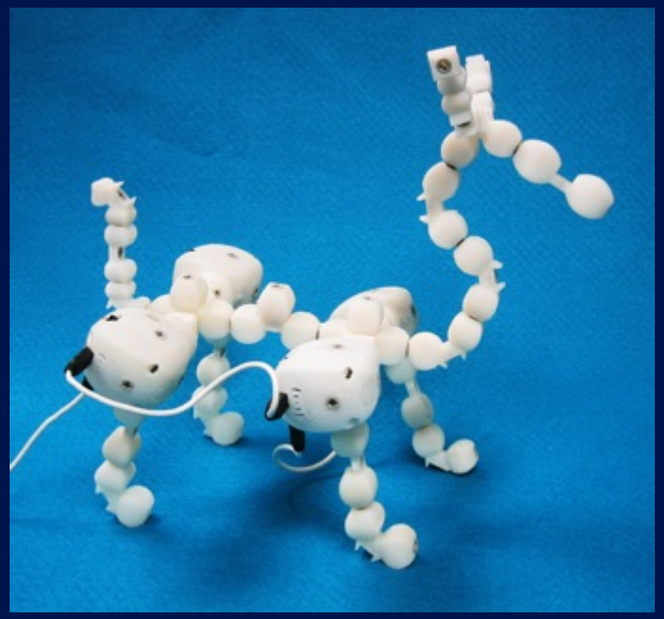
Principle of Tangible Interface Design

inTouch 98

interpersonal communication

curlybot 00

mathematics and expression / narrative



topobo 04

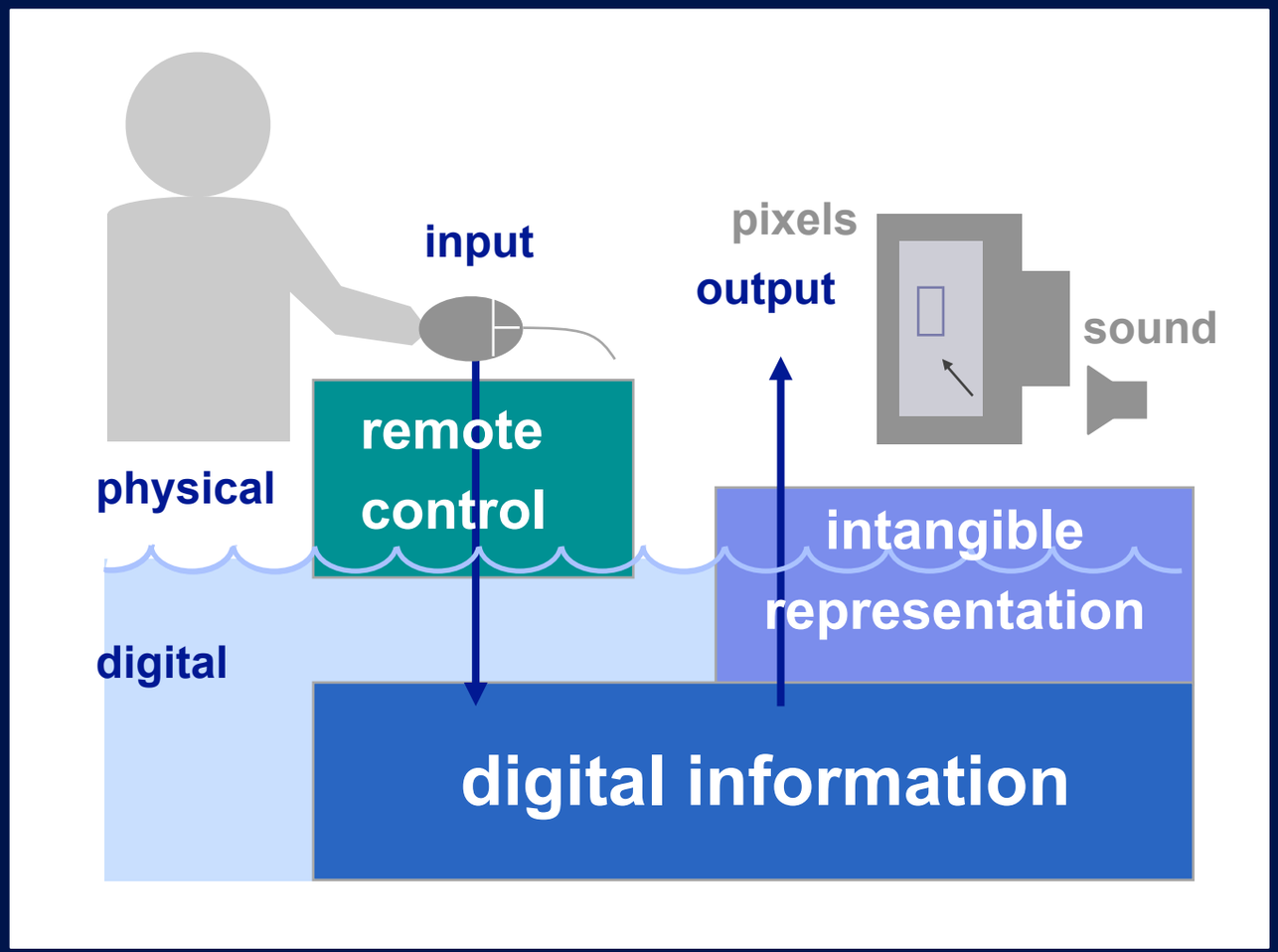
building block with kinetic memory

4

model

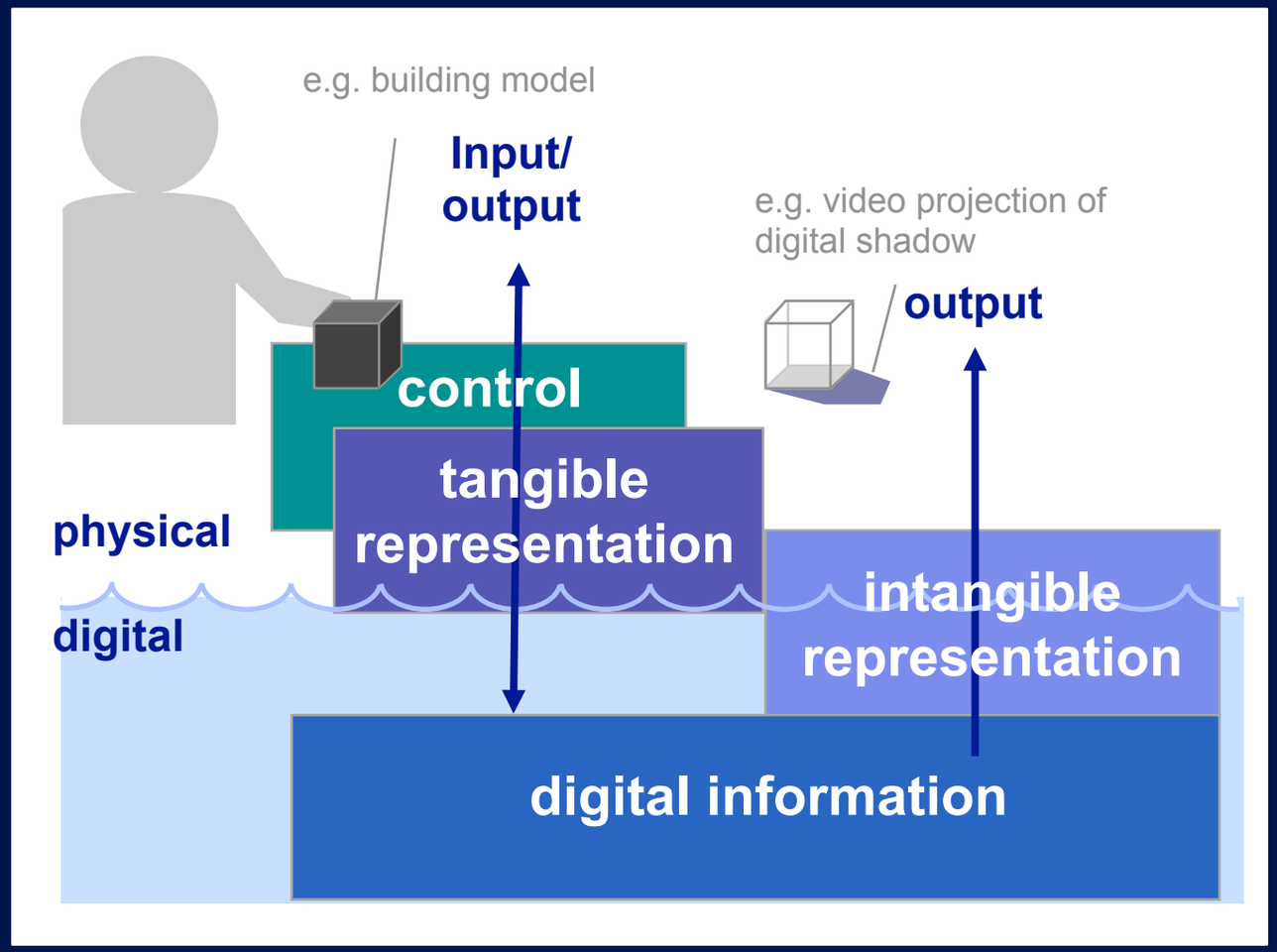
Painted Bits (GUI)

General input devices as remote-controllers of intangible representation (pixels on a screen)



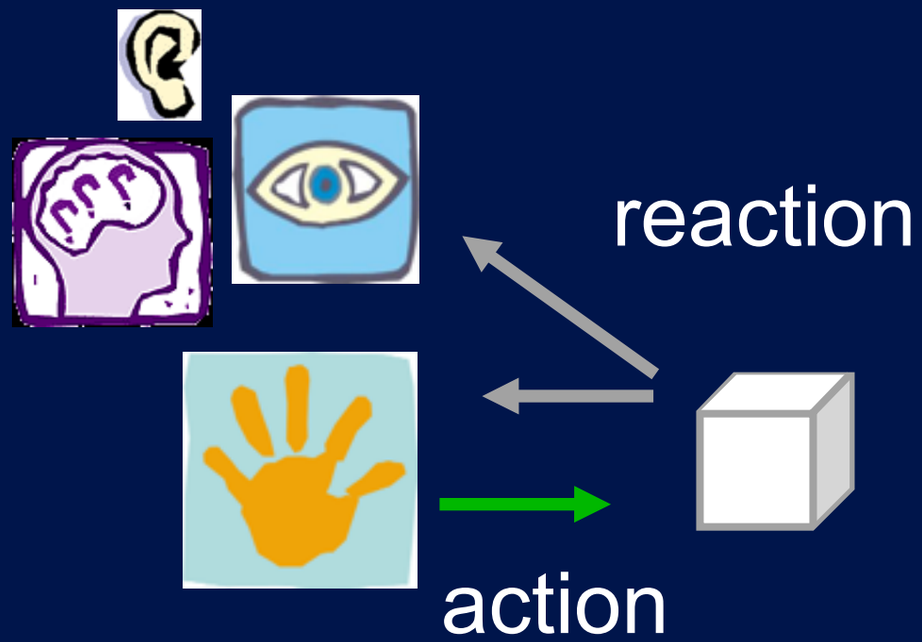
Tangible Bits (TUI)

Tangible representation as interactive control mechanism to manipulate the information represented in both tangible and intangible forms



