ASU Complex Adaptive Systems Initiative
Arizona State University

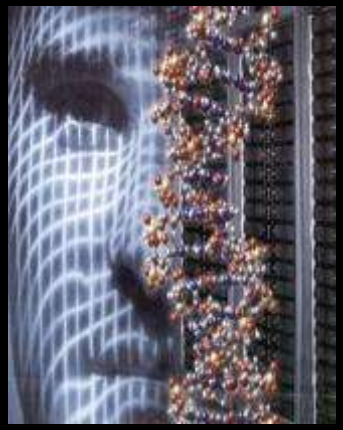
Understanding the Design Principles and Dynamics of Complex Adaptive Systems

Dr. George Poste
Chief Scientist, Complex Adaptive Systems Initiative
and Regents Professor of Health Innovation
Arizona State University
george.poste@asu.edu
www.casi.asu.edu

Presentation to Lynx Global Intelligence
Arizona State University ● April 10, 2017

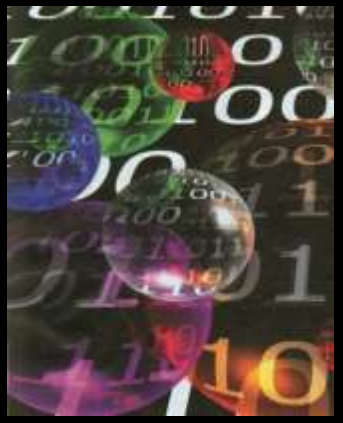
Technology Acceleration and Convergence: Escalating Complexities

Genetics, Biotechnology, Synthetic Biology



"Bio-Space"

Ubiquitous Sensing/ Devices & Social Networks



"Connected Space"

Advanced Computing Mega- & Meta- Data

"Analytics Space" and "Surveillance Space"

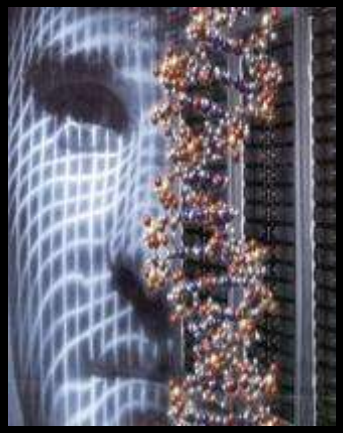
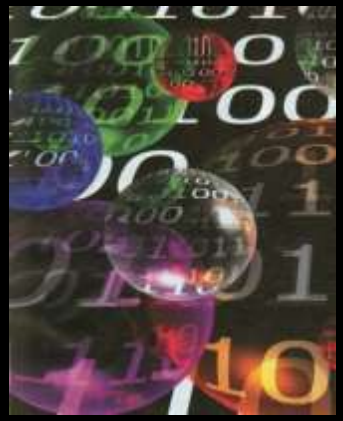
Robotics and Advanced Autonomous Systems

"Design Control Space"

Neurosciences and Human-Machine Interactions

"Cognitive Space"

Technology Acceleration and Convergence: Escalating Complexities

Genetics, Biotechnology, Synthetic Biology	Ubiquitous Sensing/ Devices & Social Networks	Advanced Computing Mega- & Meta- Data	Robotics and Advanced Autonomous Systems	Neurosciences and Human-Machine Interactions
				
"Bio-Space"	"Connected Space"	"Analytics Space" and "Surveillance Space"	"Design Control Space"	"Cognitive Space"

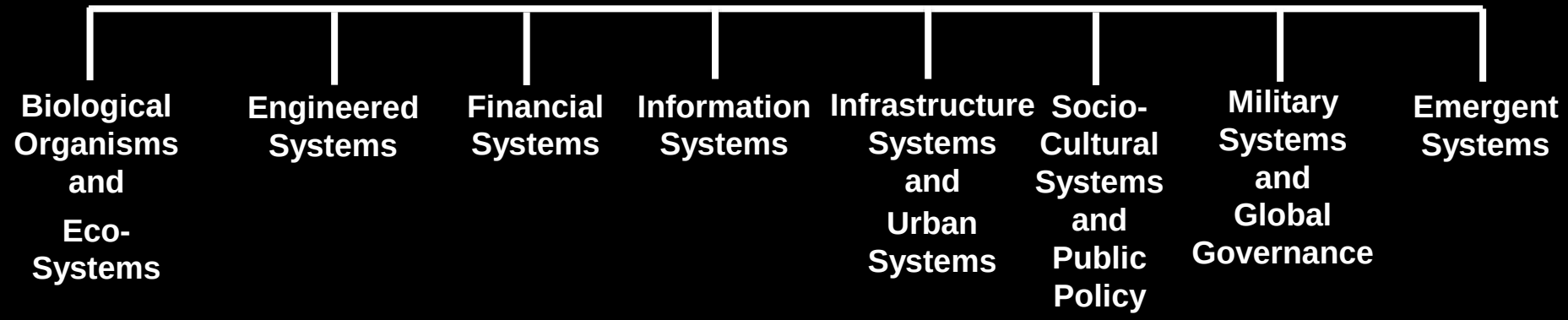
New Patterns of Technology Fusion, Evolution and Adoption

New Knowledge Networks

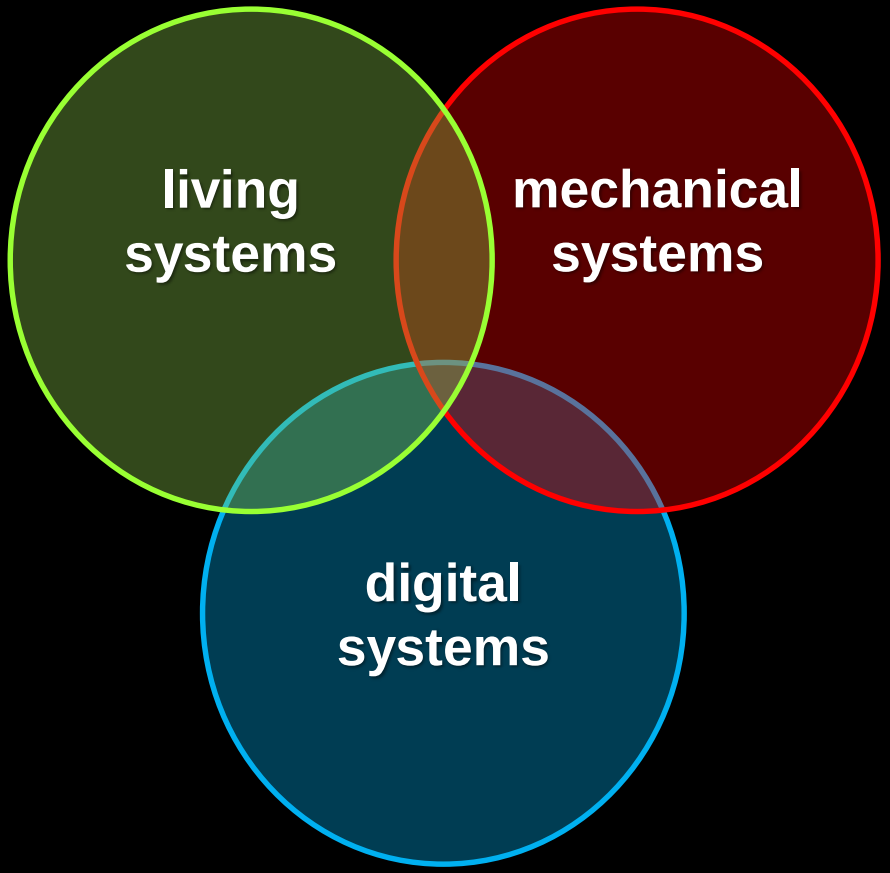
New Participants

New Markets and Business Models

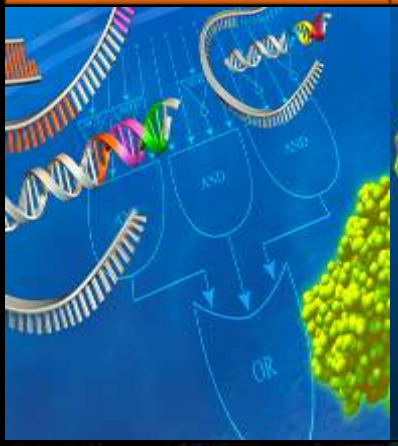
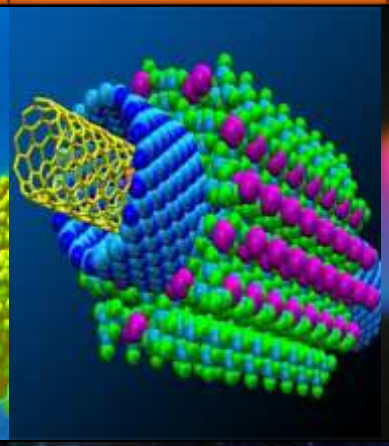
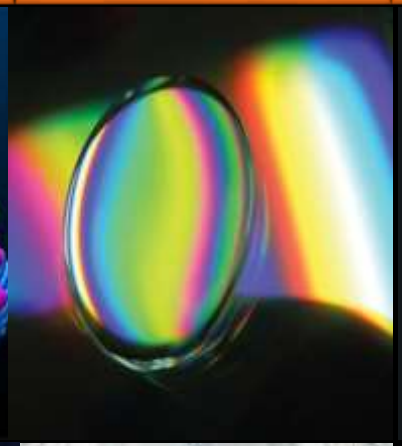
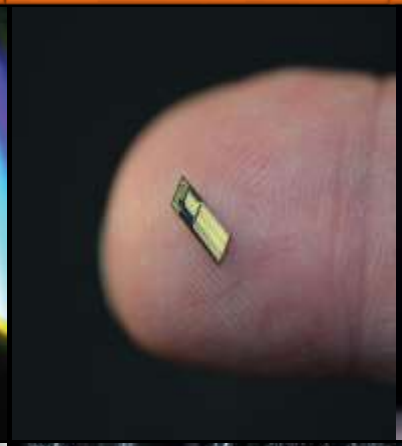
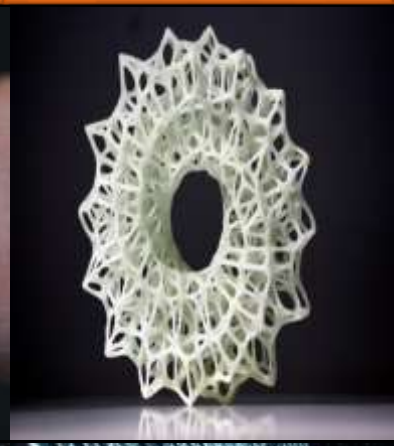
Complex Adaptive Systems



Convergence, Connectivity and Complexity



Cross-Sector technology Convergence and New Patterns of Complexity

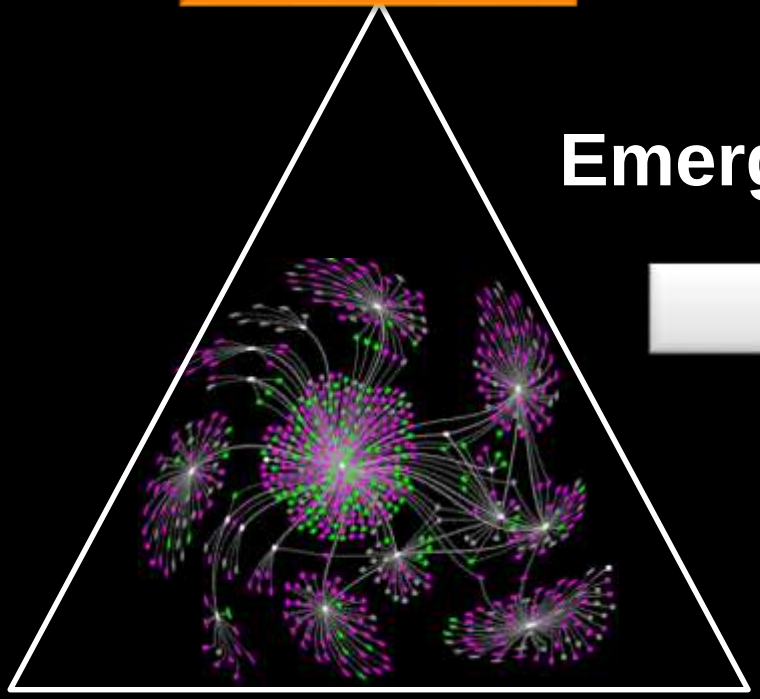
Genetic and Synthetic Biology	Nanotechnology and Novel Materials	Photonics and Optics	Sensors and IoT	3-D Manufacturing
				
