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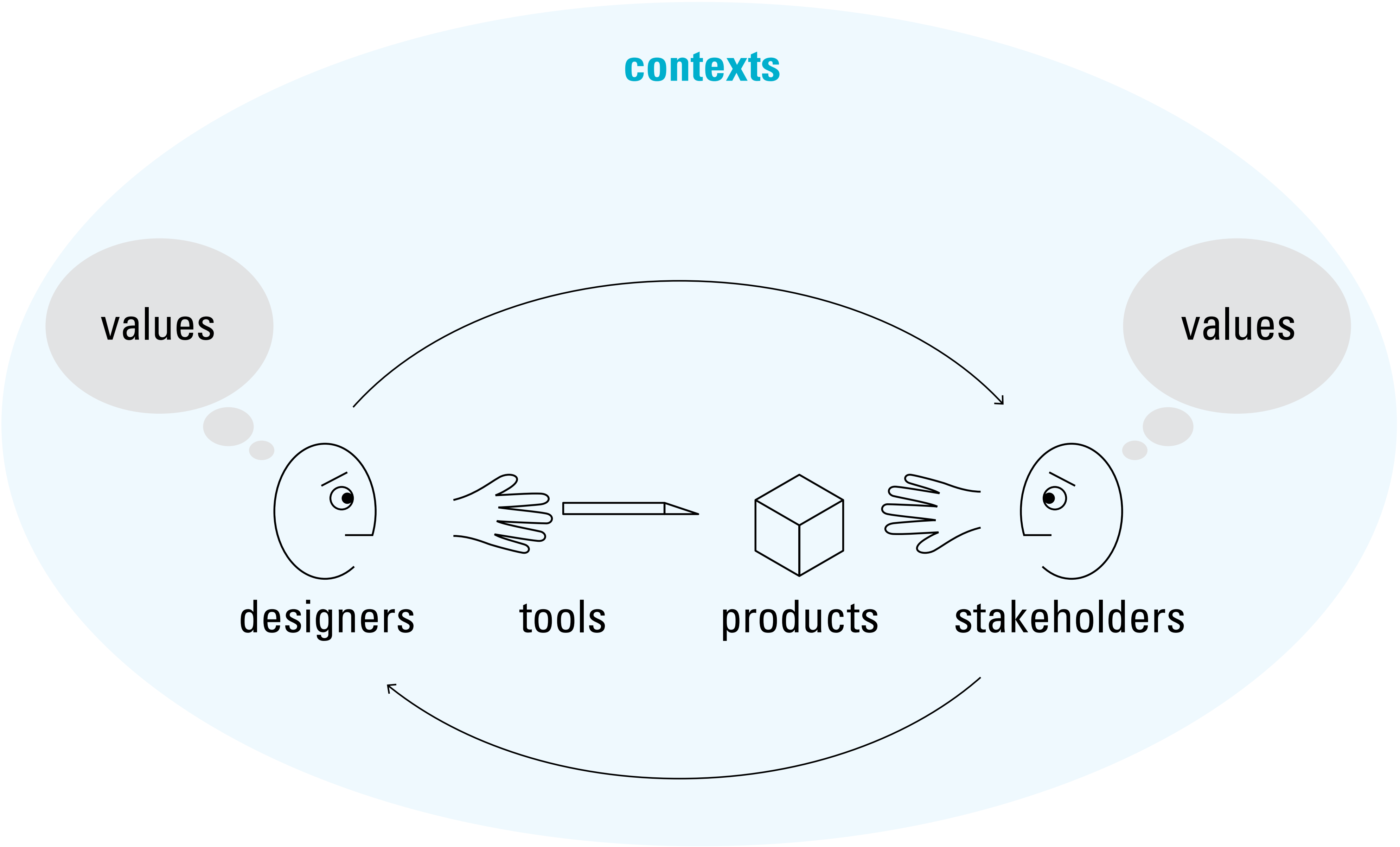
How the Data Economy is Changing Design Practice

Hugh Dubberly
Dubberly Design Office

Presentation posted at
http://presentations.dubberly.com/IDEEC_SJSU.pdf

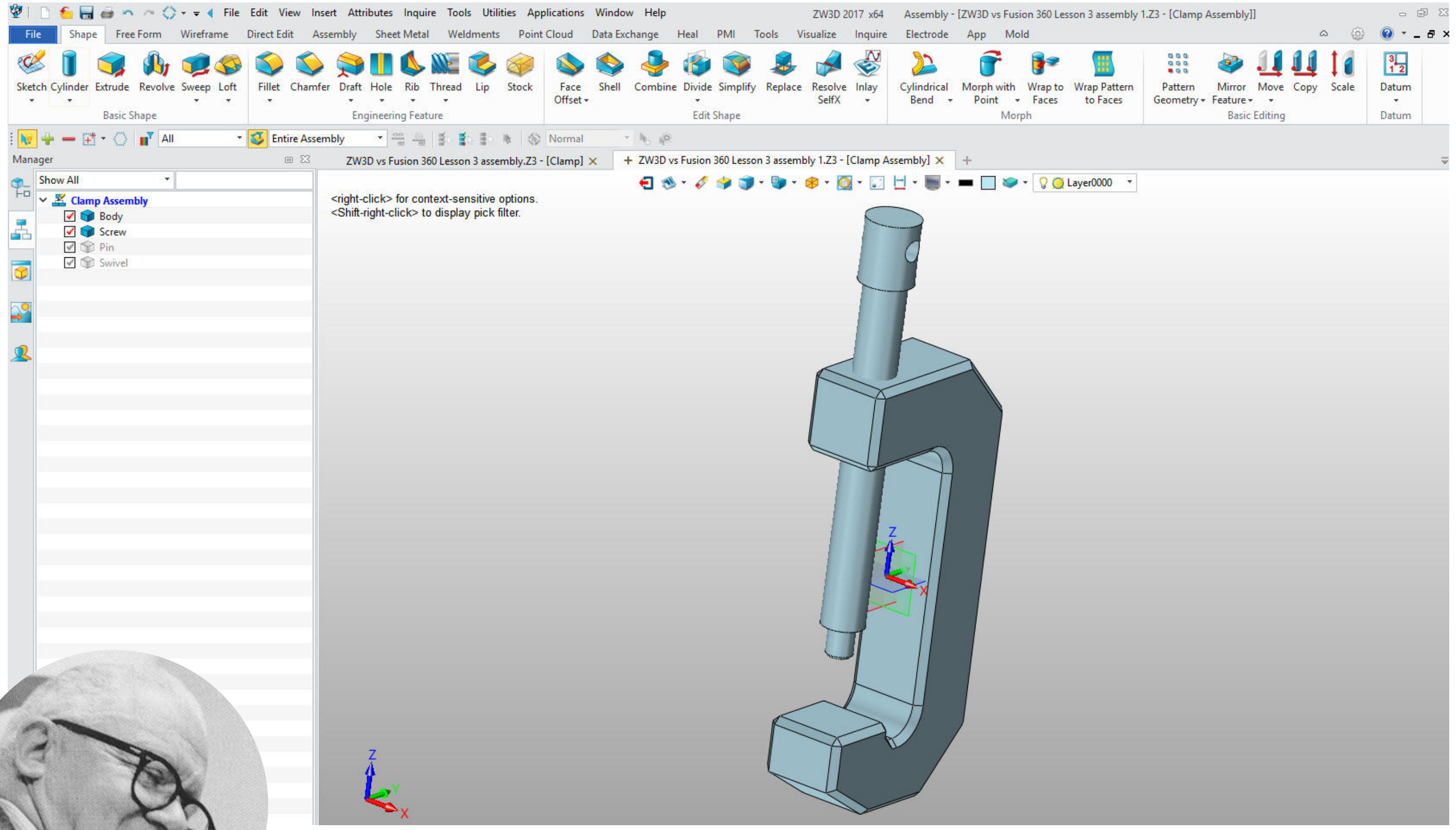
Design practice is continually evolving.

- **What** we design —
  the “**product**” of designing
- **How** we design —
  the **methods** which entail designing and the **tools** used in designing
- **Who** designs —
  stakeholders: producers, consumers, sponsors, and others
- **Why** we design —
  goals, **values**, language
- **Where** we design —
  the **context** of designing

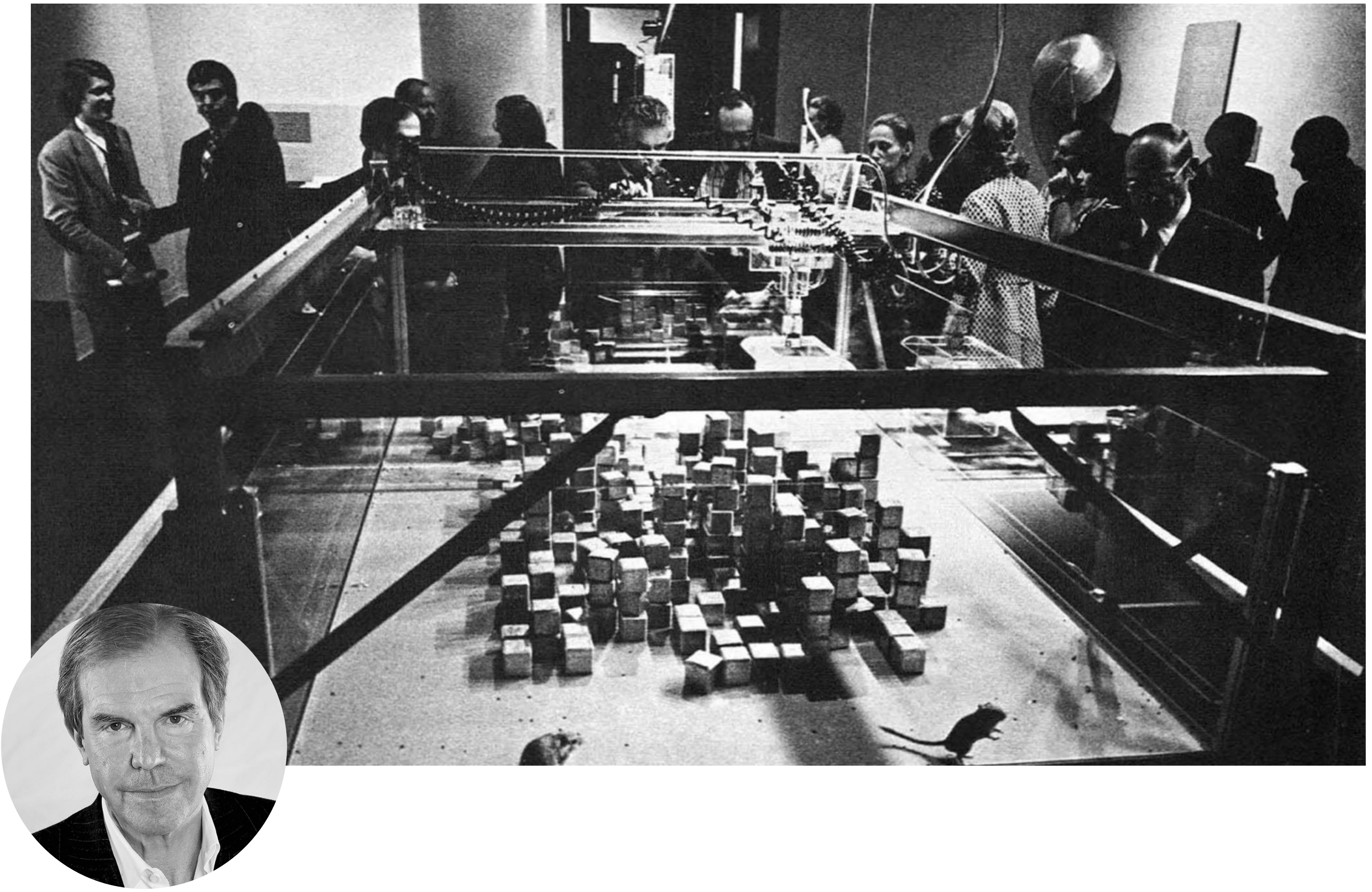


In the last 50 years, design's biggest change has been computing.

Computing as Tool, augmenting the design process.



Paul Rand

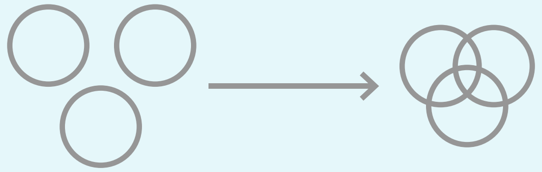


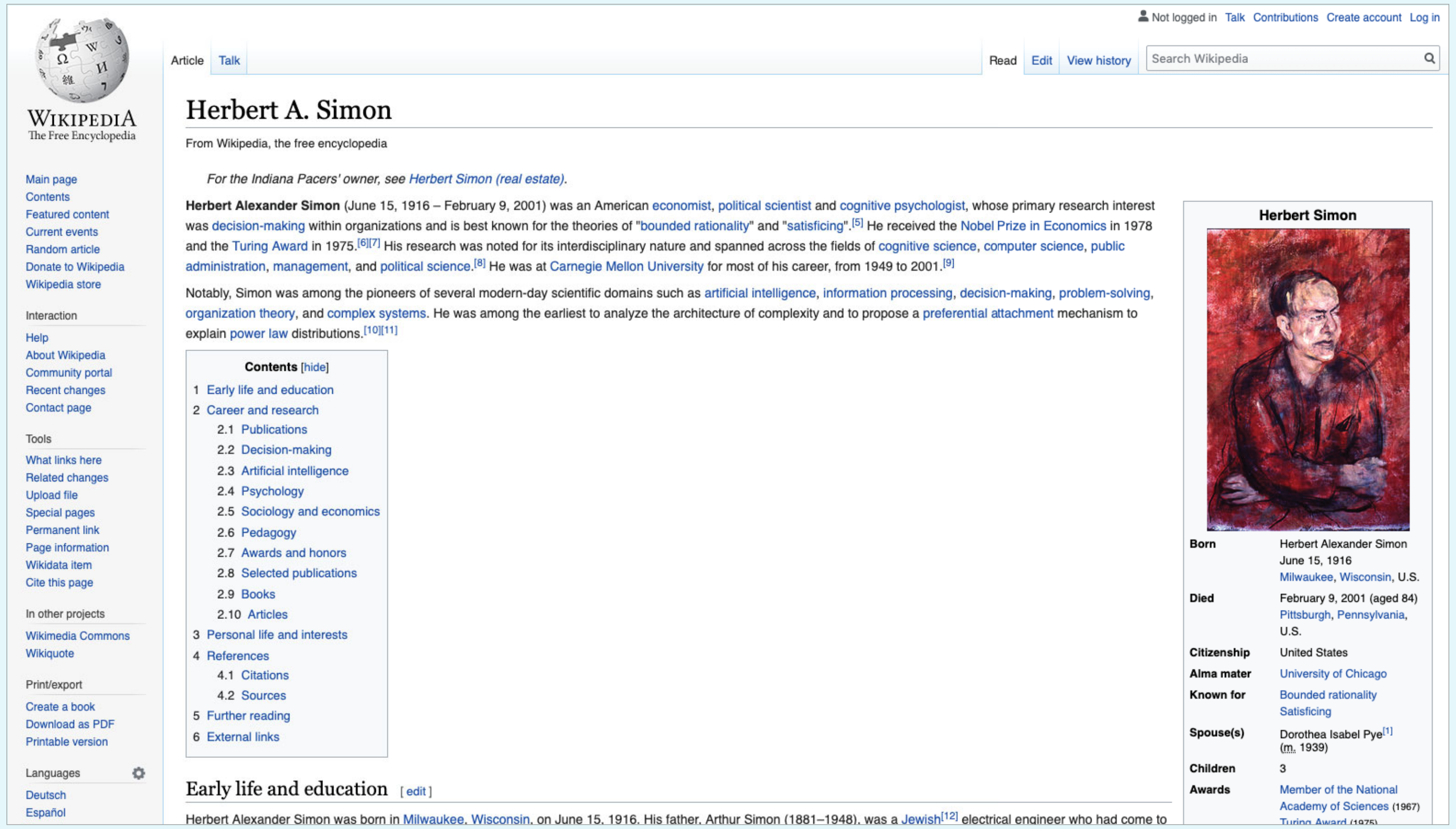
Nicholas Negroponte

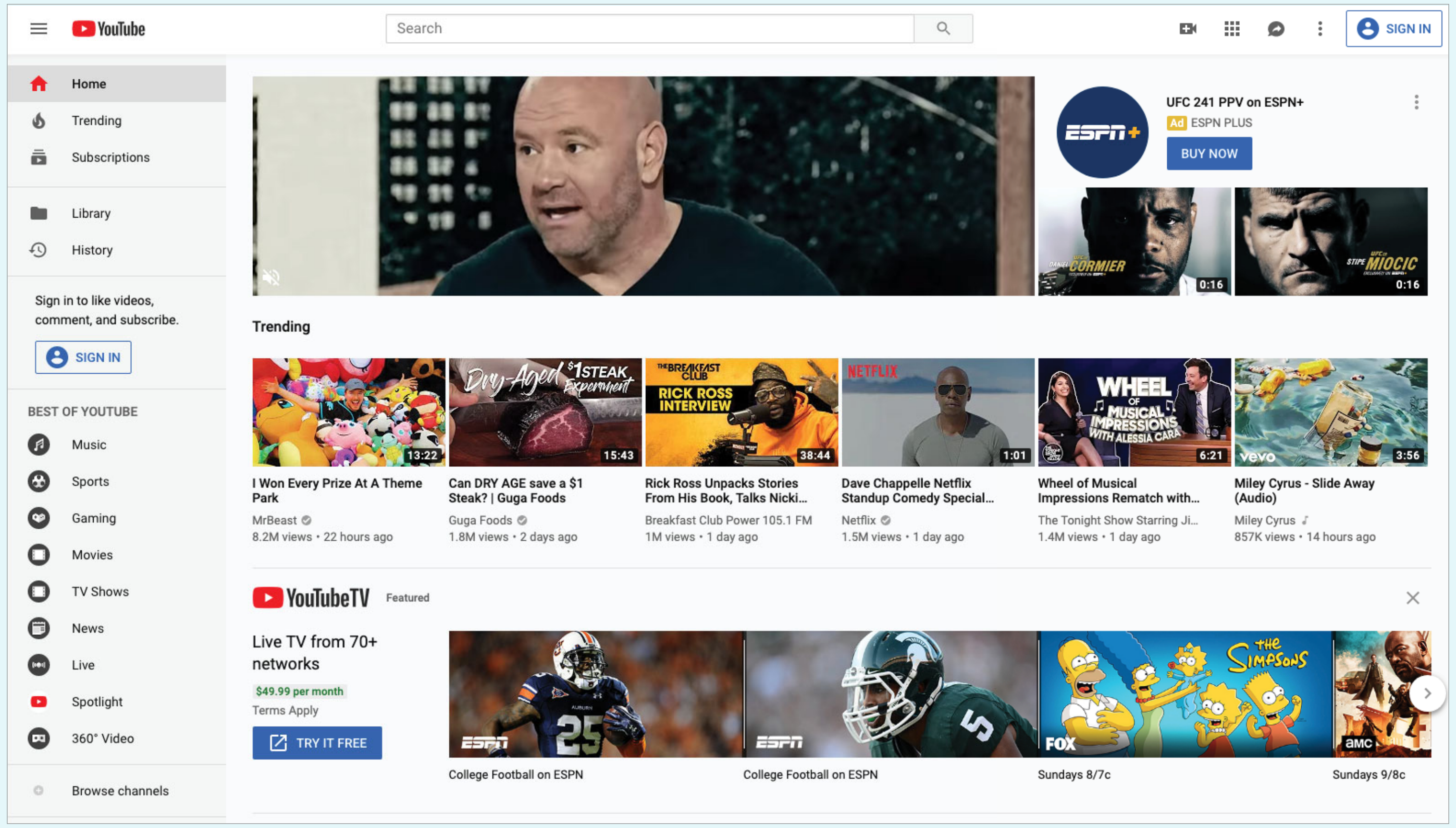
From production tool, e.g. AutoCAD

To collaboration partner, e.g. the Architecture Machine

Computing as Medium, for sharing information.



