ASU Complex Adaptive Systems
Arizona State University

ASU Sandra Day O'Connor College of Law
Arizona State University

The Acceleration, Convergence and Globalization of Advanced Technologies: Escalating Complexity, Disruptive Change and New Networked Organizations

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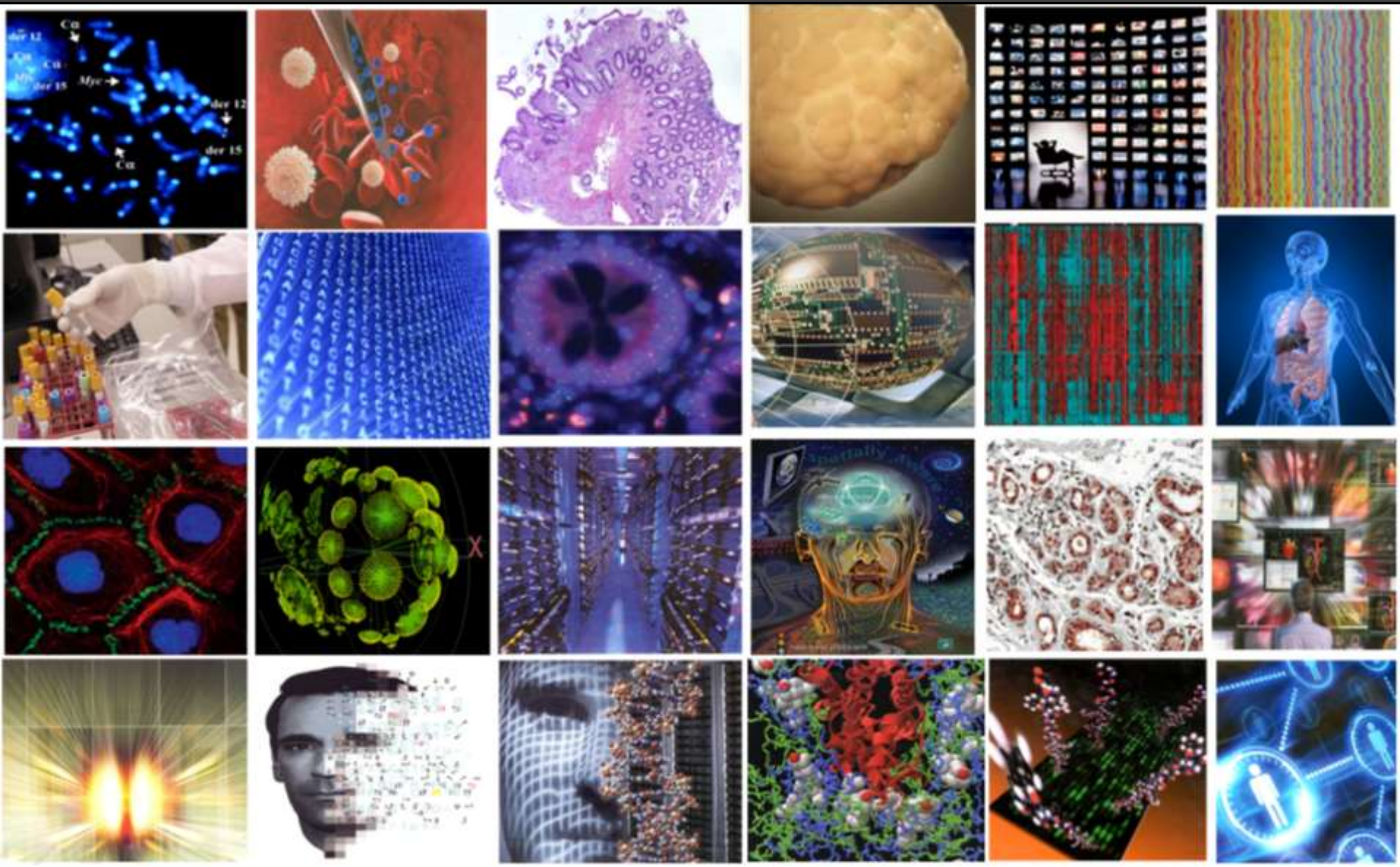
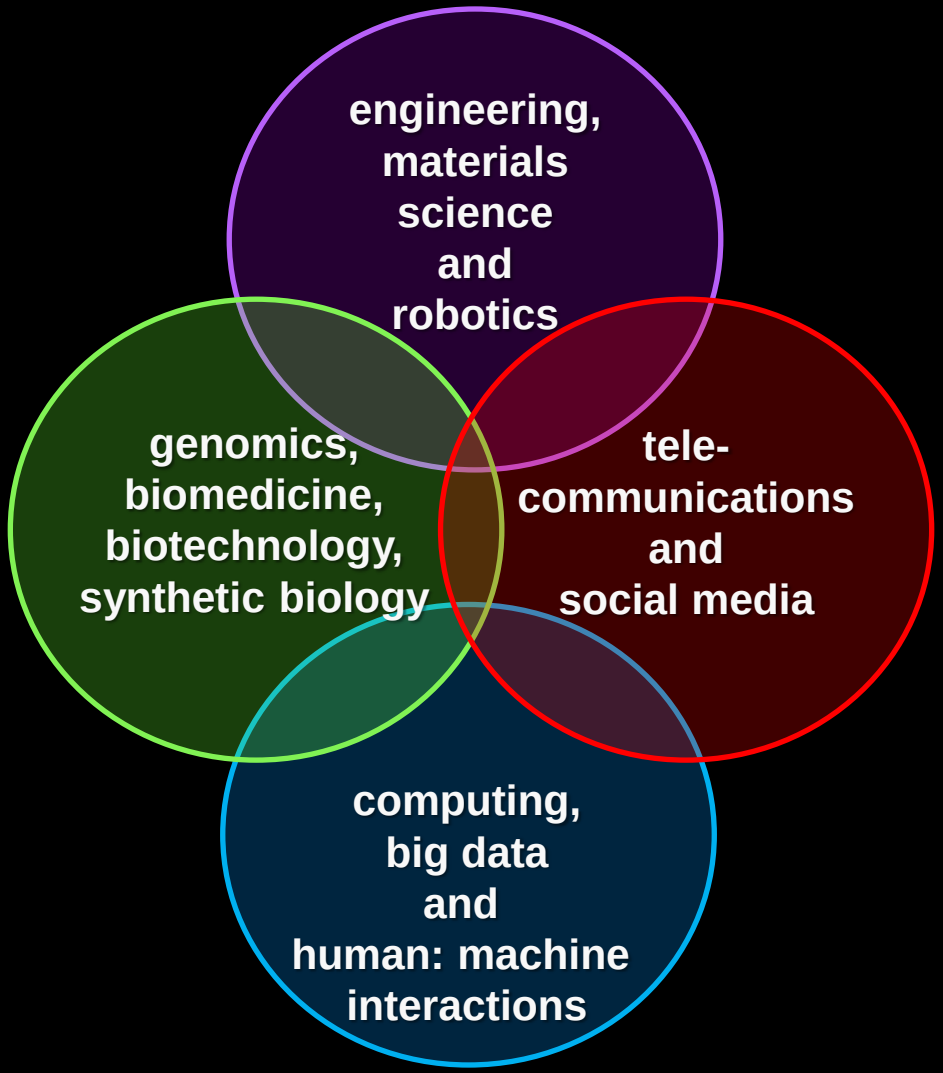
Conference on Governance of Emerging Technologies: Law, Policy and Ethics
Wild Horse Pass Resort, Chandler, AZ.
21 May 2013

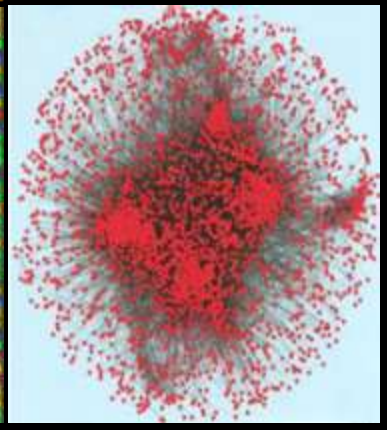
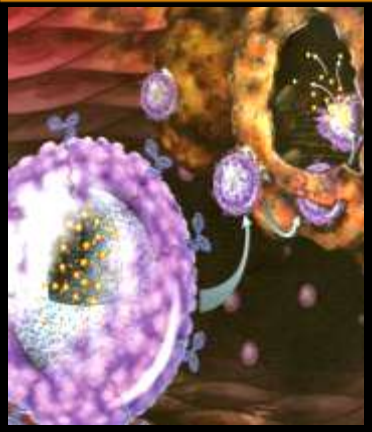
Slides available @ http://casi.asu.edu/



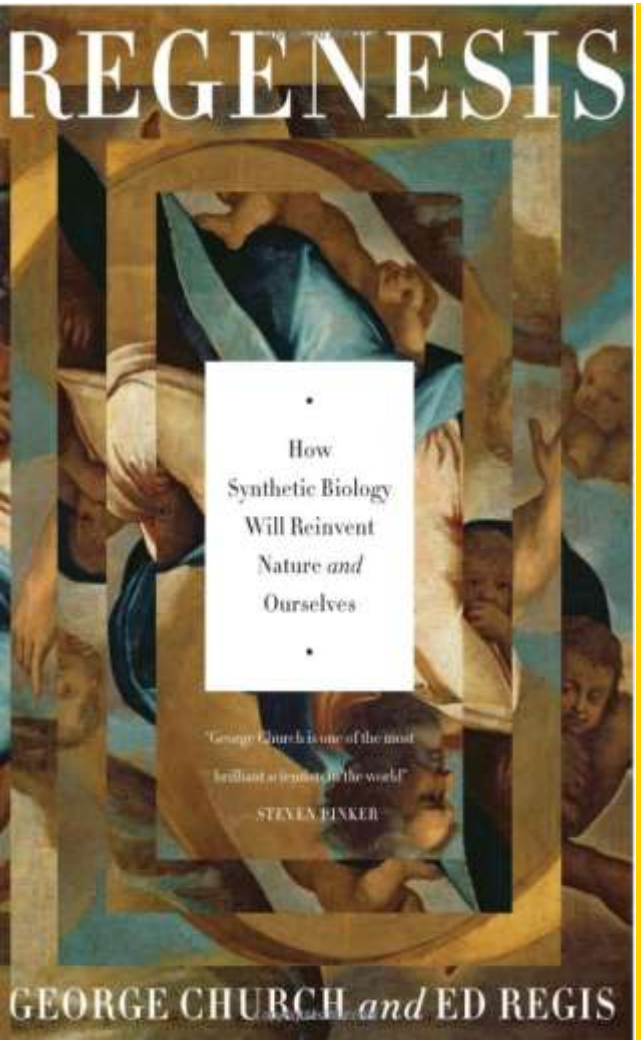
Technology Acceleration, Convergence and Disruption

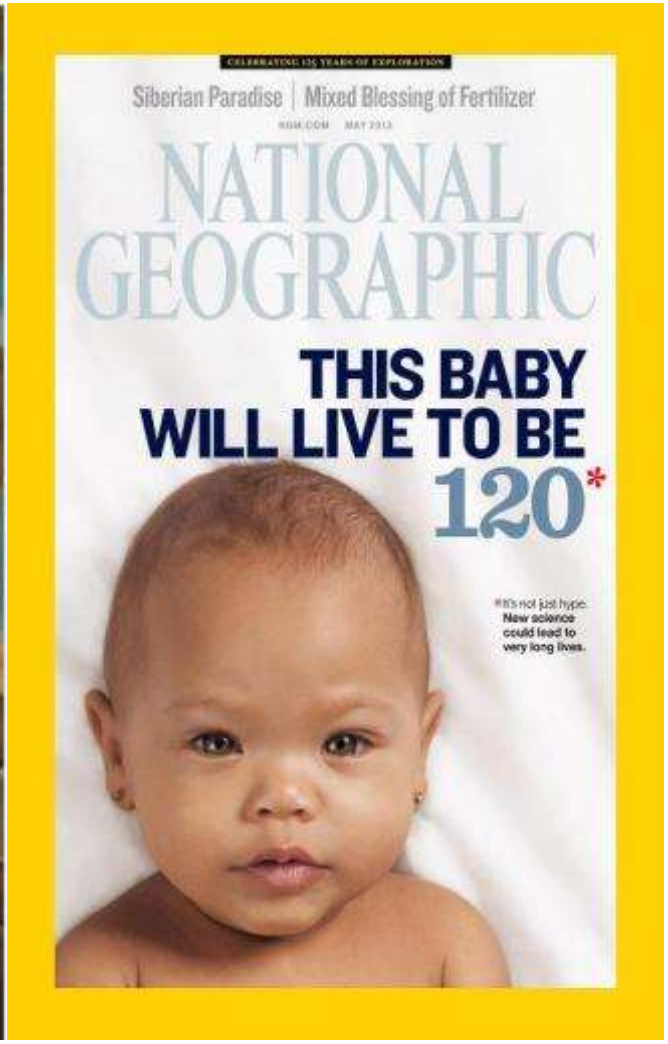


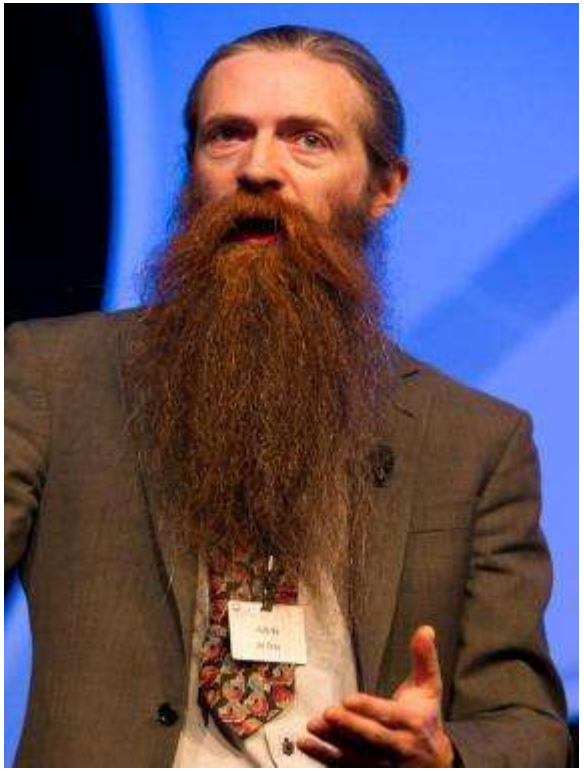
Transcending Boundaries: Technology Convergence in Biomedicine

