PUTTING FOOD ON THE TABLE: A REVIEW OF THE IMPORTANCE OF AGRICULTURE RESEARCH

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED FIFTEENTH CONGRESS

FIRST SESSION

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PUTTING FOOD ON THE TABLE: A REVIEW OF THE IMPORTANCE OF AGRICULTURE RESEARCH

Thursday, November 2, 2017

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 10:35 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Barbara Comstock [Chairwoman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
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Congress of the United States
House of Representatives
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515-6301
(202) 225-6371
www.science.house.gov

Putting Food on the Table – A Review of the Importance of Agriculture Research

Thursday, November 2, 2017
10:30 a.m.
2318 Rayburn House Office Building

Witnesses

Dr. Daniel Gerstein, Senior Policy Researcher, RAND Corporation

Dr. Stephen Higgs, Associate Vice President for Research and Director, Biosecurity Research Institute, Kansas State University

Dr. Stephen P. Moose, Denton and Elizabeth Alexander Professor, Maize Breeding and Genetics, Department of Crop Sciences, University of Illinois at Urbana Champaign

Dr. Elizabeth Wagstrom, Chief Veterinarian, National Pork Producers Council

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HEARING CHARTER

November 2, 2017

TO: Members, Subcommittee on Research and Technology

FROM: Majority Staff, Committee on Science, Space, and Technology

SUBJECT: Research and Technology Subcommittee Hearing:
"Putting Food on the Table – A Review of the Importance of Agriculture Research"

The Subcommittee on Research and Technology of the Committee on Science, Space, and Technology will hold a hearing titled *Putting Food on the Table – A Review of the Importance of Agriculture Research* on Thursday, November 2, 2017 at 10:30 a.m. in Room 2318 of the Rayburn House Office Building.

Hearing Purpose:

The purpose of the hearing is to examine federal agriculture research including the scope, importance, value and impact of such research. Witnesses will provide an overview of federal agriculture research efforts, particularly at the U.S. Department of Agriculture and the Department of Homeland Security. The hearing will also profile academic and industry stakeholders for their perspectives on the value and implication of agriculture research to the nation.

Witness List

- **Dr. Daniel Gerstein**, Senior Policy Researcher, RAND Corporation
- **Dr. Stephen Higgs**, Associate Vice President for Research and Director, Biosecurity Research Institute, Kansas State University
- **Dr. Stephen P. Moose**, Denton and Elizabeth Alexander Professor, Maize Breeding and Genetics, Department of Crop Sciences, University of Illinois at Urbana Champaign
- **Dr. Elizabeth Wagstrom**, Chief Veterinarian, National Pork Producers Council

Staff Contact

For questions related to the hearing, please contact Raj Bharwani of the Majority Staff at 202-225-6371.

Chairwoman COMSTOCK. The Committee on Science, Space, and Technology will come to order.

Without objection, the Chair is authorized to declare recesses of the Committee at any time.

Good morning, and welcome to today's hearing titled "Putting Food on the Table: A Review of the Importance of Agriculture Research." I now recognize myself for five minutes for an opening statement.

The purpose of today's hearing is to examine federal agriculture research including the scope, importance, value, and impact of such research. Agriculture research is a broad term that can include the study of diseases that threaten the nation's animal agriculture industry and public health. It can also refer to research to increase and improve crop and yield production through advancements in science and technology. In other words, we rely on the research to help protect the Nation from disasters, and we rely on it to help prepare us for the future, one in which agriculture research will benefit from developments in precision and automated technologies such robotics and artificial intelligence.

In the Commonwealth of Virginia, agriculture research is an important topic for my constituents and for me because agriculture is such a critical industry. According to the Virginia Department of Agriculture and Consumer Services, agriculture is Virginia's largest industry by far with nothing else coming a close second. People are actually surprised that Virginia—for those of us in northern Virginia, we might be a little surprised that agriculture still holds as the top industry. The industry has an economic impact of $70 billion annually and provides more than 334,000 jobs in the Commonwealth.

In the 10th Congressional District, agriculture's key role is felt far and wide, from the rows upon rows of apple and peach orchards in the western counties to the ever-growing wine industry, craft breweries and distilleries. We also have dairy and cattle farms too.

Our distinguished panel today represents a variety of perspectives to explain the value and impacts of agriculture research. We will hear about the food security and economic and national security implications of a natural disaster or a terrorist attack on our crops and livestock. We will also hear about industry research efforts and practices, and an academic perspective on innovative efforts to more efficiently increase and improve crop yields.

These are important considerations because agriculture research impacts all of us. As an example, one need only go back to the avian flu outbreak—which I'm not sure if I might be having a flu outbreak here—of 2014 and 2015, which resulted in almost $900 million in expenses to federal and state governments, the slaughter of more than 50 million birds, and an estimated cost to the U.S. economy in excess of $3 billion.

I look forward to hearing about federal and other stakeholder agriculture research efforts from our witnesses today. I hope to understand how the research is coordinated and complemented to protect America's food sources so that we may all continue to safely and abundantly put food on our tables for the foreseeable future.

[The prepared statement of Chairwoman Comstock follows:]

COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
Lamar Smith, Chairman

For Immediate Release
November 2, 2017

Media Contacts: Thea McDonald, Brandon VerVelde
(202) 225-6371

Statement from Chairwoman Barbara Comstock (R-Va.)

Putting Food on the Table – A Review of the Importance of Agriculture Research

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[The prepared statement of Ms. Johnson follows:]

OPENING STATEMENT
Ranking Member Eddie Bernice Johnson (D-TX)

House Committee on Science, Space, and Technology
Subcommittee on Research and Technology
"Putting Food on the Table: A Review of the Importance of Agricultural Research"
November 2, 2017

Thank you Chairwoman Comstock and Ranking Member Lipinski for holding this hearing, and thank you to the expert witnesses for being here this morning. It has been many years since this committee has examined the state of agricultural research supported by our federal agencies. Many people may assume that only the U.S. Department of Agriculture (USDA) supports agricultural research. Of course, USDA is a leader in agricultural research, and for more than 100 years has played a central role in connecting the resulting science and technology to farmers through the Extension offices and land grant institutions across our nation. However, a few other agencies also play key roles in advancing agricultural science and contributing to food security.

The National Science Foundation supports most of the basic plant biology research that underpins advances in agricultural technology. In the late 1990's, NSF took the lead in an interagency effort to sequence economically relevant plant genomes. NSF continues that program today as the Plant Genome Research Program. NSF research also advances our understanding of the agricultural impacts of a changing climate. In 2016, NSF launched a program called Innovations at the Nexus of Food, Energy, and Water Systems to study how society can best integrate across the natural and built environments to provide for a growing demand for food, water and energy in sustainable ways. And NSF has long supported important research into the societal aspects of agriculture, such as public perception of genetically modified foods. Due to the potential for biofuels to replace some of our fossil fuel consumption, the Department of Energy has also funded basic and applied research on plants and the processes by which plants may be transformed into clean-burning biofuels. Advances in plant biology supported by DOE will likely have applications to food security as well.

Finally, the Department of Homeland Security, through its Science and Technology Directorate, supports critical research that will help us protect our food supply, our health, and our associated economic security from both naturally occurring diseases and intentional attacks. In that regard, we will hear from several witnesses today about the essential research planned for the National Bio- and Agro-Defense Facility under construction in Kansas. This Committee has sole or shared jurisdiction over all of these programs. In addition, it is our responsibility to look holistically across the federal portfolio of agricultural research, including the important research carried out by USDA.

Many of us hail from urban areas. And that leads some of us to pay less attention to what's happening on our nation's farms. However, we all depend on the productivity and security of our agricultural sector. It is incumbent on all of us policymakers to understand the evolving challenges to national and global food security, and how that should drive a forward-looking research agenda across the relevant federal agencies, in partnership with farmers and with the private sector. I look forward to today's testimony and discussion, and I yield back.

Chairwoman COMSTOCK. I now recognize the Ranking Member, the gentleman from Illinois, Mr. Lipinski, for his opening statement.

Mr. LIPINSKI. Thank you, Chairwoman Comstock, for holding this hearing and the witnesses for being here today. Certainly in my State of Illinois, agriculture is huge, so there's no question that people know that.

Often, the major research issues that we talk about here on the Research and Technology Subcommittee are not the subjects of everyday dinner conversation. But today, we are actually talking about dinner. I was hoping to see some product here for us this morning, but that's all right.

Putting safe and affordable food on the table is something many of us take for granted. However, there is an entire ecosystem of innovation and public-private partnerships that make it possible for farmers to continue to meet the needs of a growing population.

Agricultural science is multidisciplinary, spanning fields from engineering to economics. As Dr. Moose from the University of Illinois at Urbana-Champaign can attest, UIUC's Crop Sciences department includes research in statistics, ecology, environmental sciences, plant biology, horticulture, plant genetics, plant pathology, and weed science.

Likewise, major discoveries and innovations that assist in crop production come from unexpected places. For example, new genetic editing technologies that began in a microbiology research lab promise major leaps forward for agriculture. In another example, NASA supported the development of satellite image refinement software for its research that also helps agricultural researchers study the effects of population and climate on crop field acreage.

Agricultural researchers work closely with farmers to help translate all of this science into practice, while farmers continue to help define the research agenda for food security. Research and development is a system of feedback loops, not a linear path. There's rarely a clean line between basic and applied research in any field of inquiry, and today's topic is no exception.

It is important to remember this as we examine the need for flexible, sustainable federal support for agricultural research. Both government and private sector investments support agricultural research. Multiple federal agencies support efforts to advance our Nation's leadership in agricultural research. These agencies work in close collaboration with the agricultural industry. Unfortunately, as federal budgets are tightened, academic researchers have less funding to move their science through the development process; therefore, the private sector supports an increasing share of agricultural research.

While the private sector has an important role, we must continue to provide a balance of public and private funding in order to ensure both a pipeline of basic research and a research agenda driven by the needs of farmers and the public. Our lack of dedication to sustainable funding could cost us global competitiveness in certain areas of agricultural technology and put our food security at risk within the lifetime of many of us.

A number of factors can affect the quality, availability, and safety of the plants and animals that help feed our families, including

extreme weather, pests, and disease. In the face of emerging infectious diseases and new technological tools such as genetic editing, we must also be vigilant about intentional contamination and disruption of our food supply. I hope there is some discussion today about how researchers and industry are taking into consideration the agricultural impacts of a changing climate and growing population, and how those factors will help shape the research agenda. On the biosecurity front, which is one focus of this hearing, several of the today's witnesses will testify about the critical need to implement sustainable funding policies for the new National Bio and Agro-defense Facility under construction in Manhattan, Kansas.

Now is the time to consider a federal strategy to increase the scale of agricultural research across the relevant agencies, encourage balanced federal-private sector partnerships, and ensure that our future agricultural workforce is equipped with the necessary science and technology skills to meet the food and biosecurity challenges of today and tomorrow.

Finally, I would like to note that agricultural research also has applications beyond food security. For example, the Department of Energy recently awarded UIUC five years of funding to establish one of four new Bioenergy Research Centers that will provide a new generation of sustainable bioenergy and other bio-based products.

I thank all of the witnesses for being here today to share their expertise, and I yield back.

[The prepared statement of Mr. Lipinski follows:]

OPENING STATEMENT
Ranking Member Daniel W. Lipinski (D-IL)
of the Subcommittee on Researeh and Technology

House Committee on Science, Space, and Technology
"Putting Food on the Table: A Review of the Importance of Agriculture Research"
November 1, 2017

Thank you Chairwoman Comstock for holding this hearing and the witnesses for being here today. Often, the major research issues that we talk about on the Research and Technology Subcommittee are not the subjects of everyday dinner conversation. But today, we are actually talking about dinner. Putting safe and affordable food on the table is something many of us take for granted. However, there is an entire ecosystem of innovation and public-private partnerships that make it possible for farmers to continue to meet the needs of a growing population.

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Chairwoman COMSTOCK. Thank you, Mr. Lipinski, and given my challenges with my cold and my voice today, I'm going to defer to Mr. Marshall to be able to introduce our witnesses, which also include someone from his district, so thank you, Mr. Marshall, for taking over those duties.

Mr. MARSHALL. Thank you, Chairwoman Comstock, and let me just start by saying thank you to the SST staff who's done a fabulous job of organizing this. I had no idea how much work it might be, and you all have been a thrill and an honor to work with, and to my staff as well. Lauren Orndorff, my science, space, and technology staff person, has done a great job organizing the witnesses and so honored to be able to introduce you all.

First is Dr. Daniel Gerstein, who's the Senior Policy Director at the RAND Corporation. He's also the Adjunct Professor at American University in Washington, DC. Previously, Dr. Gerstein served in the Department of Homeland Security as Acting Under Secretary and Deputy Under Secretary in the Science and Technology Directorate. He graduated from the United States Military Academy and has a master's degree from Georgia Tech, the National Defense University and the U.S. Army Command and General Staff College. He also earned a Ph.D. in biodefense from George Mason University. Thanks, Dr. Gerstein, for coming.

And my next witness is our own Dr. Stephen Higgs, who's the Associate Vice president for Research and Director of the Biosecurity Research Institute at my alma mater, Kansas State University, and we both got our purple ties on. Go Cats! This institution is a unique biocontainment research and education facility. Dr. Higgs is responsible for oversight, coordination, and expansion of the Institute's Biosecurity Research and Education programs. The Institute is located next to the National Bio and Agro-Defense facility, which we call NBAF back home, a biosafety level IV facility which is currently under construction and when completed will make Manhattan, Kansas, the Silicon Valley of bio and agro-defense. As it becomes operational, Dr. Higgs' proximity and experience will be invaluable to bringing that operation online. Previously, Dr. Higgs served as the President of the American Society of Tropical Medicine and Hygiene as well as Editor in Chief of Vector-borne and Zoonotic Diseases. Dr. Higgs earned a bachelor of science with honors in zoology from the Kings College in London and his Ph.D. in parasitology from Reading University in the United Kingdom. Welcome, Dr. Higgs, to Washington, D.C., and we look forward to your testimony. So much appreciate the tour you gave us back home as well.

The next witness is Dr. Stephen P. Moose. He's Denton and Elizabeth Alexander Professor of Maize Breeding and Genetics in the Department of Crop Sciences at the University of Illinois at Urbana-Champaign. His research focuses on understanding how gene regulatory programs may be modified for crop improvement. Dr. Moose spent two years as a Project Leader at DeKalb Genetics Corporation in Monsanto Company using biotechnology to enhance corn grain nutritional quality. Dr. Moose received a bachelor's of science degree in biology from Case Western Reserve University and a Ph.D. in genetics and crop science from North Carolina State University.

And finally, Dr. Elizabeth Wagstrom is our final witness, Chief Veterinarian of the National Pork Producers Council. During her career, Dr. Wagstrom has worked the intersection of animal and public health including as a practicing Veterinarian, an Epidemiologist and Public Health Veterinarian, an industry organization staff member and in academia. Dr. Wagstrom holds a doctor of veterinary medicine and master's in preventive medicine degrees from Iowa State University.

And we start with our testimony by recognizing Dr. Gerstein for five minutes to present his testimony.

TESTIMONY DR. DANIEL GERSTEIN,
SENIOR POLICY RESEARCHER,
RAND CORPORATION

Dr. GERSTEIN. Well, thank you very much. I'm very pleased to be here. Good morning, Chairwoman Comstock, Ranking Member Lipinski, and distinguished members of the Subcommittee. I thank you for the opportunity to testify today on federal research and development for agricultural biodefense.

Since the establishment of the Department of Homeland Security (DHS) in 2003, the Department in complete coordination with the Department of Agriculture has served in a central role in agricultural biodefense, particularly in research and development. During my service as Acting Under Secretary and Deputy Under Secretary of the Science and Technology Directorate, my duties included oversight and support for U.S. agricultural biodefense R&D including the work at the Plum Island Animal Disease Center, or short, Plum Island, several academic Centers of Excellence related to agricultural biodefense and tens of millions of dollars annually in research and development funding.

It is also during this period when DHS led by the S&T Directorate developed the justification and secured funding for the National Bio and Agro-Defense Facility (NBAF) at Manhattan, Kansas, as the replacement for the Plum Island facility.

My testimony today will largely draw on these experiences. In my remarks, I'd like to place federal R&D efforts for agricultural biodefense in context. To do this, I will develop several themes.

