“The Emergence of Digital Mirror Worlds”

Global Interdependence Center

La Jolla, CA

February 3, 2020

Dr. Larry Smarr

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Jacobs School of Engineering, UCSD

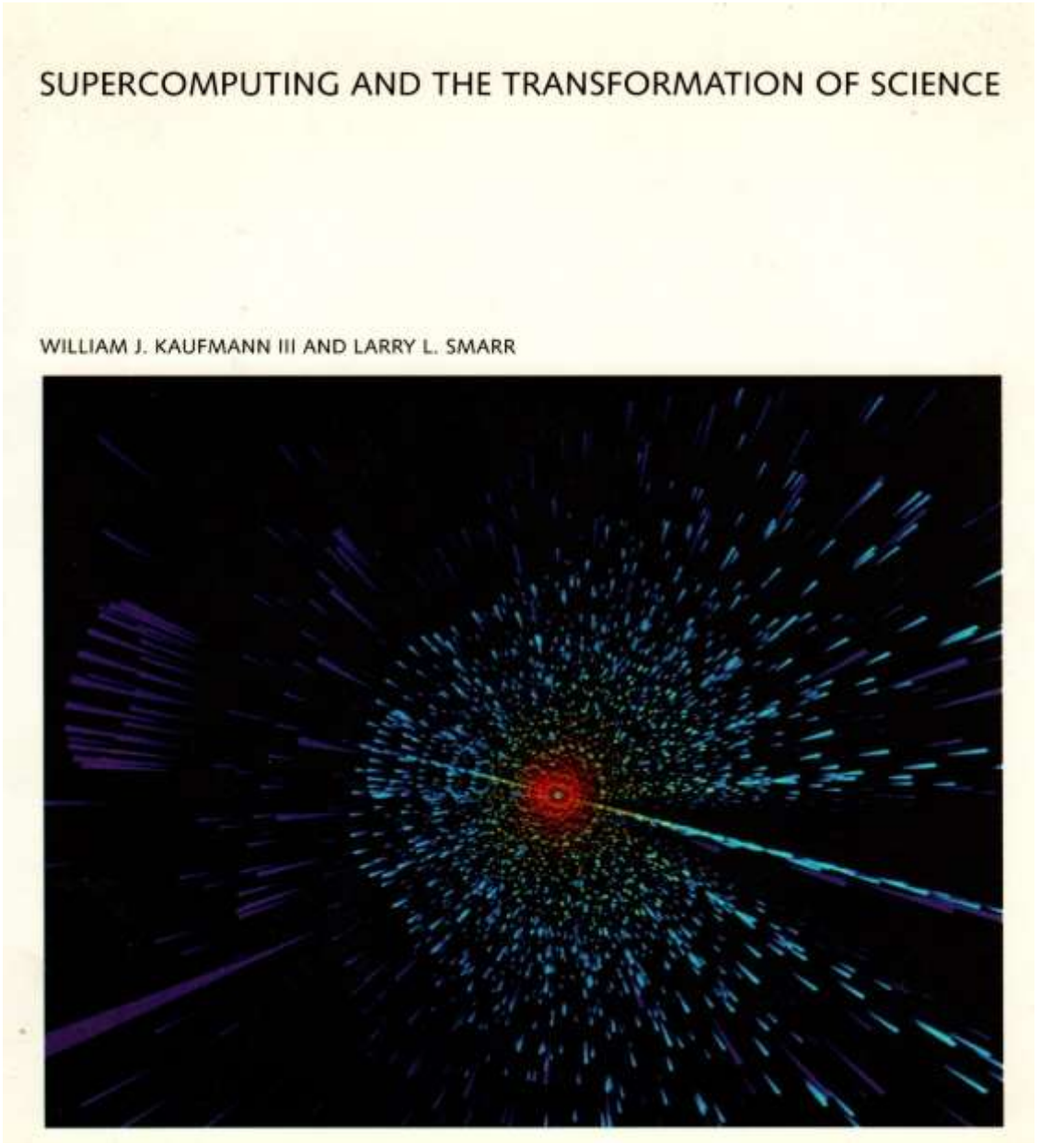
http://lsmarr.calit2.net

Supercomputers Enabled Solution of the Laws of Physics to Create the First “Mirror Worlds” of Physical Systems



National Center for Supercomputing Applications (NCSA)
1986 Cray XMP2/4

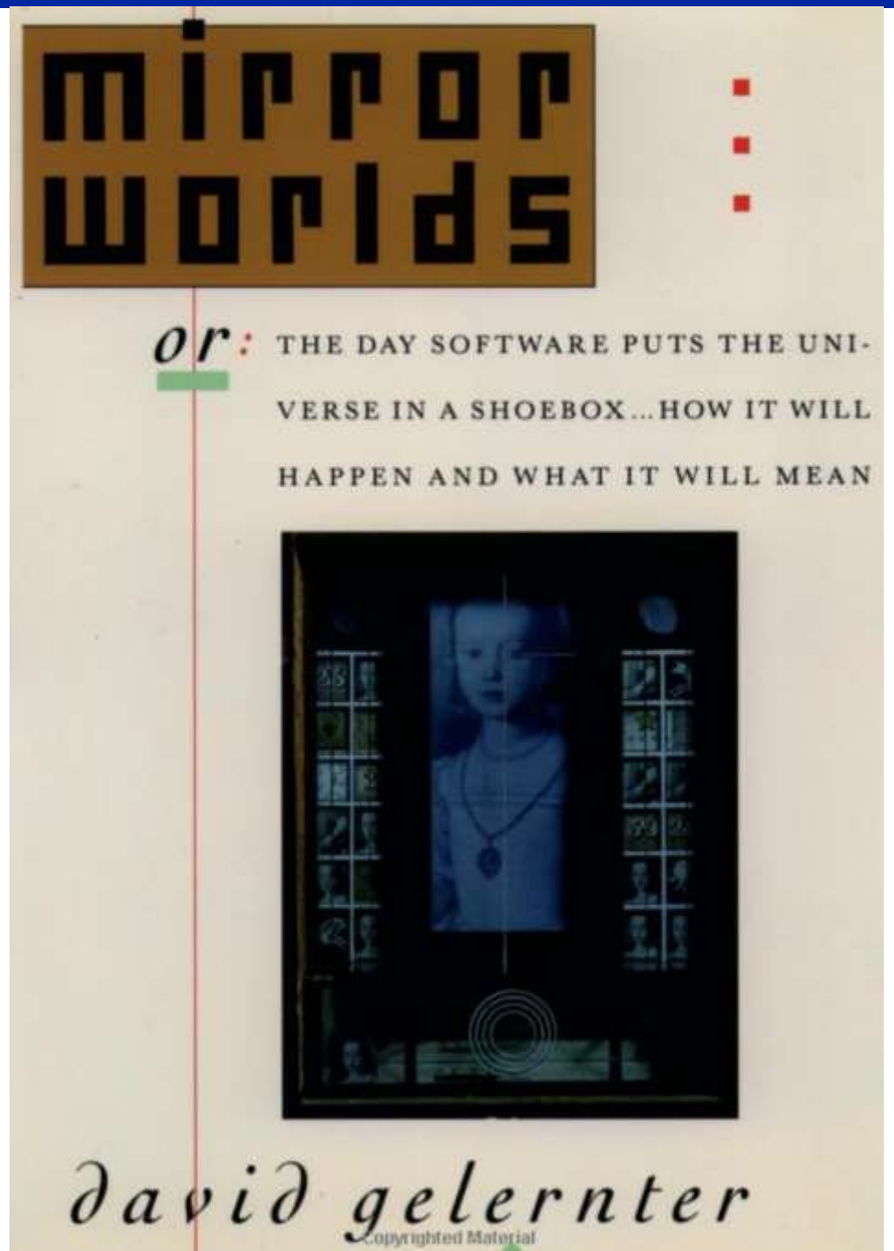
Today’s iPhone is 200x Faster!