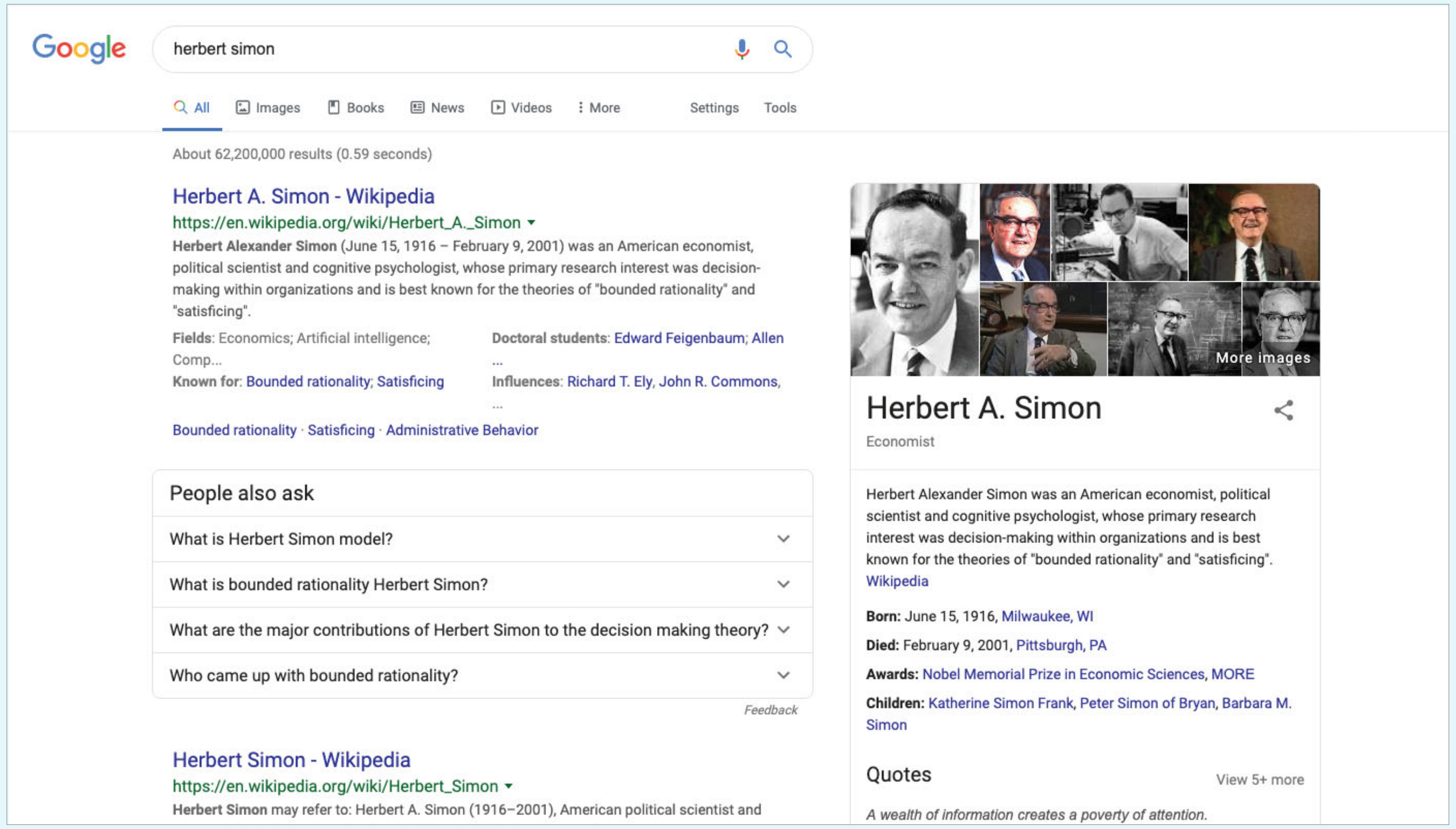




For education

And for entertainment

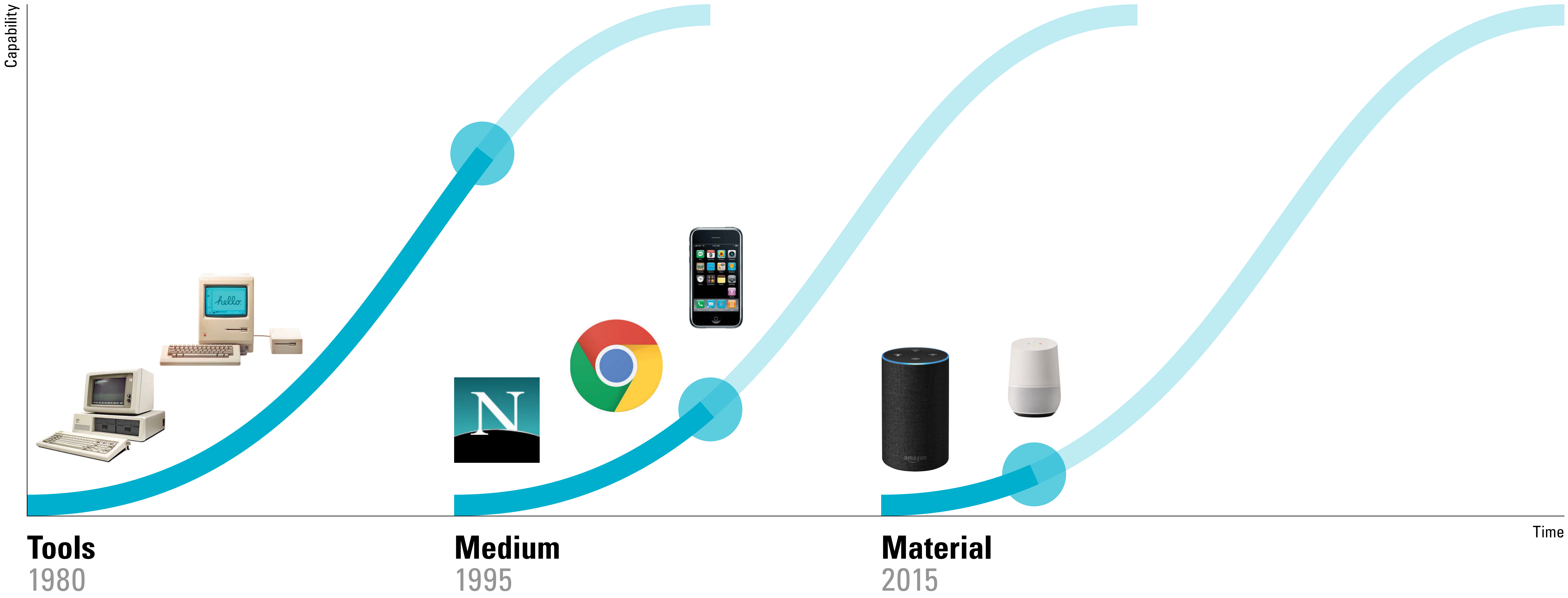
Computing as Material, to be shaped into products.



For good

And for evil

Each of these “digital transformations” is at a different stage.



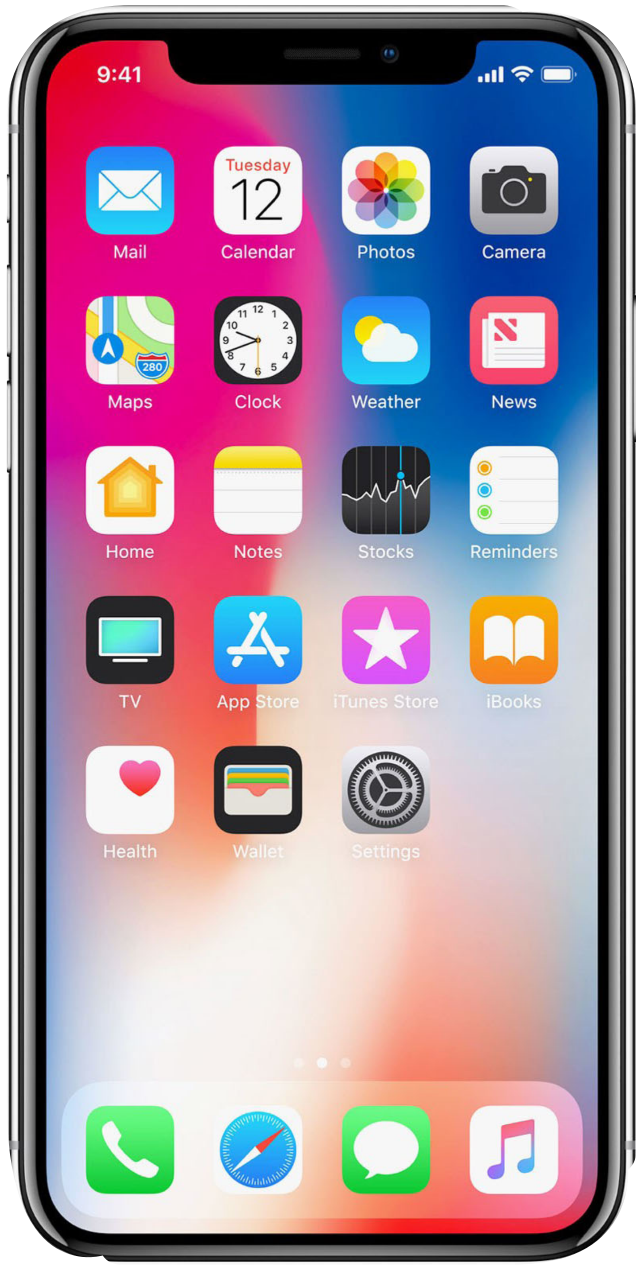
Five trends are driving new types of products, enabled by data:

–Sensors
–Smart, connected products
–Big data
–On-demand computing
–AI

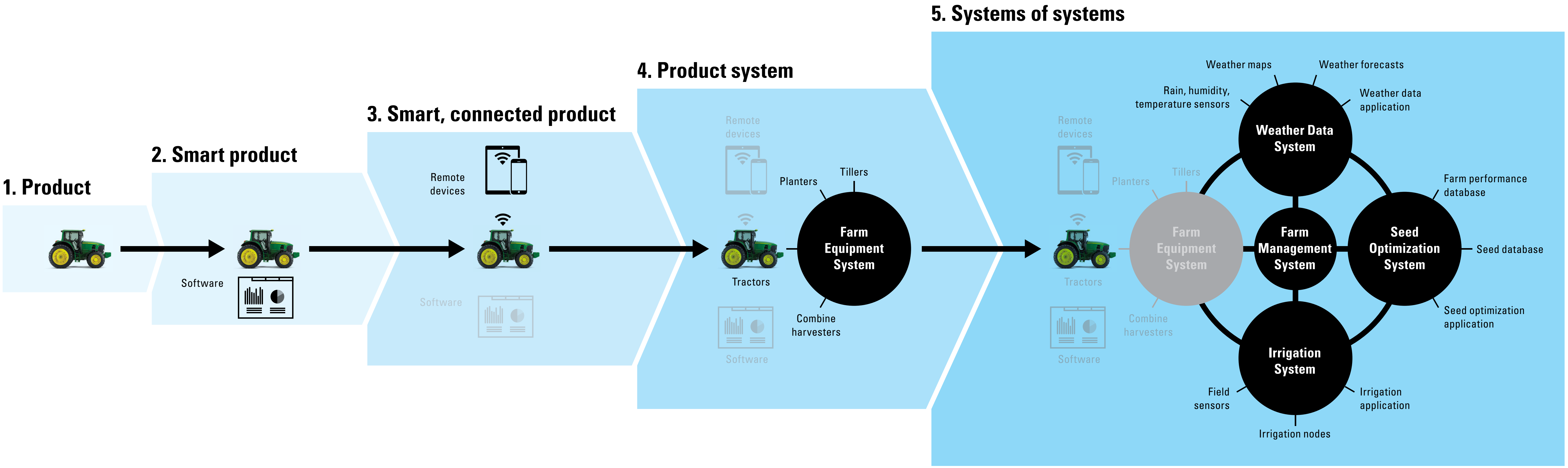
1 The proliferation of sensors printed on chips, installing measurement capability all around us.

iPhone includes a dozen sensors:

- Camera
- Gyroscope
- Barometer
- Proximity sensor
- Ambient light sensor
- Moisture sensor
- Microphone
- Accelerometer



2 Built into smart, connected products (IoT), adding microprocessors and WiFi to everything.



"…smart, connected products are transforming competition" and "redefining industry boundaries."

— **Michael Porter**, HBR, 2014

3 The (really big) data they generate, measuring and recording every change.

Added every minute:

Twitter	473,400 tweets
Snapchat	2,000,000 shares
Instagram	49,380 posts
LinkedIn	120 new users
Google	2,400,000 searches
YouTube	300 hours of video

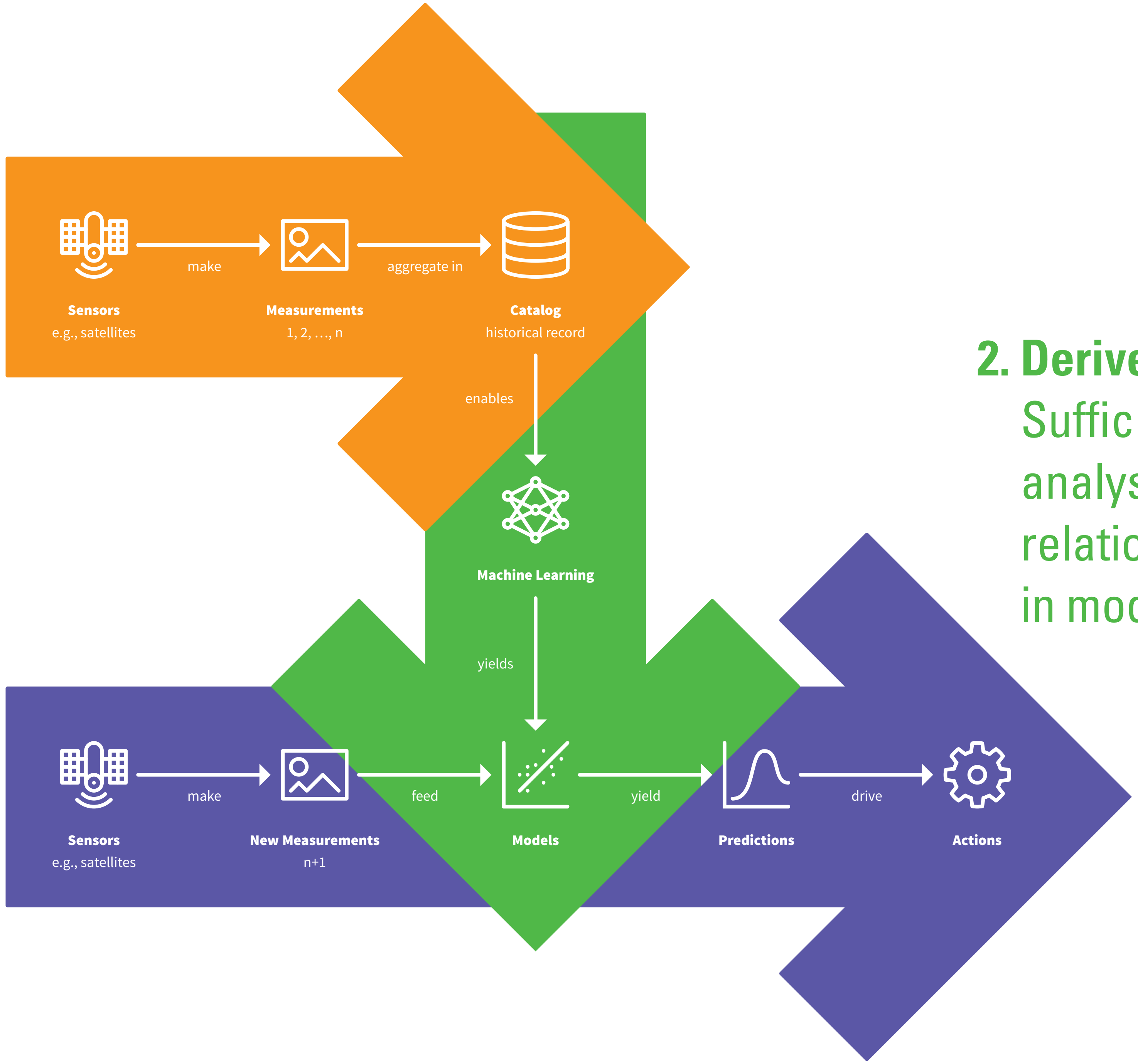
4 The “cloud,” on-demand computing resources, with marginal costs, falling toward zero.

