Biosecurity: A Multi-Dimensional Challenge of Escalating Complexity and Urgency

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BioSecurity and Pandemic Resilience: Winter 2022
BIOE 122, EMED 122/222, PUBLPOL 122/222
Stanford University School of Medicine
Virtual Lecture
12 January 2022
Biosecurity

- multi-dimensional challenges of escalating complexity and urgency
- more than detection and control of infectious diseases
- diverse constellation of threats affecting biological systems with the potential to generate profound societal and geopolitical instabilities
  - local, national, international
- the multiplicity of complex inter-dependencies and connectivities threat must be evaluated for threat assessment
Biosecurity

- escalating complexity imposes new challenges for institutions and policy makers
- decision-making in the face of accelerating change and accompanying uncertainties
History of Biosecurity Threats: Pandemics and Plagues

- multi-millennial history of major societal dislocations
- large scale disruptions, often over extended periods
- sadly, a consistent theme of neglect and threats ignored
  - reactive versus proactive preparedness
  - proliferation of public fear, distrust, scapegoating and social divisions
  - triggers for major cultural change
  - economic/shifts in geopolitical power and political and military ascendancy
The Relentless Ever-Changing Dynamics of Infectious Diseases

- Old foes resurgent: Rx – resistance
- Omnipresent pandemic threats
- New foes: emerging infectious diseases

- Climate change and new vector ranges
- Bioterrorism and bioweapons
- Dual-use research of concern

Examples:
- SARS-CoV-2
The Evolution of a Bioincident

- detection of atypical event (speed of alert)
- containment (stamp out at the source)
- prevent spillover (sparks to ignite a fire)
- mitigation (flatten the curve and reduce demand on finite resources)
  - large scale testing and contact tracing
  - slow the spread and assess herd immunity
- maintenance of essential services and public order
- surge capacity, supply chain logistics and triage priorities for allocations of finite resources
- reliable information and public trust in actions by authorities (managing the worried well)
U.S. National Security Policy and Biodefense
A Coronavirus pandemic was a recognized threat.
Sars-CoV-2 Revealed Major Shortcomings in US Public Health Capabilities
What Became All Too Familiar Scenes in 2020 and 2021
What Became All Too Familiar Scenes in 2020 and 2021
A Critique of the US Response to COVID-19

Consistent Inconsistency

Politics + Science = Politics
## A Report Card on US Response to COVID-19 Across Two Administrations

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**Operation Warp Speed: “A”**

Innovation to Develop SARS-CoV-2 Vaccines at Unprecedented Speed
The Commitment and Resiliency of Front-Line Personnel: Pre-Vaccine Risk Exposure in Healthcare Delivery

- first responders
- military services
- ICU’s
- clinical laboratories
- waste disposal
- burn-out
Civic Volunteerism and Societal Resiliency
Unprecedented Failure of Governance and Public Health Policy

- failures of preparation
- failures of response
multiple warnings of zoonotic-EID risks ignored
chronic underinvestment in preparedness
failure of public institutions and national leadership

conflicting and confusing messaging
disinfection campaigns and foreign interference
domestic political divisiveness
A Portrait of the SARS-CoV-2 Pandemic

delayed detection and political obfuscation in emergency declarations

stark deficiencies in scale of needed diagnostic testing and slow engagement of private sector

underappreciated role of asymptomatic infections in pandemic spread

failure of test and trace campaigns

proliferation of highly variable epidemiological models

inadequate spread and scale of US viral sequencing to map variant distribution/evolution
A Portrait of the SARS-CoV-2 Pandemic

- slow, fragmented response and recovery capabilities
- outdated national stockpile and limited countermeasures
- economic disruption and monetary policy
- amplified disparities and inequities
- inadequate international cooperation
A Critique of the US Response to COVID-19

- political stridency
- partisan politics
- ever changing messaging
- media sensationalism
- proliferation of disinformation on social media
- public confusion and mistrust
A Critique of the US Response to COVID-19

- Politics plus science = politics = consistent inconsistency
- Lack of coherent national policies and assignment to individual states
  - Variable performance and policies on testing, face masks and level of ‘lock down’ needed
  - States forced to compete for purchase of critical PPE and diagnostic resources
- Hypocritical failure of some USG and state leaders to follow own recommendations
Faster Detection Saves Lives:
The Primacy of Diagnostics in Biosurveillance and Preparedness Mobilization