W H Freeman & Co (1993)

In 1992 Computer Scientist David Gelernter Published a General Theory of Mirror Worlds

Our Current Era is Experiencing an Unrelenting Exponential Increase of Data Creation From A Wide Range of "Chunks of Reality"



"Mirror Worlds are software models of some chunk of reality...

Oceans of information pour endlessly into the model…

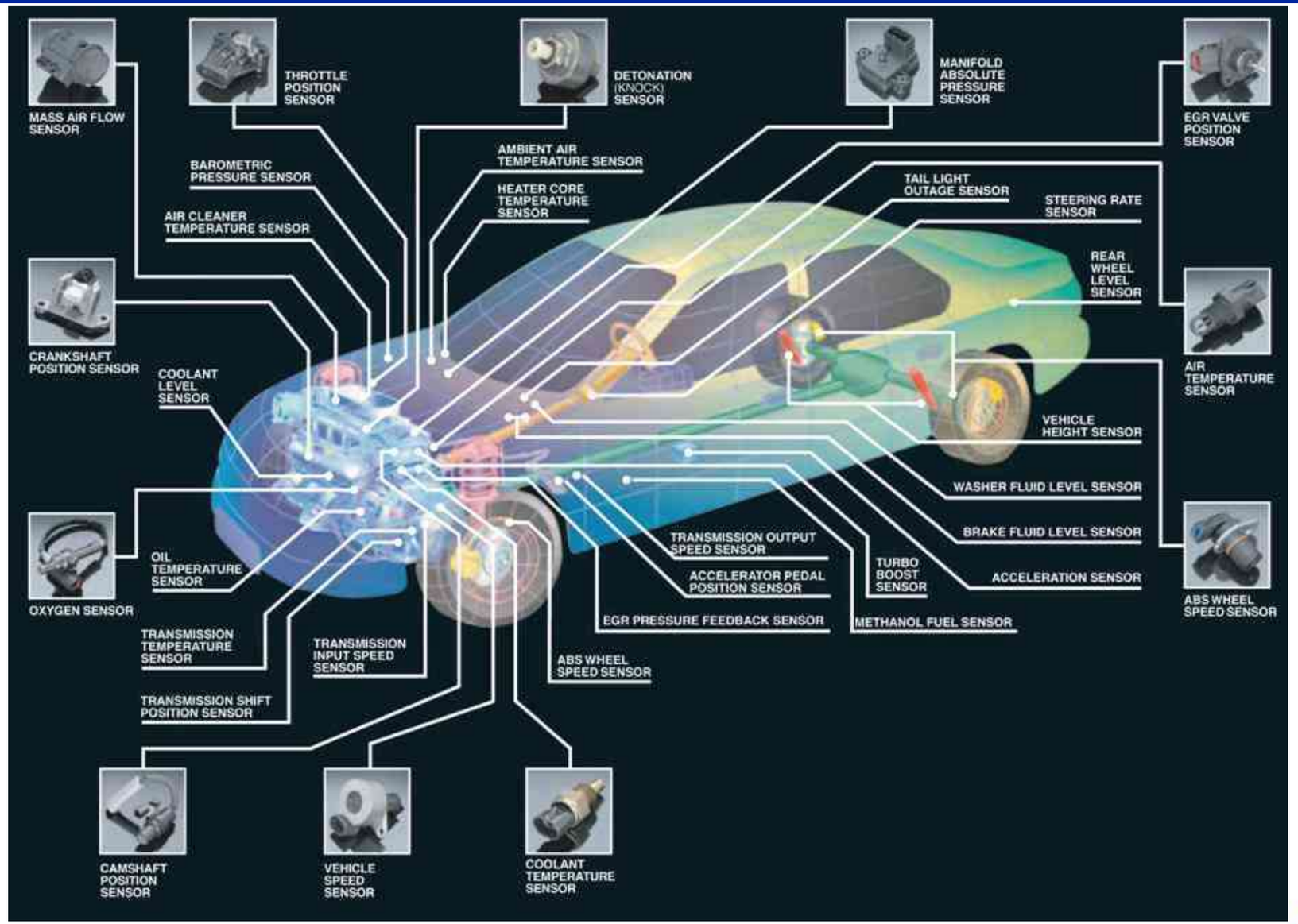
So much information that the model can mimic the reality's every move, moment-by-moment."

Modern Cars Have Massive Sensor Arrays Which Record Time Series Enabling Computer Diagnostics For Early Warning

From Mirror Worlds To Digital Twins

Before the computer diagnostics technology, most car owners did not know something was wrong with the engine until something drastic happened, such as overheating or running out of gas.

www.thepeoplehistory.com/carelectronics.html



http://blog.asautoparts.com/5-common-symptoms-of-faulty-car-sensors/

Digital Twins of Manufactured Products Are Becoming the New Normal for Large Companies

www.ibm.com/internet-of-things/trending/digital-twin

"A digital twin is a virtual representation of a physical object or system across its lifecycle, using real-time data to enable understanding, learning and reasoning."

IBM

"The whole Tesla fleet operates as a network. When one car learns something, they all learn it. Each driver using the autopilot system becomes an expert trainer for how the autopilot should work."
-Elon Musk, CEO Tesla



https://fortune.com/2015/10/16/how-tesla-autopilot-learns/

The Transition from Car “Sickcare” to Car “Healthcare” Was Enabled by Pattern Recognition Using Big Data Analytics

