Innovation Demands Boldness: Meeting the Challenges of Escalating Complexity

Dr. George Poste
Director, Complex Adaptive Systems Initiative and Del E. Webb Chair in Health Innovation
Arizona State University
george.poste@asu.edu
www.casi.asu.edu

Workshop, September 29th & 30th
Westin Kierland Resort Hotel in North Scottsdale
From the Steam Engine to the Search Engine:
Two Centuries of Innovators

They Made America
Harold Evans

SCIENCE
A HISTORY OF DISCOVERY IN THE TWENTIETH CENTURY
TREVOR I. WILLIAMS

THE NOBEL CENTURY
A CHRONICLE OF GENIUS
INTRODUCTION BY ASA BRIGGS

THE AMERICAN CENTURY
Varieties of Culture in Modern Times
Norman F. Cantor
Author of The Civilization of the Middle Ages and The Sacred Chain
Picture Essays by Mindy Cantor
American Progress: Manifest Destiny by John Gast (1872)

- “A New Order of the Ages”
- unfinished pyramid as symbol that US will always grow, improve and build
“…..banking establishments are more dangerous than standing armies, and the principle of spending money to be paid out by posterity …..is but swindling futurity on a larger scale”

“Manufactures are now as necessary to our independence as to our comfort.”

Thomas Jefferson
US Services and Manufacturing
2000-2009

- Financial services expanded from 10 to 45% of the earnings of the S&P 500 in 2009
- In 2000 high-technology products generated positive trade balance and a $50 billion deficit in 2007
- 47% of revenue for US S&P countries now earned overseas
- The equity cult: from 1952 to 2006 US pension funds increased equity weighting from 17% to 69%
- $249 billion net loss in US stock-based mutual funds since 2007
Systemic Risk

- Delusional faith in unfettered markets and global free trade
  - Transactional and short term focus
- Replacement of domestic manufacturing base with service industries
- Off-shoring of design and engineering now marketing may follow manufacturing
- “Bread and circuses”: rampant consumerism, political populism and quick fixes
- Trade imbalance, deficits and unsustainable debt
- Ad hoc and conflicting economic, political and regulatory policies
- Decline of the national innovation ecosystem?
From Small-Time to Prime-Time: Companies with #1 Global Market Share

<table>
<thead>
<tr>
<th>Company</th>
<th>Industry</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAMSUNG</td>
<td>flash memories, hard disks, flat screen monitors</td>
<td>South Korea</td>
</tr>
<tr>
<td>ARACRUZ</td>
<td>market pulp for paper products</td>
<td>Brazil</td>
</tr>
<tr>
<td>SASOL</td>
<td>synthetic fuels</td>
<td>South Africa</td>
</tr>
<tr>
<td>TSMC</td>
<td>logic semiconductors</td>
<td>Taiwan</td>
</tr>
<tr>
<td>MISC</td>
<td>liquefied natural gas shipping</td>
<td>Malaysia</td>
</tr>
<tr>
<td>GAZPROM</td>
<td>natural gas</td>
<td>Russia</td>
</tr>
<tr>
<td>Tenaris</td>
<td>oil pipes</td>
<td>Argentina</td>
</tr>
</tbody>
</table>
“Intel can move wherever it must to thrive but I sometimes wonder how my grandchildren will earn a living”

Dr. Craig Barrett
Former Chairman, Intel
“Intel’s goal is to support a transition from manufactured in China to innovated in China”

Remarks by Paul Otellini CEO, Intel at celebration to launch the initiative. Great Hall, Beijing

• investment will generate additional $1 billion in profits over 10 years versus operating same facility in US
21st Century Dung

- US exports of scrap metal and waste exports to China in 2008 of $7.6 billion
- exceeds exports of next three strongest categories
  - semiconductors, aircraft and parts, oil seeds and grain
- US trade deficit with China
  - $250 billion with $100 billion in high-tech goods
  - computer equipment China’s biggest export to US ($46 billion)
Vulnerability of Global, National and Local Supply Chains in a Major Epidemic/Pandemic