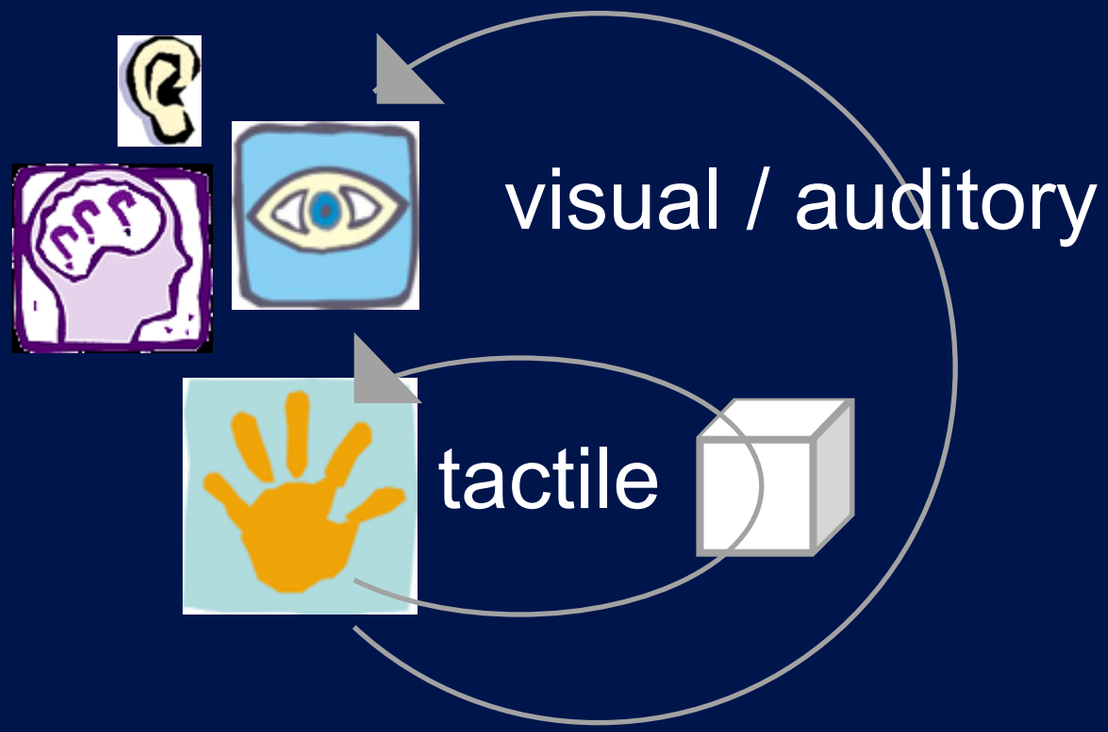
Double Interaction

Physical Interaction



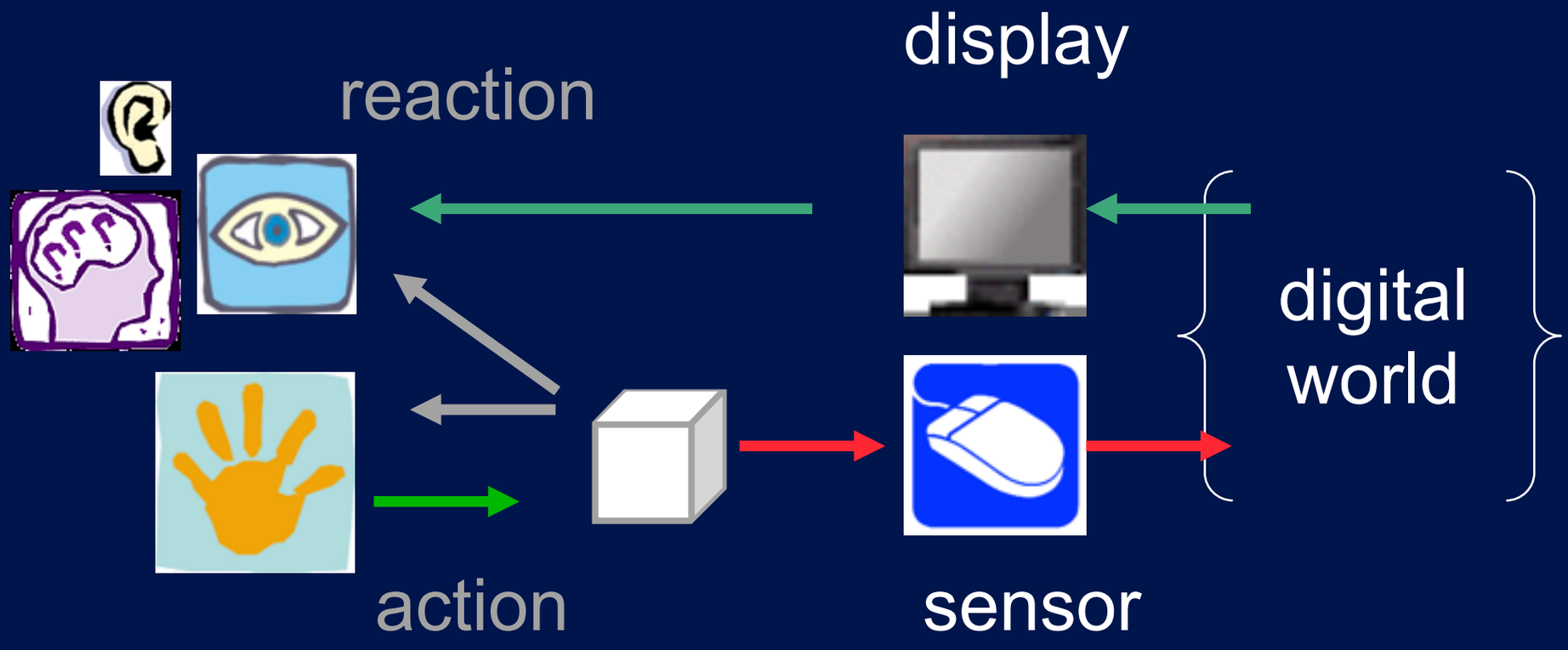
Physical Interaction

Physical Interaction



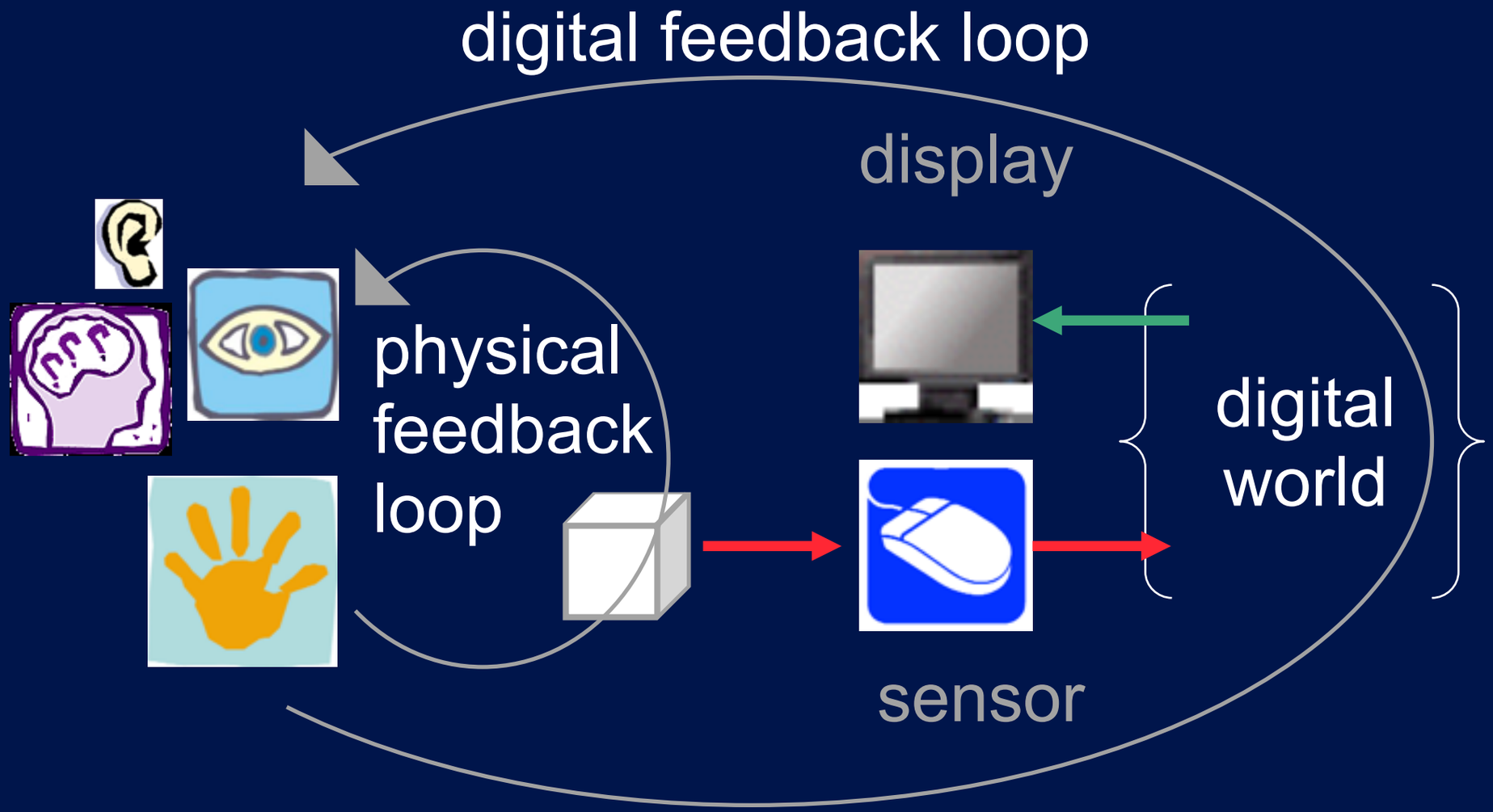
Physical Interaction

Double Interaction Loops: Physical and Digital



Physical Interaction + Digital Interaction

Double Interaction Loops: Physical and Digital



Physical Interaction + Digital Interaction

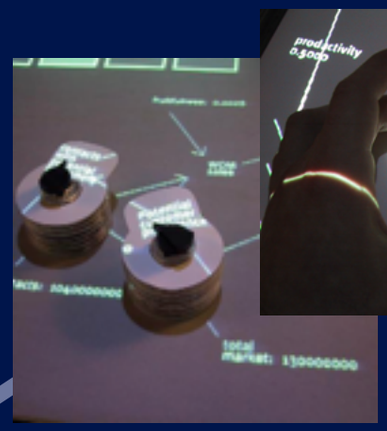
5

workbench

Evolution of Workbench

for Collaborative Design and Tangible Thinking

1999
PingPongPlus

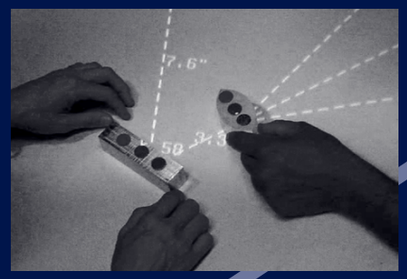


2000-02 Sensetable

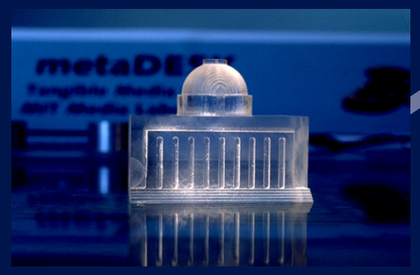
2001-02
Senseboard

2002
Actuated Workbench

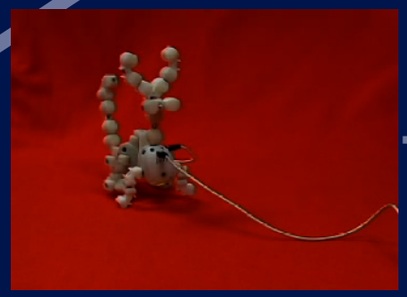
1997
I/O Bulb



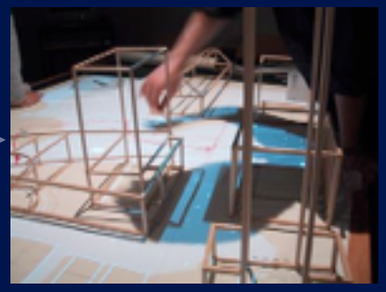
1997-8 Illuminating Light



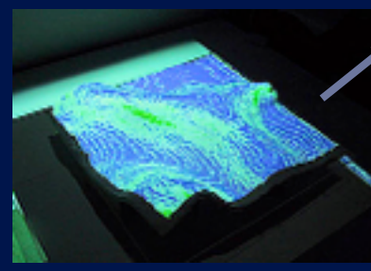
1996-7 metaDESK



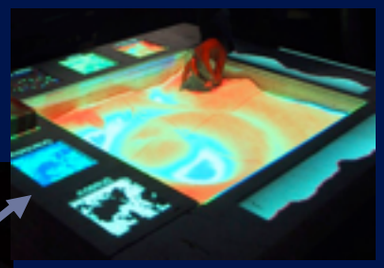
1998-9 Urp



2000-02
Luminous Table



2001-02
Illuminating Clay



2002
SandScape

光影

digital light & shadow

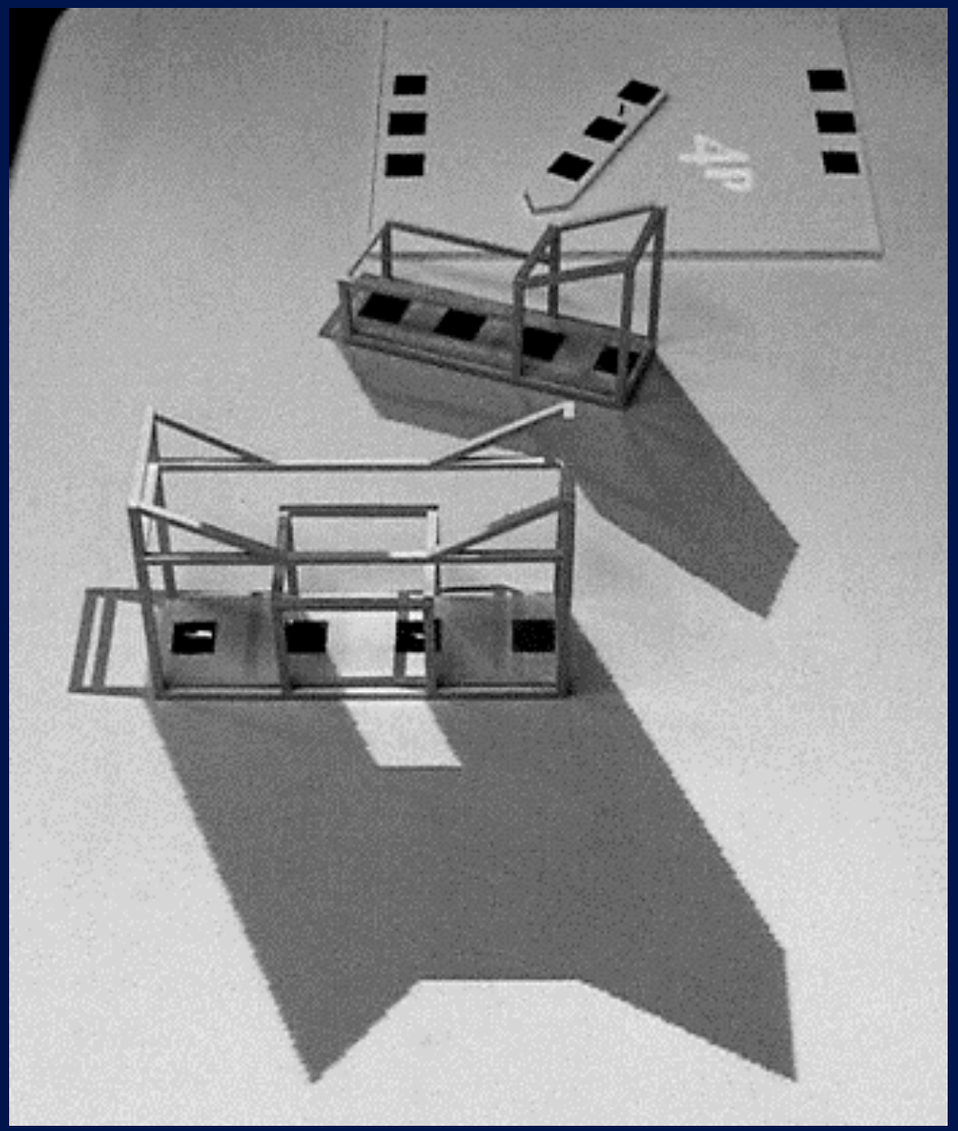
I/O Bulb and Luminous Room

Underkoffler and Ishii, 1997 - 1999

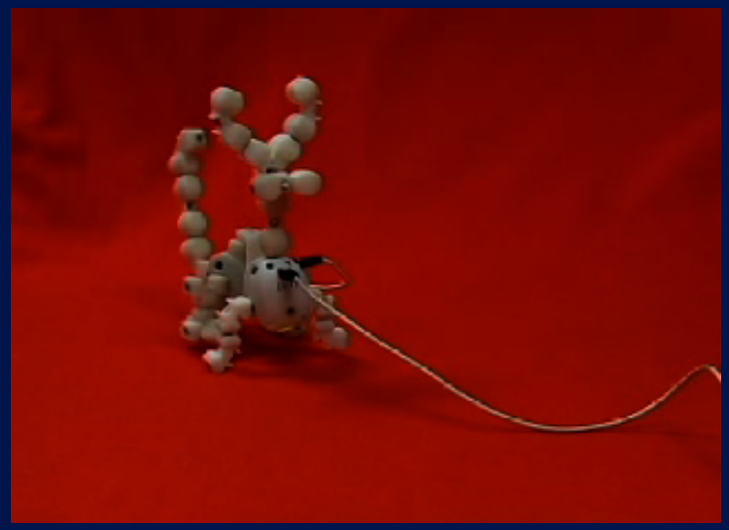
- **I/O Bulb**
  - High resolution output, two-way information
- **Luminous Room**
  - Multiple I/O bulbs illuminating architectural space

- **Give life to architectural surfaces and physical objects.**
- **Enable direct manipulation of digital world by grasping and manipulating objects with digital shadows.**

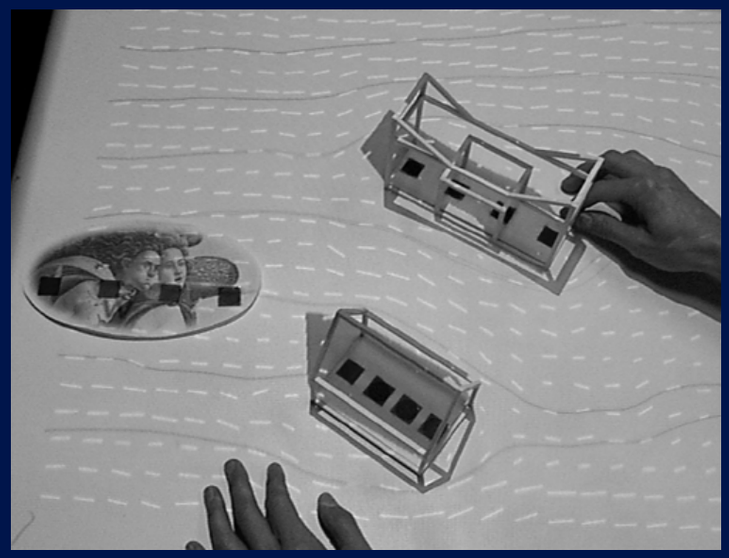
Urp:
Urban Planning Workbench (an I/O Bulb AP)
Underkoffler and Ishii, 1997 - 1999



digital shadows

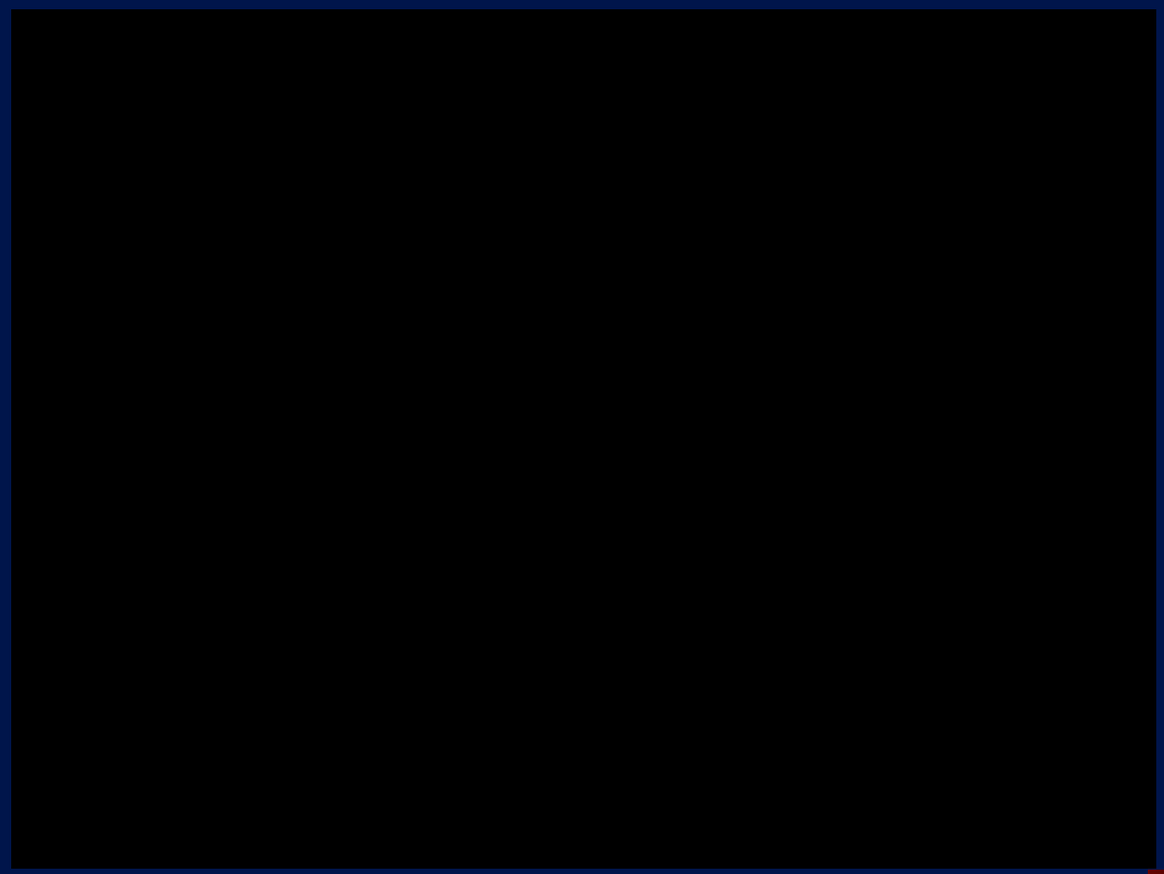


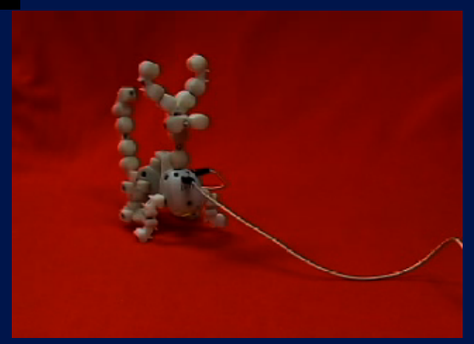
light reflections



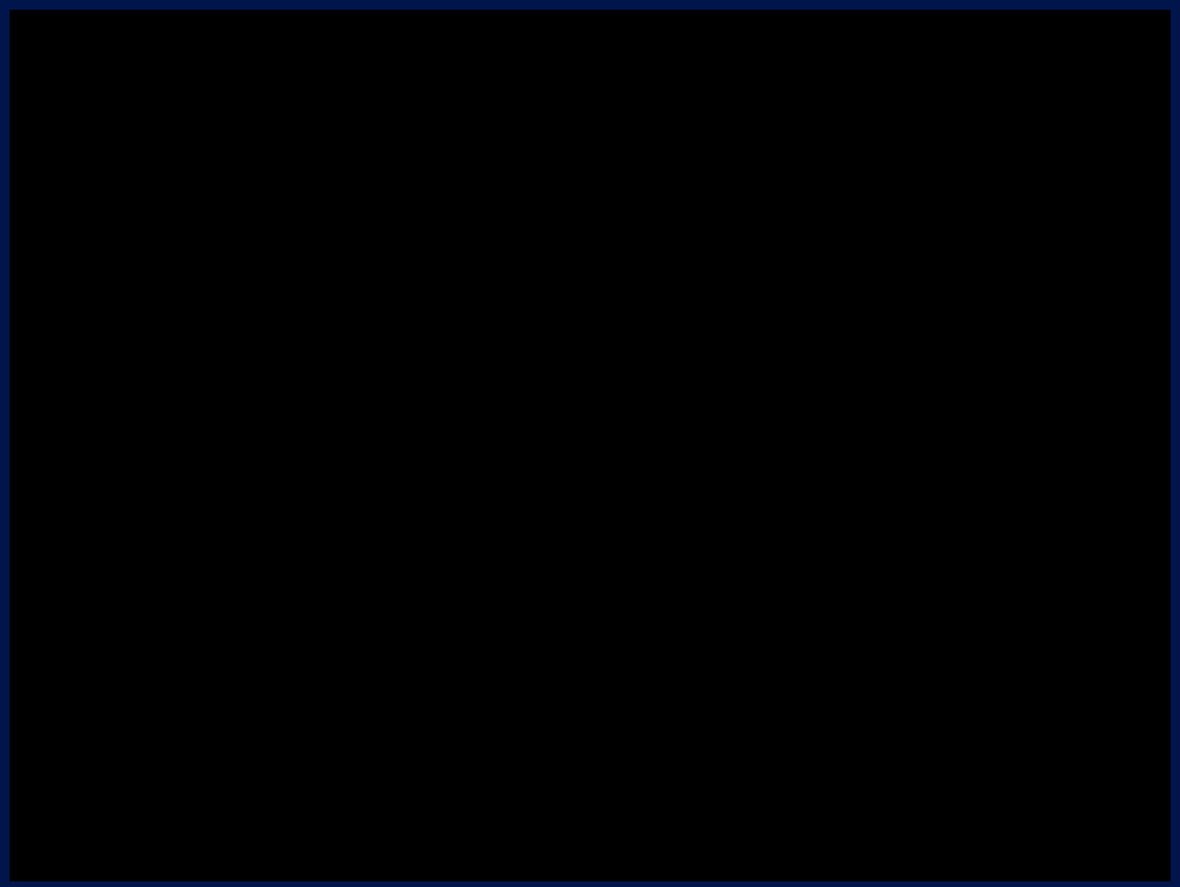
wind

Urp:
Urban Planning Workbench
Underkoffler and Ishii, 1997 - 1999

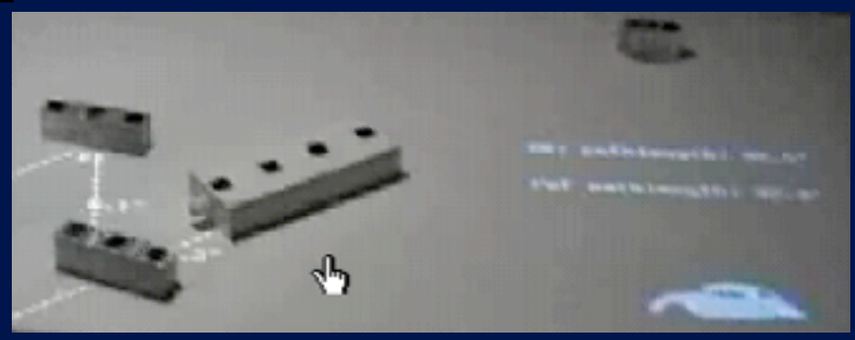




Luminous Room
with multiple I/O Bulbs
Underkoffler and Ishii, 1997 - 1999

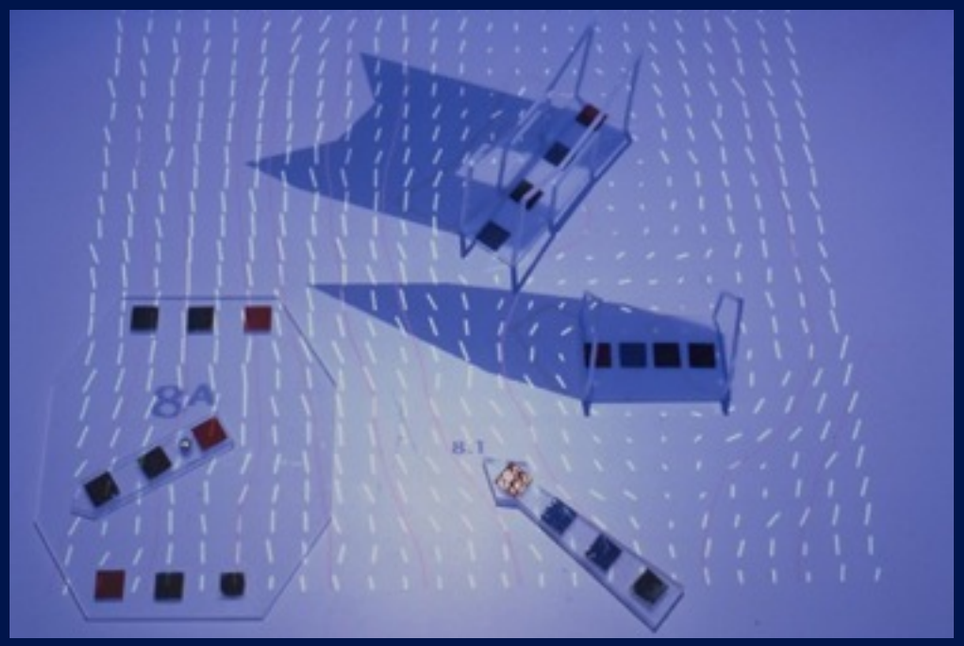


Distributed Illuminating Light



Integration of Tangible and Intangible Representations

Principle of Tangible Interface Design



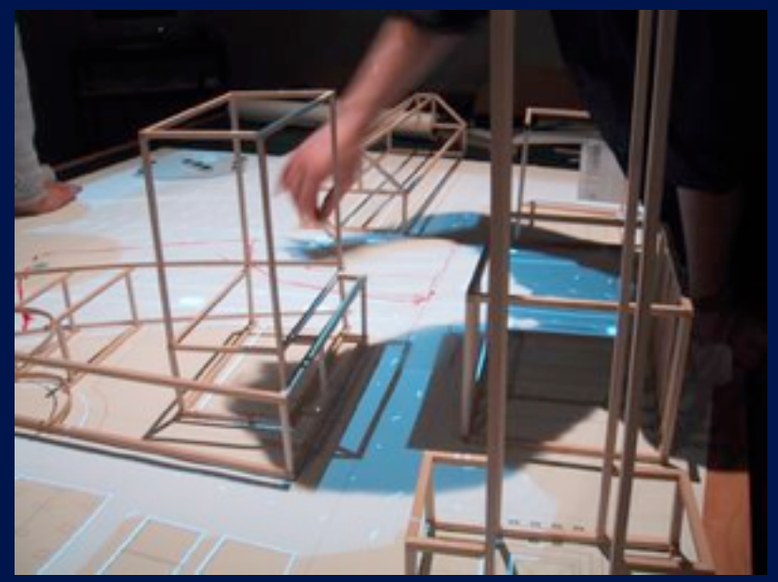
Urp 99

Luminous Table

in Urban Design Studio at MIT

Ben-Joseph, Ishii, Underkoffler, Chak, Yeung, Piper, 1999-2001

Urban Planning Workbench used in the spring 2000 / 2001 MIT courses



Luminous Table

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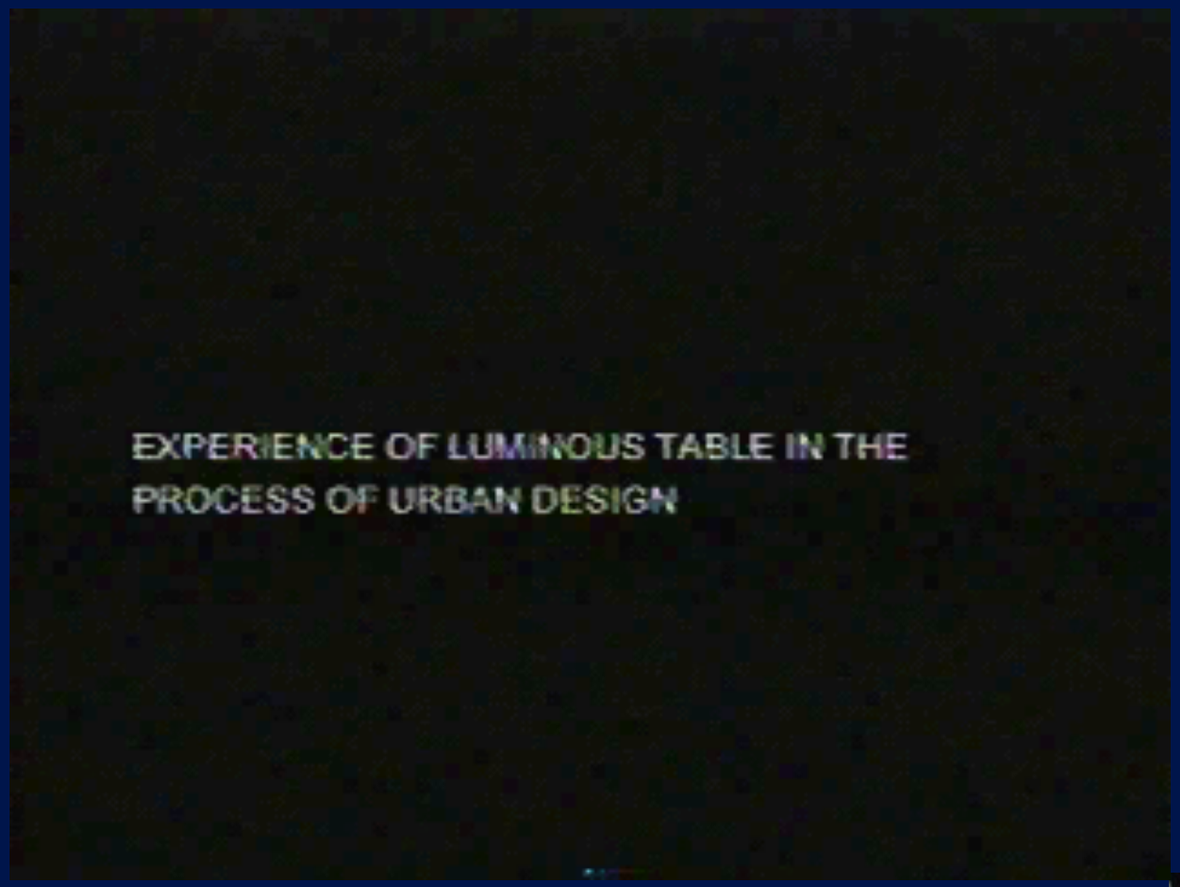
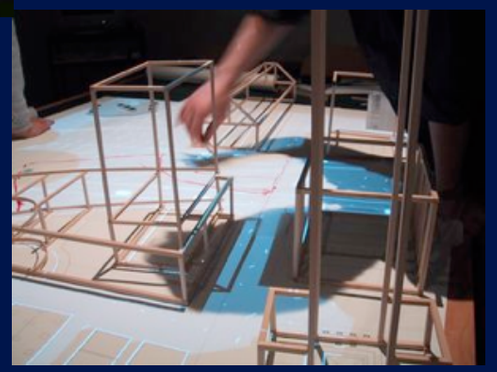
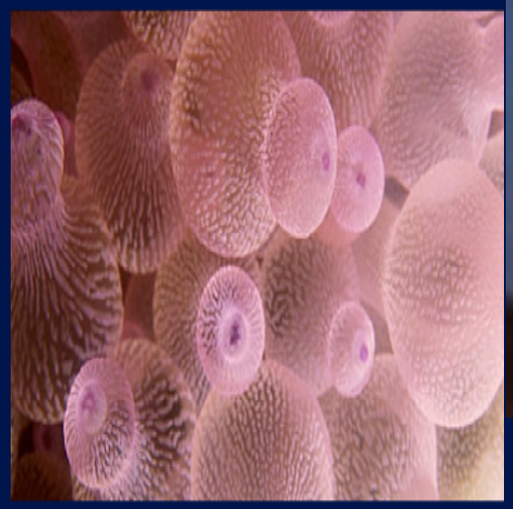


Urban Planning Workbench used in the spring 2000 / 2001 MIT courses



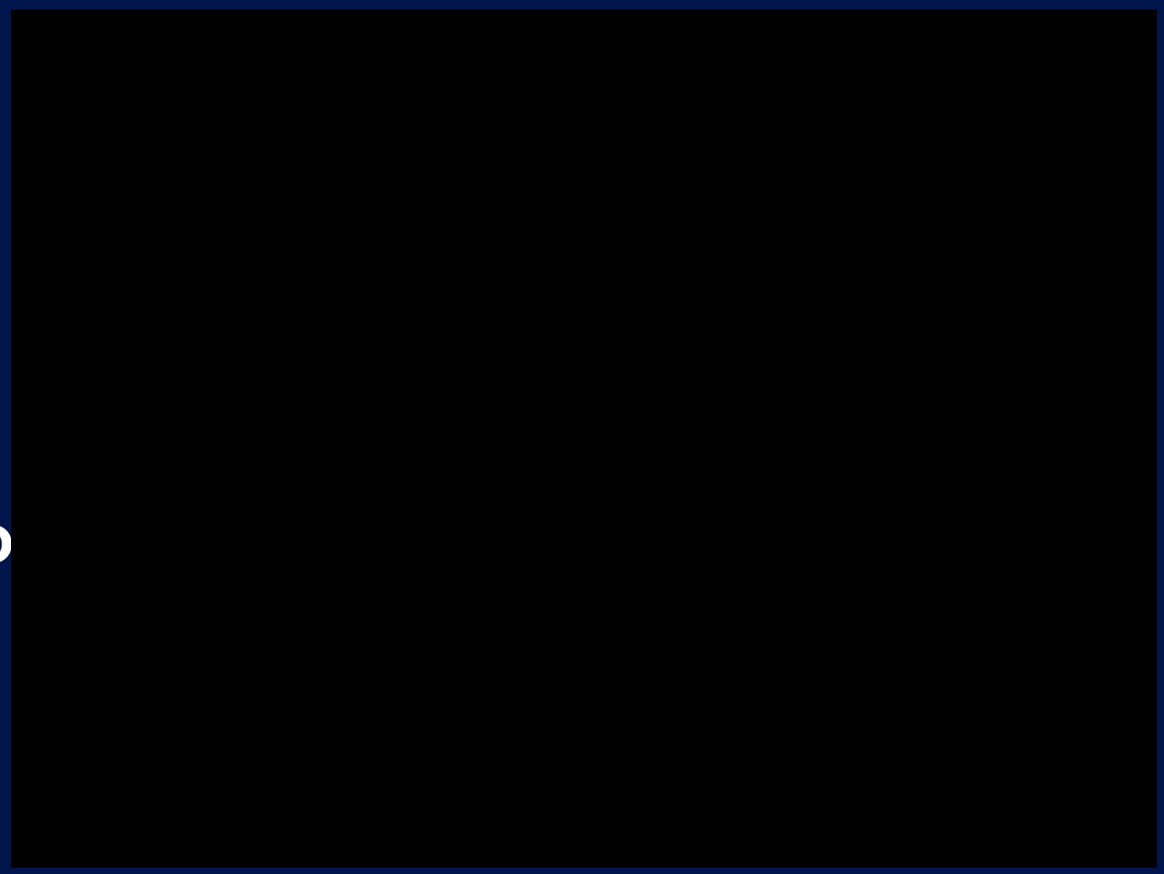
Sensetable

James Patten & Hiroshi Ishii



- **TUI platform to track multiple objects and their states on a table with video projection**