				
Cognitive Computing and Neurotechnology	**Robotics and Automation**	**Man-Machine Interactions**	**Machine Learning**	**Deep Learning and Artificial Intelligence**

Complex Adaptive Systems

- emergence of complex, coherent, large scale collective behavior and very rich structure by repeated non-linear interactions of simpler components (agents)
- self-organizing complexity and non-linear behavior
- operate at far-from-equilibrium states: highly optimized tolerance (HOT)
- robust (resilient) to frequently encountered perturbations (fitness) but fragile to major disruption by rarely encountered perturbations/novel convergent forces
  - triggered ‘emergence’ of shift to new system state with highly different properties
  - unintended (unanticipated) consequences

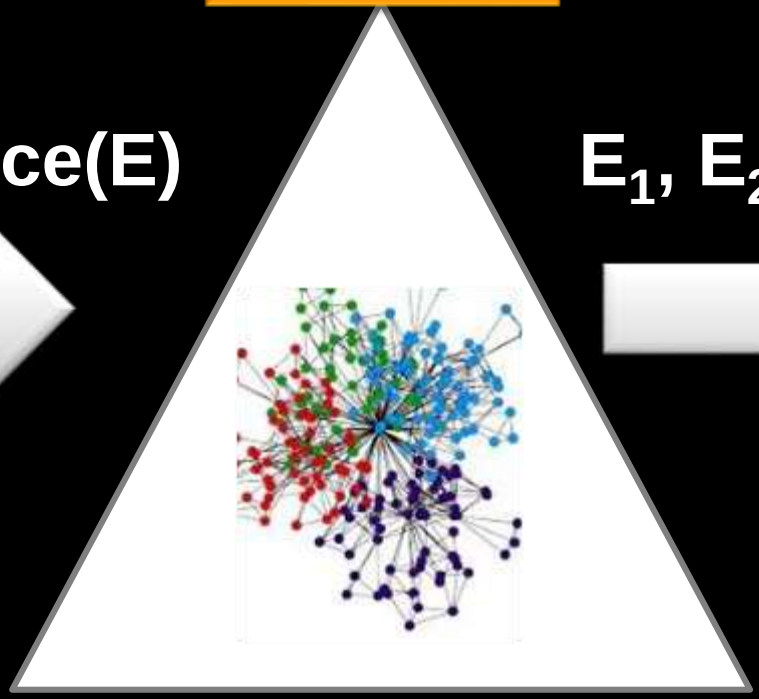
Understanding State Shifts in Complex Adaptive Systems and Identification of Triggers of Emergence

network topology



Emergence(E)

state shifts

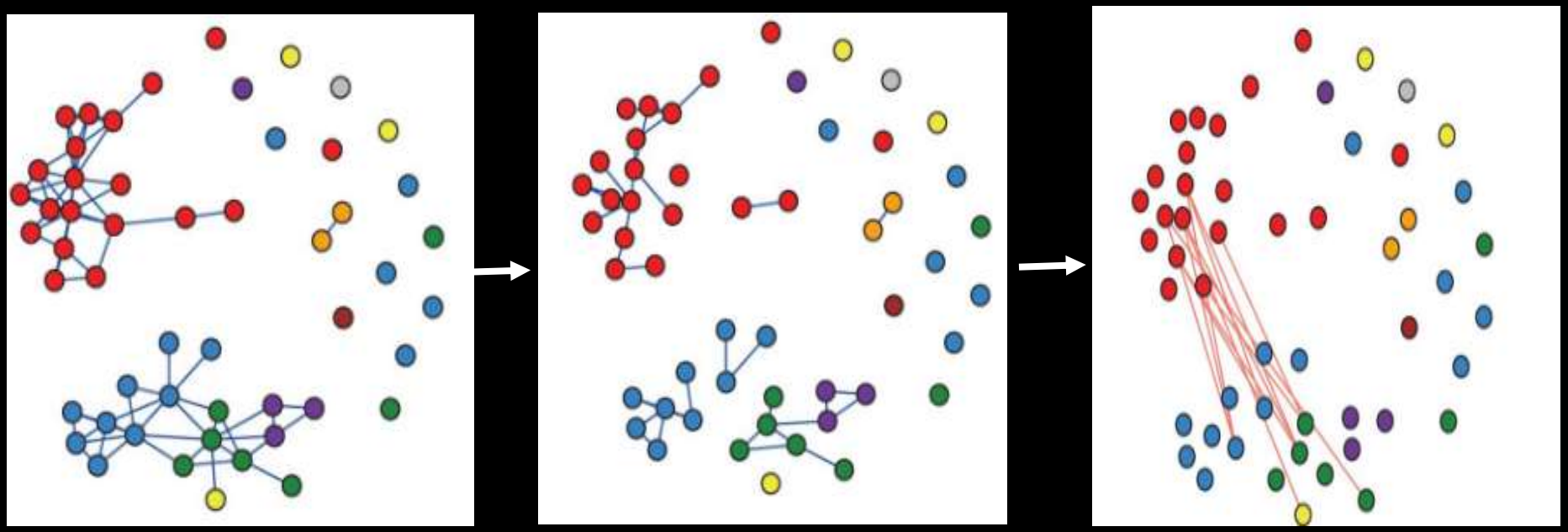


$E_1, E_2 \ldots E_n$

- Black Swans
- dislocations
- tipping points
- irreversible cascades
- phase shifts
- perturbations
- inflection points
- unintended consequences
- critical thresholds
- bifurcations
- trigger points


nature
THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE
12 May 2011
TAMING COMPLEXITY
The mathematics of network control — from cell biology to cellphones
PAGES 158 & 167

Understanding Network Organization and Dynamics in Complex Adaptive Systems



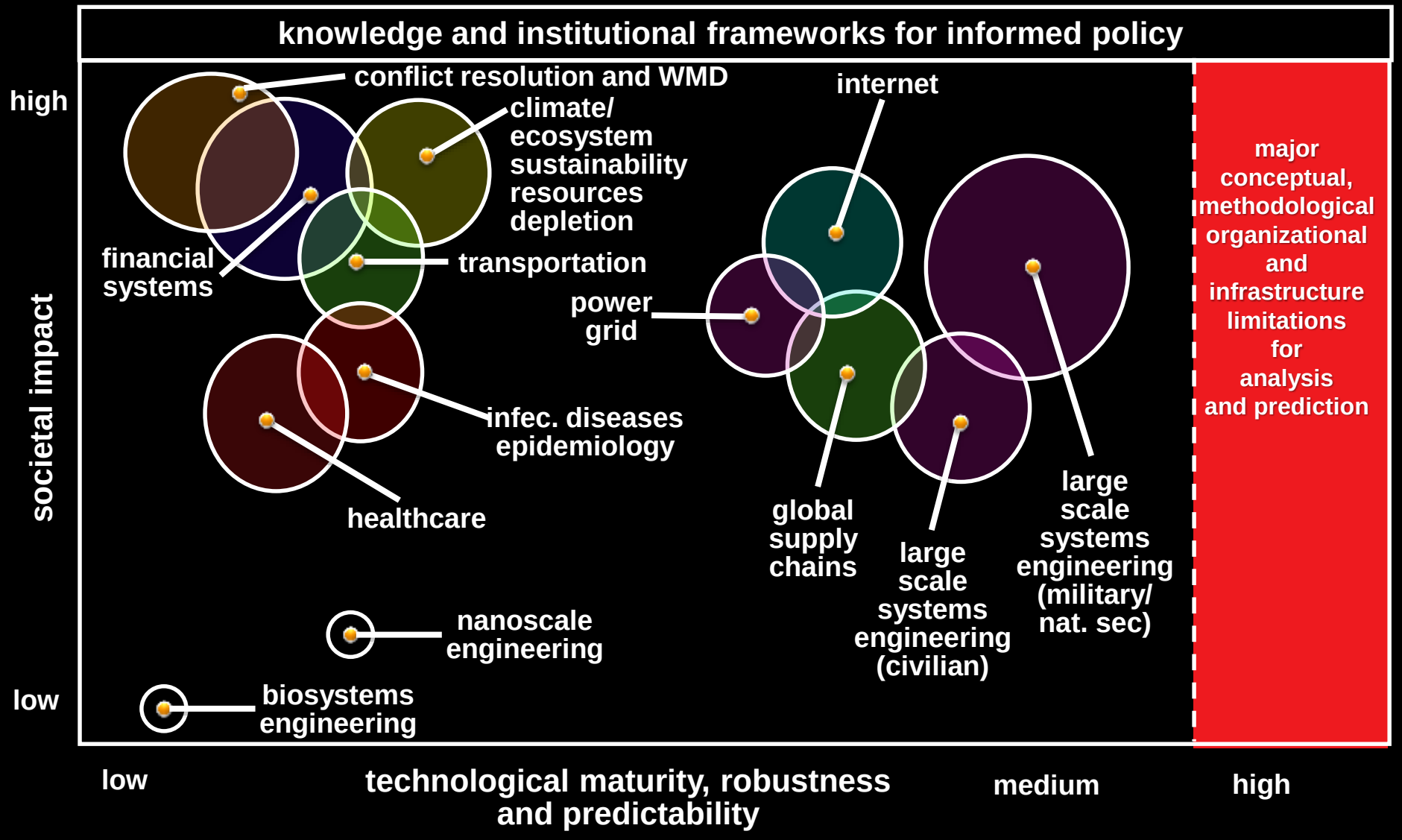
X X´ X´(d) Vs. X´(nd1) X´(nd2) X´(nd…n)

new analytical tools for proactive monitoring of system state space(s) and timely intervention(s) to channel emergent behavior to most desired trajectories

Complex Adaptive Systems

- what is the minimum amount of information about past and current behavior of a system that is needed to optimally predict the behavior of the system in the future?
- what are the signals of pending major shifts in system state and what are the most likely emergent trajectories and end states
- how can CAS design principles used to better inform construction and safety of human-engineered systems and generate methods for improved analysis and behavior prediction in both technological and social networks?

