Biosecurity:
Enhancing Security in an Increasingly Unsecure World

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

Guest Lecture
Biology and Society Bio 311/HPS 340; Fall 2012
4 October 2012
Slides available @ http://casi.asu.edu/
Biosecurity

- **biodefense**
  - combating malevolent biological assault from terrorists/nation states
  - not just humans as targets (animals, food supply)
  - not just bugs (dual-use biology and disruption of key body biological pathways)

- **public health**
  - combating naturally occurring biological threats

- **dual-use technologies**
  - scientific methods and knowledge which can be used for both beneficent and malevolent purposes
Biosecurity

- collective term embracing biodefense, public health and dual-use technologies
- fundamental component in national security
- understanding how changes in biological systems threaten health and societal stability
  - directly and indirectly
  - infectious disease, food production, climate change
  - disruption of transportation and supply chains, economic loss and risk of civil disorder
- chronic social and economic instabilities as triggers of political turmoil and military conflict
Global Health: Understanding the Implications of Major Economic and Environmental Dislocations
Biosecurity

- identification of the threat spectrum (awareness, intelligence)
  - static, dynamic, overt or covert
  - natural or anthropogenic
- adequacy of detection, pre-emption, preparedness, recovery and attribution capabilities (resiliency)
- risk assessment and needed level of investment in protection and preparedness (public policy)
- who pays for preparedness? (public policy, market dynamics)
- who is responsible/accountable for biosecurity? (public policy, organization, politics, media responses)
- myriad ethical and legal issues (surveillance, civil liberties, rationing, counter-terrorism targets, publication of dual-use knowledge)
A Dangerous Void in Seeking Answers to Big Questions and Solutions to Global Challenges
Preparedness: Building Resilient Systems and The “All Hazards” Challenge
The ‘Fog of Disaster’: Crisis Standards of Care and Proliferation of Unanticipated Events and Consequences
Infectious Disease: A Powerful Force in Human Evolution
Terrorism and The New Calculus of National Security and Foreign Affairs
“We believe the 9/11 attacks revealed four kinds of failures; in imagination, policy, capabilities and management.”

9/11 Commission Report 2004
New Polarities and Asymmetries

- nation state adversaries
- geographically constrained adversaries
- dominant concept of national identity
- formal, national governing structures for diplomacy
- western social democratic ideologies and international legal codes of conduct
- non-state actors
- new group identities via internet virtualscapes
- virtual Jihadist movement/caliphate
- autonomous cells and global terror networks
- theocratic fundamentalism
- ‘no limits’: ‘duty to kill’
New Polarities and Asymmetries

- massive cost of defense against expanding threat spectrum/sources
- increasing fraction of scientific discovery with dual-use potential
- disruptive technologies
- low cost offensive advantage to adversaries
- threat proliferation and diversification
- rapid technology diffusion
- synthetic biology, cyberspace and outer space as new strategic vectors of radical change
  - industrial competitiveness
  - national security
How do you stay one step ahead of the nation's threats when they're always moving in new directions?
Building Resilient and Agile Systems for Biosecurity

- Bioterrorism
- Infectious Diseases of Natural Origin
- Environmental and Ecological Impacts on Disease Emergence
1407 species of human pathogens

- 538 bacteria
- 208 viruses
- 317 fungi
- 57 protozoa
- 287 helminths
- 60% are zoonoses
- over 70% zoonoses arise from interactions with wildlife
- Emerging Infectious Diseases (EIDs)
  - 58 in last 25 years
  - viruses significantly over-represented
  - helminths under-represented
The Global Public Health Challenge Posed by Rapid Urbanization in Developing Countries

- High Disease Transmission
- Expanded Eco-niches and Increased Zoonotic EID Risks
- Major Deficits in Health Infrastructure
- Lack of Safe Water
- Toxic Waste
“I will show you fear in a handful of dust”
T.S. Elliot

09-11-01
This is next.
Take Penicillin now.
Death to America.
Death to Israel.
Allah is great.
Bruce Ivins, the Anthrax Attacks, and America's Rush to War

The Mirage Man

David Willman

Winner of the Pulitzer Prize

American Anthrax

Jeanne Guillemin

Fear, Crime, and the Investigation of the Nation's Deadliest Bioterror Attack
THE SOVIET BIOLOGICAL WEAPONS PROGRAM: A HISTORY

MILTON LEITENBERG
RAYMOND A. ZILINSKAS
Delusion and Reality

“It is time to close the book in infectious diseases and declare the war against pestilence won”


“The future of humanity and microbes will likely evolve as episodes of our wits versus their genes”