- **Applications**
  - **Music “Audiopad” in collaboration with Ben Recht**
  - **System Dynamics simulatio for Supply Chain Analysis**
  - **Chemistry**

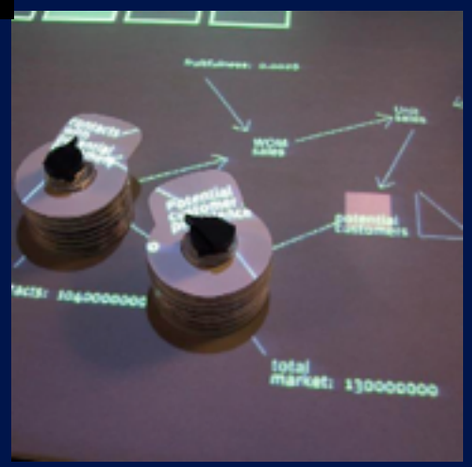


Business

System Dynamics Simulation for Supply Chain Analysis

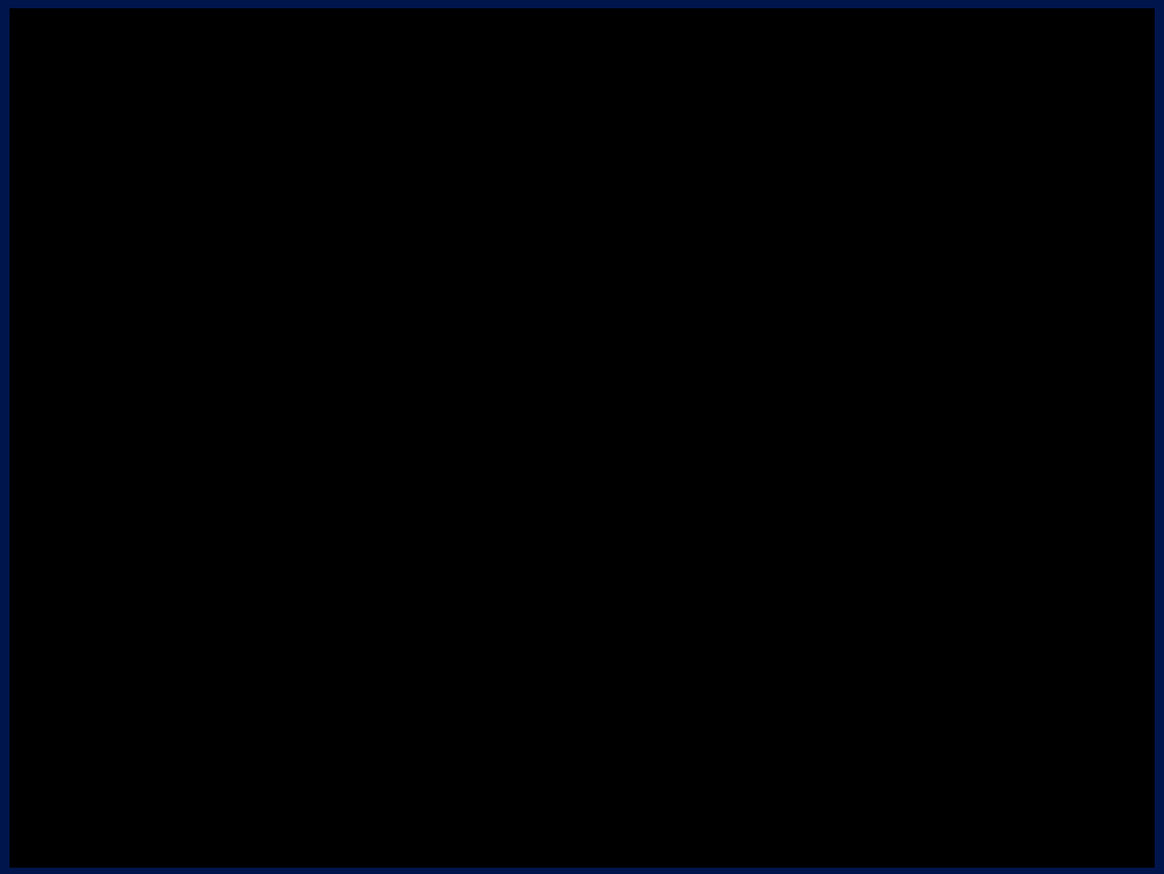
Patten, Hines, Malone, Murphy-Hoye & Ishii 00-03

Collaboration with Intel and MIT Sloan School



System Dynamics Simulation for Supply Chain Analysis

Patten, Hines, Malone, Murphy-Hoye & Ishii 00-03



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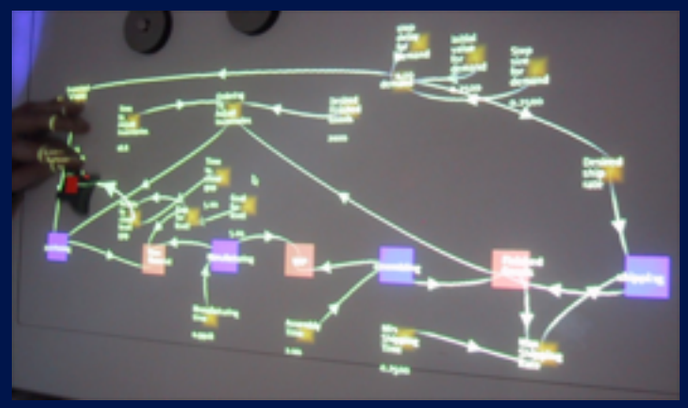


IP Network Design Workbench
NTT Comware + TMG

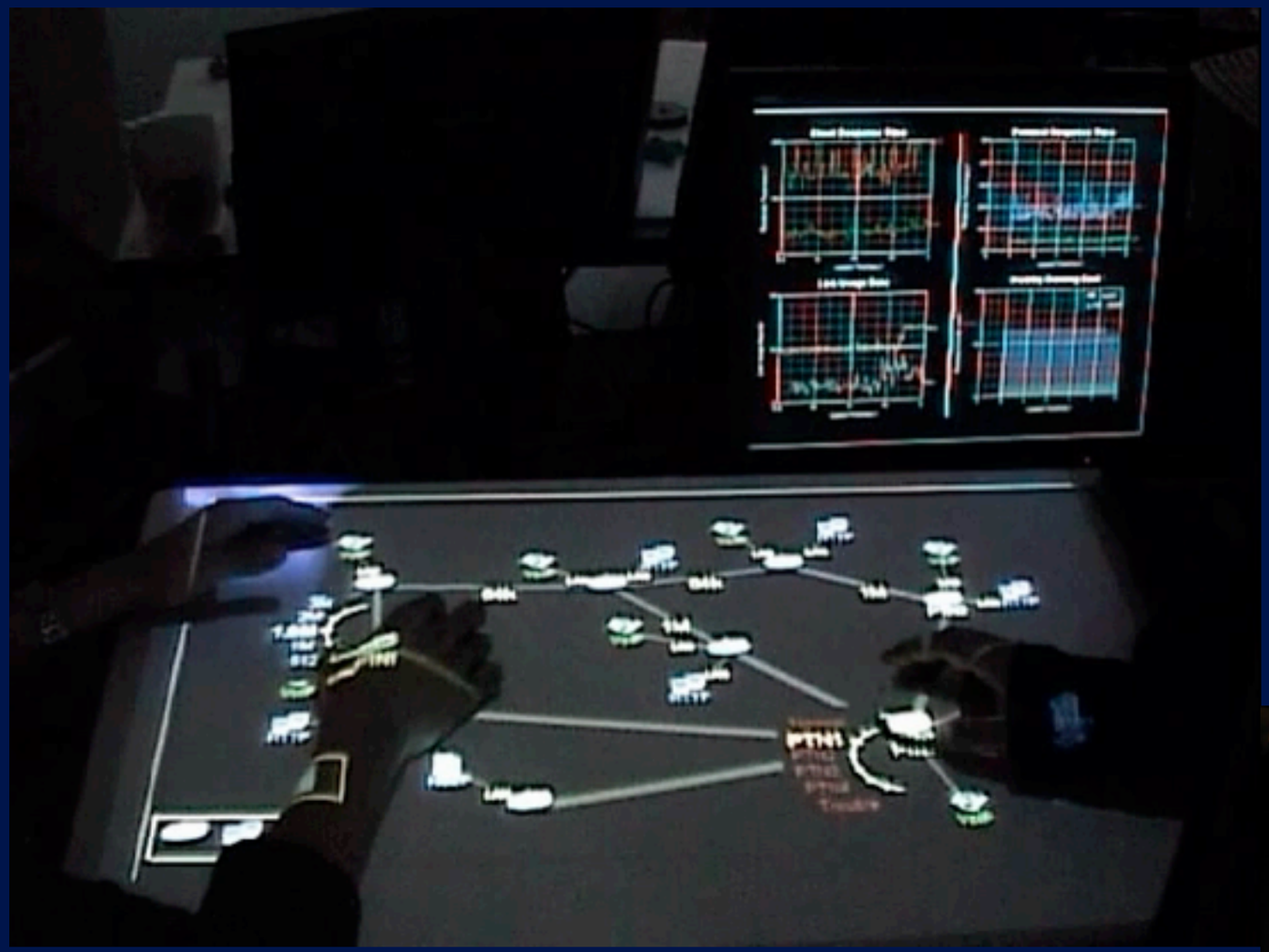
- **Event-Driven Simulation + NTT Comware's network design consulting expertise**

- **TUI supports cooperative direct manipulation of IP Network simulator.**

IP Network Design Workbench: NTT Comware + TMG (sensetable)

- **Based on Event-Driven Simulation Engine and NTT Comware's NW consulting expertise**
- **This workbench helps designers to evaluate the effects of changing topology, bandwidth, server location in real time, to optimize the network performance.**
- **TUI supports cooperative direct manipulation of IP Network simulator.**

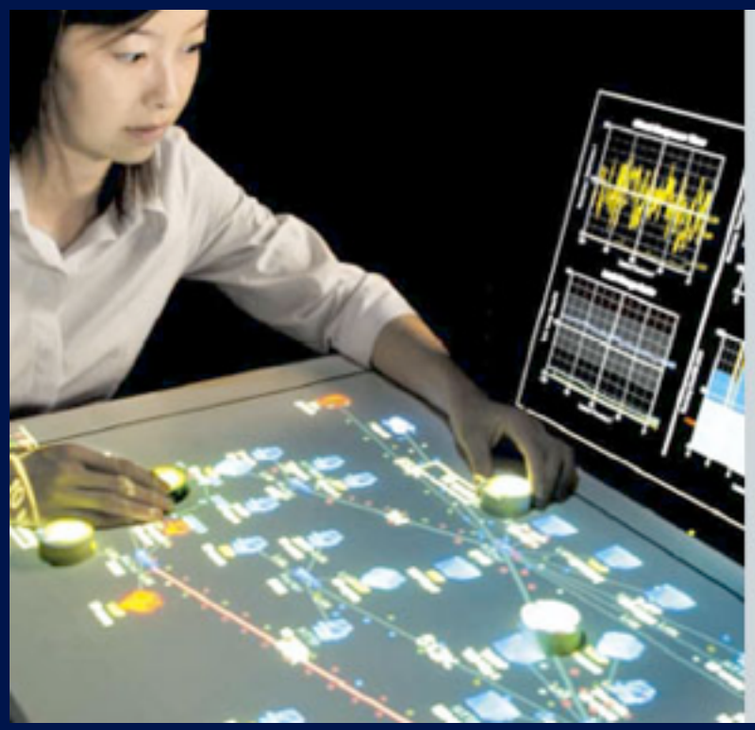
IP Network Design Workbench
NTT Comware + TMG



- Event-Driven Simulation
- TUI supports cooperative direct manipulation of simulator to evaluate the effects of changing topology, bandwidth, server location in real time, to optimize the network performance.

Thanks to Mr. Kase, Mr. Hirano, Mr. Narita, Ms. Kobayashi, Mr. Tanaka, and many other NTT Comware people.

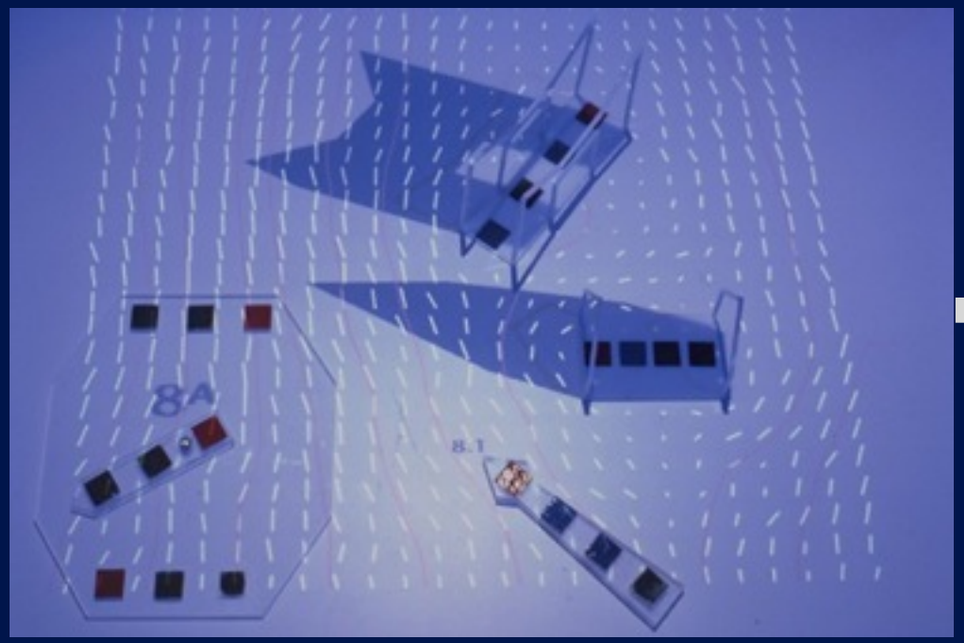
BusinessWeek Nov. 3, 2003



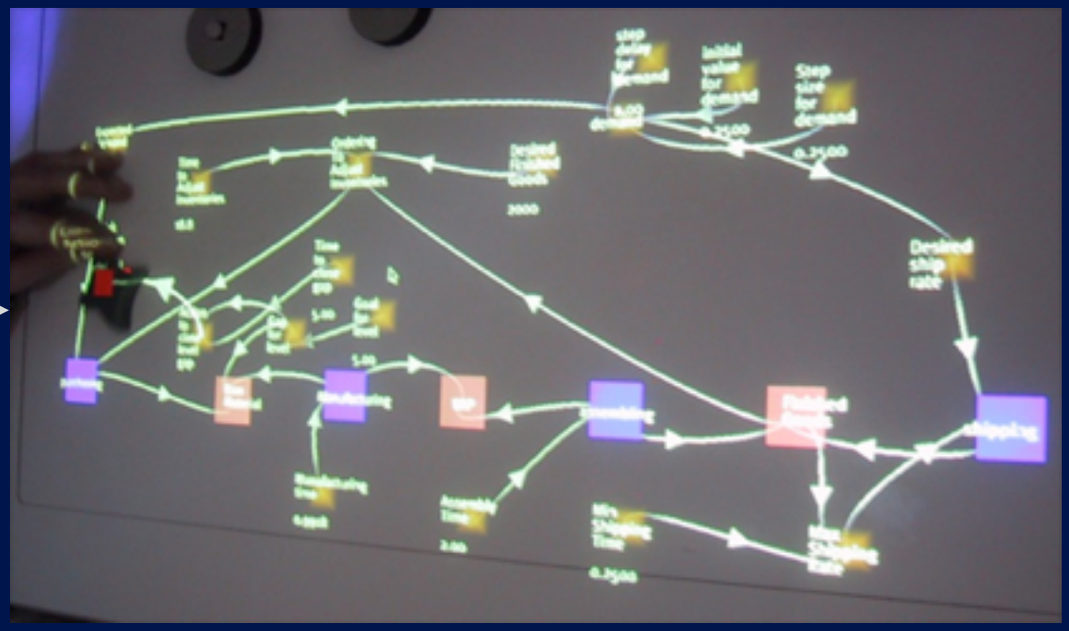
Data Workbench
Want to upgrade your company's computer network—or redesign it from scratch? This "sensetable" has a built-in antenna that reads what's happening to objects on the table representing network routers, storage systems, mail servers, and the like. The data are transmitted to a computer that instantly remodels the network and projects the new design. Additional information about the cost and capacity of the upgraded network is displayed on screens.

From Physical World Model to Computational Abstract Model

Principle of Tangible Interface Design



Urp 99



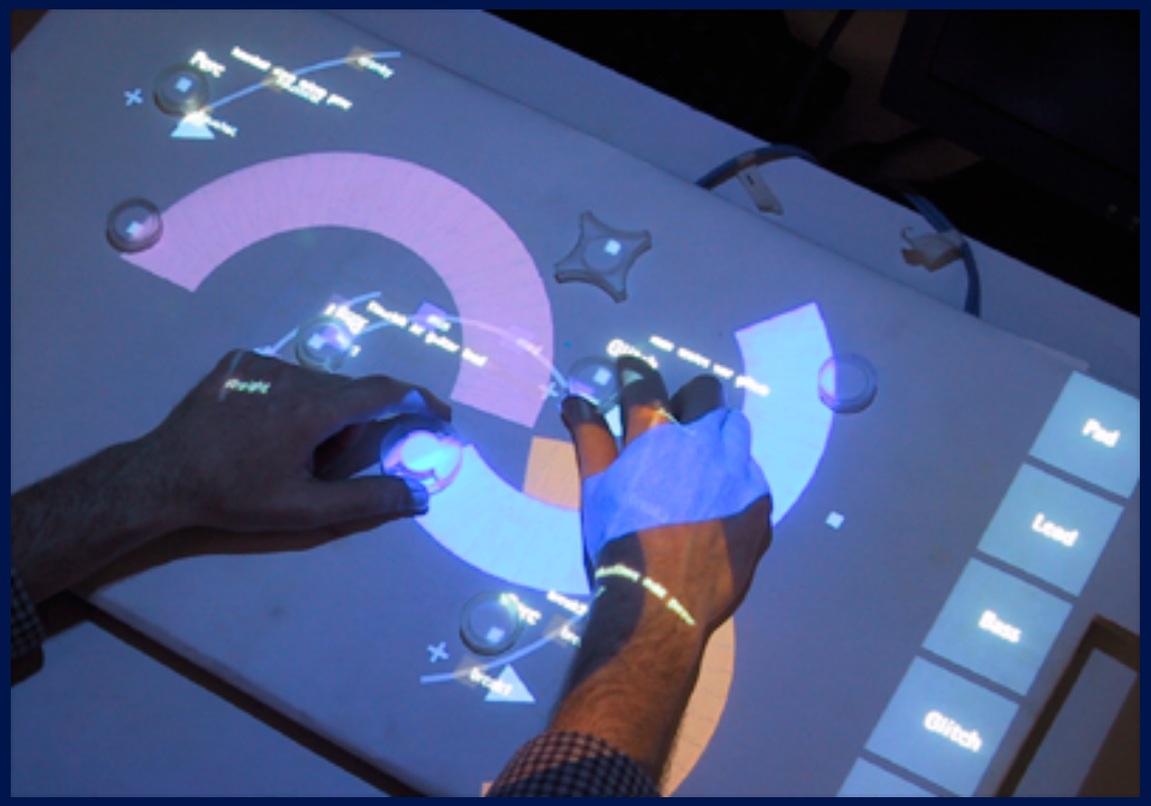
System Dynamics Simulation 03

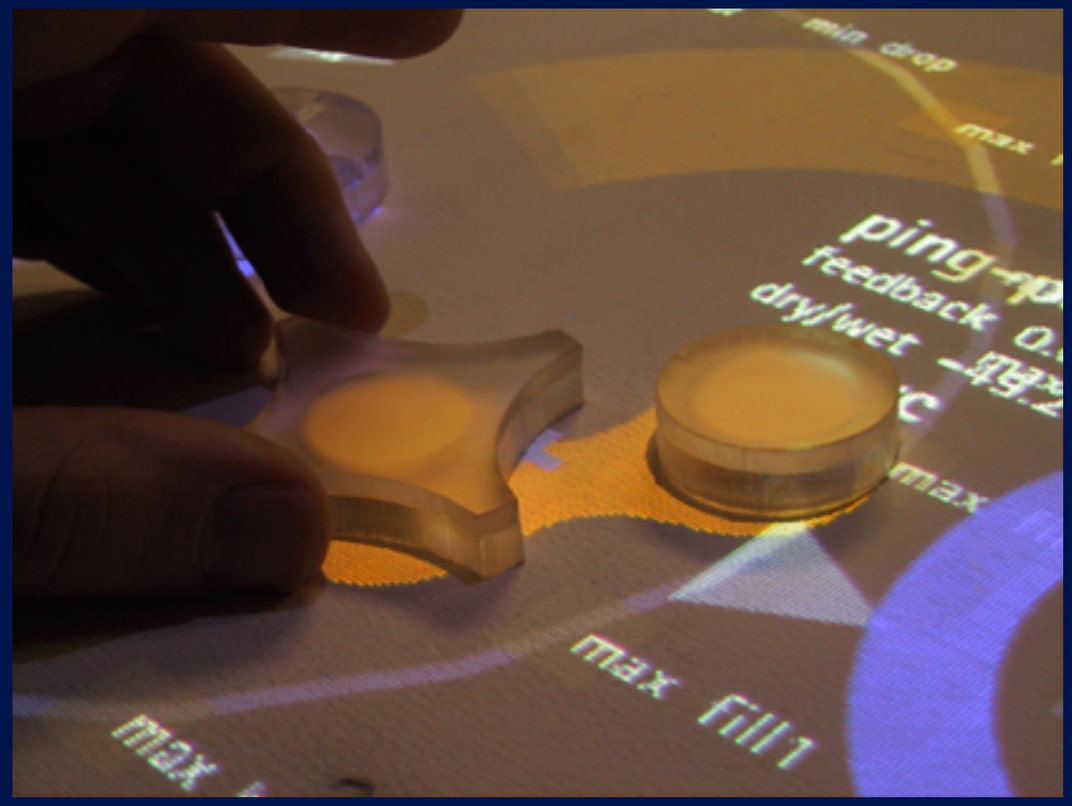
音楽

music

Audiopad

James Patten and Ben Recht (Physics & Media)