Profile: signatures of infectious agents

Detect: rapid automated PON/POC diagnostics

Act: real-time situation awareness, decisions

surveillance sans frontières

genomics of pathogen evolution

dual-use research and engineered biothreats
The COVID-19 Pandemic and the Primacy of Rapid Detection

- lack of transparency and IHR compliance reporting (12/19-1/20)
- Wuhan/Hubei lock down (1/23/20) but extensive flights to foreign countries for prior 2 weeks
- constraints on export of PPE while US still exporting
- launch of aggressive global disinformation campaign

- reluctance to demand data from PRC (early 1/20)
- misplaced praise for PRC “extraordinary control measures”
- slow declaration of Public Health Emergency of International Concern (PHEIC) (1/30/20)
Test, Test, Test and Trace, Trace, Trace!

- the critical ‘tandem’: without BOTH the system is blinded
  - true prevalence (MDx) and herd immunity (serological)
  - control of super-spreader events and suppression of new hot spots
A Case Study in Ineptitude

- arrogant rejection of WHO PCR test
- first tests kits contaminated/inaccurate
- six-week delay (March 2020) before distribution to Departments of Health in individual states
  - pandemic unchecked and spreading
  - contact tracing compromised
- tardy outreach to engage private sector for scaled up testing and kit manufacture
Global Tracking of Mutational Changes in SARS-COV-2 Samples
US Epidemiological Data and SARS-CoV-2 Variant Genome Sequencing Lack Scale, Speed and Accuracy

- fragmented reporting systems as major barrier to timely data capture of actionable data
- different reporting formats from different states and inadequate systems inter-operabilities
- reliance on international data from countries with centralized data frameworks and biosurveillance systems (UK, EU, Israel, S. Africa)
- predictable outcome of long-term neglect and investment at national and state levels
The US Public Health System: Data Backwaters

- massive gaps in timely capture, analysis and sharing of data
- widespread dependence on paper documentation/FAX transmission
- over one-third of local health departments cannot access electronic data from local emergency departments
- fragmented and tardy capture and limited interoperability of data feeds at Federal level

M. Wallace and J.M. Sharfstein (2022) NEJM 386, 1
Individual Rights Versus Public Good
Countering Disinformation: A Growing Challenge in Public Health Communications and Sustaining Public Trust

- purposeful dissemination of inaccurate information on social media
- manipulate public opinion, increase socio-political tensions and erode trust in authorities/decisions
- active role of PRC and Russia in COVID-19 pandemic
The COVID-19 Debacle: The Scientific and Political Failures Reflect Larger Legislative and Societal Pathologies

- Dysfunctional National Governance, Lack of Bipartisanship and Legislative Paralysis
- Technical Illiteracy and the Retreat from Complexity
- Dangerous Societal Divisions on Multiple issues
- A Threat to National Security and Technological Competitiveness?
The Shadow Pandemic

- “long-Covid” - unknown incidence and clinical outcomes
- delays and disruption in disease screening, diagnosis and optimum treatment for non-COVID diseases
- medication non-adherence and reduced Rx refills
- increased incidence of mental health, SUD and suicide
- uncertain long-term implications for educational and socialization for K-12 populations during lock down
- disproportionate impact on underrepresented minorities
- ‘burn out’ in health care personnel
The Longer-Term Economic Consequences of COVID-19

- government and central bank policies
  - $17 trillion debt expansion
  - future for inflation and taxation?
- business sector recovery
  - HIC vs LIC
- catalyst for PRC economic ascendancy?
The Rapid Spread of Omicron: An Opportunity to Shift to a New Equilibrium?

Flatten the Curve (2020)
Control Pandemic Spread (2020-2021)
Widespread Exposure and Herd Immunity (1Q/2022)?
Endemic Pathogen Joining the Four Prior Circulating Human Coronaviruses?
SARS-CoV-2: The Great Reset

- lessons learned?
- what will the ‘new normal’ look like?
- what will be the recovery time for different countries and business sectors?
- new geopolitical instabilities?
- a US-PRC cold war for economic, technological and military dominance?
PREPARE FOR TOMORROW'S THREAT TODAY
The Risk Hierarchy

- known knowns (even if ignored)
- known unknowns (intelligence, surveillance for prompt detection)
- unknown unknowns (adaptive survival and resilience)

Hon. D. Rumsfield
US Secretary of Defense
Public Health and Healthcare Delivery:
Two Largely Separate Domains
With Different Priorities and Economics