BMW Using IBM Predictive Analytics in Auto Production, Repairs

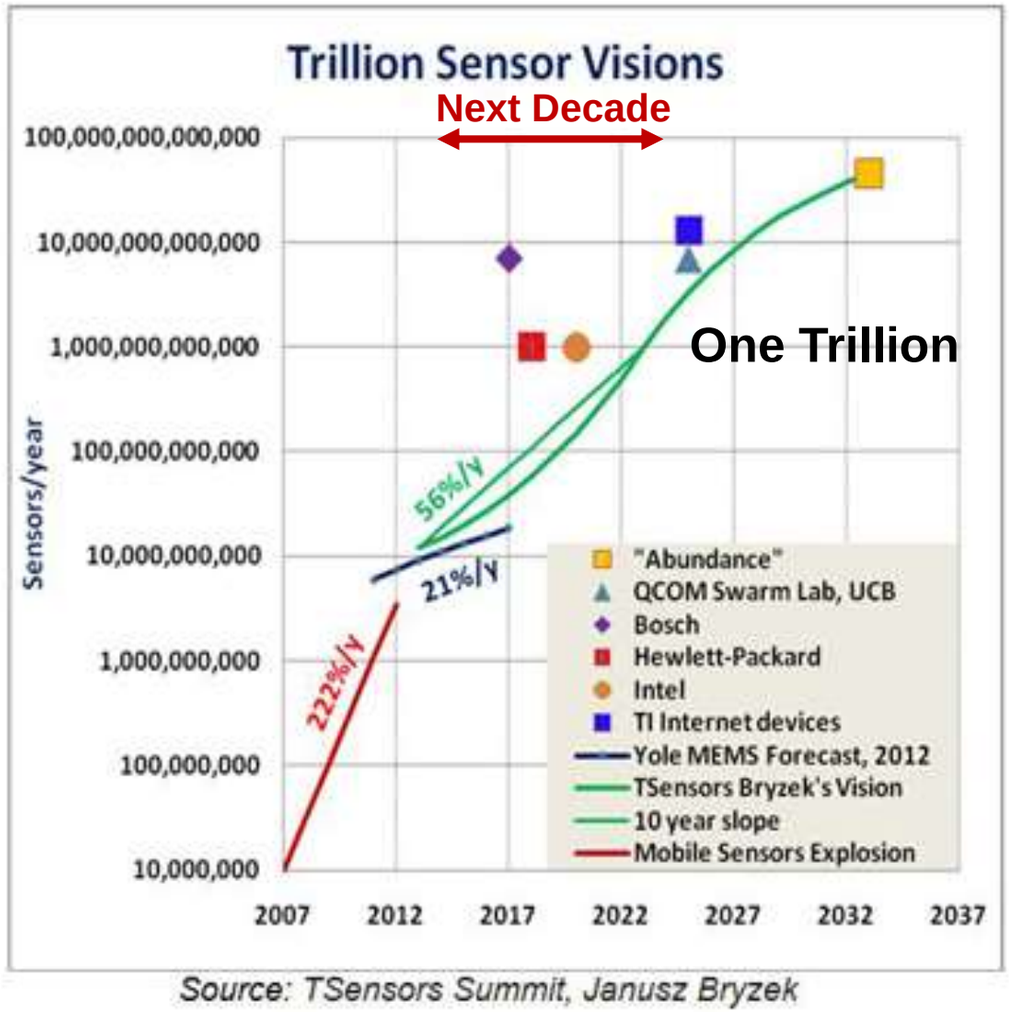
By Darryl K. Taft | Posted 2014-03-12 Print

eWEEK®

“… using IBM big data and analytics technology, all available data sources can be analyzed to discover patterns and anomalies to predict and anticipate maintenance needs.

The Planetary Computer, Computing Digital Twins of Manufactured Objects, Fed by a Trillion Sensors, Will Drive a Global Industrial Internet

T SENSORS SUMMIT™ FOR TRILLION SENSOR ROADMAP



Source: TSensors Summit, Janusz Bryzek



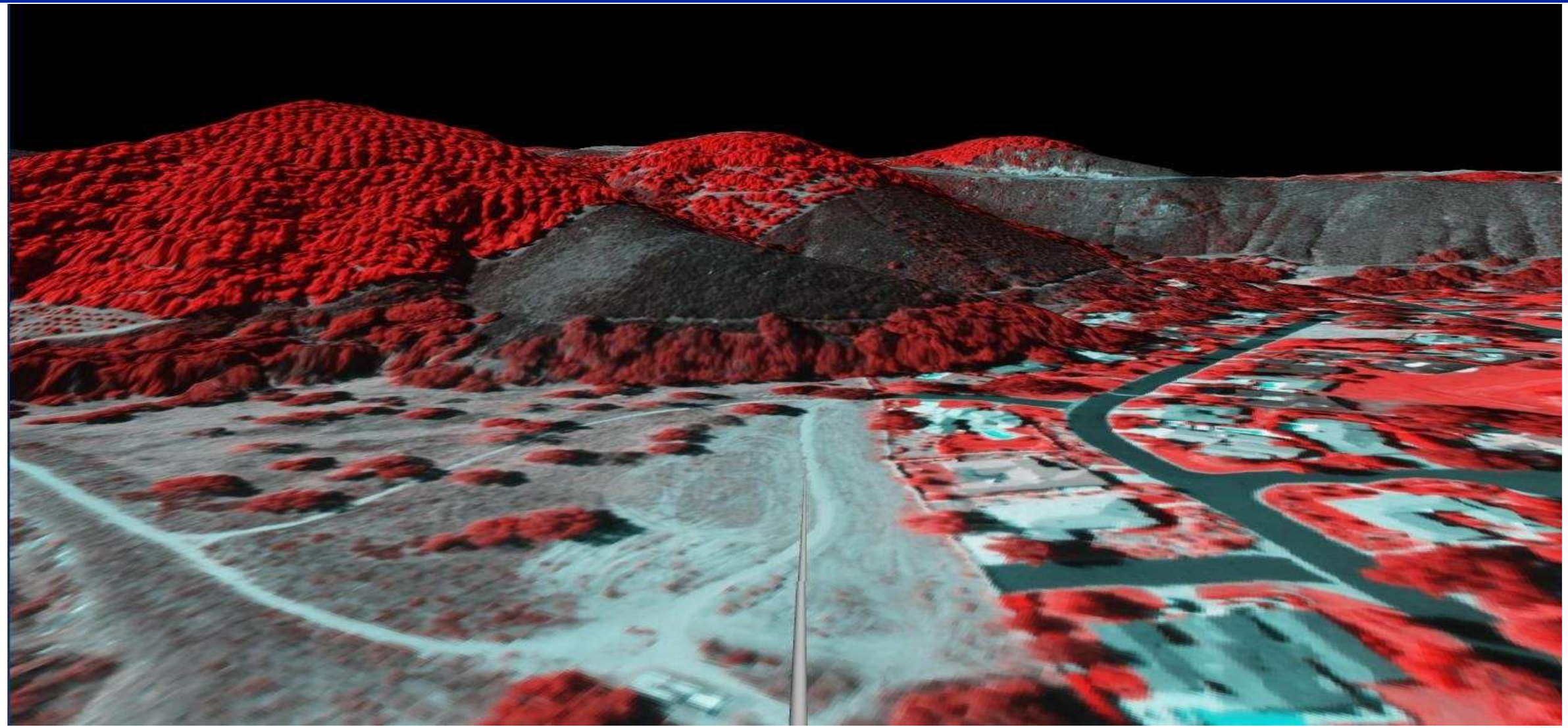
www.tsensorssummit.org

"Within the next 20 years the Industrial Internet will have added to the global economy an additional $15 trillion."
--General Electric

www.ge.com/docs/chapters/Industrial_Internet.pdf

www-bsac.eecs.berkeley.edu/frontpagefiles/BSACGrowingMEMS_Markets_%20SEMI.ORG.html