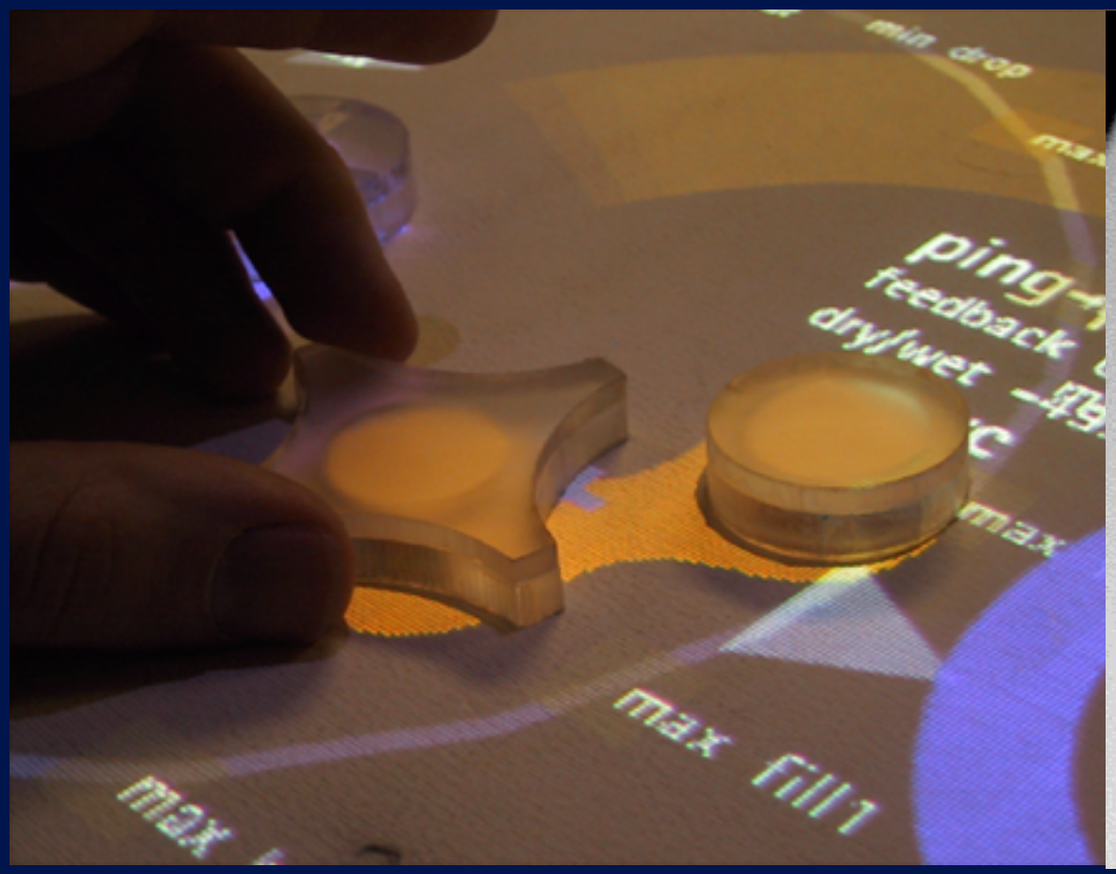


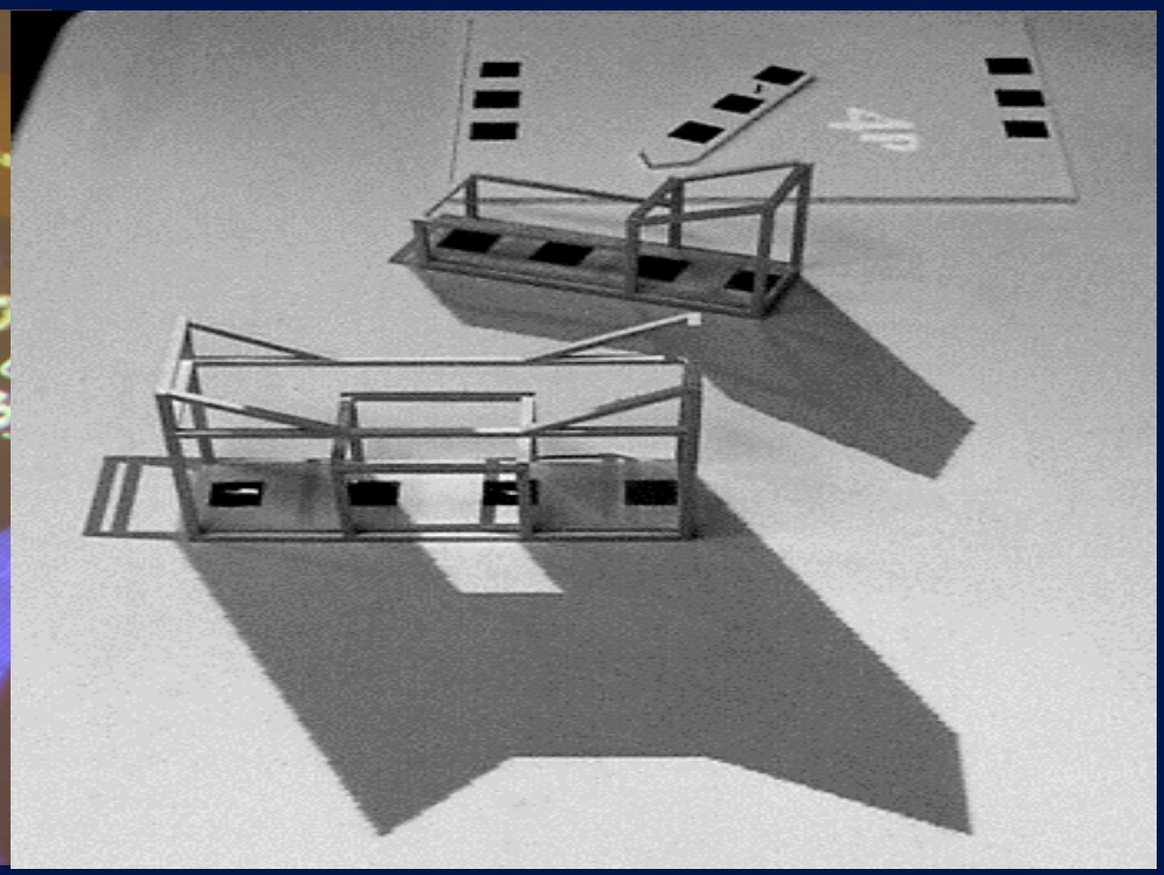


- A new way to perform electronic music.
- Designed to combine the expressive power of traditional musical instruments with the modularity of a computer
- Based on the Sensetable project.

Audiopad

James Patten and Ben Recht* (*Physics & Media Group)





- A new way to perform electronic music.
- Designed to combine the expressive power of traditional musical instruments with the modularity of a computer
- Based on the Sensetable project.

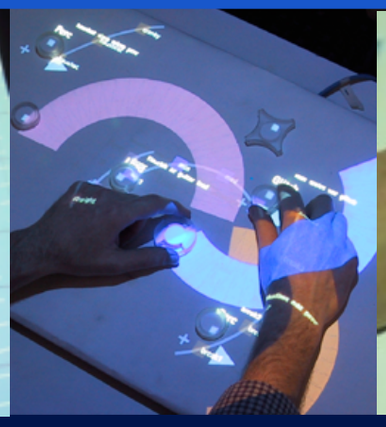
Sensetable:
TUI Platform + Applications

Applications

Hardware platform

TMG

Urp
[fluid dynamics]



Audiopad

CircuiTUI

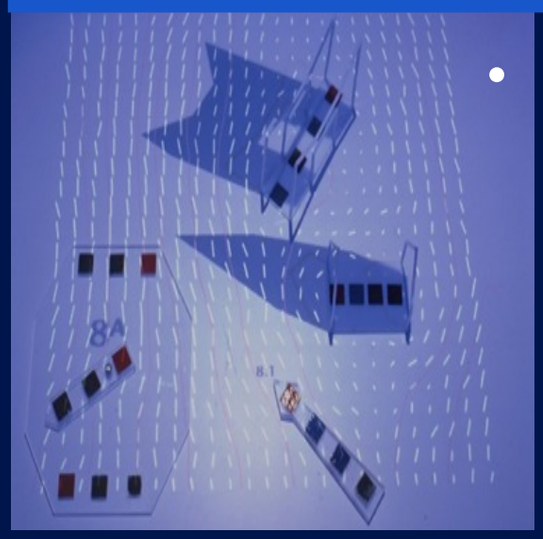
TMG + Intel + Sloan

Supply Chain Visualization
[System Dynamics]

NTT Comware + TMG

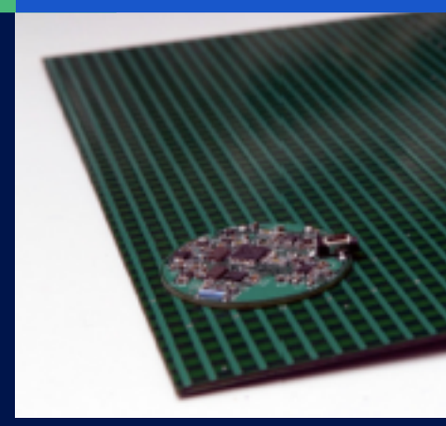
IP Network Designer
[Event Driven Sim]

Business Process Analyzer
[Event Driven Sim]



- **Sensetable:**
  TUI platform to track multiple objects and their states on a table with video projection

NTT Comware Sensetable Product 2003



Patten Studio

駆動

Actuation

Actuated Workbench

Dan Maynes-Aminzade, Gian Pangaro & Hiroshi Ishii 02

Function

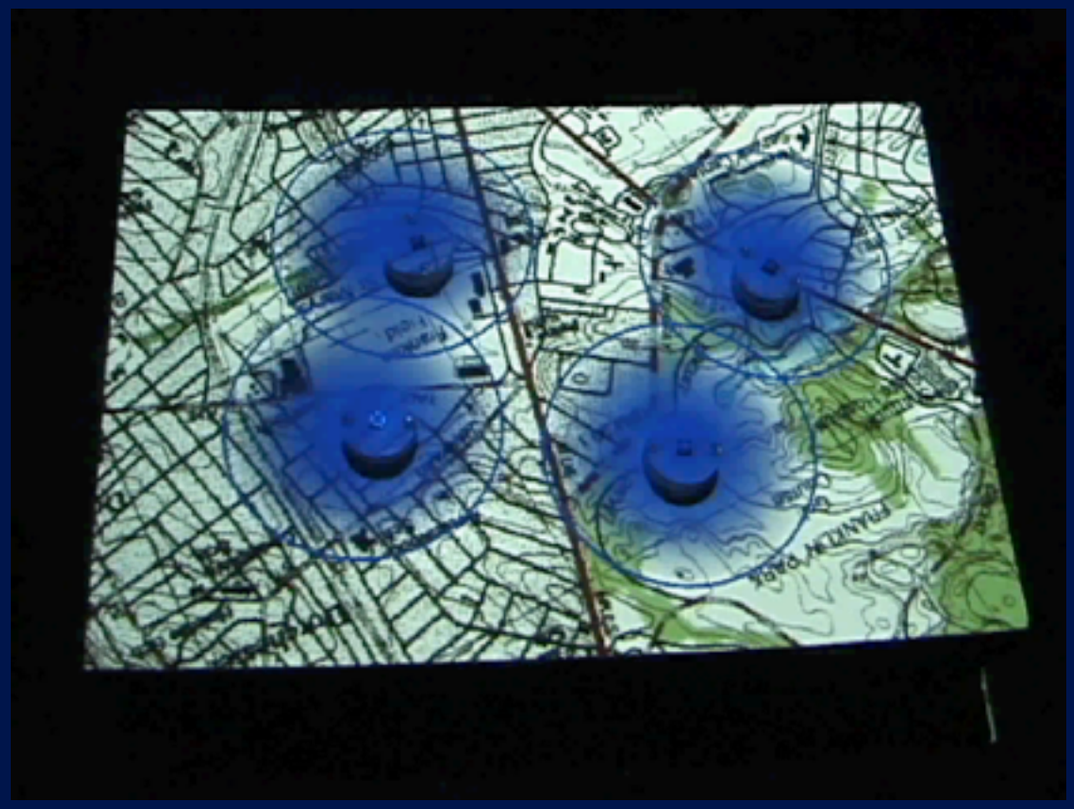
Magnetic forces to move objects on a table in two dimensions.

Application

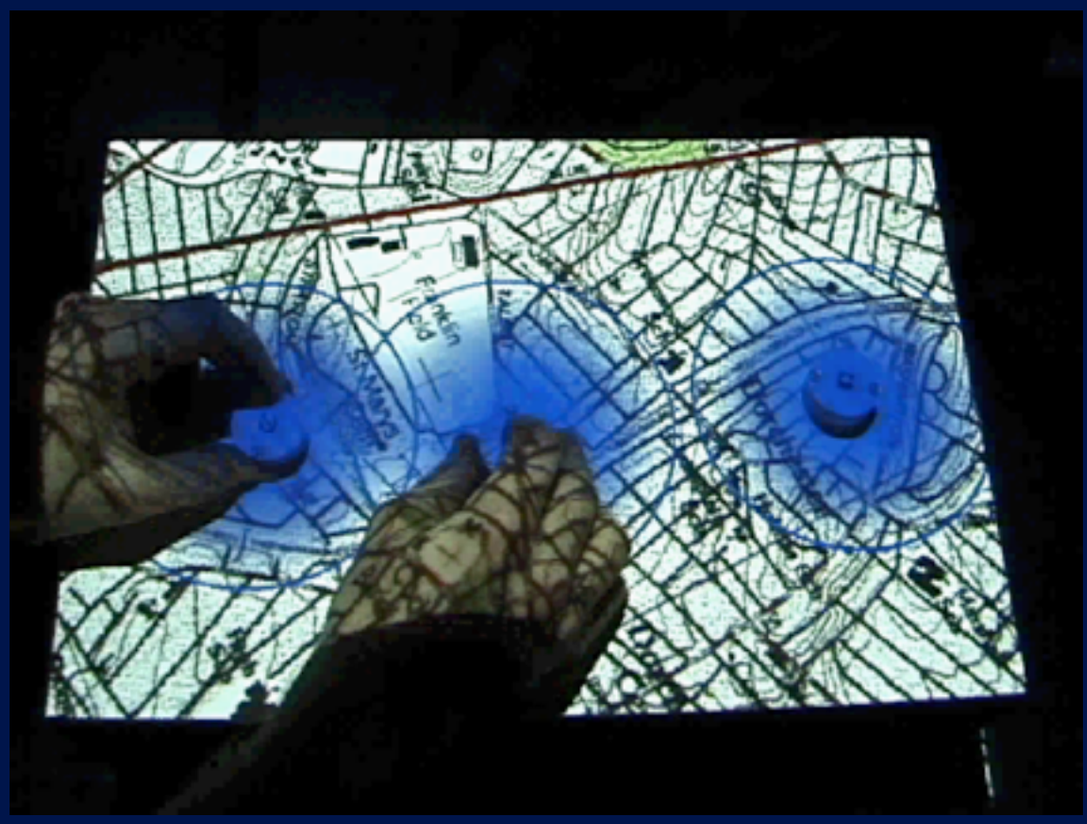
Augment existing “Sensetable” providing an additional physical dynamic display capability.

Actuated Workbench

Dan Maynes-Aminzade and Gian Pangaro & Hiroshi Ishii 02-03



without actuation



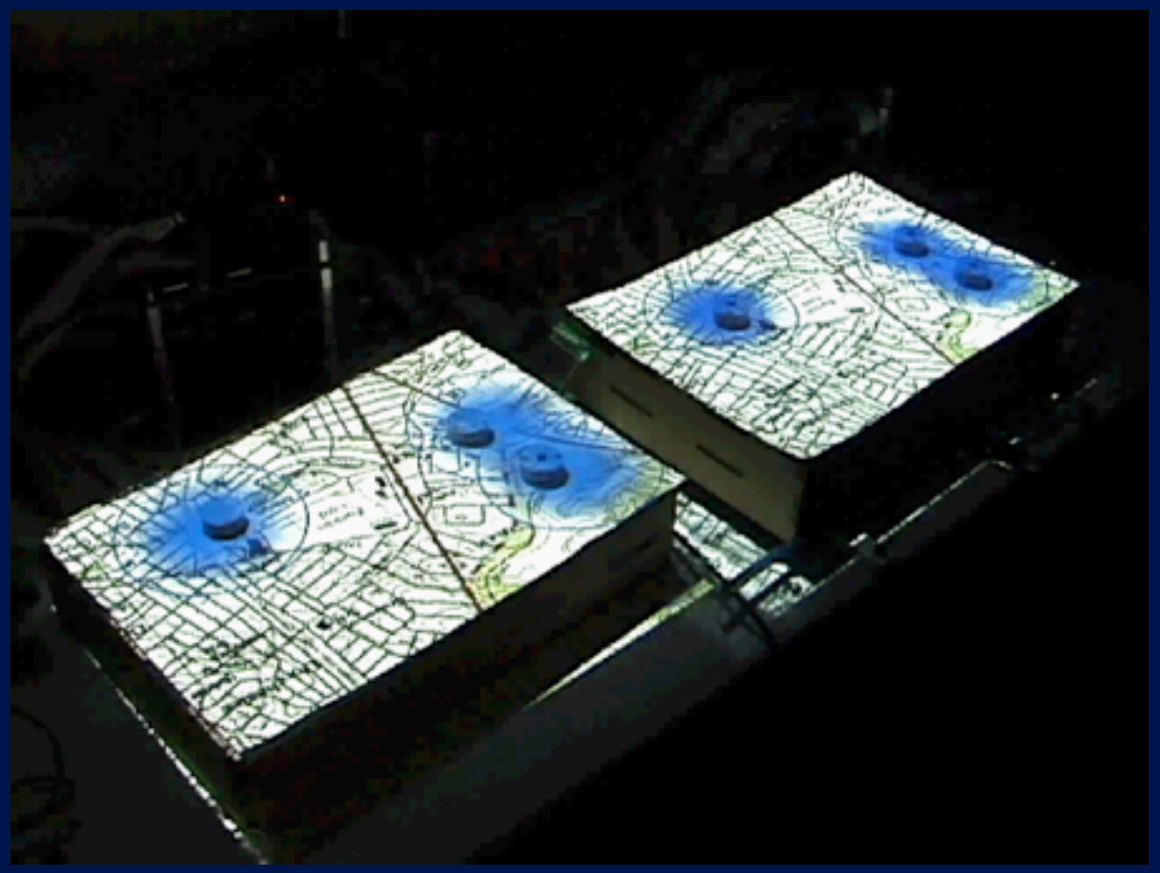
with actuation

Application 1

- Clearing up inconsistencies that arise from the computer's inability to move the objects on the table

Actuated Workbench

Dan Maynes-Aminzade and Gian Pangaro & Hiroshi Ishii 02-03

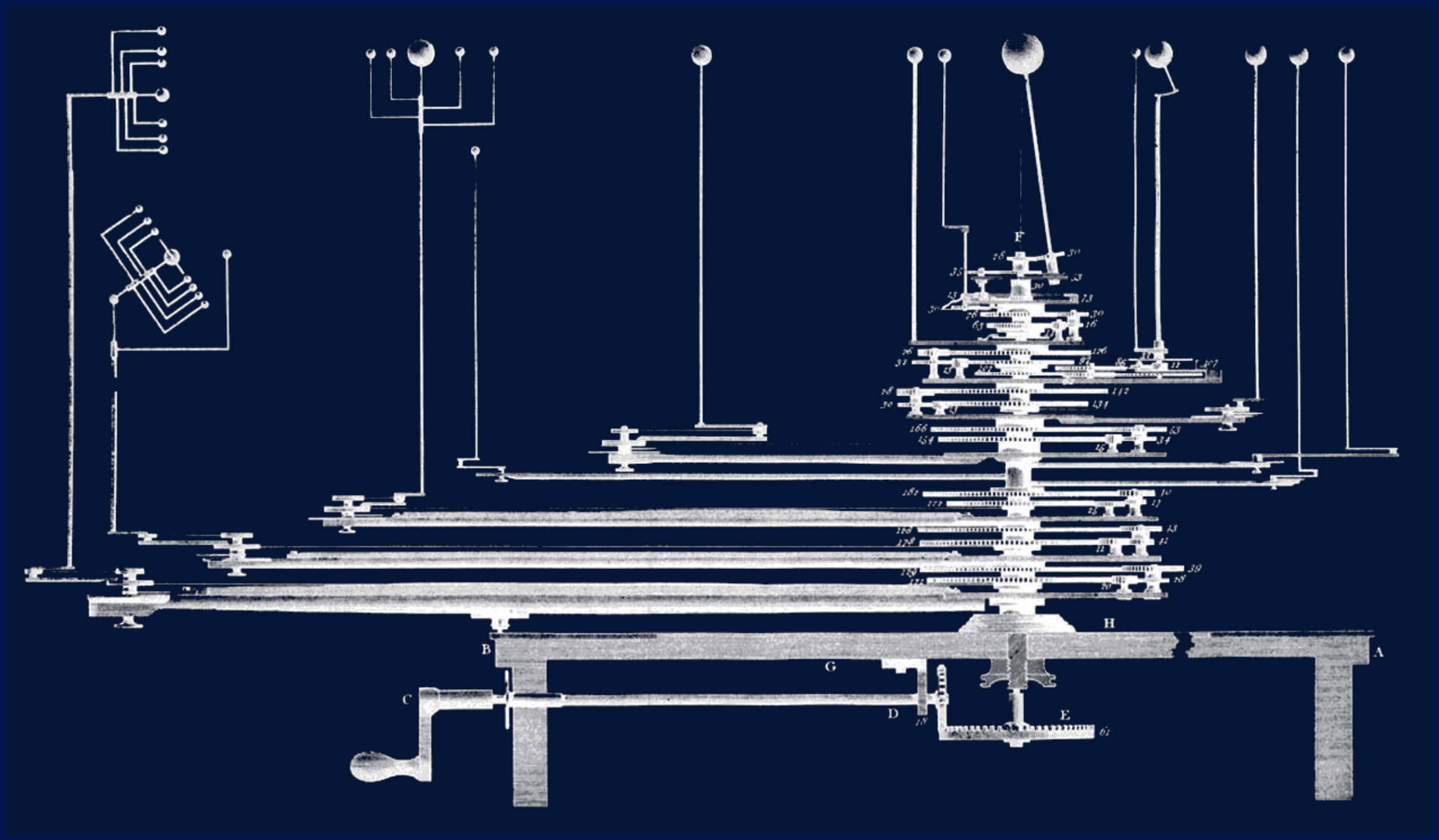


- Synchronization of distributed “Sensetables” in realtime remote collaboration

触考

Tangible Thinking

Mechanical Representation of Knowledge: Orrery



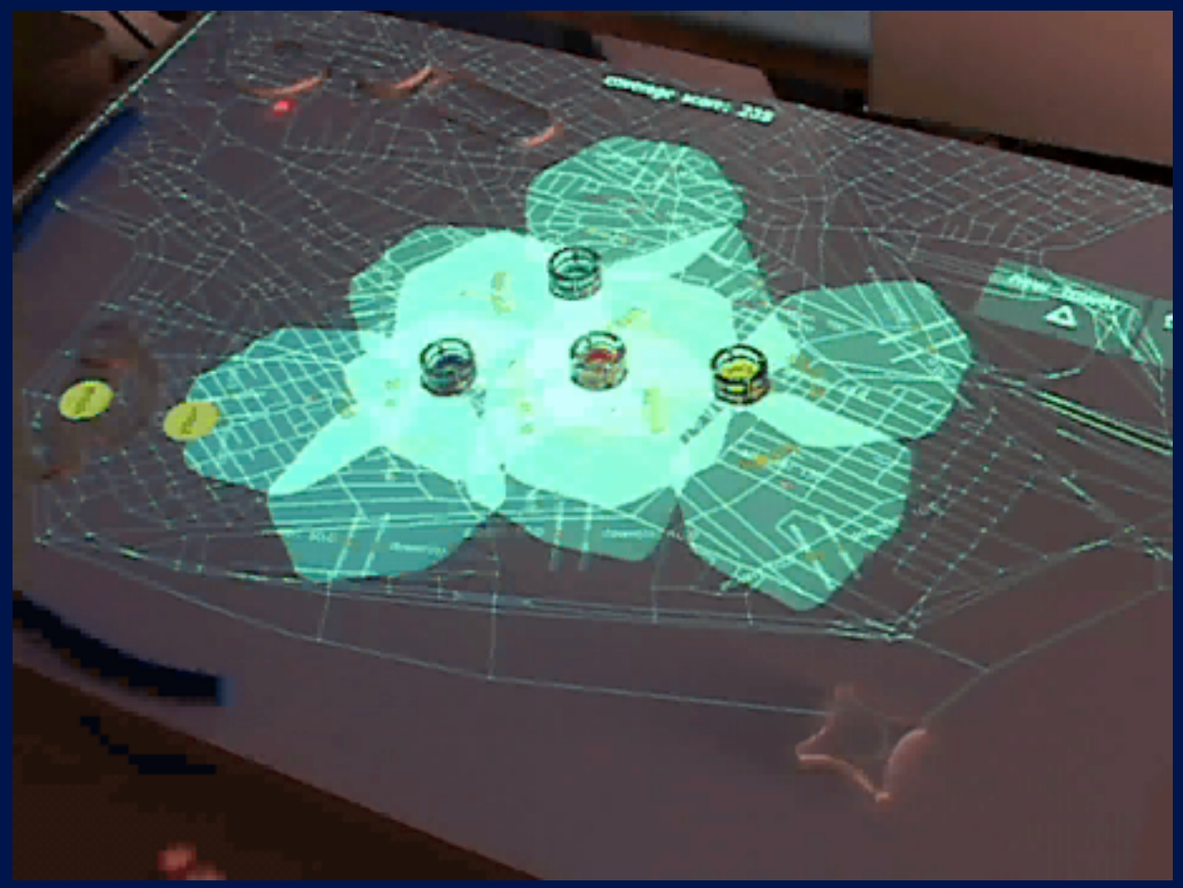
機械

制約

Mechanical Constraints

PICO Interaction Techniques

James Patten and Hiroshi Ishii CHI 2007



legible

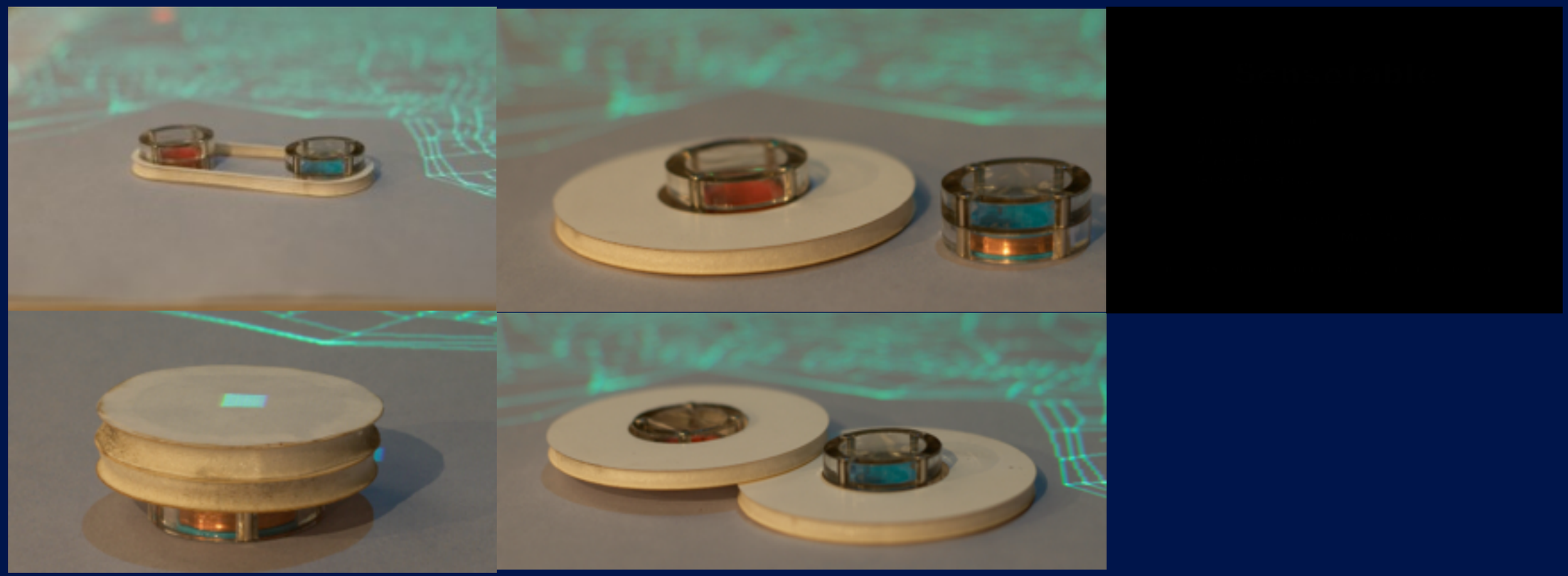
flexible

Mechanical constraints, coupled with computer-controlled actuation, provide a novel and effective way to interact with computers.