First, federal agriculture research must be considered within the global biological threats that span a broad spectrum from emerging infectious disease to the deliberate use of biological pathogens. Second, agriculture security is a national security and economic security issues. Third, U.S. laws, policies, and regulations are part of a larger international system of disease monitoring and reporting. And finally, robust, well-coordinated biodefense R&D is an essential component of maintaining a healthy and vibrant agricultural sector.

In the interests of time in my oral remarks, I'll focus on the fourth theme regarding federal agricultural biodefense R&D, specifically developing several important areas of emphasis that should be considered.

The first is, research and R&D solutions must be systems-oriented. Investments have to be balanced and there are no silver bullets. A comprehensive system must include threat awareness, prevention and protection, surveillance and detection, and response

and recovery. Second, good disease monitoring will be important to continuity of business. Early detection, rapid response and recovery, and ensuring accurate communications across all interested governmental and non-governmental entities is essential. These areas require appropriate R&D support and funding. Third, cross-sector collaboration including end-user participation will be vital for developing preparedness and response capabilities. Livestock industry and producers, government officials including state and local animal health officials, the biopharmaceutical industry and veterinarians, first responders, and diagnostic laboratories must all collaborate on research and development to identify solutions that will be essential. Fourth, opportunities to field-test technologies worldwide should be identified. Countries with endemic zoonotic diseases of interest to the United States government and agricultural sector should be identified and approached to ascertain their willingness to work as partners for countermeasure and vaccine trials. Fifth, next-generation zoonotic disease training should continue to be developed. Education programs that target gaps in the agricultural biodefense workforce to include in research and development would be extremely useful. And finally, consistent funding for agricultural biodefense efforts is essential. Achieving the level of protection for this area will require specific investments in research and development in facilities such as Plum Island and NBAF. It also implies that state and local communities have the necessary funding to operate and maintain the labs that are part of the National Animal Health Laboratory Network. To do otherwise creates unnecessary risks for a $1 trillion portion of the U.S. economy.

I appreciate the opportunity to discuss federal R&D For the agriculture biodefense sector, and I look forward to your questions. Thank you.

[The prepared statement of Dr. Gerstein follows:]

Federal Research and Development for Agricultural Biodefense

Daniel M. Gerstein

CT-482
Testimony presented before the House Science, Space, and Technology Committee, Subcommittee on Research and Technology on November 2, 2017.

For more information on this publication, visit www.rand.org/pubs/testimonies/CT482.html

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Published by the RAND Corporation, Santa Monica, Calif.

Federal Research and Development for Agricultural Biodefense

Testimony of Daniel M. Gerstein[1]
The RAND Corporation[2]

Before the Committee on Science, Space, and Technology
Subcommittee on Research and Technology
United States House of Representatives

November 2, 2017

Good morning Chairman Comstock, Ranking Member Lipinski, and distinguished members of the subcommittee. I thank you for the opportunity to testify about Federal Research and Development for Agricultural Biodefense.

Introduction

Since the establishment of the Department of Homeland Security (DHS) in 2003, the department has served a central role in agricultural biodefense, particularly in research and development (R&D). During my service as the Under Secretary (Acting) and Deputy Under Secretary of DHS's Science and Technology Directorate from 2011 to 2014, my duties included oversight and support for U.S. agricultural biodefense R&D, including the work at the Plum Island Animal Disease Center (PIADC), several academic centers of excellence related to agricultural biodefense, and tens of millions of annual R&D spending. It was also during this period when DHS, led by the S&T Directorate, developed the justification and secured funding for the National Bio & Agro-Defense Facility (NBAF) at Manhattan, Kansas, as the replacement facility for PIADC. My testimony today will largely draw on these experiences.

In my remarks today, I would like to place federal R&D efforts for agricultural biodefense efforts in context. To do this, I will develop several themes. First, federal agriculture research must be considered within a broad spectrum of global biological threats, from emerging infectious disease to the deliberate use of biological pathogens. Second, agriculture security is an issue of both national and economic security. Third, U.S. laws, policies, and regulations are part

[1] The opinions and conclusions expressed in this testimony are the author's alone and should not be interpreted as representing those of the RAND Corporation or any of the sponsors of its research.

[2] The RAND Corporation is a research organization that develops solutions to public policy challenges to help make communities throughout the world safer and more secure, healthier and more prosperous. RAND is nonprofit, nonpartisan, and committed to the public interest.

of a larger international system of disease monitoring and reporting framework. Finally, robust, well-coordinated biodefense research and development is an essential component of maintaining a healthy and vibrant agricultural sector.

Biodefense R&D serves as a hedge against the wide variety of growing threats to the agricultural sector. It should be thought of as a necessary, yet costly, insurance policy to protect this vital industry. Funding the $1.2 billion NBAF was an important step in protecting the agricultural sector.[3] However, disparities still exist between the federal funding provided for human health versus agricultural biodefense R&D.[4]

Global Biological Threats

The agriculture and food sectors of the U.S. economy accounted for almost $1 trillion dollars—5.5 percent of the U.S. gross domestic product (GDP) in 2015. Agriculture and related industries[5] account for approximately 11 percent of U.S employment. Farms directly contributed $136.7 billion, or slightly less than 1 percent, of the U.S. GDP and accounted for 2.6 million jobs.[6]

The range of biological threats facing the agricultural industry continues to grow. Emerging infectious diseases (EID)[7] have continued to spread across the globe, and the number of diseases becoming endemic in the United States has continued to increase. At the same time, concerns about deliberate threats to the agriculture sector remain and in some cases, continue to grow.

"Socio-economic, environmental and ecological factors" have fueled the spread of EID. In a study analyzing 335 EID events between 1940 and 2004, such events were determined to be "significantly" increasing. Of great importance to the agricultural sector, 60.3 percent of these diseases are zoonotic—diseases with a nonhuman animal source—and 71.8 percent originated in wildlife. These statistics combine to imply that the U.S. agricultural sector is very much at risk; controlling the spread of these diseases could be very challenging.[8]

Global travel and an increasingly mobile population (both human and livestock) highlight the potential for foreign animal disease to rapidly spread, spreading diseases that have never been in or have been eradicated in the United States. Foot and Mouth Disease (FMD), eradicated in the United States in 1929, is endemic in parts of Asia, most of Africa, and the Middle East. It also

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[3] The $1.2 billion estimate was for the construction and commissioning of NBAF.

[4] Tammy Beckham, "American Agriculture and Our National Security," testimony before the House Committee on Agriculture, Washington, D.C., November 4, 2015.

[5] Food-related industries include forestry, fishing, and related activities; food, beverages, and tobacco products; textiles, apparel, and leather products; food and beverage stores; and food service, eating and drinking places.

[6] U.S. Department of Agriculture (USDA), "Ag and Food Sectors and the Economy," last updated October 17, 2017.

[7] Centers for Disease Control and Prevention (CDC), "EID Journal Background and Goals," last updated May 30, 2014.

[8] Kate E. Jones, Nikkita G. Patel, Marc A. Levy, Adam Storeygard, Deborah Balk, John L. Gittleman, and Peter Daszak, "Global Trends in Emerging Infectious Diseases," *Nature*, Vol. 451, February 21, 2008, pp. 990–993.

occurs in Latin America, but is largely controlled by zoning.[9] Introduction of FMD in the United States would paralyze our exports of agricultural products, require a massive culling of potentially infected animals, and mandate a vaccination program to prevent further spread of the virus.

African Swine Fever (ASF) is a viral hemorrhagic fever; some strains are considered to have a 100-percent mortality rate. ASF has occurred in Europe, South America, and the Caribbean. Some of the outbreaks have been halted, while others continue to plague livestock in these areas. Some countries have managed to eradicate ASF, but the time and cost have been significant. For example, in Spain and Portugal, eradication took 30 years. Complete depopulation was required to rid Malta and Dominican Republic of the ASF virus. The virus is currently moving across Eastern Europe with alarming speed, with outbreaks in Georgia, Russia, and Ukraine. As of 2015, there were also reports of infection in Lithuania, Latvia, and Poland. The disease has spread when migrating wild boars infect domestic livestock populations.

A host of other zoonotic diseases are of concern to the agriculture sector and bear scrutiny. Highly Pathogenic Avian Influenza (HPAI) infections in 2014 and 2015 resulted in 223 cases of HPAI in domestic flocks in 15 states and the culling of 48 million chickens, turkeys, and other poultry to halt the spread of the disease.[10] The Ebola outbreak from 2014 to 2016 affected ten countries (including the United States). It caused 11,325 deaths out of 28,652 cases. These examples demonstrate the reach and speed of these zoonotic diseases.[11]

Changing climate patterns cause changing disease patterns for humans, plants, and animals. One example of a changing disease pattern is the Zika virus, a zoonotic disease spread by mosquitoes that has the potential to cause birth defects and long-term neurological effects in affected populations. The *Aedes aegypti* and *Aedes albopictus* mosquitoes, which are the known vectors of the disease, are now endemic to almost half of the continental United States—implying negative prospects for preventing endemic Zika.[12] While there is no evidence of Zika being passed directly from livestock to humans, we do know that livestock can become infected by the Zika virus through mosquito bites. Additional research is necessary to understand the effects of the Zika virus in animals, including livestock.[13]

Equally concerning is the potential for the deliberate introduction of these diseases or bioterrorism. Such an event would have serious national security and economic effects.

A National Security and Economic Security Issue

The Amerithrax attacks in 2001 caused a serious reevaluation of the potential for deliberate use of a biological pathogen to inflict harm, kill people, and even destroy economies. The

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[9] World Organization for Animal Health, "Foot and Mouth Disease: What is Foot and Mouth Disease," undated.

[10] Joel L. Greene, "Update on the Highly-Pathogenic Avian Influenza Outbreak of 2014–2015," *Congressional Research Service*, July 20, 2015.

[11] CDC, "Ebola (Ebola Virus Disease): 2014–2016 Ebola Outbreak in West Africa," last updated June 22, 2016.

[12] CDC, "Zika Virus: Potential Range in US," last updated September 20, 2017.

[13] Daniel M. Gerstein, "Cuts to US Bioterror Funds Risk Peril in Event of Attack," *The Hill*, June 6, 2017.

mailing of five anthrax-laden letters through the U.S. postal system resulted in the infection of 22 people, five of whom died; the treatment of some 30,000 people with high-strength antibiotics; and the decontamination of several buildings.[14] The total cost of the decontamination was estimated to be over $320 million.[15] Another important outcome was the dramatic increase in funding for U.S. government civilian biodefense spending, from $685.1 million in 2001 to over $8 billion in 2009.[16]

In considering the potential for an agricultural bioterror attack, one must remember that opportunity and malicious actors coexist in what could be a dangerous combination should such actors decide to attack agricultural targets. One analysis assessed that FMD-endemic countries collectively contain three-quarters of the world's population.[17] Furthermore, the nature of many zoonotic diseases is such that little planning or weaponization would be required to perpetrate such an attack. In the case of FMD or ASF, only an exchange of fluids containing the virus would be necessary to cause such an outbreak. Finally, as much of the focus has been on human bioterrorism, this leaves agro-bioterrorism as a perceived soft target.

Recognition of the biological attack threat became so pervasive that in the 2005 Homeland Security Planning Scenarios, four of the 15 scenarios were directly related to a bioterror attack (a fifth was a natural outbreak of pandemic influenza). Particularly noteworthy, two of the scenarios involved attacks on the agriculture and food system (terrorists infecting livestock at specific locations and terrorists contaminating food with anthrax in processing facilities).[18]

The economic impact of an agricultural biological incident would include direct loss of crops, livestock, and assets; secondary losses in upstream and downstream markets; lost export markets; significant price effects; and an overall reduction in economic growth. It would also require the unplanned expenditure of resources for response and recovery. Secondary and tertiary effects include long-term environmental problems (the need to bury/lime the killed animals) and social and political impacts, such as reduced confidence in government, reduced confidence in food safety, and social disruption resulting from fear.

In the United Kingdom, a 2001 FMD outbreak resulted in dire consequences, with 57 farms affected, 2,026 cases confirmed, six million animals destroyed, and economic losses of estimated

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[14] Department of Justice, *Amerithrax Investigative Summary*, Washington, D.C., February 19, 2010.

[15] Ketra Schmitt and Nicholas A. Zacchia, "Total Decontamination Cost of the Anthrax Letter Attacks," *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science*, Vol. 10, No. 1, 2012.

[16] Crystal Franco, "Billions for Biodefense: Federal Agency Biodefense Funding, FY2008–FY2009," *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science*, Vol. 6, No. 2, 2008.

[17] T. J. D. Knight-Jones and J. Rushton, "The Economic Impacts of Foot and Mouth Disease—What Are They, How Big Are They and Where Do They Occur?" *Preventative Veterinary Medicine*, Vol. 112, No. 3–4, November 1, 2013, pp. 161–173.

[18] Brookings Institute, "Homeland Security Planning Scenarios and Summary Descriptions," undated.

losses from FMD of U.S. $10.7 to $11.7 billion.[19] Additionally, 60 farmers' suicides were attributed to loss of livelihood from the FMD incidents.[20]

More recently, a Kansas State University study on the potential effects of an FMD outbreak found "estimated losses to producers and consumers at approximately $188 billion and additional government losses at $11 billion, assuming no emergency vaccination was implemented."[21] Even with an emergency vaccination program, the losses were estimated to be $56 billion for producers and consumers and $1.1 billion in governmental costs.[22]

The HPAI outbreak was costly for the poultry industry, with turkey and laying hen losses estimated at nearly $1.6 billion and economy-wide losses are estimated at $3.3 billion. Eighteen U.S. trading partners imposed bans on U.S. poultry and products, and 38 others imposed partial or regional bans on shipments from states or parts of states with HPAI cases. Three of the top 10 destinations for U.S. poultry meat in 2014—China, Russia, and South Korea—have banned all imports of U.S. poultry.[23]

Both experience and estimates indicate the potential for adverse national and economic security outcomes from a biological incident, either naturally occurring or deliberate. Entire industries could be devastated, and recovery from such an event could take years even in the best of cases.

U.S. Laws, Policies, and Regulations as Part of a Larger International System

International public health and security institutions provide the basis for U.S. agricultural biodefense efforts. The World Health Organization, Food and Agriculture Organization of the United Nations, and World Organization for Animal Health combine to provide technical information on diseases, strategies for preventing outbreaks of infectious diseases and monitoring for human and animal health issues.

The global "One Health" concept recognizes that human health, animal health, and the environment are inextricably related.[24] These linkages allow for better understanding of the complex relationships between humans, animals, and the environment, in many cases allowing earlier disease identification in one sector by observing the spread of disease in another sector. For example, understanding which strains are circulating in the flyways of the avian populations

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[19] Dustin L. Pendell, John Leatherman, Ted C. Schroeder, and Gregory S. Alward, "The Economic Impact of a Foot-and-Mouth Disease Outbreak: A Regional Analysis," paper prepared for presentation at the Western Agricultural Economics Association Annual Meeting, Portland, Oreg., July 29–August 1, 2007.

[20] Oklahoma Agriculture Food and Forestry, "At What Cost? 2001 and 2007 Foot and Mouth Disease Outbreak United Kingdom," undated.

[21] Kansas State University, "New Research Shows the Simulated Economic Impact of a Foot-And-Mouth Disease Outbreak," *ScienceDaily*, October 27, 2015.

[22] Kansas State University, 2015.

[23] Greene, 2015.

[24] CDC, "One Health," last updated August 1, 2017.

can assist in predicting which strains of seasonal influenza are likely to be most prevalent in humans.[25]

The Biological and Toxin Weapons Convention prohibits the "development, production, acquisition, transfer, retention, stockpiling and use of biological and toxin weapons."[26] It entered into force in 1975 and has served as the unequivocal norm against the use of biological weapons. This international convention pertains to the use of biological pathogens or toxins for use against humans, animals or plants.

United Nations Security Council Resolution 1540, established in 2004, mandates "all states shall refrain from providing any form of support to non-state actors that attempt to develop, acquire, manufacture, possess, transport, transfer or use nuclear, chemical or biological weapons and their means of delivery, in particular for terrorist purposes."[27]

U.S. law concerning biological weapons is contained in law regarding weapons of mass destruction in 18 U.S.C. Sec. 2332a. The law was originally established in 1996 (and has been updated several times). It prohibits use of "any weapon involving a biological agent, toxin, or vector."[28] Other legal mechanisms codified in international and national export control laws serve to limit the proliferation of potentially dangerous dual-use material, equipment and knowledge.

The security of our agriculture and food production systems is critical to our economic, social, political well-being, and security. Given this broad array of interests, a wide range of stakeholders have direct and indirect interests in agricultural biodefense.