Calit2 Has Created a Digital "Digital Twin" of San Diego County



0.5 meter Image Resolution
2 meter Elevation Resolution

Interactive Virtual Reality Viewing of San Diego County “Digital Twin” Includes Live Feeds From 200 Meteorological Stations



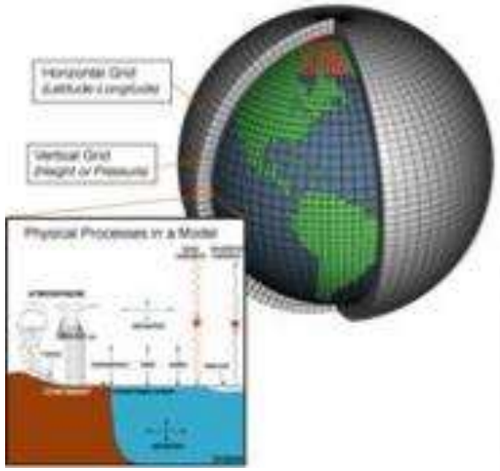
Jessica Block at Calit2’s Qualcomm Institute

Supercomputers Use Satellite & Weather Sensors to Feed a “Digital Twin” of Wildfire Evolution



Real-Time Meteorological Sensors

Weather Forecast

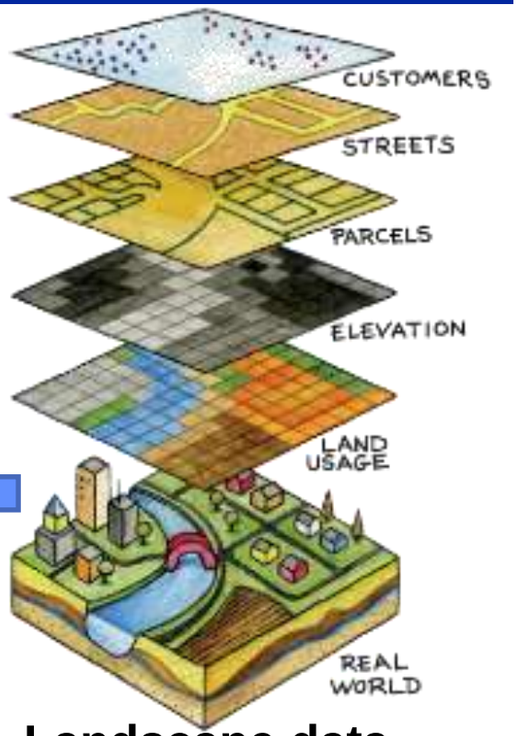




Source: Ilkay Altintas, SDSC



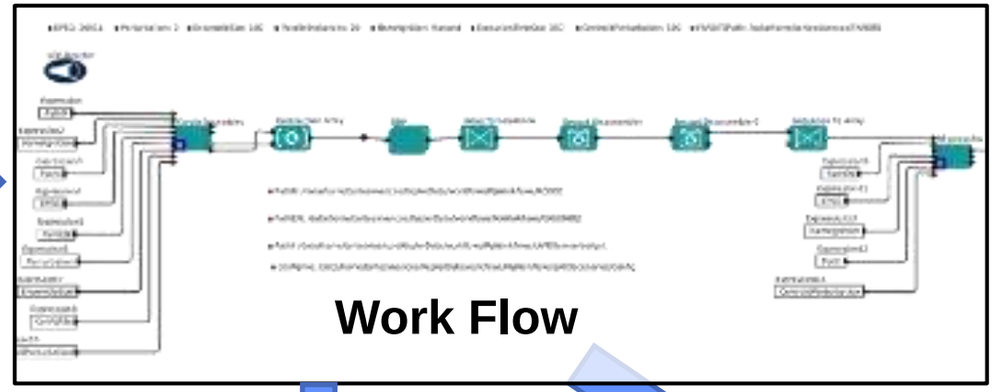
WIFIRE



Landscape data

PRP





Work Flow



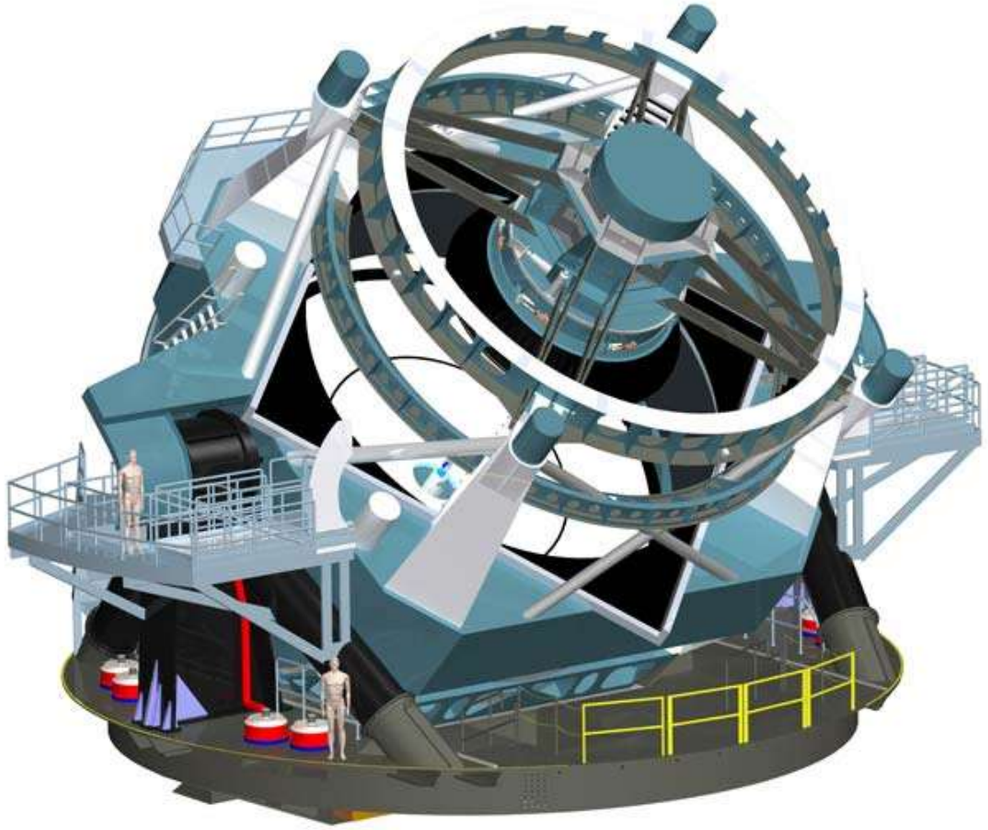




Next Generation Telescopes Will Produce Ultralarge Datasets Continuously Creating a "Digital Twin" of the Observable Universe