Dr. Joshua Lederberg, Nobel Laureate
Science (2000) 6, 427-30
Preparedness: Building Resilient Systems

“It’s no use saying: “We’re doing our best.” You have got to succeed in doing what is necessary”
Sir Winston Churchill

“Our role is to protect against the unseen, the unexpected and the unknown”

“It’s not what you don’t know that can hurt you. It’s what you can’t find”

Donald Rumsfeld
US Secretary of Defense
Preparedness: Building Resilient Systems

- is the problem defined?
- are there actions for meaningful intervention?
  - tractable, measurable
- if not, how can these be developed and implemented (resources, infrastructure, logistics cost)?
- what are the principal risks and obstacles to success? (technical, economic, political, social, legal)
- how are these barriers being addressed and, if not, what is needed to reduce/eliminate them? (vulnerability assessment)
Preparedness: Building Resilient Systems

- Are the necessary resources available: financial, personnel, skills, infrastructure?
- Have all elements been tested under simulated emergency situations?
- Are organizational structures and processes sufficiently agile for rapid response?
- Are roles, responsibilities and accountabilities defined and understood for every constituency involved?
  - From local to global
The Three Core Components of Bioincident Management

- Command and Decision Authorities
- Healthcare System and Public Health Capabilities
- Maintenance of Civil Order and Public Trust

• 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 Imperative for Integrated CB Defense Capabilities

CB Threats & Hazards
- Agent Delivery
- Doses on Target
- Downwind Dispersal
- Doses Absorbed
- Symptoms

Medical Pretreatment

Individual & Collective Protection

Installation Force Protection

Contamination Avoidance and NBC Battle Management (Detection, Identification, Reconnaissance & Warning)

Medical Treatment

Information Systems

Decontamination, Restoration

Sustained Combat Power
National Biomonitoring Notification Architecture

CIVILIAN

Biowatch

DEPARTMENT OF DEFENSE (DoD)

Installation Protection

Coordinated Data: Positive Detections

Interagency National Operations Center

Networked Information: Verified Notifications
Speed Matters!
Delayed Detection Kills Lives

- Global surveillance against infectious disease outbreaks
  - E.H. Chen et. al. (2010) PNAS 107, 21701
- 398 WHO-verified outbreaks 1996-2009
- Median times
  - 23 days for event detection
  - 32 days for public communication
  - 35 days for official laboratory confirmation
  - 48 days for inclusion in WHO Disease Outbreak News
No Ambiguity - No Error: No Problem!
The Omnipresent Dilemma of Uncertainty When Political Leaders Want Certainty

“Insufficient data, Captain”

“Insufficient data is not sufficient, Mr. Spock. You’re the Science Officer. You’re supposed to have sufficient data all the time”

Star Trek
The Immunity Syndrome
Detection of Infectious Disease Threats:

Not A Hazmat or Wide Area Sensor Network Solution

Emergency Rooms and Farms Will be the Front Line
Surveillance Systems for the Rapid Detection and Control of Infectious and Parasitic Diseases

- Signatures of Pathogenic Organisms
- Global Network of Surveillance and Diagnostic Testing Systems
- Rapid Analysis and Response to Diagnostic and Surveillance Information

Profile | Sense | Act
--- | --- | ---
![Profile] | ![Sense] | ![Act]
The Ever Shifting Dimension of EIDs

West Nile Virus, New York 2001

Monkeypox, USA May-June 2003

West Nile Virus, Dallas, TX 2012

African Swine Fever, Russia 2012
Emerging Infectious Diseases (EIDs)
The Rationale for Integration of Historically Separate Domains and Responsibilities

The most effective control route for zoonotic threats to humans is via the relevant animal population(s).

Knowledge of the potential impact of ecosystem perturbations on emergence of novel zoonoses must be accorded high priority.

Disparity in animal and human public health capacity undermines global disease control.

“One Health”
Global Transport and Trade: New Interactions of People, Animals and Product Supply Chains

The Super Vector

World Container Traffic Doubled Since 1997

Billion Cross-Border Travelers

Global Food Networks
Geodemographic Information Systems (GIS): Real-Time, Front Line, Ground Zero Data from Field Sampling and Sentinels
Maintaining Global Preparedness for a High Virulence Pandemic

- H1N1: high transmissibility - low virulence/mortality
- H5N1: low transmissibility – high virulence/mortality
- H5N1 x (H1N1) or (X): potential for devastating pandemic
Sensor Networks for Remote Health Status Monitoring: Wireless Integrated Data Systems