135	Telecom Company China	**CTcluster** - Sugon TC6000, Xeon Gold 6140 18C 2.3GHz, 10G Ethernet Sugon	54,000	1,928.0	3,974.4	520
136	Descartes Labs United States	**Amazon EC2 C5 Instance cluster us-east-1a** - Amazon EC2 Instance Cluster C5, Xeon Platinum 8124M 18C 3GHz, 25G Ethernet Amazon Web Services	41,472	1,926.4	3,981.3	
137	Energy Company China	Huawei 2288H V5, Xeon Gold 6150 18C 2.7GHz, 10G Ethernet Huawei Technologies Co., Ltd.	49,680	1,914.4	4,292.4	733

5 Pattern-finding software (AI: DL, ML, CV, NLP), algorithms making sense of measurements.

1. Gather histories

Sensors make a series of point in time measurements. As measurements accumulate, a historical record emerges.



2. Derive models

Sufficient historical data enables analysts to discover patterns and relationships—these are codified in models.

3. Predict futures

Once trained, new measurements are fed through the model to predict the future—enabling us to act today.

“Smart, Connected [Data-Enabled] Products” offer four capabilities.

Monitoring

1 Sensors and external data sources enable the comprehensive monitoring of:
– The product’s condition
– The external environment
– The product’s operation and usage

Monitoring also enables alerts and notifications of changes

Control

2 Software embedded in the product or in the product cloud enables:
– Control of product functions
– Personalization of the user experience

Optimization

3 Monitoring and control capabilities enable algorithms that optimize product operation and use in order to:
– Enhance product performance
– Allow predictive diagnostics, service, and repair

Autonomy

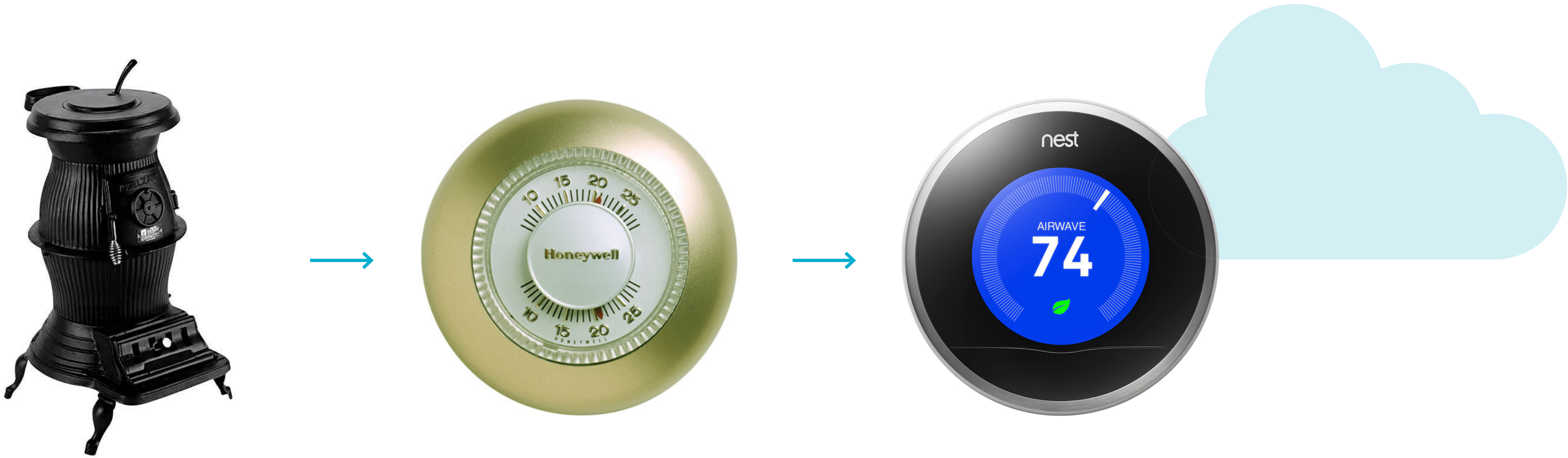
4 Combining monitoring, control, and optimization allows:
– Autonomous product operation
– Self-coordination of operation with other products and systems
– Autonomous product enhancement and personalization
– Self-diagnosis and service

— **Michael Porter**, HBR, 2014

Data-enabled products shift how and what we design.

From
Physical artifacts — objects

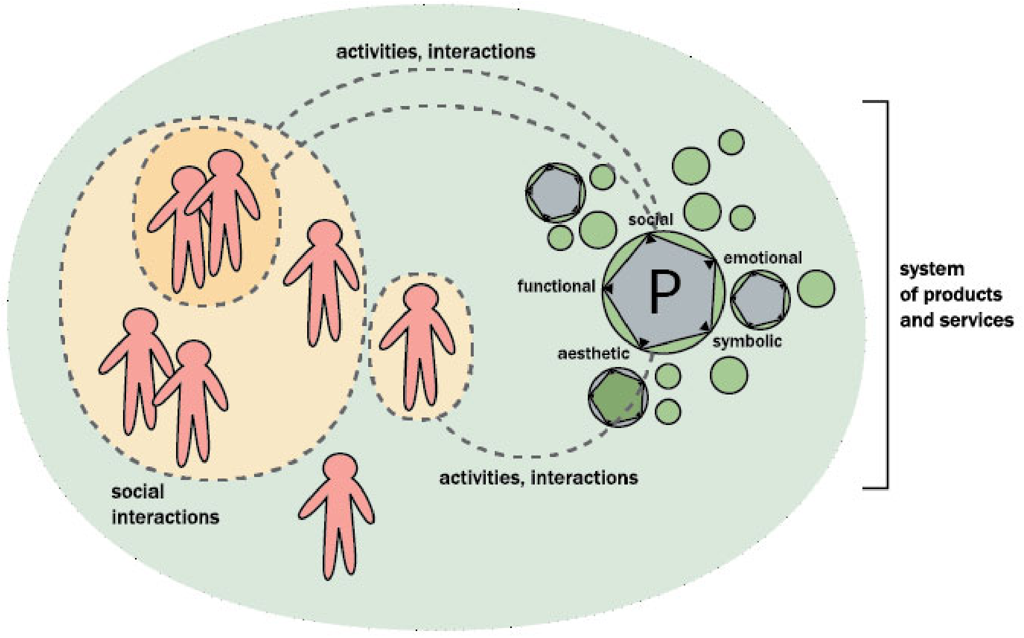
To
Adaptive systems — ecologies



Product Design	Human Factors	Interaction Design	Service Design
Focus Groups	Usability Studies	Data-driven Design	Model-driven Design

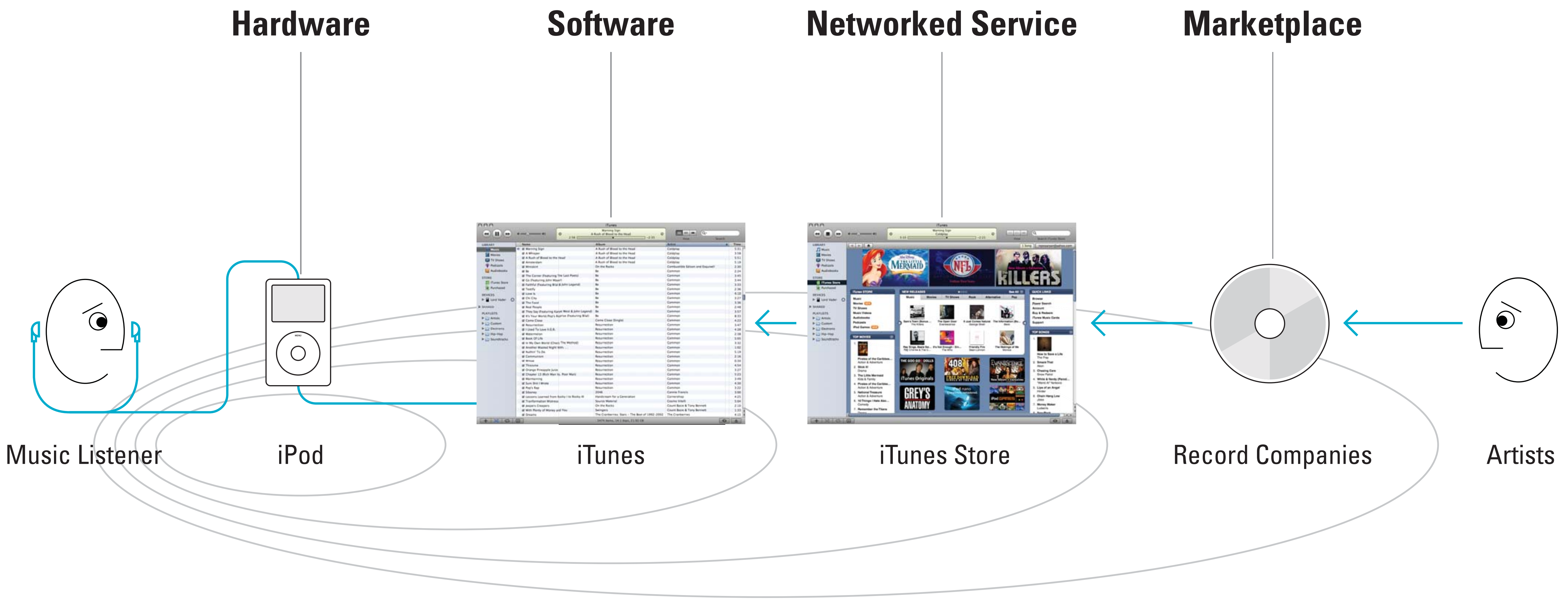
We might call them “product-service ecologies”.

“...networks of products, services, technology, people, and collective and collaborative interaction are generating value for the populations they serve.”



— **Jodi Forlizzi**, HCII, CMU, 2008

iPod was at the heart of an early product-service ecology.



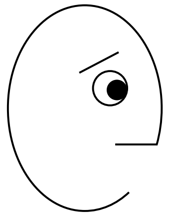
Kodak may have been one of the first product-service ecologies.