Large Synoptic Survey Telescope (LSST)

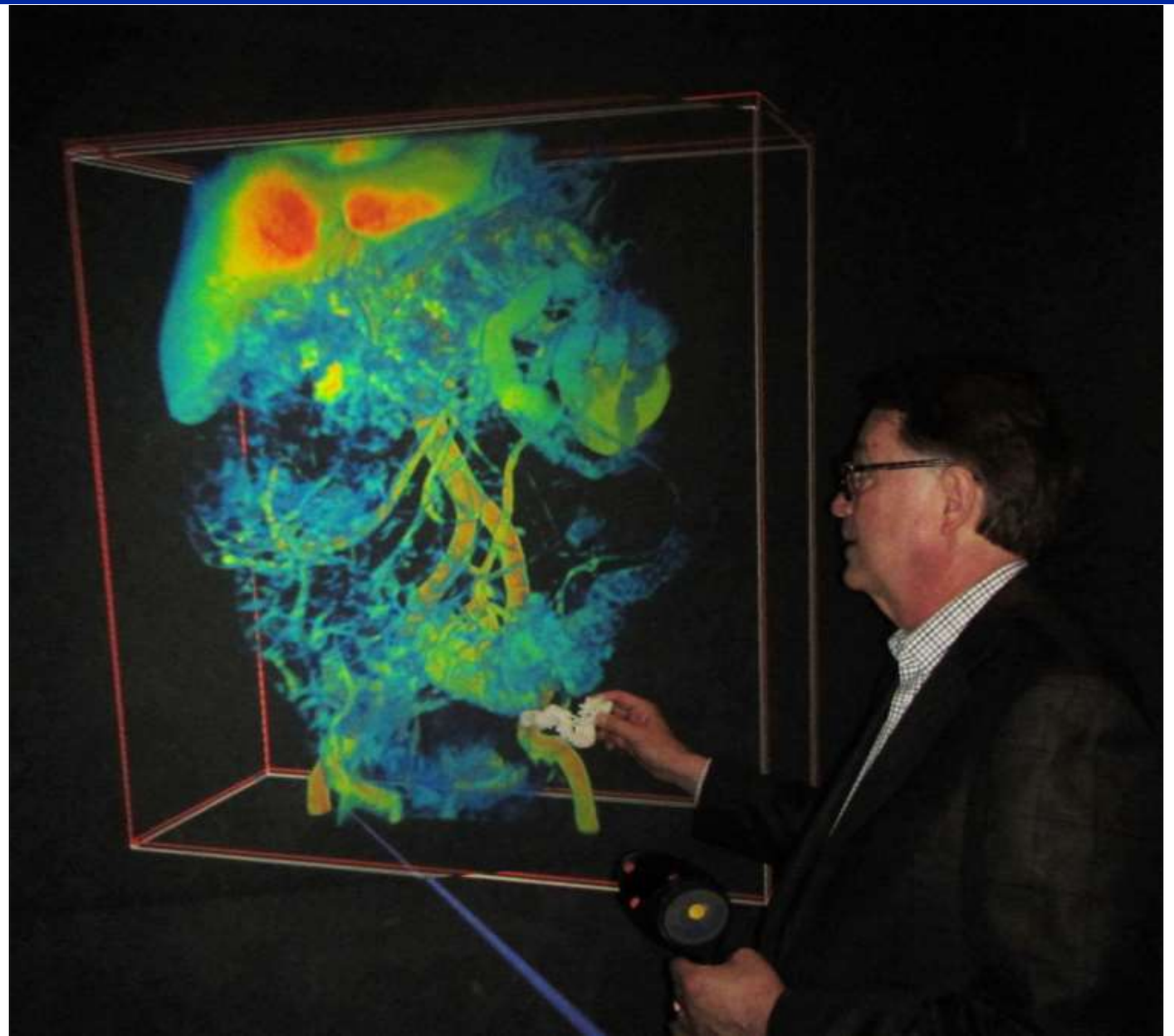
3.2 Gpixel Camera
Tracks ~40B Objects,
Creates 1-10M Alerts/Night
Within 1 Minute of Observing
1000 Supernovas Discovered/Night