ad hoc

Mechanical constraints

Guiding the motion of physical objects to guide the computational process



Mechanical constraints

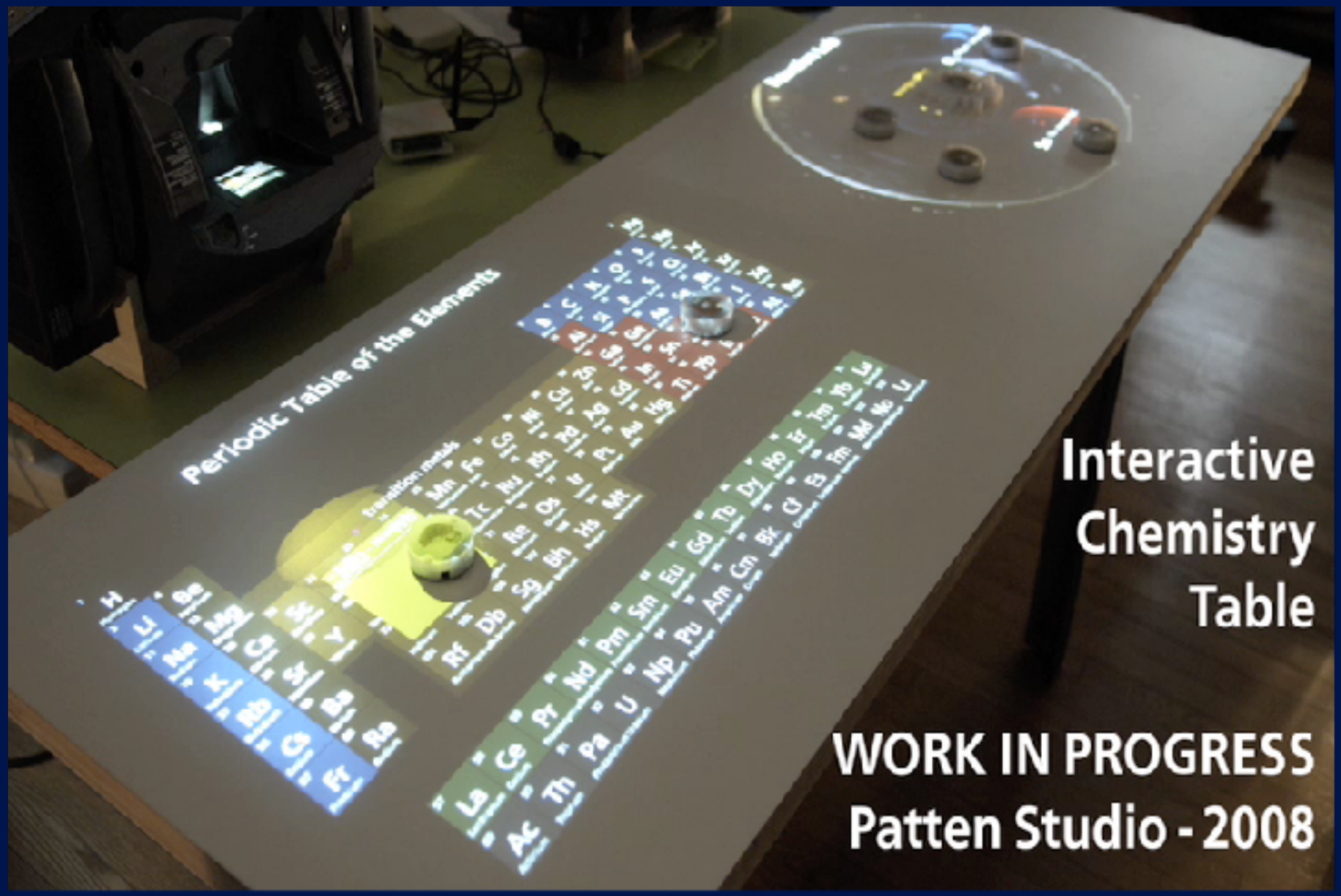
- legible

- flexible

- ad hoc

Sensetable

James Patten, Patten Studio

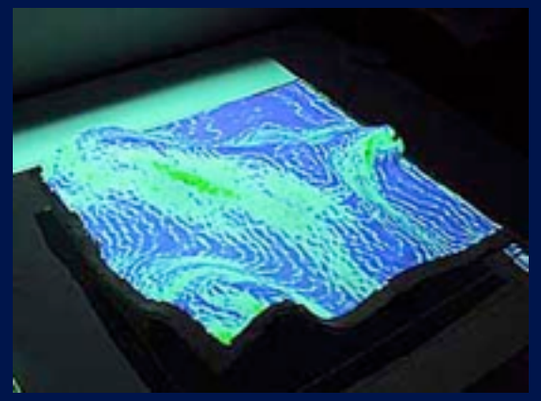


3D連続

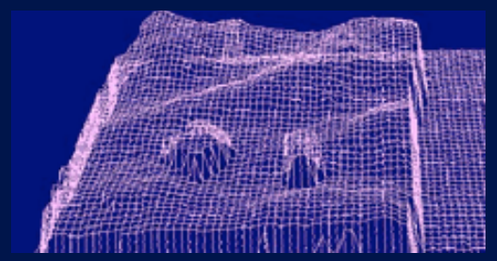
3D Continuous

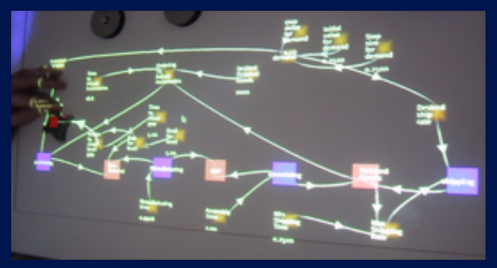
Illuminating Clay

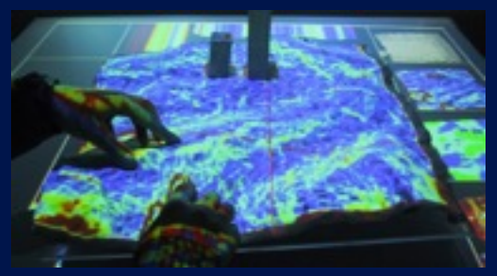
Ben Piper, Carlo Ratti & Hiroshi Ishii 01



- **3-D Tangible Interface for Landscape Analysis**





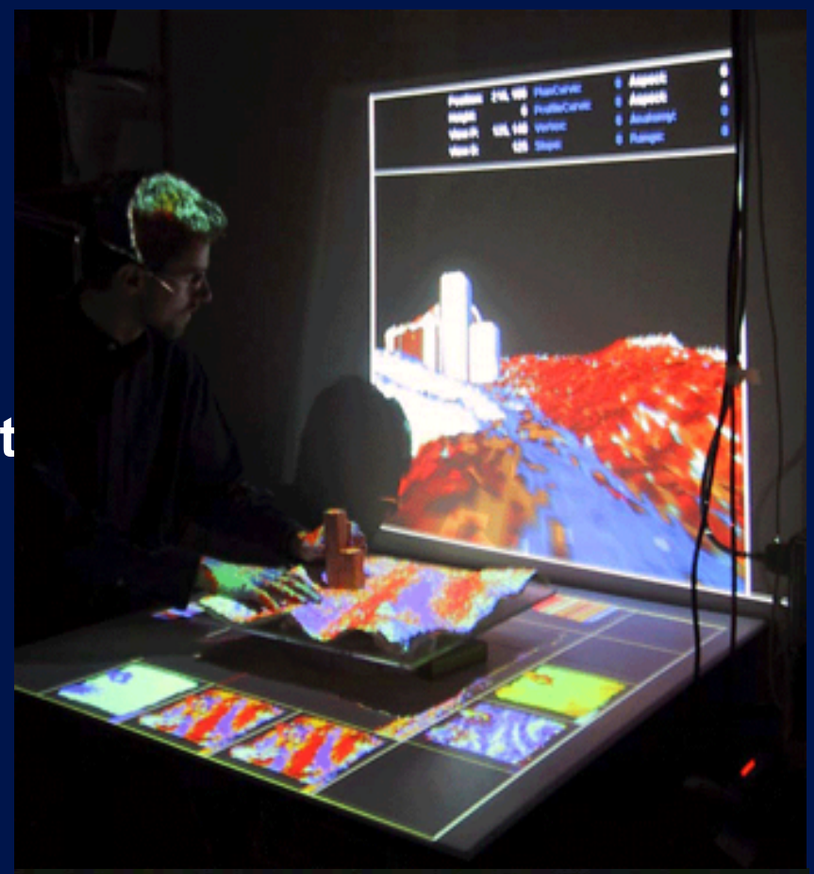


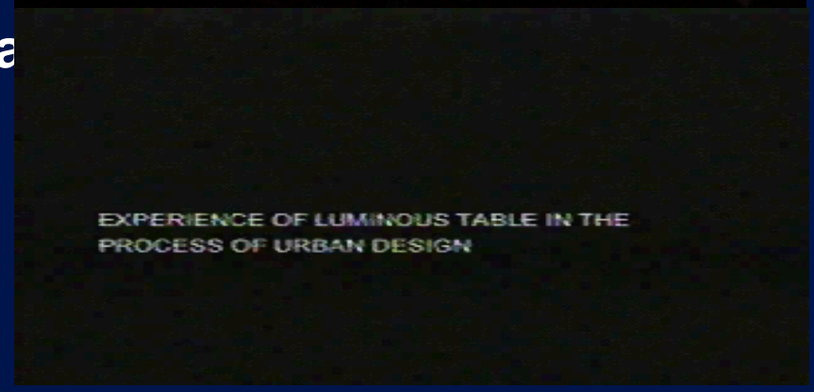
1. Physical Manipulat

2. 3-D Capture

3. Computational Ana

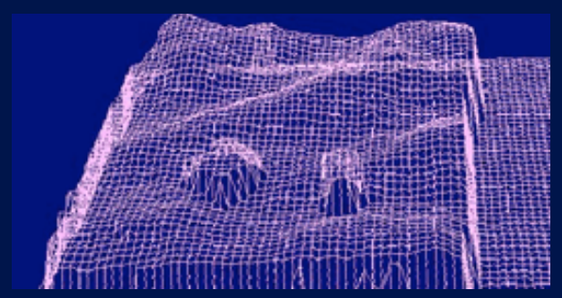
4. 3-D Projection

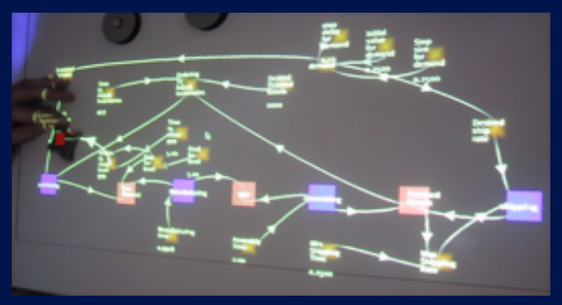


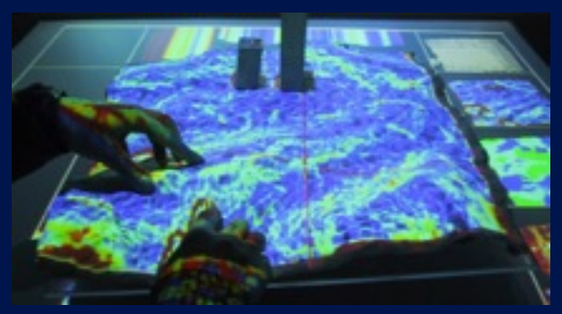


Illuminating Clay

Ben Piper, Carlo Ratti & Hiroshi Ishii







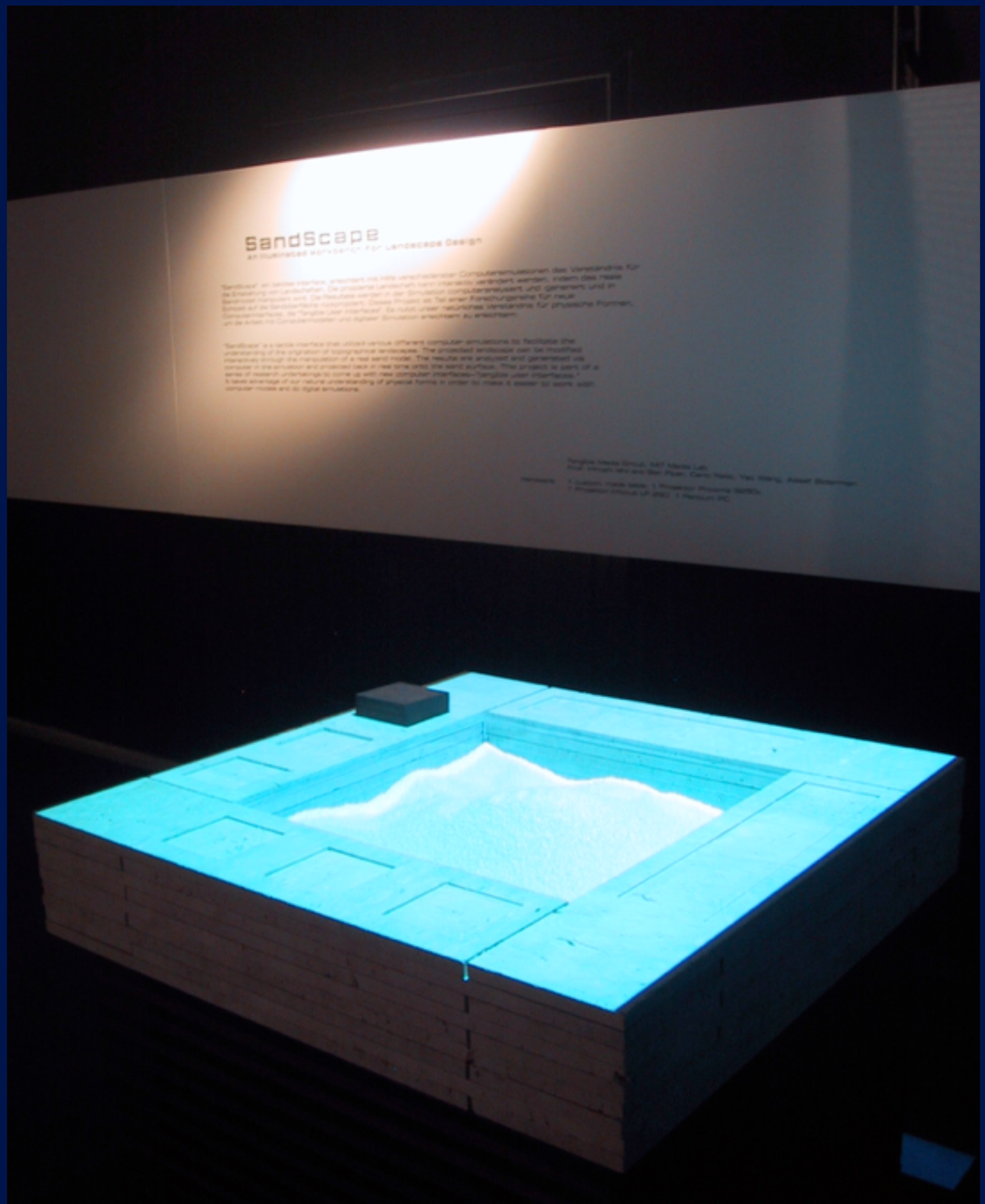
- Physical Clay as 3-D Physical Input & Visual Display for intuitive manipulation and understanding of spatial relationships
- 3D Laser Scanner + Video Projector

SandScape

Hiroshi Ishii,
Carlo Ratti,
Ben Piper,
Yao Wang, and
Assaf Biderman

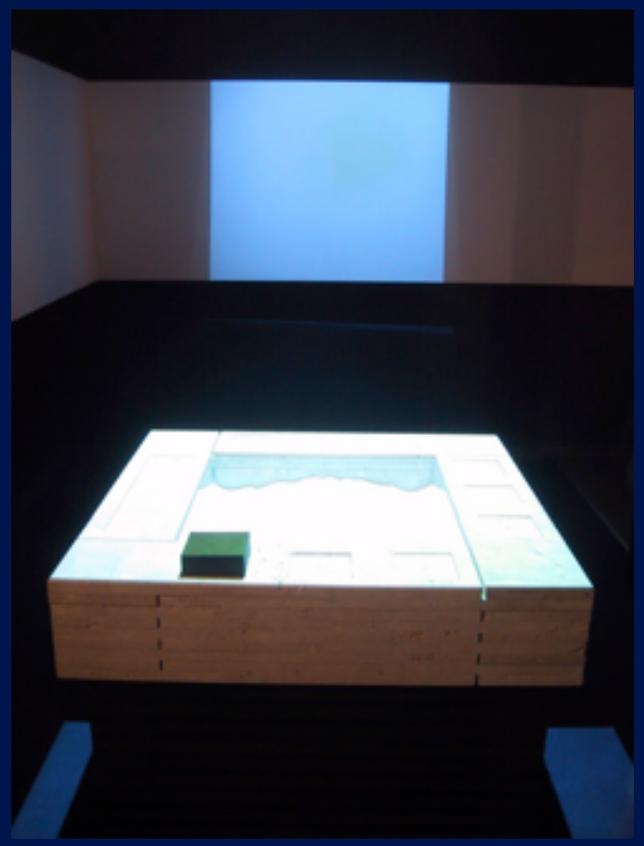
Tangible Media Group

MIT Media Laboratory

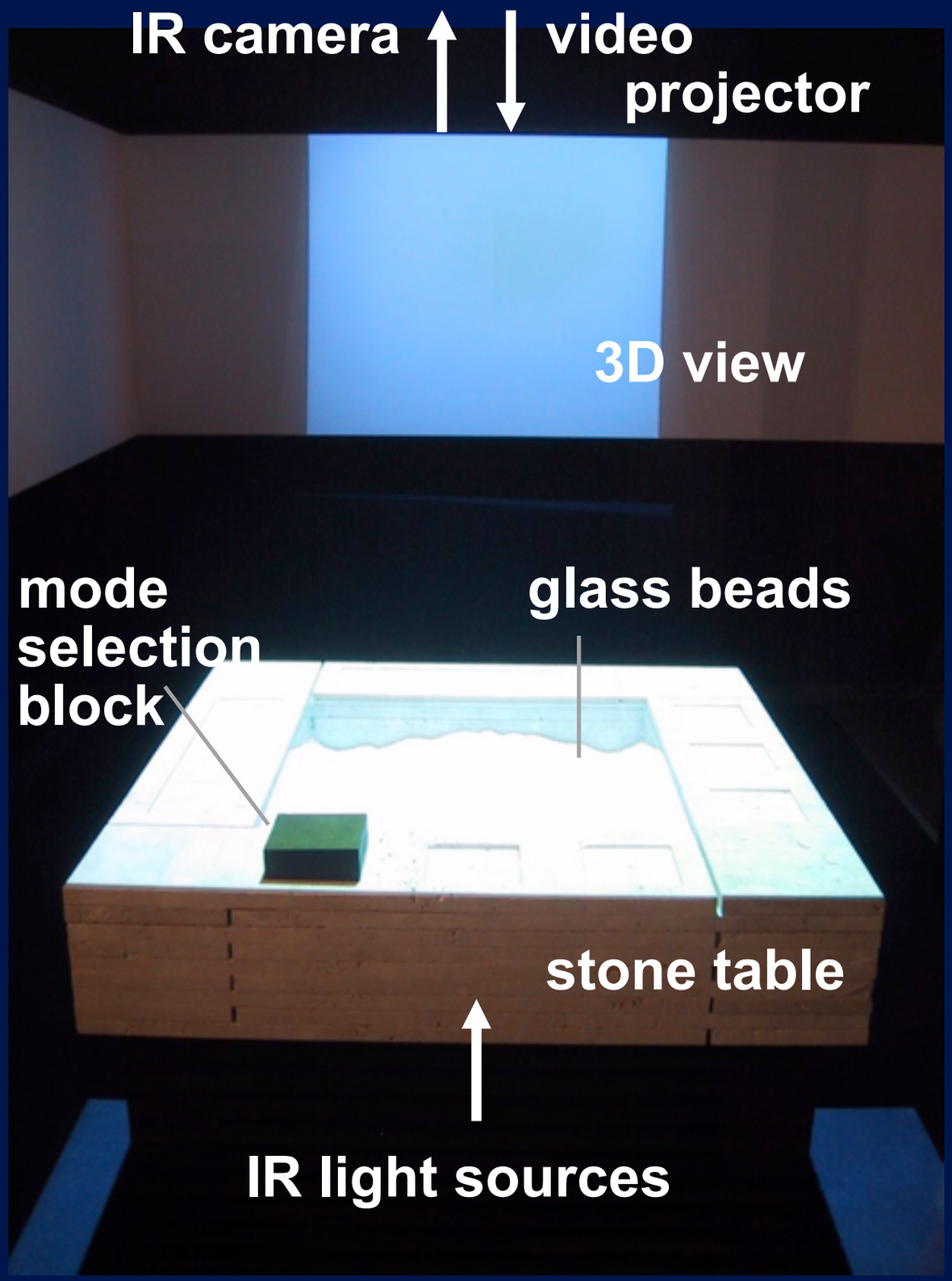


SandScape

Ars Electronica Center



Users can alter the form of the landscape model by manipulating sand while seeing the resultant effects of computational analysis projected on the surface of sand in real-time.



System

A ceiling mounted IR camera captures the radiance of the light passing through the sand model to determine the geometry of the surface.

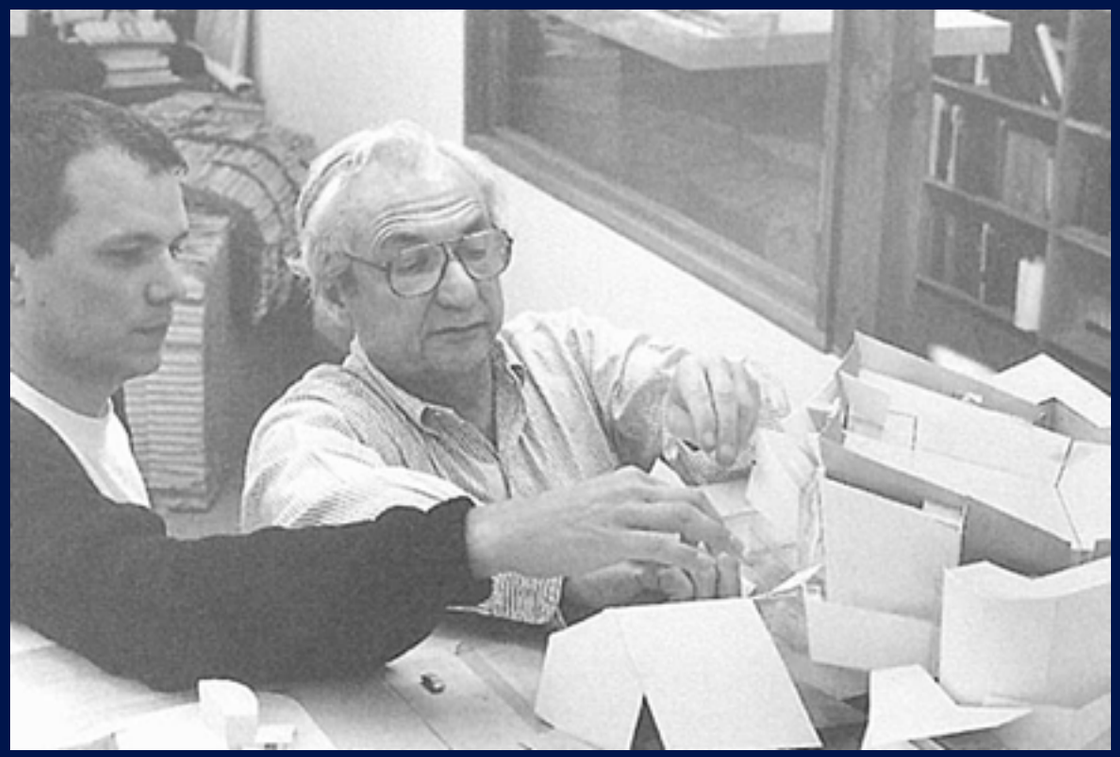
The resulting landscape analysis is projected back on to the surface.