The CAS Landscape



A Strategic Planning Matrix for the Design of New Large Scale Pan-University Research Projects

GRAND CHALLENGE APPLICATION DOMAIN TEAMS (ADTs)

Precision Medicine	Sustainability	Earth and Space Systems	Synthetic Biology and Organism Engineering	National Security
				

CROSS-CUTTING EXPERTISE DOMAIN TEAMS (CETs)

- directed molecular assembly and novel materials: design of novel diagnostics, sensors, devices and targeted therapeutics and vaccines
- mapping the design architecture, topology and patterns of information flow in complex networks
- big data analytics, cognitive computing, man-machine interactions, machine learning and artificial intelligence
- ethical, legal and public policy implications of new technologies

Sensor World

Ubiquitous Sensing

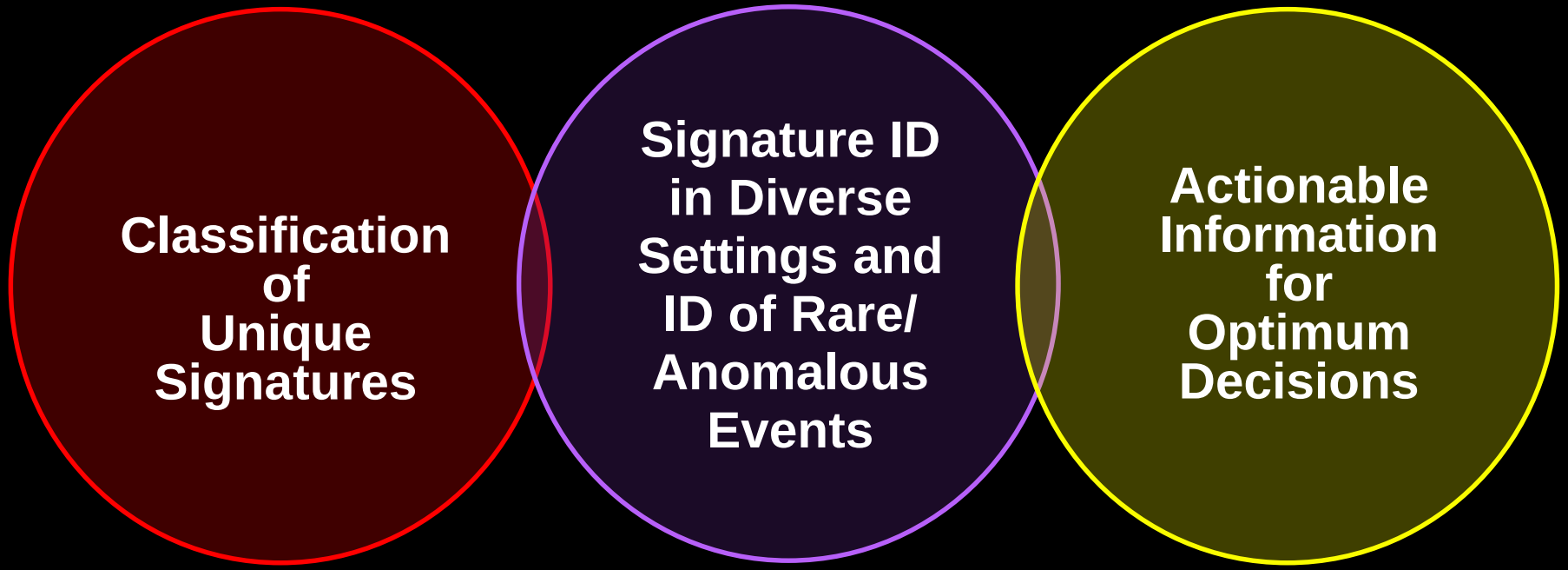
Internet – of – Things (IoT)

Biometrics and Surveillance

AORTA: Always On, Real Time Awareness

Faster Data, Smarter Analytics, Better Decisions

Integrated Functional Platforms to Exploit Technology Convergence



Profile

Biotechnology, Clinical Medicine, Ecosystems and Mathematical/Statistical Tools for Complex Signal Profiling

Sense

Nanotechnology, Automation and Miniaturization Engineering, Materials Science, Electronics

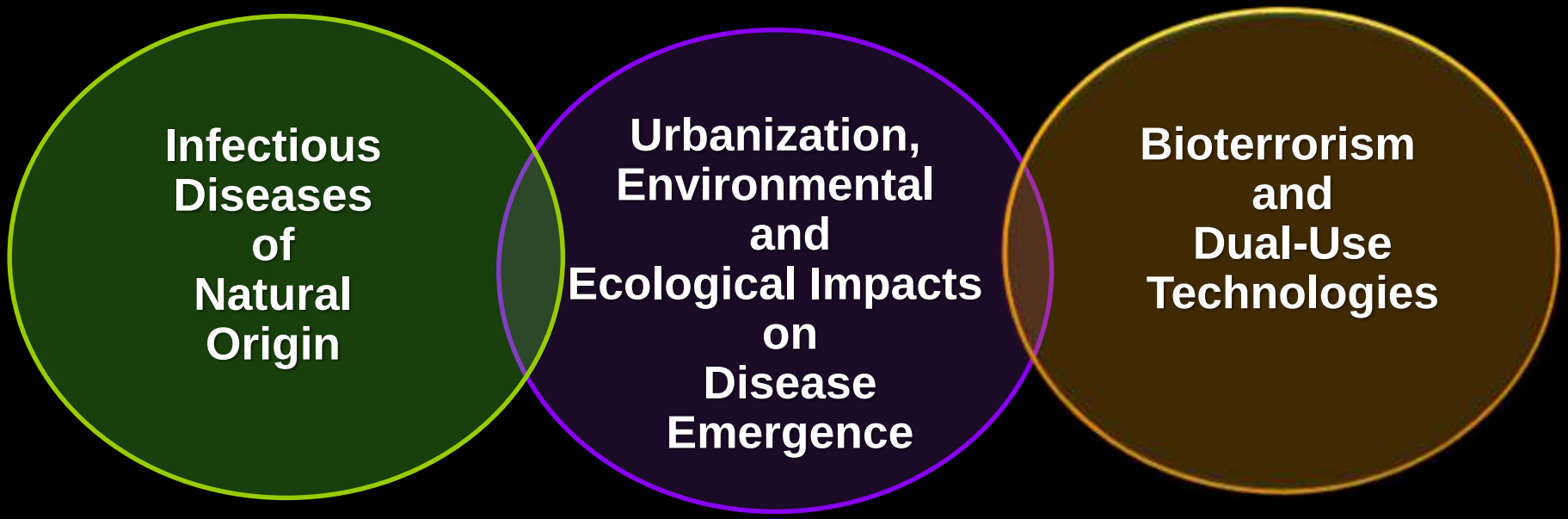
Act

Large Scale Informatics, Data Science, Decision Theory

Escalating Complexity: The Interaction of Complex Systems and Ever Denser Systems-of-Systems

- biosecurity
- urbanization
- bioincident management and sustaining critical systems
- dual use technologies and the expanded biothreat spectrum
- monitoring individual behavior
- big data analytics, deep learning and artificial intelligence
- keeping humans-in-the-loop: new vistas in education for a data-centric world

The Biosecurity Triad



Anthropogenic Effects on Ecosystem Stability and Altered Patterns of Infectious Diseases

famine

contaminated water

desertification

depletion of natural resources

climate change and new vector ranges

new vulnerabilities

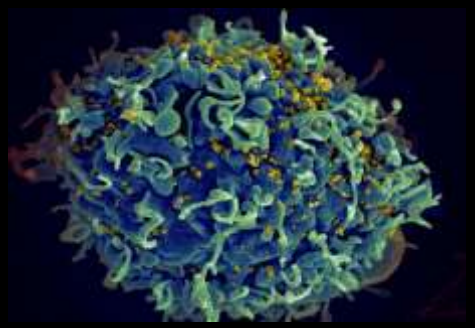
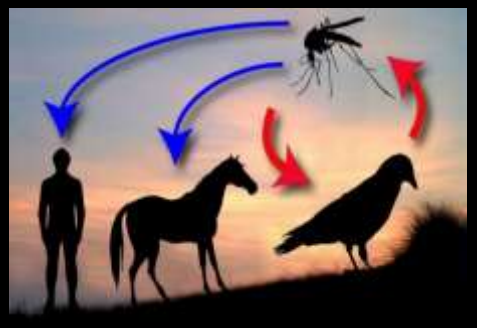
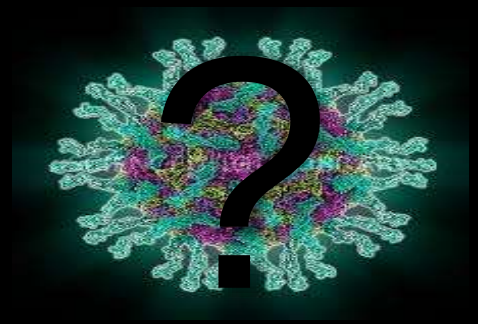
Urbanization and Mega-Cities in Developing Countries and the Increased Threat of Exotic Zoonotic Diseases

High Population Density With Inadequate Biosurveillance

Major Gaps in Health Infrastructure and Disease Reporting

Expanded Eco-niches and New Zoonotic Exposures/Risks

One Health:
Recognition of the Importance of Zoonotic Diseases as Human Health Threats

pandemic (avian) influenza	HIV	West Nile virus	MERS- CoV
			
			
Ebola virus	bush meat food chain	Zika virus	what's out there?

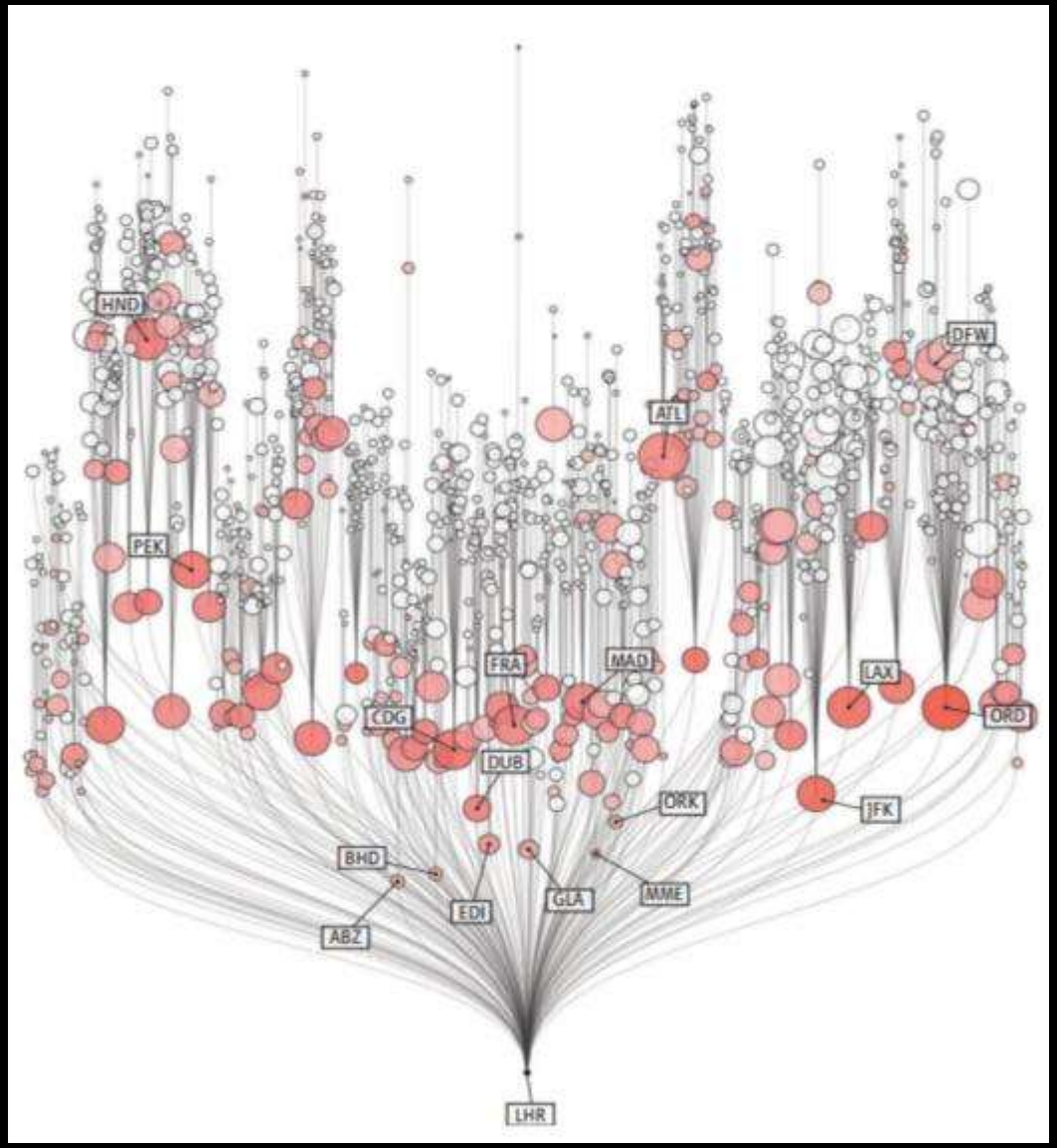
Geodemographic Information Systems (GIS): Ground Zero Data