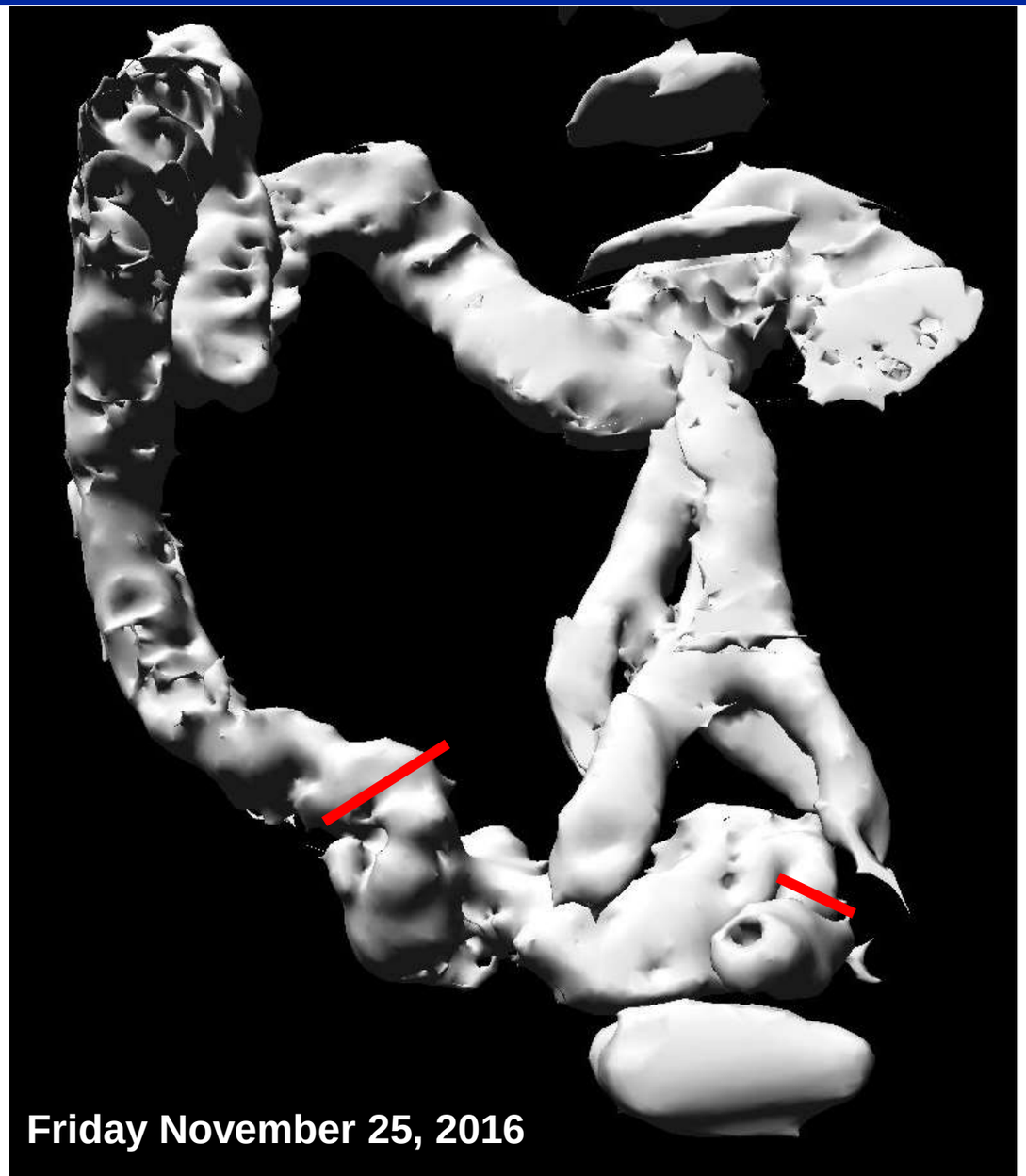


3D Volumetric Visualization From 150 MRI Slices Creates a Transparent Larry “Digital Twin”

Calit2’s Jurgen Schulze from January 2012 MRI



Pre-Surgical Planning in Virtual Reality:
From Digitally-Enabled Future Patient to Digitally-Enabled Future Doctor





Colon visualization by Jurgen Schulze, Calit2;
Photo credit Tom DeFanti, Calit2

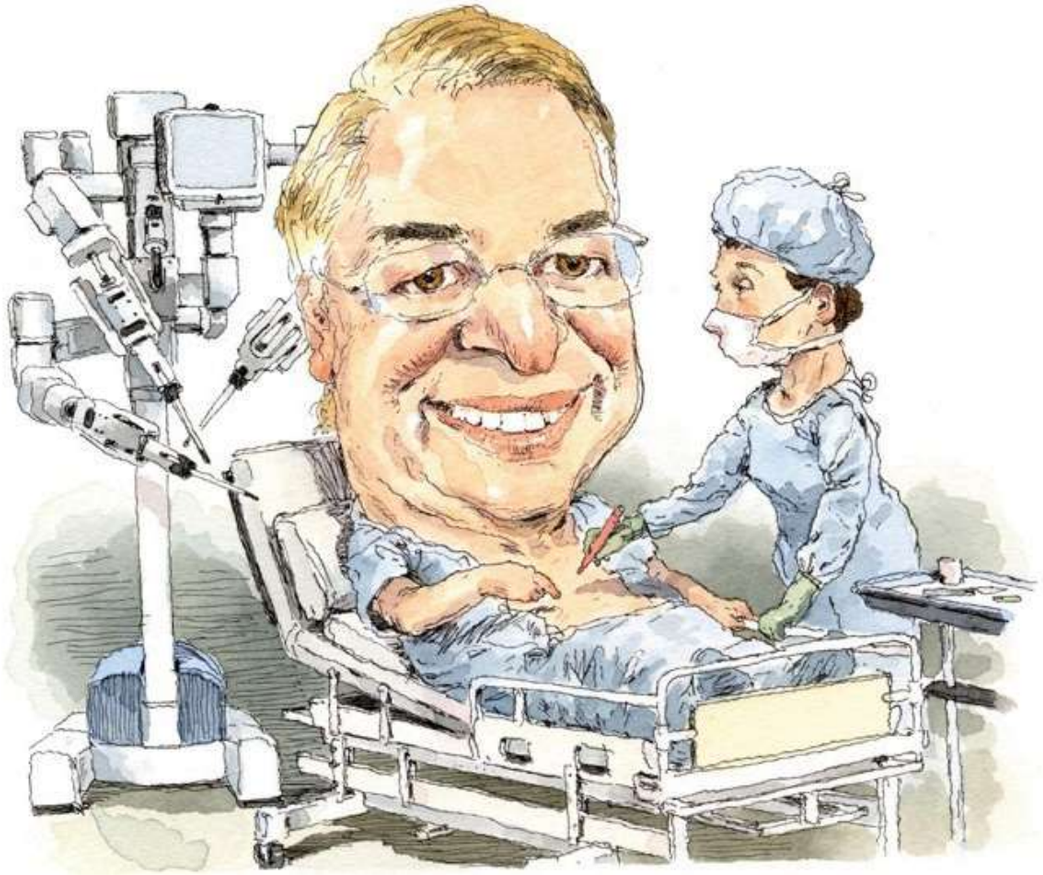
The Ability to See Inside Myself Led to My Co-Planning My Own Surgery