Medicines

- “just-in-time” supply networks
  - major hospitals 2/3 deliveries per day
- majority of drug intermediates, excipients and final products sourced off-shore
- 95% generic drugs used in US (64% of total Rx) are made off-shore, primarily in PRC and India
- no national stockpile for routine prescriptions
• can the world accommodate continued economic growth at a pace that the public has come to expect?
• can Western labor markets withstand the competitiveness of emerging nations?
• are standard theories of ‘comparative advantage’ that are central to traditional economic policy relevant in a global context?
• how will Western countries address the economic/infrastructure/production “voids” created by population ageing?
• how we innovate for sustained competitiveness?
“Actually, these aren’t bad times to be delusional.”
Meeting Previous Grand Challenges
The application of ingenuity to improve individual quality-of-life and promote societal systems that protect and expand literacy, aspiration, economic prosperity, security and sustainability
Beyond Innovation

Source: Info Week 13 September 2010
“Innotatore: an alterer, disturber”
Florio 1598

“…..this world shall either be abolished by annihilation,
or be innovated, and as it were, transfigured.”
T. Boyle 1674

“There are many who supposing themselves wiser than others,
endeavor to innovate. ”
T. Hobbes 1651

“The insights of economics do not illuminate the process of innovation”
J. P. Lewis 1959

“The Air Force sounded more exciting and more innovative.”
N. Armstrong 1970
Incremental Innovations

- linear extensions of established methods, products and services
- a.k.a. minnovation
- value proposition easily understood by consumers, producers and financial markets
Disruptive Innovations

- non-linear and radical shifts in technology trajectories that replace the status quo
  - products and/or services
  - processes: reduced time and cost
- Schumpeterian ‘creative destruction’
- a.k.a. dislocation, discontinuity, tipping points, infections, ‘Black Swans’
- new value proposition rarely sensed and often rejected by current KOLs/companies/financial markets
- typically arise at margins of existing domains or at the convergent interstices between separate domains
Reverse Innovation

- traditional innovation based on assumptions of affluence and abundance
- for emerging markets affordability and sustainability will drive innovation
- reverse innovation (GE): transfer of innovation from emerging to established markets
Reconfigured Innovations

- creation of novel products/services incorporating features/competencies from different industries
  - sensors and smart devices
- reconfigurations can also be highly “disruptive”
- use of available technology in a novel way
  - hijacked planes in 9/11, IEDs
  - cybercrime
“Constructively Discontent”
Transcending Boundaries: Emergent Domains Arising from Technology Convergence

- Systems and Synthetic Biology
- Targeted Rx and Gene Controls
- Regenerative Medicine
- HPO
- Genetic Identity

- Bio-Enhancement
- Bionic-Enhancement
- Cognitive Enhancement
- Genetic Enhancement
- Bio-Stratified Population
<table>
<thead>
<tr>
<th>Molecular Foundries</th>
<th>Novel Materials</th>
<th>Micro-Devices</th>
<th>Ubiquitous Sensing</th>
<th>Robotics</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Molecular Foundries" /></td>
<td><img src="image2" alt="Novel Materials" /></td>
<td><img src="image3" alt="Micro-Devices" /></td>
<td><img src="image4" alt="Ubiquitous Sensing" /></td>
<td><img src="image5" alt="Robotics" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ambient Intelligence</th>
<th>Digital Cultures</th>
<th>Cogint</th>
<th>Intelligent Machines</th>
<th>Competition and Espionage</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image6" alt="Ambient Intelligence" /></td>
<td><img src="image7" alt="Digital Cultures" /></td>
<td><img src="image8" alt="Cogint" /></td>
<td><img src="image9" alt="Intelligent Machines" /></td>
<td><img src="image10" alt="Competition and Espionage" /></td>
</tr>
</tbody>
</table>