The public health and security institutions collectively have served as foundations for numerous U.S. presidential policies, directives, and executive orders for biodefense including in the agricultural sector.

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[25] Mathieu Fourment, Aaron E. Darling, and Edward C. Holmes, "The Impact of Migratory Flyways on the Spread of Avian Influenza Virus, *BMC Evolutionary Biology*, Vol. 17, No. 1, May 25, 2017.

[26] United Nations Office for Disarmament Affairs (UNODA), "The Biological Weapons Convention," undated.

[27] UNODA, "UN Security Council Resolution 1540 (2004)," undated.

[28] United States Code, Title 18, Section 2332a, Use of Weapons of Mass Destruction, 1996.

Table 1. Presidential Directives and Legislation Related to Agricultural Biodefense

Presidential Directives and Legislation Related to Agricultural Biodefense	Description
Homeland Security Act of 2002	PIADC transferred to DHS; DHS provides for USDA/APHIS/ARS activities on site
Animal Health Protection Act (7 U.S. Code § 8306—Seizure, Quarantine, and Disposal) (2002)	Authorized the Secretary of Agriculture to declare an extraordinary emergency due to "the presence in the United States of a pest or disease of livestock and that the presence of the pest or disease threatens the livestock of the U.S." The Secretary is granted authority to take action within states if state-directed control/eradication measures are found to be inadequate
Emergency Support Function (ESF) 11—Agriculture and Natural Resources	Activation of a coordinated federal incident response (as part of the *National Response Framework*) in the event of a threat to U.S. agriculture or food security. Integrates the federal, state, tribal, and local response to an outbreak of a contagious and/or economically significant pest or disease
HSPD-9—Defense of United States Agriculture and Food (January 30, 2004)	DHS and USDA are to "develop a plan to provide safe, secure, and state-of-the-art agriculture biocontainment laboratories that research and develop diagnostic capabilities for foreign animal and zoonotic diseases."
HSPD-10—Biodefense for the 21st Century (April 28, 2004)	Assigns roles and responsibilities for preventing, protecting against, and mitigating biological events. Describes the four key areas—or pillars—of national biodefense (including agriculture).
HSPD-18—Medical Countermeasures against Weapons of Mass Destruction (January 31, 2007)	Establishes policy to address the challenges presented by chemical, biological, radiological, and nuclear weapons of mass destruction and the need for medical countermeasures.
HSPD-21—Public Health and Medical Preparedness (October 18, 2007)	Applies and expands the four pillars of biodefense from HSPD-10 to public health preparation.
Food, Conservation, and Energy Act of 2008 (Farm Bill 2008) (June 18, 2008)	Authorizes Secretary of Agriculture to issue FMD permit to successor facility to Plum Island (removes statue to require FMD on PIADC)
A National Blueprint for Biodefense (Bipartisan Report of the Blue Ribbon Study Panel on Biodefense) (October 2015)	Panel on Biodefense to assess how much has been done to address the biological threat and what remains undone. Despite significant progress on several fronts, the Nation is dangerously vulnerable to a biological event. The root cause of this continuing vulnerability is the lack of strong centralized leadership at the highest level of government.

NOTE: APHIS = Animal and Plant Health Inspection Service; ARS = Agricultural Research Service; HSPD = Homeland Security Presidential Directive.

Research and Development is an Essential Component of Maintaining a Healthy and Vibrant Agricultural Sector

Multiple government and nongovernmental organizations have responsibilities and authorities in agricultural biodefense. The types of R&D each organization performs relate directly to the missions implied and specified by the responsibilities and authorities of each. Furthermore, since the agricultural sector is almost exclusively owned and operated by the private sector, close collaboration between the government and industry is imperative.

For example, USDA is the lead for food, agriculture, natural resources, rural development, and nutrition. Therefore, R&D directly related to these activities would be conducted by the USDA. Embedded in these responsibilities is the requirement for preparedness and response for

any FAD incident affecting domestic livestock or poultry.[29] This requirement is shared by USDA and DHS. Specifically, if requested by the Secretary of Agriculture, directed by the President, or if more than one federal agency becomes "substantially" involved in the incident, DHS may assume the lead for coordination of the response to a FAD incident.[30]

Therefore, in the case of preventing, protecting, mitigating, responding and recovering from an agriculture biodefense event (either naturally occurring or deliberate), USDA and DHS exercise a shared role, which requires "development of a coordinated strategy to adequately protect the Nation against biological threats to animal agriculture."[31] DHS, through the S&T Directorate, largely focuses on supporting the nation's response to a large-scale FAD incident and the bioterror threat.

The Homeland Security Act of 2002 made DHS the lead for bio and agro-defense research and development at PIADC. HSPD 9 in 2004 tasked the Secretaries of Agriculture and Homeland Security to develop a joint agro-defense strategy and criteria for the NBAF facility location. Specifically, it required the departments to "develop a plan to provide safe, secure, and state-of-the-art agriculture biocontainment laboratories that research and develop diagnostic capabilities for foreign animal and zoonotic diseases."

Since this legislation was enacted, DHS has managed the PIADC with elements from the USDA—APHIS and ARS—working on agro-biodefense issues. While the type of work has varied over time, a majority of the recent R&D at PIADC has focused on FMD, ASF and Classic Swine Fever (CSF). This relatively narrow R&D focus is based on several factors, including capacity limitations at PIADC, workforce expertise, and program cost.

To offset these factors, several strategies have been pursued for gaining access to necessary R&D. Commensurate with their responsibilities and authorities, other departments and agencies within the U.S. government conduct and/or fund R&D to support preparedness and response activities. For example,

- The Department of Health and Human Services develops policy on pandemic preparedness. It also provides guidance on using antiviral or antibiotic prophylaxis and personal protective equipment, and it supports U.S. border surveillance efforts.
- The Department of the Interior monitors and investigates wildlife disease, manages and protects public health on federal lands, and supports response to zoonotic outbreaks.
- The Environmental Protection Agency (EPA) provides technical assistance, expertise, and support for decontamination and disposal issues; supports investigations and provides intelligence support; and provides assistance and information on public health/medical aspects of hazardous materials.
- The Department of Justice coordinates the investigation of criminal activities if bioterrorism or agroterrorism are suspected.

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[29] USDA, "About the U.S. Department of Agriculture," undated.

[30] USDA, *APHIS Foreign Animal Disease Framework Roles and Coordination: FAD PReP, Foreign Animal Disease Preparedness and Response Plan*, Washington, D.C., September 2016.

[31] DHS, *National Bio and Agro Defense Facility (NBAF): Site Cost Analysis*, July 25, 2008.

- The Department of Defense supports USDA for animal disease preparedness, response, and recovery efforts. [32]

Additionally, in areas where departments and agencies overlap responsibilities and authorities, cross-government coordination of R&D efforts normally occurs. For example, on the management of the depopulation of infected livestock from a potential FMD outbreak, DHS, USDA, and EPA have important roles and dialogue and coordination has occurred on the issue.

Within DHS S&T, a variety of R&D programs were underway in key FAD areas. Tools to support planning and response drive requirements for countermeasures development and inform post-outbreak response activities by creating scalable (local to national) simulation and modeling tools to analyze potential responses and control options to minimize FAD spread were being developed. Diagnostic tests, agricultural screening tools, biosurveillance capabilities and data integration procedures to identify infected animals more rapidly were also being considered. Vaccines to prevent disease in healthy animals, limit disease spread among a herd, and maintain business continuity were being developed. Depopulation activities including disposal and decontamination were also being examined.

One of the major accomplishments from this R&D was the development of an FMD vaccine. Research from academia supported early efforts, PIADC scientists conducted R&D—including herd studies—and a vaccine developer from industry licensed and manufactured the vaccine. It is now available for use in the event of an FMD outbreak.

NBAF, the replacement for the PIADC, will provide new and important capabilities in agricultural biodefense. It will provide modern Biosafety Level (BSL)-2, BSL-3Ag, and BSL-4 laboratory space to conduct research and provide enhanced diagnostic capabilities on high-consequence foreign animal and zoonotic diseases in livestock. It will also provide increased capacity for herd studies and trials, which should decrease the time required to gain USDA approval for agricultural countermeasures and vaccines.[33] Increased capacity could also allow the study of zoonotic diseases other than FMD, CSF, and ASF. These diseases include Rift Valley Fever, Newcastle Disease Virus, Ebola, Venezuelan Equine Encephalitis, HPAI, and perhaps even a new zoonotic EID that would require study in a BSL-4 containment facility.

One cautionary note is in order regarding NBAF. Operating and maintaining high-containment biological laboratories is costly and requires consistent funding. The recent proposal by DHS to close the National Biodefense Analysis and Countermeasures Center (NBACC), a specially designed facility for conducting bioterror threat assessments and bioforensics, was based on fiscal pressures.[34] While the final disposition of NBACC has yet to be determined, NBAF could experience the same tensions if it is not properly utilized and funded.

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[32] These examples come from a USDA briefing (USDA, "Roles and Coordination, APHIS Foreign Animal Disease Framework" September 2016.)

[33] The Center for Veterinary Biologics, a unit in Veterinary Services under APHIS in the USDA, under the jurisdiction of the Virus-Serum-Toxin Act, regulates veterinary biologics products in the United States.

[34] Daniel M. Gerstein, "A Countering Bioterrorism Facility Worth a Second Look," *RAND Corporation*, June 2, 2017.

Another strategy has been collaboration with international partners on FAD issues. Australia maintains an agricultural high containment laboratory that is investigating the Nipah and Hendra viruses, two relatively recently discovered zoonotic diseases that are of concern. By collaborating closely with Australia on researching these viruses, the U.S. benefits without having to directly conduct the R&D. Collaboration with Sweden on *Francisella tularensis* (the causative agent for tularemia)—a potential bioterror weapon—has expanded our knowledge of this pathogen. Likewise, collaboration with the United Kingdom, following their two FMD outbreaks in 2001 and 2006, filled in important knowledge gaps for development of preparedness and response capabilities.

The National Animal Health Laboratory Network (NAHLN) has its roots in the Homeland Security Act of 2002 and the HSPD-9. The network represents a shared enterprise bringing together Federal, State, and university-associated animal health laboratories to support "early detection, rapid response, and appropriate recovery from high-consequence animal diseases."[35] The network contains two reference laboratories in Ames, Iowa, and Plum Island, New York, operated by the federal government and includes over 60 state and university-associated laboratories. State support for the NAHLN has totaled almost $100 million annually.[36]

State and local authorities—in particular, those with large agricultural industries—have developed plans for preparing for and responding to an agricultural biodefense incident. While these entities are not involved in R&D, they must coordinate with the federal and industry planning efforts and would benefit by awareness of R&D that is ongoing.

The private sector and academia have made and must continue to make essential contributions to agro-biodefense R&D. Industry's central role is obvious given the that ownership and operation of the enterprise is almost exclusively within the private sector. As such, industry is involved in all aspects of ensuring the continuing vitality of and innovation in the agricultural sector, including in biodefense. Any disruption to normal functioning of the agricultural system could result in loss of access to U.S. and foreign markets and large financial losses. Programs such as tracking of livestock, control at border locations, pen-side diagnostics, tracking of agricultural by-products from farm to table, and rapid response and recovery to outbreaks are essential functions that involve and are supported by the agricultural industry.

Academia provides R&D as well as innovation that are imperative for continued improvements in agro-biodefense. Early research on specific diseases improves understanding of the mechanisms of action of specific diseases and can help develop diagnostics, countermeasures, and vaccines. The DHS S&T Directorate recently funded two Centers of Excellence co-led by three universities doing agro-biodefense: the Food Protection and Defense Institute, led by the University of Minnesota, and the Zoonotic and Animal Disease Defense, co-led by Texas A&M University and Kansas State University.[37]

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[35] USDA, "About NAHLN," last updated November 2, 2016.

[36] APHIS, "National Animal Health Laboratory Strategic Plan," September 2014.

[37] DHS, "Science and Technology: Welcome to the Centers of Excellence," undated.

Looking to the Future

Several areas of emphasis should be considered for future agricultural biodefense R&D.

- R&D solutions must be systems-oriented. The full range of threats—from naturally occurring dangers to deliberate use of biological pathogens—should be examined. Analysis should also include the full range of activities, from international spread of disease to the U.S. supply chain, which begins with transborder crossing of livestock to the farm-to-table activities that underpin the agricultural sector. Improvements in processes and technologies can improve outcomes and protect these critical sectors.
- Good disease monitoring will be important to continuity of business. It enables early detection, rapid response and recovery, and accurate communications across all interested governmental and nongovernmental entities. Delays in any of these critical components will cause greater economic losses and delay recovery.
- Cross-sector collaboration, including end-user participation, is vital for preparedness and response capabilities. The livestock industry and producers, government officials (including state animal health officials), the biopharmaceutical industry and veterinarians, first responders and diagnostic laboratories will need to collaborate in real-time to solve problems and break any logjams that occur. This must also include developing trust between government and industry to accelerate capability development. R&D collaboration can be important to ensuring that the full range of needs are being met.
- Opportunities to field test technologies worldwide should be identified. Countries with endemic zoonotic diseases of interest to the U.S. government and agricultural sector should be identified and approached to ascertain their willingness to work as partners for countermeasure and vaccine trials.
- Next-generation zoonotic disease professional training should continue to be developed. Education programs that target gaps in agriculture defense workforce (to include in R&D) would be useful. Standardized training programs for first responders and the agriculture sector could assist in preparedness and response for an agricultural biodefense incident.
- Consistent funding for agricultural biodefense efforts is essential. Achieving the level of protection for this area will require investments in R&D, including in facilities such as PIADC and NBAF. States and local communities also must have the funding to operate and maintain the labs that are part of the NAHLN. Underfunding endangers a $1 trillion portion of the U.S. economy.

Conclusions

Agricultural biodefense is a crowded space with responsibilities shared across federal, state and local government officials to private industry that largely owns and operates the sector.

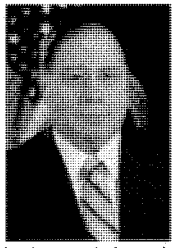
Since the establishment of DHS in 2003, USDA and DHS have had a shared role in agricultural biodefense, particularly in the area of R&D.

While much progress has been made in developing systems to oversee, track, and monitor FAD internationally and in the United States, the threats continue to grow because of socio-economic, environmental and ecological factors. With more global travel and trade and

encroachment into formerly uninhibited areas, the opportunities for the spread of disease continues to increase as does the potential for a FAD to penetrate the United States.

I appreciate the opportunity to discuss Federal Research and Development for Agricultural Biodefense and look forward to your questions.

Dr. Daniel M. Gerstein
Dmgerstein@msn.com or gerstein@rand.org
C: 703.582.9121, W: 703.413.1100 x 5130



Dr. Daniel M. Gerstein joined the RAND Corporation in December 2014. Previously, he served in the Department of Homeland Security from August 2011 to December 2014 as Under Secretary (Acting) and Deputy Under Secretary in the Science and Technology Directorate. He is also an Adjunct Professor at American University in Washington, D.C.

Dr. Gerstein has extensive experience in the security and defense sectors in a variety of positions while serving as a Senior Executive Service (SES) government civilian, in uniform, and in industry. In DHS, he was responsible for the development and execution of the directorate's over $1 billion annual budget and championed the incorporation of operational analysis and technology roadmaps within the Department's research and development portfolio.

He began his professional career in the U.S. Army, serving on four continents while participating in combat, peacekeeping, humanitarian assistance, counterterrorism and homeland security. Dr. Gerstein also served for more than a decade in the Pentagon in various high-level staff assignments. Following retirement from active duty, Dr. Gerstein joined L-3 Communications as Vice President for Homeland Security Services, where he led an organization providing WMD preparedness and response, critical infrastructure security, emergency response capability and exercise support to U.S. and international customers. Before joining DHS, Dr. Gerstein served in the Office of the Secretary of Defense (Policy) as Principal Director for Countering Weapons of Mass Destruction (WMD).

Dr. Gerstein also has extensive experience in international negotiations having served on the Holbrooke Delegation that negotiated the peace settlement in Bosnia; developed and analyzed negotiating positions for the Conventional Armed Forces in Europe (CFE) talks; and developed an initiative to improve cross border communications between Andean Ridge nations. Additionally, Dr. Gerstein led an effort to develop a comprehensive biosurveillance system for the Department of Defense and led the Army's most comprehensive restructuring since World War II.