Consumer Camera
Hardware

Film
Software

Devolop Negatives
Service Network

Order / Re-order Prints
Service Network



Brownie Model E
1917

Film roll

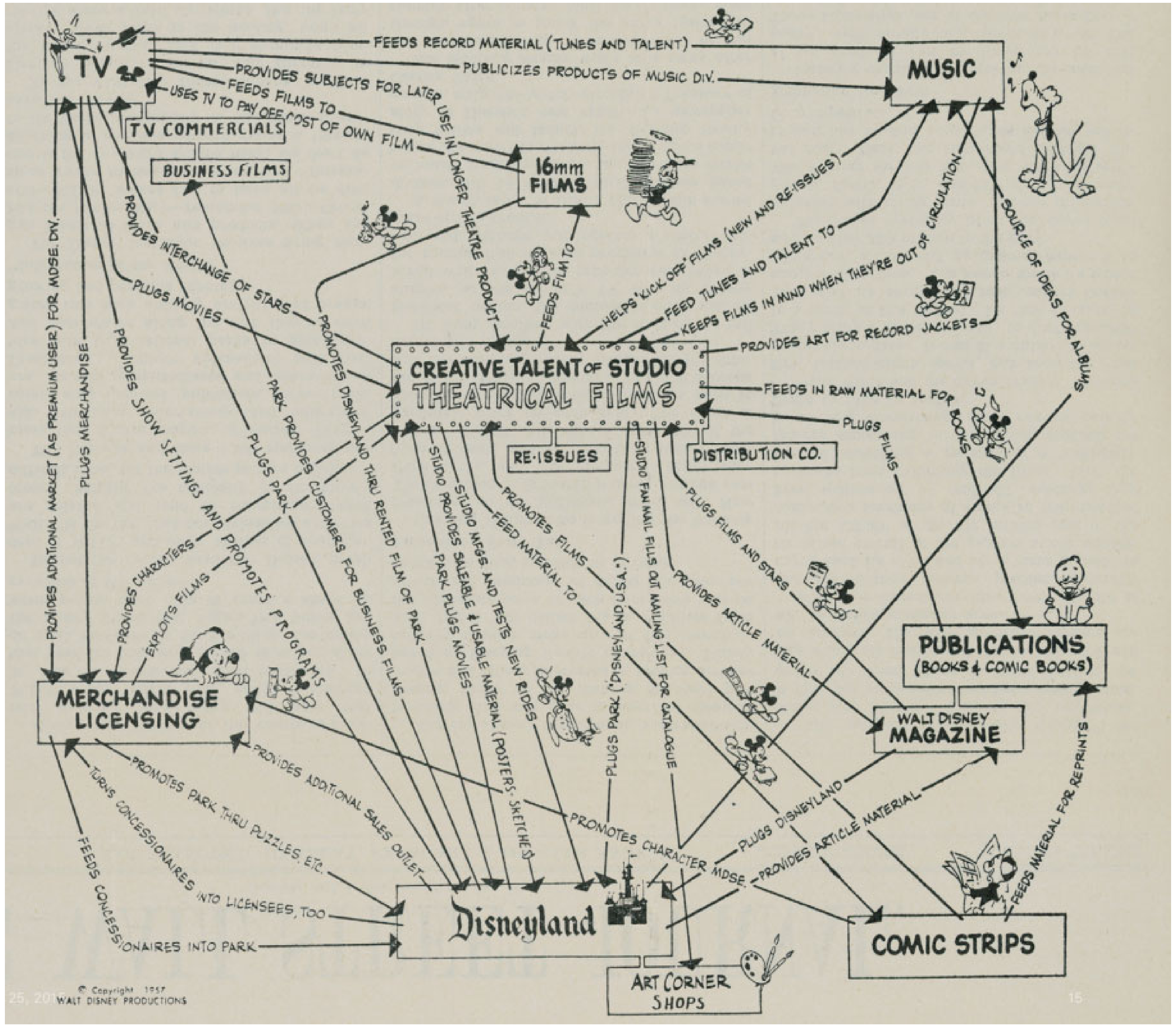
Brownie Hawkeye
1949

Film roll

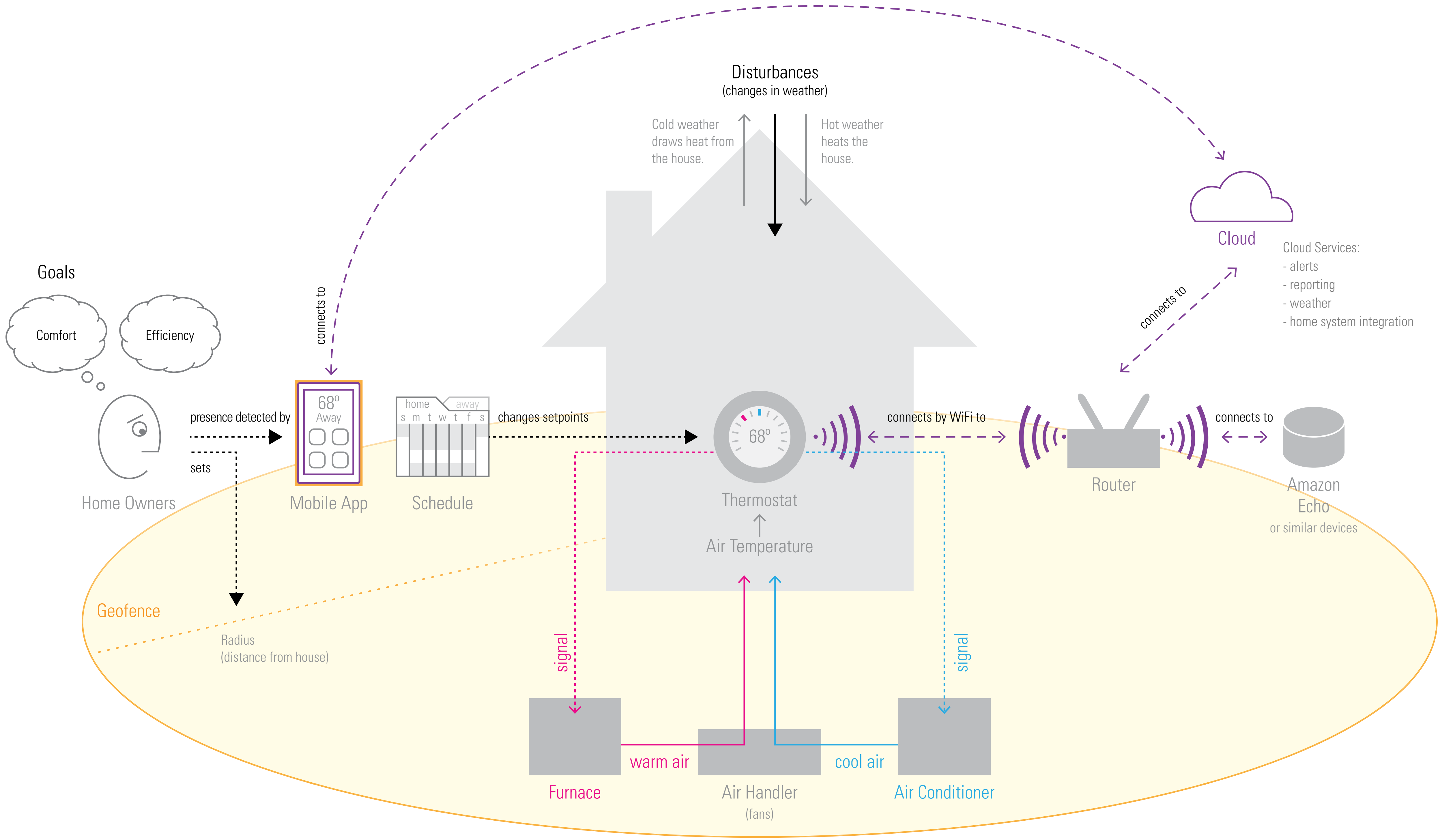
Instamatic
1966

Film roll in cartridge

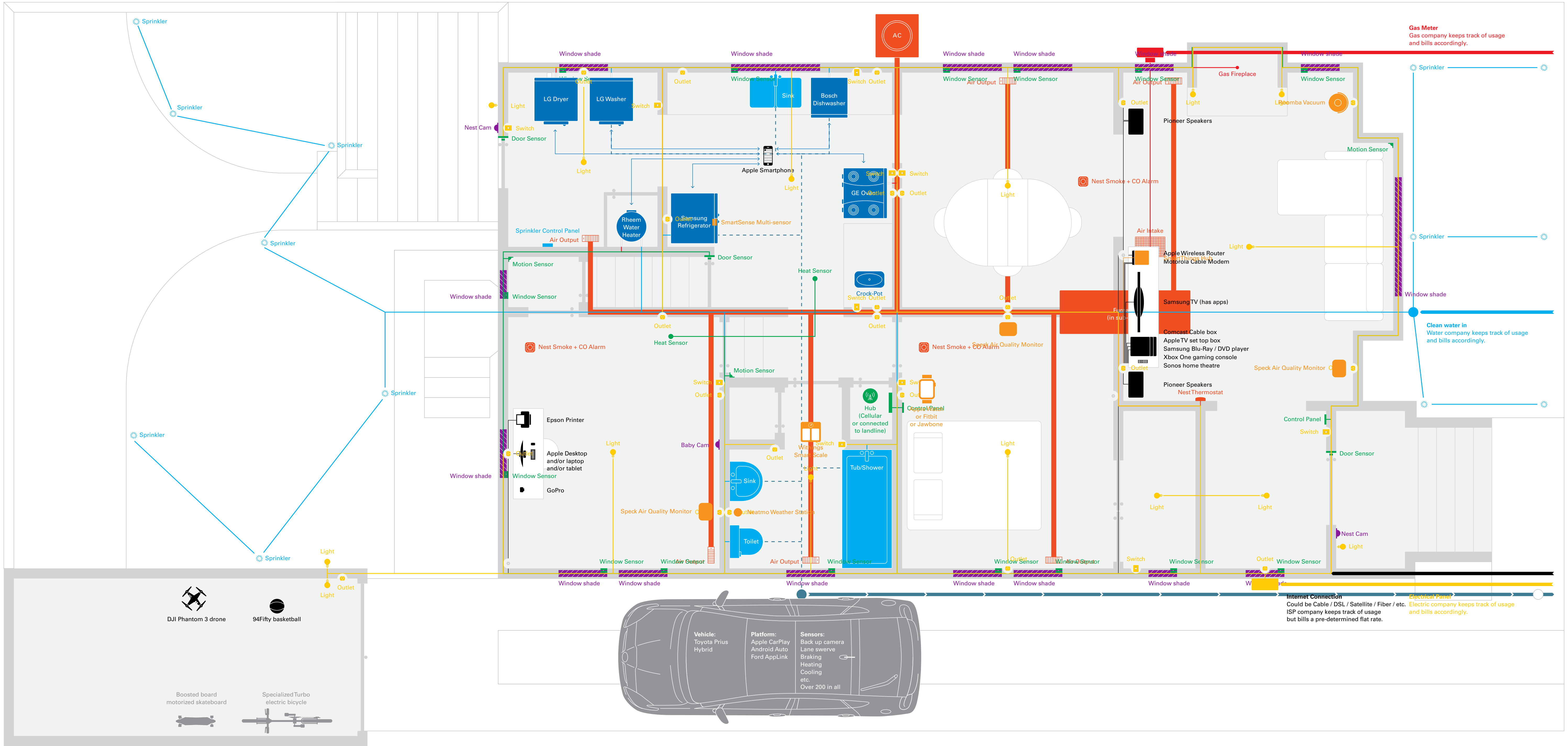
Disney thought in terms of ecologies 50+ years ago.



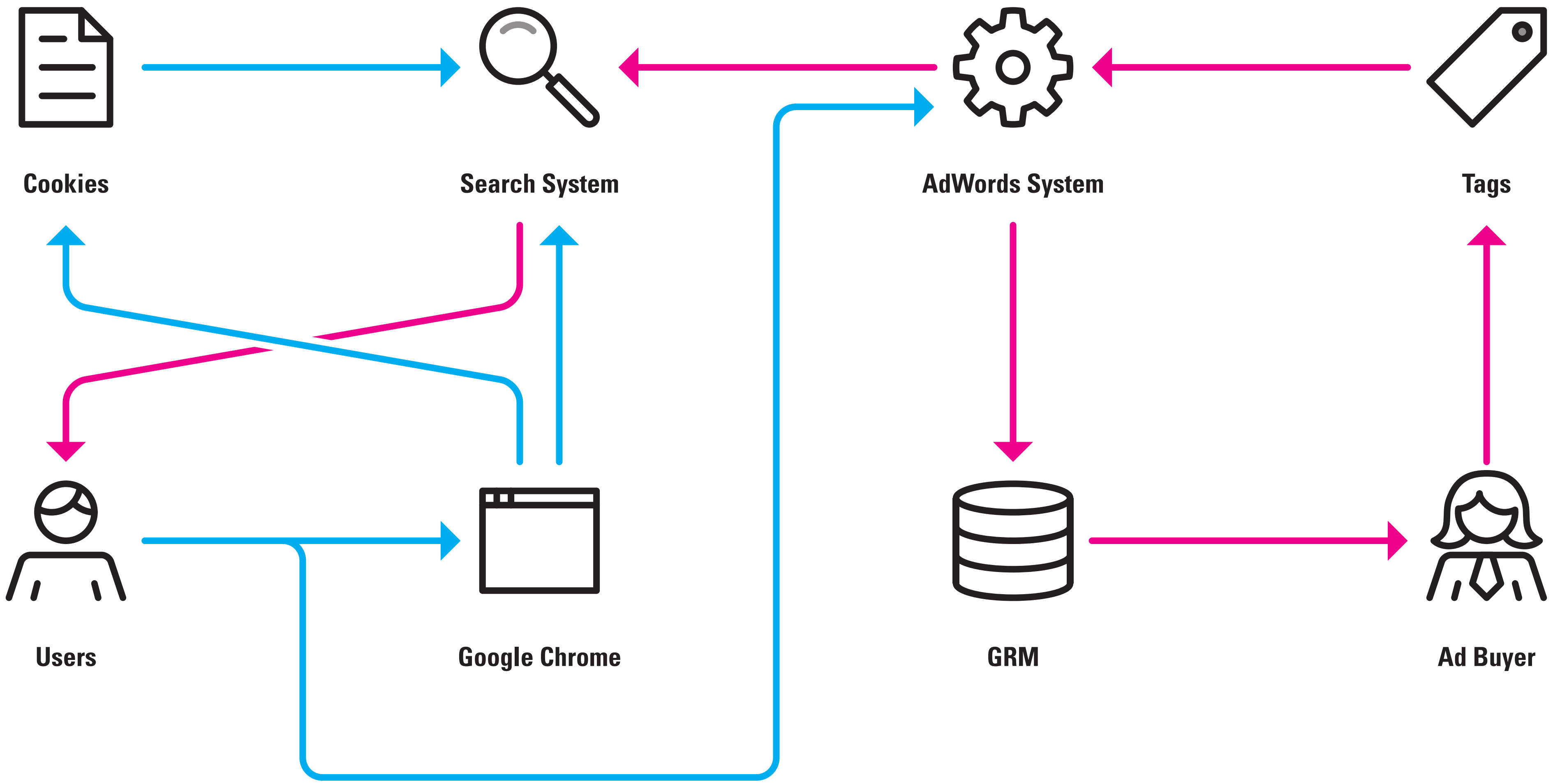
A smart thermostat gathers together a larger network of products, services, people, and their interactions.



The HVAC network is part of an even larger home ecology.



Google Search, Chrome, AdWords, and Relationship Manager (GRM) are a rich, product-service ecology.



A few other signals of this massive change:

- Self-driving cars, trucks, and drones
- IBM Watson Health
- GE Predix and Siemens MindSphere
- Apple Siri, Viv (now Samsung), Amazon Alexa, Google Assistant, Facebook M, Microsoft Cortana
- FBI’s Facial Analysis, Comparison, and Evaluation (FACE) Services has access to more than 400 million photos.

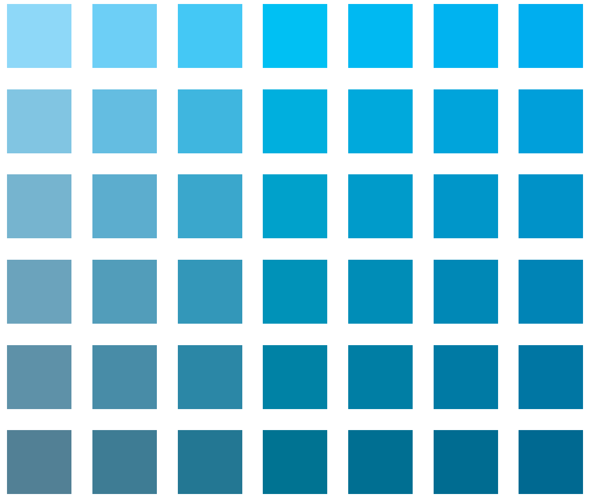
Only recently, have we begun to talk about data as a material.

A-B testing has become the norm on large services.

"When a company is filled with engineers,... data eventually becomes a crutch for every decision,...

Yes, it's true that a team at Google couldn't decide between two blues, so they're testing 41 shades between each blue to see which one performs better....

I can't operate in an environment like that."



— **Douglas Bowman**, 2009

https://stopdesign.com/archive/2009/03/20/goodbye-google.html

A lot is at stake —
personal values and shareholder value.

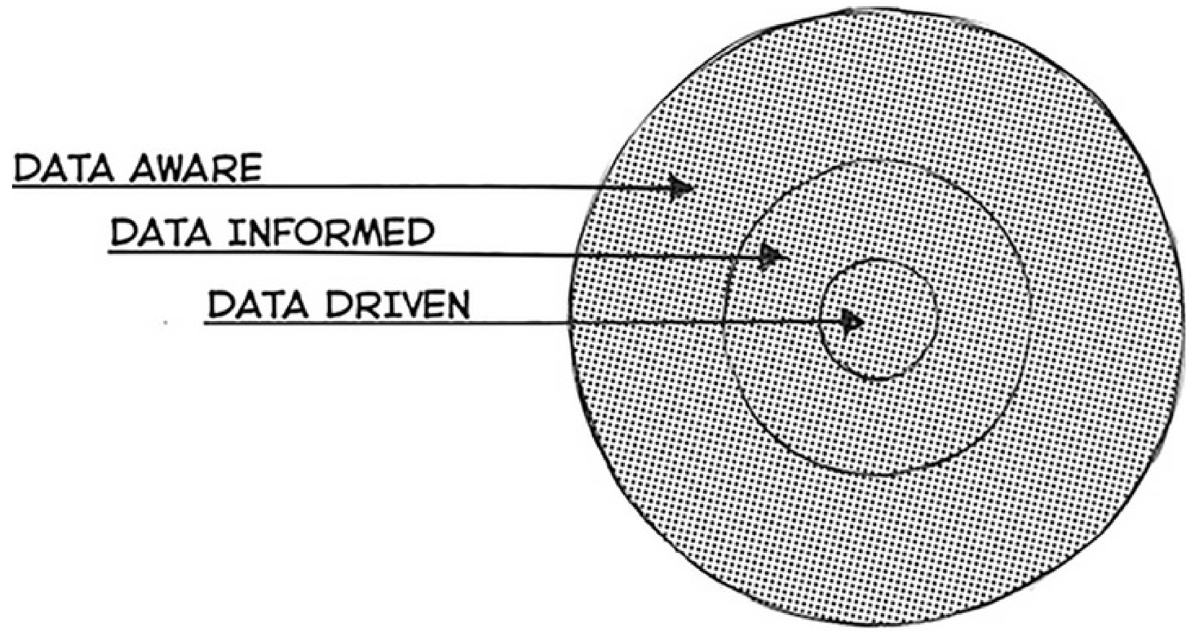
"It turns out, the difference between one shade of blue and another, at the scale of Google search, can be worth millions of dollars per year."

— **Irene Au**, 2012, personal communications

A Model of Data-driven Design

"Design is and always has been informed by data....

By harnessing and leveraging the power of data at scale... new ways to understand people, 'users,' are emerging."



— **Elizabeth Churchill et al.,** *Designing with Data: Improving the User Experience with A/B Testing,* 2017

Stages of data-enabled products

New Kind of Nature

Autonomous / self-driving
Semi-autonomous
Model driven / data animated
Data driven
Data informed
Data aware

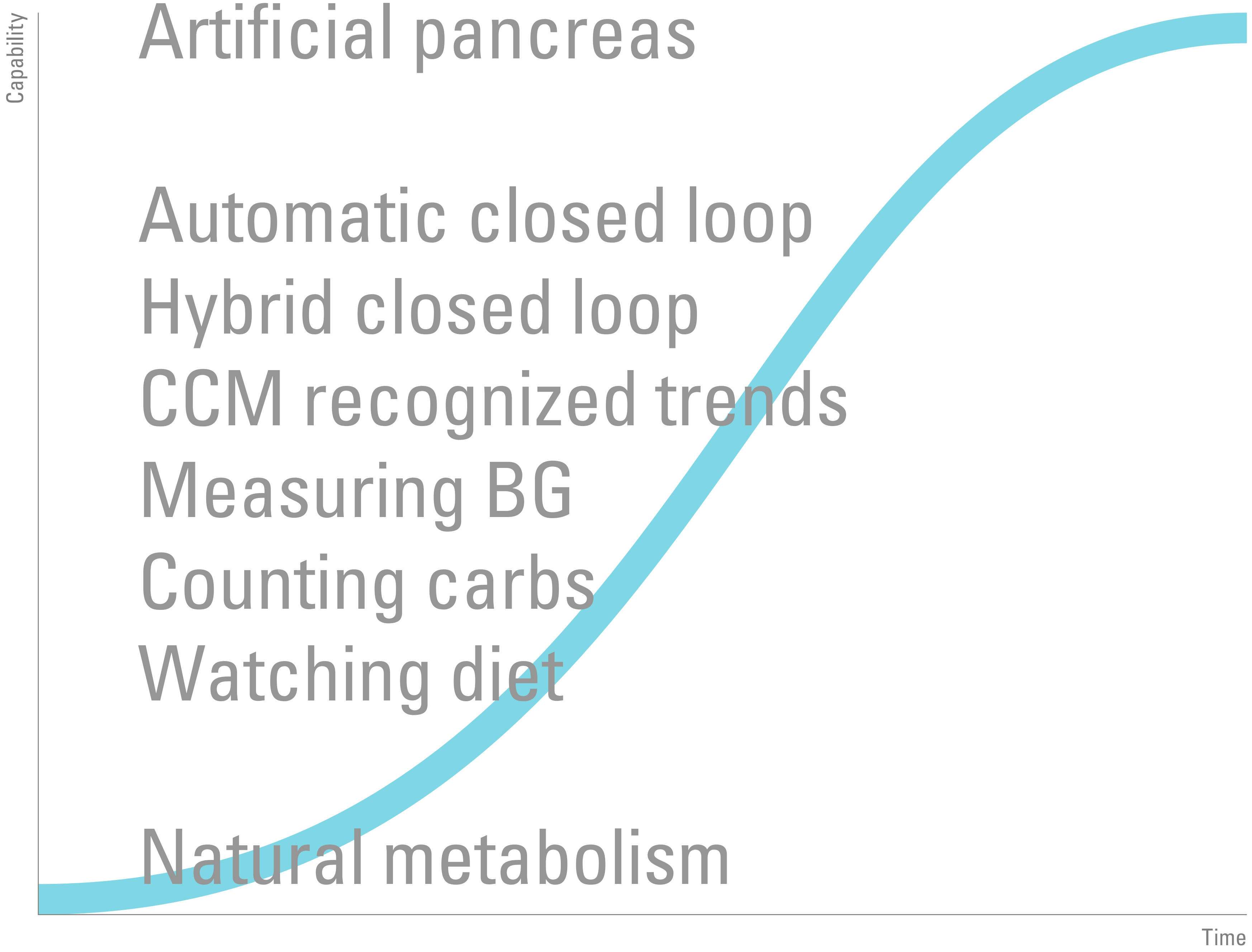
State of nature

For example:

Artificial pancreas

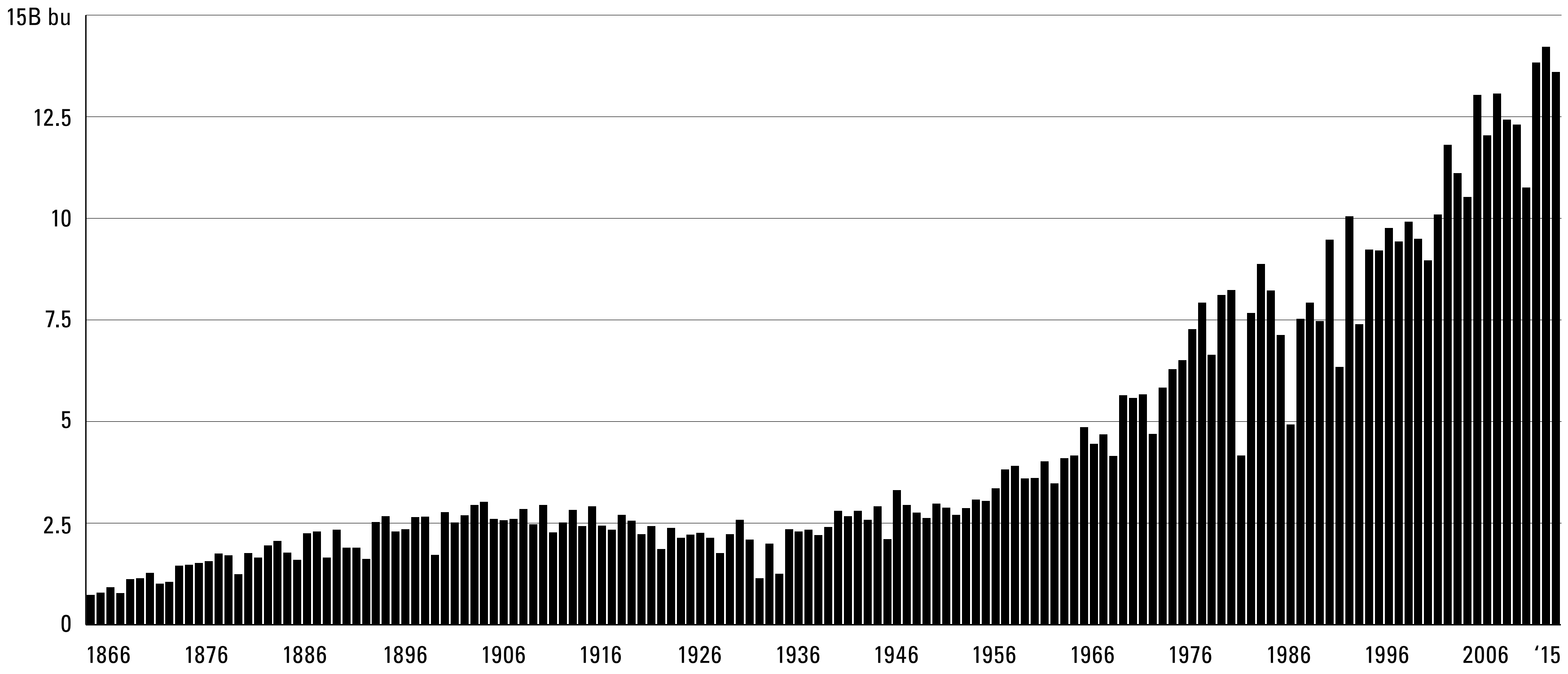
Automatic closed loop
Hybrid closed loop
CCM recognized trends
Measuring BG
Counting carbs
Watching diet

Natural metabolism



Example: Predicting crop production

Since 1886, USDA has been predicting corn production—by hand.