**Massive Computing Power and Analytical Parsing**
The Strategic Environment for Technology

- Disruptive Technologies
- Technology Convergence
- Dual-Use Technologies
- Technology Acceleration
“For the first time in history, the United States is raising a generation of children who may live sicker, shorter lives than their parents. We must act now to reverse this trend.”
The Economic, Social and Clinical Benefits of Proactive Mitigation of Disease Risk and Chronic Disease Co-Morbidities

Health Status

- Healthy/Low Risk
- At-Risk
- High Risk

20% of the Population Generate 80% Cost

- end-of-life care
- chronic disease progression
- chronic disease early stage
- acute disease

multiple co-morbidities

Value

Cost
From Pharmaceuticals to Phamasuitables

Disease Subtyping:

Right Rx for Right Disease

Individual Variation and AE risk

Right Rx for Right Patient
Tracking and Mitigating The Major Cost of Inefficiencies in Healthcare

- **Overt Error**
- **Non-Compliance**
- **Adverse Rx Events**

- **Hospital-Acquired Infections**
- **Cost of Hospital Re-admissions**
- **Inaccurate, Inaccessible or Ignored Information**
Connected Care

Technology-enabled Care at Home

Produced by the Deloitte Center for Health Solutions

State of Technology in Aging Services According to Field Experts and Thought Leaders

By:
Majd Alwan, Ph.D.,
Center for Aging Services Technologies (CAST)
American Association of Homes and Services for the Aging (AAHSA)

and

Jeremy Nobel, M.D., M.P.H.,
Harvard School of Public Health

Report Submitted to: Blue Shield of California Foundation

February 2008
Remote Health Monitoring and Chronic Disease Management

Information for Proactive Health Awareness (Wellness)

Lifestyle and Fitness
Social Networks and Consumer: Patient Empowerment

Source: R&D Directions May 2010
The Key Strategic Elements in the Evolution of Healthcare

- molecular diagnostics for disease prediction, prevention, earlier detection
- biomarkers for health status profiling
- risk management
- health status monitoring
- optimized decisions
- e.care: EMR, PHR integrated care and wellness
- • prevention
- • disease subtyping and Rx choice
- • compliance
- • m.health

molecular medicine
m.health
“Managing Mega-Data”

- **Volume**
- **Scale**
- **Global networks**

- **Heterogeneity**
- **Integration**
How Much New Technology Can We Afford?
The Global Public Health Challenge Posed by Rapid Urbanization in Developing Countries

<table>
<thead>
<tr>
<th>High Disease Transmission</th>
<th>Lack of Safe Water</th>
<th>Toxic Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Slum area" /></td>
<td><img src="image2" alt="Children in polluted water" /></td>
<td><img src="image3" alt="Toxic waste" /></td>
</tr>
</tbody>
</table>

- Major Deficits in Health Infrastructure
- Expanded Eco-niches and Increased Zoonotic Risks
Bad Bugs and Few New Drugs

NO ESKAPE!

NO INCENTIVES FOR INDUSTRY INVESTMENT
Geo-demographic Information Systems (GIS): Real-Time, Front Line, Ground Zero Data from Field Sampling and Sentinels
The Global Food Supply: New Tensions and Risk of Conflicts

- food chain increasingly complex, international and inter-dependent
- food production over next 25 years ≈ total for last 10,000 years
- expanding middle class (1-2 billion) in NICs and some LDCs and increased demand for grain and meat projected to increase by 160% by 2020
- famines, shortages and food riots in LDCs
- least expensive sourcing also least safe
- the impact of climate change
And man made life

The first artificial organism and its consequences
Synthetic Biology and Building A New Industrial Ecology
Engineering Novel Organisms with Novel Functions
Synthetic Biology

Emerging technology with myriad applications across diverse industrial sectors and military applications.