(Epi)Genomics and Precision Medicine	Systems and Synthetic Biology	Targeted Rx and Gene Controls	Regenerative Medicine	HPO
				

Bio-Enhancement	Bionic-Enhancement	Cognitive Enhancement	Genetic Enhancement	Microbiome Metagenomics
				





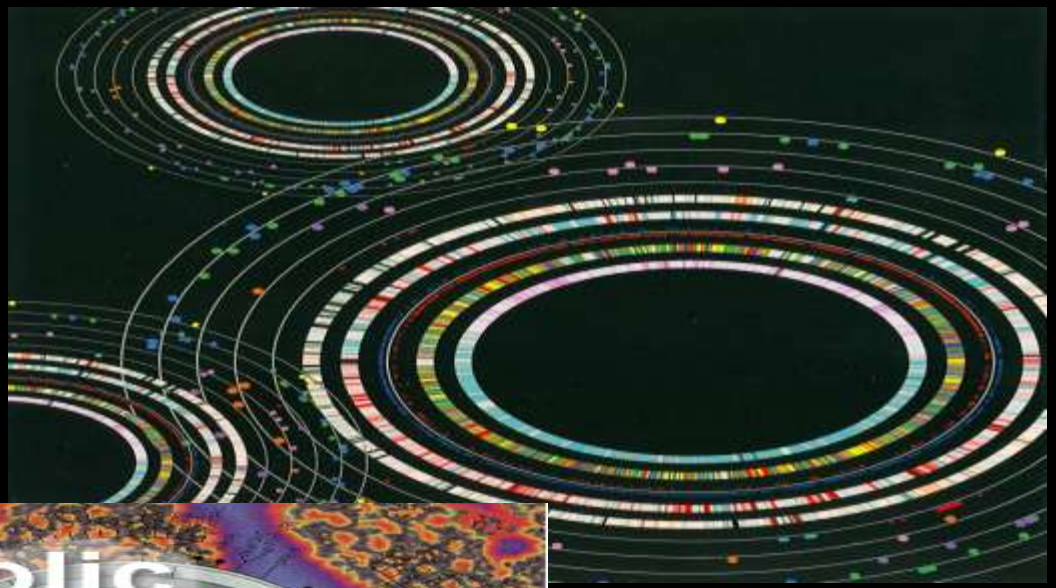


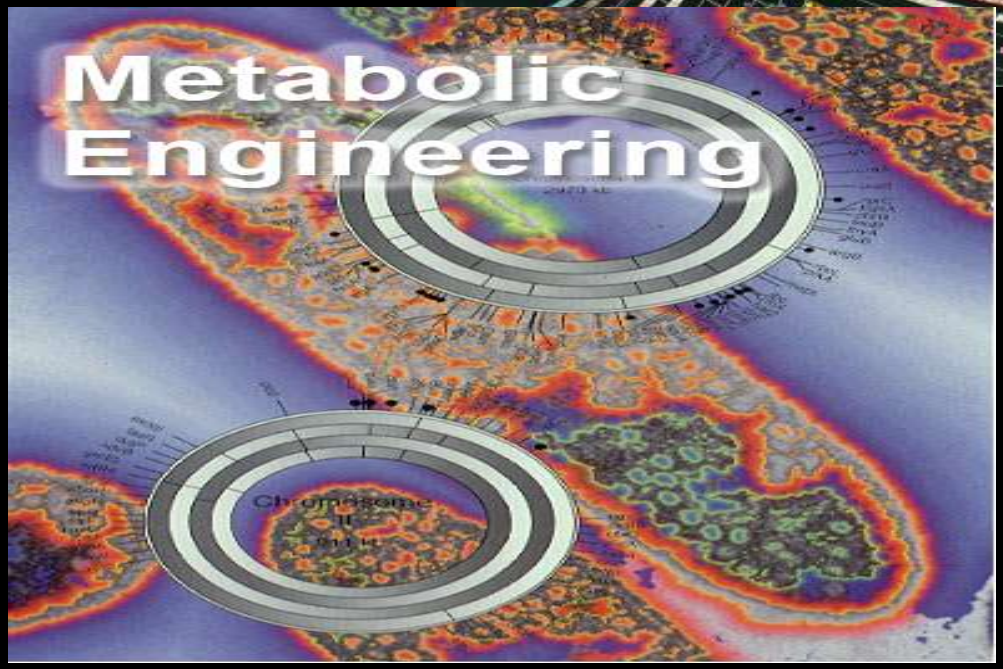
“Engineered Negligible Senescence”

Aubrey de Grey

Synthetic Biology:
Engineering Novel Organisms with Novel Functions

Programmable Genomes

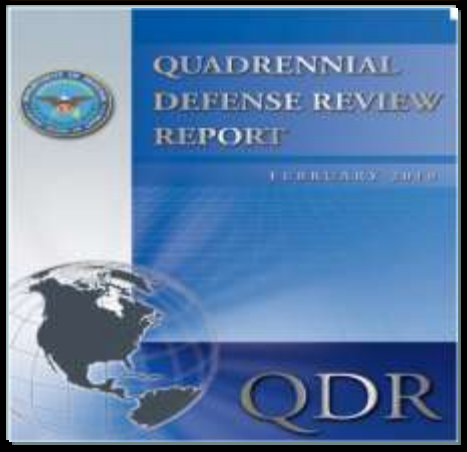
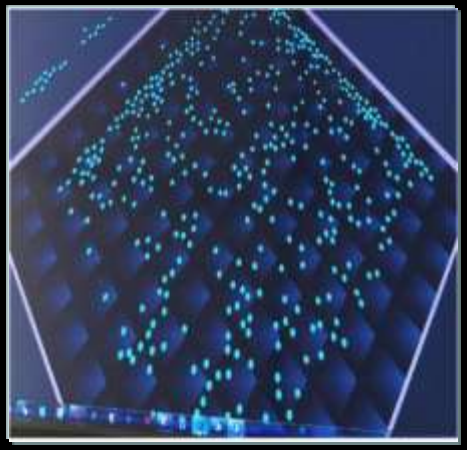




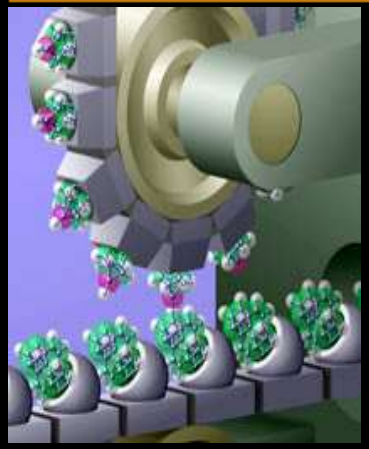
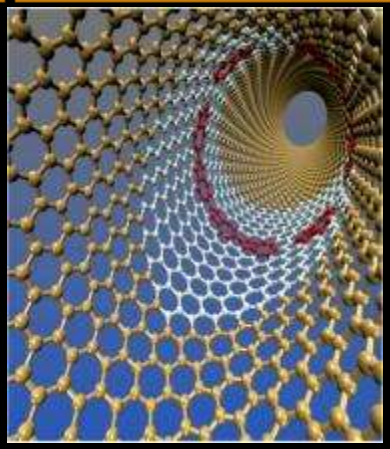
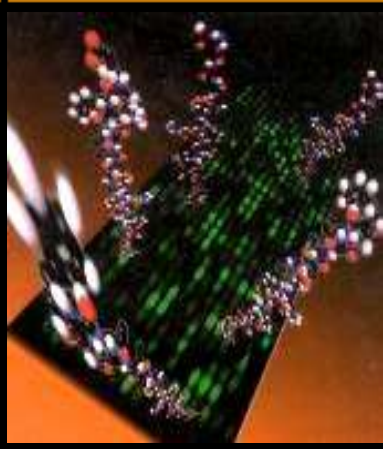
A New Industrial Ecology and Novel Biosyntheses

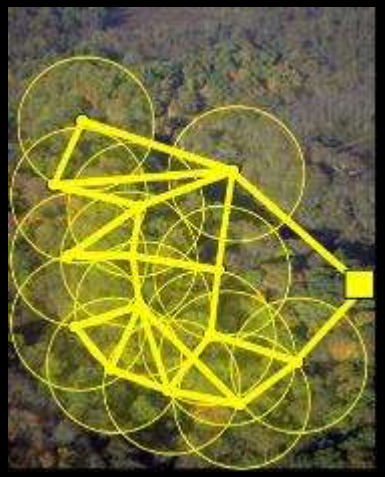
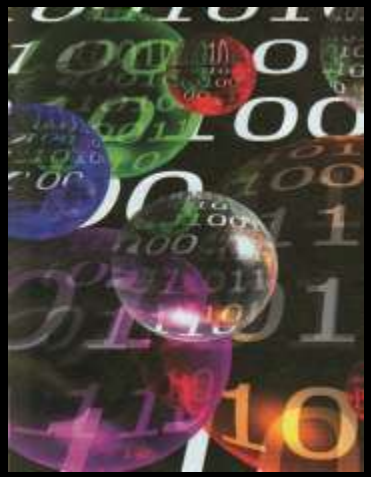
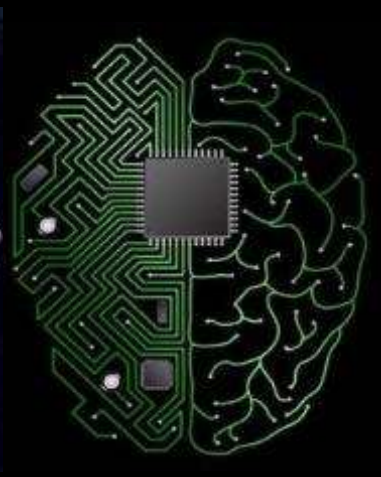
The BRAIN Initiative (2 April 2013)
Brain Research Through Advancing Innovative Neurotechnologies

New Technologies and National Security

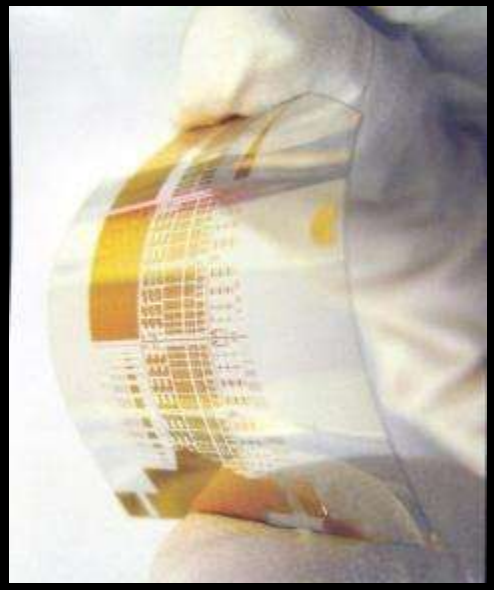
Net-Centric Strategies	Advanced Avionics	Drones	Robot Swarms
			
			
Food Security	**Transportation Security**	**Cyber-Security**	**Dual-Use Technologies**

Sensor World

Molecular Foundries	Novel Materials	Micro-Devices	Ubiquitous Sensing	Reconfigurable Sensors
				

Ambient Intelligence	Digital Cultures	Cogint	Intelligent Machines	Competition and Espionage
				

Novel Materials



- flexible superfast electronics

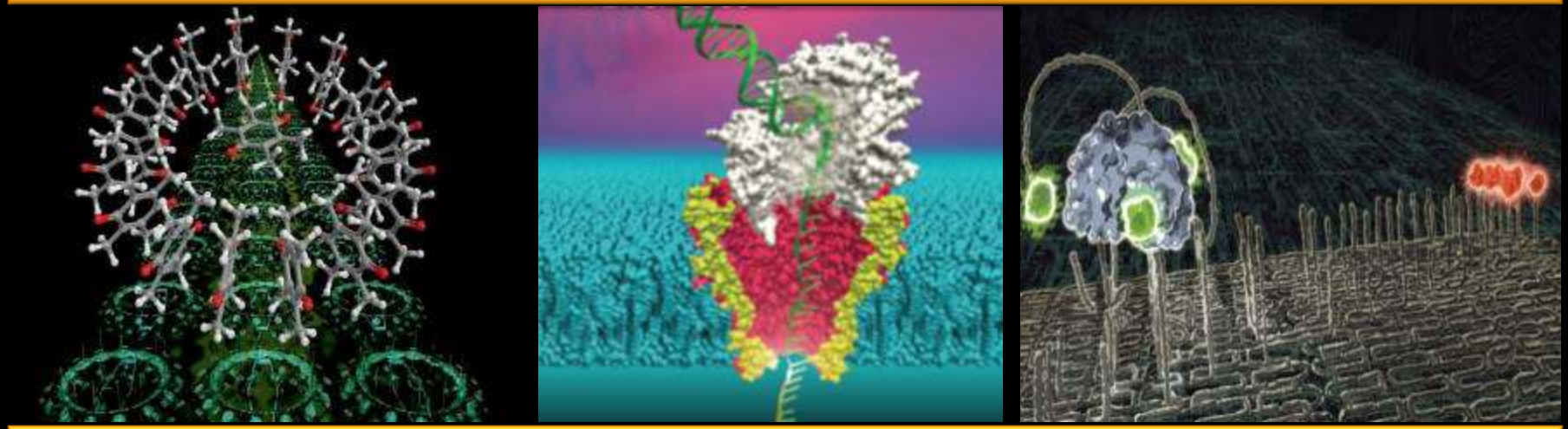
- non-reflective coatings
- black body materials