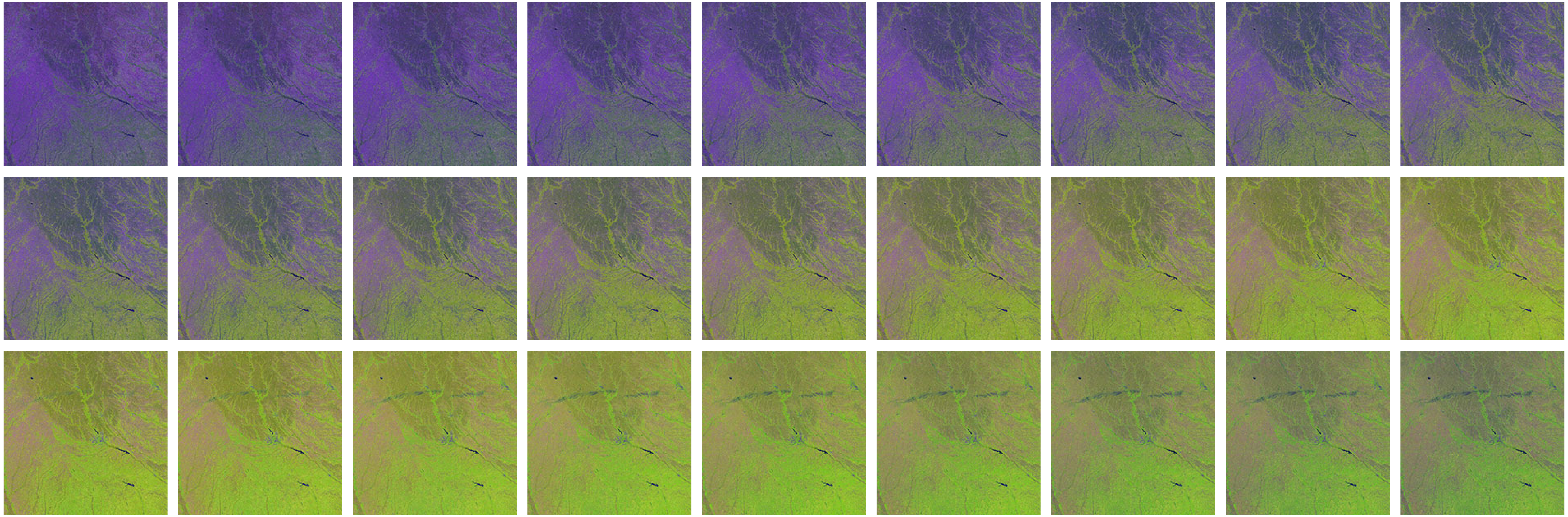


Micro view: sensors in fields

Plants attached to sensors, connected to networks, generating data.

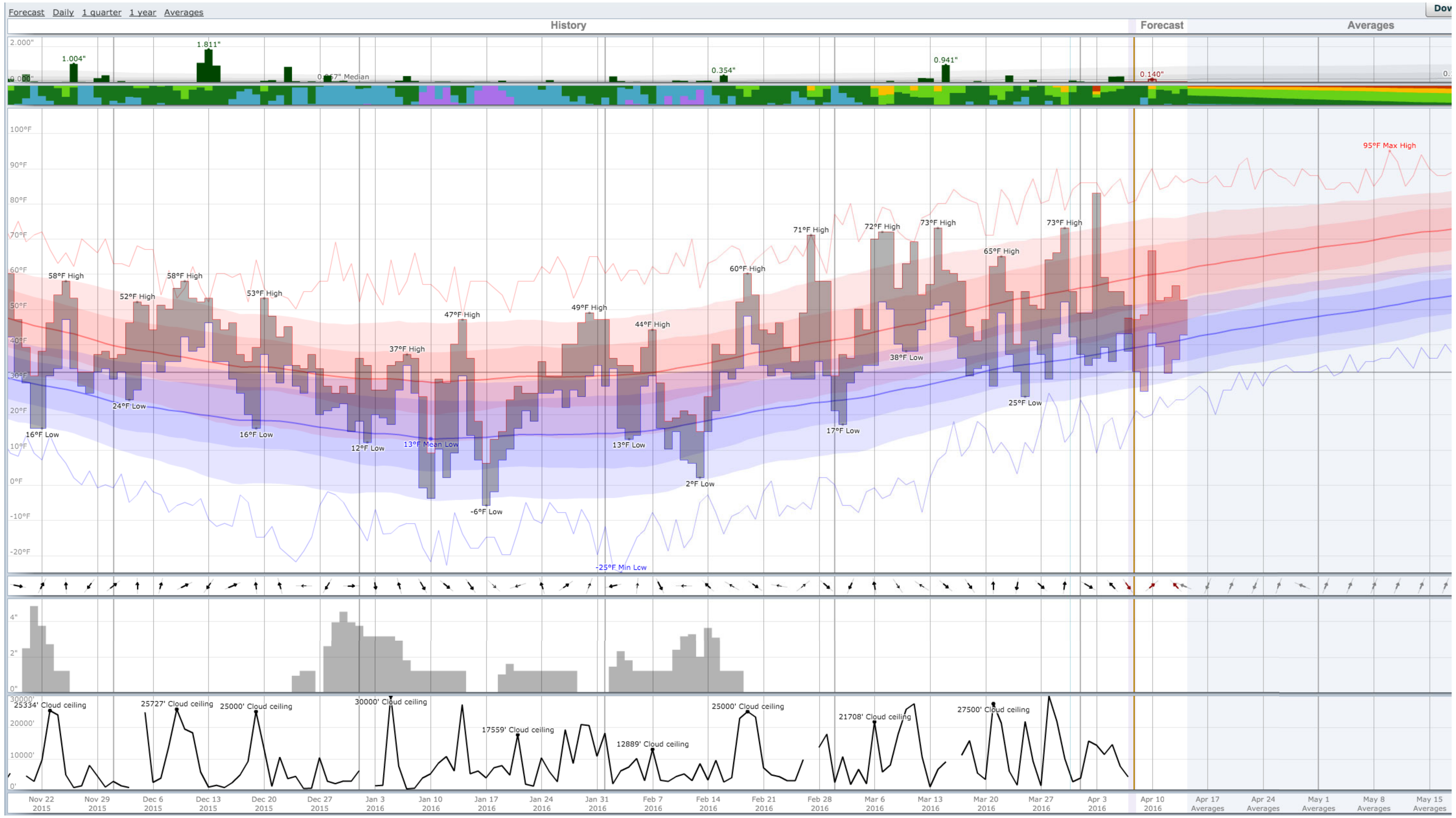
Macro view: processed satellite images of crop growth over time,
e.g., central Iowa, March 29 to October 23, in 8 day increments.

Algorithms automatically align images,
mask clouds,
and detect vegetation.

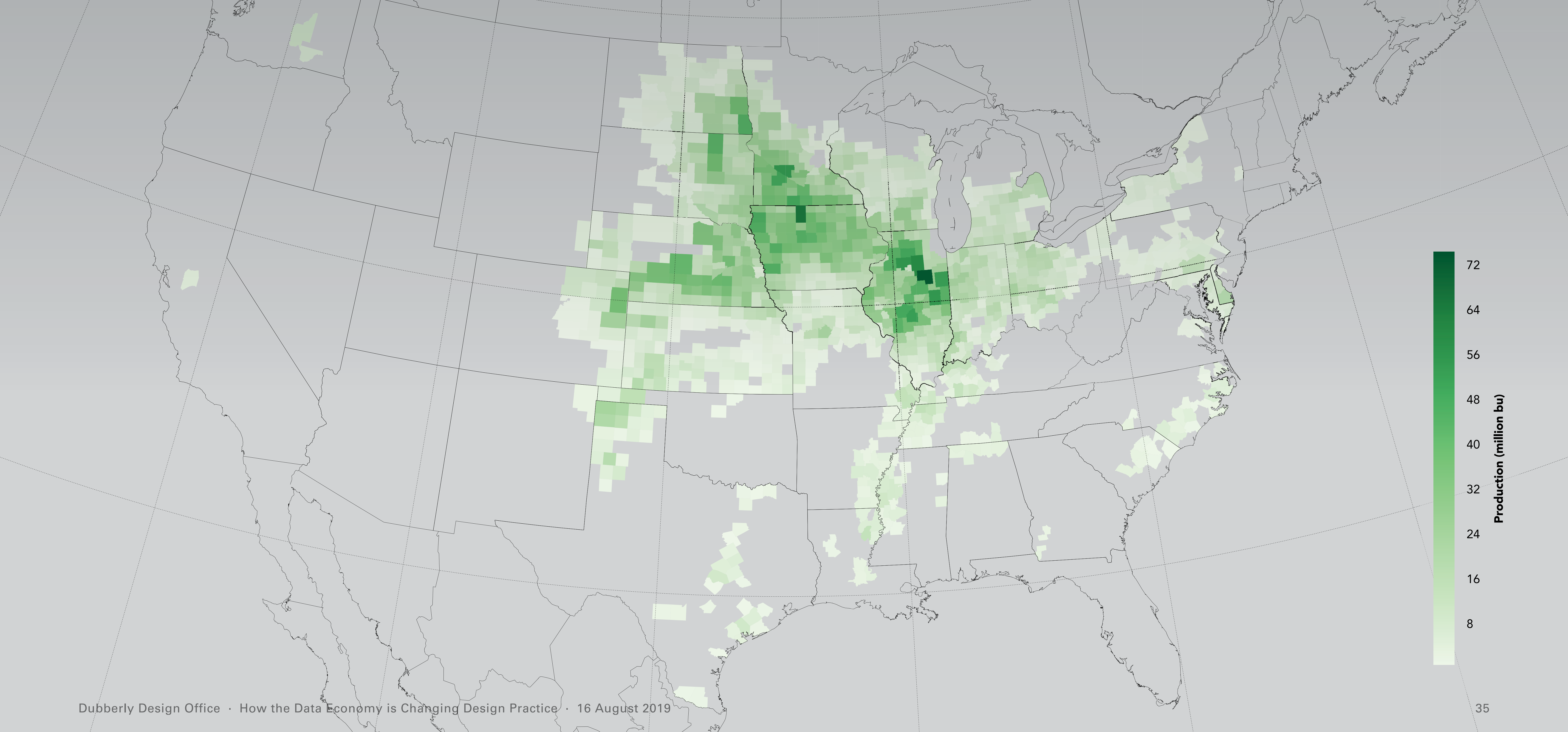


Daily weather data can augment machine learning.

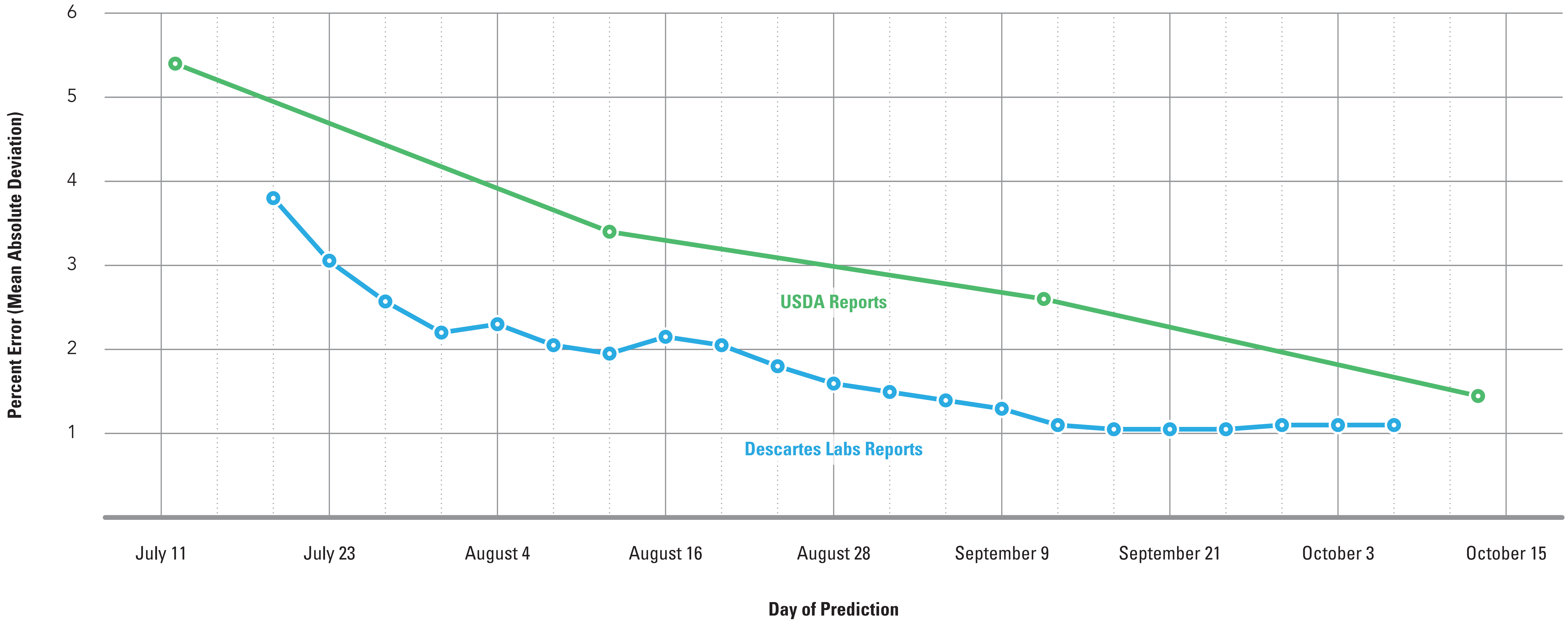
Precipitation,
temperature,
wind direction and speed,
snow cover,
and cloud cover
can aid forecasting.



In 2015, Descartes Labs used satellite images, weather data, and ML to automate prediction of corn production for the first time.