- Healthcare
- Public Health
- Agriculture
- Functional Foods
- Novel Materials
- Textiles
- Bioenergy and Biofuels
- Industrial Enzymes
- ‘Green’ Mfg
- Bio-remediation
- Clean Water
- Ubiquitous Sensors
Novel Materials

- Flexible superfast electronics
- Non-reflective coatings
- Black body materials
- Metamaterials
- Switchable materials
Nano- and Meso-Scale Engineering and Directed Molecular Assembly for Novel Materials, Sensors and Self-Assembling Devices
Robotics

4D Jobs: Dull, Dirty, Detailed and Dangerous
“Every age has its own kind of war, its own limiting conditions and its own peculiar preconceptions.”

Claus von Clausewitz

- security policy is determined by changing threats and their deployment
- there is no single security policy that serves all needs equally well
Convergence and Complexity in National Security

- new doctrinal dynamics for new threats
- asymmetric warfare, terrorism and non-state actors
- homeland defense
- WMD proliferation
- cyberspace, space, sea and air
- diplomacy, strategic engagement, new institutions and treaties
- instabilities generated by natural phenomena
  - disease, food production, water scarcity
  - depletion of natural resources
- openness of stability of worlds common spaces (the commons)
How concerned are you about the potential for technology surprise?

Have you ever experienced surprise?
“Each of the three last Administrations have been slow to recognize and respond to the biothreat”
Future Trajectory Trends and Threat Expansion

New ‘Dual-Use’ Technologies
Strategic Plan for Outreach and Education On Dual Use Research Issues

Report of the
National Science Advisory Board for Biosecurity (NSABB)

December 10, 2008

THE DUAL-USE DILEMMA
The New Strategic “Spaces” in Military Affairs and National Security

Systems and Synthetic Biology

Ubiquitous Sensing

Brain: Machine Interactions

Infocosm and the Metaverse

Militarization of Space

“Biospace”

“Connected Space”

“Smart Space”

“Cyberspace”

“Outer Space”

Constantly Emerging and Evolving Multi-Dimensional Matrices of Knowledge Ecologies

Global Challenges

Systems of Innovation
The PRC Strategy for Cyberwar

“to cut off the enemy’s ability to:
– obtain, control and use information
– influence, reduce and destroy decision-making and command decision”

Cyber-Attacks and Vulnerable Infrastructure: Compromising Critical Systems
Great Expectations:
Intelligent Monitoring Systems for Improved Analysis of National Security Threats and Their Implications

- dramatic expansion in ‘signatures for interest’
- formidable data mining and context analytics
- new tradecraft
- new open sources (OSINT)
- new ways to validate sources
- new technical competencies
- new knowledge integration tools
- new behaviors
The Infocosm: Emerging Networks of Global Connectivity
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 capabilities for modeling potential major instabilities/perturbations
- complex legal, ethical and social implications
“digital traces”
- expanded sensor repertoires of routine devices

estimated 7 trillion wirelessly connected devices and objects by 2017 (c.1000/person)

mobile devices and monitoring consumer habits
- behavioral targeting
- contextual targeting
- social network profiling

the politics of privacy
- growing pressure for legislative oversight
- US Energy and Commerce Internet Subcommittee
- EU Article 29 Working Party

two-thirds of new products now come with some electronic component or tracking potential
Enhancing Human Capabilities to Use the Increased Volume, Diversity and Complexity of Information Flows
Cognitive Biology, Customized Data Formats and Visualization for Improved Decision-Making
Exabyte World*

- multipetabyte data sets emerging
  - national security, big science
  - medical imaging
- Large Hadron Collider estimated 15 petabytes/year
- smart electricity grid
  - stream of four numbers transmitted every second (current, phase, frequency, time)
  - 0.05 gigabytes per customer/year
  - 100 million customers ≡ 50 petabytes/year before compression