- geolocation data (where)
- temporal information (when)
- contextual information (what)
- improved decision support (action)
Geodemographic Information Systems: Mapping Disease Patterns and Modeling Trends

Anomaly Detection and Early Alert

Disease Progression

Satellite Surveillance and Predictive Modeling of Disease Trends
Building Resilience: Complex Systems-Based Integration of Diverse Functions and Organization
Modeling the Exposure Zone Geography (NCB) and Contagion (B)
The Lag Phase in Bioincident Detection

Primary Care Physicians and Pharmacists → initial non-specific illness → Hospitals → unusual illness patterns → BIOINCIDENT CONFIRMATION
Location, Location, Location
Consequence and Crisis Control in a Bioincident

COMMAND CENTER

- public health
- logistics
- communications

- medical
- law
- coordination

- local
- national
- international

- regional

Primary Care Physicians and Pharmacists

“The Worried Well”

Hospitals

- acute care
- triage
- mortuary

Neighborhood Emergency Help Centers

- patient registration
- Dx triage
- transport logistics
- mass Rx/vaccination

Media

Community Outreach and Citizen Mobilization

- police, EMS
- volunteers
- military
Use of GIS for Management of Population Movement, Healthcare Facilities and Supply Chains for Optimum Bioincident Control
Distribution of Medical Emergency Supplies for a Major Epidemic/Pandemic

- pre-positioning for known threats: The Strategic National Stockpile
- rapid movement by commercial carriers
- managing political/public/media responses for bioincidents with limited or no Rx/vaccine options
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
- out-patient prescription drugs
  - insurance company limits on prescription volume (USA)
- 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
Medical Countermeasures (MCMs) for Special Populations: Emergency Use Authorization

<table>
<thead>
<tr>
<th>Children</th>
<th>Pregnant</th>
<th>Aged?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immunosuppressed</td>
<td>Impaired Major Organ Function</td>
<td>ICU-Critical Care</td>
</tr>
</tbody>
</table>

- Children
- Pregnant
- Aged?
- Immunosuppressed
- Impaired Major Organ Function
- ICU-Critical Care
Control of Population Movement and Supply Chain Networks
Vulnerability of Global, National and Local Supply Chains in a Major Epidemic/Pandemic

Energy

Net Power Generation in the US by Fuel Source, 2007

- Coal, 48.70%
- Nuclear, 19.40%
- Natural Gas, 21.50%
- Hydroelectric, 6%
- Other Renewables, 2.50%
- Other Gas, 0.40%
- Other, 0.30%
- Petroleum, 1.60%

- 48.70% Coal
- 19.40% Nuclear
- 21.50% Natural Gas
- 6% Hydroelectric
- 2.50% Other Renewables
- 0.40% Other Gas
- 0.30% Other
- 1.60% Petroleum

Energy Generation Map of the United States
The first question President Obama received during his press conference on April 29, 2009 was: “Why aren’t you closing the Mexico-US border to prevent the entry of swine flu?”
Informing the Public: A Critical and Unenviable Challenge

● media sensationalism and public panic
● pressure on governments to make illogical but politically expedient decisions
● in a severe outbreak the shock factor from level of fatalities will be unprecedented in modern peace times with unpredictable consequences
● unpredictable unilateral decisions by other governments, restricting trade, travel and shipment of goods
● extended supply chains might break down completely
The Crucial Role of the Media in Incident Management

- Pre-recorded Modules
- Familiar (Trusted?) Face(s)
- Credibility and Reality
- Setting Examples to Limit Civil Disorder
- Authoritative Leadership
- Community Cooperation
International Response, Coordination and Containment of Global Incidents

- international Health Regulations and timely alerting
  - incentives not penalties
- epicenter “cordon sanitaire” and quarantine
  - prudent resource deployment
- national sovereignty
  - decisions
  - samples
  - treatment
- priorities for rationed distribution of treatments
  - producer nations vs. epicenter vs. DCs
- lack of harmonized international response policies
Comfort, Complacency and Commitment

“But I must go and meet the danger there, or it will seek me in another place, and find me worse provided.”

- William Shakespeare, Henry IV
..... and then a technical miracle cure occurs with dramatic rapidity
..... and always created by an individual scientific genius
Bad Bugs and Few New Drugs
OUTBREAK: Deadliest Pandemics in History

Because a virus doesn’t care about state lines or national borders, it can wipe out millions and span multiple continents rapidly. Here is a look at the infectious diseases the world has battled throughout history.

**What is a Pandemic?**
Derived from the Greek word pandemos meaning “pertaining to all people,” a pandemic is a widespread disease that affects humans over a wide geographic area.