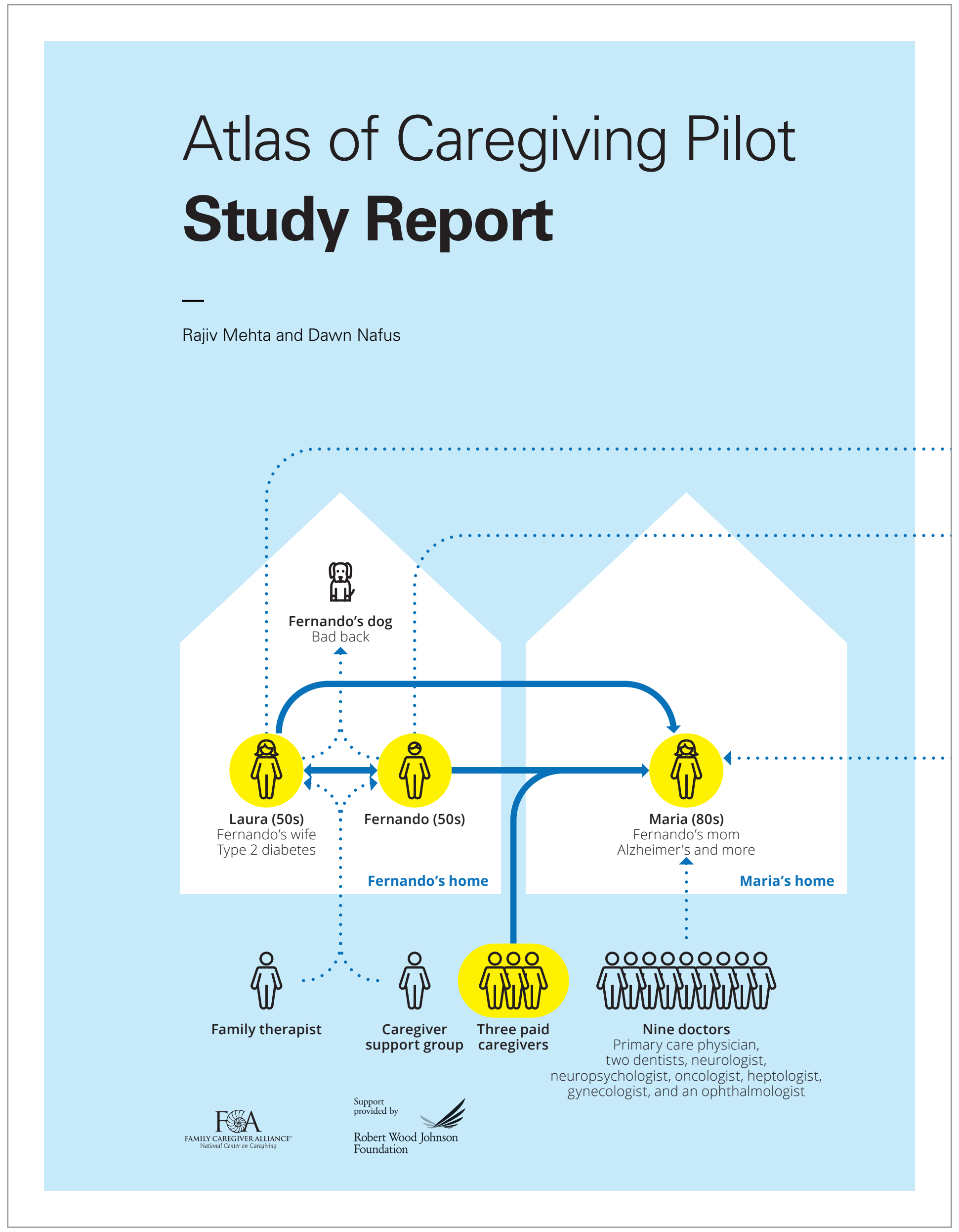


Descartes Labs predicted US corn production — within about 1.9% of actual numbers later reported by USDA.



Example: Measuring family caregiving

In 2015, Robert Wood Johnson Foundation funded a pilot study to look at new ways of measuring family caregiving.



Robert Wood Johnson Foundation

We looked at 14 households, with 20 participants, with 21 chronic conditions.

Ana's household

Ana

Ana (50s) has had **cystic fibrosis** since birth. She devotes several hours a day to care for her own condition. She also cares for her teenage son Albert, who has **depression**.

Chantal's household

Chantal

Chantal (50s) has resigned work to care for her mother Debby (80s) who requires 24x7 care for **dementia**. Additional support comes from a paid home aide and other family members.

Fay's household

Fay

Only-child Fay (30s) cares for her mother Josephine (70s) who has **Alzheimer's**. With no one to help her, she has put PhD studies on hold to provide 24x7 care.

Gabrielle's household

Gabrielle

Gabrielle (60s) is the primary caregiver of her mother Karen (101), who has **Alzheimer's**. Gabrielle also has health issues of her own and the sleepless nights and caregiving needs of her mother have taken a toll.

Hanna's household

Harvey

Hanna Gaston

Hanna and husband Gaston care for her brother Harvey, who has **epilepsy** and **pneumonia/sepsis**. Gaston also cares for his mother, while managing his own **chronic pain** and **edema**. Both Hanna and Gaston also work.

Fernando's household

Fernando Laura

Fernando and his wife Laura (50s) are the primary caregivers for Fernando's mother Maria (80s) who has **Alzheimer's** disease as well as other health conditions. Together, Fernando and Laura have built a care network to support Maria.

Ida's household

Ida

Ida (70s) cares for her husband Ian (70s) who has **Lewy Body Dementia** and **Dysautonomia**. They moved to San Francisco to be nearer to their children two years ago.

Nadine's household

Nadine

Nadine (50s) lives with her husband Jerry and two teenage sons, Larry and Karl. Karl has **Type 1 Diabetes**. Nadine is his primary caregiver.

Odette's household

Odette

Odette (70s) and her husband Marco (70s) share their home with several other people: their son, son-in-law, and five tenants. Marco has **Parkinson's** disease. Odette is his primary caregiver, but several others are also involved.

Nate's household

Nate Patty

Nate and Patty, both in their 30s, care for each other. Patty has **multiple sclerosis** (MS) and Nate has **glioblastoma**, a terminal condition.

Sally's household

Sally

Sally (50s) cares for her son Pablo (20s), who has behavioral and emotional difficulties stemming from **XYY Chromosome Disorder**.

Tammy's household

Tammy Rafael

Tammy (40s) and her husband Rafael (50s) care for their pre-teen children, Wanda and Sam. Wanda has severe **epilepsy** and **cerebral palsy**. She requires 24x7 care. Sam has severe **autism** and also requires a lot of care.

Teddy's household

Teddy

Teddy (40s) and his wife are the primary caregivers for their two young sons, Van and Walter. Van has **Aspergers (ADHD type)** as well as **encopresis**, and Walter has **cyclical vomiting syndrome**.

Omar's household

Omar Cindy

Omar (40s) and his separated wife Cindy (40s) share a home with their young son Bob, who has **Aspergers**.

Using 12 sensors

Measuring 16 factors

Photographs
GPS and timestamp

Narrative Clip

Blood Volume Pulse
Calculated to derive heart rate

Acceleration X
Acceleration Y
Acceleration Z
Calculated to derive average motion

Electrodermal Activity
(EDA)

Skin Temperature

Empatica E4

Presence
At home or away

SmartSense Presence Sensor

Motion
In which room and how active

SmartSense Motion Sensors

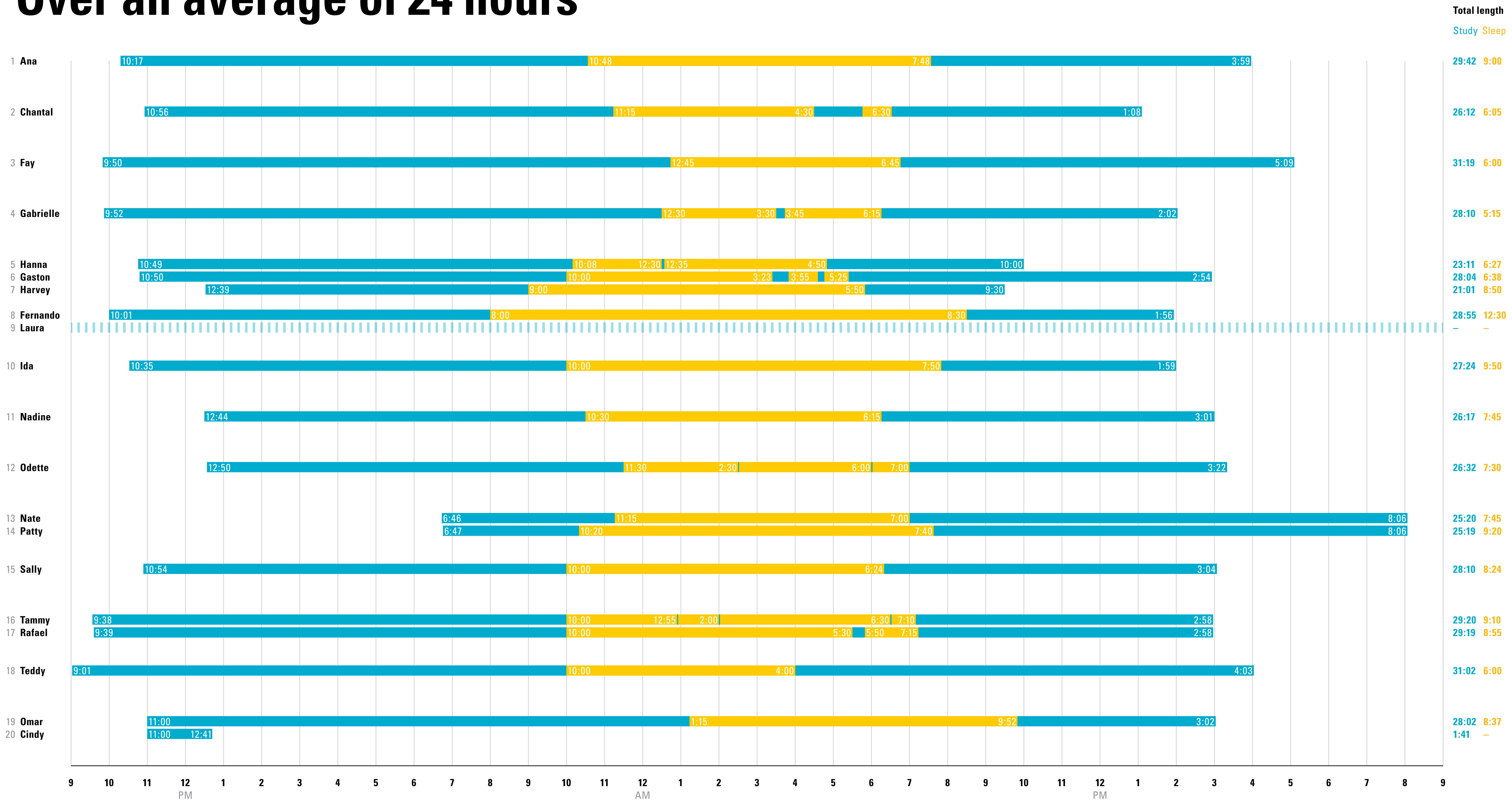
Humidity
Temperature
Barometric pressure
C02
Noise
Indoor unit

Netatmo Indoor Weather Station

Humidity
Temperature
Outdoor unit

Netatmo Outdoor Weather Station

Over an average of 24 hours



Resulting in 5 GB of data—just from the watch.

The BVP sensor is running at 64 Hz.
That means it makes a reading every 1/64th of a second.
60 seconds comprise a minute;
60 minutes comprise an hour; and
36 hours is the maximum duration of one of our study sessions.

In other words, one study session comprises 2,160 minutes,
and just one of the sensors is collecting 3,840 samples per minute.

That's 8,294,400 samples collected over the course of one 36-hour session.

8,294,000	samples for BVP (at 64 Hz)
4,147,200	samples for X axis acceleration (at 32 Hz)
4,147,200	samples for Y axis acceleration (at 32 Hz)
4,147,200	samples for Z axis acceleration (at 32 Hz)
518,000	samples for EDA (at 4 Hz)
518,000	samples for skin temperature (at 4 Hz)
21,772,800	samples of raw data for one participant
×19	participants
413,683,200	or nearly half a billion data points

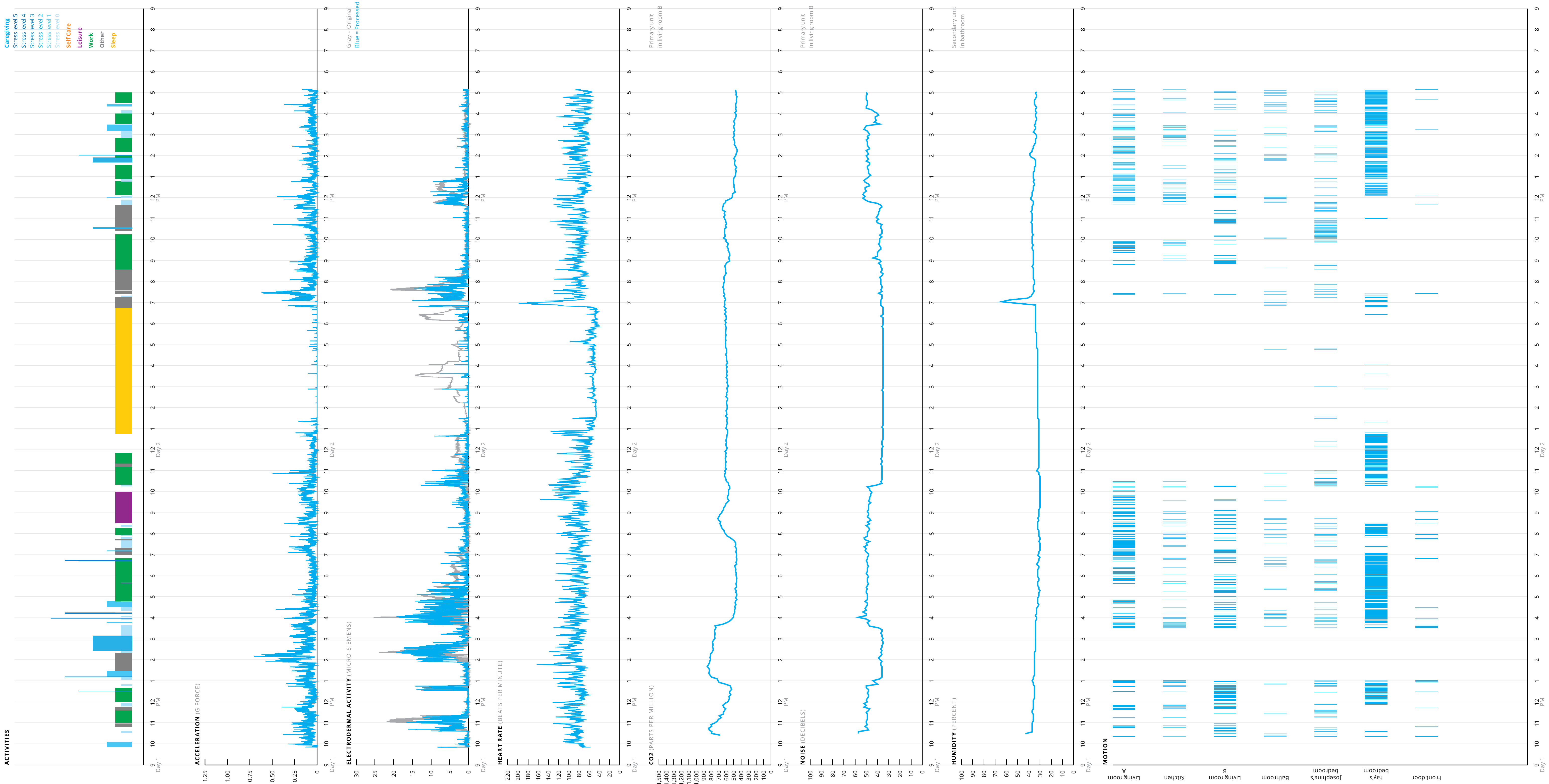
Photo log for Fay one of the participants

Black squares replace recognizable faces to ensure privacy.

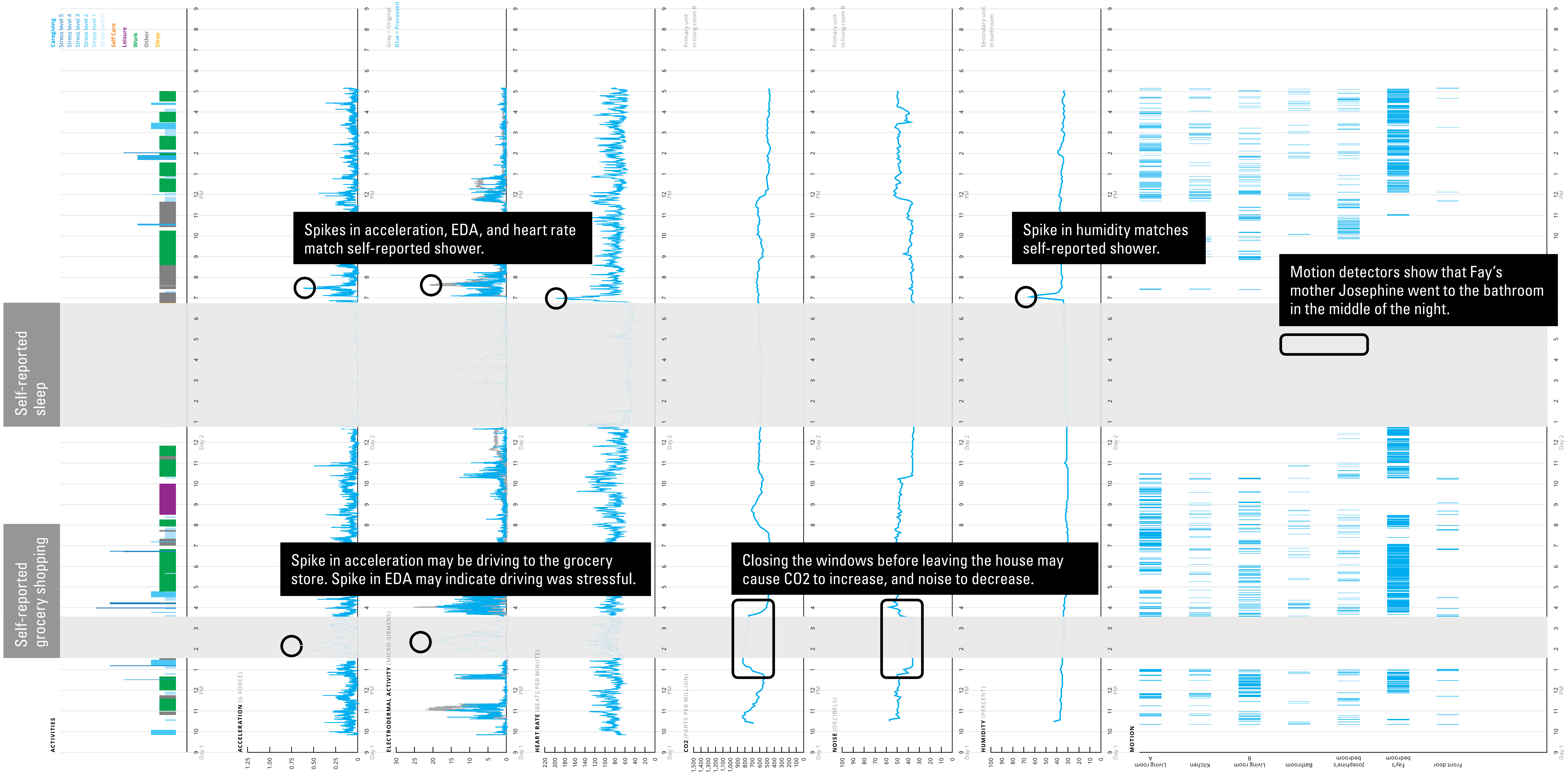
Gray squares indicate when participants turned the camera off.