- metamaterials

- switchable materials

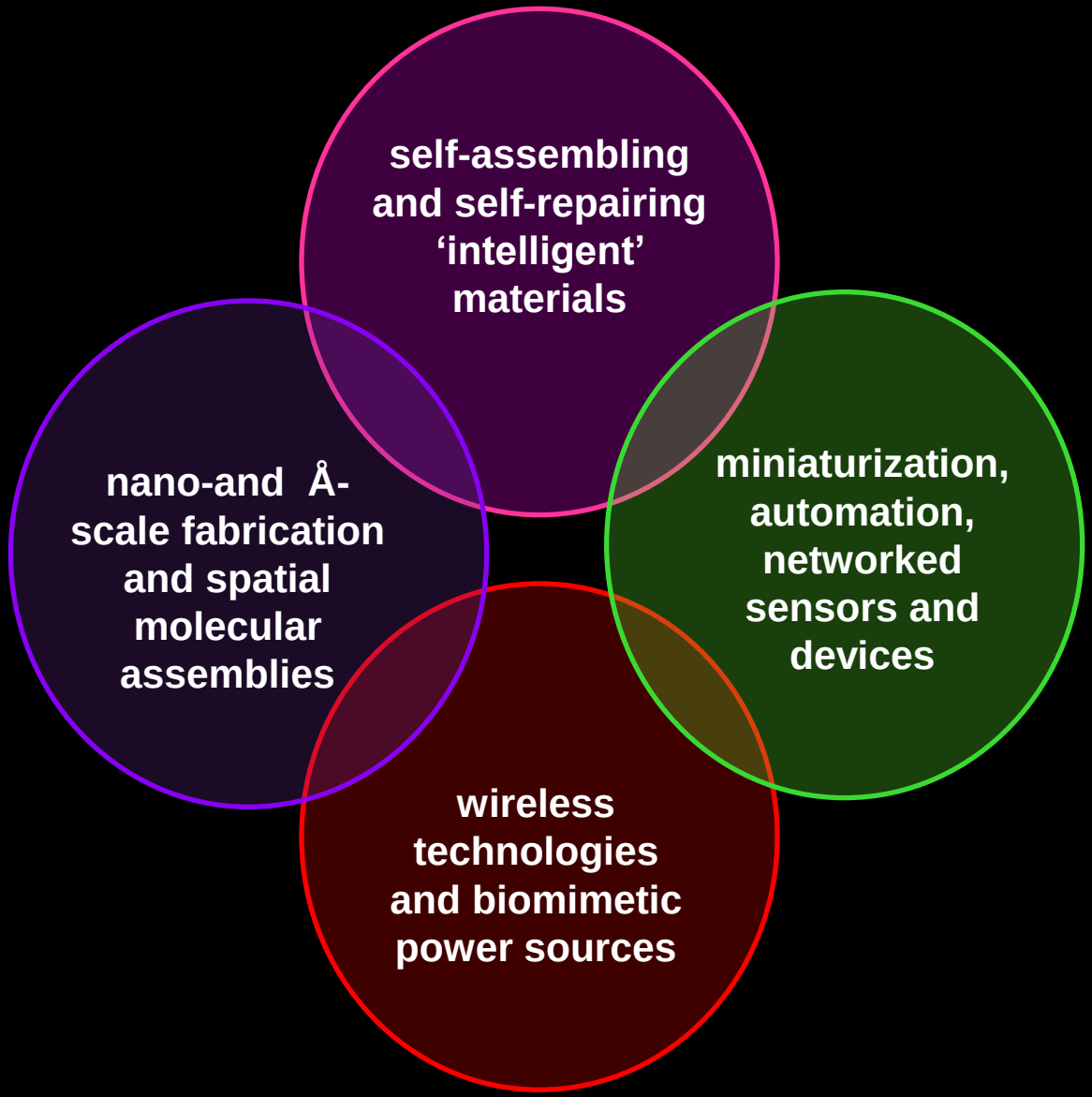
Directed Molecular Assembly and Materials Science

Sensors and Molecular Machines

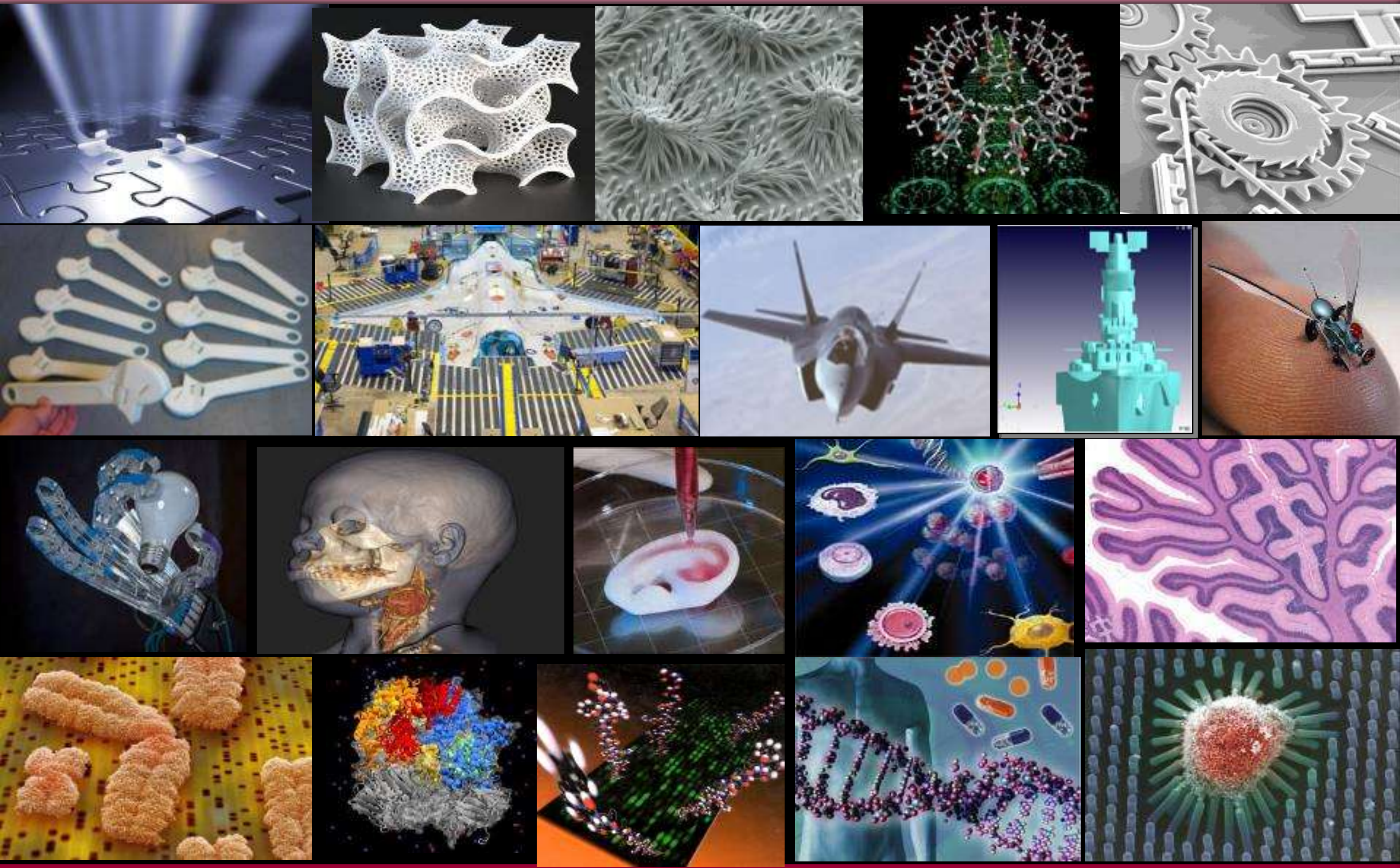


Biomimetic Design: Organic-Inorganic Hybrids

Sensor World:



Advanced Manufacturing
Digital Programming of 3-D Fabrication and New Assembly Technologies



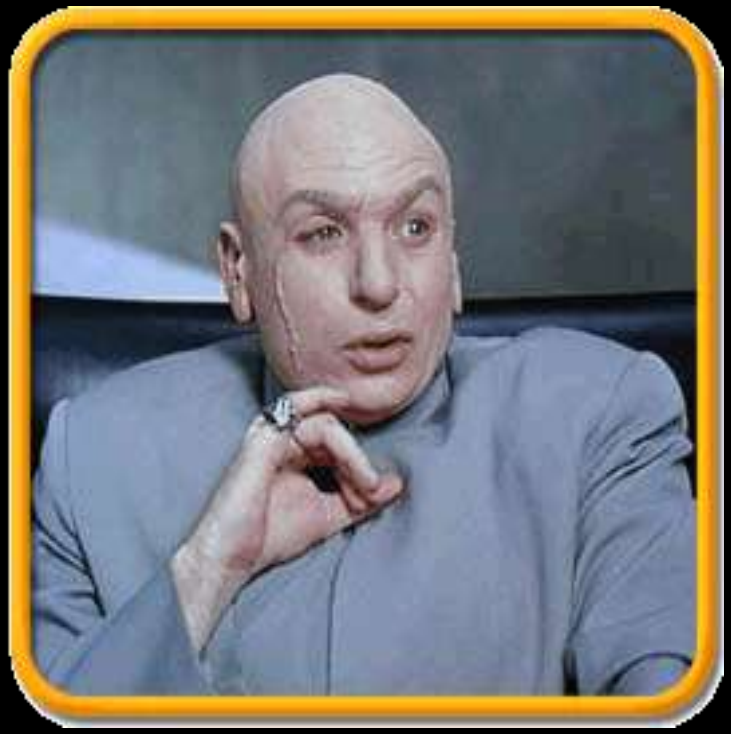
Robotics
4D Jobs: Dull, Dirty, Detailed or Dangerous





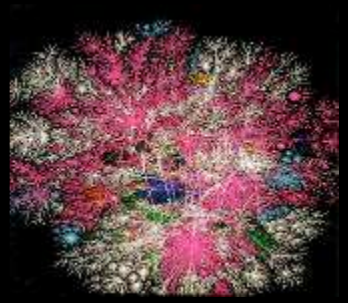

The Momentum for Transition to Autonomous Systems

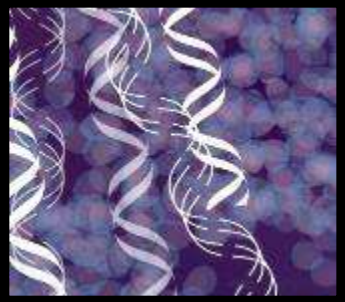
Future Trajectory Trends and Threat Expansion



New ‘Dual-Use’ Technologies

The Expanded Dimension of the ‘Bio’ Challenge





- thinking beyond ‘bio’ as just infectious agents (bugs)
- systems biology
  - targeted disruption of ANY body function
  - novel C and B threats
- synthetic biology
  - exploring biospace: designing new life forms
  - designer organisms to attack materials/infrastructure

Dual-Use Research of Concern (DURC)

Nature (2012) 482, 153

COMMENT

INFLUENZA Further explanation of the NSABB recommendations p.158

PRIMATES Imitation and social learning in apes p.159

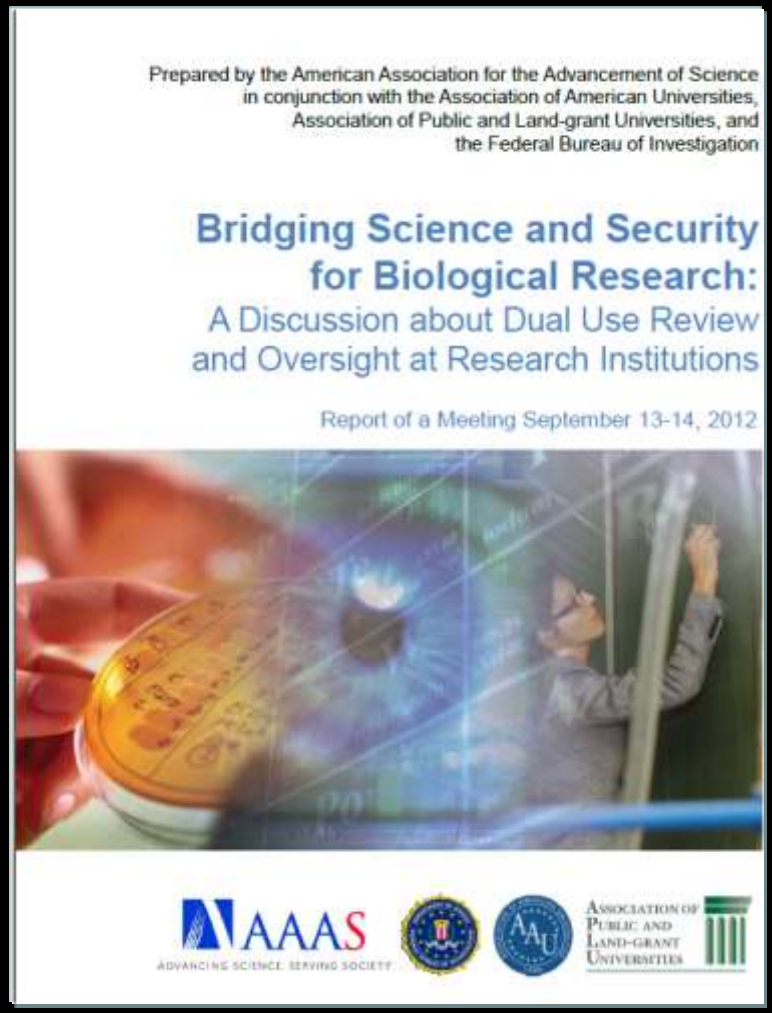
HISTORY John Dee's sweaving of scientific magic in the Elizabethan court p.160

CONSERVATION Trade in whale 'quotas' may be insufficient protection p.162

Pathogenic H5N1 avian influenza has led to the culling of hundreds of millions of birds. A human-transmissible form could have much worse consequences.