*J. Beyea (2010) Science 328, 979
The Intellectual Frontiers of Computer Science

- network science and analytics
- mobile computing
- enterprise computing
- distributed systems and grids
- cognitive biology and user-interface design
- visualization
- artificial intelligence
- cyberspace protection
next-generation (synthetic) neural networks
  – self-assembling
  – use of parallelism for process subdivision:
    “imagitrons: and “perceptrons”” (Imagination Engines)

Ideas Autonomously and Intelligently Designed by Non-Human, Machine Intelligence
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”
The Marriage of the Hard and Soft Sciences
New Networks of Intellectual Fusion

Behavioral Economic and Social Technologies (BEST)

- massive data sets
- open source networks
- new analytical models/tools for non-linear systems
- multi-scale networks

Acceleration and Convergence in Science and Technology
Social Sciences

- poor cousin to the hard sciences
- from no data to data overload
- vast increase in computing power and limitless pool of participants profiled via internet actions
- unprecedented opportunity to study human behavior and interactions in real time
- define domains in which individual or collective behavior dominates
Can Economics Be Transformed from the Dismal Science into Definitive (Predictive) Sociology?
The Biology of Decision-Making: Understanding Cognitive and Confirmation Biases

“Extraordinary Popular Delusions and the Madness of Crowds”
Charles Mackay, 1841

“Irrational Exuberance”
Alan Greenspan
Chairman, US Federal Reserve
Myths, Rumors and Irrational Behavior: Cognitive and Confirmation Biases

- cultural reinforcement by herd psychology
- amplification by the toxic echo-chamber of the modern media
- higher predisposition for acceptance in periods of uncertainty, stress, disorder, fear
- the sunk cost fallacy: reluctance to acknowledge/reverse major decisions with high economic/emotional/personal tolls
- decreased ‘generalized trust’ but increased ‘particularized trust’
  - Farhad Manjo: True Enough-Learning to Live in a Post-Fact Society
- prewired mechanism for resolution of cognitive dissonance?
Ingenuity Capital

- social
- intellectual
- financial
- institutional
- legal
“Why Johnny Can’t Read”
Rudolf Flesch 1955

“Why Johnny Can’t Write”
Newsweek 8 Dec. 1975, pp 58-65

“Why Johnny Now Speaks Like His Texts and His Tweets”
REPORT TO THE PRESIDENT

PREPARE AND INSPIRE:
K-12 EDUCATION IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH (STEM) FOR AMERICA'S FUTURE

Executive Office of the President

President’s Council of Advisors on Science and Technology

SEPTEMBER 2010

PREPUBLICATION VERSION

Source: http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stemed-report.pdf

Source: http://www.changetheequation.org/
“It is common for young men and women who have had years of education to know nothing of the world.”

Doris Lessing
Acceptance Speech for Nobel Prize in Literature

“If colleges were businesses, they would be ripe for hostile takeovers complete with serious cost-cutting and painful reorganizations.”

Annual Survey 2010
Science Education

- truth is an issue of intellectual integrity
- science education is an ethical issue
  - informed (literate) citizenry in era when increasing problems and solutions involve S&T
  - endow individuals with capabilities to evaluate evidence
  - assess risk versus benefit
  - demand informed policy and responsible governance
  - opportunities denied or realized
- some would argue it’s also moral issue
Business Education: Have MBA Programs Distorted Priorities and Metrics for Business Performance?

- aspiration of best graduates to join major financial and consultancy houses
- ranking of B.schoo; by graduate starting salaries
- primary source of now discredited financial market prediction models
- narrow, disproportionate focus on finance/economics versus analysis and management of the trends shaping escalating complexity
- predominant curriculum channeling to non-S&T topics creates dangerous knowledge void in corporations/financial markets
Curriculum of the future?

