



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

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



Technology Acceleration, Convergence and Disruption



Transcending Boundaries: Technology Convergence in Biomedicine







CELEBRATING IOS YEARS OF EXPLORATION



"Engineered Negligible Senescence"

Aubrey de Grey

Synthetic Biology: Engineering Novel Organisms with Novel Functions



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



New Technologies and National Security



Sensor World

Molecular	Novel	Micro-	Ubiquitous	Reconfigurable
Foundries	Materials	Devices	Sensing	Sensors
			ERECTOR CONTRACTOR OF CONTRACT	
Ambient	Digital	Cogint	Intelligent	Competition
Intelligence	Cultures		Machines	and Espionage
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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:

self-assembling and self-repairing 'intelligent' materials miniaturization, nano-and Åautomation, scale fabrication networked and spatial sensors and molecular devices assemblies wireless technologies and biomimetic power sources

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



INFLUENCE Further explanation of the NSABB recommendationsp.**58** social learning in apes 9.58 HISTORY John Dee's weaving Elizabethan court 9.180

e'sweaving CINEELWINN Trade in whate gic in the 'quotas' may be insufficient urt µ180 protection µ182



Pathogenic H5M1 avian influenza has led to the culling of husdreds of millions of birds. A human-transmissible form could have much worse cossequence

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 H5NI 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





Accelerating Convergence: Conceptual, Technological, Informational and Commercial



New Patterns of Technology Fusion, Evolution and Adoption

New Knowledge Networks

New Participants New Markets and Business Models

The Evolution of Production



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

- 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



The Proliferation of Mobile Devices in Healthcare







Siri, does this look malignant?

Mobile Devices and Telemedicine



Robotics: Telemedicine and Home Healthcare



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
- Iongitudinal 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



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)
- Iarge 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

















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?

TRANSACTIONS: GIVING SOME ACCOMPT OF THE PRESENT

OF THE PRESENT Undertakings, Studies, and Labours

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 Fames Allefry in Duck-Lane,' Printers to the Royal Society.



THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

The transformation of scientific publishing - Mat 425

A NEW PAGE

Open Data Systems and Crowd Sourcing in Biomedical R&D





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 Economy





Shared Resources



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

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?

ns		
'Black Swans'		
phase transitions		

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



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



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" "Nu (Knowledge is (T 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: <u>http://casi.asu.edu/</u>