Adaptations of avian flu virus are a cause for concern

Members of the US National Science Advisory Board for Biosecurity explain its recommendations on the communication of experimental work on H5N1 influenza.



Prepared by the American Association for the Advancement of Science in conjunction with the Association of American Universities, Association of Public and Land-grant Universities, and the Federal Bureau of Investigation

Bridging Science and Security for Biological Research:

A Discussion about Dual Use Review and Oversight at Research Institutions

Report of a Meeting September 13-14, 2012

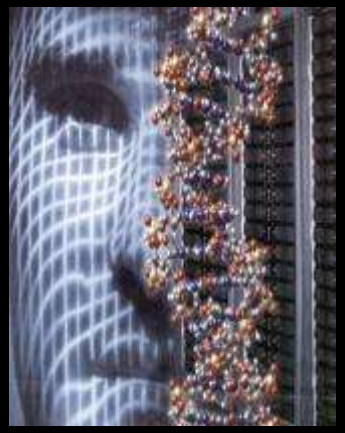
AAAS

ADVANCING SCIENCE, SERVING SOCIETY

Association of Public and Land-grant Universities

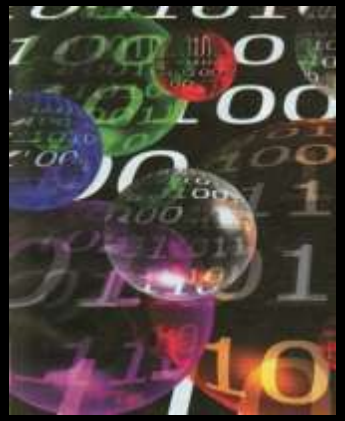
Accelerating Convergence: Conceptual, Technological, Informational and Commercial

Biomedicine, Biotechnology, Synthetic Biology



“Bio-Space”

Ubiquitous Sensing/ Devices & Social Networks



“Connected Space”

Advanced Computing and Modeling

“Cyberspace” and “Simulation Space”

Neurosciences and Human-Machine Interactions

“Cognitive Space”

Disruptive Technologies

?

“Competition and Opportunity Space”

New Patterns of Technology Fusion, Evolution and Adoption

New Knowledge Networks

New Participants

New Markets and Business Models

The Evolution of Production

Agrarian	Industrial	Digital
		
		
		

Major Themes in Technological Innovation

- automation
- miniaturization
- ubiquitous sensing/ambient intelligence
- networked connectivities and clouds
- massive parallelism
- big data and analytics
- co-evolution of human: machine relationships
- the digital infocosm

The Internet of Things
Embedded Sensors, Image Recognition and Mobile Devices

- over 50% of 15 billion internet connections are “things”
- 50 billion intermittent connections
- 70 billion mobile app downloads
- rise of ‘virtual appliances’ and software/services for infrastructure and application workloads
- two thirds of new products now come with some electronic component with performance/tracking potential

“The fourth site of care is going to be the Internet.”

George Halvorson
CEO, Kaiser Permanente
Statement at ONC 2012 Annual Meeting

m.Health

Real Time Remote Health Monitoring and Chronic Disease Management

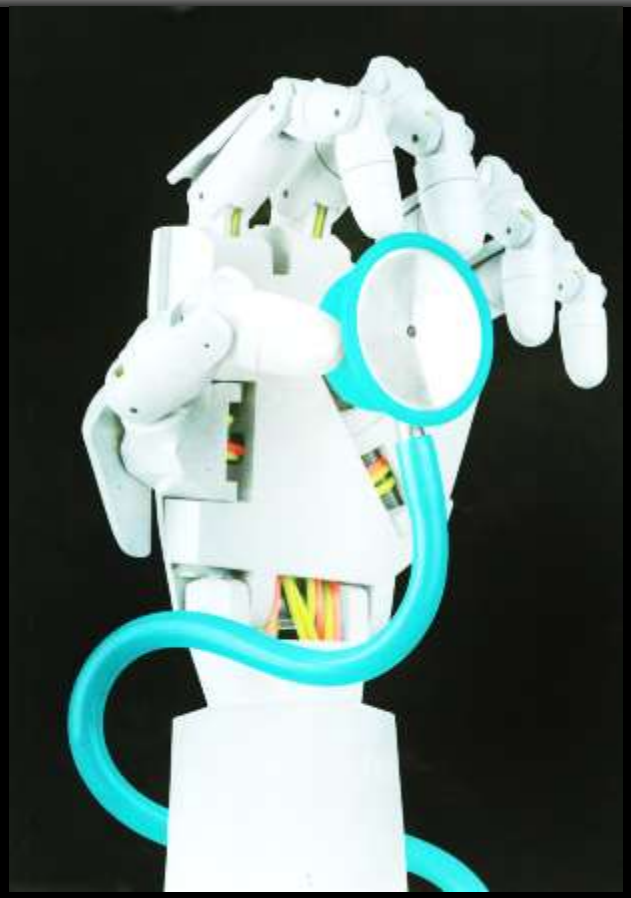
Lifestyle and Fitness

Information for Proactive Health Awareness (Wellness)

The Proliferation of Mobile Devices in Healthcare

Mobile Devices and Telemedicine

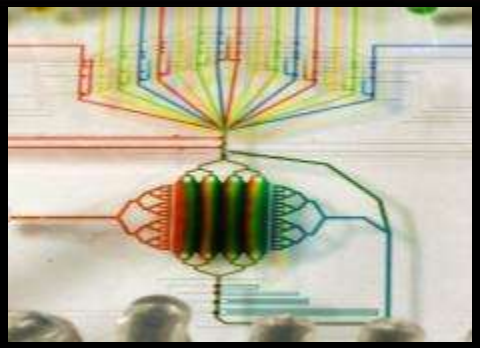
Robotics: Telemedicine and Home Healthcare



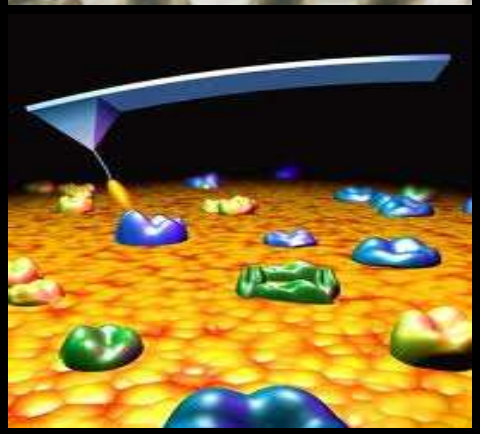
RP-VITA Remote Presence Robot:
(iRobot Corp) FDA 510(k) clearance 1/24/13

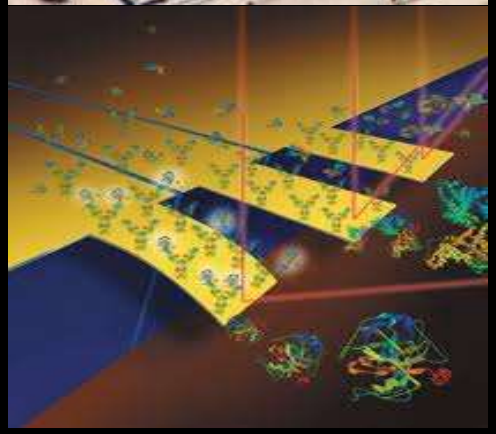
Geodemographic Information Systems (GIS): Real-Time, Front Line, Ground Zero Data from Field Sampling and Sentinels

Miniaturization of Analytical Technologies

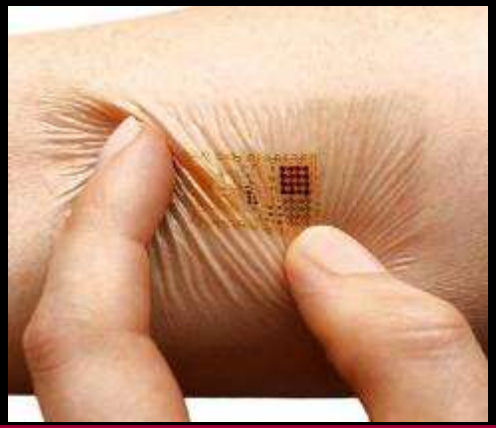


“Lab-on-a-Chip”



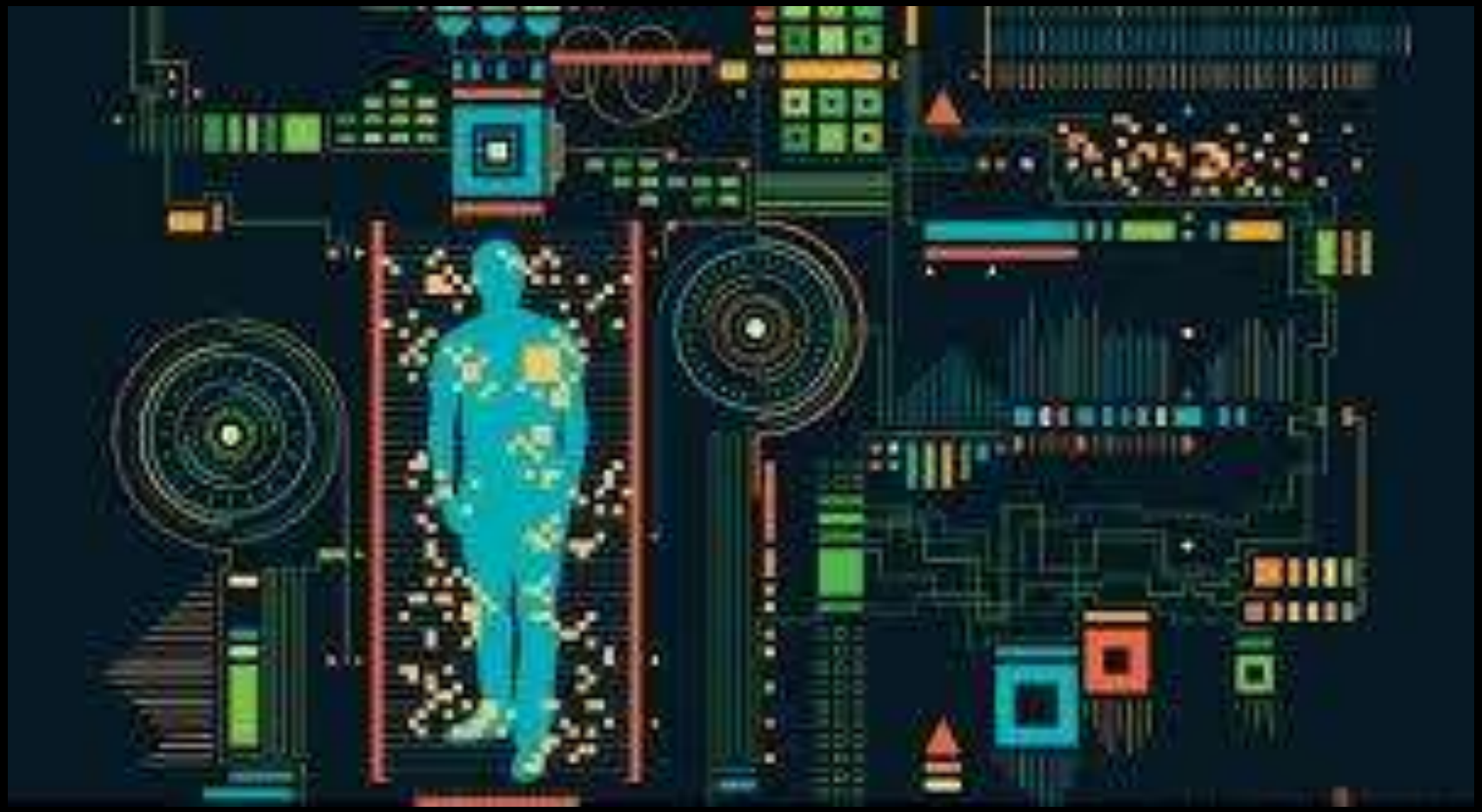


“Lab-on-a-Tip”