Dr. Gerstein is a frequent national security contributor. He has published numerous books, articles and commentaries on a wide variety of national and homeland security issues. He has also been interviewed on numerous television and radio programs including CNN, CNBC World, Hill Online, Voice of America, WUSA9 News and Federal News Radio. He has testified in front of Congress on several occasions.

He has been awarded numerous foreign, military and civilian awards, including the Department of State's Distinguished Service Award and the U.S. Army Soldiers Medal for heroism. He is also a member of the Council on Foreign Relations.

He graduated from the United States Military Academy and has masters degrees from Georgia Tech, the National Defense University and the U.S. Army Command & General Staff College, and a Ph.D. in Biodefense from George Mason University.

Chairwoman COMSTOCK. Thank you.
And we'll now recognize Dr. Higgs.

**TESTIMONY OF DR. STEPHEN HIGGS,
ASSOCIATE VICE PRESIDENT FOR RESEARCH AND DIRECTOR,
BIOSECURITY RESEARCH INSTITUTE,
KANSAS STATE UNIVERSITY**

Dr. HIGGS. Good morning, Chairman Comstock, Ranking Member Lipinski, Chairman Smith, Ranking Member Johnson and members of the Subcommittee, my name is Stephen Higgs and I'm the Director of the Biosecurity Research Institute, the BRI, at Pat Roberts Hall, Kansas State University. It's a privilege to be here today.

The BRI's mission is leading through research and education to protect agriculture and the public from biological threats. Over 20 different pathogens have been studied at the BRI but recent studies are focused on agents listed as priorities for the National Bio and Agro-Defense Facility (NBAF).

The State of Kansas committed $35 million to the NBAF Transition Fund to support activities aligned with the NBAF mission. Additional funds have been provided by federal agencies including the U.S. Department of Agriculture, the Department of Homeland Security, and from stakeholder industries, notably the National Pork Board.

For the first time since the 1980s, we have conducted livestock studies with the zoonotic Rift Valley fever virus in the United States. As I speak today, we are assessing susceptibility of white-tailed deer to Rift Valley fever virus. This is an important collaboration between Kansas State University and the USDA's Arthropod Borne Animal Diseases Research Unit.

Using currently circulating Japanese encephalitis virus, another vector-borne zoonotic pathogen, we have infected North America mosquitoes and domestic swine. The BRI is the first non-federal U.S. facility ever to be approved to work on African swine fever and classical swine fever viruses.

To perform NBAF-related agricultural research since 2011 over 250 people have been trained and passed the background checks required for registration to work with so-called select agents that are NBAF priorities. Fellowships to train transboundary animal disease professionals have been supported by funds from the Department of Homeland Security although we have unfortunately heard that they lack the funds to support this important NBAF-related training beyond 2018. I did, however, meet the deputy administration of USDA's Office of National Programs to discuss collaborative efforts between the University and the USDA for NBAF workforce development.

As the first operational land grant university, Kansas State has 150 years of committed agricultural research, some of which is described in my written testimony. As I comment more on NBAF, I am not representing the views of DHS or USDA. NBAF is not just a replacement for the aging Plum Island. NBAF will provide a critical new capacity to enhance the Nation's ability to understand and respond to the world's most dangerous pathogens. NBAF will enable research with livestock infected with agents requiring biosafety level IV containment. It's remarkable to me that other coun-

tries have federally funded laboratories to do such work but the United States does not. As in other countries, we must have a long-term federal funding commitment to support not just the operation of NBAF but also the vitally important research and training that will be performed there.

In 2015, the bipartisan Blue Ribbon Study Panel on Biodefense published its national blueprint for biodefense. Sadly, the most important conclusions were that the U.S. lacked leadership, a strategic plan and dedicated budget for biodefense. Last January, two panel members held a hearing at Kansas State titled Agrodefense: Challenges and Solutions. Congressman Roger Marshall provided a Congressional perspective. Interestingly, in the subsequent report, it was recommended that the DHS and the USDA should develop a business plan for NBAF. When in Manhattan members met leaders of the Kansas Intelligence Fusion Center. With expertise on diseases of plants, animals and people, members of the Center's biothreat team helped to evaluate many reports related to biological threats to U.S. citizens and agriculture.

Eighteen years ago, President Wefald of Kansas State testified before the U.S. Senate's Emerging Threat Subcommittee to discuss biological weapons, the threats to our agricultural economy and food supply. With little tangible action since then, we face a prospect of managing under crisis conditions a biological event that is spreading out of control from state to state. These threats go far beyond disrupting our ability of putting food on the table. They have serious consequences on employment, trade, and global economy.

And on that note, I thank you for the opportunity to talk.

[The prepared statement of Dr. Higgs follows:]

STATEMENT FOR THE RECORD
By
STEPHEN HIGGS Ph.D., F.R.E.S., F.A.S.T.M.H
ASSOCIATE VICE PRESIDENT FOR RESEARCH AND
DIRECTOR, BIOSECURITY RESEARCH INSTITUTE
KANSAS STATE UNIVERSITY

Before the

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

"PUTTING FOOD ON THE TABLE – A REVIEW OF THE IMPORTANCE OF AGRICULTURAL RESEARCH"

NOVEMBER 2, 2017

Good morning Chairman Comstock, Vice-chairman Abraham, Ranking-Member Lipinski, and Members of the Subcommittee on Research and Technology.

My name is Stephen Higgs, and I am the Director of the Biosecurity Research Institute (BRI), Pat Roberts Hall, Kansas State University.

Thank you for the opportunity to speak to you today regarding the importance of our relationships with the National Bio and Agro-defense Facility that is under construction in Manhattan, Kansas, and the significance of this with respect to potential threats to American Agriculture

Kansas State University's Biosecurity Research Institute (BRI): Agriculture research and current and expected relationships with the National Bio and Agro-defense Facility (NBAF)

The mission of Kansas State University's Biosecurity Research Institute (BRI) is "leading through research and education to protect agriculture and the public from biological threats." The construction of the 113,000 square-foot facility was completed in 2007 at a cost of approximately $54 million. Within the 41,000 square-foot space dedicated to research and education, 31,300 is designed and operated for high-containment research suitable for pathogens requiring biosafety level three (BSL-3) procedures. The agricultural focus of the BRI's program is unusual in its breadth, with purpose-designed areas equipped for research on foodborne pathogens, plant pathogens, and pathogens that infect animals, including livestock and humans.

Following the selection of Manhattan, Kansas as the site for construction of the National Bio and Agro-defense Facility (NBAF) in 2009, the State of Kansas committed $5 million a year for seven years – the NBAF Transition Fund – to support research, education, and training activities aligned with the mission of NBAF. Research at the BRI since 2009 has included studies with more than 20 different pathogenic organisms including *Bacillus anthracis* (anthrax), *Brucella melitensis* (brucellosis), *Yersinia pestis* (plague), porcine epidemic diarrhea virus, porcine

reproductive and respiratory syndrome virus, and Schmallenberg virus. Recent studies on animal pathogens have focused largely on agents that were listed as priorities for NBAF; however, research on other animal pathogens — such as highly pathogenic avian influenza, yellow fever virus, and Zika virus — and research on plant and foodborne pathogens has continued in designated areas.

Refocusing on NBAF priority pathogens at the BRI has required some construction work and considerable investment to meet federally mandated regulations related to research with the high-consequence pathogens that will ultimately be used at the NBAF. The long approval process that involved multiple inspections by Centers for Disease Control and Prevention (CDC), U.S. Department of Agriculture (USDA), and Department of Homeland Security (DHS) personnel culminated in the BRI gaining approval as the first non-federal U.S. facility to work on African swine fever virus (ASFV) and classical swine fever virus (CSFV), also known as hog cholera. Prior to receiving approval, one veterinary pathologist was supported by the NBAF transition fund to work in the Australian Animal Health Laboratories (the Australian government's NBAF equivalent). Both of these pathogens could cause high mortality rates in domestic and feral swine if introduced into the U.S., with significant effects on production and trade. Multidisciplinary and collaborative research at the BRI has focused on methods of diagnosing the pathogens, approaches to developing vaccines — including expression of viral proteins using a variety of platforms — and, in collaboration with scientists at Lawrence Livermore National Laboratories, research to characterize at a genetic level the interactions between the ASFV and the infected swine host. Some funding has been provided by stakeholder industries, notably the National Pork Board.

From 2011-2016, another veterinary pathologist was supported, in part by DHS funds and in part by Kansas NBAF transition funds, to work at the Plum Island Animal Disease Center (PIADC). Her doctoral project on ASFV was co-supervised by two PIADC USDA scientists. Upon graduation, the student was offered and accepted a position at the Friedrich-Loeffler Institute (Germany's NBAF equivalent). As we move forward with workforce development for NBAF, it is important that we align training with needs and develop and execute a retention plan.

Research in the BRI with Rift Valley fever virus (RVFV) involved the first studies with livestock to be performed in the U.S. since the 1980s. Ongoing collaborative research between K-State scientists and scientists of the USDA's Arthropod Borne Animal Diseases Research Unit (ABADRU), based at the Center for Grain and Animal Health Research (CGAHR) in Manhattan, Kansas, is investigating — for the first time ever — the capacity of RVFV to infect North American white-tailed deer. As observed with West Nile virus that was introduced in the U.S. in 1999, the involvement of wild animal reservoir species is a critical component by which foreign transboundary animal diseases (TADs) can become established in the U.S. if they are accidentally or deliberately introduced here.

Work with Japanese encephalitis virus (JEV) at the BRI included the first infections of North American mosquitoes with currently circulating JEV strains and detailed evaluations of infections of swine. With the exception of JEV, all of the viruses and most of the other pathogens that will be used at the NBAF are designated as Select Agents (SA). The term SA was first used in the 1997 Select Agent rule (42 CFR part 73) to define biological agents and toxins

determined to "have the potential to pose a severe threat to public health and safety." The Federal Select Agent Program (FSAP) was expanded by new USDA rules in 2002 to include pathogens determined to have the potential to pose a severe threat to animal health or animal products (9 CFR part 121) or to plant health or plant products (7 CFR part 331). These additional SA rules were called for by the USA PATRIOT Act (2001) and Public Health Security and Bioterrorism Preparedness and Response Act (2002), which were written in response to the 911 attacks and subsequent Amerithrax letters.

These studies have involved multiple K-State scientists, primarily from the College of Veterinary Medicine, with expansion of their research support teams. Since the commencement of NBAF-related research in 2011, over 250 people have completed training, passed the required background checks, and been approved for Select Agent Registration. With a turnover of approximately 15 SAR-approved people per year, the BRI now has an SAR-approved workforce of approximately 115 people at a given time, with an additional 30 researchers that work on pathogens that are not SA.

NBAF will require a workforce of approximately 400 people, but it is unlikely that many of the existing PIADC staff will relocate to Manhattan. As a result, K-State is committed to helping train the future NBAF workforce. The BRI research already mentioned contributes to this workforce training effort because graduate, veterinary, and undergraduate students are working on many of the projects supported by the NBAF transition fund.

In addition, an $887,000 award from DHS supports "Research and Development Fellowships for Transboundary Animal Disease Professionals." A supporting award of $500,000 from the NBAF transition fund indicated K-State's commitment. Although the training is primarily based at the BRI, we developed an agreement with Boston University's National Emerging Infectious Diseases Laboratories (NEIDL) to provide training for fellows in BSL-4 practices and procedures. The inclusion of BSL-4 pathogen research in livestock at NBAF is an entirely new scope above and beyond what can be performed at PIADC or anywhere else in the U.S. No facility in the U.S. can presently provide the BSL-4 training for agricultural research that will be needed in the NBAF. With appropriate investment, this training could be developed at the BRI. In 2017, we held a class on TADs taught by K-State faculty under the direction of Dr. Alfonso Torres, a past director of PIADC. The BRI's relationship with Dr. Torres includes his position as an external advisory board member, but also as a facilitator that has enabled me to participate in teaching a course at PIADC.

Training at the BRI has been expanded for alignment with the needs of NBAF, to include five new for-credit courses offered though the Department of Diagnostic Medicine and Pathobiology in the College of Veterinary Medicine. For the USDA, we have taught a high-containment laboratory practices and techniques course offered over two years to scientists selected by the USDA from 15 different countries, but we were recently informed that funds are inadequate to support the course in 2018.

The operation of the BRI by K-State was a significant factor in the selection of Manhattan as the site for NBAF construction. Furthermore, not only was the land on which NBAF is being constructed donated by the University to DHS, but the State of Kansas also provided $307

million as a contribution to construction costs, and the City of Manhattan contributed another $5 million. These early commitments to support NBAF provided a foundation on which we have built an excellent, trusting relationship with DHS and the USDA. We expect to continue our research, educational, and training activities on NBAF priority pathogens at the BRI, and we will work to build upon our existing relationships with DHS and the USDA. As NBAF progresses toward operation, we expect to expand our activities to help train the needed workforce. We will consider any request from DHS and USDA to support current PIADC needs and needs related to bringing NBAF online.

Last week, two K-State leaders and I met with the new Deputy Administrator of USDA's Office of National Programs to discuss workforce development and training related to NBAF and how the BRI, College of Veterinary Medicine, and CGAHR staff could work together to plan strategically to accomplish staffing and research goals. In addition to research, NBAF will also have responsibility for the diagnosis of pathogens in samples collected from animals with symptoms such as vesicular diseases that could indicate infection with TADs. Ultimately, we want to provide expertise and other support to enable NBAF to gain SA approval, begin its research mission, and establish training programs that have been ongoing at the PIADC for decades.

Kansas and Kansas State University's role in the field of agriculture research
Kansas State University is a leader in addressing global food system challenges as we work to feed a world population that is estimated to reach more than 9 billion by 2050. As a land-grant university, we are proud of our 150-year commitment to making the best use of resources and protecting our population. Areas in which we excel include:

- Developing and using cutting-edge tools such as unmanned aerial systems and mobile applications to collect and analyze phenotypic plant data such as disease resistance, plant height, or seed size to develop improved crop varieties;
- Developing feed nutrition, genetics, and artificial insemination techniques that help pigs grow 30 percent faster — with 20 percent less feed per pound of gain — than they did 20 years ago;
- Developing technologies and strategies to help farmers effectively manage groundwater;
- Fighting antimicrobial resistance in agricultural production through research that helps reduce use of antibiotics while protecting animals from common diseases and helps identify how diseases are spread through feed ingredients and other vectors;
- Applying knowledge gained from international agricultural research in areas such as sorghum breeding to increase U.S. production and fight the sugarcane aphid, a growing threat in Kansas;
- Fighting common wheat diseases that decrease worldwide yields with interdisciplinary teams that have developed wheat breeding lines with genetic resistance to disease vectors and the diseases themselves;
- Decreasing postharvest loss by developing new controls for pests of food products and detecting resistance to fumigant pesticides for stored grain;
- Engineering better agricultural machinery and precision agriculture to help farmers optimize production; and
- Developing vaccines to protect animal health.

As mentioned above, research at the BRI, together with related training and education, is considerably broader than the activities planned for NBAF that focus strictly on TADs in livestock (excluding poultry). With principle investigators from K-State's College of Agriculture (Department of Plant Pathology, Department of Animal Science and Industry), the BRI has conducted research on wheat blast disease and multiple Shiga-toxin producing strains of *E. coli.* As described above, since 2009, projects supported by several state, federal, and industry awards have involved more than 20 different pathogens, including *Bacillus anthracis*, known as anthrax. As new pathogens like Zika virus continue to emerge, the BRI has the capability and expertise to quickly respond and develop collaborative projects to improve our understanding of the agents and assist with the development of diagnostics and vaccines.

K-State's National Agricultural Biosecurity Center located in Pat Roberts Hall with the BRI, has received funding to support the U.S. National readiness program that provides training to first responders who would be involved in controlling an outbreak of a foreign animal disease (FAD). The NABC has received funds from the Kansas NBAF transition fund to identify routes by which TADs might enter the U.S. and thus more effectively target surveillance at high-risk areas.

On June 15 of this year, Dr. John Floros, Dean of K-State's College of Agriculture, gave testimony to the Senate Committee on Agriculture, Nutrition, and Forestry and described the importance of agricultural research. As mentioned in his testimony, K-State has four federally funded Feed the Future Innovation Laboratories. On November 4, 2015, Dr. Tammy Beckham, then Dean of K-State's College of Veterinary Medicine, delivered testimony to the House Committee on Agriculture on "American Agriculture and Our National Security" and discussed the significant issues revealed in the bipartisan report of the Blue Ribbon Study Panel on Biodefense (see below).