The Atlantic

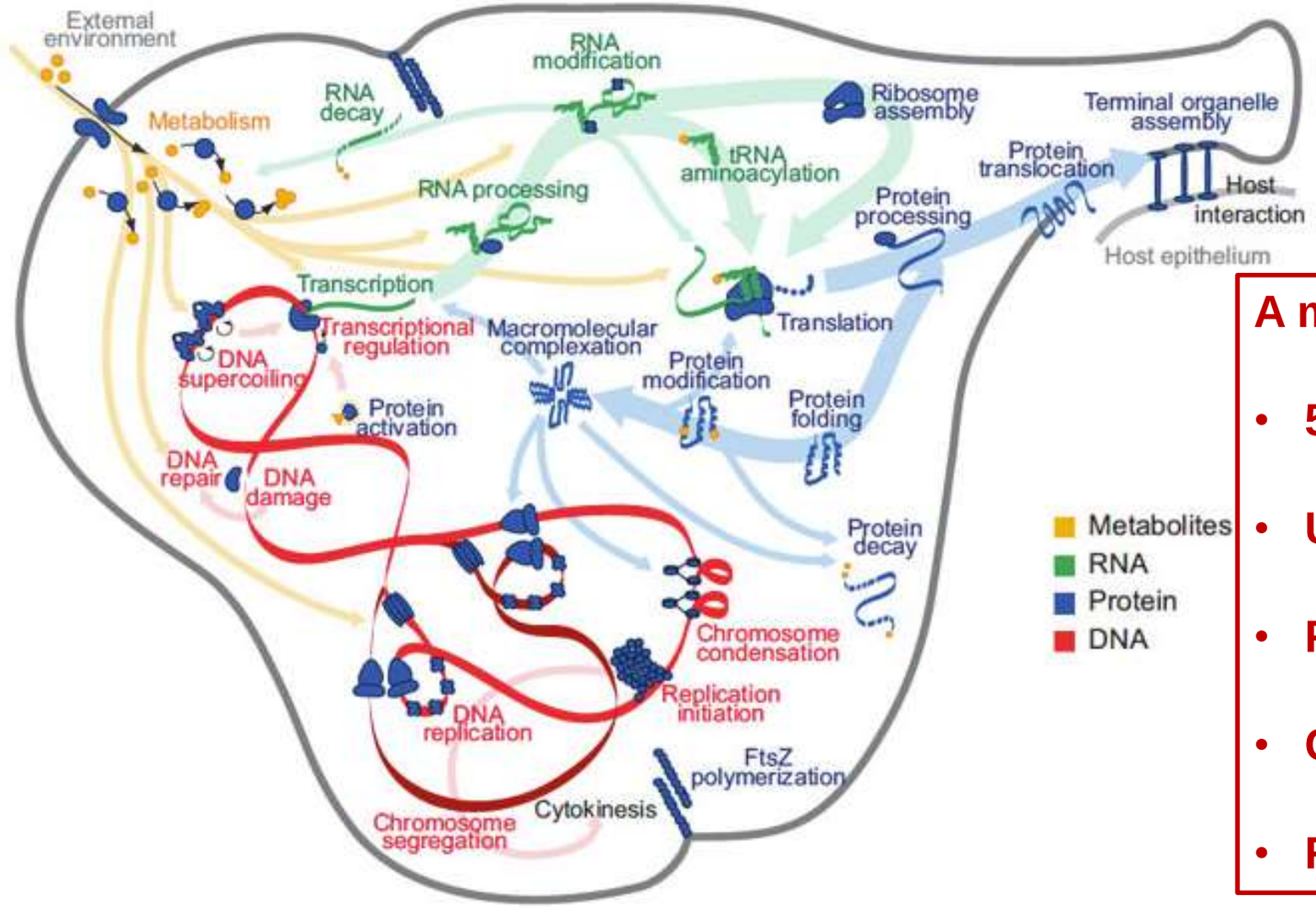
The Man Who Saw Inside Himself

For years, Larry Smarr has used a supercomputer to monitor his health and peer at his organs. Recently, he used his knowledge to help direct his own surgery.

MARK BOWDEN | MARCH 2018 ISSUE | HEALTH



Digital Twins of Whole Living Cells
"A Computational Model Predicts Phenotype from Genotype"



Cell

Cell *150*, 389–401, July 20, 2012

A model of *Mycoplasma genitalium*,

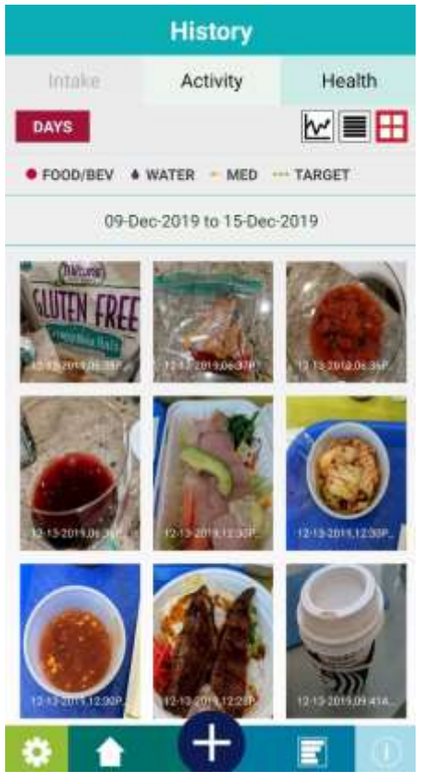
- **525 Genes**
- **Using 1,900 Experimental Observations**
- **From 900 Published Studies,**
- **Created a Software Model,**
- **Requires 128 Computers to Run**

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The Dawn of Virtual Cell Biology

I Use Many Personal Sensors, Which Stream My Data to Clouds, To Quantify My Body, Detect Changes, & Drive Behavioral Change



MyCircadian Clock- Food & Drink



FitBit - Daily Steps, Heart Rate, Sleep



Withings/iPhone- Blood Pressure





Abbott Libre - Continuous Glucose



Withings WiFi Scale - Daily Weight

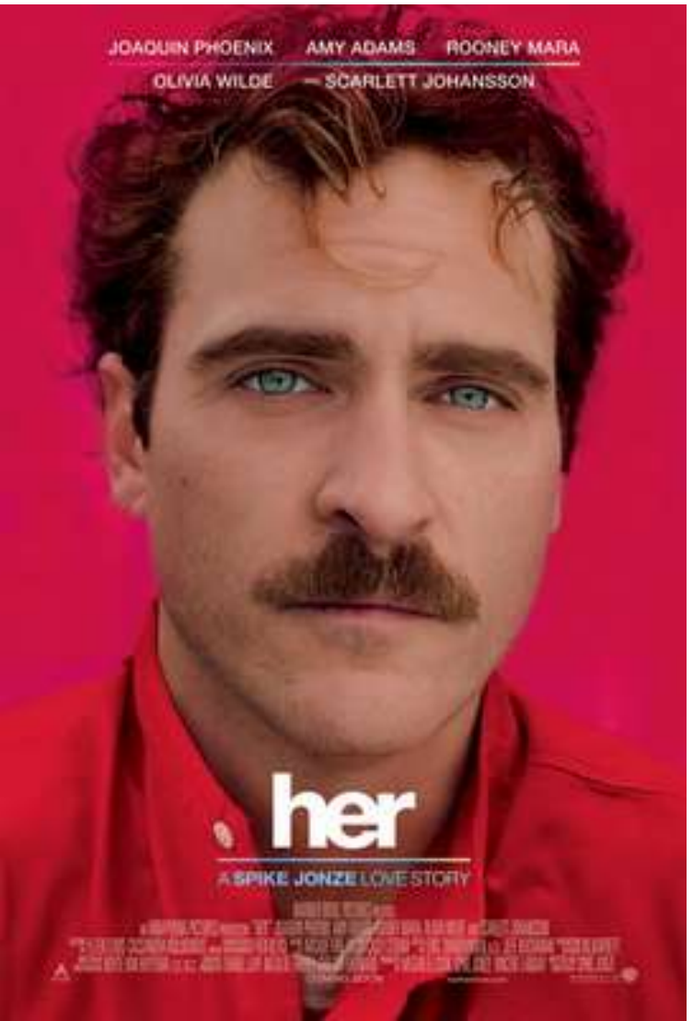


Apple Watch 5 - Heart Rhythm



Oura Ring - Temperature, Sleep, HRV

A Vision for Healthcare in the Coming Decades



Using this data, the planetary computer will be able to build a computational model of your body and compare your sensor stream with millions of others. Besides providing early detection of internal changes that could lead to disease, cloud-powered voice-recognition wellness coaches could provide continual personalized support on lifestyle choices, potentially staving off disease and making health care affordable for everyone.