“Lab-Always On”
and
“Lab-On-Me”

The Measured (Quantified) Self: Real Time Biometrics of Health Status



Every Individual Becomes Their Own Control

Health eHeart: Framingham Meets e.World

- recruitment of 1 million participants
- from profiling every two years (Framingham) to daily monitoring
- longitudinal observational monitoring with every individual acting as own control
- large sample size and avoidance of selection bias
- 1.5% cohort = entire Framingham study (15,000 participants)

Gray Technologies:
Independent But Monitored Living for Aging Populations

compliance

cognitive stimulation

Fujitsu's 'smart walking stick'

Early Alert to Clinical Deterioration

Use of Appliances

Mobile Devices, Sensors and Remote Health Status Monitoring: The Changing 'Care Space' and Improved Continuity in Care Provision

- from fixed, tethered, compartmentalized, provider-centric facilities

to

- distributed- and virtual-architectures linking multiple providers, home, work and the internet

expanded 'points-of-touch' with the health systems

improved continuity of care and data integration

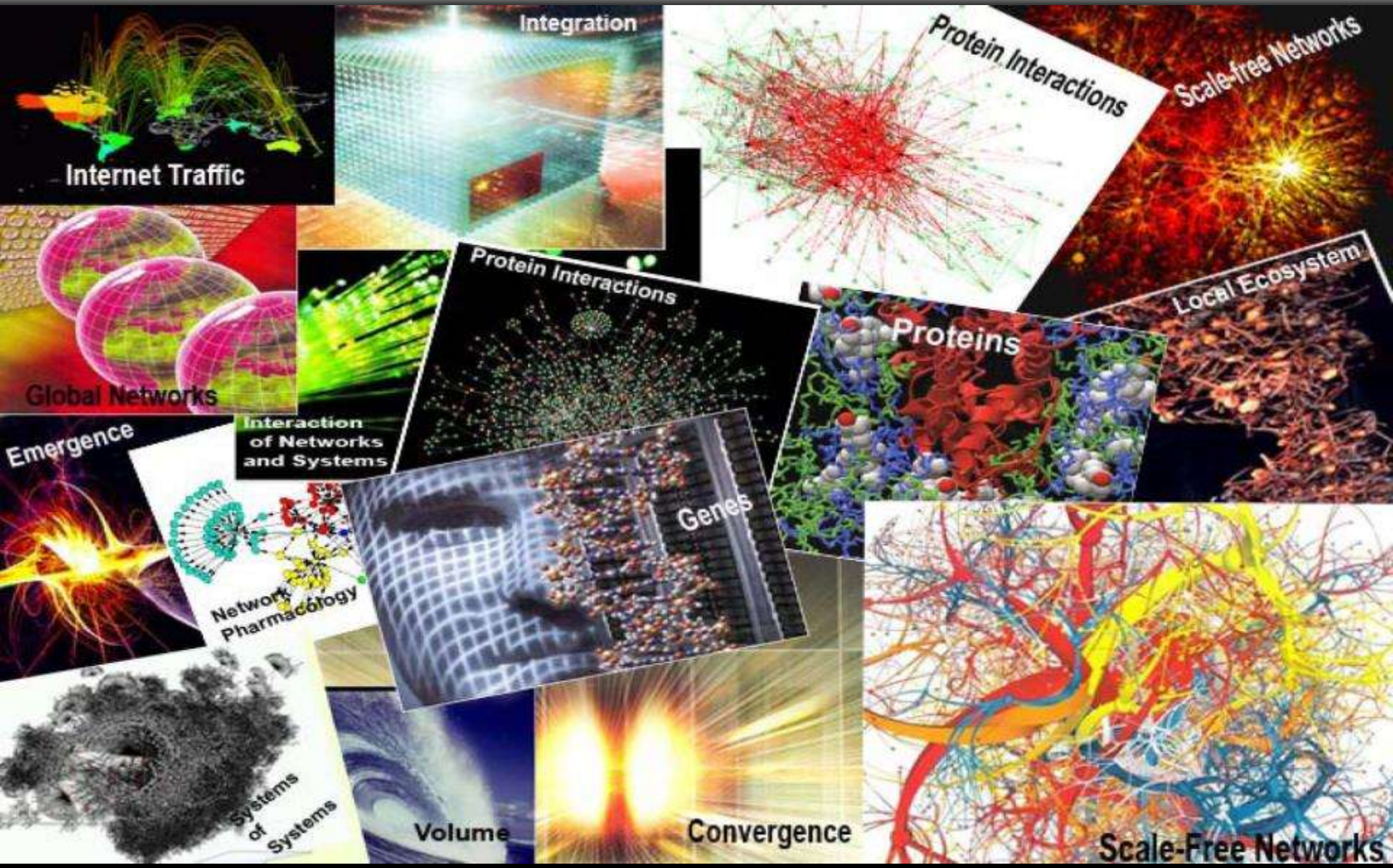
- from reactive, incident-centric, poorly coordinated and sequential referrals and inefficient post-incident follow-up(s)

to

- pervasive, persistent monitoring of health status for pre-emptive risk mitigation, improved compliance and personal stewardship of health

Retail Healthcare:
New Services and Value-Based Shopping for Healthcare

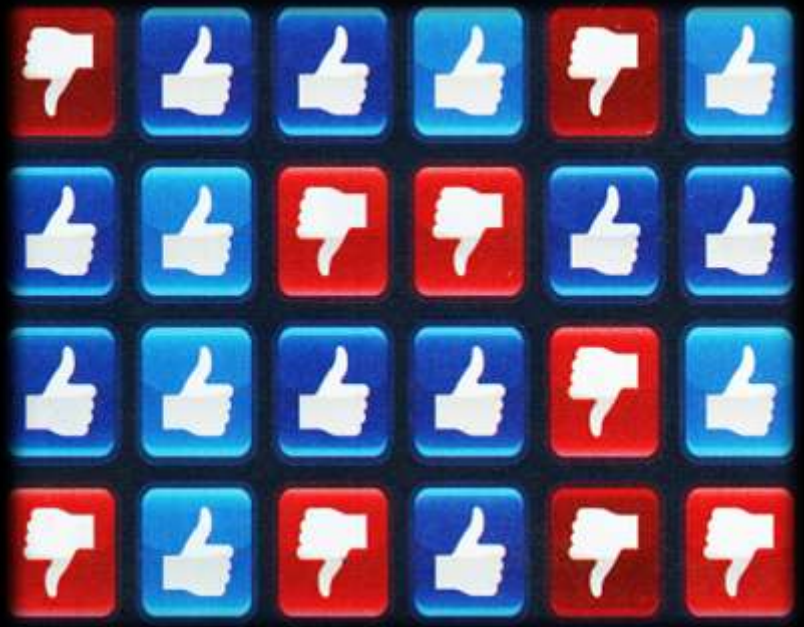
Data: The Fastest Growing Resource on Earth



Ubiquitous Sensing: (Ambient Intelligence)
AORTA: Always On, Real Time Analytics

- instant information: anything, anywhere, anytime
- the internet of things
- miniaturized sensors and a monitored world
  - infrastructure, agriculture, health, finance, ecosystems, security, military
- from deep blue to deep space to inner space
- “intelligent” adaptive sensor networks (swarms)
- global connectivity and network information architecture(s)
- large scale simulation and modeling capabilities

Digital Traces

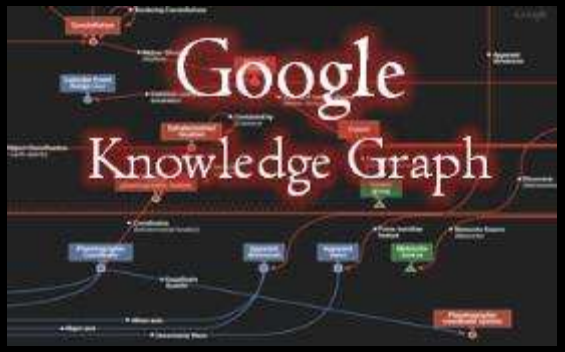


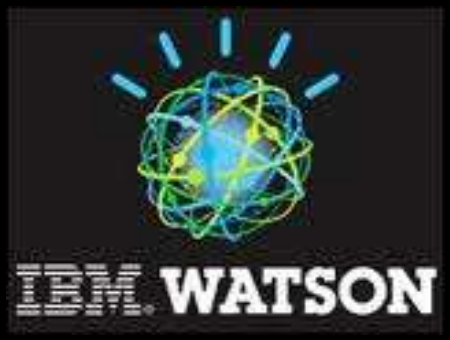
- every click you make
- every twitter feed you update
- every Facebook friend you add
- every Four Square location you log
- every cell phone call you transmit
- every time you use your credit card

Social Behavior Becomes Quantifiable

- who knows why people do what they do?
  - the fact is that they do!
- these actions can now be traced and measured with unprecedented precision
- with sufficient data, the numbers reveal increasingly predictable behavior and individual risk patterns
- new business opportunities in multiple sectors including healthcare
- new ethical and legal issues regarding privacy and data security

Natural Language Processing, 'Trained Systems' and Big Data Analytics

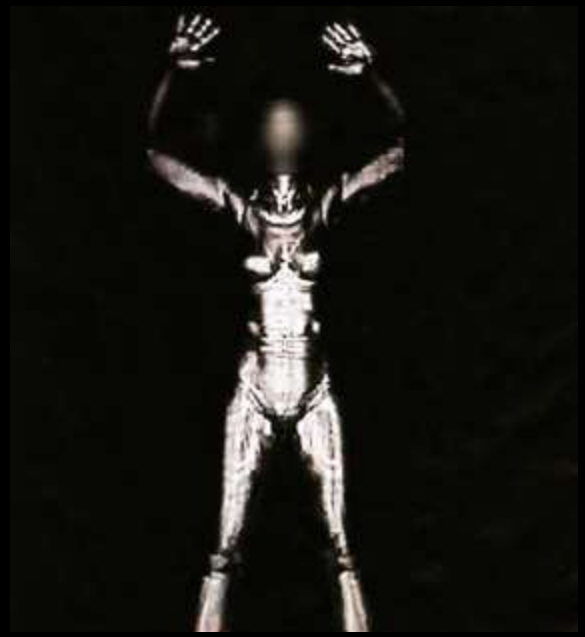




amazon.com

NETFLIX

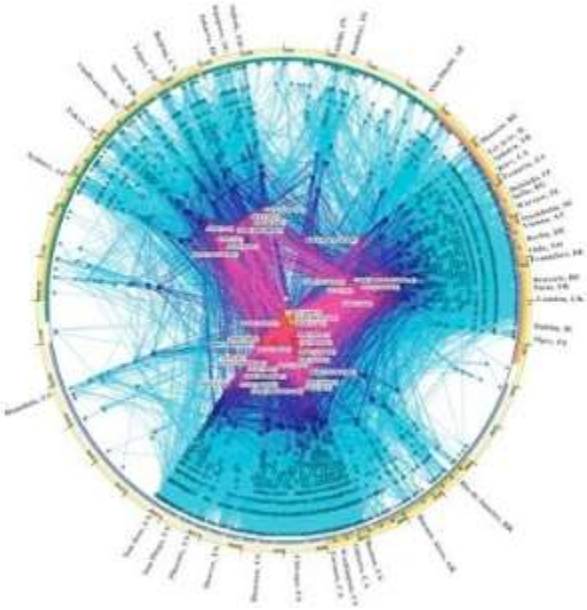
NEXT GENERATION IDENTIFICATION



The Emergence of Big Data Changes the Questions That Can Be Asked

Isolated Data

Complex Networked Data



Complex Computational Data

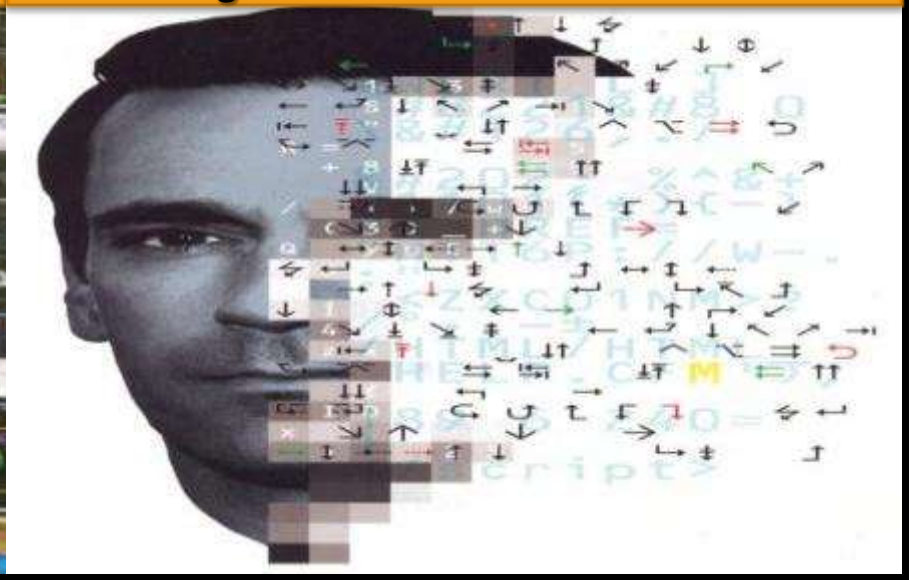
Big Data: Volume, Variety, Velocity, Veracity, Value