- different outcomes and value propositions
- different organizations and infrastructure
- different skills/competencies
- different investment patterns: public vs private sector

($4 trillion)

care delivery to individuals

public health and population-based Initiatives (US $50 billion)
Underinvestment in Public Health Capabilities to Address Pandemic Threats

- Cascading effect of public health failure as threat to stability of conventional healthcare delivery systems
- Major disruptions in supply chains, commerce, employment and education

- Care delivery to individuals
- Public health and population-based initiatives (US $50 billion)

($4 trillion)
Real Time Data: The Foundation of Situational Awareness for Timely and Rational Decisions
“Breakthrough cases are tracked by passive reporting (voluntary reporting) but this does not provide the full picture.” (Doh!)

Dr. Rochelle Walensky
Director, CDC
Press Conference 10 December 2021
The US Public Health System: Neglected Investment, Decentralized Fragmentation and Stark Deficits in Real Time Data Tracking

Federal

- 21 different agencies (e.g. CDC, FDA, NIH, EPA, USDA)

State

- 29 independent, 21 are part of larger agency
- state health controls all local health in only 7 states

Local

- 2459 health departments, only 404 as units of State health
- 1887 locally governed
COVID Data Tracker (as of 28 December 2021)

- cases and deaths by vaccination status (current only to Sept. 2021)
- breakthrough hospitalizations by vaccination status (current only to August 2021)
- no data provided on gender, race for breakthrough cases
- CDC allows at least 4 weeks lag time to link surveillance data to Immunization, Information System (ISS)
- data derived from only 27 jurisdictions
Networked Wearables/Sensors/Devices (IoMT) for Remote Health Status Monitoring and Real-Time Situational Awareness

- distributed POC/PON networks
- low cost, miniaturized, automated
- microfluidic systems and multiplex analysis of multiple pathogens
- immediate electronic upload to centralized data bases
- new power sources for extended sensor lifetimes
- biocontainment safety for POC/PON/in-home platforms
What’s Out There?
Comprehensive Global Biosurveillance and Preparedness
for the Next Epidemic/Pandemic Threat

SARS-CoV-2

Agent-X
What’s Out There?

A Global Inventory of Natural Microbial Threats to Humans and Vital Agricultural/Ecological Resources

The Predominance of Zoonoses as Emerging Infectious Disease Threats: The “One Health” Perspective

Natural Pathogens as Attractive Substrates for Engineering New Bioterrorism and Biowarfare Threats
“One Health” - The Importance of Zoonotic Diseases as Human Health Threats: A Rich Reservoir for EIDs and Genetic Manipulation

pandemic (avian) influenza

HIV

West Nile virus

MERS-CoV

Ebola virus

bush meat food chain

Zika virus

SARS-CoV-2
‘One Health’ Biosurveillance:
The Need to Rebuild the Front Line in Biopreparedness

Natural reservoirs and ecological niches of emerging viruses

Susceptible human host

- range and physical contact
- environmental factors

- demographics
- cultural, political and economic factors
- health system capacity to detect/respond

Meet the relatives

Researchers have found a host of coronaviruses similar to SARS-CoV-2 in bats and pangolins in China and neighboring countries. The closest relative, RaTG13, was found in a bat living in a cave in Yunnan province.

*Pangolins were confiscated by customs officers in China but were captured elsewhere.*

https://www.science.org/doi/epdf/10.1126/science.acx8984
The ‘One Health’ Concept

- identify ever shifting inter-relationships between human and animal hosts and environmental changes as drivers of zoonotic/epizootic risk
- still largely siloed investments
  - public health programs for human populations
  - livestock and crop protection
  - environmental and ecosystem initiatives
- concept gaining traction in Schools of Public Health and Veterinary Medicine
- slow embrace by healthcare systems and poor integration as core element of coherent national/international public health policies and investment
Urbanization and Mega-Cities in Developing Countries and the Increased Threat of Exotic Zoonotic Diseases

- High Population Density With Inadequate Biosurveillance
- Expanded Eco-niches and New Zoonotic Exposures/Risks
- Major Gaps in Health Infrastructure and Rapid Disease Reporting
Increased Refugee Migration, Humanitarian Disasters and Increased Infectious Disease Events
Water Security and Global Health
The Growing Challenges of Global Food Security
Implications of Climate Change for the U.S. Army

Department of Defense
Climate Risk Analysis

October 2021
Who Pays for Preparedness?