White squares indicate the start and stop of the study.

Summary diagram for Fay

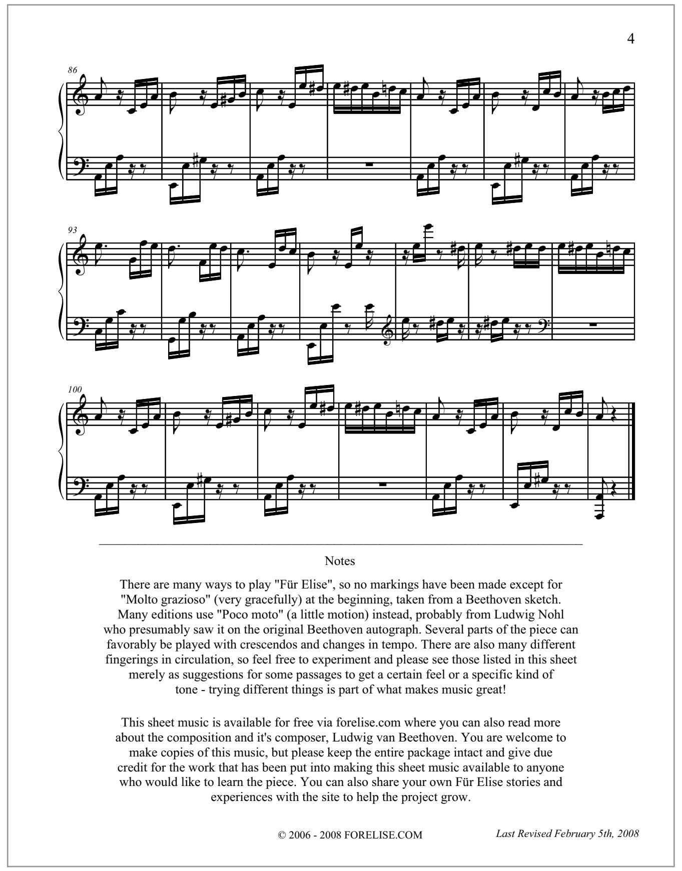


Analyzing summary data for insights

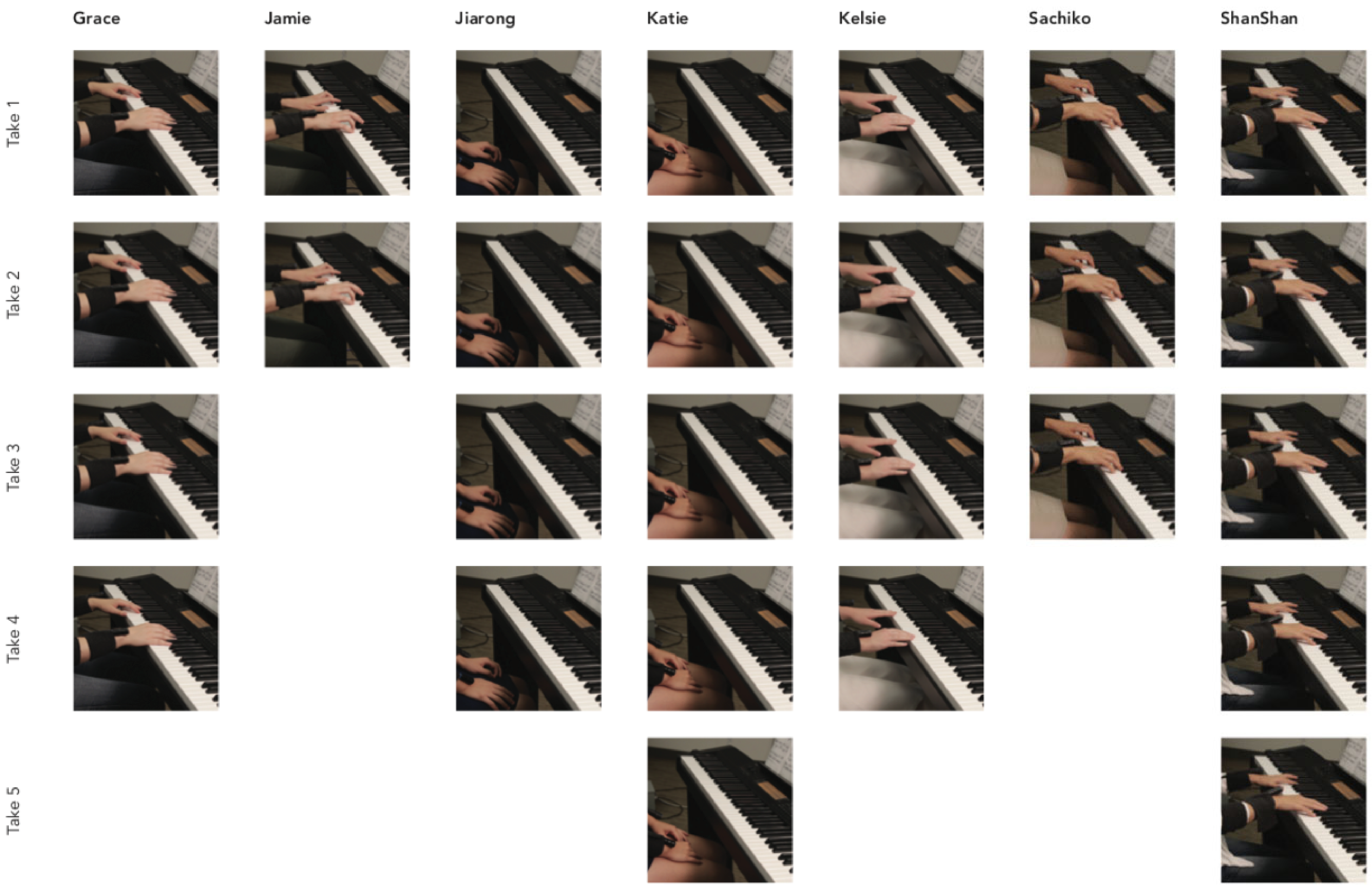


Example:
Identifying expert behaviors

An experiment was created to track hand movement during multiple piano performances of Beethoven’s Für Elise.

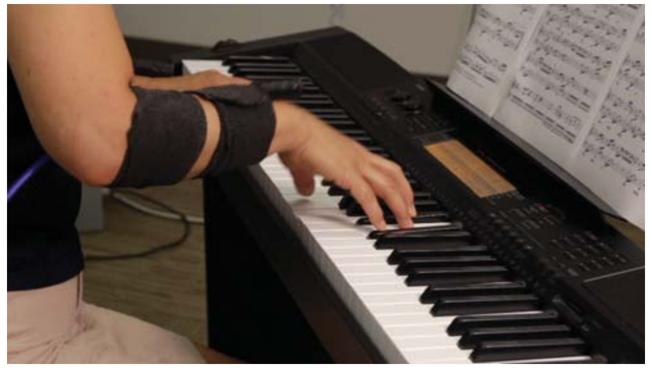


Twenty-five performances by seven performers were tracked and recorded.



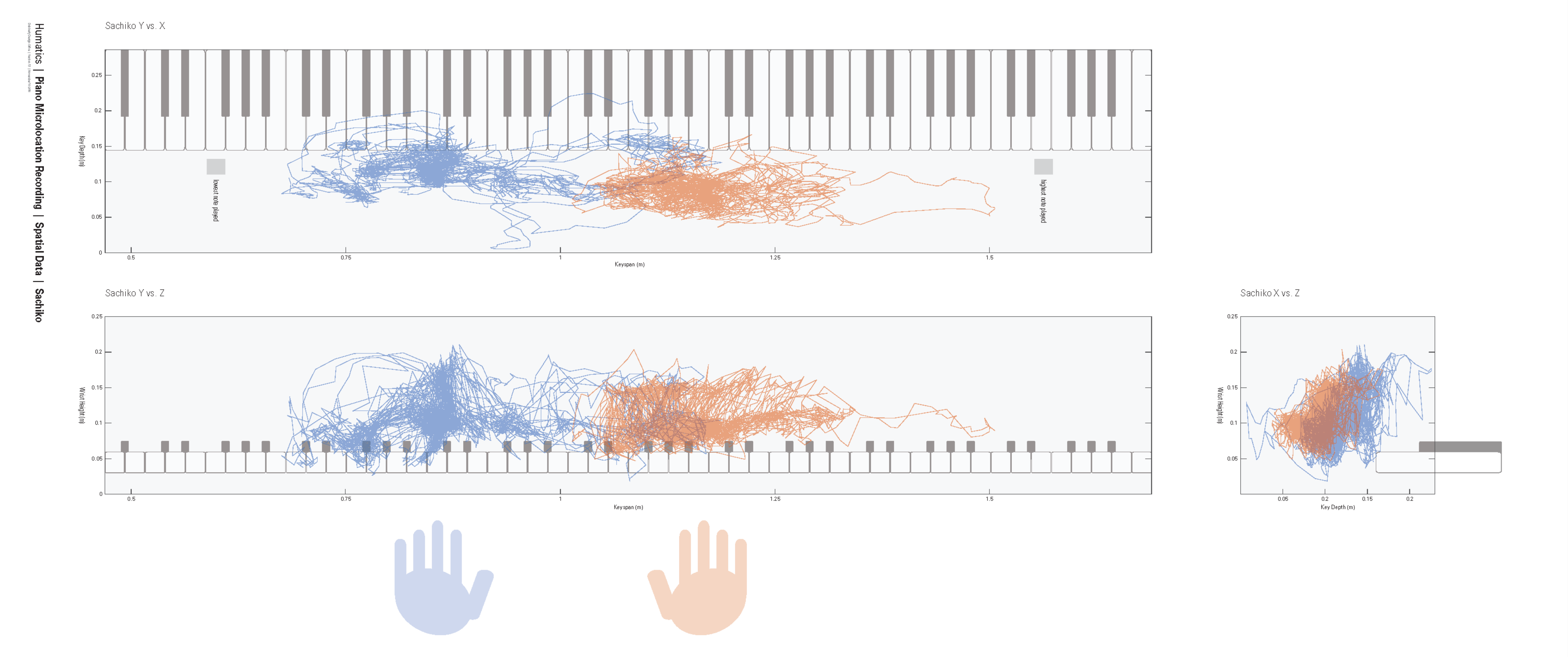
Hypothesis: advanced players move their wrists to a greater degree.

Listening and watching videos of sample performances by Jamie and Sachiko gave a clue.

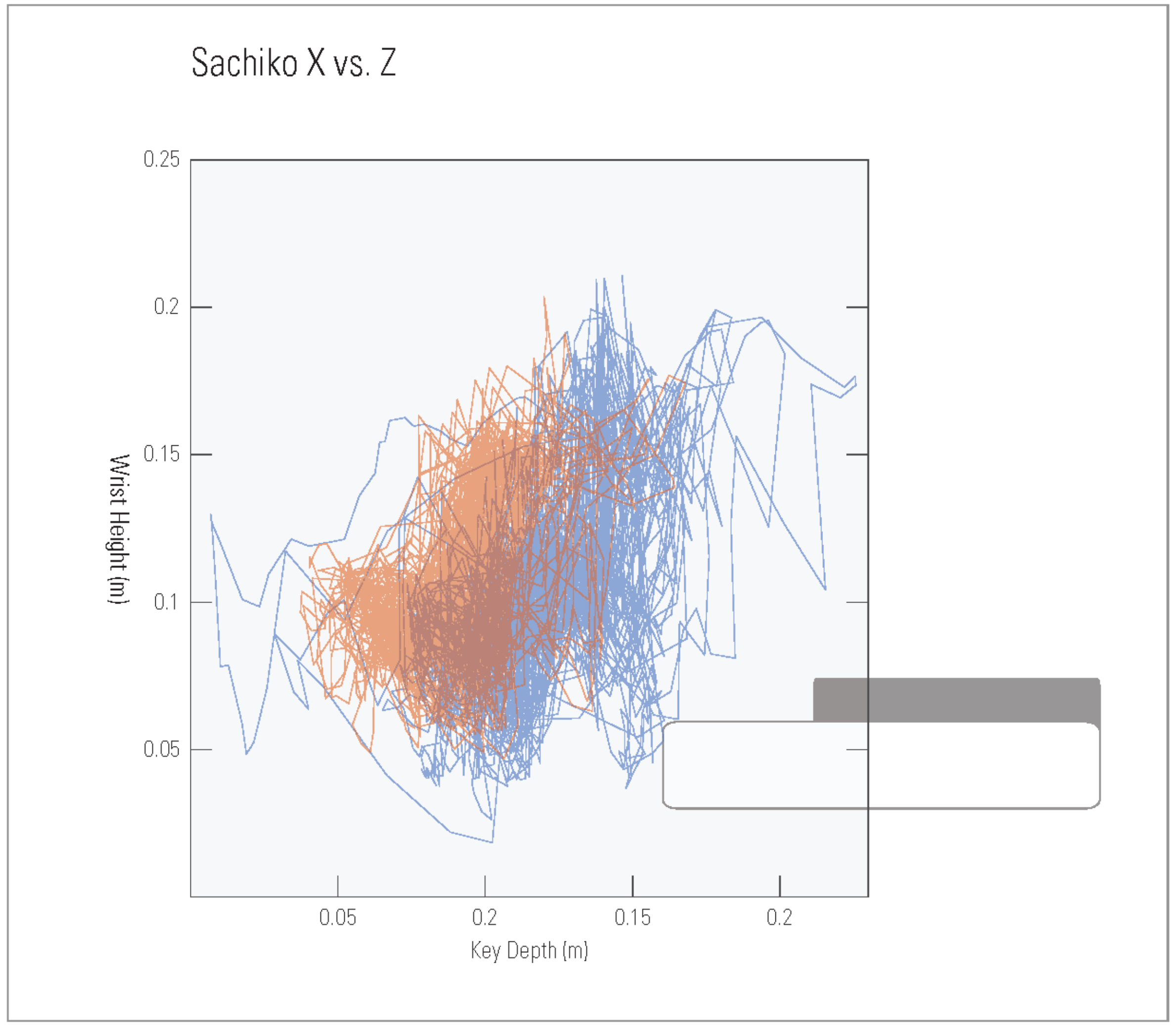


Sachiko’s performance was clearly better. Her wrists moved up and down as she played the piece, while Jamie’s wrists were relatively flat.

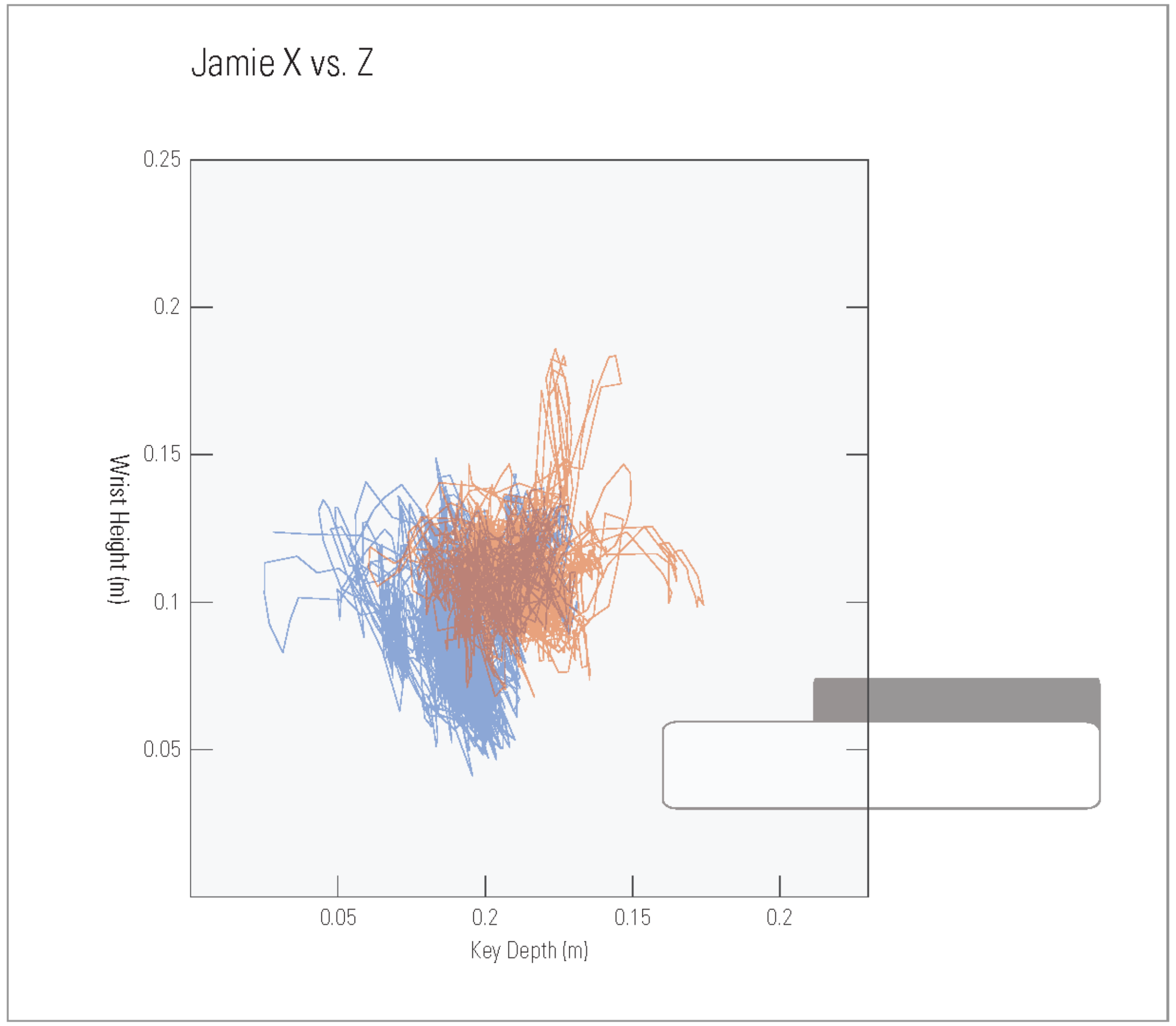
The orthographic projections are more revealing.