The lectures at Singularity University cover ten core topics:

- Futures studies and forecasting
- Policy, law and ethics
- Finance, entrepreneurship and economics
- Networks and computing systems
- Biotechnology and bioinformatics
- Nanotechnology
- Medicine and neuroscience
- Artificial intelligence and robotics
- Energy and environmental systems
- Space and physical sciences
Automated Industrial Processes

- Cost reduction, open access and cloud computing as key drivers of automated invention technologies
- Prosumers and continuous redesign of products/services
- Parallel improvements in low cost automated fabrication tools for manufacturing (plus offshoring)
- Escalation of dual use dilemma and hacker threats
- Implications for IP law
Automated Industrial Processes

- cost reduction, open access and cloud computing as key drivers of automated invention technologies
- prosumers and continuous redesign of products/services
- parallel improvements in low cost automated fabrication tools for manufacturing (plus offshoring)
- escalation of dual use dilemma and hacker threats
- implications for IP law

Impact on Employment and Higher Education Curricula
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
SCIENCE
AND
SECURITY
IN A
POST 9/11
WORLD

A Report Based on Regional
Discussions Between the
Science and Security
Communities

BEYOND
"FORTRESS AMERICA"
National Security Controls on Science and
Technology in a Globalized World

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES
outdated USG export controls created market niche for foreign competitors

- European Aeronautic Defence and Space Company
- Swiss Propulsion Laboratory
- Thales Alenia Space
- M. Torres (Spain)

off-shoring by US companies to avoid export controls and access foreign markets
Asymmetries in Global Trade

- tolerance of dumping, currency manipulation and other free-trade distortions by neomercantile countries
  - accelerates offshoring of US-based production
  - lower cost seen as benefit to US consumer despite impact on domestic industry
  - opponents condemned as Smoot-Hawley protectionists

- coercive agreements for both investment and technology transfer for access to foreign markets

- disadvantageous bilateral agreements to promote perceived higher geopolitical priorities
  - PRC ARJ21 commuter jet and Taiwan

- uncoupling of the strategic primacy and attention accorded geopolitics/national security from formulation of robust economic and industrial policies
National Policies

- Purposeful doctrine and proactive strategies
- Predominantly reactive short-term policies

Geopolitics
Military affairs
National security

Erratic engagements and ad hoc policies

Agriculture, education, energy, environment, financial markets, healthcare, telecommunications, transportation

Dominant input from academic/civil service sources with limited private-sector expertise

Trade, industry, intellectual property, competitiveness, sustainability
Current Regulatory Frameworks Are Anachronisms

- traditional regulatory models designed for oversight of “one purpose” industries
- lack experience, knowledge and agility to shape and regulate emerging industrial ecosystems
  - inter-agency communication and decision authorities
  - convergent industries
  - global supply chains
  - internet commerce and crime
  - state-owned industries versus free market policies
  - implications of emerging technologies
- undermine competition and innovation
- susceptible to ‘gaming’ by anti-industry activists
The Schizophrenic Attitude Towards Strategic Planning for National Competitiveness

- pervasive distrust of corporatism in academia, media and politics
- time, cost and risk to master technical complexity
- legislation and regulation focused internally to limit competitive dynamics of domestic base becomes de facto industrial policy and failure to assess competitive risk from foreign investment patterns
- timidity in opposing free-trade distortions and asymmetries imposed by emerging neo-mercantile nations
National Industrial Policies

- 863 Program
- State-Owned Assets Supervision and Administration Commission (SASAC)
- World’s largest sovereign wealth fund
- Council on Economic Planning and Development
- Green Silicon Island
- Singapore Development Authority
- A*
- Ministry of International Trade and Industry
The Dynamics of Neo-mercantilist Markets