Comprehensive Front Line Sampling of Sentinel Species

Real-time Intelligence and Faster Preparedness

Mobile Devices, Disease Tracking, Contact-Tracing and Education

Coming to an Airport Near You:



Modeling Airport Connectivities, Traffic and Distance Relationships and Implications for Epidemic Spread via the Global Aviation Network

From: A. R. McLean (2013) Science 342, 1330

Global Urbanization

- 28 megacities in 2016
- 70% current/projected megacities in countries with Global Conflict Risk Index probability of conflict within 10 years
- unprecedented stresses on infrastructure and services by 2030
  - food (35%↑), water (40%↑), energy (50%↑)
- susceptibility to extreme weather/natural disaster
  - littoral locations, slums

ASU DECISIVE Project: Institute for Humanitarian Support

DEPLOYABLE CITIES

wellington.reiter@asu.edu

There are presently 60 million global refugees, many in difficult arid conditions with limited resources. The encampments to which they are confined frequently become unintended long-term communities. The **Deployable Cities** initiative responds to this dire situation by creating the premier center for the design and delivery of empowering environments for this deserving population. The proposed facility, located on the Polytechnic Campus of ASU, will bring together the following: 1) the research/academic assets of the university, 2) a full capacity airport, 3) a research park for corporate partners, 4) a digital platform for distance education delivery, and 5) a selected group of supporting organizations/foundations. The essential element of the proposal is the focus on capacity building for the ten of thousands of trainees, fellows, and leaders who will gain skills under simulated conditions comparable to those in the field. This experience will be supplemented by state-of-the-art labs, classrooms, conference facilities, and housing designed to accommodate an on-site population of 5000.

Ethiopia

ASU DEPLOYABLE SYSTEMS

- **WATER PRODUCTION** — Zero Mass Water
- **ENERGY PRODUCTION** — LightWorks/solar/microgrids
- **FOOD SYSTEMS** — TBD-ASU + partners
- **HEALTH SUPPORT** — TBD- ASU + partners
- **DISTRIBUTED EDUCATION** — EdPlus
- **DEPLOYABLE STRUCTURES** — Fulton/Del Webb/prototyping
- **PROVISIONAL "CITY" DESIGN** — ASU + multinational design firms

objective: global capacity exchange

CAMP PROTOTYPING

1000 person working encampment
full-scale, on site situation modeling
equipment technology proving ground
cargo loading/deployment/set up
global event space, conferences
housing, clinic, school, agriculture
communications/digital networks

test bed

CAPACITY BUILDING

4000 person training center
air travel/fellowships/expenses
culture exchange/language skills
multicultural governance
camp design institute

logistics

$

$

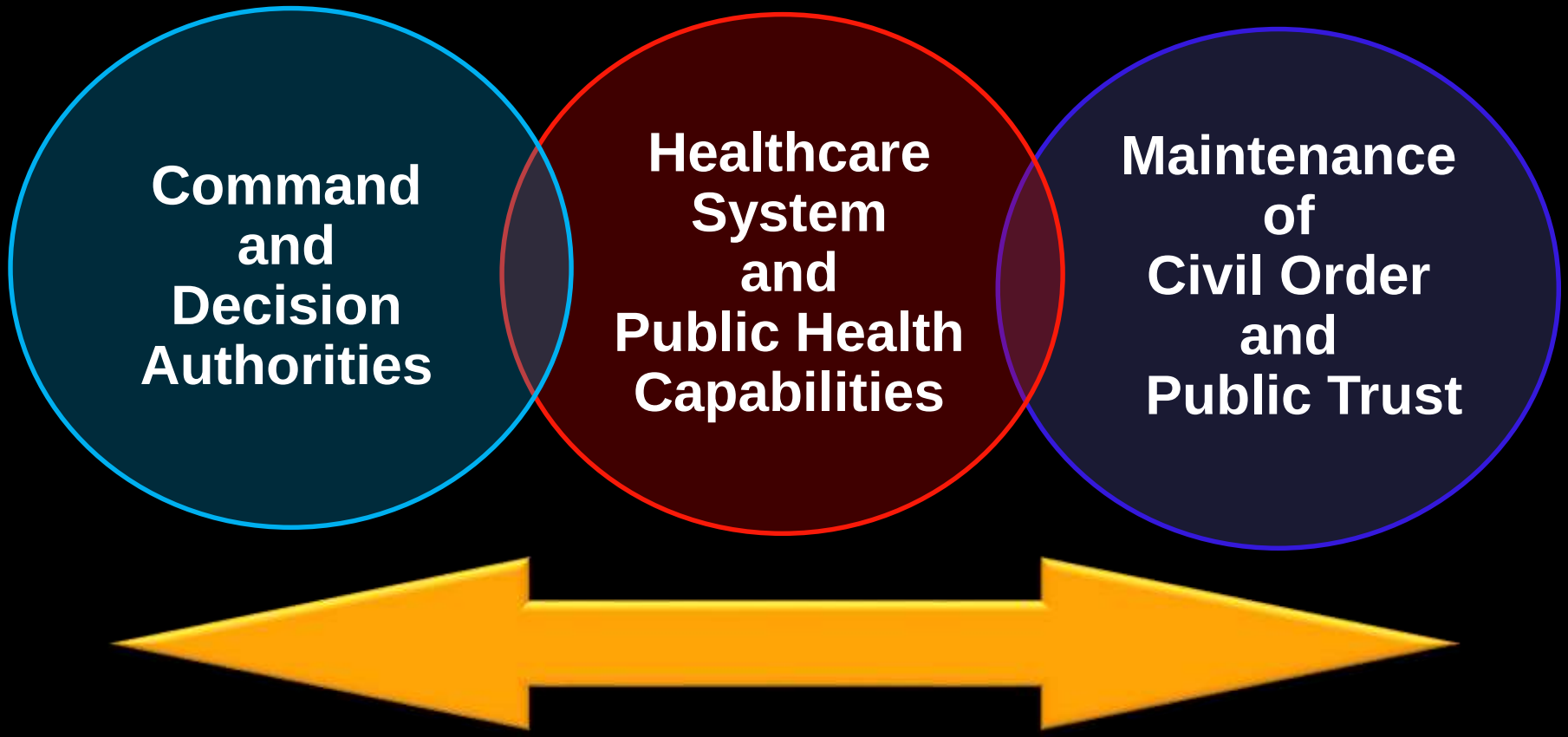
SUPPORTING GOV./NGO'S

- UNHCR
- UNICEF
- CARE
- World Bank
- Int. Org. for Migration
- Doctors w/o Borders
- World Vision
- Mercy Corps
- Gates Foundation
- OCHA
- OFDA
- USCR
- USAID
- DHS
- industry
- corporations
- etc

UNIVERSITY AND REGIONAL ASSETS TO BE DIRECTED TOWARD PROJECT

FULTON SCHOOL	GIOS/ WALTON	GATEWAY AIRPORT	RESEARCH PARK	POLY CAMPUS	ED PLUS	CAREY SCHOOL	SERVICE ACADEMY	ASU GLOBAL
applied research	sustainability energy/water	FedEx	NEXUS City	applied research real estate	distance education	humanitarian logistics	integrated training	funding/ contracts

The Three Core Components of Bioincident Management



- robust inter-operable communication networks for real-time situational awareness and rapid actions
- managing the media and the ‘worried well’
- transparency, credibility and public trust

The ‘Fog of Disaster’: Crisis Standards of Care and Proliferation of Unanticipated Events and Consequences

Breakdown of Civil Order and Incident Management

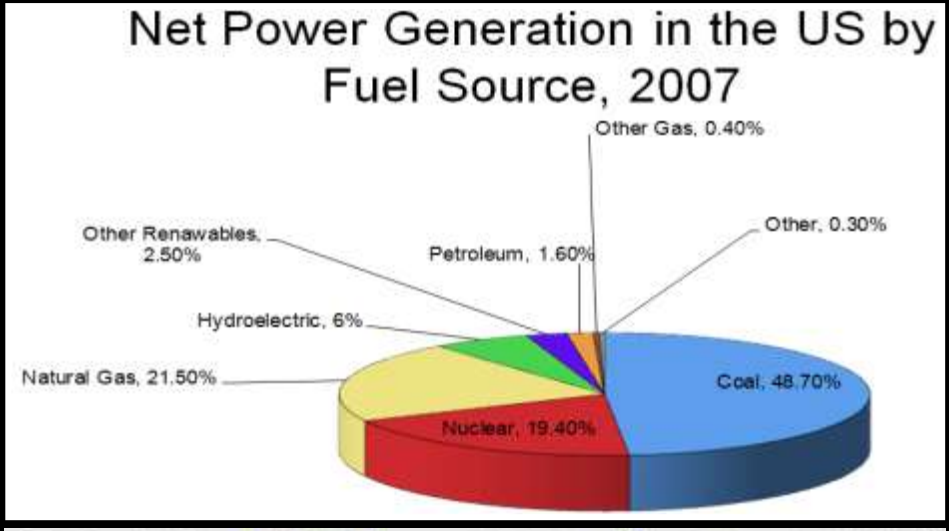
Constrained Mobility

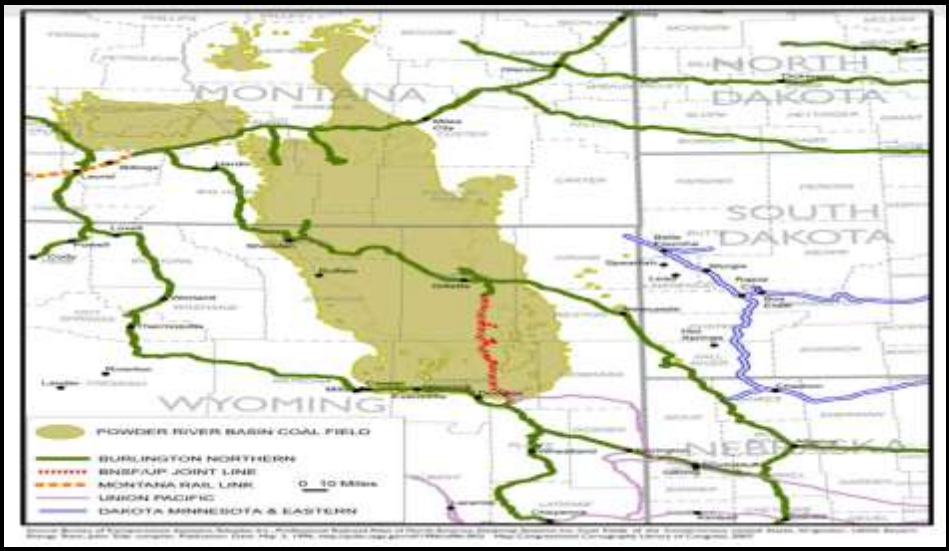
Constrained Access

Sustaining Critical Systems and Infrastructure

Vulnerability of Global, National and Local Supply Chains in a Major Epidemic/Pandemic