Comparing side view plots is the most revealing.

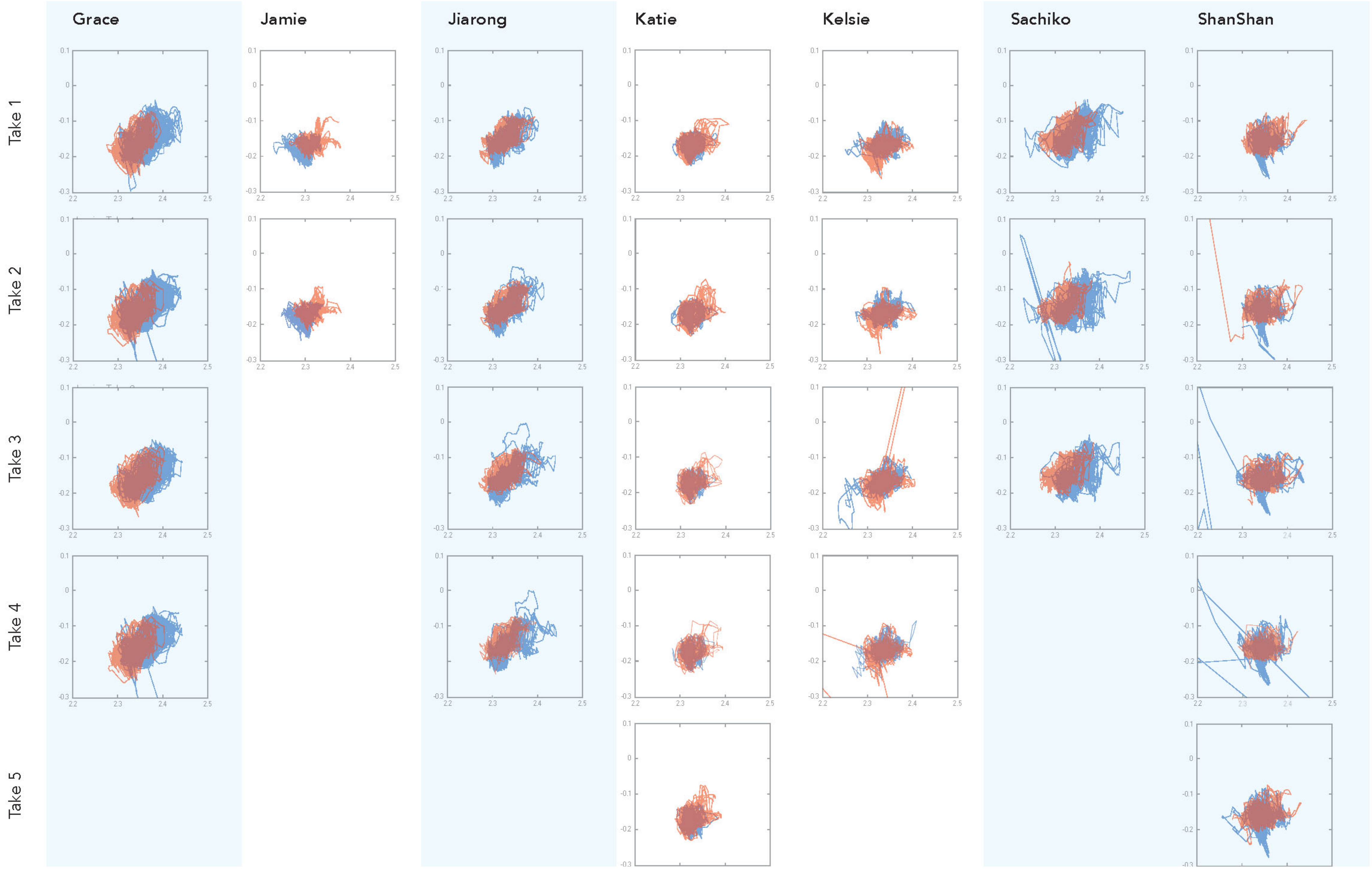


Sachiko



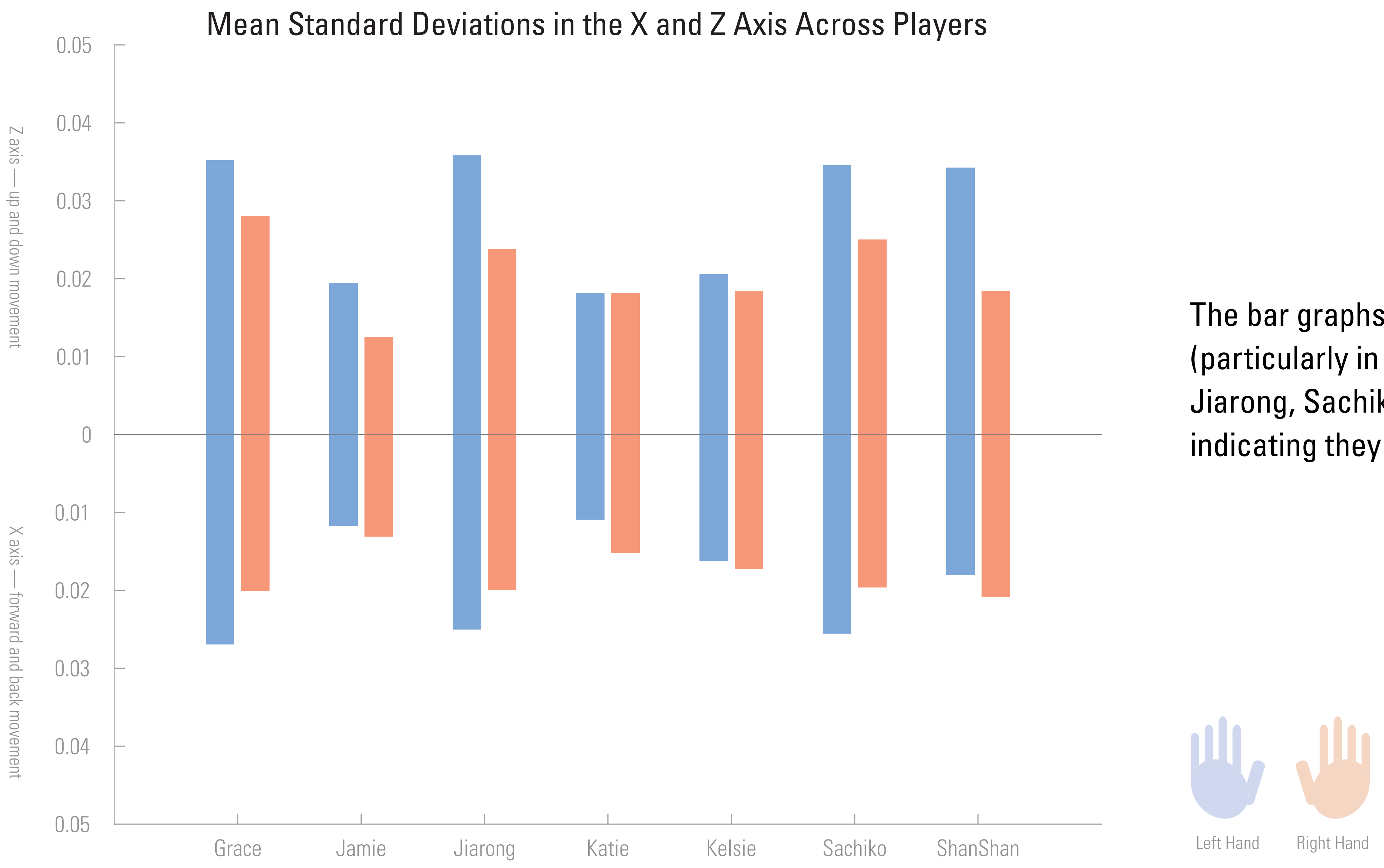
Jamie

Side view plots for all performances— the differences are obvious.



Advanced players

Calculating standard deviation shows a clear pattern.



The bar graphs show greater movement (particularly in the left hand) for Grace, Jiarong, Sachiko, and ShanShan—indicating they are advanced performers.

What does this all mean?

"… a building cannot be viewed simply in isolation.
It is only meaningful as a human environment.
It perpetually interacts with its inhabitants,
on the one hand serving them
and on the other hand controlling their behavior.

In other words structures make sense
as parts of larger systems that include human components
and the architect is primarily concerned
with these larger systems;
they (not just the bricks and mortar part)
are what architects design."

— **Gordon Pask**, *The Architectural Relevance of Cybernetics*, 1967

"In most people's vocabularies,
design means veneer. It's interior decorating.
It's the fabric of the curtains and the sofa.
But to me, nothing could be further
from the meaning of design.
Design is the fundamental soul
of a man-made creation
that ends up expressing itself
in successive outer layers
of the product or service."

— **Steve Jobs,** *Fortune,* January 24, 2000

A matrix of design: the six types
Jay Doblin, 1987

Tangible objects and messages	Sets of coordinated products and the people who operate them	Competing unisystems
Appearance Products Christmas ornaments Medals Trophies	**Appearance Unisystems** Restaurant environment South Street Seaport Disneyland	**Appearance Multisystems** The fashion industry
Performance Products Crowbars Paper clips	**Performance Unisystems** Compact kitchen NASA space mission United Airlines	**Performance Multisystems** The airline industry The computer industry

From “A Short, Grandiose Theory of Design,” STA Design Journal

Era analysis: evolution of design
Joi Ito, 2017

Objects (physical and immaterial)	**Systems**	**Complex Adaptive Systems**

*"Design has also evolved
from the design of objects
both physical and immaterial,
to the design of systems,
to the design of complex adaptive systems.*

*This evolution is shifting the role of designers;
they are no longer the central planner,
but rather participants
within the systems they exist in.
This is a fundamental shift —
one that requires a new set of values."*

— **Joi Ito**, "Design and Science," January 11, 2016

John Maeda has offered a sort of era analysis.

1 **Classical Design**
There is a right way to make what is perfect, crafted, and complete.

2 **Design Thinking**
Because execution has outpaced innovation, and experience matters.

3 **Computational Design**
Design for billions of individual people and in real time, is at scale and TBD.

—Design in Tech Report, 2018

Stephen Anderson says, "The future of design is complexity + computation."

Design 1.0
Product

Design 2.0
Experience

Design 3.0
Outcomes

—https://medium.com/@stephenanderson/the-future-of-design-computation-complexity-a434d2da3cd5

Richard Buchanan proposed “four orders of design.“

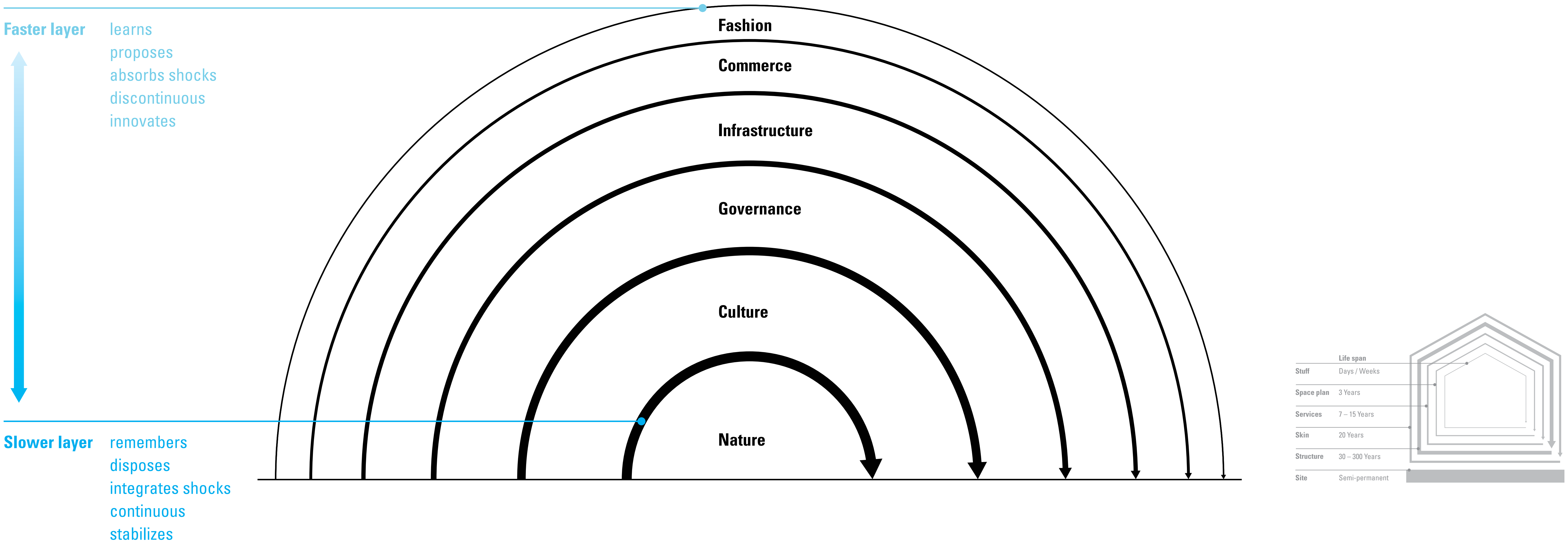
1 **Communications —**
a focus on meaning and symbols

2 **Artifacts —**
a focus on form and things

3 **Interactions —**
a focus on behavior and action

4 **Fourth order —**
a focus on “environments and systems in which all other orders exist“

Stewart Brand has proposed “a pace layer model.“

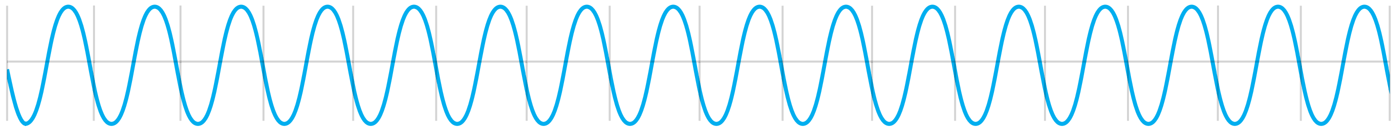


Pace layers in product management Jorge Arango, 2018

Faster
More Volatile

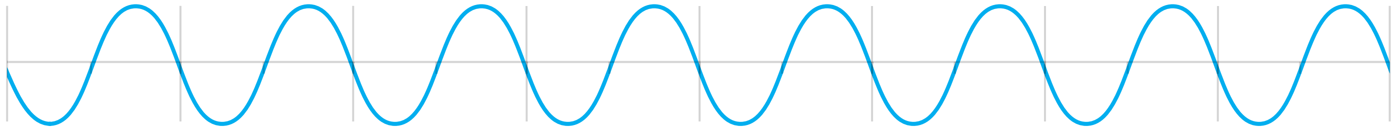
Form

User interfaces through which people interact with products and services—where structure is articulated...



Structure

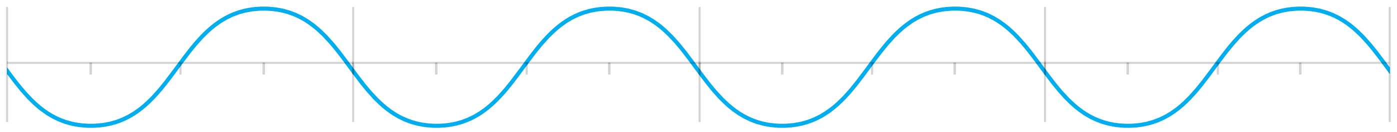
The relationships between particular semantic elements that will inform end products and services.



Designers tend to operate in these layers

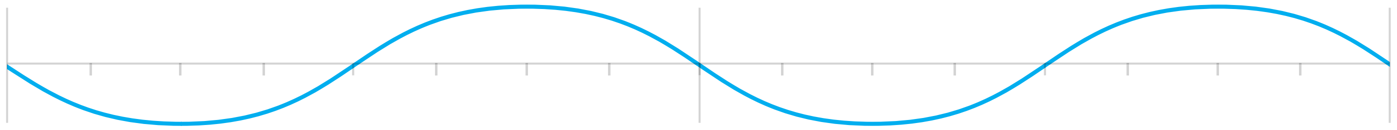
Governance

How the organization shapes itself to implement its strategy. The rules and means of engagement...



Strategy

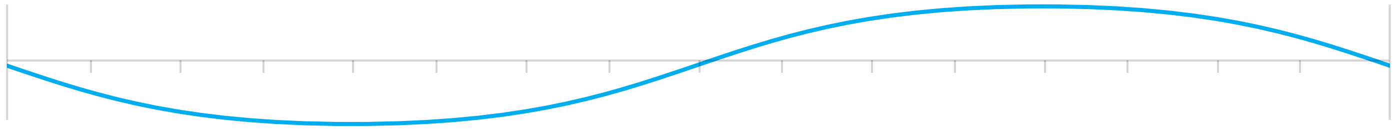
How the organization aspires to do things differently to strive towards its purpose; how it's going to compete.



Slower
More Stable

Purpose

Why the organization, team, or product exists.
An aspiration, not a goal since it can never be achieved...



Designing with data and systems

	from:	to:
Values	**Seek simplicity**	**Embrace complexity**
Designer’s role	**Expert/Deciding**	**Collaborator/Facilitating**
Construction	**Direct**	**Mediated**
Stopping condition	**Almost perfect**	**Good enough for now**
Result	**More deterministic**	**Less predictable**
End state	**Completed**	**Adapting, growing**

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