The Obligate Role of Private-Public Partnerships in Biosecurity Policy

Engaging the Private-Sector Health Care System in Building Capacity to Respond to Threats to the Public’s Health and National Security
Emergency Medical Countermeasures: Warnings Long Ignored

(2010)

The Public Health Emergency Medical Countermeasures Enterprise
Innovative Strategies to Enhance Products from Discovery Through Approval
Workshop Summary

(2016)

The Nation’s Medical Countermeasure Stockpile
Opportunities to Improve the Efficiency, Effectiveness, and Sustainability of the CDC Strategic National Stockpile
Workshop Summary

(2021)

Ensuring an Effective Public Health Emergency Medical Countermeasures Enterprise
Notice the Resemblance?
Hygiene and Quarantine as the Only Effective Containment Absent Drugs or Vaccines

Bubonic Plague
Physician 15th Century

Ebola, Liberia
21st Century

COVID-19
21st Century
Therapeutics and Vaccines: Critical Dependence on Private Sector Innovation and Investment
Development of Medical Countermeasures (MCMs) for Emerging Infectious Diseases (EIDs) and Biodefense

- limited private sector engagement until global emergency created by COVID19
- poor productivity of USG agencies (NIH, DOD, CDC) despite multi-billion investment (2001-present)
- pre-Covid BARDA under-funded to meet ‘translational mission’ to transfer USG innovation to industry
- FAR and annual budget cycle as obstacles to long-term R&D cycles (5-10 years)
- private sector engagement largely limited to small biotechnology companies with no proven track record of FDA-product approval
  - USG as source of non-dilutive capital
  - limited VC interest in EIDs and biodefense (market failure)
Market Failure

- lack of incentives for private sector to undertake high risk/high-cost R&D absent guaranteed markets and ROI
  - MCMs for pandemic threats, EIDs and biowarfare select agents
  - neglected diseases of the developing world
  - antibiotic resistance

- outsourcing of critical medical supply chains (China, India)
  - generic drugs (80% of US prescriptions)
  - active ingredients for key drug classes (antibiotics)
  - PPE
  - devices (ventilators)
The COVID Pandemic and Global Supply Chain Disruption

BUILDING RESILIENT SUPPLY CHAINS, REVITALIZING AMERICAN MANUFACTURING, AND FOSTERING BROAD-BASED GROWTH

100-Day Reviews under Executive Order 14017

June 2021

A Report by
The White House

Including Reviews by
Department of Commerce
Department of Energy
Department of Defense
Department of Health and Human Services
Cyber-biosecurity: How to protect biotechnology from adversarial AI attacks

ELEONORE PAUWELS
Dual-Use Technologies and Expansion of the Biothreat Spectrum

Beyond Bugs: Next-Generation Biothreats Based on Genetic Engineering and Cognitive Manipulation
Advances in the Biosciences and the Expanded Dual-Use Dilemma

- mapping the functional properties of living organisms at the molecular level
- understanding the molecular signaling information networks (biocircuits) that control specific biological functions
  - cells, tissues, organs, whole organisms

- new technologies to alter the properties of existing organisms
- design of biological functions/organisms for which there is no known evolutionary precedent
- powerful new tools for genome modification
  - read, write, edit
Dual-Use Technologies and Expansion of the Biothreat Spectrum

- deliberate engineering of microorganisms for biowarfare/ bioterrorism
  - evade detection and circumvent therapeutic countermeasures
  - new virulence features to alter target organs
  - induce high levels of chronic disease and unsustainable economic burden to healthcare systems
  - expand the spectrum of vulnerable host species (animals, crops, ecosystem disruption)
Dual-Use Technologies and Expansion of the Biothreat Spectrum: ‘Beyond Bugs’

- new biothreats that do not involve microorganisms
- potential to target any lifeform or biological functions based on knowledge of the underlying molecular control systems
  - “biocircuit modulators”
- although viruses could theoretically be designed to attack specific biocircuits the more likely scenario will be to design chemical molecules to hit the circuit(s) of interest
Mapping Genetic Control Circuits in Human Organs and Cells: New Dual-Risk Challenges

GTex Consortium
Synthetic Biology and Dual –Use Research: Thinking ‘Beyond Bugs’