**Key:**
- **Pandemic:** 1918
- **Death Toll:** 25 million

**HIV/AIDS**
- **25+ million**
- 1983 - Today

**Plague of Justinian**
- **25 million**
- 541 - 750

**Smallpox**
- **300+ million**
- 15,000 BC - 1799

**Spanish Flu**
- **50-100 million**
- 1918 - 1919

**Third Pandemic**
- **12 million**
- 1855

**Black Death**
- **75 million**
- 1340 - 1371

**Measles**
- **200 million**
- 7th Century BC - 1963

**Tuberculosis**
- **700 BC - Today**

**Typhus**
- **4 million**
- 430 BC - Today

**Cholera**
- **3 million**
- 1857 - Today

**Hong Kong Flu**
- **1 million**
- 1968 - 1969

**Third Pandemic**
- **12 million**
- 1855

**Yellow Fever**
- **16th Century - Today**

**Honorable Mentions**

Although the following viruses do not have a figure for total amount of lives claimed, they continue to terrorize various areas around the world.

**Malaria**
- **1600 - Today**

**Common Symptoms**
- Chills, Headache, Fever, Jaundice, Muscle Pain, Nausea, Vomiting, Seizures

**Death Toll**
- According to the World Health Organization’s 2000 “World Malaria Report,” an estimated 780,000 people are killed by the virus every year.

**Tuberculosis**
- **700 BC - Today**

**Common Symptoms**
- Chest Pain, Cough, Fever, Chills, Fatigue

**Death Toll**
- There are almost 2 million tuberculosis-related deaths worldwide every year.

**Yellow Fever**
- **16th Century - Today**

**Common Symptoms**
- Bleeding, Fever, Nausea, Vomiting, Delirium, Seizures, Jaundice

**Death Toll**
- Worldwide, 30,000 deaths are caused by the infection every year.

Sources:
- Mayo Clinic
- Centers for Disease Control and Prevention
- World Health Organization
- New York Times
- National Center for Biotechnology Information

A Collaboration Between Good and Column Five
Comfort and Complacency: The Enemies of Vigilance and Preparedness
“WOULD YOU LIKE THAT TO BE A STEAK WITH A BROAD-SPECTRUM ANTIBIOTIC, OR ONE WITH A VARIETY OF THERAPEUTIC PROTEINS?”
NO ESKAPE!: Resistant Bugs and Few New Drugs

- Increasing resistance in G+ and G- pathogens in hospital and community settings
- The ESKAPE pathogens
  - *Enterococcus faecium*
  - *Staphylococcus aureus*
  - *Klebsiella pneumoniae*
  - *Acinetobacter baumanii*
  - *Pseudomonas aeruginosa*
  - *Enterobacter species*
SOI H1N1 Influenza ("Hamageddon?")
“If this virus was killing more of its victims, there’d be lots of questions about whether this vaccine was produced soon enough”

Dr. Michael Osterholm
Director, CIDRAP, Univ. Minnesota
USA Today 8 Oct. 2009
Challenges in Development and Production of Pre-pandemic Influenza Vaccine

- Ultimate causative agent is not known
- Timing cannot be predicted
- 13 billion doses required
- Harmonized global policies
  - Production
  - Priorities for use
  - Rapid regulatory approval
“Millions demand it, millions refuse it, and millions don’t know what to think”

John Carroll
Editor, FierceBiotech (23 Oct. 2009)
Vaccine Safety:
Media Sensationalism and Celebrity Quackery
Mass Casualty Decontamination Challenge

How do you go from decontaminating a few ambulatory, protected responders…

…to hundreds of incapacitated, unprotected civilians?
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
Synthetic Biology:
Engineering Novel Organisms with Novel Functions

Programmable Genomes

Metabolic Engineering

A New Industrial Ecology and Novel Biosynthesis
ATTGACTGCAA .............................(design specifications)
Pandemic Avian Influenza as a Natural and/or Engineered Pathogen

From: F. Guterl. Scientific American June 2012
**Oversight of Synthetic Biology:**

**Risk, Regulation and Responsibility**

<table>
<thead>
<tr>
<th>Biosafety: Risk from Legitimate R&amp;D/Industrialization</th>
<th>Biosecurity: Deliberate Use to Cause Harm</th>
<th>Biohackers and Democratization of New Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Biohazard Symbol]</td>
<td>![Lock with Biohazard Symbol]</td>
<td>![Hand Holding a Microscope with &quot;DIY BIO&quot; Text]</td>
</tr>
</tbody>
</table>