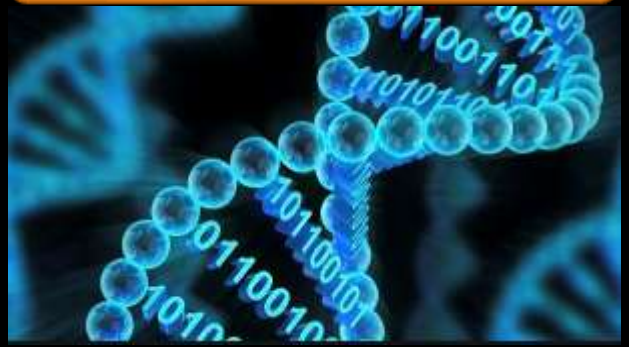
Energy





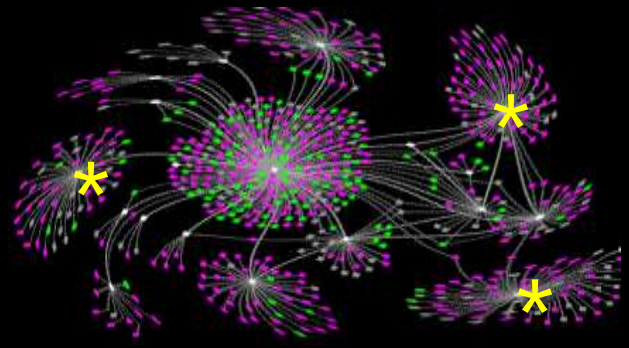
New Technologies and Increased Complexity of Dual-Use Issues in Biosecurity: Synthetic Biology, Genome Editing and Manipulation of Biological Circuits

digital biology: "it from bits"



de novo synthesis of organisms

engineered virulence



华大基因学院
BGI college
华大基因研究院
BGI research

targeted modification of any biological circuit in any

mapping neural circuitry and brain – machine interfaces

accelerating technological diffusion

Synthetic Biology, Genome Editing and National Security: The Ultimate Dual-Use Technology for Modification of Biological Systems?

Statement for the Record

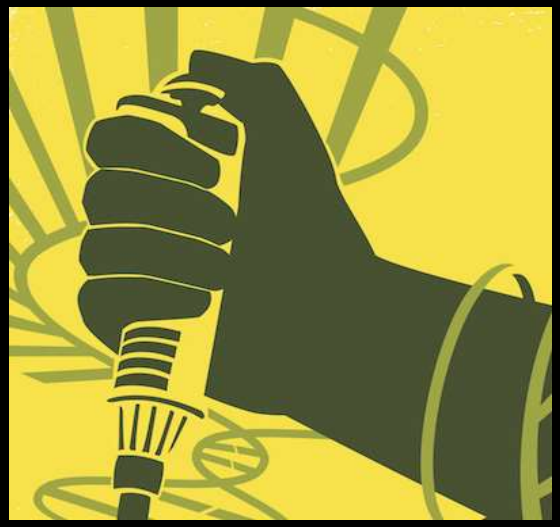
Worldwide Threat Assessment
of the
US Intelligence Community

Senate Select Committee on Intelligence

James R. Clapper

Director of National Intelligence

February 9, 2016



Technology Diffusion, Automation, Simplification and Cost Reduction

New Oversight Mechanisms and International Harmonization

Tracking Personal Behavior and Activities

Non-Consented Digital Signatures
(Trails/Exhaust/Dust)

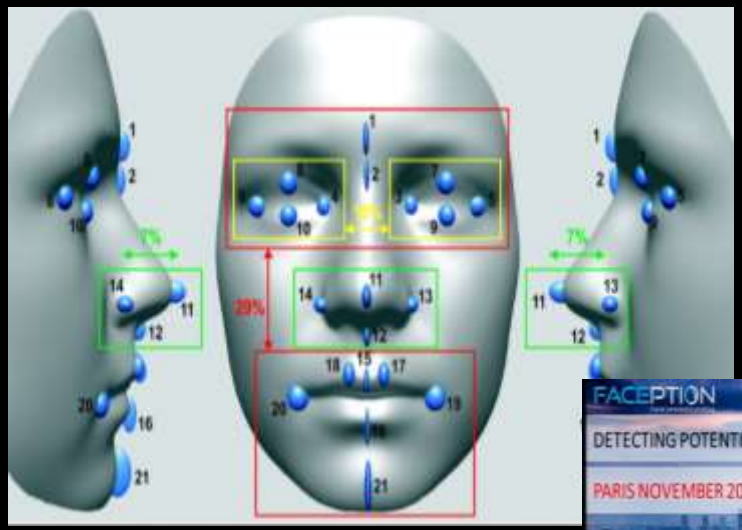
Predictive Behavioral Analytics

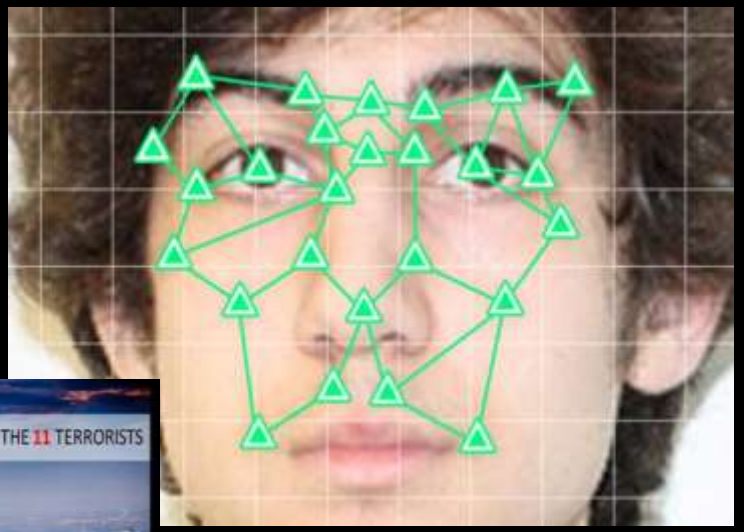
Digital Exhaust

- every move you make
- every twitter feed you update
- every facebook friend you add
- every internet search you log
- every cell phone call you transmit
- every time you use your credit card

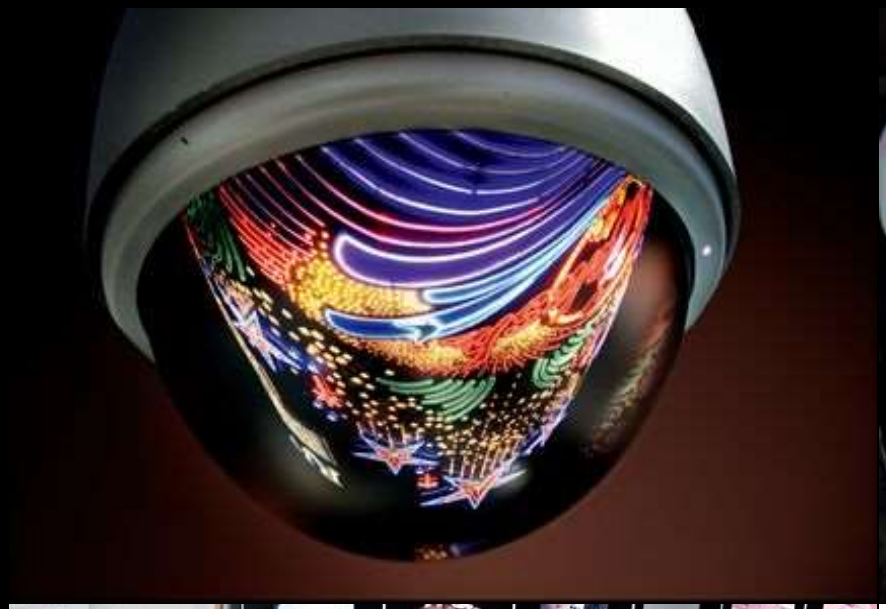
SOMETHING AND/OR SOMEONE IS TRACKING YOU

Facial Recognition and Identification of Terrorism Suspects

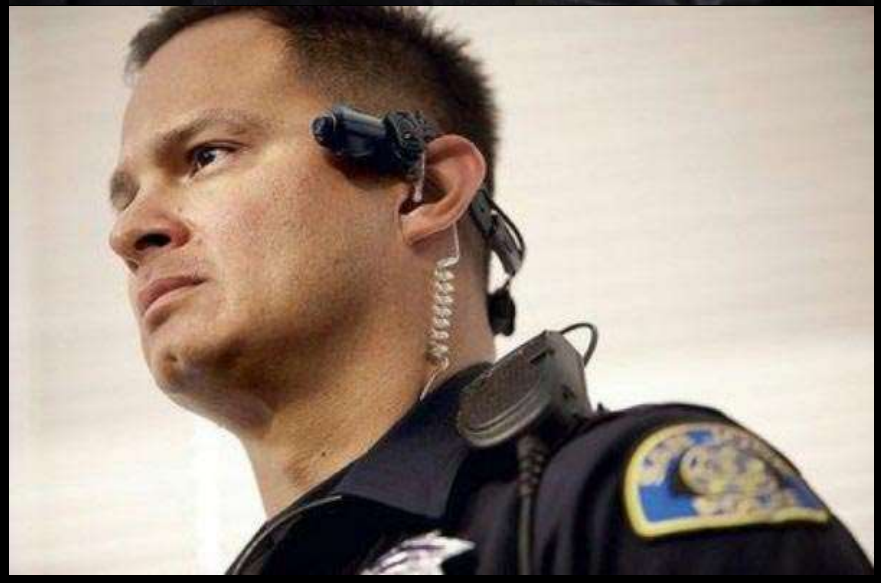




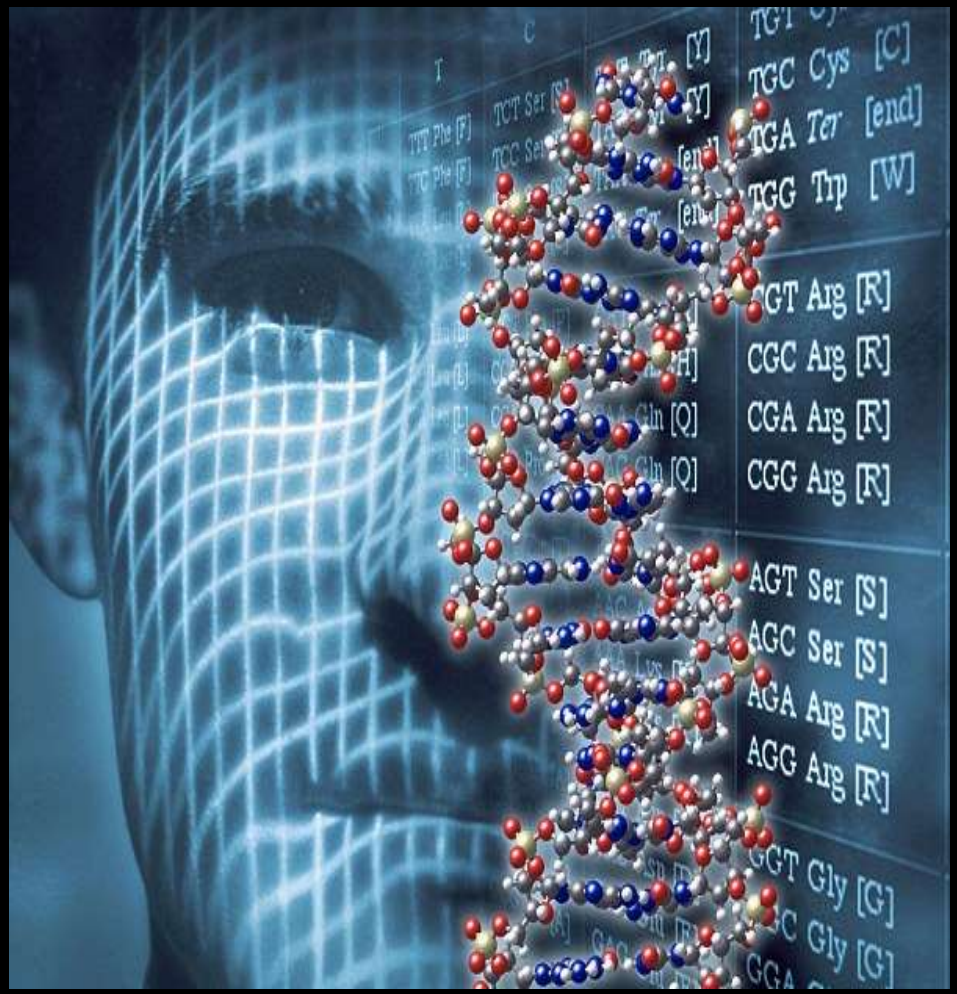
Computer-Based Facial Recognition Plus Idiosyncratic Patterns of Body Language and Movement