- Precision medicine: mapping molecular networks - (circuit diagrams) of every cell type in the body and the circuit disruptions that cause disease
- Roadmap for next-generation CBW agents to target specific molecular circuits
National Security Implications of Genomic Data on Populations

Population Databanks

Foreign Access to Data

Individual Profiles

Data Security

iCarbonX

华大基因

BGI
Next Generation Chemical Threat Agents: ‘Inspired by Biology’

- design of next-generation chemical weapons targeted to specific biocircuits
- acute versus chronic effects
- altered immune functions
  - activation: autoimmune disease
  - immunosuppression: vulnerability to multiple infections
- neuromodulation
  - trigger fear, panic, hallucinations, aberrant memories
  - reduce thresholds for violence, addictive behavior
China’s Export of Fentanyl and Derivatives
Dual-Use Technologies and the Expanding Biothreat Spectrum

- rate of technology progress and risk expansion outpacing current national and international oversight mechanisms
- new classes of dual-use biothreats will arise from intensifying national competitiveness for commercial domination of advanced technologies
  - synthetic biology, neuroscience and AI (among others)
- CBW Convention and national export controls were designed to address more narrow, well-defined risks
  - “select agents”
Gray Zone Threats

An Emerging Dimension of Hybrid Warfare

Implications for Biosecurity
Darker Shades of Gray: The Emerging Dimension of Hybrid Warfare

- lawfare: exploiting loopholes to seed confusion and dissent
- deception, disinformation and propaganda
- weaponized narratives ("fake news")
- plausible deniability
Gray Warfare and Biosecurity

- targeted psychological manipulation of cognition and beliefs
- undermine societal trust in political leadership and institutions
- promote social division, tension and civil unrest
- ‘fake news’ and self-reinforcing ‘echo chamber’ propaganda on social media
- parallel dimension to cyberwarfare but more subtle, insidious and longer-term impact
‘Big Tech’ and the Global Digital Ecosystem

- increasing pervasive reach of data collection on individuals, institutions, societies and governments
Big Data Meets Neuroscience – The Ultimate Technological Triad: Consumerism, Commerce and Control

- Social media profiling
- Artificial intelligence
  - Surveillance
  - Manipulation
- Neuroscience and mechanistic mapping of cognitive pathways
Big Data Analytics: From Consumerism to Control?
Surrender of Personal Privacy and Autonomy For Access to the Convenience of the Digital Economy

- anticipating our “wants and needs” as the core business model
- the confessional of social media
- click-based commercial and political targeting
- covert data use and distribution by large data companies/governments
- access and prediction of your mental state(s)?
National Leadership in Advanced Technologies: The Quest for Corporate and Military Superiority

- biotechnology
- genomics
- synthetic biology
- artificial intelligence
- quantum computing
- control of low earth orbits
  - commercial
  - military
PRC: Strategy for Global Commercial and Military Dominance

- military - civil fusion plan
- major R.& D. investments and sophisticated biotechnology/computing expertise
- purposeful creation of large diaspora for training in US/EU universities
- relentless industrial espionage and relentless cyber- exfiltration efforts
- mapping the genetic diversity of human populations
The Conviction of Charles Lieber, Chair, Dept. of Chemistry, Harvard University
(21 December 2021)
The Origin of SARS-CoV-2

Bat-Derived Zoonose?

Biocontainment Breach at Wuhan Institute of Virology?
‘Science’ in Pandemic Times

• IHR non-compliance by failure to promptly report novel pathogen and human-to-human transmission to WHO (12/20 and 1/20)
• Censorship of internal scientific, clinical and public health communications about SARS-CoV-2 without political approval
• Lack of transparency in data provided to WHO investigation panel
• Launch of disinformation campaign (USAMRID Ft. Detrick as source of the pandemic)
The Unresolved Origin of SARS-CoV-2
Evidentiary Standards in the Analysis of the Origin of SARS-CoV-2

Statement in support of the scientists, public health professionals, and medical professionals of China combating COVID-19

We are public health scientists who have closely followed the emergence of 2019 novel coronavirus disease (COVID-19) and are deeply concerned about its impact on global health and wellbeing. We have watched as the scientists, public health professionals, and medical professionals of China, in particular, have worked diligently and effectively to rapidly identify the pathogen behind this outbreak, put in place significant measures to reduce its impact, and share their results transparently with the global health community. This effort has been remarkable.