建現

Design Media

Physical Design Media

- Clay
- Cardboard
- Wooden Blocks
- Found Objects



Frank O. Gehry, Architect

Physical Outcomes

Stata Center 2002

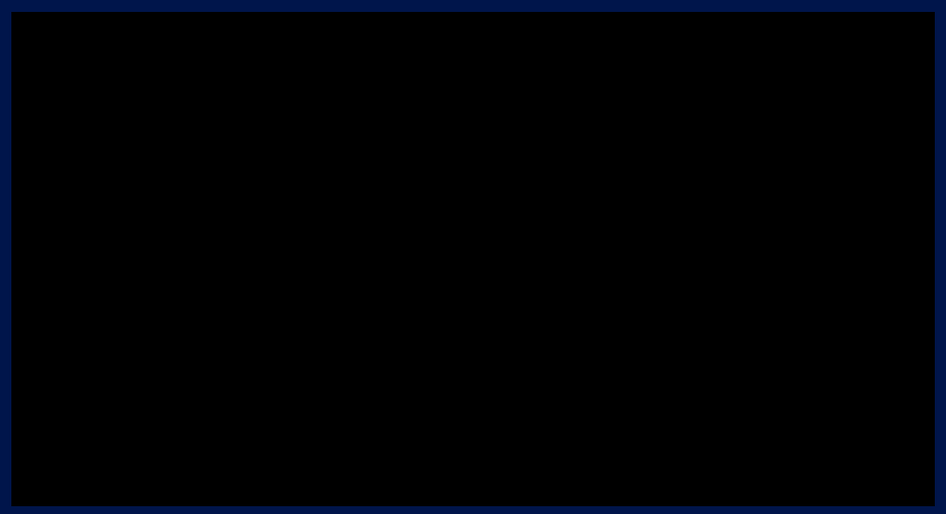
Lack of Continuity Between Physical and Digital Representation in Design

Physical

Ease of manipulation
Clearer communication
Aids spatial understanding

Digital

Greater precision
Easy distribution
Quantitative analysis



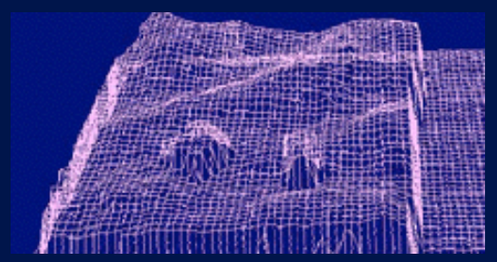
How can we merge these media?

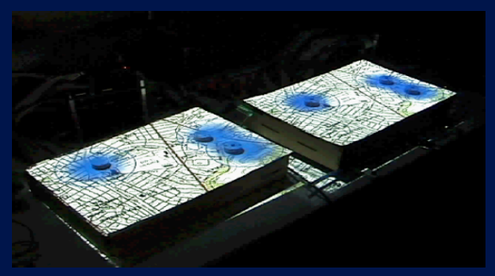
Tangible Design Media for Seamless Form Giving & Computational Reflection

Physical | **Upper Stream** → **Digital** | **Lower Stream**

Rough and rapid form giving with hand for ideation

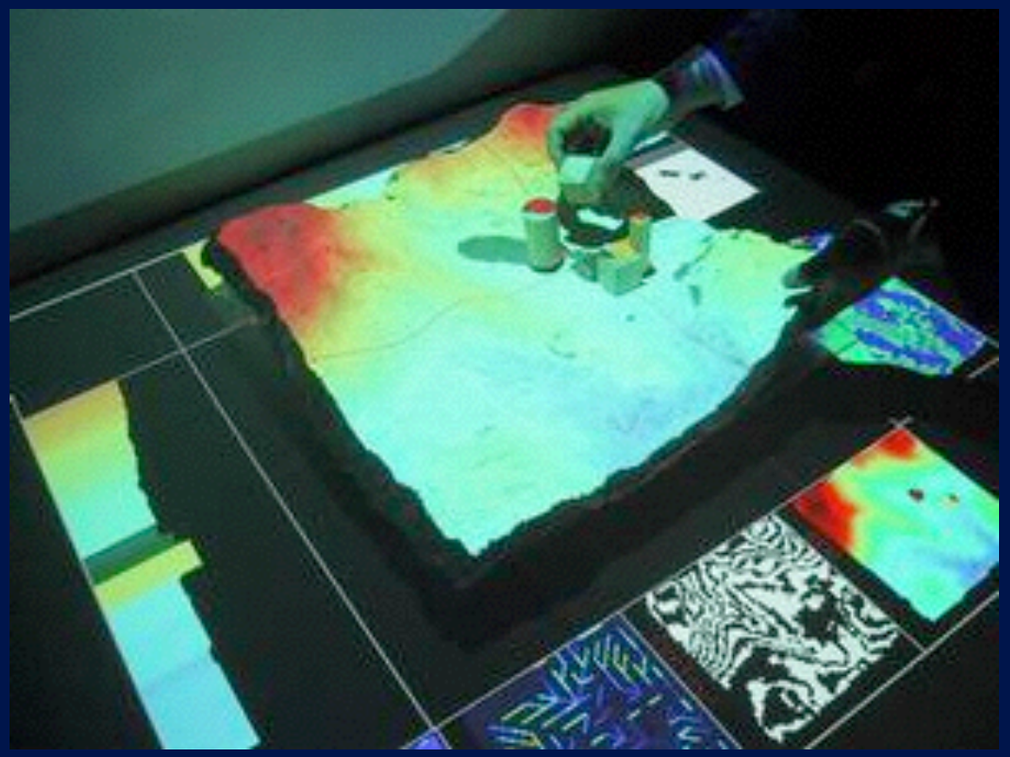
Precise and quantitative computational reflection





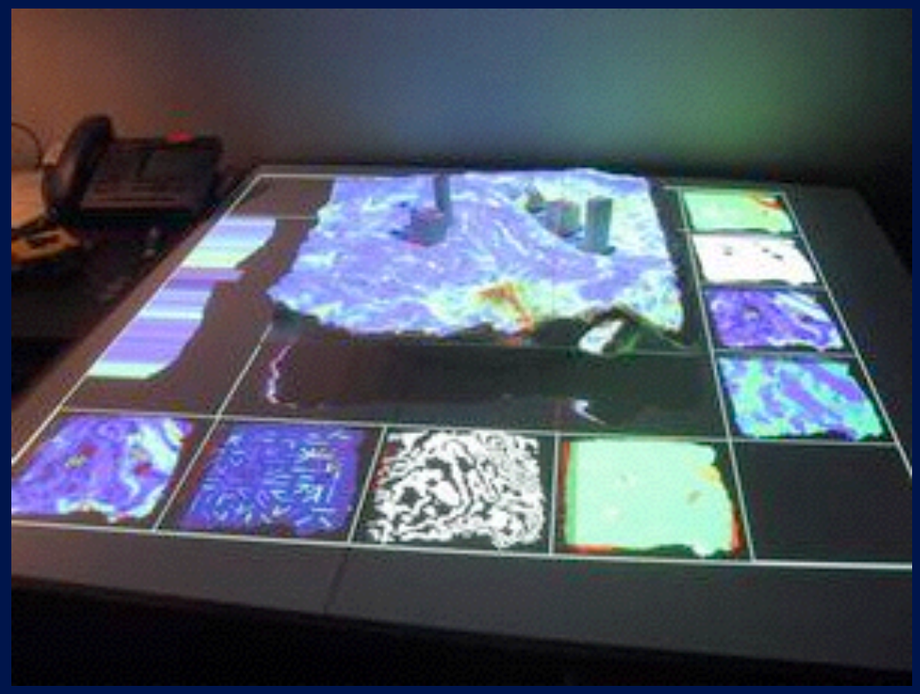
simultaneous form giving + computational reflection

Representation of Idea Matters …



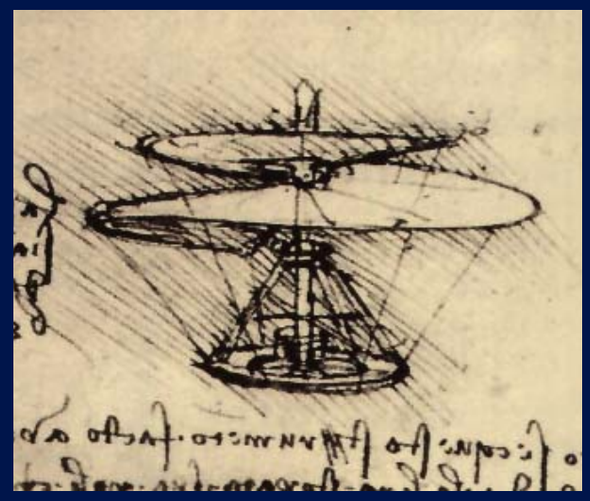
e.g.
- Mathematical representation
- Drawings
- Physical models
- Computational models

… because the mental operations are made possible by the representation.
… GUI/CAD is not for ideation.

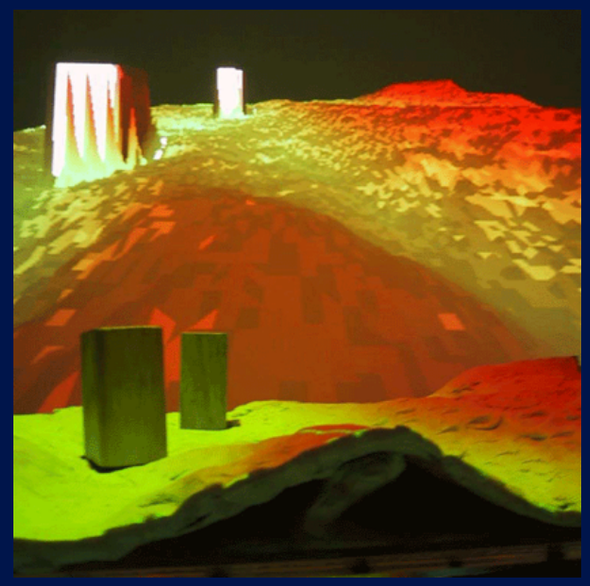


Media for Design Thinking

- **Visual Thinking**
  - **sketch**



- **Tangible Thinking**
  - **tactile manipulation of physical representations coupled with digital computation**
  - **design + analysis**



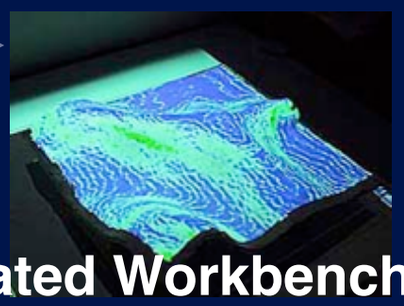
Evolution of Workbench

for Collaborative Design and Tangible Thinking

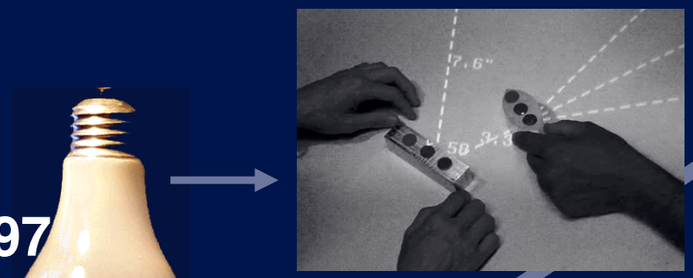
1999
PingPongPlus

2000-02 Sensetable

2001-02
Senseboard

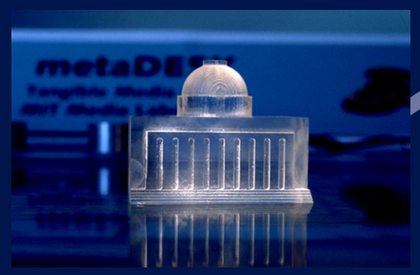


2002
Actuated Workbench

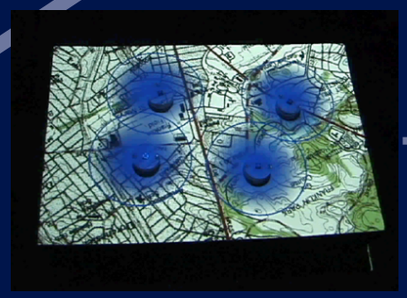


1997-8 Illuminating Light

1997
I/O Bulb

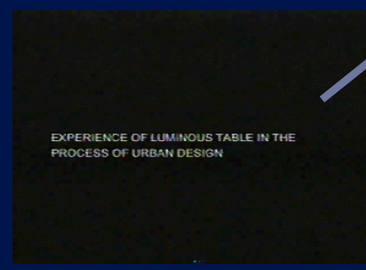


1996-7 metaDESK

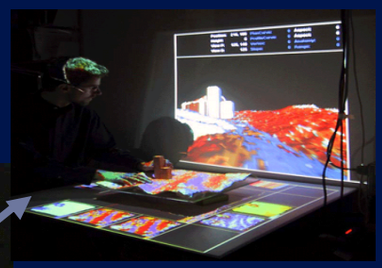


1998-9 Urp

2000-02
Luminous Table



2001-02
Illuminating Clay



2002
SandScape

游

play

PingPongPlus

Ishii, Lee, Wisneski, Orbanes 1999

- **Digital augmentation of ping pong play with "reactive table."**
- **Ball tracking using microphone array underneath table.**
- **From competition to collaboration**

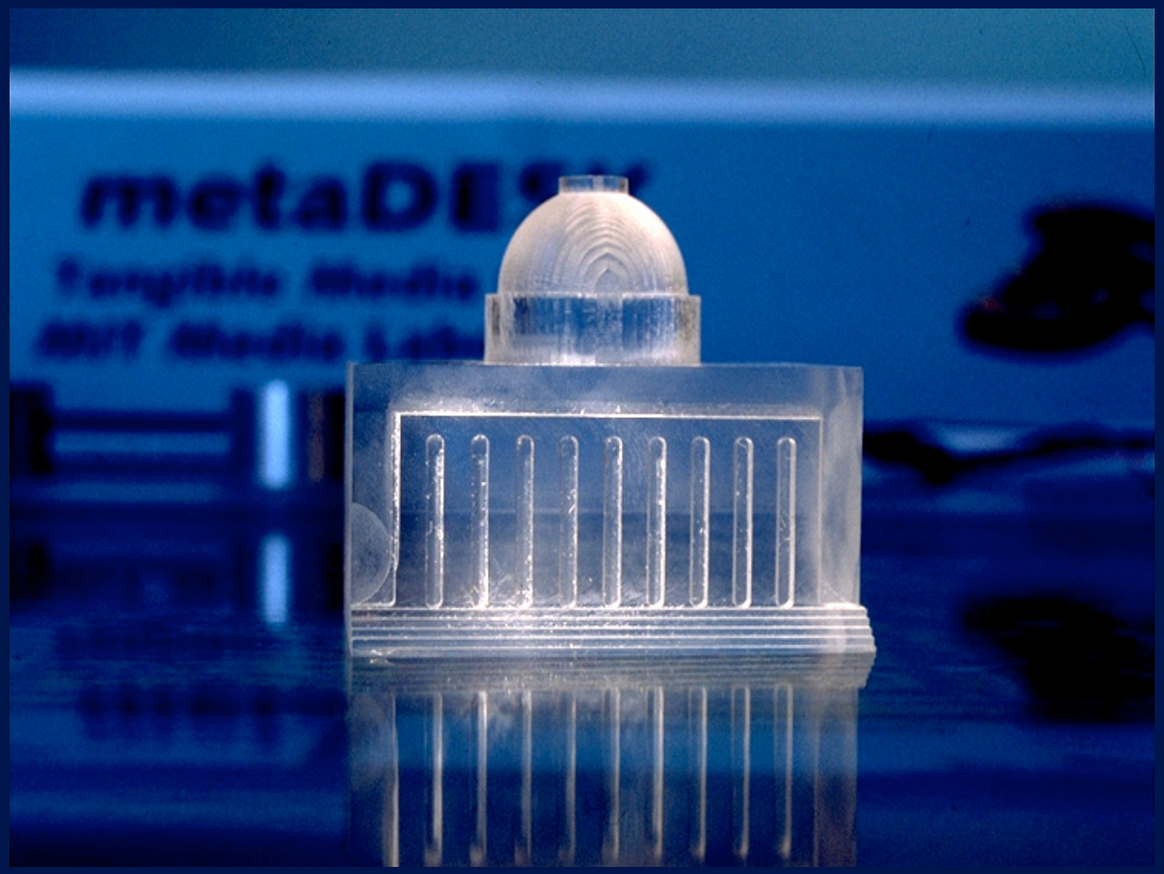
PingPongPlus

Ishii, Lee, Wisneski, Orbanes 1999

- Digital augmentation of ping pong play with "reactive table."
- Ball tracking using microphone array underneath table.
- “From competition to collaboration”

- ICC, Tokyo 2000
- Centre Pompidou, Paris 2003
- Victoria and Albert Museum, London 2005

PingPongPlus at Centre Pompidou, Paris 2003



- Digital augmentation of ping pong play with "reactive table."
- Ball tracking using microphone array underneath table.
- “From competition to collaboration”

Invisible
extension of body - good fit

- customize
- personalize
- adapt
- co-evolve

Visible
center of focus - goal of task

- Critical representation of task
- Ball has to be always visible in the foreground with a table as reference
- You need an interface (paddle) to control the ball

6

augmentation

Augment

Digital Augmentation of Existing Familiar Objects

Principle of Tangible Interface Design

Bottles 99

HandSCAPE 00

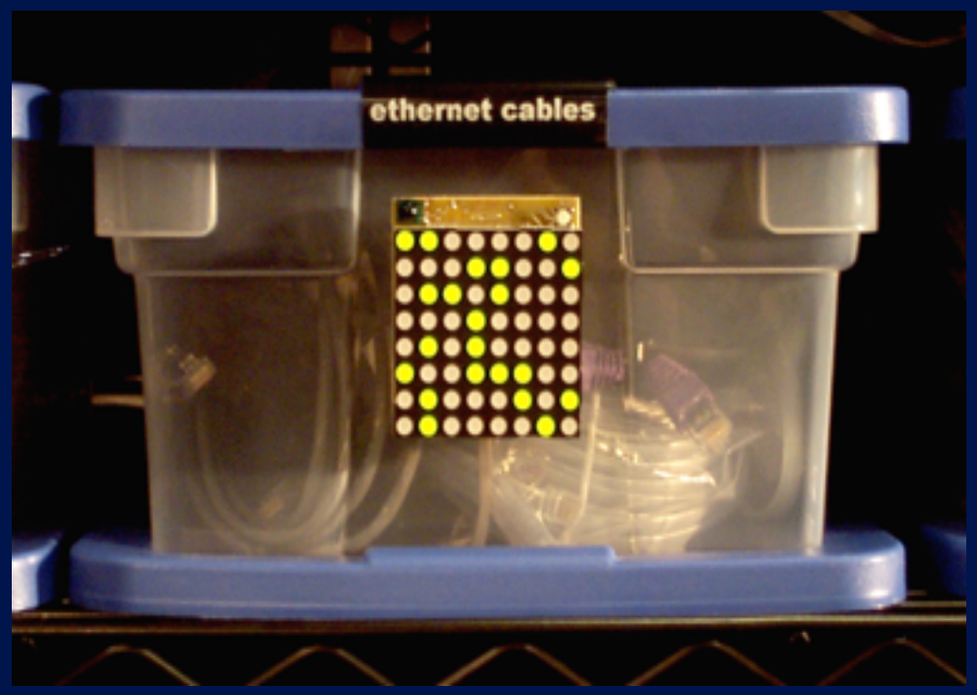
I/O Brush 04

Count

TouchCounters:
Interactive Electronic Labels for Physical Containers (Yarin and Ishii 99)

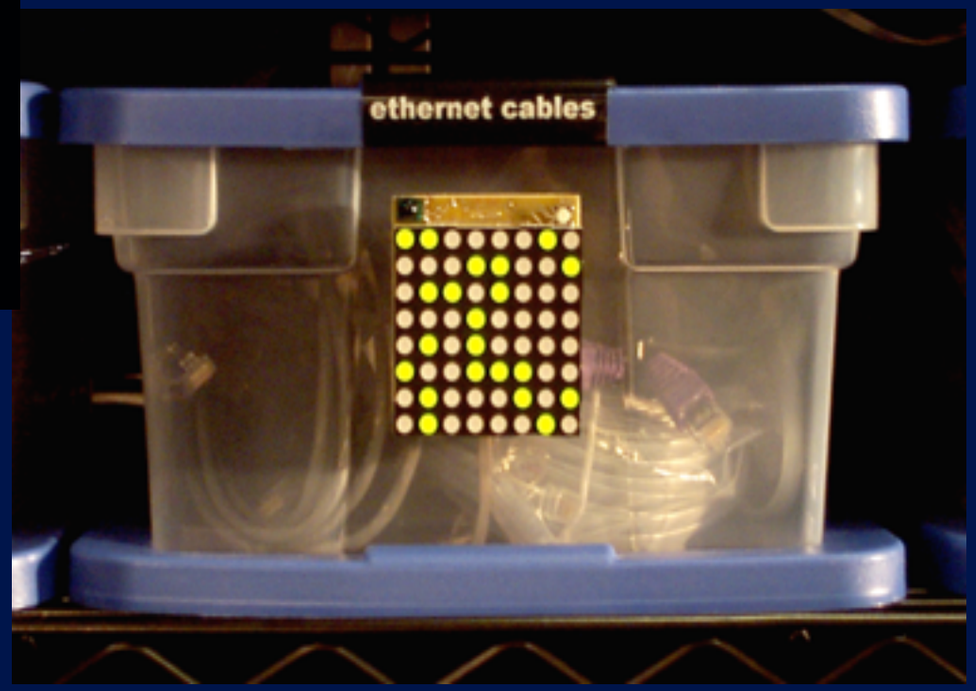
“Distributed visualization of usage history”:

Physical objects and surfaces that display their history of use



TouchCounters:

Interactive Electronic Labels for Physical Containers (Yarin and Ishii 99)



Measure

HandSCAPE 2000

Jay Lee, Victor Su, Hiroshi Ishii

透明

transparent

“The Computer for the 21st Century”

“The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.”