Evolution of Dynamic Interfaces for Computer-Based Individual Recognition and Real Time Decisions



Your Molecular Uniqueness



genome

proteome
exposome
immunosignature

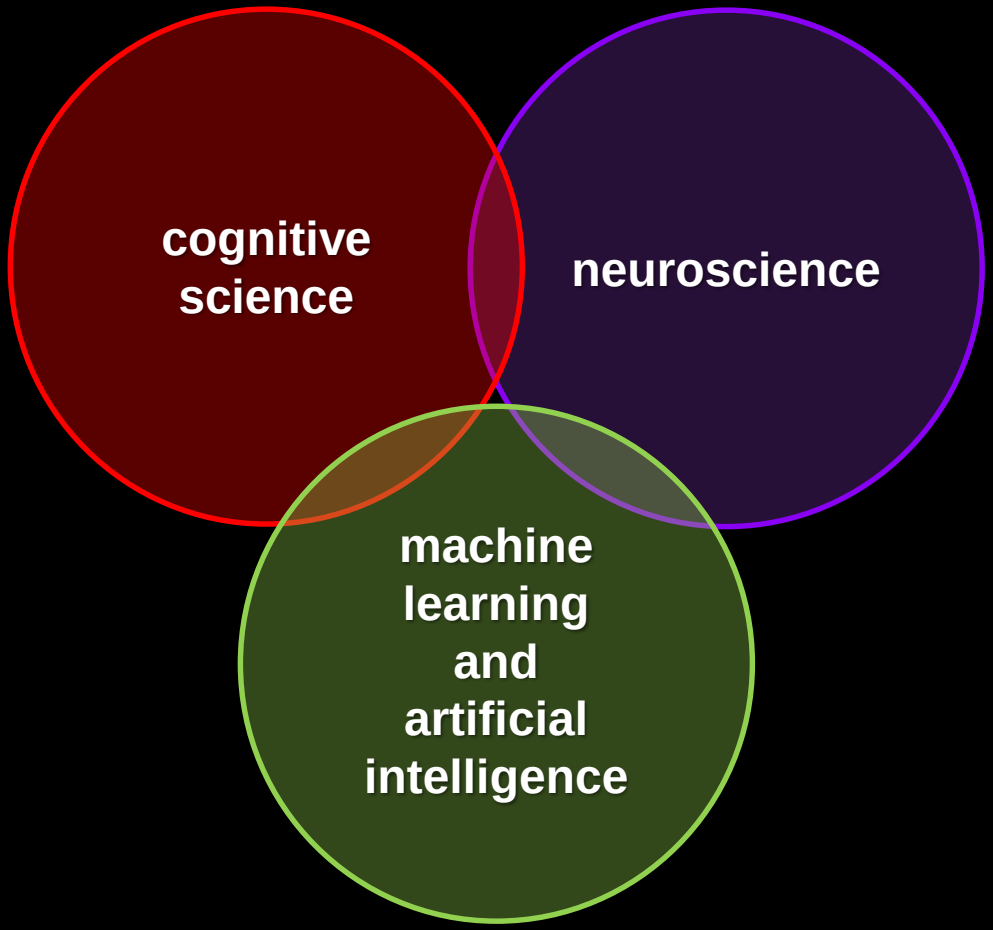
Big Data and Analytics: Integration of Diverse Data Streams for Comprehensive Real Time Situational Awareness

“Actionable Intelligence Starts at Ingestion”

The Big Data V6 Challenge:
The Pending Zettabyte-Brontobyte Worlds

- volume
- velocity
- variety
- veracity
- visualization
- value

Convergence:
Computational Rationality and Convergence of Intelligence Paradigms in Brains, Minds and Machines



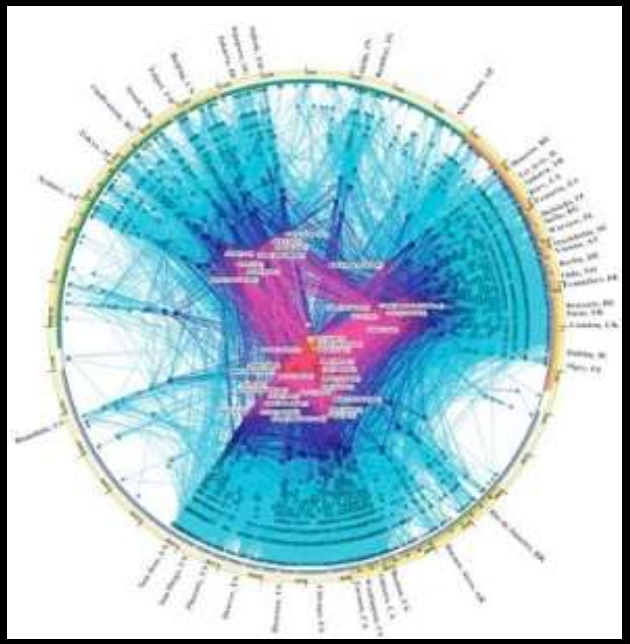
The Pending Era of Cognitive Computing and Decision-Support Systems: Overcoming the "Bandwidth" Limits of Human Individuals

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

Automated Learning Systems: The Future of 'Search' and Decision Support

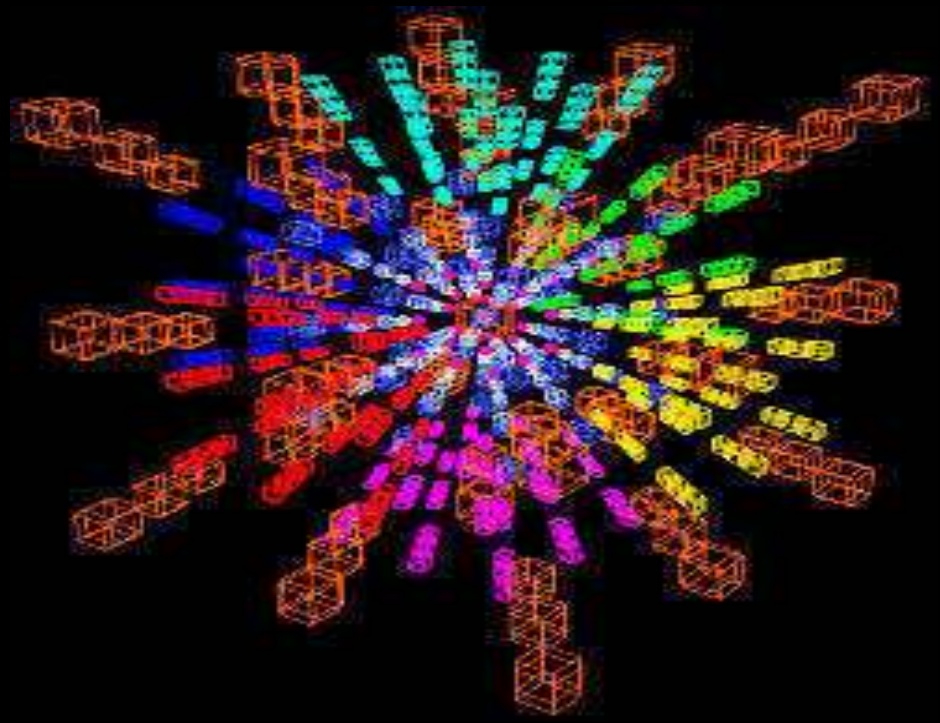
- deeper understanding of content and context structured text plus natural language processing of unstructured inputs
- search all things
  - integrated traditional document semantic sources with video, objects, speech
- why should you have to ask first?
  - smart machines and understanding where/what the user is doing
- why wait for the slow brain to catch up to the fast machine (S. Redmore, Lexalytics)

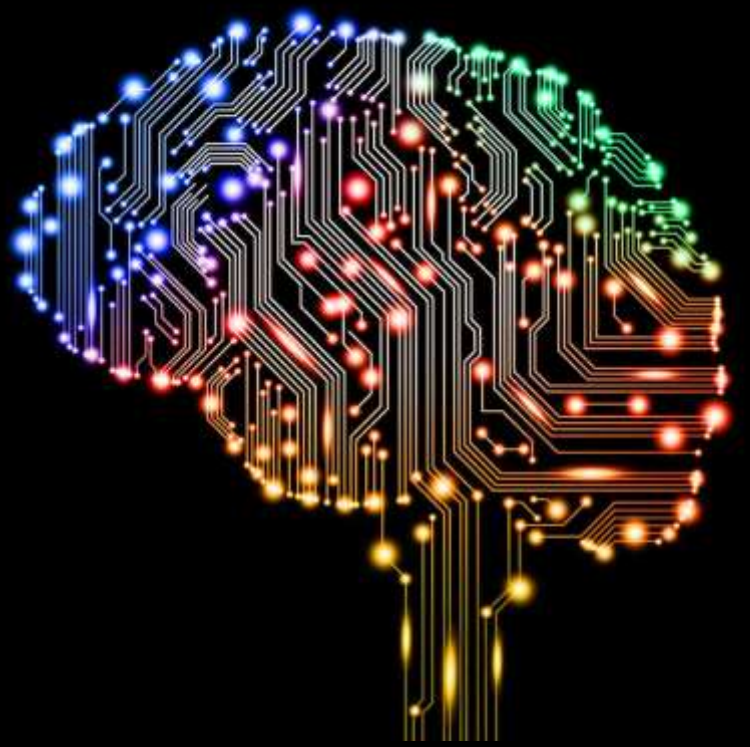
The Emergence of Big Data Changes the Questions That Can Be Asked



Isolated Data	Complex Networked Data	Complex Computational Data

Automated Context: Data Finding Data
"Intelligence at Ingestion"