NBAF capabilities compared with PIADC and BRI's relationship with PIADC

Although not representing views of DHS or USDA, as the K-State's BRI Director, I am reasonably well informed on the mission and research intents for NBAF, both from personal interactions with DHS and USDA personnel and from publicly available information. The NBAF is not just a substitute for the Plum Island Animal Diseases Center (PIADC), but rather will provide a new capability that has long been missing from the repertoire of the nation's ability to understand and respond to the world's most dangerous pathogens. Approximately 70% of new, emerging, and reemerging human diseases are estimated to have transmission cycles that involve other animals — so-called zoonotic diseases. Stopping or slowing the spread of zoonotic diseases in the animal host could go a long way in protecting human health, but there has been little focus on that approach to date. Research at the PIADC precludes working on zoonotic diseases such as JEV and RVFV.

The NBAF will not only address this obvious omission from a program designed to better understand the threat of TADs, but much more importantly, it will enable research with livestock infected with agents that require BSL-4 containment. National, federally funded laboratories to study these highly dangerous pathogens are operated in a few other countries, and yet, the U.S. has lacked this capacity. NBAF will overcome this deficiency and therefore a long-term federal

funding commitment to support not just the operation of the facility, but also the vitally important research and training that will be performed there is critical.

Since the 1950s when the PIADC became operational, revolutionary advances have occurred in materials and technologies related to the construction and the safe, secure operation of biocontainment facilities. The NBAF will employ all that are currently available to become the most advanced facility of its kind in the world. The Kansas NBAF transition fund has supported a project at the BRI to evaluate the efficiency of the autoscan HEPA filtration housing systems that will be installed as a critical safety feature to ensure containment of pathogens in research areas of the NBAF. Such state-of-the-art design elements will ensure a level of safety, security, and structural integrity that exceed the standards set for such facilities.

NBAF will involve technologies that are highly dependent on a degree of computer connectivity monitoring that was unimagined when PIADC was built. With this dependence on IT comes both enhanced awareness and control for safety and security and some vulnerabilities for intrusion and disruption. In 2015, the BRI organized a Biocontainment Information Technology Directors conference, the first such meeting of its kind. Participants included PIADC personnel. IT personnel at the BRI remain in contact with the meeting participants, including those from PIADC.

BRI and Kansas State University's Research and Development activities with federal, state and local agencies and industry stakeholders
The BRI and other K-State entities have a diverse range of formal and informal relationships with both government agencies and industry. These go beyond financial relationships involving extramural funding and support of academic activities. For example, researchers at the USDA ABADRU and at PIADC have been given adjunct appointments in K-State academic units, including the College of Veterinary Medicine and the Department of Entomology in the College of Agriculture. Embedding future NBAF scientists into our research and educational activities not only provides opportunities for collaborative research, but also enables full participation on the committees of doctoral students that will have the relevant skills and interest for future employment at the NBAF. As mentioned above, the BRI provides high-containment research space for USDA ABADRU scientists.

A dedicated position of NBAF Liaison reports directly to the K-State president, and this enables leveraging long-established relationships with local and multinational industries whose interests and expertise are related to NBAF activities. Under this direction, stakeholder meetings have been organized in Manhattan to bring together PIADC personnel, including USDA scientists, DHS managers, senior Federal officials, and potential industry partners. This work complements some of the activities of the DHS NBAF Partnership Development Director, with whom we have a longstanding relationship.

Awareness of Threats to U.S. Agriculture and the Blue Ribbon Study Panel on Biodefense
In 2003, the National Academies of Sciences releases its report, "Countering Agricultural Bioterrorism," having been charged to *"Evaluate the ability of the United States to deter, prevent, detect, thwart, respond to, and recover from intentional biological attacks on the nation at the live plant and live animal stage of food and fiber production."* The impetus for this was

the realization that not only was U.S. agriculture susceptible to foreign diseases that could devastate productivity, but also that malicious actors had developed capacity to produce — and indeed had successfully produced in large quantities — agents that could be deliberately used against our agricultural industry.

In October 2015, a bipartisan report of the Blue Ribbon Study Panel on Biodefense was published. "A National Blueprint for Biodefense: Leadership and Major Reform Needed to Optimize Efforts"[1] made 33 major recommendations, but perhaps the most important conclusions were that:

(1) "there is no centralized leader for biodefense;"
(2) "there is no comprehensive strategic plan for biodefense;" and
(3) "there is no all-inclusive dedicate budget for biodefense."

One might have hoped that this stark declaration of the nation's lack of preparedness to detect, respond to, or, ideally, to anticipate and prevent an attack would have resulted in action, and yet the panel's follow-up report released in December 2016 proved otherwise. "Biodefense Indicators" revealed little progress on addressing any of the recommendations.

To begin addressing the agricultural shortcomings in the 2015 Blueprint, two members of the Blue Ribbon Study Panel held a hearing at K-State on January 26, 2017 titled, "Agrodefense: Challenges and Solutions." Kansas Congressman Roger Marshall provided a "Congressional Perspective" to launch the hearing. Nine others then presented to the Blue Ribbon members during three formal sessions. The first panel that I was on dealt with "Prevention and Deterrence;" the second with "Surveillance and Detection;" and the third with "Preparedness, Response, Recovery, and Mitigation." In addition, a luncheon keynote by Indiana State Veterinarian Dr. Bret Marsh, titled "Leadership in Protecting the Agricultural Sector," was highly informative.

In October 2017, the Panel published its findings from this hearing in "Defense of Animal Agriculture."[2] One pertinent comment was that "DHS and USDA should develop a business plan for the operation of the National Bio and Agro-defense Facility" that "should engage the public and private sectors; consider domestic and global markets for agrodefense research and development; and identify a dollar figure that defines both need and opportunity." A concern was expressed that "the president's Fiscal Year 2018 budget request would eliminate all agriculture and animal-specific research by the DHS Science and technology Directorate." The panel is meeting again today to discuss "the Implementation Plan for the National Biodefense Strategy and how the Administration should go about implementing the Strategy."

The day before the Blue Ribbon Study Panel hearing at K-State last January, the Panel heard from the Kansas Intelligence Fusion Center (KIFC) regarding its Biothreat Team efforts. I would like to conclude my written testimony by noting the relevance of the KIFC endeavors to this Committee's work and today's topic.

Shortcomings with the biological intelligence enterprise has been a major concern of the Blue Ribbon Study Panel, and the members were pleased to hear that Kansas has focused on biothreats for years, having cleared subject matter experts (SMEs) with expertise on infectious diseases of plants, animals, and people. That allows the KIFC to work to prevent disease

outbreaks of all kinds (operating "left of boom") rather than just attempting to diminish the severity of an outbreak after it hits (operating "right of boom"). Moreover, biological intelligence can monitor naturally occurring disease outbreaks globally — potentially predicting how and when the disease might come to the U.S. — and it can assess telltale signs of terrorist groups and state actors working on bioweapons. With agricultural pathogen SMEs involved on the Biothreat Team, the KIFC is not limited to monitoring only human biothreats.

When NBAF becomes operational in 2022/23, it will be able to conduct biological threat assessments on emerging livestock pathogens, whether animal-only or zoonotic. The BRI could conduct those assessments today for plant, animal, and food pathogens, with the exception of zoonotic pathogens for which there is no treatment (BSL-4 pathogens). When the BRI was completed about a decade ago, the required infrastructure was put in place to allow us to interface with the intelligence community regarding emerging biological threats.

Conclusion

Awareness of the impact that readily available biological agents would have if they were used against us is increasing — in both ourselves and in those who would harm us. Such action would not only disrupt "putting food on the table," but also would have serious consequences on employment, trade, and the global economy. This awareness is not new, but modern technologies make such an event increasingly feasible and increasingly likely. Interestingly, in 1999, then-K-State President Jon Wefald testified before the U.S. Senate's Emerging Threats Subcommittee regarding the surreptitious "agricultural biological weapons threat" to America's agricultural economy and food supply." K-State had proposed a "Homeland Defense Food Safety, Security and Emergency Preparedness Program" earlier in 1999. One cannot help but ask at what point we will be having such discussions while trying to manage — under crisis conditions — a biological event that is rapidly spreading out of control from state to state.

1. Blue Ribbon Study Panel on Biodefense. *A National Blueprint for Biodefense: Leadership and Major Reform Needed to Optimize Efforts – Bipartisan Report of the Blue Ribbon Study Panel on Biodefense*. Hudson Institute: Washington, DC, October 2015.

2. Blue Ribbon Study Panel on Biodefense. *Special Focus: Defense of Animal Agriculture*. Blue Ribbon Study Panel on Biodefense: Washington, DC. October 2017.

Stephen Higgs, PhD, FRES, FASTMH

Associate Vice President for Research
Director, Biosecurity Research Institute
Peine Professor of Biosecurity
University Distinguished Professor,
Diagnostic Medicine and Pathobiology
Kansas State University, Manhattan, Kansas

Immediate Past President, American Society of Tropical Medicine and Hygiene
Editor-in-Chief, Vector-Borne & Zoonotic Diseases

Stephen Higgs, an expert in vector biology, arthropod-borne infectious diseases, immune modulation and vaccine evaluation, became the director of Kansas State's Biosecurity Research Institute (BRI) in July 2011. He is responsible for oversight, coordination and expansion of the institute's multidisciplinary bio-secure research and education programs. This modern facility is the center for all select agent research at Kansas State University, and includes large animal spaces (ABSL-3) and an insectary (ACL-3) which allows for studies with animals and vectors in high containment. The mission of the BRI, "Leading through research and education to protect agriculture and the public from biological threats," is epitomized by its unique integration of interdisciplinary work on pathogens that infect livestock, people, and plants or contaminate food. As part of DHS workforce development plans for staffing NBAF, a DHS-funded fellowship program is based at the BRI. In addition, Dr. Higgs contributes to administration of a $35M award to facilitate collaborative and complementary research and training with State and Federal agencies related to the National Bio- and Agro-Defense Facility (NBAF).

Higgs serves as associate vice president for research, holds the Virginia and Perry Peine biosecurity chair and is a university distinguished professor in diagnostic medicine and pathobiology at K-State's College of Veterinary Medicine. He has held positions at the University of Texas Medical Branch, Colorado State University, and in the United Kingdom at Oxford and London. He has published more than 165 peer-reviewed papers, 18 book chapters and is active with past and ongoing membership on national and international research program review panels. Higgs served on The National Academies of Sciences, Engineering and Medicine review group, Gene Drive Research in Non-human Organisms, who published the book, *Gene Drives on the Horizon: Advancing Science, Navigating Uncertainty, and Aligning Research with Public Values*.

Developing collaborative, multidisciplinary research and education programs has resulted in funding awards through numerous competitive grants from Federal and private organizations to include the Bill & Melinda Gates Foundation He is a fellow and immediate past president of the American Society of Tropical Medicine and Hygiene and a fellow of the Royal Entomological Society. He is editor-in-chief of the international journal *Vector-Borne and Zoonotic Diseases*, and an editorial board member of *Health Security (*formerly *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science)*.

Higgs earned a doctorate in parasitology from Reading University in the United Kingdom and a bachelor of science with honors in zoology from King's College in London.

Chairwoman COMSTOCK. We now recognize Dr. Moose.

TESTIMONY OF DR. STEPHEN P. MOOSE,
DENTON AND ELIZABETH ALEXANDER PROFESSOR,
MAIZE BREEDING AND GENETICS,
DEPARTMENT OF CROP SCIENCES,
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Dr. MOOSE. Good morning, Chairwoman Comstock, Ranking Member Lipinski, and other distinguished members of the Subcommittee. Thank you for the opportunity to discuss with you putting food on the table.

I come to you today with a very personal commitment to this topic. My wife and I both grew up on farms. We were brought together by a state-sponsored fellowship for graduate school at North Carolina State University. We farmers became scientists. We have since devoted our lives through both education and research to bringing science back to the farm.

I will discuss with you three topics today: the government support of agriculture research, the partnerships among farmers and scientists and the private sector, and then the value of agriculture research. Although I'm using examples from my own personal experience, I'm here to represent the broad enterprise that is agriculture research.

So looking at the support, Abraham Lincoln sprouted agriculture research in this country through the creation of the People's Department, the United States Department of Agriculture. He also created through the Morrow Act the land grant universities. From their beginnings, land grant universities have shared with the federal government and they're the core of this shared responsibility of agriculture research. The largest piece of the federal research pie supports university research through competitive grants, and these come primarily through the USDA but also the National Science Foundation and, as Mr. Lipinski mentioned, the Department of Energy. Federal funding supports a healthy diversity of small exploratory research to large, multi-institutional centers. Furthermore, agriculture research is filled with many interagency partnerships. States and local communities also partner extensively on technology transfer and business development through Agriculture Innovation Districts such as the Research Triangle Park in North Carolina where universities are often the nucleus for job growth.

Lincoln's vision also considered fundamentally linked research and education. This year the University of Illinois celebrates 150 years of teaching farmers to become scientists and scientists to study the farm. We train the next generation of science leaders and the workforce.

So let's talk about partnerships. There's a long history of cooperation with agriculture research. I show in the picture, it's actually the longest running plant genetics experiment in the world, which I actually continue, me and my team. This experiment began in 1896 when a professor went to a local farmer's field, sampled ears of corn, and then decided to select for higher or lower grain protein, and the goal for this was to improve nutrition for animal feed. He did not know that this experiment would continue annu-

ally for the next 120 years, and as shown in the picture are my graduate students who completed that 120th cycle of this experiment.

In addition to the valuable knowledge we've gained about plant breeding, the earliest commercial corn hybrids, the parents, came from this germ plasm. Also, high-oil corn, which is a value-added trait that's been marketed since the 1990s, came from this experiment. So you just really don't know when this research will pay off. During the last 15 years, the National Science Foundation, the Plant Genome Research program, the USDA, as well as DuPont Pioneer and Monsanto Company, have supported this experiment.

So let's talk about the value then of these investments. Agriculture research generates tremendous long-term benefits to the U.S. economy. I show in the next slide there where just the example of corn, average corn yields in the United States. This tremendous increase has been powered by the compounding benefits of advances in science that I list there with genome editing and Big Data now being the emerging fields, if you will. And so these will drive further enhancements and yield nutritional quality and environmental resiliency.

Each bushel of corn yields $300 million at the farm gate and $1 billion to the U.S. consumer. Interestingly, for each of the technologies I list there, there was a lag period of at least a decade or more from the time of the initial discovery to the commercial application, and so one significant value of agriculture research is to reduce the risks for commercial adoption.

Finally, the last thing I will say is that there's an essential value to agriculture research that helps connect science with society, it connects farmers with science, and farmers to society, a three-way loop. So only two percent of our population is now engaged in agriculture. The other 98 percent are interested in food and through research, they're interested in research, so that value is immense.

So working together, future agriculture research will continue to put farm and food on the table.

Thank you.

[The prepared statement of Dr. Moose follows:]

BEFORE THE UNITED STATES HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

Stephen P. Moose

Denton and Elizabeth Alexander Professor of Maize Breeding and Genetics

Department of Crop Sciences
University of Illinois at Urbana-Champaign

2 November 2017
Washington, DC

Chairwoman Comstock, Ranking Member Lipinski, and members of the Subcommittee, thank you for the opportunity to participate in this important discussion today.

I am currently a Professor of Maize Breeding and Genetics, in the Department of Crop Sciences at the University of Illinois. Crop Sciences is housed in the College of Agriculture, Consumer, and Environmental Sciences, but I also have long-standing collaborations with our Institute for Genomic Biology and many other campus groups. I lead a research, education, and outreach program that focuses on genomic applications to crop improvement, in particular "big grasses" such as corn, sorghum, and more recently *Miscanthus* as a potential dedicated bioenergy crop (http://mooselab.cropsci.illinois.edu/). My laboratory group sequences plant genomes, designs

and builds variations into these genomes using breeding and biotechnology approaches, and then evaluates the performance of these genomes in the field. Our largest project is aimed at solving the genetic mysteries of hybrid vigor and nitrogen use efficiency in corn. I have taught courses in plant biotechnology and genomics for each of the past 18 years, where hundreds of students actively learn how to translate discovery into innovation. I am also active in service to my profession, for example as a member of the Advisory Board for the Department of Energy's Joint Genome Institute, and to the broader public, through presentations about crop biotechnology to a diversity of audiences.