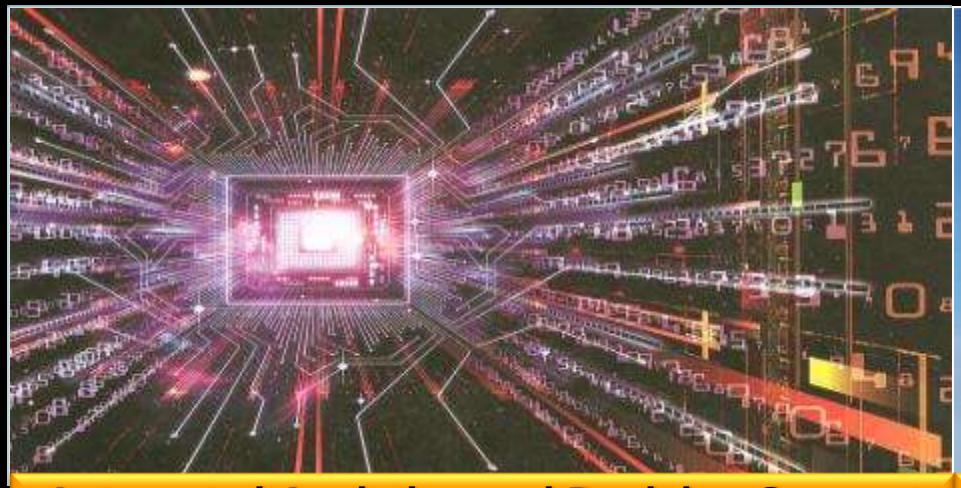
The Pending Zettabyte Era
1,000,000,000,000,000,000,000

The Increasing Complexity of Informed Decision Making

Data Deluge

Cognitive Bandwidth Limits

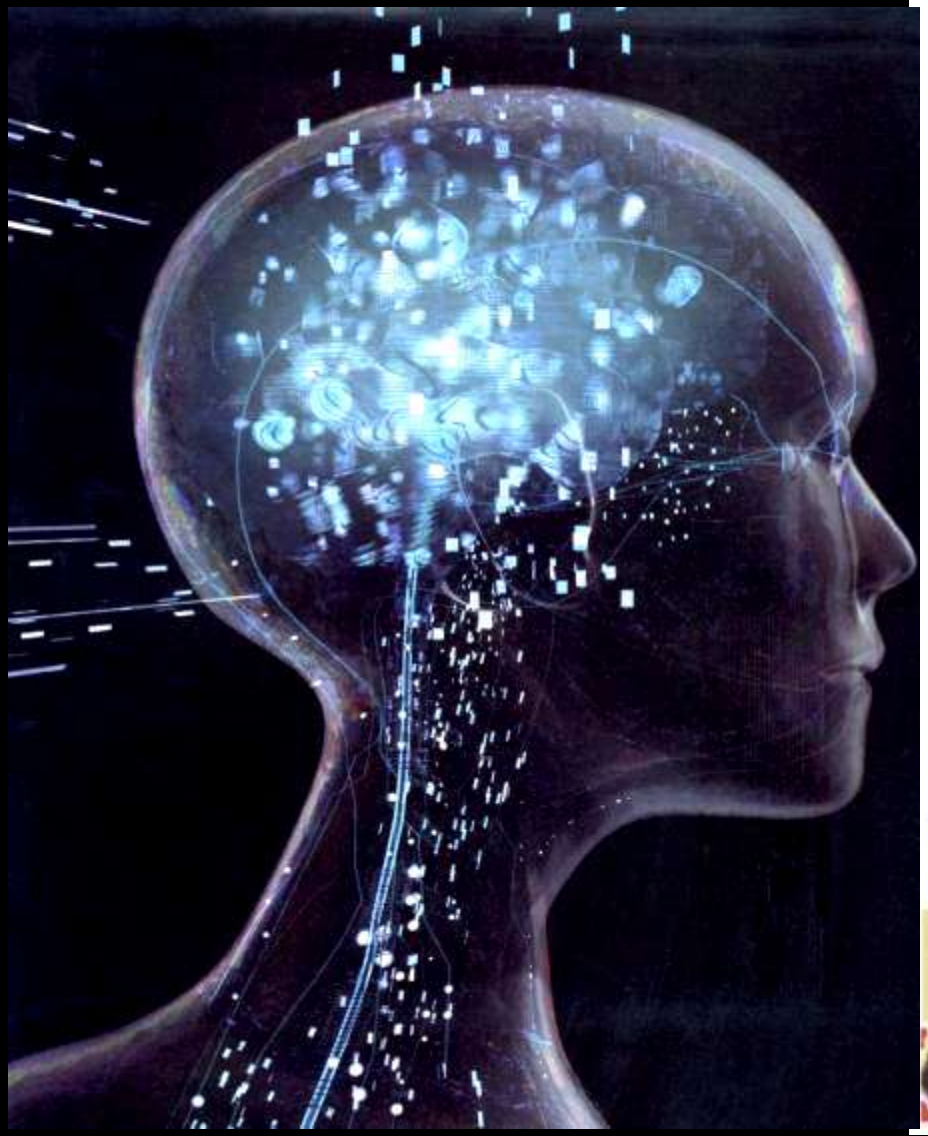


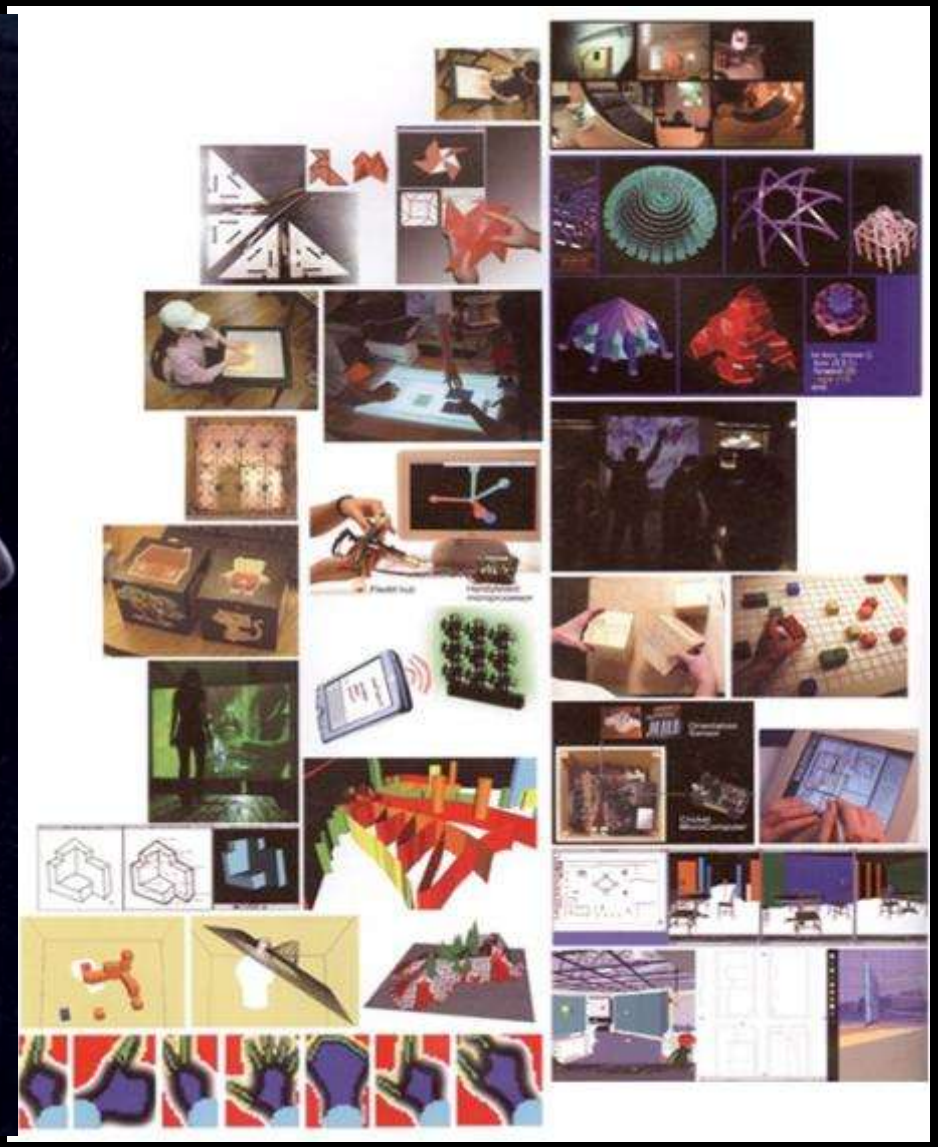


Automated Analytics and Decision Support

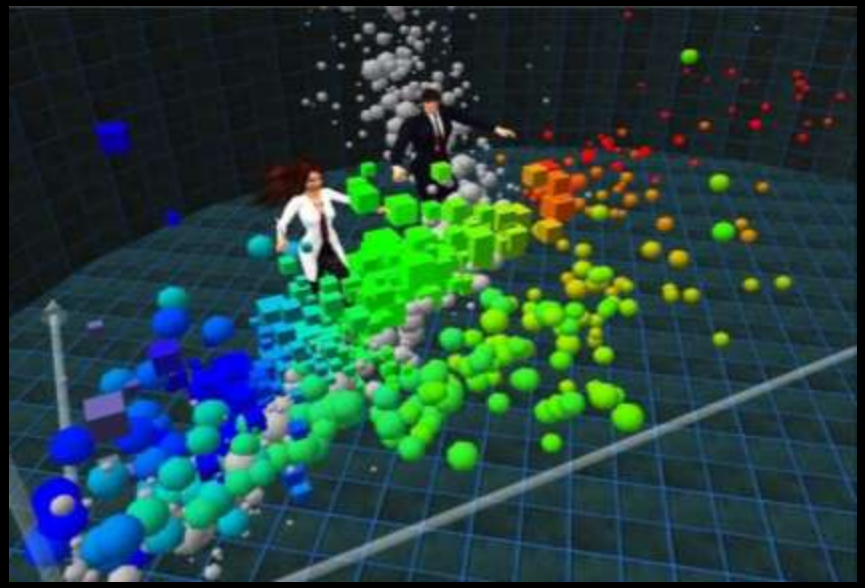
Facile Formats for Actionable Decisions

Cognitive Biology, Customized Data Formats and Visualization for Improved Decision-Making





Computing Systems and Interactive Displays: From Defense to Gaming to Interactive Dynamics for R&D and Business Processes



Pervasive Computing:
The Next Major Transition?

Does Anyone Read Printed Journals Anymore?

PHILOSOPHICAL
TRANSACTIONS:
GIVING SOME
ACCOMPT
OF THE PRESENT
Undertakings, Studies, and Labours
OF THE
INGENIOUS
IN MANY
CONSIDERABLE PARTS
OF THE
WORLD

Vol I.
For Anno 1665, and 1666.

In the SAVOY,
Printed by T. N. for John Martyn at the Bell, a little without Temple-Bar, and James Allestry in Duck-Lane,
Printers to the Royal Society.

Open Data Systems and Crowd Sourcing in Biomedical R&D


AltusEd


Open
Learning
Initiative


KHANACADEMY


U
UDACITY


COMPLEXITY
EXPLORER


iTunes U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ASU online
ARIZONA STATE UNIVERSITY