We sign this statement in solidarity with all scientists and health professionals in China who continue to save lives and protect global health during the challenge of the COVID-19 outbreak. We are all in this together, with our Chinese counterparts in the front line, against this new global threat.

nothing but create fear, rumours, and prejudice that jeopardise our global collaboration in the fight against this virus. We support the call from the Director-General of WHO to promote scientific evidence and unity over misinformation and conjecture.14

We want you, the science and health professionals of China, to know that we stand with you in your fight against this virus.

We invite others to join us in supporting the scientists, public health professionals, and medical professionals of Wuhan and across China. Stand with our colleagues on the frontline!

We speak in one voice. To add your support for this statement, sign our letter online. LM is editor of ProMED-mail. We declare no competing interests.

Charles Calisher, Dennis Carroll, Rita Colwell, Ronald B Corley, Peter Daszak, Christian Drosten, Luis Enjuanes, Jeremy Farrar, Hume Field, Josie Golding, Alexander Gorbalenya, Bart Haagmans, James M Hughes, William B Karesh, Gerald T Keusch, Sai Kit Lam, Juan Lubroth, John S Mackenzie, Larry Madoff, Donna Mazet, Peter Palese, Stanley Perlman, Leo Poon, Bernard Roizman, Linda Saif, Kanta Subbarao, Mike Turner

Investigate the origins of COVID-19

On 30 December 2019, the Program for Monitoring Emerging Diseases notified the world about a pneumonia of unknown cause in Wuhan, China (1). Since then, scientists have made remarkable progress in understanding the causative agent, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), its transmission, pathogenesis, and mitigation by vaccines, therapeutics, and non-pharmaceutical interventions. Yet more investigation is still needed to determine the origin of the pandemic. Theories of accidental release from a lab and zoonotic spillover both remain viable. Knowing how COVID-19 emerged is critical for informing global strategies to mitigate the risk of future outbreaks.

In May 2020, the World Health
‘Science’ in Pandemic Times: The Origins of SARS-CoV-2 Controversy

- a revealing and not always reassuring insight into the ‘culture’ of western science
- premature dismissal of leak hypothesis given the extensive phylogenetic distance between proposed bat reservoir and SARS-CoV-2
- despite comprehensive field sampling of regional bat species no precursor with closer phylogenetic status yet identified
  - Laos 2021 isolate only a minor gain in phylogenetic similarity
premature dismissal of Wuhan lab leak as viable alternative the natural zoonotic spread of a bat coronavirus to humans

coordinated campaign (IH/2020) by zoonosis KOLs advocates to portray lab leak hypothesis as a fringe, conspiracy theory

unrevealed COI by zoonosis KOLs regarding Wuhan collaborations and concern that scrutiny of GoF studies on bat coronaviruses would curtail future broader GoF research
The Case for the Lab-Leak Hypothesis
The Origin of SARS-CoV-2

“Without transparency and sharing of data (by PRC) I don’t think the origins (search) could reach a successful conclusion.”

Dr. Tedros Ghebreyesus
WHO Director General
December 2021

“We urgently call for closer international cooperation, increased vaccine supply and sharing and rapid information exchange.”

Dr. George Gao
Head, Chinese CDC
Nature (2021) 600,408

- prevent, detect and respond to infectious disease
- safeguard economies
- end the cycle of panic and neglect
- need for sustained investment commitment
- essential public health capacities represent recurring cost

Global Health Security Agenda
Unfortunate Truisms in Public Health:

- Comfort and Complacency Erode Robust Preparedness
- Out-of-Sight, Out-of-Mind
- If Nothing Happens, the Preparedness Budget is Neglected or Reduced
- Why Don’t We Learn from History?
The Imperative for Proactive Actions for Robust Biosecurity

- need for higher priority of biosecurity in national security strategy and international engagement
- development of more sophisticated threat assessment capabilities
- strengthen and integrate surveillance, analysis deterrence capabilities in national security, IC, and public health
- closer coupling of public health and healthcare delivery systems
- greater investment in robust threat mitigation capabilities
  - new diagnostic technologies and MCMs
  - obligate private sector engagement
  - supply chain logistics
  - workforce expertise and readiness training
- international cooperation and harmonization
Guaranteed Certainties!

- escalating technological complexity
- new dual use technologies and the expanded threat spectrum
- intensified international competition for commercial and military dominance of advanced technologies
- decision-making in the face of greater uncertainty
“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)
“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)

“Plus ça change, plus c’est la même chose”

Slides available @ casi.asu.edu/presentations