I also come to you today with a strong personal commitment to today's topic, "*Putting Food on the Table...*". I was raised on a farm of dairy, honey, and hay. I first learned about genetics when I was 14, and became sufficiently fascinated with it to make it my career. I attended Case Western Reserve University, the only school in Ohio at that time which offered an undergraduate degree in biotechnology. I earned my doctorate at North Carolina State University, through the support of a graduate fellowship sponsored by the state of North Carolina. Even better, they also recruited my future wife, Shawn Carlson, to Raleigh. Shawn's family farms 1500 acres of dry beans and other crops in Michigan, including direct marketing to restaurants and stores. Once we farmers became scientists, we then began our journey to bring science back to the farm. We have done this through positions in both the crop biotechnology industry and universities, from California to Connecticut, and back to the Midwest. I share my story with you because it emphasizes my thoughts about the topics you invited me to discuss with you today. I am a living product of valuable contributions from local, state and federal governments, as well as strong partnerships among farmers, universities, and the private sector. ***Together, agricultural research connects farmers and scientists, and brings innovation back to the farm.*** These combined efforts have powered tremendous advances in agriculture that enable farmers to meet world demands for nutrition and the bioeconomy, and represent a solid foundation for future research and innovation with global impact. Simply stated, our agricultural research system is the envy of the world, with substantial benefits to U.S. citizens and the world.

I was invited to discuss with you the following three topics:

- Agriculture research efforts at the federal, state, and local government levels.
- The extent to which federally funded researchers at universities and other research institutions are partnering with the private sector, including with farmers, to advance agricultural research;
- The value of agricultural research and implications for the nation and world.

For each, I will highlight how past innovation has revolutionized society and our quality of life, and link these to future prospects for creating further value through agricultural research. For brevity, my examples will emphasize corn genetics, a truly American science, but I am here before you today as only one representative for the broader agricultural research ecosystem. This includes not only crops and livestock, but also engineering, food processing, economics, and environmental science. In each of these disciplines, agricultural research connects the farmer to science and scientists to farmers. Because of the strong public interest in food, agricultural research also engages society with both scientists and farmers, in ways that enrich all of our lives.

Agriculture research efforts at the federal, state, and local government levels

Formalized government investment in agricultural research in the United States was sprouted in the rich prairies of Illinois. One of our country's greatest Presidents, Abraham Lincoln, signed into law the creation of the "People's Department" the United States Department of Agriculture (USDA), as well as the National Academies of Science (since expanded into National Academies of Medicine and Engineering), and through the Morrill Act, land-grant universities. From their onset and continuing to the present, land-grant universities such as the University of Illinois have served as the core of shared investment between states and the federal government to support agricultural research. The products from these engines of discovery have made our country the unquestioned world leader in science and innovation for agriculture.

American leadership in agricultural research is founded on an extensive network of national support. Federal funding comes through a variety of institutions, including national or regional laboratories managed by the Departments of Agriculture or Energy, capacity-building through the Hatch Act, competitive grant programs, and dedicated investments for specific research needs deemed important by the taxpaying public. An example of the latter would be the national network of USDA germplasm centers, some of which are embedded on campuses such as the University of Illinois with the Maize Genetics Cooperation Stock Center. The largest piece of this federal agricultural research "pie" is distributed through competitive grant programs administered by the USDA (National Institute for Food and Agriculture and Foundation for Food and Agriculture Research), the National Science Foundation (many programs) and the Department of Energy (Biological and Environmental Research and ARPA-E). The majority of these federal dollars support research at universities, both public and private, and including every land-grant university in the nation. Federal funding supports a healthy diversity of research projects, from small exploration grants to large multi-institutional centers. Furthermore, agricultural research is one topic where different agencies have created valuable partnerships. Two specific examples with which I have been involved include the Interagency Working Group on Plant Genomes (https://nifa.usda.gov/sites/default/files/resources/plant_genome_init.pdf), and the USDA-DOE Plant Feedstocks Genomics for Bioenergy.

Building on the successes and impact of the above cooperative federal investments, state and local governments also provide critical support for agricultural research of regional relevance. In addition to their substantial funding to land-grant universities, many states include agricultural research in their budgets. It is important to emphasize that due to the diversity of climates and agricultural systems in our country, broad geographic representation is an important facet of our research network. States and local communities also partner extensively on technology transfer and business development, through agriculture innovation districts such as the Research Triangle Park in North Carolina, and 39 North in St. Louis. Universities are often the nucleus for such districts, and link great ideas with startup business skills, the early-stage business investment community, and job growth. Two notable examples of successful companies that were nurtured in our own Illinois Research Park include iCyt and their novel technologies for rapid genetic typing of livestock, and Chromatin, one of the first synthetic biology companies for crop plants.

Abraham Lincoln's vision considered agricultural research and education fundamentally linked. Modeled after what is now known as Michigan State University, the Morril Act created the public land-grant universities for teaching agriculture, and brought engineering to American colleges. This year, the University of Illinois at Urbana-Champaign celebrates 150 years of teaching farmers to become scientists and scientists to study the farm, facilitating the exchange of

knowledge to improve agriculture. Our students earn undergraduate and graduate degrees in many disciplines, including engineering, business, the life and environmental sciences, health and community development. They become the next generation of researchers and a well-trained workforce. Importantly, the quality of student education is enriched by substantial federal and state support for faculty, infrastructure, research costs and student aid. NSF, USDA, and DOE each support fellowships for graduate education and research training, research experiences for undergraduate students, and additional training for the most promising postdoctoral scientists. We professors also do not stop teaching when the tassels turn at graduation. All grants awarded by the NSF must foster broader impacts, which in many cases include outreach programs to actively connect scientists, the public, and agriculture. At Illinois we formalize this in our annual Corn Breeders' School, where industry professionals return to the "classroom" for two days to network and be updated on latest advances.

On our university campuses, we also develop future leaders of the agricultural research enterprise. Importantly, the land-grant mission has always embraced the under-served, with a historical emphasis on rural citizens, but now expanding to urban communities. In my specific discipline, the University of Illinois launched the careers of both Dr. Robert Fraley and Dr. Mary Dell-Chilton, pioneers of the agricultural biotechnology industry, and many other important leaders of academic and industry research. At my institution, Dr. Robert Jones was raised in a sharecropping family, progressed through the land grant system as a student, professor, and is now the Chancellor at the land-grant university in Lincoln's home state. The farmer became a scientist. And my current Dean, Dr. Kimberlee Kidwell, gained her passion for plant breeding as an undergraduate student at Illinois with Dr. John Laughnan, who discovered that truly delicious American treat known as Illini SuperSweet corn. The scientist became a farmer.

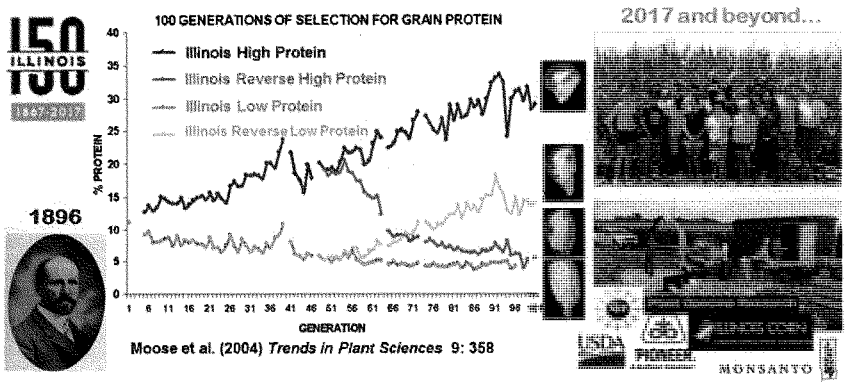


Figure 1: The Illinois Long Term Selection for grain protein in corn seeds. Starting with ears collected from a local farm in 1896, more than a century of breeding has produced the known extremes for grain protein and a suite of correlated nitrogen use efficiency traits. Today, my team of scientists and students studies the genetics of this experiment, with the support from government agencies, leading companies, and farmer groups.

The extent to which federally funded researchers at universities and other research institutions are partnering with the private sector, including with farmers, to advance agricultural research;

The above already touches on a key message regarding partnerships to advance agricultural research among universities, the private sector, and farmers. There is a long history of cooperation among all across the agricultural sector, which now forms a robust network for new discoveries and their application. I first illustrate by an example from my own federally-funded research, which continues to learn from the longest running continuous plant genetics experiment in the world.

Dr. Cyril Hopkins was the Head of the very first Department of Agronomy in the nation, at the University of Illinois. Having read Charles Darwin's books on natural selection, Dr. Hopkins wondered if those principles could be applied to improving the nutrition of corn kernels. Dr. Hopkins obtained ears of corn from a local farmer, and with the help of his graduate student Edward East, initiated experiments to select corn with the highest or lowest concentration of seed protein. A similar experiment was started for high and low seed oil. The experiment has been conducted nearly every year since, with my current team of students just completing the 120th cycle of selection (http://mooselab.cropsci.illinois.edu/longterm.html). Research performed on the experiment over the years has demonstrated the power of breeding and selection to change plant traits, has revealed the genetic control of seed nutritional quality, and more recently has enabled the discovery of genes that improve nitrogen use efficiency in corn.

From its beginning and throughout its history, there has been active collaboration with both farmers and seed companies. The earliest corn hybrids used the Illinois germplasm as parents. The high oil selections form the basis for hybrids that have been marketed since the 1990s for their enhanced nutritional value as animal feed. The NSF Plant Genome Research Program and USDA have funded genomic studies of the selected populations, which reveals genes that program the remarkable trait variation that is observed. Both DuPont Pioneer and Monsanto have supported research on the experiment to better understand plant breeding principles and how corn plants acquire and use nitrogen. In addition, hundreds of students have gained direct breeding experience as caretakers of this unique genetic resource. Some of these students were supported by the Illinois Plant Breeding Center (http://plantbreeding.illinois.edu/), where seed companies invest in education and research training of future scientists. Most recently, the farmer-supported Illinois Corn Marketing Board has generously provided graduate fellowships to sponsor students who continue the selection experiment, and to participate in a broader national network for public sector corn genetic improvement, the Genomes 2 Fields project.

The above is just one personal example. There are many similar stories from across the nation that involve long-term partnerships among federally-supported university researchers, the private sector, and farmers. Some additional highlights involving the University of Illinois:

- **"Using Precision Technology in On-Farm Field Trials to Enable Data-Intensive Fertilizer Management"**, a USDA-AFRI grant led by Dave Bullock in the Department of Agricultural and Consumer Economics. This project facilitates data collection and management to help farmers make informed decisions aimed at reducing the environmental impacts of nitrogen fertilizers. Another goal is to improve agricultural research and agribusiness collaborations between the U.S. and Latin America.

- **"Participatory Organic Corn Breeding and Testing Network"** This recent award from the Organic Agriculture Research and Extension Initiative (OREI) to Carmen Ugarte will enable farmers, researchers, and consumers to participate in breeding corn optimized for organic production. In the spirit of "field to table", farmers will help test maize germplasm developed at the University of Illinois and the Mandaamin Institute in Wisconsin, and consumer feedback will guide further improvements.
- **"USDA Producer Education Tool Project"**, USDA Farm Services Agency grant to Jonathan Coppess and the National Coalition for Producer Education. Based on the popular ***farmdoc*** platform, the project develops web-based tools to aid producers make farm-level decisions with regional data input regarding choices offered in the Agricultural Act of 2014.
- **"Center for Advanced Research in Drying"**, a NSF Industry/University Cooperative Research led by Hao Feng and Irfan Ahmad (http://www.dryingresearch.org/). A joint project with the Worcester Polytechnic Institute in Massachusetts and significant industry collaboration, research focuses on efficient and sustainable technologies for drying moist, porous materials such as food and other agricultural products, forestry products, chemicals, textiles, and biopharmaceuticals.
- **"Bio-Conversion of Herbaceous Biomass to Sugars and Biofuels using a Two-Stage Low Severity Pretreatment."** A partnership between Dr. Vijay Singh and the USDA-ARS National Center for Agricultural Utilization Research, this project is developing an integrated bioprocess using advanced yeast strains developed by ARS. This project complements the effort funded by the State of Illinois to build the Integrated Bioproducts Research Laboratory (IBRL). When completed in 2018, the IBRL will provide a uniquely designed space for direct industry-university collaboration for the development of bioproducts from scalable biorefining capacity.

The value of agricultural research and implications for the nation and world.

Agriculture, food, and related industries contributed nearly $100 billion, or nearly 6%, to the U.S. gross domestic product (GDP) in 2015 and employed 11% of Americans (USDA Economic Research Service). On the farm, only 1.4% of the population is able to supply most of our domestic calories, and via exports is a major global contributor to feeding the world. Although agricultural research certainly cannot claim credit for all of this bounty, Figure 2 illustrates through historical increases in U.S. corn yields the compounding benefits from new discoveries and technology innovation, which give birth to new industries and gains in efficiency. Edward East, Hopkin's graduate student, helped produce the first corn hybrids in the 1920s. Continued research at universities and the USDA created the germplasm that companies like Dekalb Genetics and Pioneer HiBred developed into the first commercially successful hybrids (nicknamed "mortgage lifters") in the 1930s. Over the next 50 years, progressively greater efficiencies in hybrid improvement through public-private research partnerships drove ever-higher corn yields. Beginning around 1980, major advances in molecular biology, biotechnology and genome science during each successive decade have helped maintain increases in yields of corn and many other crops and livestock. More recently, multi-scale and high-throughput methods for measuring plant traits in digital formats, named "phenomics" as a play on the word genomics, have become an

active area of research that links engineering automation and "big data" science with crop improvement. Finally, genome editing promises yet another leap forward both as a basic research tool and to design crops with improved yields, nutritional qualities, and environmental resiliency.

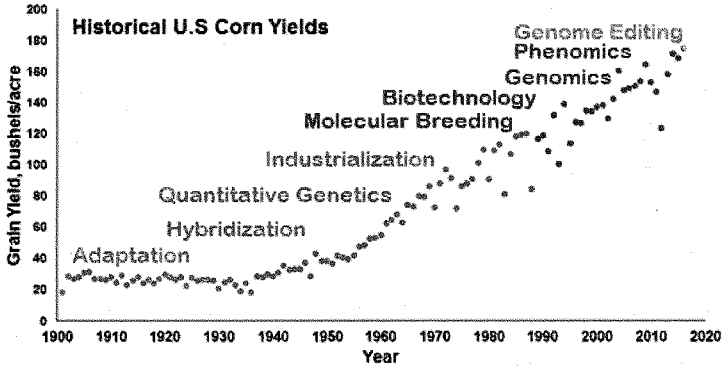


Figure 2: Progressive application of major outcomes from agricultural research that have powered dramatic and continuous increases in U.S. corn yields throughout the past century. U.S. average corn yields from USDA, with data points colored according to the era where that research advance first became a major contributor to yield increases. Similar plots could be drawn for other crops and livestock.

Interestingly, for each of the technology advances indicated in Figure 2, there was a lag period of a decade or more from the initial discovery or research breakthrough to first commercial applications. This delay arises from the substantial risks associated with translating new ideas into successful products. One significant value to agricultural research is to reduce these risks and accelerate commercial adoption. Increasing the pace of innovation is critical to meeting projected greater global demand for food and agricultural products.

The United States is the global leader in agricultural research. U.S. scientists are engaged worldwide in elevating agriculture, through indirect technology diffusion but also direct interactions with international researchers who work at universities, government institutes, the network of Consultative Group of International Agriculture Research (CGIAR) centers, and private foundations. Furthermore, U.S. farmers are the best educated in the world. Continued support for agricultural research will keep America at the forefront of discovery, and bring those discoveries to the farm. We should be vigilant to avoid the "brain drain" experienced by the European Union during the last two decades, where despite an early headstart and its status as an equal scientific rival to the U.S. in biotechnology research during the 1990s, EU governments could not agree on policies to manage this new science to the benefit of their citizens. Unfortunately, their dispute has also slowed agricultural innovation throughout Africa and Asia. China is also now sending signals that it intends to develop a strong bioeconomy, through the purchase of Syngenta by ChemChina and the designation of biotechnology as a strategic emerging industry by the Chinese government.

Figure 2 also emphasizes that investments in agricultural research have long term value, which accrues from the continuous cycle of education, discovery, and application. In strictly economic terms, the effectively linear increase in U.S. corn yields of approximately two bushels per year generates an annual return of more than $600 million dollars at the farmgate, with

additional value being generated via processing into food and energy. When other crops and livestock are considered, it is easy to project an annual value from agricultural research in the billions.