CAPELLA UNIVERSITY


coursera


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straighterline


EPGY
Education Program
for Gifted Youth


Stanford | ONLINE


WizIQ
education.online


Stanford University
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edX

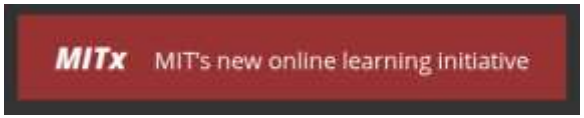

CLASSROOM 2.0
web 2.0 | social media | & more


PACE UNIVERSITY


open
study


INTRODUCTION TO
Artificial Intelligence
STANFORD


MERLOT
Multimedia Educational Resource
for Learning and Online Teaching


MITx
MIT's new online learning initiative

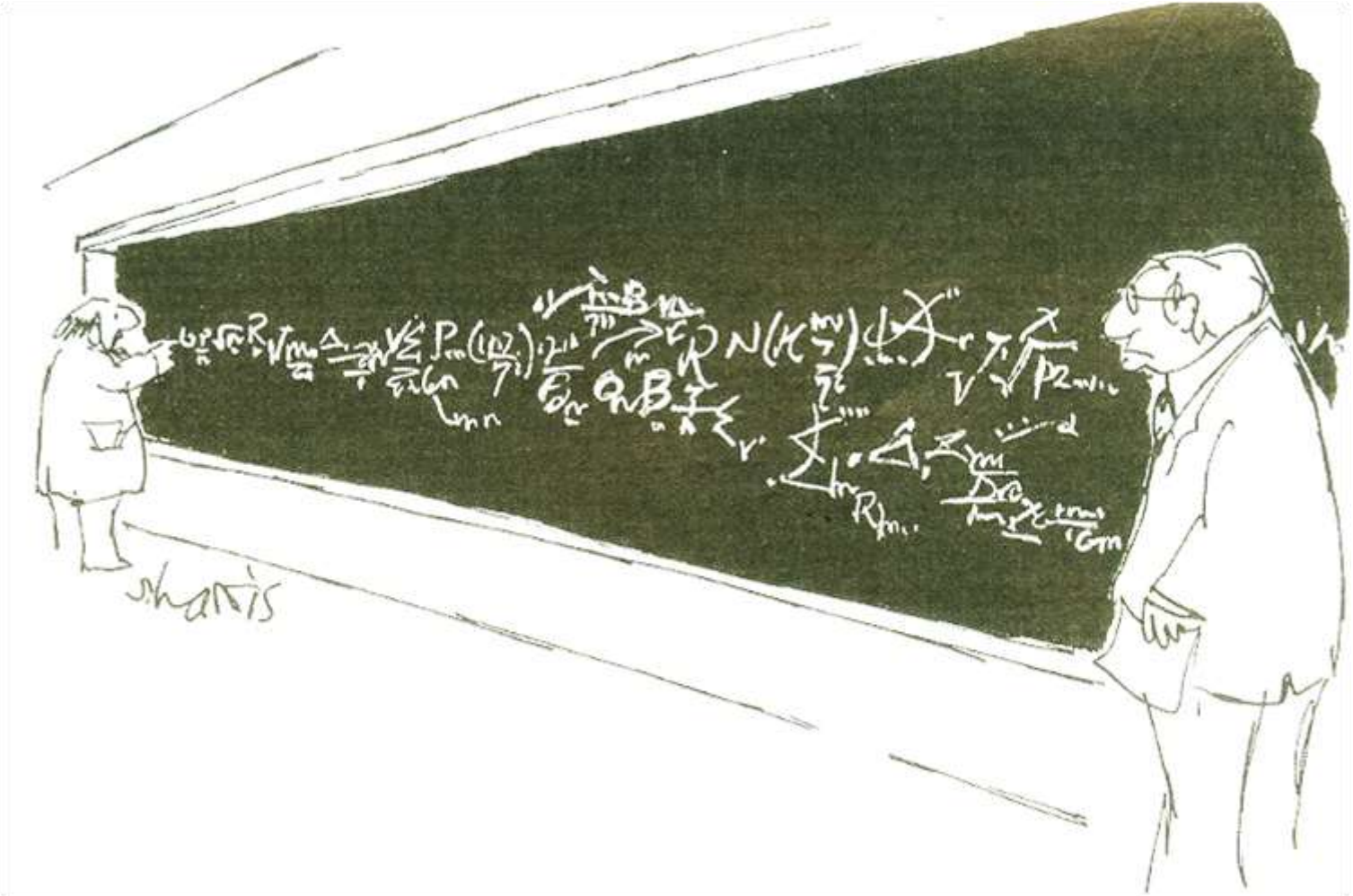
The Pending Era of Cognitive Computing Systems: Overcoming the "Bandwidth" Limits of Human Individuals

- limits to our expertise
- limits to our multi-dimensionality
- limits to our sensory systems
- limits to our experiences and perceptions
- limits to our objective decision-making

Touch the Future:
Computing Platforms as Socio-Biological Systems

- modification of social patterns
- modification of cognitive structures
- memes as selection agents
- “the brain(s) in the cloud”

‘Here’s Where you made your mistake.’



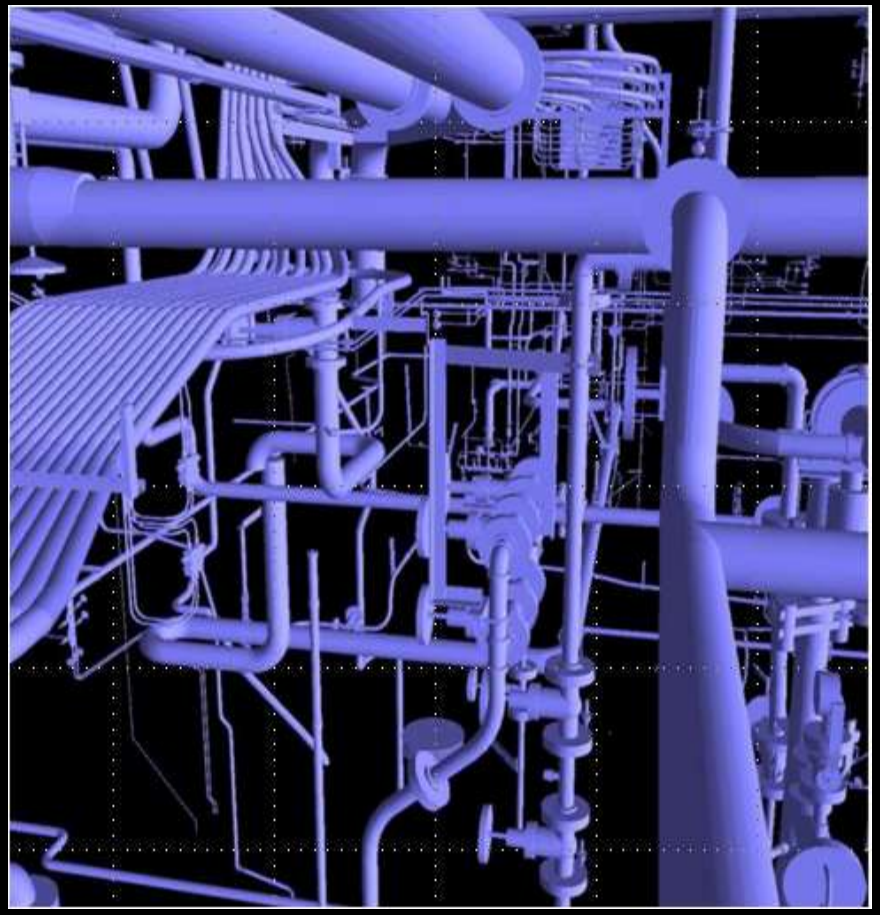
Am. Sci. (2013) Jan. pg. 17

Computer, Explain It To Me Again

- exponential growth of big datasets and multi-dimensional datasets
- bumping up against our conceptual and cognitive constraints (limits?)
- computational theorems, discoveries and explanations that transcend our interpretive capacities
- neuromorphic computing: learned tasks and improvements without explicit programming
- our last invention? (Jack Good and Alan Turing)
  - creation of machines able to develop ever more intelligent machines

Cyberinfrastructure for High Performance Computing (HPC) and Cloud Computing (CC) for Large Scale Datasets

Not All Digital Pipes are Created Equal



“Digital Darwinism”

- a pending digital divide
  - growing imbalance between different end user populations and their ability to embrace data scale and complexity
  - institutions unable to access and analyze large data sets will suffer ‘cognitive starvation’ and relegation to competitive irrelevance
- understanding the structure of information and its productive application/customization will emerge as a critical institutional competency

“This new world of data-centric computing
requires use to rethink, from the ground up,
how we build our computers
where we do our computations
how do we do our statistics and, ultimately,
how we do our science.”

Alexander S. Szalay (Johns Hopkins Univ.)
Computing in Science and Engineering, Nov. 2011 p. 34

Computational- and Data-Enabled Science

The Big Data Challenge:
Scale, Infrastructure, Personnel

Bigger Data and Better Questions

Thinking More Deeply About Data and Knowledge Generation

The Science of the Use of Science

**“We certainly know how to produce scientific knowledge,
including knowledge relevant to policy options.
But where is our science
of the use of science?**

Ken Prewitt
Vice-President, Global Initiatives
Columbia University
cited in Lancet (2010) 376, 500

Global Networks, Connectivities and Interdependencies

Shared Environment

Shared Resources

Shared Economy

Shared Networks

Living With Escalating Complexity and Systems We Don't Understand

Reducing Decision Uncertainty and Risk in Increasingly Interconnected Global Networks

Mapping the Design and Dynamics of Complex Systems

Understanding Complexity: A Dangerous Void in Seeking Solutions to Global "Grand Challenge" Problems

“For most of us design is invisible until it fails”: Bruce Mau. Massive Change. 2004

Comprehension of Complex Systems Requires Holistic, Systems-Based Analyses

- increasing evidence of dysfunctional nature of large organizational systems and institutions in addressing complexity
- energy
- environmental sustainability
- healthcare
- financial systems
- education
- national security

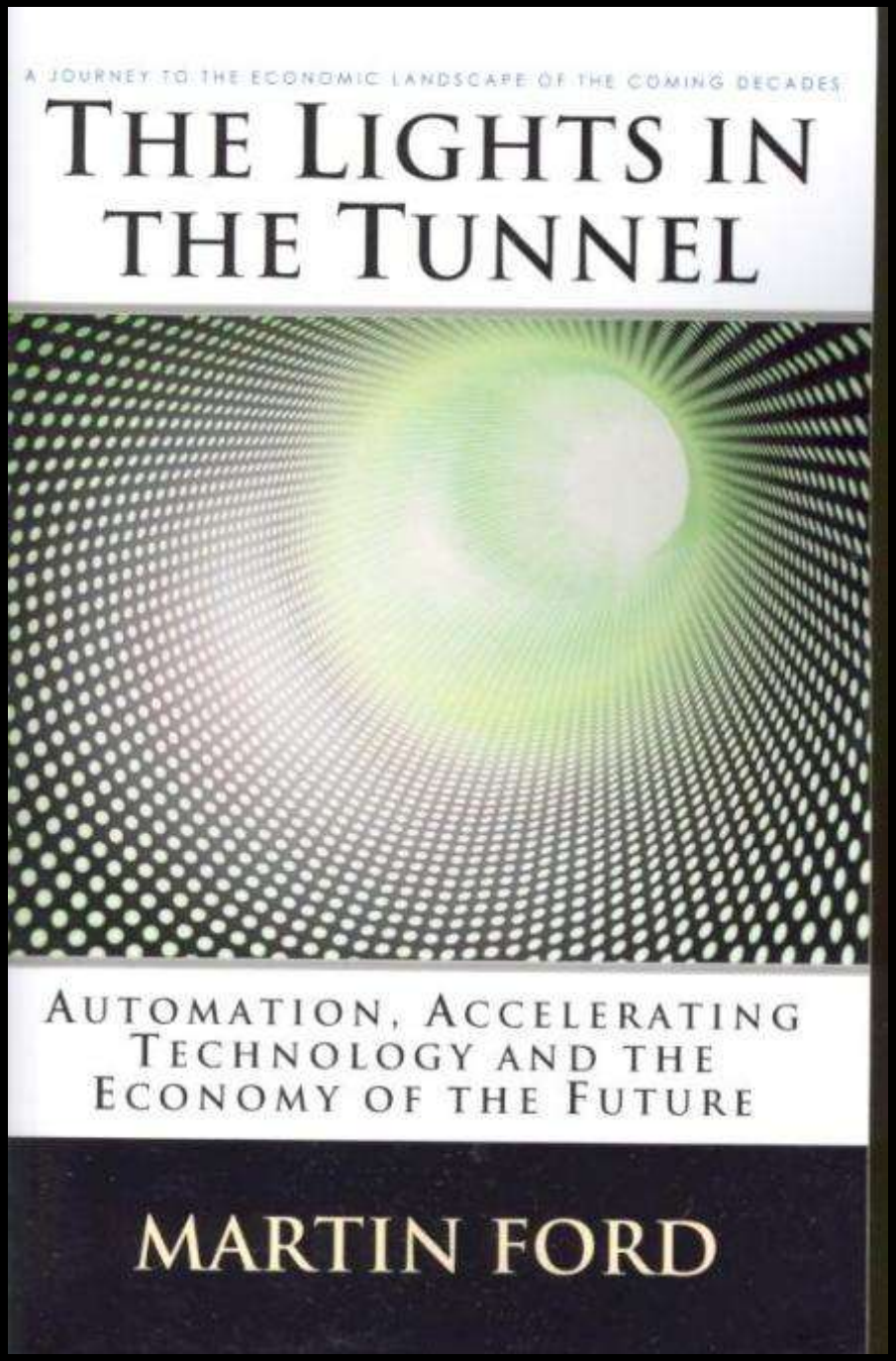
A MASSIVE AND DANGEROUS VOID IN NATIONAL AND INTERNATIONAL GOVERNANCE

The “Too World” and The Retreat from Complexity

- “too fast”
- “too complex”
- “too competitive”
- “too hard”
- “too long”
- “too risky”
- “too uncertain”
- “too unfair”

The Retreat from Complexity: Politics and Populism

- quick wins and superficial fixes to meet public expectancy and media scrutiny
- limits of elected office define strategic horizons
- selling zero-risk (US) and precautionary principle paralysis (EC)
- ideological polarization and divisiveness
- the rise of the blame and victim culture
- reinforcement by media appetite for celebrity, controversy and conflict and anti-corporatism


A JOURNEY TO THE ECONOMIC LANDSCAPE OF THE COMING DECADES
THE LIGHTS IN THE TUNNEL
AUTOMATION, ACCELERATING TECHNOLOGY AND THE ECONOMY OF THE FUTURE
MARTIN FORD

Advanced Manufacturing: Digital, Diversified, Distributed, Democratized

- continued disruption and displacement of labor-intensive, low skill activities
- undermine current advantage of low cost, low-wage countries?
- reversal of out-sourcing trend or intensification via distributed manufacturing?
- distributed manufacturing services and reversal of urbanization driven by earlier labor-intensive industrialization?

Emergence:
The Cardinal Feature of Complex Systems

creative destruction

‘Black Swans’

disruptive change

inflection points

tipping points

discontinuities

critical transitions

fragility

dislocations

phase transitions

new attractors

volatility

known unknowns and unknown unknowns

“We overestimate what we know
and underestimate uncertainty,
by compressing the range of uncertain states.”