Feature Extraction and Classification

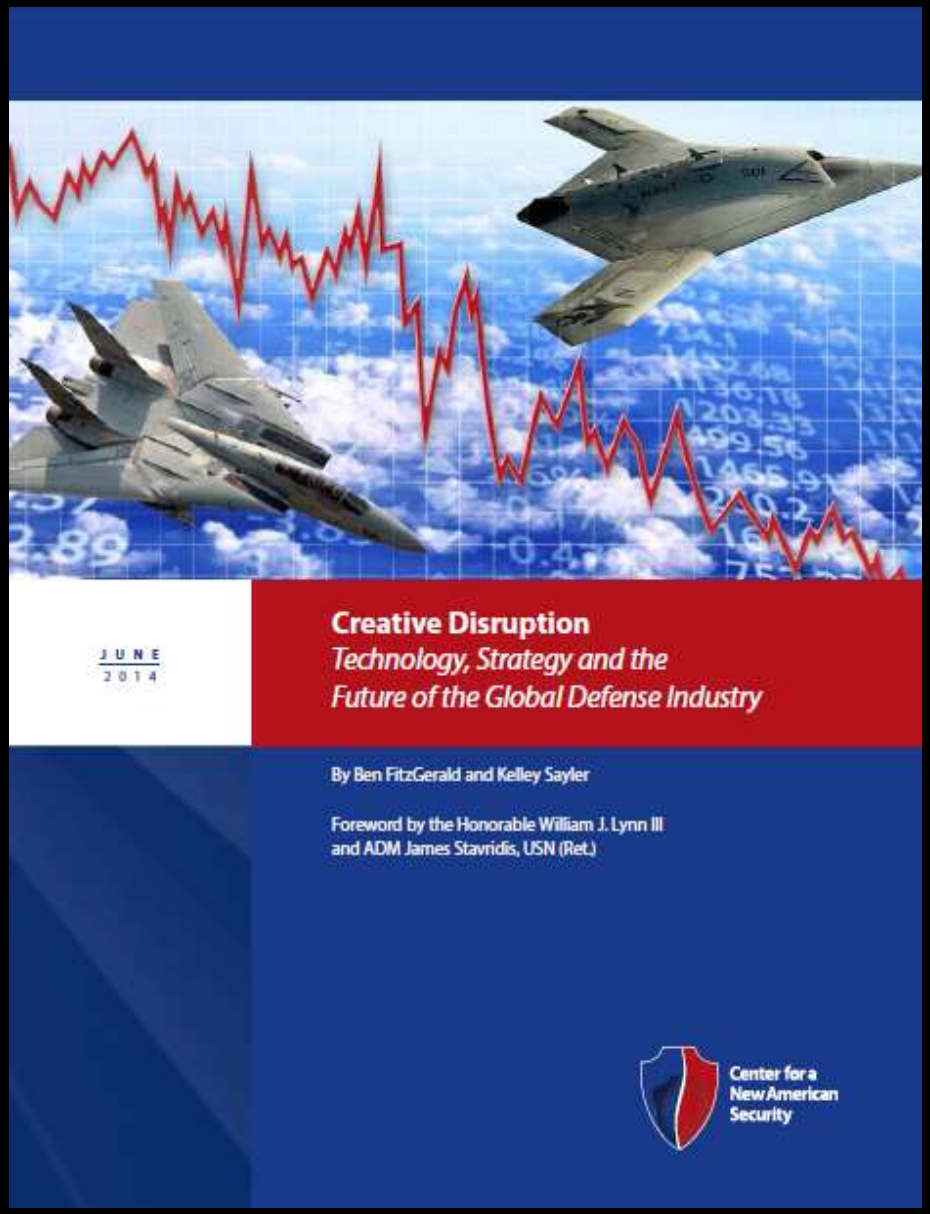
Context Analysis

Persistent Context

- **Relevance Detection**
- **Learning Systems**

- **Situational Awareness**
- **Rapid, Robust Decisions**

The Evolution of Automated Combat Systems

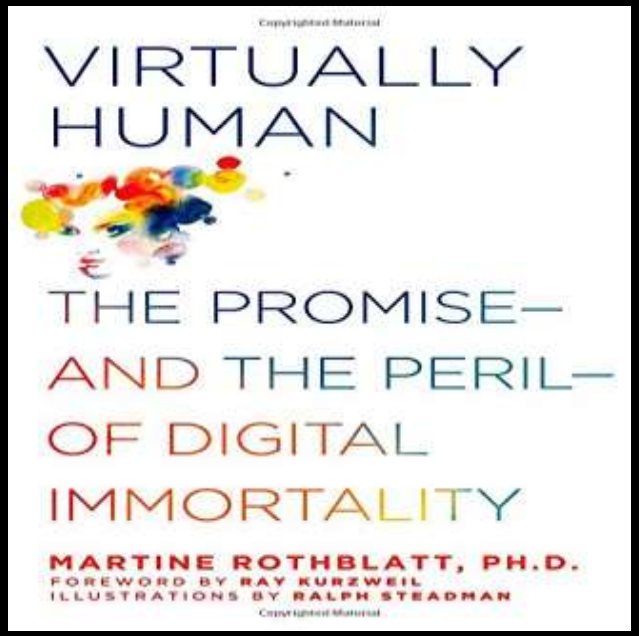


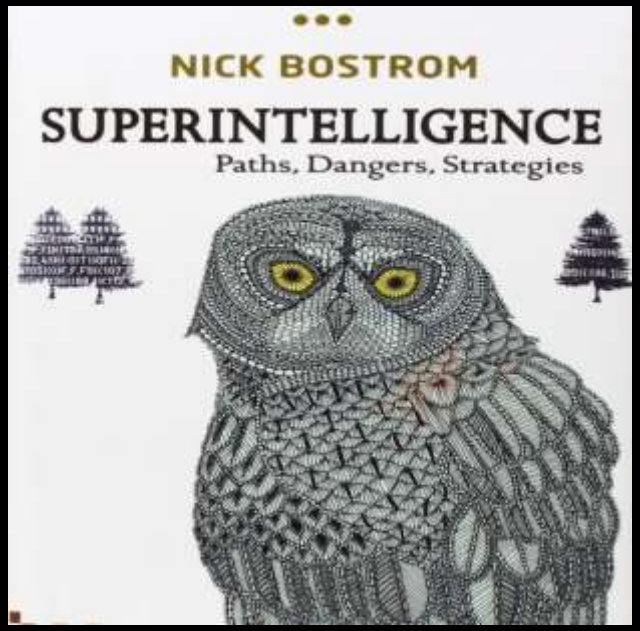
Deep Learning, Smart Machines, Artificial Intelligence and Decision Support Systems

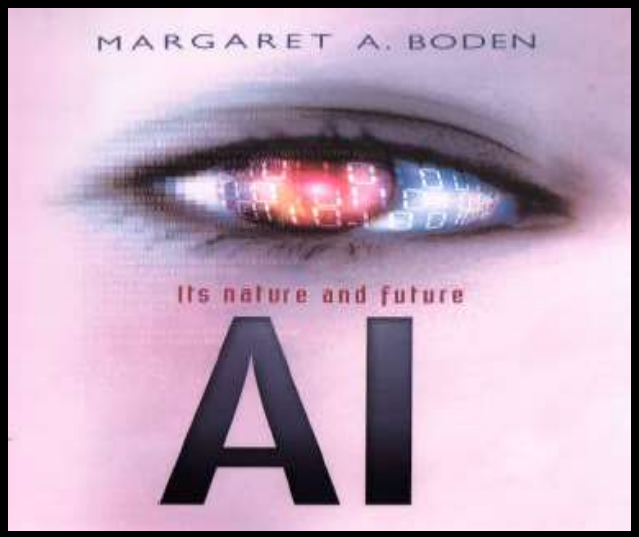
“I Can’t Let You Do That Dave”

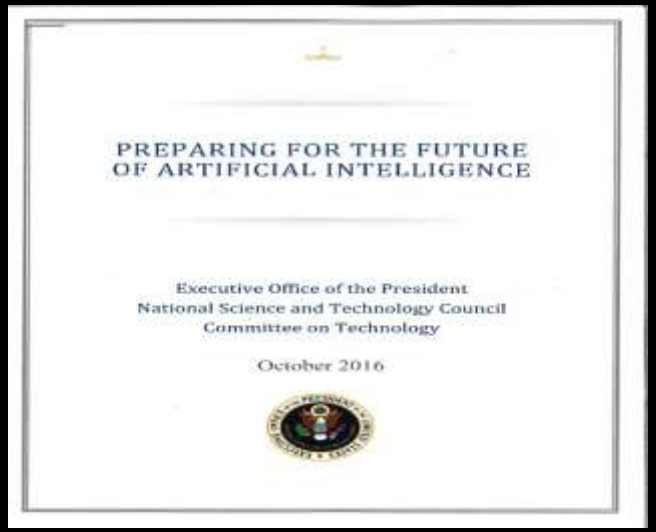
Automated Decision Support Tools and “Gated Autonomy” in the Management of Complex Systems

Deep Learning, Smart Machines and Ethical, Legal and Socio-Cultural Complexities

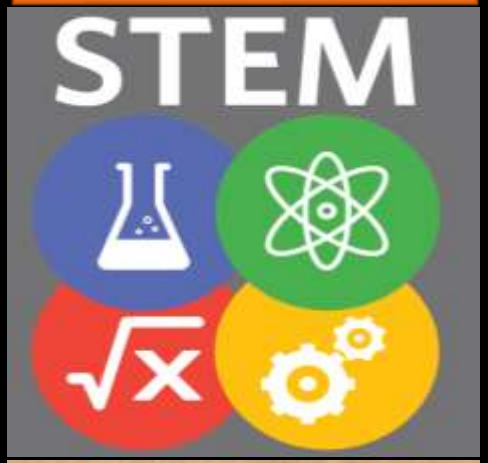
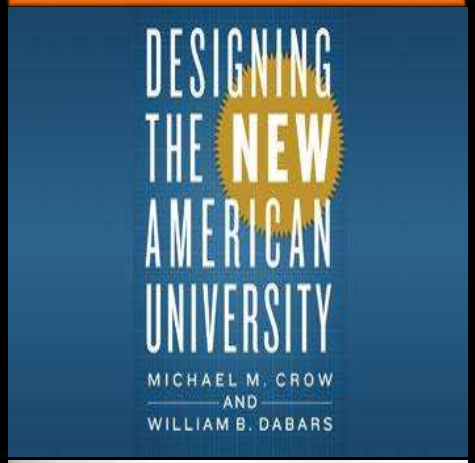
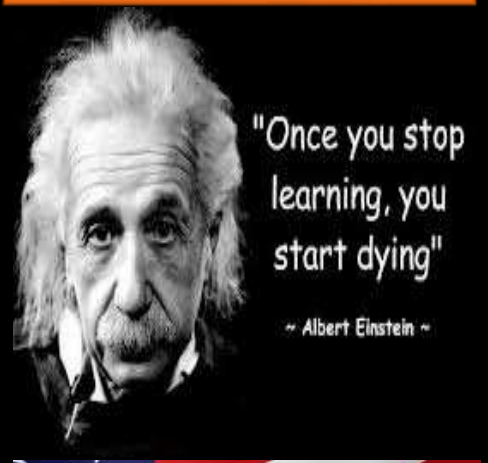
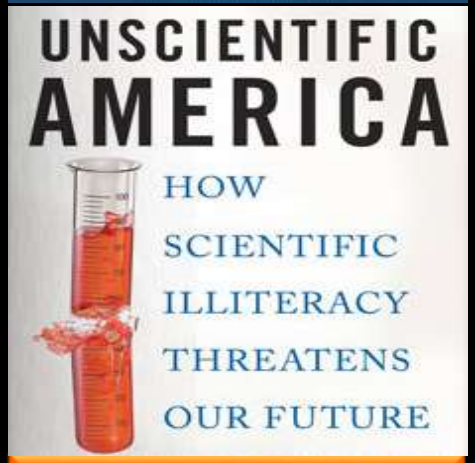