- explicit targeting of specific industries
- investment and policy support to achieve first-mover advantage and economy of scale
- explicit or implicit requirements for foreign companies to invest and transfer technology as condition for market acceptance
- currency undervaluation to promote exports
- asymmetric trade agreements that favor offshoring of US-based production promoted for geopolitical objectives
• control of 95% world’s supply of rare earth metals
  – lanthanides (57-71)
  – scandium (21)
  – yttrium (39)
• curtailed export quotas
  – 31,310 tonnes (2009)
  – 35,000/year for next 6 years
• aggressive courtships of mineral-rich African regimes
• explicit industrial policy via national development bank (BNDES)
• loan interest less than half market rates for targeted industries
  – biotechnology (agriculture), pharmaceuticals, IT
• support of M&A activity by Brazilian companies
  – Brasil Foods
  – Braskem (petrochemicals)
  – Electrobras (electricity)
• Petrosal
  – new sovereign wealth fund to develop pre-sal off-shore oil reserves
  – $224 billion over next five years
  – 65% of equipment must be purchased from Brazilian companies
Dangerous Times

- Public confidence in every economic and political institution at all time low
- Political divisiveness, short-termism and technical literacy
- Anachronistic policies and inadequate institutional agility to respond to escalating challenges
  - Accelerating change
  - Global inter-dependencies
  - ‘Emergence’ and radical discontinuities
- People respond irrationally when afraid
- Absent feeling reassured people gravitate to whatever fills the void
The Multi-Dimensional Complexity of Innovation
Features of Complex Adaptive Systems: Highly Optimized Tolerance and Far-From Equilibrium States

Convergence

• novel interactions between previously distinct agents/networks/systems

Emergence

• new patterns of convergence trigger new system with highly different and often unpredicted features
“For most of us design is invisible until it fails”:
Bruce Mau. Massive Change. 2004
omnipresent component of new socio-technological systems
• anticipation and imagination are crucial in introducing new elements into tightly coupled systems
• effects of changes and breakdowns can propagate quickly, often unseen, into domains far from their origin
• stability and safety are not static phenomena
“We think in generalities, but we live in detail.”

Alfred North Whitehead
“Has our capacity to build complex systems transcended our evolutionary cognitive abilities and agilities to comprehend multidimensional and non-visual data and devise ways to mitigate the intrinsic risks generated by escalating complexity?”

- defines the intellectual and pragmatic terrain in which human populations and individuals must identify, analyze and respond to complexity
The Imperative to Develop New Analytics for Design Parameters in Complex Systems and Predictive Modeling of Non-Linear Dynamics

- dangerous knowledge void in relation to rapid evolution of large scale networked systems
- poor prediction of precursors of critical transition or cascading system collapse
  - tipping point, critical thresholds, catastrophic bifurcations
  - “normal accidents” (C. Perrow)
- evolution of systems too complex to be understood and too important to be turned off

EARLY WARNING SIGNALS OF CRITICAL TRANSITIONS
“Plug the Damn Hole”

President Obama
Alleged commentary to staff
Washington Post 25 May 2010

THE 29 July 2010

Ignorance lays Parliament open to ‘nonsense debates’

Andrew Miller admits that busy MPs avoid science policy as it is too challenging. Paul Jump reports...
The Retreat from Complexity: The Insularity and Risk-Aversion of USG Analytical and Decision Frameworks

- ‘too hard’ problems
- denial, avoidance, paralysis
- sustained focus/funding on ‘the linearly familiar’ and funding the ‘usual suspects’
- growing and dangerous deficits in USG expertise in next generation “disruptive technologies”
The Retreat from Complexity

BIG IDEAS
GO
UNEXPLORED
AND
UNFUNDED

TIMIDITY AND PRESERVATION
OF STATUS QUO
TRUMP BOLDNESS AND
DISRUPTIVE INNOVATION
BOLDNESS!

CIA Recovery of Soviet Submarine K-129 at Depth of 16,500 feet (August 1974)

“A government or organization too timid to undertake calculable risks in pursuit of proper objectives would not be true to itself or to the people it serves.”