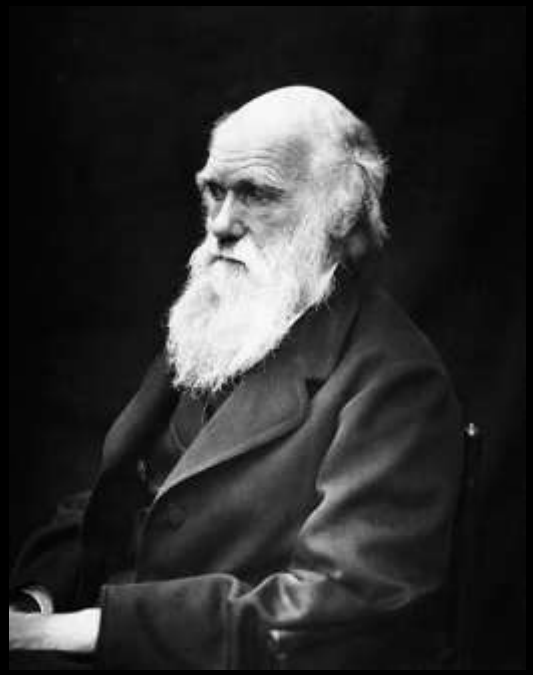
Nicholas Taleb
The Black Swan

“Fitness, Competition and Selection”: An Enduring, Shared Conceptual Lineage

Adam Smith

“The Invisible Hand”
(financial selection)

Charles Darwin



“Red in Tooth and Claw”
(natural selection)

Joseph Schumpeter

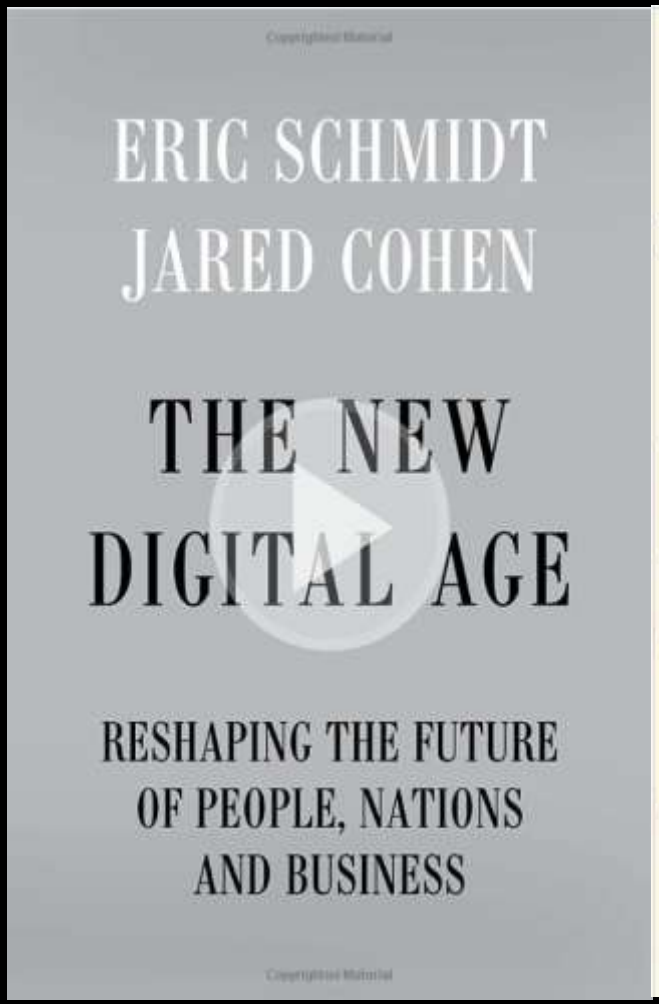
“Creative Destruction”
(innovation selection)

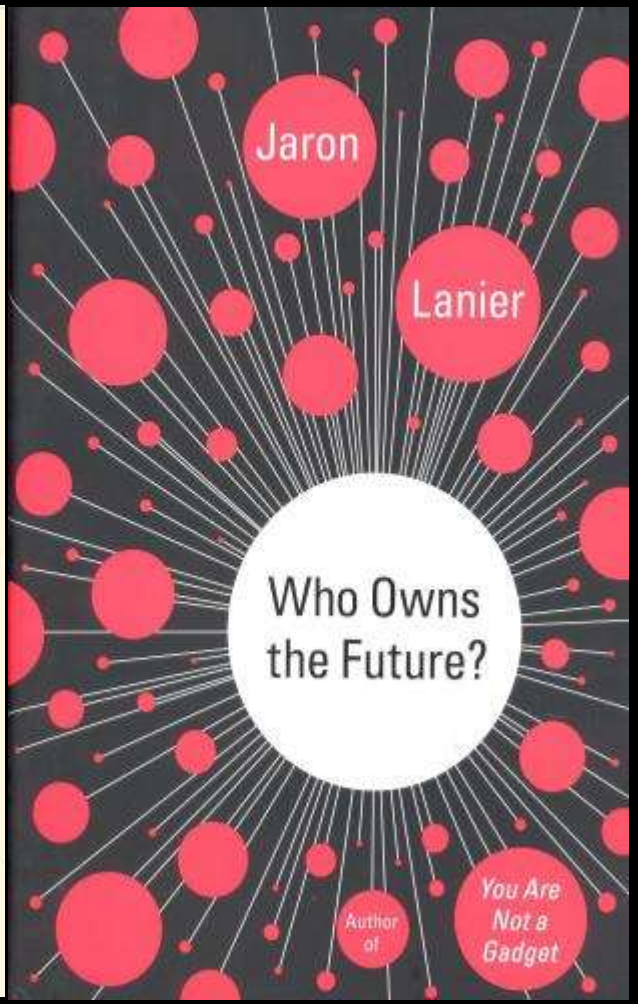
Future Thinking for Thinking About the Future:

- how do we develop and apply new tools to understand complex systems?
  - scientific research
  - technological solutions
  - education and training
  - public policy, oversight and regulation
  - institutional organization

- what is possible?
- what is probable?
- what is preferable?
- what is preventable?

The Impact, Implications and Economic Value of Massive Digital Information Networks





Complicated Systems versus Complex Systems

Distributed Degrees of (Design) Freedom (DDOF)

Complicated Versus Complex Systems

- complicated systems (low DDOF)
  - anthropogenic engineered systems
  - predictable performance of components, the assembled whole and their likely failure points
- complex systems (increasing DDOF)
  - anthropogenic and natural systems
  - more than the sum of their parts
  - levels of autonomous behavior: components, networks, system(s)
  - design of infinite-state systems
  - escalating challenge of predicting overall system behavior and state shifts (emergence) in ever more complex inter-connected networks

Complicated Systems (Low DDOF)





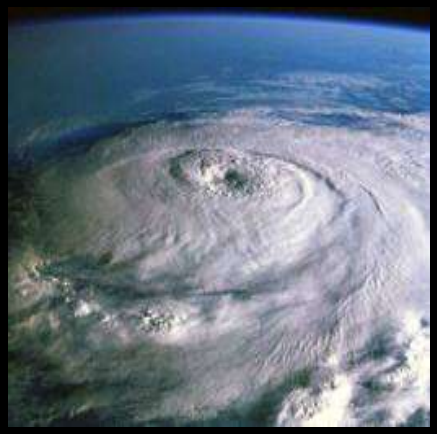


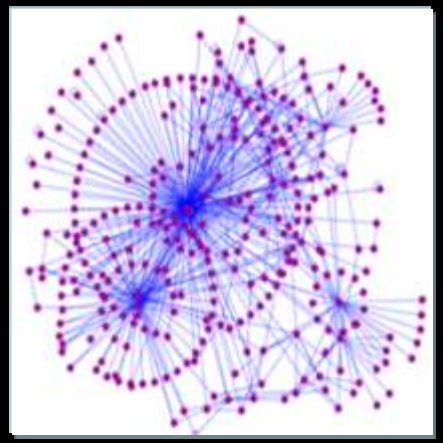

- predictable performance of components, the assembled whole and likely failure points

Complex Adaptive Systems: Increasing DDOF










- graded levels of autonomous behavior (components, system)
- escalating challenge of predicting system behavior and state shifts

Cyber-Attacks and Vulnerable Infrastructure: Compromising Critical Systems

MANDIANT

APT1

Exposing One of China's Cyber Espionage Units

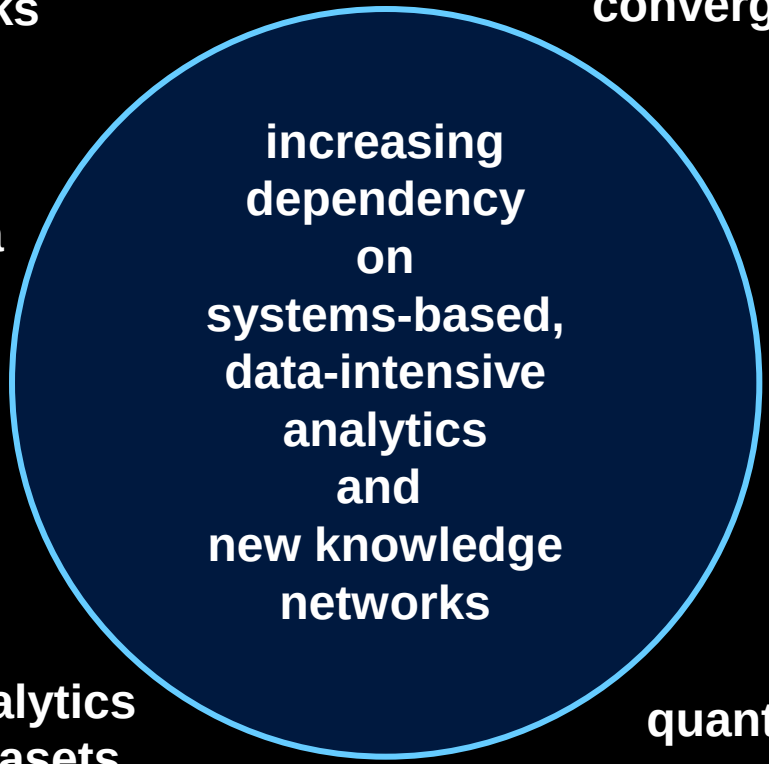
Silos Subvert Solutions!

Silos of Expertise as Obstacles to Understanding Complex Systems

- siloed organizations are typically reductionist and slow to recognize and evaluate systemic risk(s)
- reductionistic analytical methods and fragmented responsibilities for oversight and decision making predispose to hidden (undetected) risk(s)
- hidden risk(s) will eventually (inevitably?) be manifest as unanticipated events with unintended consequences
- comfort and complacency: the two most dangerous threats the proactive recognition of disruptive change

Intrinsic Tensions in the Growing Dependency of the Academic Research Community on Data-Intensive Methods and the Rise of New Knowledge Networks

New Conceptual, Methodological and Organizational Frameworks for Data-Intensive Biomedical R&D



agile knowledge networks

cross-domain convergence

team based

new curricula

large scale

intelligent systems

increased automation

integration and analytics for large scale datasets

quantitative data

ontologies and semantics and facile data sharing interoperabilities

Technology Acceleration and Convergence

- new patterns of disruptive intellectual fusion
- profound implications for education, research, business models, national security and public policy
- the siloed structure of current academic, industrial and governmental institutions is a major obstacle to assessment of the implications of the increased dependency on new trans-disciplinary, cross-sector networks and their accompanying complexity

Complexity and Complex Systems

- society is increasingly dependent on inter-connected networks of complex systems whose dynamic behavior and stability is poorly understood
- limitations in understanding complex systems, and increasingly stark inadequacies in current methods and institutions to design, monitor and direct these systems, renders society vulnerable to major disruptions
- technology convergence and acceleration, together with massive expansion in the volume, velocity and variety of data, will exacerbate these deficits and increase the probability of major disruptive events

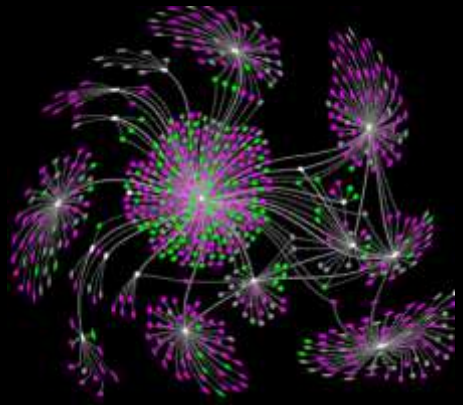
Comfort and Complacency (aka ‘Bread and Circuses”)
The Drivers of Strategic Surprise

- society is increasingly remote from the drivers and implications of emerging technologies
- the pervasive scientific illiteracy among policy makers and socio-economic elites, political populism and short-term horizons in public policy and financial systems poses a pernicious and dangerous threat to the critical evaluation of the long-term consequences of new patterns of technological change

Complex Systems and New Knowledge Networks

- success in solving increasingly urgent global challenges in health, sustainability and security will require new analytical tools, organizational structures and knowledge networks to define the behavior of inter-connected complex systems
- integration of complexity science and decision theory will assume increasing importance in education and research, drive new business models and must become a key component of better informed public policy

The Evolution of Scientific Enquiry: Robust Methods, Networked Knowledge and the Emergent Digital Infocosm



"Scienta potentia est" (Knowledge is power)

"Nullius in verba" (Take nobody's word for it)

"Omnis serta est" (Everything is connected)

0011010100110…. (Code is power)

Experimental Design

Standards and Reproducibility

Mapping Network Dynamics

Design, Monitoring and Control of Complex Digital Networks

**“Oh, God help us!
We’re in the hands of
engineers.”**

**Dr. Ian Malcolm
‘Chaotician’: Jurassic Park**

Slides Available: http://casi.asu.edu/