Mark Weiser

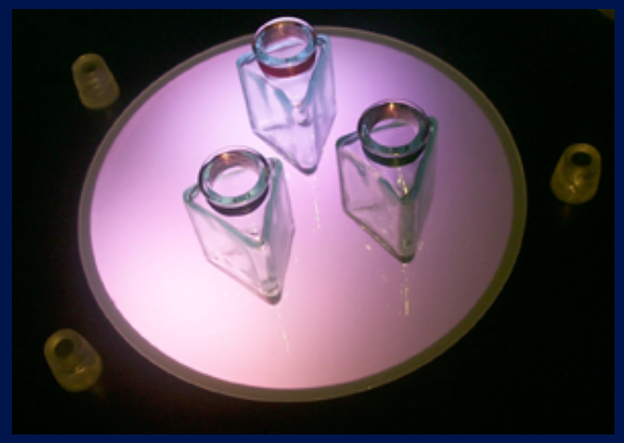
July 23, 1952 - April 27, 1999

musicBottles

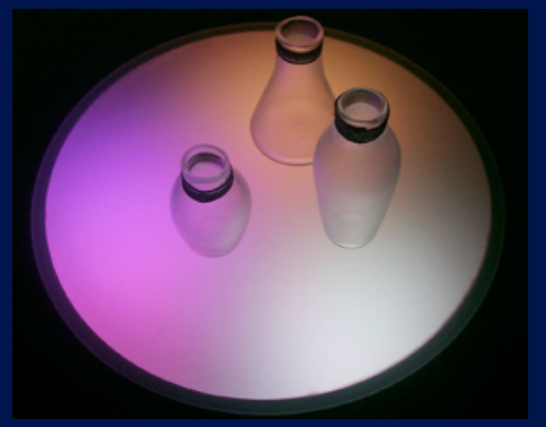
Ishii, Fletcher, Mazalek, Lee, Choo, Berzowska, Paradiso, 98-00

- **Glass bottles as "containers" and "controls" for digital information**
- **Seamless extension of metaphors and physical affordances into the digital domain**

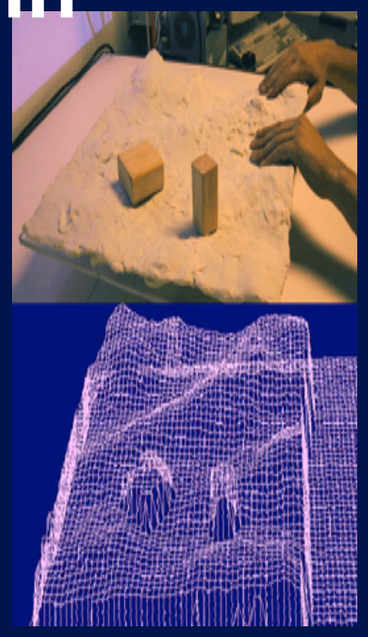
Jazz



Techno



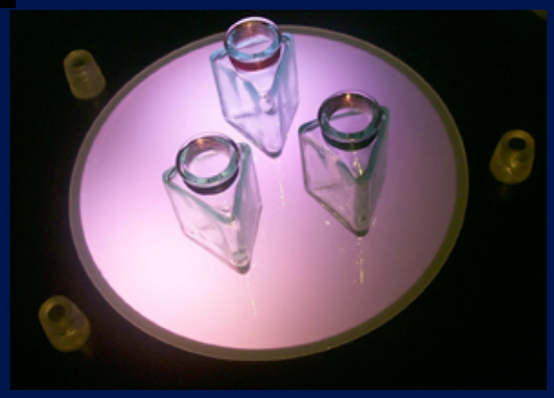
Classical



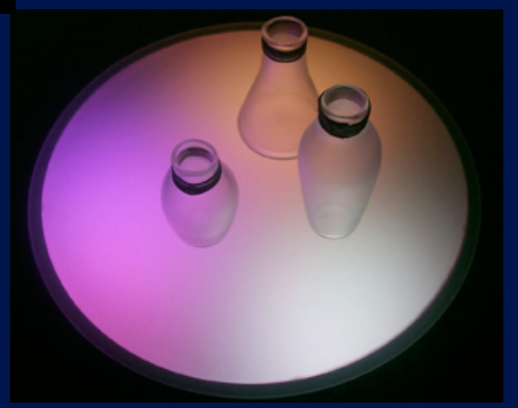
Weather

musicBottles (jazz)

musicBottles (techno)



musicBottles (classical)



Origin: Weather Bottle

present for my mother

soy sauce bottle
in her kitchen

The new standard in medication packaging

GlowCaps™

描

Paint

I/O Brush:
Motivation: Colors Around Kids

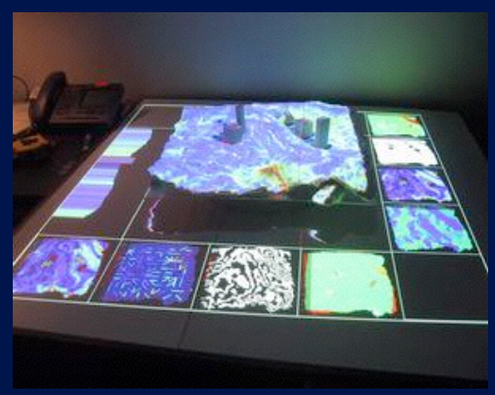
- Appreciating richness of their surrounding colors, textures, and patterns
- Identifying and working with personal material that are meaningful (Papert, 1980; Resnik, et al., 1999)




I/O Brush

Kimiko Ryokai, Stefan Marti, & Hiroshi Ishii

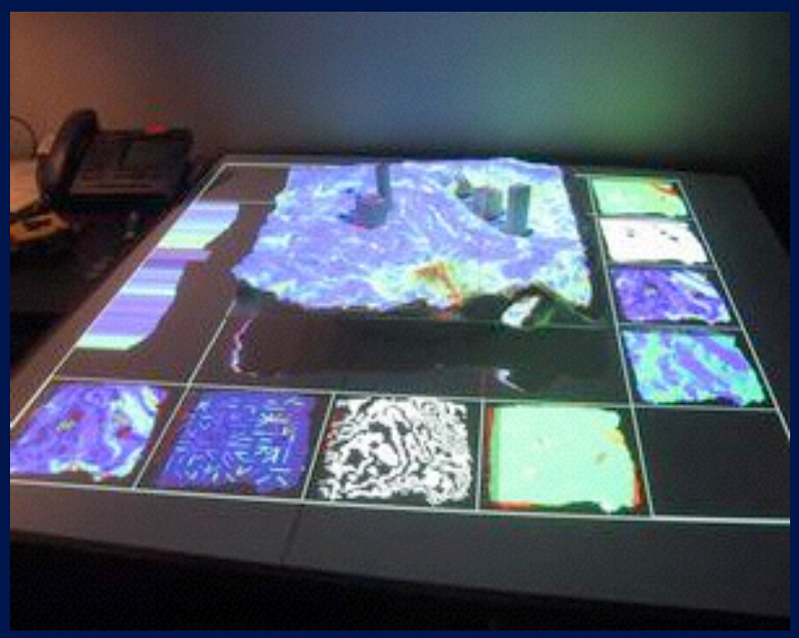
- Explore patterns of colors and textures through familiar materials
- Your environment as a color palette to draw with



I/O Brush

Kimiko Ryokai, Stefan Marti, & Hiroshi Ishii

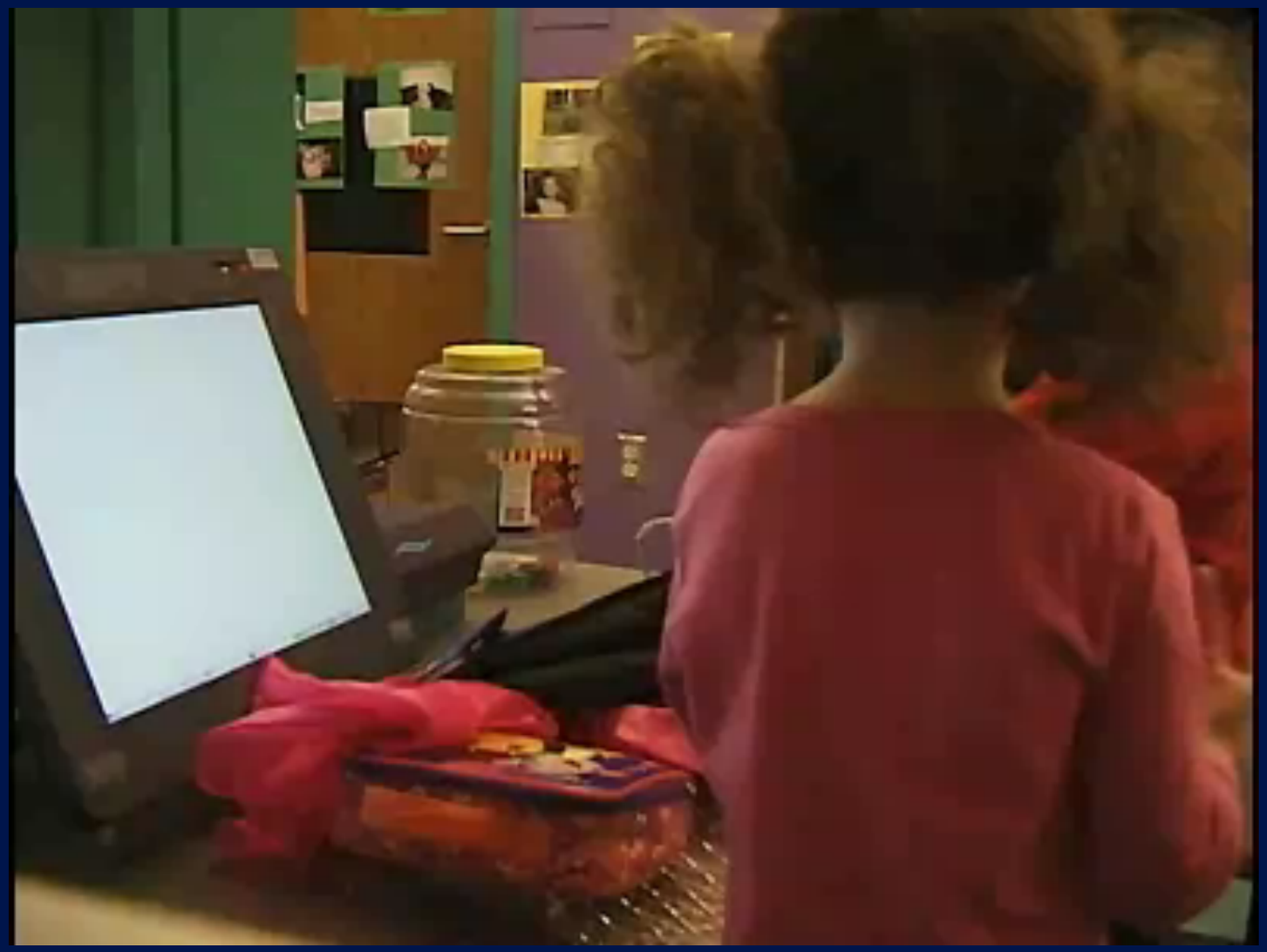
Explore patterns of colors and textures through familiar materials

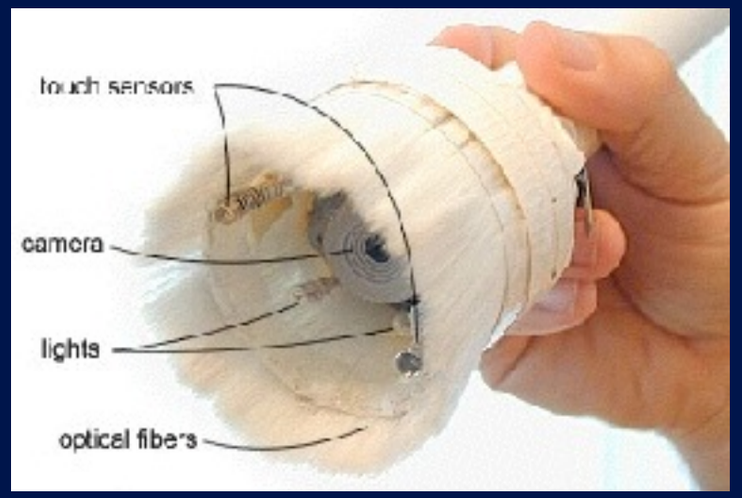


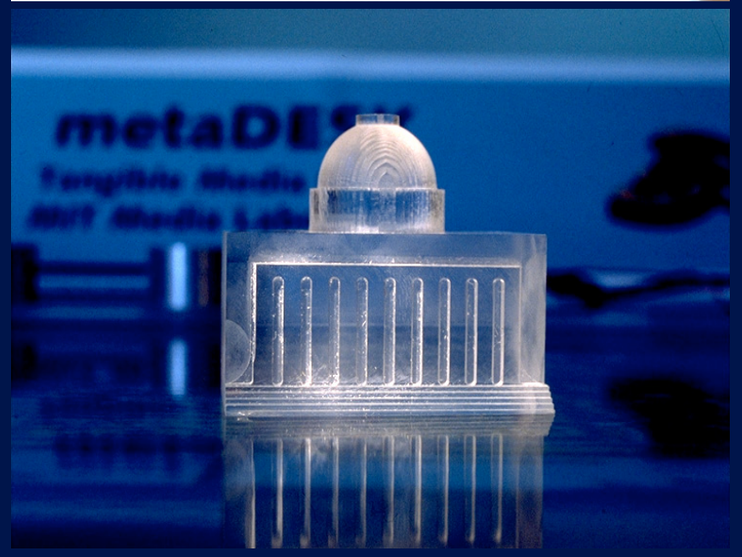
I/O Brush (video)

Kimiko Ryokai, Stefan Marti, & Hiroshi Ishii

- Draw with colors, patterns, and movements







I/O Brush History Mode

Kimiko Ryokai, Stefan Marti, & Hiroshi Ishii

- From where the ink came from?

I/O Brush Exhibition
at the Ars Electronica Center

September 2004 ~ August 2005

The World as the Palette

Colors in Barcelona

7

summary

Tangible Bits

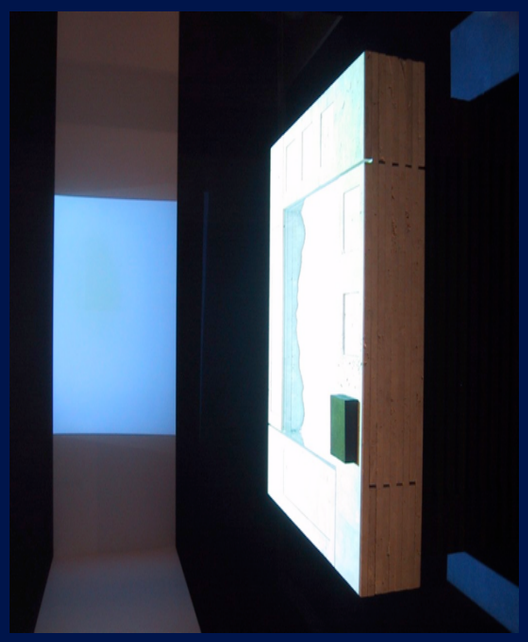
- Giving physical forms to digital information and computation, making bits
  - directly manipulable with two hands
- Continuity between physical and digital representation in design
- Supporting multi-user collaboration and "tangible thinking"

Painted Bits (GUI) and Tangible Bits (TUI)


Xerox Star

Graphical User Interface

- Intangible representation (pixels on a screen) +
- Generic input devices as “remote-controllers”


Urp running on the Sensetable

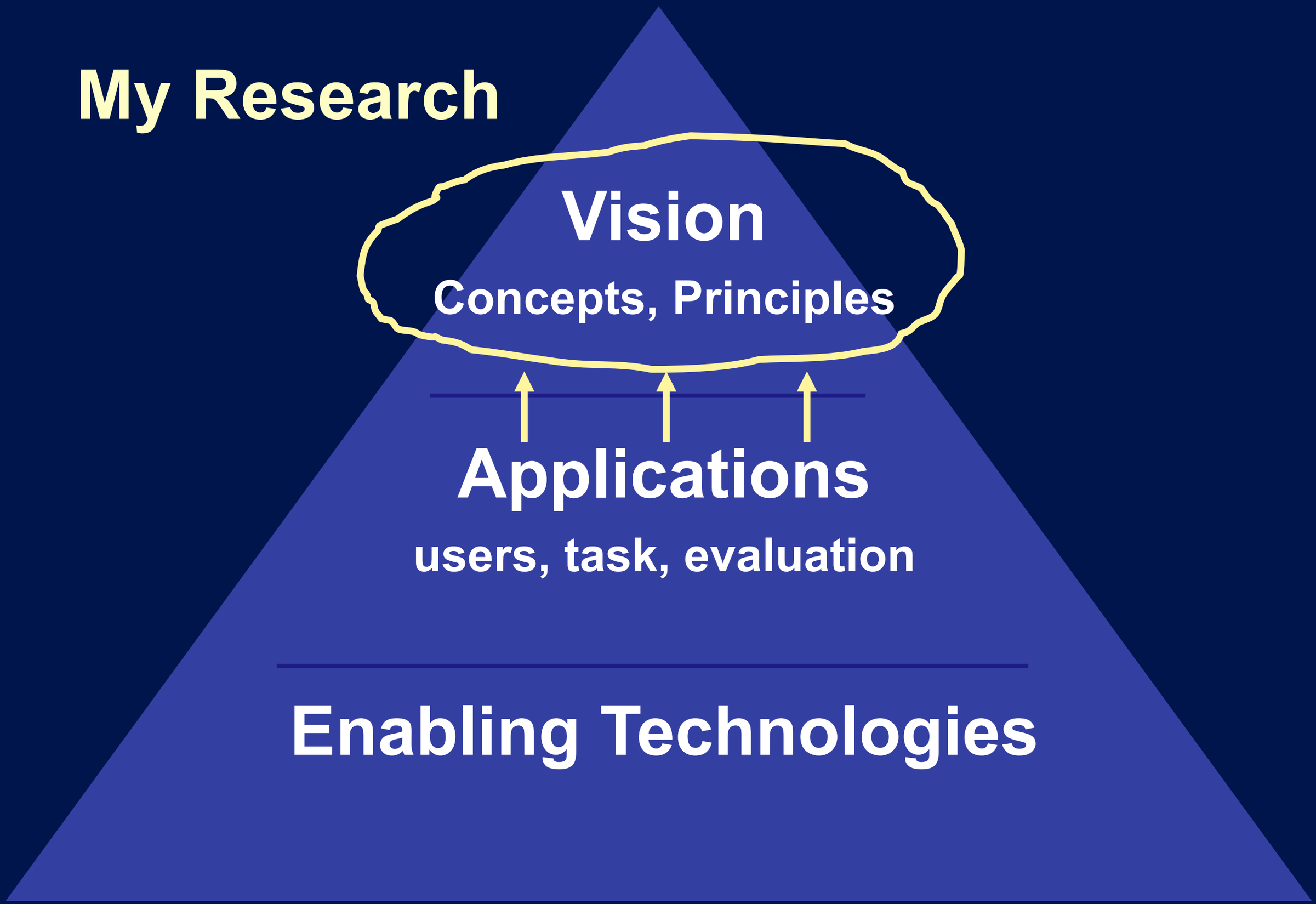
Tangible User Interface

- Tangible representation as interactive control mechanism to manipulate the information and computation
- Continuity between physical and digital representation in design

Tangible Bits

- **Reconciliation of our dual citizenship in the worlds of bits and atoms.**
- **Interaction Design**
  - **informed by sciences (HCI),**
  - **materialized by technologies (CS, EE, ME), and**
  - **shaped by industrial design, media arts and practical real-world applications.**

My Research


Vision
Concepts, Principles
Applications
users, task, evaluation
Enabling Technologies

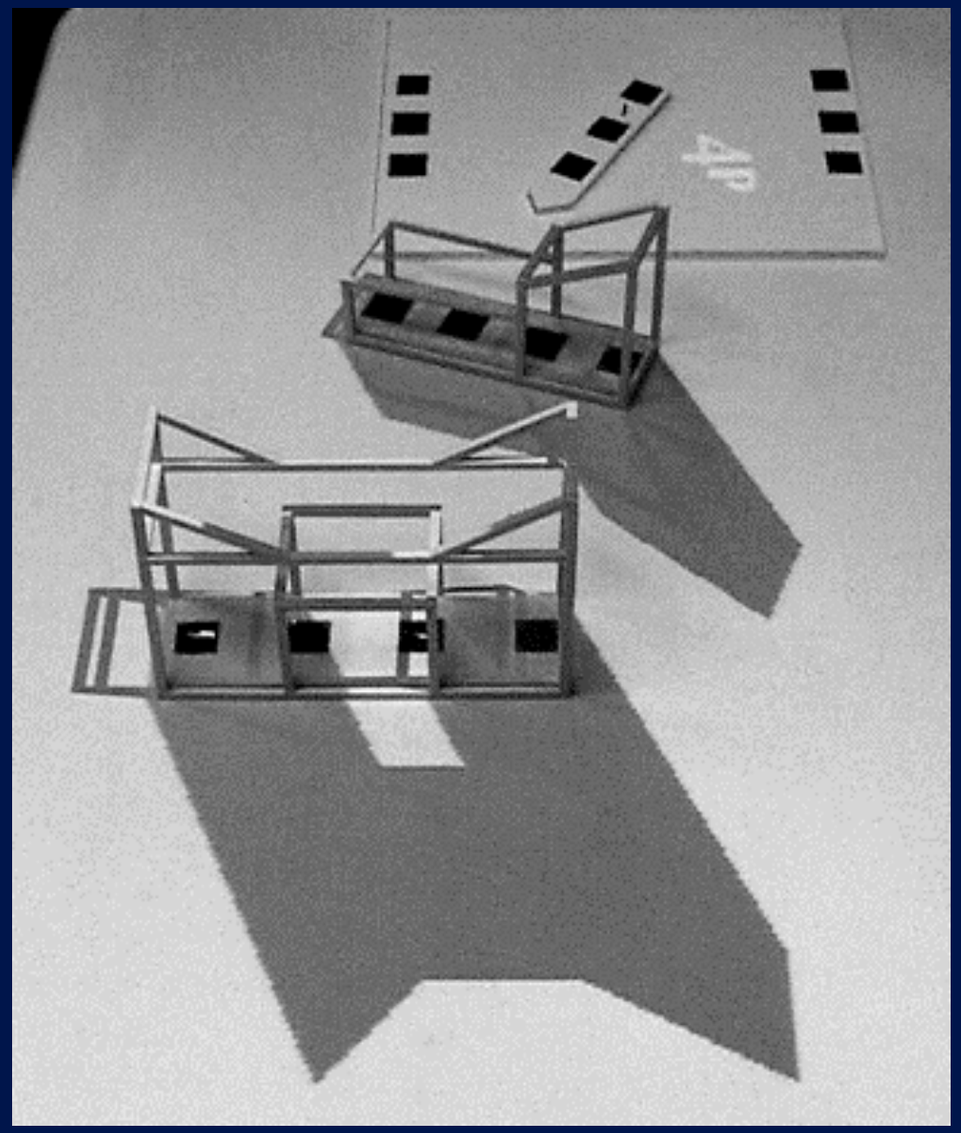
10

future

1997

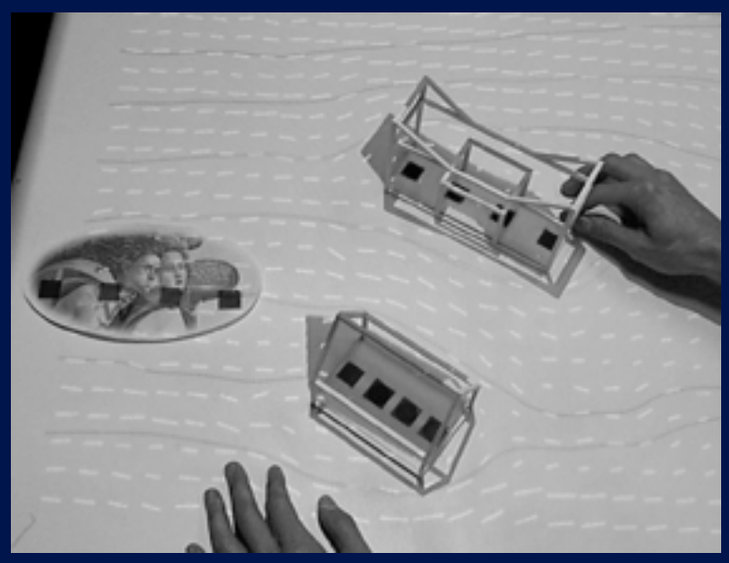
Tangible Bits Debut

Urp:
Urban Planning Workbench (an I/O Bulb AP)
Underkoffler and Ishii, 1997 - 1999