ESSAY

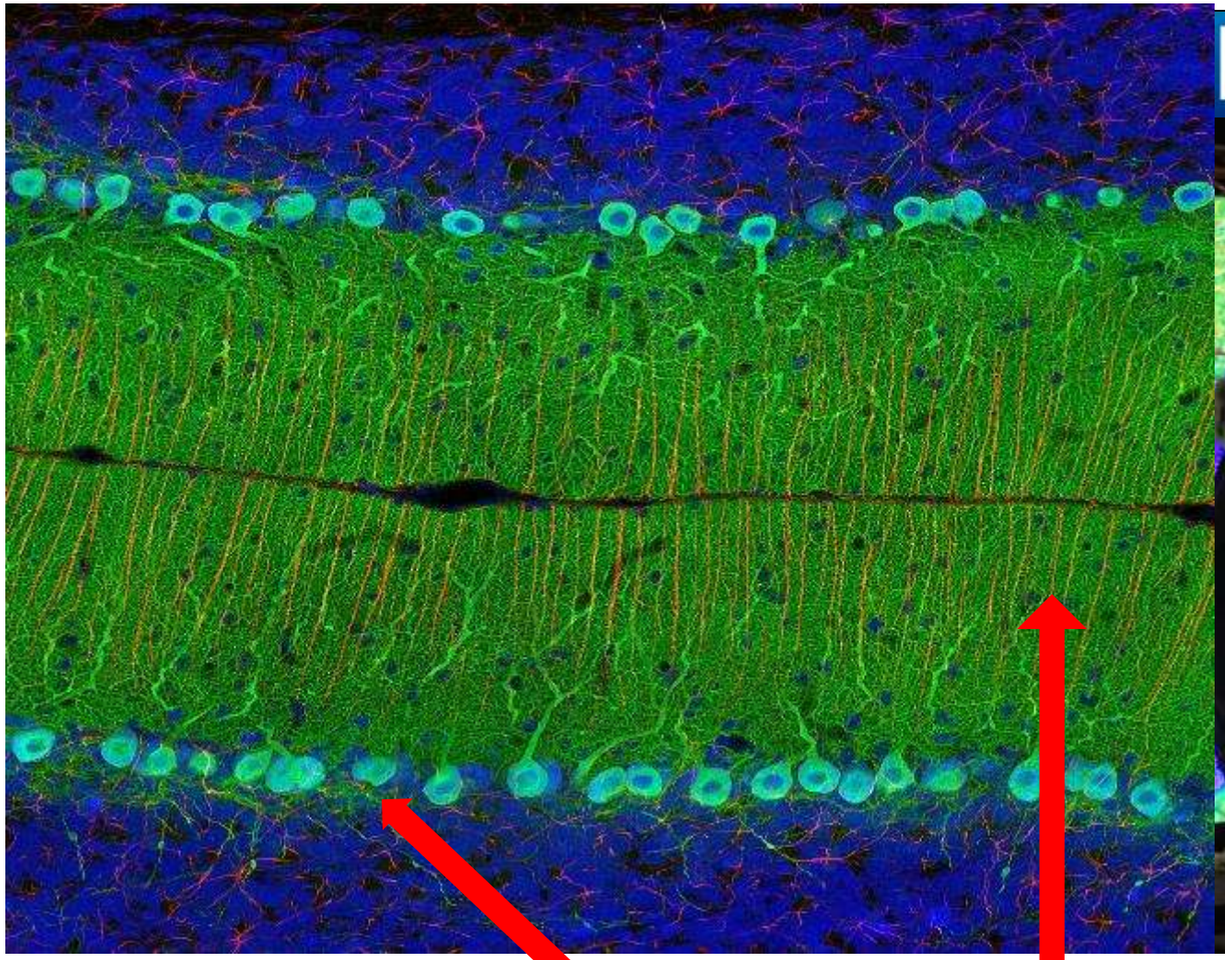
The New York Times Science

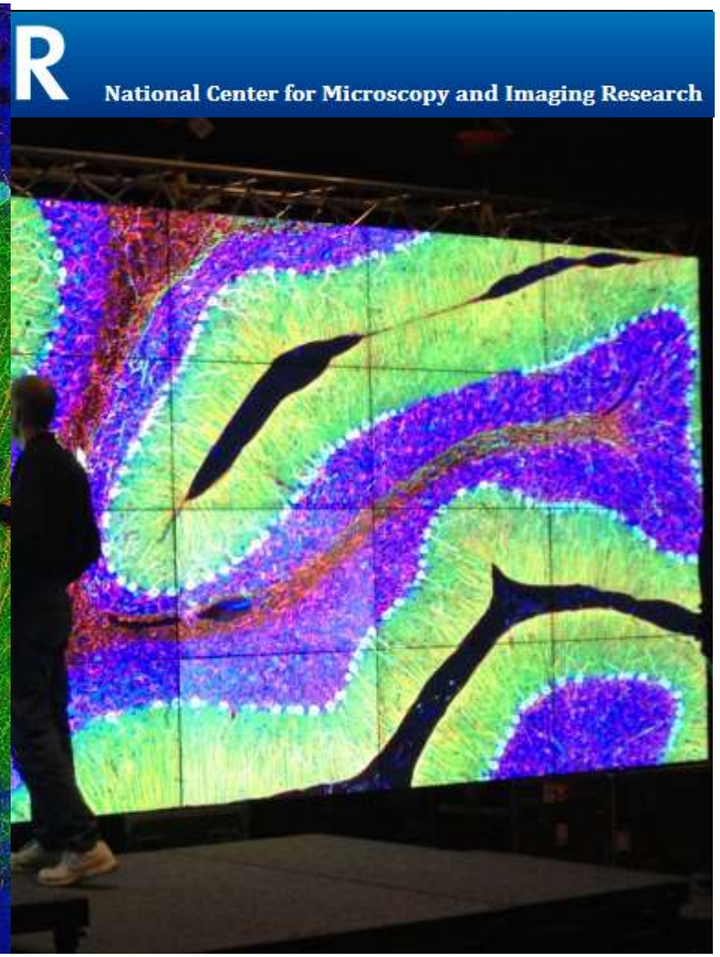
An Evolution Toward a Programmable Universe

By LARRY SMARR

Published: December 5, 2011

Reverse Engineering of the Brain:
Large Scale Microscopy of Mammal Brains Reveals Complex Connectivity





Neuron Cell Bodies

Neuronal Dendritic Overlap Region

Source: Rat Cerebellum Image, Mark Ellisman/Thomas Deerinck, UCSD

Research on Building a “Digital Twin” of the Brain is Rapidly Advancing



The Rise of Brain-Inspired Computers
Left & Right Brain Computing: Arithmetic vs. Pattern Recognition



Adapted from D-Wave

“Digital Twins” Are Coming to Consumer Business, Economics, and Perhaps Social Systems

- **“Digital Twins” of Hundreds of Millions of Consumers:**
  - **Apple ($1.4 Trillion)**
    - **More Than 75 Million Apple Watches Sold to Date**
  - **Microsoft ($1.3 Trillion)**
    - **~200 Million Windows Laptops Shipped in 2019**
  - **Google ($1 Trillion)**
    - **2 Trillion Searches/Year**
  - **Amazon ($0.9 Trillion)**
    - **175 Million Products Sold Prime Day 2019**
  - **Facebook ($0.6 Trillion)**
    - **2 Billion People Update/Day**
- **IoT Smart Homes and Cities**
- **China's Surveillance State**
- **Agent-Based Computational Economics**
- **Asimov’s Psychohistory?**