I close my remarks by also noting another essential value achieved through agricultural research, but one which it is not easy to estimate in dollars. We have witnessed tremendous changes in the science and technology used in agriculture during the past century, which have occurred during the same period that America transitioned from a majority of the population being engaged in agriculture to now less than 2%. Although society certainly reaps the benefits illustrated by Figure 2 for U.S. corn yields, most experience them only indirectly. Urbanization has unintentionally disconnected much of the populace from the innate desire to know where one's food come from. Research also shows us that some aspects of our highly-industrialized cropping systems, which are often lumped together as "Big Ag", cause environmental damage, and will require new strategies to ensure both economic and environmental sustainability. Because many in society are genuinely interested in how agriculture is practiced and food is produced, agricultural research represents a unique venue through which to engage people with scientists and farmers in the shared goal of a higher quality of life for both humans and planet Earth. One possible path for such future research is to harness the new capabilities in collection and analysis of data captured in an automated manner during farming operations. U.S. agriculture certainly benefits from its diversity of cropping systems and management practices. However, the distributed nature of manually collected data, coupled with the dynamic seasonal variations in climate, have precluded direct empirical comparisons of their productivity and environmental impacts. The "Big Data" revolution that is now upon us represents an opportunity for all farms to become research plots, where again, farmers become scientists, and science is returned to the farm. Research that generates, analyzes, and disseminates these data broadly among the many participants and stakeholders of U.S. agriculture will further improve our collective capacity to "Put Food on the Table".

Thank you for the opportunity to testify today, and I look forward to your questions.

Biography

Stephen Moose is the Alexander Professor of Maize Breeding and Genetics in the Department of Crop Sciences at the University of Illinois. His early years were spent on a small diversified farm in Northeast Ohio. He received his B.S. degree in Biology from Case Western Reserve University and obtained his Ph.D. in Genetics and Crop Science from North Carolina State University, where he discovered genes that regulate developmental timing in maize. Following postdoctoral work that identified a key regulator of maize seed composition, Dr. Moose spent two years as a Project Leader at Dekalb Genetics Corporation and then Monsanto Company, using biotechnology to enhance corn grain nutritional quality. Dr. Moose joined the faculty at the University of Illinois in 1999, where his research program focuses on understanding how gene regulatory programs may be modified for crop improvement. His efforts have focused on corn and related grasses for bioenergy applications. Dr. Moose teaches undergraduate and graduate courses on the topics of biotechnology and genome science, and how advances in these areas are being applied to crop improvement. He also frequently presents on these topics to a variety of public audiences.

Chairwoman COMSTOCK. I now recognize Dr. Wagstrom.

TESTIMONY OF DR. ELIZABETH WAGSTROM,
CHIEF VETERINARIAN,
NATIONAL PORK PRODUCERS COUNCIL

Dr. WAGSTROM. Thank you. Good morning, Chairwoman Comstock, Ranking Member Lipinski, and members of the Subcommittee. I'm Liz Wagstrom, the Chief Veterinarian of the National Pork Producers Council.

The United States is the lowest cost and most technologically innovative producer of food in the world. It is the globe's top exporter of agricultural products and has the safest food on the planet, and it's that way because of our historical commitment to research. To maintain our position in the world and keep our country food-secure, we must devote more resources to agricultural research. We need a commitment to research to help America's farmers and ranchers continue to feed this country and much of the rest of the world. The UN's food and agricultural organizations says food production needs to increase by 70 percent by 2050. That need will be met through research into more effective food production. If we don't produce more food for our growing population, are we going to start importing more and more of it to the United States? Are we really going to be okay with relying on some other country to provide for us? Yes, food is a national security issue.

The benefits of research should be obvious. In case it's not, according to the USDA's Economic Research Service, for every dollar of federal agricultural research funds invested, $20 is returned to the economy. Through better genetics, better feed rations and new animal care and housing methods, all based on research, hog farmers now produce more pigs on 78 percent less land using 41 percent less water than 50 years ago. That's why the U.S. pork industry has been a strong supporter, funder and user of agricultural research.

The National Pork Board as the federally established checkoff program has spent a significant amount of its annual budget on research over the past 10 years, funding 851 projects at more than $61 million. One disease the pork industry has invested research dollars on is porcine reproductive and respiratory syndrome. PRRS is a viral disease that can cause reproductive failure in breeding sows and respiratory issues in pigs of any age. It is the most economically significant disease now affecting U.S. pork production. Through an almost 30-year-long public-private collaboration starting with the identification of the causative agent of what we called mystery pig disease, we have made significant progress in dealing with this disease. One of those efforts, a PRRS host genetics consortium, brought together the pork industry, USDA's Agricultural Research Service, National Institute of Food and Agriculture, Genome Canada, private companies and universities to conduct multiyear studies to understand the genetics of PRRS virus infection. That has led us to the brink of developing a PRRS-resistant pig. This would be a huge step forward.

The recent outbreak of porcine epidemic diarrhea virus points to the vulnerability of U.S. agriculture to emerging and foreign animal diseases, and one of the diseases we and others in livestock ag-

riculture are particularly worried about is foot and mouth disease. An outbreak today of that disease would cost pork, corn, beef and soybean sectors alone $200 billion over 10 years. We are urging Congress to establish and fund through the next farm bill a robust manufacturing managed vaccine bank to respond to an FMD outbreak. Research can help address the alarming gap in the government's preparedness for an FMD outbreak so in addition we are requesting $30 million a year for the National Animal Health Laboratory Network, which conducts diagnostics, as well as $70 million a year for block grants to the states.

As you can tell, animal agriculture could use a lot more research dollars. Unfortunately, the commitment to agriculture research seems to have waned. According to USDA, public-sector food and agriculture research and development was 50 percent of the agency's budget from 1970 through 2008, but by 2013 had fallen to less than 30 percent.

One factor contributing to the decline is the increased operating costs of federal research facilities. It's estimated that the annual maintenance and operating costs of such a facility are ten percent of the cost of building it. So over and above research dollars, there must be a commitment to operating funds for federal agriculture research facilities such as NBAF, which is scheduled to open in 2022. These infrastructure needs are a critical issue. As an example, because of maintenance issues, the Plum Island Animal Disease Center cannot at this time conduct food animal research onsite, and that's a full five years ahead of the expected opening of NBAF. There must be a renewed commitment to funding research which will allow America's farmers to effectively feed a growing world population, improve public health, and strengthen national security.

In conclusion, the U.S. pork industry strongly supports and urges a significant increase in funding for federal intramural and extramural agricultural research to help America's farmers and ranchers continue feeding a growing world with safe, wholesome and nutritious food.

[The prepared statement of Dr. Wagstrom follows:]

Written Testimony of the National Pork Producers Council

On

Agricultural Research

Before the House Committee on Science, Space & Technology Subcommittee on Research and Technology

November 2, 2017

Introduction

The National Pork Producers Council (NPPC) is an association of 43 state pork producer organizations that serves as the global voice for the nation's pork producers. The U.S. pork industry represents a significant value-added activity in the agricultural economy and the overall U.S. economy. Nationwide, more than 60,000 pork producers marketed more than 118 million hogs in 2016, and those animals provided total cash receipts of nearly $240 billion. Overall, an estimated $23 billion of personal income and $39 billion of gross national product are supported by the U.S. pork industry.

Iowa State University economists Daniel Otto, Lee Schulz and Mark Imerman estimate that the U.S. pork industry is directly responsible for the creation of more than 37,000 full-time equivalent pork producing jobs and generates about 128,000 jobs in the rest of agriculture. It is responsible for approximately 102,000 jobs in the manufacturing sector, mostly in the packing industry, and 65,000 jobs in professional services such as veterinarians, real estate agents and bankers. All told, the U.S. pork industry is responsible for nearly 550,000 mostly rural jobs in the United States.

U.S. pork producers today provide 25 billion pounds of safe, wholesome and nutritious meat protein to consumers worldwide, and exports add significantly to the bottom line of each U.S. pork producer. U.S. exports of pork and pork products totaled 2.3 million metric tons – a record – valued at $5.94 billion in 2016. That represented almost 26 percent of U.S. production, and those exports added more than $50 to the value of each hog marketed. Exports supported approximately 110,000 jobs in the U.S. pork and allied industries.

Importance of Research

The United States is the lowest-cost and most technologically innovative producer of food in the world; it is the globe's top exporter of agricultural products and has the safest food on the planet. And it's that way because of its historical commitment to research.

That commitment became particularly prominent in the 1950s, following declines in the number of farms and farmers and the population booms that came after each of the two world wars. (A popular 1919 song was "How Ya Gonna Keep 'em Down on the Farm (After They've Seen Paree)?".) In 1910, there were 92.2 million Americans, 6.4 million farms and 32 million farmers; by 1950, there were 161.3 million people, 5.6 million farms and 25 million farmers. (Today, there are about 2 million farms and 6.6 million farmers for a U.S. population of 330 million.)

The country needed to find new and better ways to produce more food on fewer farms for a burgeoning citizenry, not only in the United States but in the more interconnected world. (Prior to World War II, the United States was fairly isolationist, its one-year and seven-month involvement in the Great War notwithstanding.)

That prompted a significant increase in agricultural research investment, from both the public and private sectors and in terms of production practices and innovations. The era saw scientific developments such as disease-resistant crops, hybrid plants and new pesticides and research that supported increased use of commercial fertilizers and anhydrous ammonia to boost crop yields. It was in the years immediately after World War II and into the '50s that saw a significant transition to "modern" machinery. It wasn't until 1954, for example, that the number of tractors on farms exceeded the number of horses and mules.

Much of the work then was being conducted by plant scientists at land-grant colleges and at the few federal research facilities that existed, and it was at this post-war time that agricultural production – thanks in large part to research and development – began to soar. In fact, since 1948, U.S. agricultural productivity has more than doubled.

In 1953, the Agricultural Research Service (ARS) was established in the U.S. Department of Agriculture to coordinate the research functions of various departments within the agency. (Its predecessor, the Agricultural Research Administration, which was established in 1942, also oversaw research from a number of bureaus, including the

bureaus of Animal Industry, Dairy Industry and Plant Industry and the Office of Experiment Stations.) In 1954, USDA established the Plum Island Animal Disease Center (PIADC), which conducts research on animal pathogens to protect farmers, ranchers and the national food supply.

The U.S. pork industry has been a strong supporter, funder and user of agricultural research, which plays a critical role in helping America's pork producers raise healthy animals and produce safe, wholesome and nutritious pork.

The National Pork Board, federally established by the Pork Promotion, Research and Consumer Information Act of 1985, spends a significant amount of its annual budget on research. In 2016, for example, it funded 95 research projects, spending more than $7.1 million. Over the past 10 years, it has funded 851 projects at more than $61.4 million – most by university researchers but some with ARS researchers.

In 2015, the National Pork Board, through a one-time $15 million research grant over five years, established the Swine Health Information Center (SHIC) to protect and enhance the health of the U.S. swine herd in part through targeted research investments that help minimize the impact of disease threats.

Last year, for example, SHIC funded a project to help define disease introduction risks that come from importing feedstuffs and feed components. It has preliminary results for Senecavirus A (a surrogate for Foot-and-Mouth Disease), Bovine Viral Diarrhea virus (a surrogate for Classical Swine Fever) and Bovine Herpes Virus-1 (a surrogate for Pseudorabies). In all, it funded 21 proposals at U.S. universities, one at a biotechnology company and one at Canada's national animal health laboratory. One of the preliminary results shows that virus could survive in certain feedstuffs shipped from Asia to the United States.

SHIC also is continuing to work on nationwide operational disease preparedness through its Rapid Response Program, which is developing a corps of epidemiological

investigators to respond to emerging, transboundary and endemic swine diseases. It has a cooperative agreement with USDA to help fund rapid response investigations, if the agency's participation is approved by the herd owner(s) dealing with a disease.

Although research is vital to improving many aspects of pork production, the most critical and immediate need for the industry involves swine diseases.

Pork Industry Research

One disease that has garnered a lot of research attention is Porcine Reproductive and Respiratory Syndrome (PRRS), a viral disease characterized by two overlapping clinical presentations: reproductive impairment or failure in breeding animals; and respiratory disease in pigs of any age. PRRS is the most economically significant disease now affecting U.S. pork production.

Although reported initially in only a few countries in the late 1980s, PRRS now occurs worldwide in most major hog-raising countries. PRRS is prevalent in the United States and exists both in epidemic and endemic forms.

Over the past 20 years, there has been much research on the PRRS virus. Although much now is known about it, details on control of the disease for all types of hog-raising operations are far from complete. Pork industry consolidation over the past 15 years has led to entire production systems being designed around strategies for controlling or eliminating the disease.

PRRS also serves as an example of coordination between the public and private sectors, with the National Pork Board funding 242 projects totaling more than $15.5 million on the disease between 1997 and 2016 and working with USDA on two PRRS Coordinated Agricultural Projects (CAPs) – one in 2004 and the other in 2008 that led to advancements in PRRS research.

Another collaborative research effort is the PRRS Host Genetics Consortium, which was initiated in 2007 specifically focusing on the underlying genetics of PRRS and how to better understand the exact mechanism of PRRS action as a way of finding new and novel solutions for the disease. It brought together the National Pork Board, the PRRS CAPs, USDA's Agricultural Research Service and National Institute of Food and Agriculture, Genome Canada, private companies and universities to conduct multi-year studies to understand how host genetics influence the outcome of PRRS virus infection. It, too, led to many advancements in the understanding and discovery of the genetic basis for PRRS resistance, which, in turn, has led to further research and discovery of a PRRS-resistant pig.

The private sector also looked to the public sector for help when the first case of H1N1 influenza was identified in a person in Mexico in the spring of 2009. The misnamed Swine Flu quickly moved to the United States and soon became a pandemic. Many U.S. trading partners closed their markets to U.S. pork.

To restore consumer confidence in pork and to get U.S. pork exports flowing again, the industry turned to researchers at USDA. The agency's Agriculture Research Service conducted a study to determine if H1N1 caused illness in pigs similar to that caused by classic influenzas and to determine if the virus could be spread to muscle tissue. Pigs were inoculated with the novel H1N1 virus. The study found that live H1N1 was only detected in the respiratory tract of infected pigs; the virus did not spread and replicate in other tissues. Most importantly, the virus did not spread to meat, confirming that pork from infected and recovered pigs was safe to eat. ARS's quick response undoubtedly saved pork producers millions of dollars in lost revenue.

The U.S. pork industry also worked cooperatively with the American Association of Swine Veterinarians to assure that producers and veterinarians had the latest information and science on H1N1. Additionally, NPPC and the National Pork Board worked with USDA's Animal and Plant Health Inspection Service (APHIS) to help shape guidelines so the government response was proportionate to the disease risk. The pork industry also

Chairwoman COMSTOCK. Thank you, and I now recognize myself for five minutes of questions.

Dr. Wagstrom and Dr. Gerstein, you both note in your testimonies that increased travel and trade between nations combined with the convenience of global travel would potentially make it easier today for a foreign animal disease to spread quickly once introduced in the United States, and we've certainly seen that in the past. But why have we really had limited instances of that happening, and what are the best practices for us going forward?

Dr. WAGSTROM. One of the best practices going forward is continuing to look at our customs and border protection. We on the farm have responsibilities for biosecurity and to make sure that we are careful about what we bring into our farms. We are definitely in the pork industry concerned. We have not seen foot and mouth disease since 1929, but since 2013 we've had an incursion of porcine epidemic diarrhea virus. In 2009, we had H1N1 influenza that spread through the pandemic globally, and we are now dealing with an outbreak of what's called Seneca Valley virus, and so all three of those have told us—have proven we have vulnerabilities that we need to address. I'll yield.

Dr. GERSTEIN. Thank you. Yeah, I agree with what Dr. Wagstrom talked about. I think it begins with customs and border protection being able to seal our borders. When agricultural products come through, they need to be properly inspected. There are protocols for that. We do on a routine basis find animals that should not come into the country, and of course they're turned away.

But there's more that needs to be done. Here's where research and development can really be key. We need to think about concepts such as pen-side diagnostics and having those available so that we can do a rapid testing of the livestock and ensure that if there is an issue, it's rapidly addressed. To the extent possible, we want to identify as early as we can so that we can take actions and then return the food supply to its proper state. So I think that's one example. We also——

Chairwoman COMSTOCK. Now are those being used now?