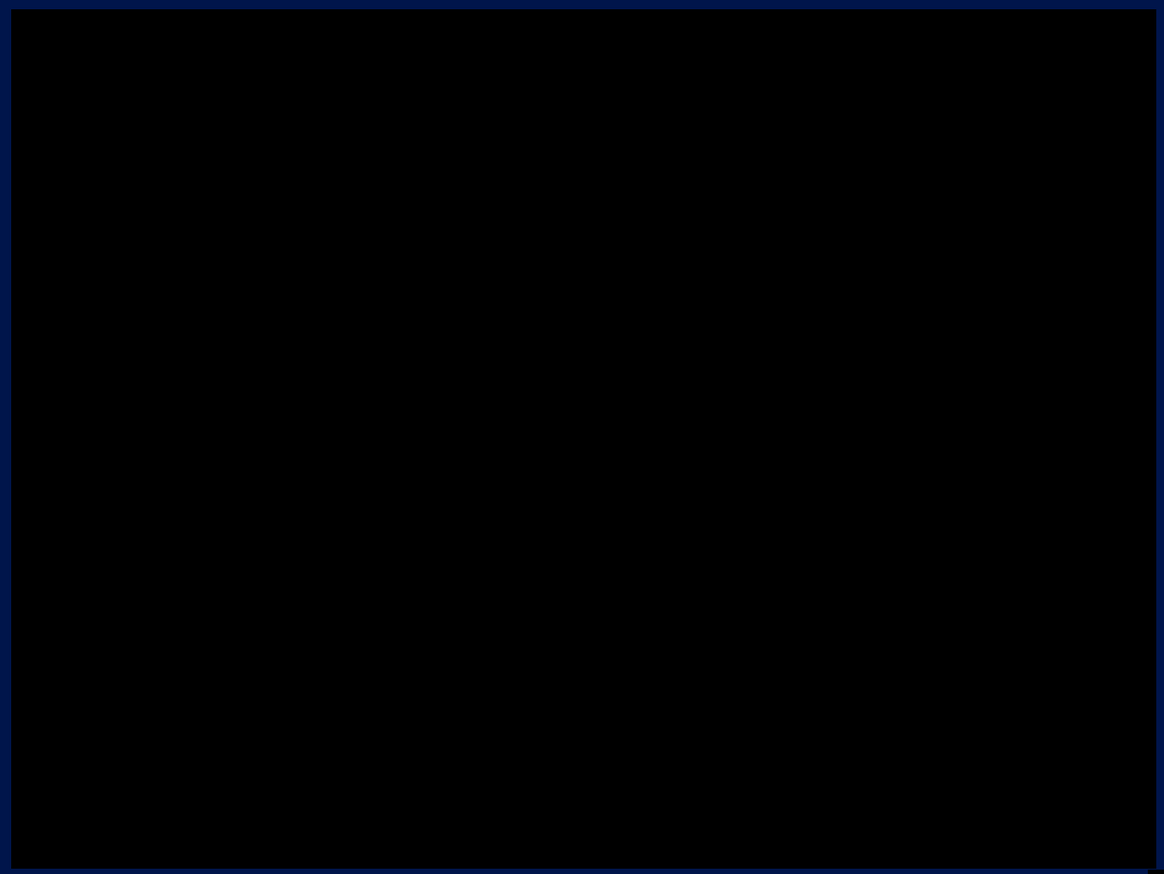
shadows

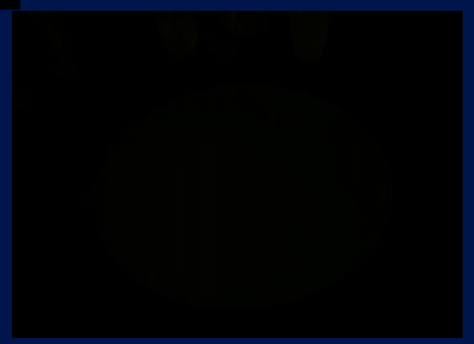
light reflections



wind

Urp:
Urban Planning Workbench
Underkoffler and Ishii, 1997 - 1999





2054

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MINORITY REPORT

AVAILABLE ON DVD & VIDEO

Minority Report

Future

SF

2008

Future is now

G+SPEAK

Gestural Technology

g-speak

Oblong Industries

g-speak

gestural interface for cinematic design

John Underkoffler, Oblong Industries

Future is not to predict, but to invent. Alan Kay

MIT Media Lab
http://www.media.mit.edu

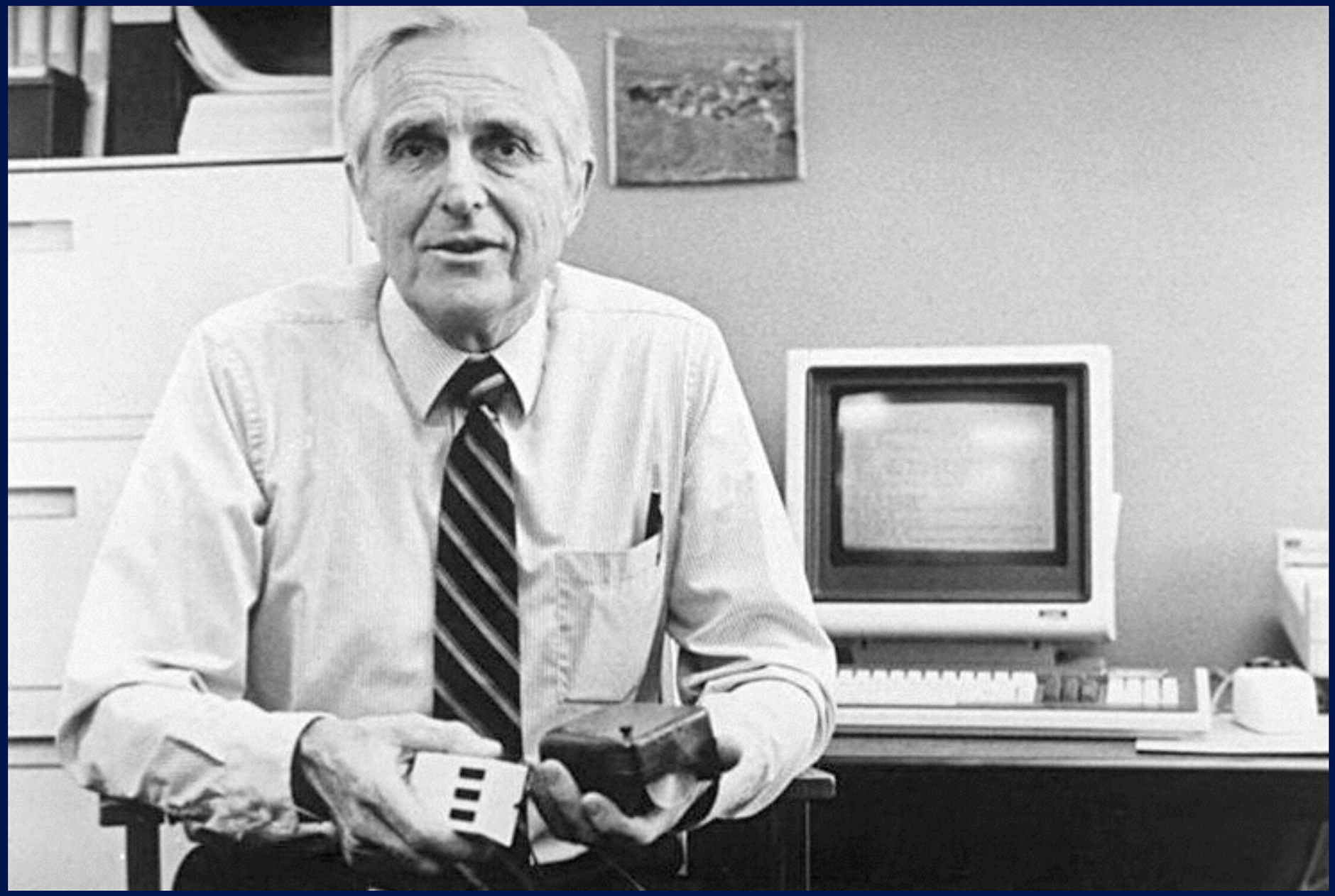
The Future is Already Here - It's Just Not Evenly Distributed.

William Gibson

11

message

Douglas Engelbart
Augmenting Human Intellect



1968

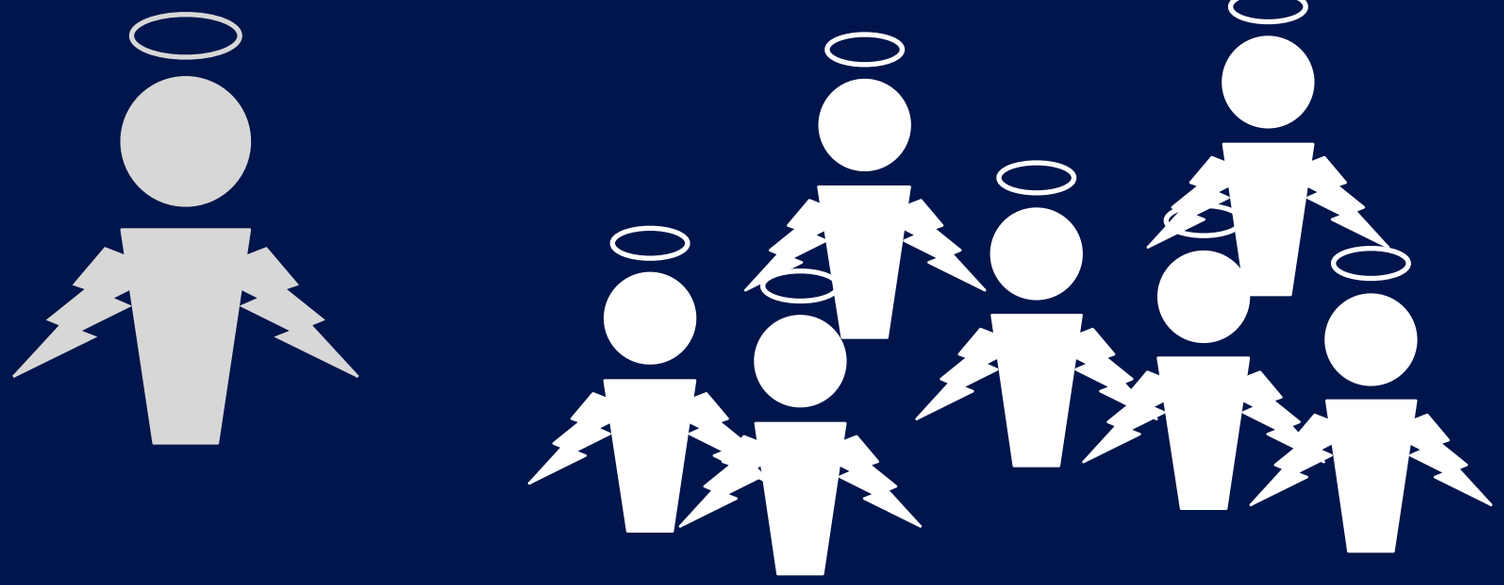
December 9th, 1968

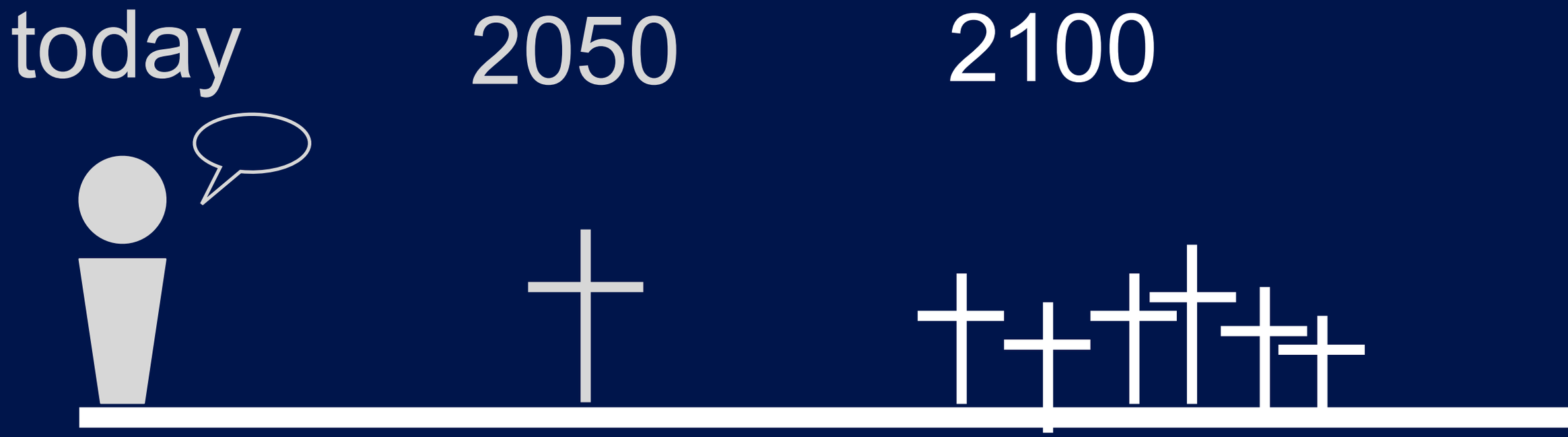
NLS (oN-Line System) demo at FJCC 68 in San Francisco

Today

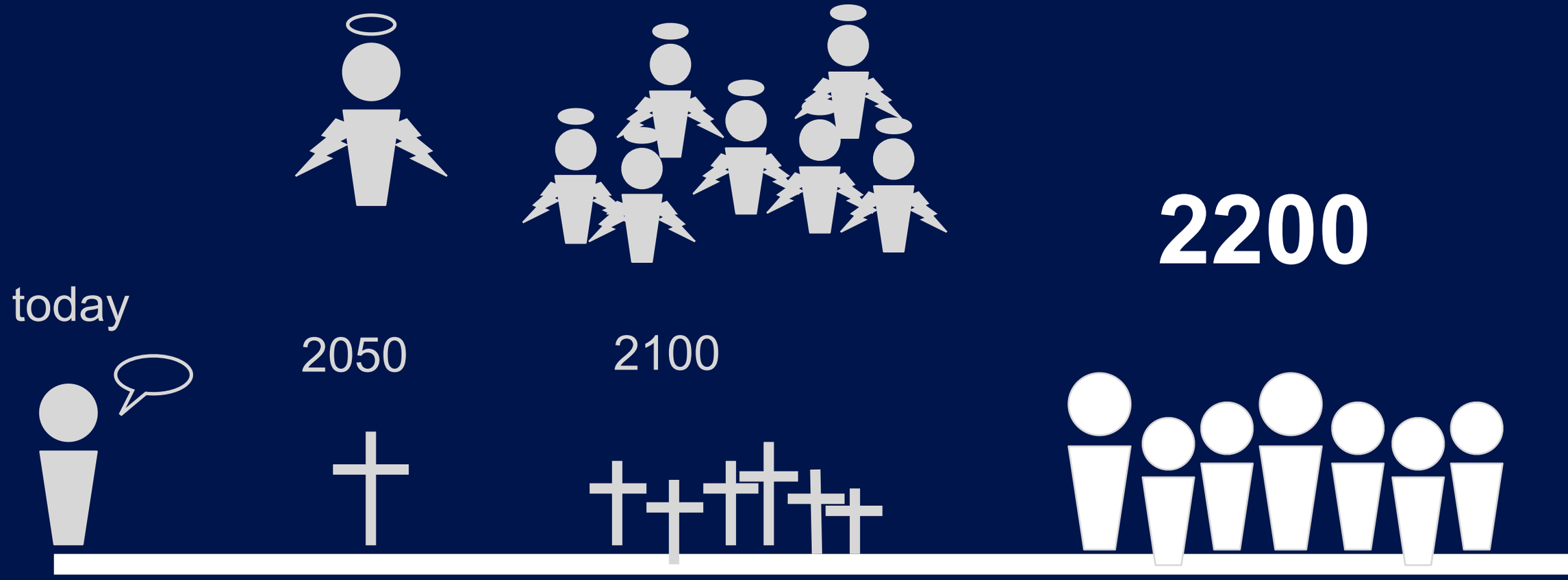
2050

2100

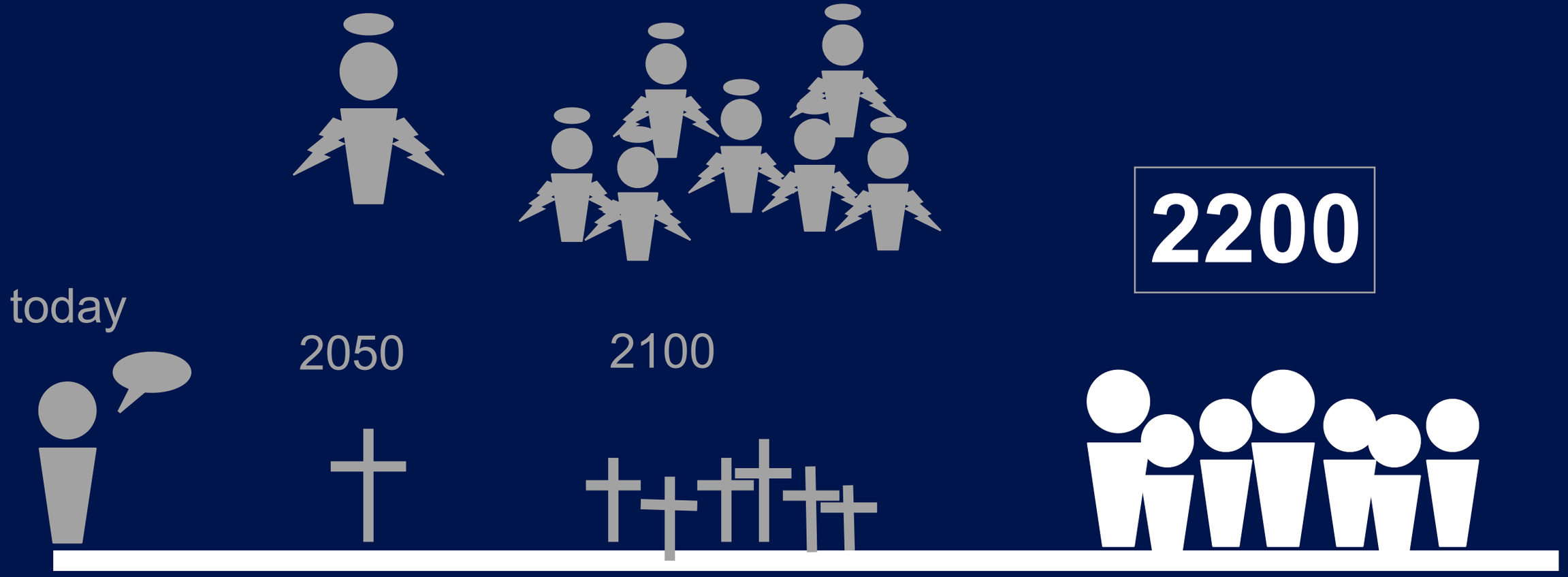




2200



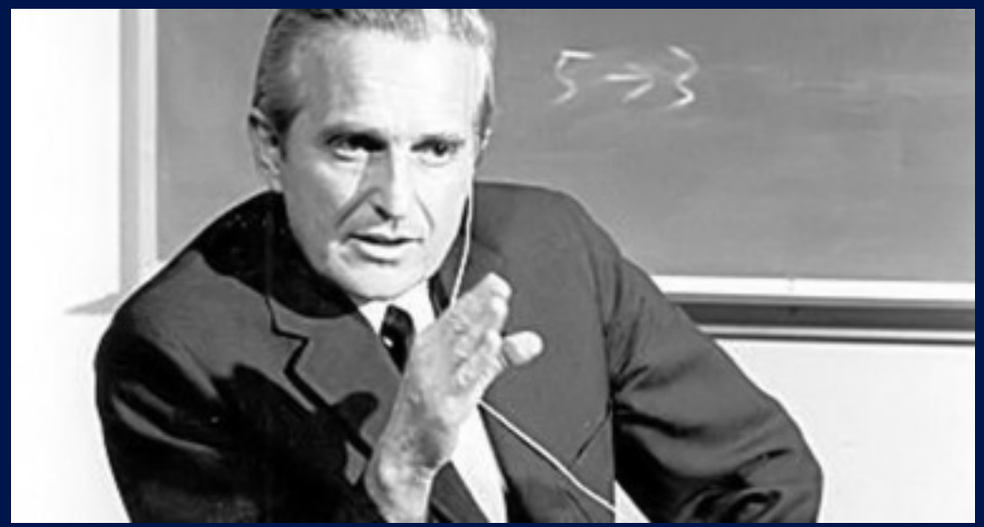
How do you want to be remembered by people living in 2200? What will you leave for them?



未来

Future

“Augmenting Human Intellect”
Douglas Engelbart



In the early 1950s, Douglas Engelbart
was struck with the notion of using computers as thinking tools
to augment the mind, ideas influenced by Vannevar Bush.

After six years of work at the Augmentation Research Center (ARC) at the SRI, he created the world's first interactive information system, NLS (oN Line System).

“The Computer for the 21st Century”

“The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.”

Mark Weiser

July 23, 1952 - April 27, 1999

1997

January 26, 1997

A message from Mark Weiser (Xerox PARC)

March 22-27, 1997

“Tangible Bits” paper presented at CHI ‘97 in Atlanta

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Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms

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ABSTRACT
This paper presents our vision of Human Computer Interaction (HCI): "Tangible Bits." Tangible Bits allows users to "grasp & manipulate" bits in the center of users' attention by coupling the bits with everyday physical objects and architectural surfaces. Tangible Bits also enables users to be aware of background bits at the periphery of human perception using ambient display media such as light, sound, airflow, and water movement in an augmented space. The goal of Tangible Bits is to bridge the gaps between both cyberspace and the physical environment, as well as the foreground and background of human activities.

This paper describes three key concepts of Tangible Bits: interactive surfaces; the coupling of bits with graspable physical objects; and ambient media for background awareness. We illustrate these concepts with three prototype systems – the metaDESK, transBOARD and ambientROOM – to identify underlying research issues.

Keywords
tangible user interface, ambient media, graspable user interface, augmented reality, ubiquitous computing, center and periphery, foreground and background

INTRODUCTION: FROM THE MUSEUM
Long before the invention of personal computers, our ancestors developed a variety of specialized physical artifacts to measure the passage of time, to predict the movement of planets, to draw geometric shapes, and to compute [10]. We can find these beautiful artifacts made of oak and brass in museums such as the Collection of Historic Scientific Instruments at Harvard University (Fig. 1).

We were inspired by the aesthetics and rich affordances of these historical scientific instruments, most of which have disappeared from schools, laboratories, and design studios and have been replaced with the most general of appliances: personal computers. Through grasping and manipulating these instruments, users of the past must have developed rich languages and cultures which valued haptic interaction with real physical objects. Alas, much of this richness has been lost to the rapid flood of digital technologies.

We began our investigation of "looking to the future of HCI" at this museum by looking for what we have lost with the advent of personal computers. Our intention was to rejoin the richness of the physical world in HCI.

BITS & ATOMS
We live between two realms: our physical environment and cyberspace. Despite our dual citizenship, the absence of seamless couplings between these parallel existences leaves a great divide between the worlds of bits and atoms. At the present, we are torn between these parallel but disjoint spaces.

Figure 1 Sketches made at Collection of Historical Scientific Instruments at Harvard University

We are now almost constantly "wired" so that we can be here (physical space) and there (cyberspace) simultaneously [14]. Streams of bits leak out of cyberspace through a myriad of rectangular screens into the physical world as photon beams. However, the interactions between people and cyberspace are now largely confined to traditional GUI (Graphical User Interface)-based boxes sitting on desktops or laptops. The interactions with these GUIs are separated from the ordinary physical environment within which we live and interact.

Although we have developed various skills and work practices for processing information through haptic interactions with physical objects (e.g., scribbling messages on Post-It™ notes and spatially manipulating them on a wall) as well as peripheral senses (e.g., being aware of a change in weather through ambient light), most of these practices are neglected in current HCI design because of the lack of diversity of input/output media, and too much bias towards graphical output at the expense of input from the real world [3].

Outline of This Paper
To look towards the future of HCI, this paper will present our vision of Tangible Bits and introduce design projects including the metaDESK, transBOARD and ambientROOM systems to illustrate our key concepts. This paper is not intended to propose a solution to any one single problem. Rather, we will propose a new view of interface and raise a set of new research questions to go beyond GUI.

FROM DESKTOP TO PHYSICAL ENVIRONMENT
In 1981, the Xerox Star workstation set the stage for the first generation of GUI [16], establishing a "desktop metaphor" which simulates a desktop on a bit-mapped

Weiser's message

Date: Sun, 26 Jan 1997 23:34:10 PST

To: ishii@media.mit.edu, ullmer@media.mit.edu

From: Mark Weiser <weiser@xerox.com>

Subject: "Tangible Bits"

Dear Hiroshi and Brygg,

I recently had a chance to read your CHI 97 paper "Tangible Bits"!

Great work! In my opinion this is the kind of work that will characterize

the technological landscape in the twenty-first century.

I do have a request. As a former professor with tenure I well understand

the need to distinguish one's work from all that comes before. And I very much

appreciate your kind acknowledgement to me. Thanks! My request is that you

help me stop the spread of misunderstanding of ubiquitous computing based

simply on its name. Ubicomp was never just about making "computers"

ubiquitous. It was always, like your work, about awakening computation

mediation into the environment. The Tabs, Pads, and Boards were simply a

way to break out of the mold while still engaging traditional computer

scientists -- although sponsoring Natalie to work on the String turned out

to be as important as any of them!

I tried to stop using ubiquitous computing because of its misleading

implication, but it keeps cropping up again, so I keep returning to it as my

umbrella name for lots of work, including Things That Think. Augmented

reality was in use for awhile, but again got balkanized in meaning. I have

started to talk about Calm Technology as a theme, but it better names a goal

than a research project. "Tangible Bits" is very nice, and maybe could

serve as an overall umbrella, but then you might lose it as the name of your

research project! I think we would all benefit if we could have an

Weiser's message (part 1)

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Weiser’s message (part 2)

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To: ishii@media.mit.edu, ullmer@media.mit.edu
From: Mark Weiser <weiser@xerox.com>
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Weiser’s message (part 3)

Date: Sun, 26 Jan 1997 23:34:10 PST
To: ishii@media.mit.edu, ullmer@media.mit.edu
From: Mark Weiser <weiser@xerox.com>
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"Tangible Bits" is very nice, and maybe could serve as an overall umbrella, but then you might lose it as the name of your research project! I think we would all benefit if we could have an allegiance to some one common thing, and define our differences within that. But we struggle with what to call that allegiance.

Weiser’s message (part 4)

Date: Sun, 26 Jan 1997 23:34:10 PST
To: ishii@media.mit.edu, ullmer@media.mit.edu
From: Mark Weiser <weiser@xerox.com>
Subject: "Tangible Bits"

Anyway, great work, and I hope to visit soon and have some good chats now that Xerox has joined the Media Lab (and I am one of the two official Xerox liasons).

-mark

(Dr.) Mark Weiser
Chief Technologist, Xerox PARC
phone: 415-812-4406 fax: 415-812-4471
email: weiser@xerox.com info: www.ubiq.com/weiser