- **Screening of Purchases/Supply Transactions**
- **Regulation, Legislation and Codes of Conduct**
- **International Harmonization**
Legal Aspects of Public Health and Counter-Terrorism Actions to Contain Bioincidents

- suspension of civil liberties
- imposition of quarantine
- triage decisions and rationing
- mandatory medical examination and treatment
- mandatory treatment with unapproved drugs and vaccines
  - informed consent
  - indemnification
  - special populations
• National Security Presidential Directive - NSPD-59/
  Homeland Security
  Presidential Directive - HSPD-24

• “Biometrics for Identification and Screening to Enhance
  National Security (5 June 2008)
The Infocosm: Emerging Networks of Global Connectivity
The Future Environment for Intelligence: A Burgeoning Infocosm and An Expanding Metaverse

- everything is a reporter
- everything goes everywhere
- everybody sees everything
- everything moves fast

- two thirds of new products now come with electronic tracking component
- maintaining more than one viable identity in the infocosm will be virtually impossible
- being off-grid will be suspicious
Shepherding the ‘FLOCK’:
Fast Local Clustering of Critical Knowledge

Senior Networks and Ambient Intelligence

Digital Anthropology

Cogint

Intelligent Machines

Massive Computing Power and Analytical Parsing
“Security is always excessive
.....until it’s not enough”
“Of course, every complex problem has an instant solution; and it’s always wrong!”

H.L. Mencken (1935)
Protecting US Infrastructure

- 87,000 communities
- 1800 federal reservoirs
- 80,000 dams
- 2800 power plants (104 nuclear)
- 5000 airports
- 120,000 miles of roads
- 590,000 bridges
- 2 million miles of pipeline
- 85% of infrastructure is privately held
Infrastructure Vulnerabilities

- 22 Kt
- 1 x 10^{14} Joules

- 20 million pounds HE
- 2.7 x 10^7 acre feet stored water
- 8.6 x 10^{15} Joules

- 3 x 10^7 acre feet stored water
- 1.2 x 10^{16} Joules

- destruction of Hoover by destruction of Glen Canyon
  - deprive 22 million people of water
  - eliminate 50% electrical power in California
  - destroy irrigation of 1.5 million acres US farmland
Cyber-Attacks and Vulnerable Infrastructure: Compromising Critical Systems
From Silos to Systems
The Fragmented Silos of USG: A Dangerous Vulnerability
Who Pays for Preparedness?

The Obligate Role of Private-Public Partnerships in Biosecurity Policy
Who Pays for Shared Global Risks from Infectious and Parasitic Diseases?

“Fewer countries have discovered, developed and registered drugs to an international standard, than have developed atomic bombs”

Chris Hentshel
Medicines for Malaria Venture

“Only industry can give us a clear answer to these questions (on Bioshield) This would require a process of government listening and industry speaking.”

Sen. J. Lieberman (I-CT)
2006
Biosecurity

- Environmental sustainability and non-renewable resources
- Global public health
- Political instability and escalating conflict
- Terrorism and international security

International Engagement, Commitment and Political Resolve
Biosecurity: A Daunting Complex Systems Challenge

- multi-dimensional, multi-disciplinary challenge
- complexity increased by disparate socio-economic, and technological capabilities in different geographies

The Obligate Need for a Systems Approach

- Political Will and Commitments for Infrastructure, Training, Research and Service

One World: One Health: One Objective
Biosecurity: A Complex System

USG

Defense and Homeland Security

Intelligence

Biosecurity

Foreign Policy

supra-national initiatives

private sector
naturally occurring infectious diseases pose an equal, if not greater, threat to society as bioterrorism

governments must accord higher priority to ‘biosecurity’ as a integral component of national security and foreign policy

(re)building a national and international infrastructure for the surveillance, diagnosis and containment of infectious diseases is fundamental to future protection against major instabilities triggered by infectious agents, whether of natural or malevolent origins
Addressing Global Challenges in Biosecurity

- mobilize new expertise networks to achieve end-to-end solutions
- funding and assembly of requisite expertise
  - cross-disciplinary, cross-sector
  - obligate role of industrial partners
- sophisticated management of complex collaboration networks whose composition will change constantly with new threats and new technologies
- financial incentives for industry for biodefense products with no civilian markets
- timely and accurate communication to the public and maintaining public support and cooperation
“History is the sum total of the things that could have been avoided.”

Chancellor Konrad Adenauer
“Politics is the art of the possible, the calculated science of survival”

Prince Otto von Bismarck

“Survival owes little to the art of politics, but everything to the calculated application of science”.

Professor Rudolph Virchow
(in reply)
Slides Available: http://casi.asu.edu/