CIA Studies in Intelligence Failure 1985
National Security Archive
Declassified 13 Feb. 2010
Preparedness and Competitiveness: Building Resilient Systems

- designing organizations, processes and performance with enduring resilience
- new competencies (table stakes)
- new capabilities (ability to win)
  - competencies + robust, agile processes
- robust, agile processes
  - understanding complexities
  - build/integrate cross-disciplinary expertise
  - constantly changing expertise matrices as the problem ‘morphs’
  - new patterns of public:private engagement
  - individual and institutional incentives
STAR METRICS

Science and Technology for America’s Reinvestment: Measuring the Effects of Research on Innovation, Competitiveness and Science

FDP Technical Data Requirements Discussion
July 15, 2010
Maintaining and Expanding The Competitive Commons
Change, Grand Challenges and Competitiveness

Disruptors

Resource Flows

Impacts
Change, Grand Challenges and Competitiveness

- Drivers
  - innovation
  - distrust and dysfunction
  - complacency
  - risk:reward
  - governance
  - geopolitics
  - globalization
  - urbanization

- Triggers
  - convergence
  - collapse
  - emergence
  - complexity

- Grand Challenges
  - sustainability
  - demographics
  - security
  - stability
  - connectivity
  - predictability

Disruptors
Change, Grand Challenges and Competitiveness

Resource Flows

Hard Assets
- traditional infrastructure
- digital infrastructure
- geography/natural resources
- workforce
- capital
- military

Soft Assets
- cultural precedents
- confidence
- aspiration
- education
- health system
- laws/regulations
- political stability
- leadership
- trust

Agile Assets
- vision
- new knowledge ecosystems
- global networks
- open-source and social media
- emerging nations/markets
Change, Grand Challenges and Competitiveness

**Impacts**

**Outputs**
- educated public/workforce
- products/services
- R&D sourcing
- manufacturing base
- workforce

**Requirements**
- strategy
- policies
- operating practices
- institutional architectures
- investment incentives
- oversight and regulation
- metrics
We Must Find a Way….

- to better understand, quantify and make explicit the linkages between
  - population growth
  - consumption growth
  - ecosystem decline
  - resource scarcity
  - political, economic and social stability
  - national security
- to communicate this knowledge to policy makers and the public
- to formulate public policies that embrace complexity and embed agility for sustained competitiveness
Engaging With Complexity

- irreducible complexity

- reducible complexity

- ‘engageable’ complexity (limits of us) and

- ‘transferable’ complexity (cross-disciplinary education and applications) and

- ‘pragmatic’ complexity (adoption by non-expert end-users)
Challenges Are Global But Politics is Still Local: The Cultural and Institutional Limits of Governance

- supranational oversight and harmonized regulation
- global commons
- WMD proliferation
- cyber-vulnerability
- terrorism
- climate change
- infectious disease
- finance and trade

Building A New International Consensus

Rude Shocks and Wake Up Calls
Reset and Redesign: Defining New Frameworks for Education, Research and Competitive Innovation

- reality (ugly and unavoidable)
- realignment (expectations and endpoints)
- repurposing (leverage and improve core assets)
- reinvention (boldness)
- robustness (agile, adaptation to relentless change)
- re-read and re-learn (history)
- radical (complex challenges will not be solved by timidity or incremental changes)
Reset and Redesign

- commit to radical reform of educational systems to embrace emerging career requirements
  - professional incentives
  - standards, metrics and accountability
  - K-12, higher education (not just STEM)
  - cultural recalibration of ‘success’ and ‘what matters’ (rewards)

- rationalize immigration policies
  - current challenges
  - attracting foreign talent to expand knowledge-based capabilities
Reset and Redesign

- retool our workforce for leadership in vanguard technologies
- rebuild high-value manufacturing and exports
- reduce national dependence on service-industries
- build and embed an intelligent digital ecosystem into every domain
Reset and Redesign

- set national goals for 2025
  - grand challenges in education, health, emerging and sustainability
  - knowledge management, national security
  - high-value jobs and manufacturing capabilities for new industries as 20% total employment
“What have future generations ever done for us.”

Groucho Marx
“The only way of discovering the limits of the possible is to venture a little way past them into the impossible”

Arthur C. Clarke
Profiles of the Future (1962)