Security: The Education and Training of the Future Workforce

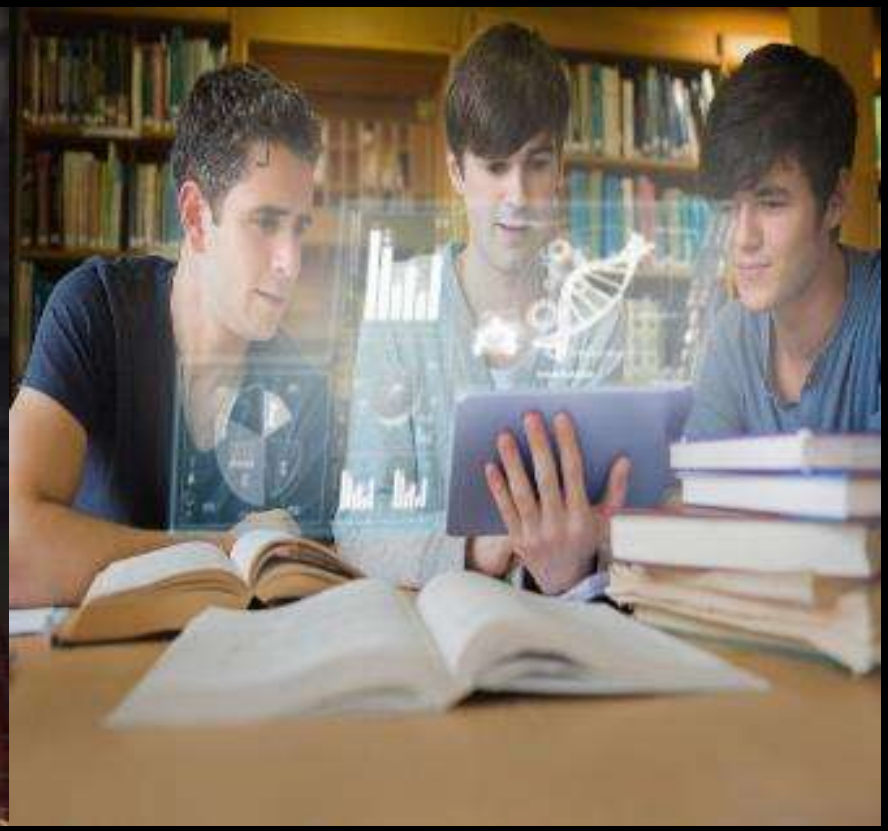
Low US - STEM Education Rankings	K-12 Education	Higher Education	Life-Long Learning
			
			
Media Sensationalism	**Reactive Policies and Political Populism**	**Public Literacy**	**Immigration Policy for Skilled Workers**

Major Opportunities (and Needs) in Education and Training in Complexity Science, Computing and Decision Science

- on-line interactive learning
- web-based collaboration tools
- multi-institutional education and training
- externships, public: private partnerships for future workforce preparation

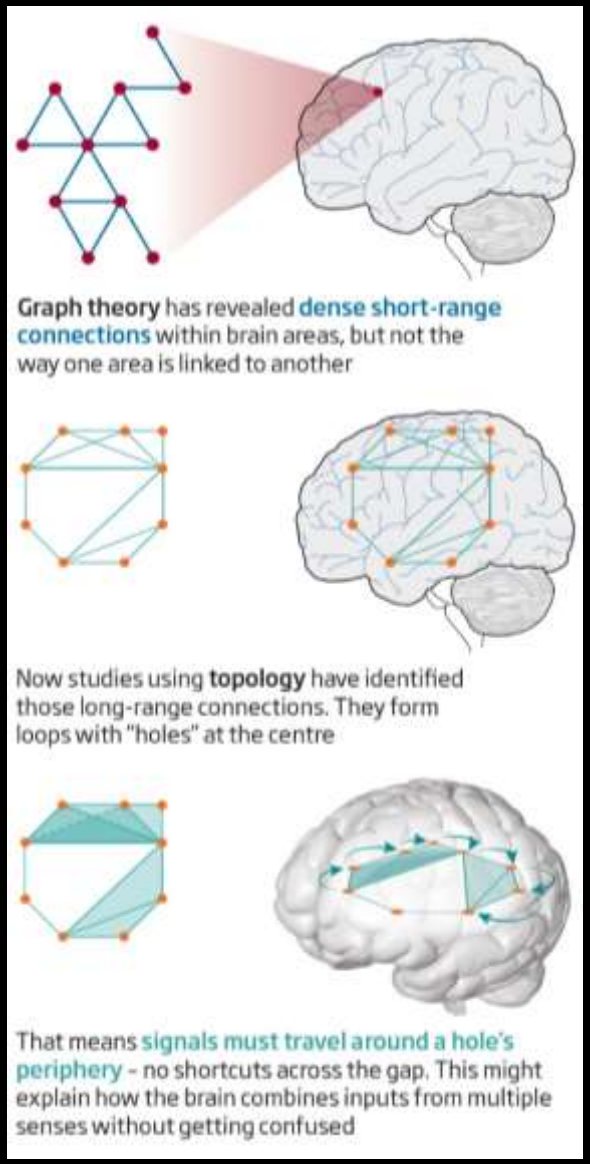
Virtual and Augmented Realities and Training for Complex, Dynamic Tasks

Advances in Cognitive Neurosciences and New Patterns of Cognitive Processing



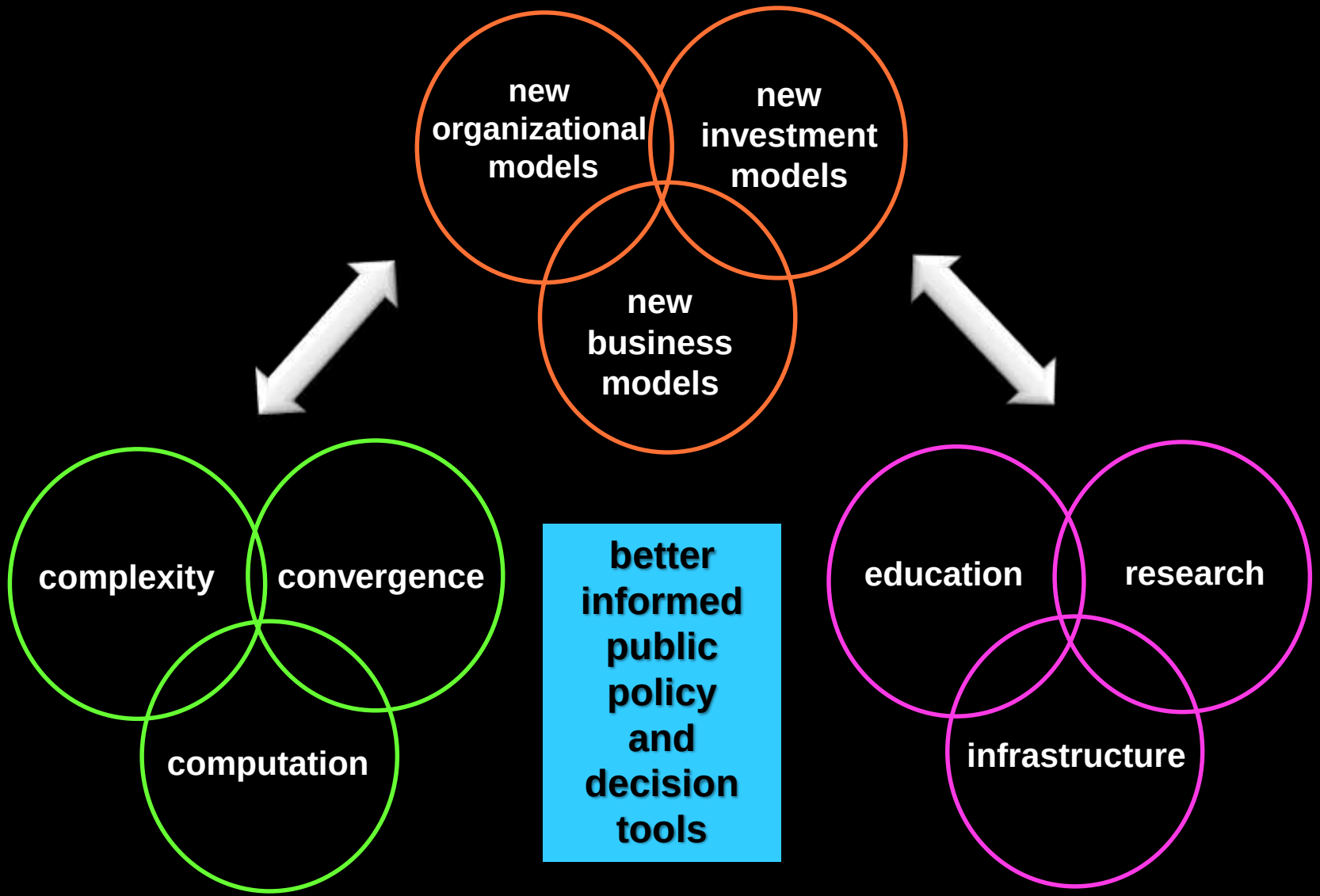
- optimize information representation (perception)
- neuroplasticity and selection of new cognitive mechanisms
- modulation of brain function to optimize comprehension

Mapping the Connectome: Deconvolution of Signal Flow in the CNS



From: C. Williams(2017) New Sci. March 25

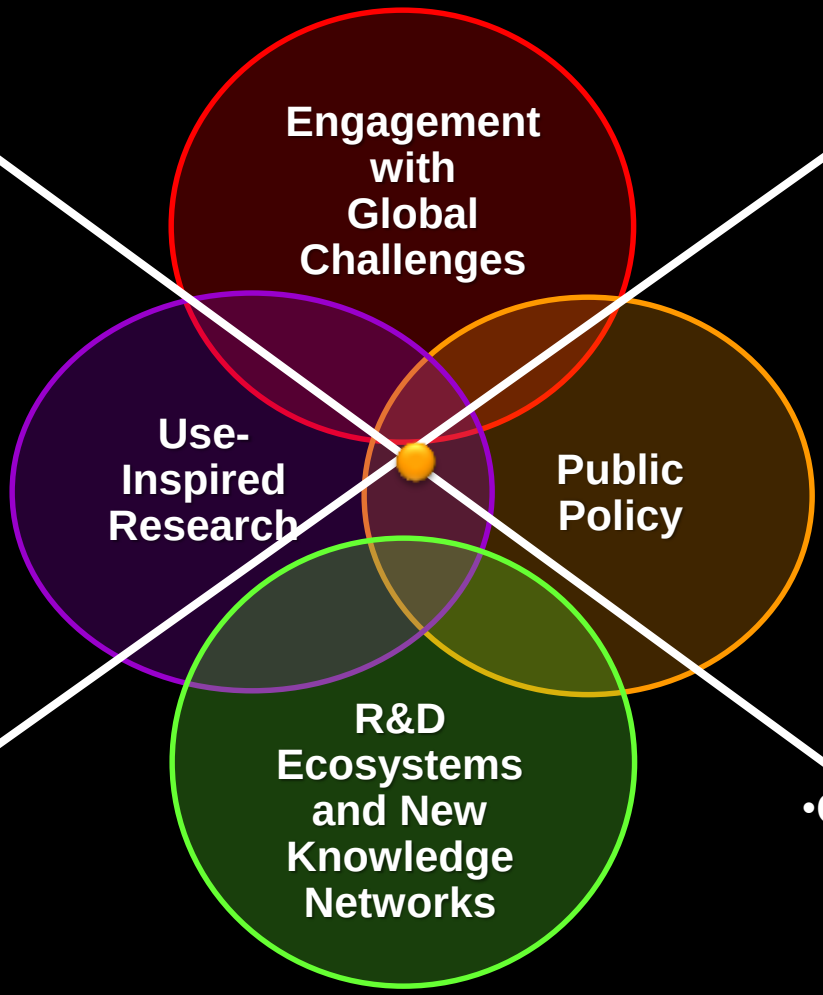
New Knowledge Networks for the Study of Complex Adaptive Systems



Systems of Innovation:
Building a Competitive Knowledge Enterprise

- human and knowledge capital
- entrepreneurial translation
- future workforce education

- social systems
- informed decisions for public policy



• CAS as integration theme
  – concepts
  – organization
  – operations
  – education
  – funding

•CAS ubiquity
- Intellectual fusion
- emergent disruptive technologies
- big data: machine intelligence

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