Dr. GERSTEIN. Well, there are some pen-side diagnostics that have been looked at in terms of research and development. I'll leave it to, you know, the experts in terms of how much they are using them within the different industries but we had been—when I was with Homeland Security, we had been looking at pen-side diagnostics as something very key.

I think the recent responses to diseases such as Ebola and Zika point out that we have a lot of work to do, research and development in areas such as threat awareness. I remember going to a session with the former head of the Centers for Disease Control and Prevention about a month after the Zika virus had come into the country, and he made the comment that, you know, before this we had about an eighth of an inch thick file on Zika and today it's five inches thick. Well, I mean, we can't wait until something occurs and then react, and this means that we have to work globally with partners, we have to understand how disease is progressing, we have to make sure that all of our systems, biosurveillance, are tuned so that when something occurs, it can be an immediate re-

sponse and not wait and be reactive. Those are just a couple thoughts.

Chairwoman COMSTOCK. Thank you.

And Dr. Higgs or Dr. Moose, if you have any comments on that.

Dr. HIGGS. Well, we talked about diagnostics but the key thing is actually getting those applied where we need them. We have relatively poor surveillance. We don't look at most of the material coming in. We have a group at the BRI, the National Agricultural Biosecurity Center, who's doing some pathway analysis to look at routes by which pathogens could make it into the country, but if we don't have the surveillance out there, then we're already sort of behind the curve.

Chairwoman COMSTOCK. Thank you.

Dr. MOOSE. I would only add that in addition to the animals, there's also plant diseases that can have a serious impact. We've had those happen in the past, not in recent history, but we know worldwide there's, for example, a fungus that's had a big problem with wheat, a big impact on wheat production. Luckily it's not been in the United States. The same goes for soybean. South America deals with a disease that luckily we don't have here, but we don't have it here because in part there's a surveillance system in place.

Chairwoman COMSTOCK. Thank you.

And I now yield to Mr. Lipinski for five minutes.

Mr. LIPINSKI. Thank you. I want to start by talking about innovation hubs and incubators. It's something that I've spent a lot of time on here in this Committee, not necessarily on the side with agriculture but something that I know we all know can be very helpful. So I wanted to ask Dr. Moose, I know in your written testimony you describe the importance of Agriculture Innovation Districts such as University of Illinois Urbana-Champaign's Illinois Research Park. Can you expand on the approach of the research park to supporting early-stage businesses, what are the key strategies that you use, how the federal government may be able to help more on that?

Dr. MOOSE. Sure. So at the University of Illinois, we do have a research park, and what its function is, is to take these great ideas from the campus and provide assistance in both the physical infrastructure and support for business development. The also serve to connect those early startup businesses with the business venture community. It doesn't have to be necessarily just venture capital but we'll call it the investment community, and so those connections then help transition—it's called the valley of death often where there'll be an idea, has a great potential, but then fails to reach commercial application. And so the research park at Illinois has a number of ways it does that. I actually have personal experience with that. My wife's company was gestated, if you will, or nurtured in enterprise works at the research park. They now are based in Texas but they're one of the leading sorghum seed genetics companies. And there's another one also called iCyt that has a very new technology on how to type both animal and plant genetics, and that technology has really changed how we do that kind of work, and that was started in a lab actually down the hall from me. The research park helped transition them into a business and now

they're a subdivision within Sony Corporation. They were brought into that field.

And there are many examples of this all throughout the country of usually universities being the nucleus but not necessarily where again ideas are nurtured and cross through that, I call it de-risking where there's a huge risk. There's often talk about balance between research and development and industry and university work, and the way I like to describe that is, there's an R&D, research and development, and companies are really good at the D. They have a big D and a little R. Universities are a big R and little D, and then things like the research park would be the "and", the ampersand, that in between that helps make those links succeed.

Mr. LIPINSKI. Is there anything that the federal government can do better to help this process, help anything like what University of Illinois is doing and others?

Dr. MOOSE. I believe so. I think there are a number of federal agencies that recognize this technology transfer aspect. For example, the NSF now has what's called I–Corps where the idea is that young entrepreneurs who have a good research idea, they actually can be supported for a period of time to investigate the business prospects, and they can do this in a way where they're not jeopardizing their career in a sense by taking time off, if you will, from the academic track. So that's one example. The USDA also has started those things. And then just the base of research, the federal support, enables those good ideas to happen, and also the facilities that may be there. I know, for example, the research park at Illinois makes use of the resources that are on our campus because of federal and state support. So possibly just identifying where those can happen more fruitfully would be an important role of the federal government.

Mr. LIPINSKI. Thank you, and thank you for the commercial there for I–Corps. As many of my colleagues on the Committee know, I'm the one who for many years has been talking up I–Corps, and I know University of Illinois has done a great job in terms of the number of teams that go through I–Corps, so it's good to hear how successful that has been.

Thank you, and I yield back.

Mr. MARSHALL. [Presiding] I now recognize Dr. Abraham for five minutes.

Mr. ABRAHAM. Thank you, Dr. Marshall, and thanks for spearheading this hearing. In my opinion, this will be one of the more important hearings that we in Science, Space, and Technology hear in the entire year.

Dr. Gerstein, I read your book, "Bioterror in the 21st Century," and I really think it should be required reading for every Member of Congress if we're responsible for legislating and appropriating money for bioterror. It's eye-opening, and as you alluded to, the mass casualty count could be horrific. It would pale to anything we've ever seen before.

The field of genetic engineering, genetic modification, whatever you want to call it sometimes gets beat up pretty bad in the press but if my medical history serves me right, I think this goes back to maybe 30 or 40 years ago when the pseudorabies vaccine with recombinant DNA was actually on the scene and unfortunately a

lot of people don't understand that hep B vaccines, interferon that we use for cancer, all these wonderful things in technology and medicine that not only save lives but feed our world are due to research and technology.

Dr. Wagstrom, you said that, you know, we'll need 70 percent of food production increase by 2050, which means, you know, we're looking at 200 bushel acre soybeans, 300 bushel acre corn which is not obtainable now, but if we are expected as America to feed the world as we heretofore have always done, then we've got to get there.

We have in this Committee and it's certainly gone national and worldwide now, we've heard about the CRISPR–Cas9, the genetic engineering technology. I know, Dr. Gerstein, you've written extensively on the horrors of CRISPR in a bioterrorist's hands, and we know the wonderful things it can do with single and now multiple gene mutation as far as curing children with leukemia, curing possible children with sickle cell, those types of deal.

So I guess my question, and all of you are eminently qualified to weigh in on this, where do we go from here? We need to move forward. We need to move forward very quickly, and you know, what's the next step in your opinion? Dr. Gerstein, I'll start with you and just go down the line.

Dr. GERSTEIN. Well, thank you for that, and thanks for the plug for the book.

Mr. ABRAHAM. It's a great book.

Dr. GERSTEIN. Thank you. So you know, I'm going to come at this from a Department of Homeland Security perspective and say that what I worry about is either accidental use of something or deliberate use of something that results in a catastrophe, some sort of biological pathogen, and so I'm going to kind of stick to those. When I talk about areas like CRISPR as a technology, I don't talk about it as being a danger but it could be a danger if the technology is misused, and so the key for us is to understand that in the realm of biotechnology, much of the area has become very deskilled. You know, if you talk to people from the old weapons program that we had back in the '50s and '60s, they talked about people at the bench with good hands, and today, many of those technologies don't require good hands and you can do fine in preparing pathogens that can be very useful as biological weapons, or you could make manipulations to genomes that could actually be dangerous. And so I worry about monitoring the different areas where the technology is being used and understanding what a potential—an individual with, say, nefarious intent could be doing with that. In fact, that's one of the reasons why the Director of National Intelligence in 2016 had identified the gene editing as a worldwide global threat, and that caused a great deal of fervor, but I think what he was signaling was that biotechnology has gotten to the point where it really does reside in many cases not just in labs but in our communities as well.

Dr. HIGGS. I'll just make a comment on CRISPR–Cas9. I was on the National Academy committee reviewing that technology. I suppose it was the speed of development which shocked me. By the time we held our first meeting, I was getting emails, for $120 you

could buy these kits suitable for high school students to do this. It was just astounding.

Dr. MOOSE. Thank you also for this question. I view the genome editing field, of which CRISPR–Cas is sort of the main technology, it will revolutionize how we improve crops because crop improvement through biotechnology, I will call it tinkering, it's like playing with Lincoln Logs whereas the CRISPR–Cas, we will be able to basically take a genome and it'll be like a word processor—edit, change a letter here or there—and do that in a designed way. So the speed and precision at which we'll be able to do that is wonderful.

I use the example of our 120-year experiment. We actually in my lab right now are trying using CRISPR–Cas to see if we can accelerate that to a five-year time frame. We're trying to make some of those same changes that breeding took 120 years to accumulate, can we do this in five. So the speed and precision will be phenomenal.

That said, and it's been alluded to in the earlier answers, that also democratizes, if you will, the ability to practice this technology, and so that may be a real role for the federal government in how do we connect the technology with society, with the end users, and make that so that the recognition of its potential and the responsibility to use it is—that society understands that and is engaged in that process. I yield.

Dr. WAGSTROM. Thank you for the question. Obviously technology affects all sorts—all areas of agricultural production, especially in pig production. We look at it as a way to help us maximize animal health and animal welfare and help us produce that 70 percent more food. For us, obviously PRRS is an immense issue. It's a pathogen that causes a lot of secondary bacterial infections, probably one of the reasons we use some of the antibiotics we do. So we look at developing a PRRS-resistant pig, we think we'll not only be able to have healthier pigs but use less antibiotics. We also see technology as a potential to help us develop alternatives to the current antibiotics we use that may have less antibiotic-resistant consequences throughout the food chain.

I sit as—I'm a liaison to the Presidential Advisory Committee, our council on combating antimicrobial-resistant bacteria, and we've actually—one of our recommendations in our last report is that we put together an Innovation Institute within the USDA that would help people who are researching alternatives to antimicrobials and other areas try to go through an uncertain regulatory process because these are uncertain where they belong in the regulatory chain and get those commercialized. So we look at not only a technology as improving pig breeding but also improving our tools to raise our animals.

Mr. ABRAHAM. Thank you, Dr. Marshall, for the extra time.

Mr. MARSHALL. I now recognize Mr. Beyer for questions.

Mr. BEYER. Thank you, Dr. Marshall, very much.

My favorite line in history is that America was born on a farm in Virginia. It's really important that you all are here, and I really want to thank Chairman Comstock and Ranking Member Lipinski for putting this on.

It's especially important because this Administration has repeatedly undermined science, particularly in agencies where science should be the key component. Just this week, Secretary Pruitt issued a directive to prevent scientists at the EPA from serving on the agency's Scientific Advisory Board if they have had even one EPA grant. And last month, Kathleen Hartnett-White was nominated to chair the Administration's Council on Environmental Quality despite the fact that she denies overwhelming scientific consensus on climate change and has said on the record carbon emissions are harmless and should not be regulated.

And unfortunately, the U.S. Department of Agriculture is no exception. Sam Clovis, who was the Administration's pick to be the Chief Scientist, is not a scientist of any kind, much less an agricultural scientist, and we just learned this morning that he's withdrawn his application nomination for that.

So the American people, Republican, Democratic and everything else, deserve a higher standard of experience and accomplishment from the top scientific leaders in our government. We're very pleased to have top scientific leaders with us here this morning.

Dr. Moose, I'm fascinated with your background as a geneticist, and I'm much impressed by the work of the Land Institute in Salina, Kansas. We've been arguing that all of nature's ecosystems are perennial polycultures. Agriculture is largely annual monoculture, which basically is short-term, high-yield perspective rather than the long term. And 85 percent of human populations' calories come from annual crops. There are perennials—olive trees, grapes, alfalfa, things like that, fruit trees—but their work is trying to figure out how do we move agriculture from annuals to perennials, first by the domestication of wild perennials or by the perennialization of existing annuals. So as a maize breeding and plant geneticist, what's your perspective on the work of the Land Institute and this notion of moving to perennial polyculture to avoid soil erosion, all the bad things that happen when you have to turn the soil every year?

Dr. MOOSE. Yes, so thank you, Mr. Beyer. I am aware of the Land Institute. I think they have a very—it's a good approach that they're taking. There are clear environmental benefits, sustainability improvements that can be achieved with perennials. I believe part of the reason that much of our agricultural systems are an annual base, and first they are more productive on an annual basis, so you will get higher yields from an annual crop than a perennial crop because the perennial crop is actually investing some of that photosynthesis below the soil, which is obviously a good thing too, but that's one reason.

The second one, though, is also this risk on the farm. If I have a perennial—and so I know a little bit about this because I study miscanthus also, which is a perennial grass that's been touted as a possible bioenergy crop, a dedicated bioenergy crop, and it's an amazing plant. There's a lot to learn from it. But one risk that comes with that is, it takes three years to establish and get to productivity. The stand may last 10, 15 years but we only have one variety of that kind of plant for bioenergy. So if a disease was to come in, it might wipe out that crop and we would not have many options in terms of replacing it. So annuals offer a flexibility which

reduces risk, and I guess what I would advocate in terms of the best systems are those that combine the benefits of annuals with the benefits of perennials, and so research in that area is going on. I believe it would be good to increase that effort.

Mr. BEYER. Great. Thank you very much.

Dr. Higgs, you said and wrote, and I'm going to quote, "A concern was expressed"—this is in the Blue Ribbon Study Panel—"that the President's fiscal year 2018 budget request would eliminate all agriculture and animal-specific research by the DHS Science and Technology Directorate." I'd just love if you could please emphasize for all of us that this is a matter of national security and shouldn't be partisan at all.

Dr. HIGGS. No, you're absolutely correct, and the beauty of this panel is that it is bipartisan because the needs of this country go beyond politics in terms of food and agriculture. We all eat. And having the funding to do that research is absolutely critical. I alluded to our training that we've got and that Homeland Security seems not to have funding to sustain that training after 2018 at the moment. We hear about the levels of funding that is required to do the research and the training but that is not being translated into those funds actually being appropriated to support that.

Mr. BEYER. Great. Thank you very much.

Mr. Chair, I yield back.

Mr. MARSHALL. I now recognize Mr. Lucas for questions.

Mr. LUCAS. Thank you, Mr. Chairman, and before I turn to Dr. Wagstrom for a specific question, I think it's worth noting the wondrous system that we have in the United States. I mean, the Morrow Act of 1862, a couple of you are from those institutions. For the first time in the history of the world with President Lincoln's signature on that Act, we made it possible for someone who did not come from wealth or social status to go to college, to have an opportunity in agriculture or mechanics in the sciences to have a college education, a most amazing accomplishment, and the technology, the training that's come from that.

A lot of times some of my idealistic friends here in Congress say why we should spend public dollars to do anything, let the private industry do it all, but you produce the scientists who fuel both higher education, research, and the private industry, correct? You're the pipeline that produces the brilliant people who go on to drive that, so that is important, that coalition, that combination, those public resources in producing our next generation of scientists.

We talk about the animal and health and plant issues. USDA and sometimes again we on the Ag Committee, and I share both that Committee assignment and this one, are criticized for the people that we have around the world but we literally have agents in foreign countries examining plants and animals before they come to the United States. We have people in foreign countries because agriculture is a free-flowing trade, we have people looking at disease issues there before they can be certified to bring their product into the country. So the investments we make, which are sometimes not so exciting in the eyes of the appropriators and some of other colleagues, are very necessary. The biggest USDA research facility outside the United States is, what, Mont Pierre, France?

Been there for a century looking at things that come into the country beforehand.

Now, a little more of a particular focus, Dr. Wagstrom. We've talked earlier about foot and mouth, or as my grandfather called it, hoof and mouth, the most amazing, viciously aggressive virus that we've kept out of the country for 88 years, which does still exist in other continents and places around the world. Visit with me for a moment if you would a little more in detail about the Homeland Security Presidential Directive Number 9 from 2004 about establishing a national policy to defend our agriculture and our food systems, and in particular the concept of the national veterinarian stockpile of vaccines.

Dr. WAGSTROM. Thank you, Mr. Lucas. We have a very small North American bank, very small. It wouldn't vaccinate all the pigs and cattle around Guymon, Oklahoma. It's that small. What we need is a vaccine bank that will protect us against all 23 strains of foot and mouth disease that are circulating around the world.

Mr. LUCAS. And foot and mouth is an example of one of the things we need to be prepared to——

Dr. WAGSTROM. Correct.

Mr. LUCAS. —defend ourselves against, one of.

Dr. WAGSTROM. Correct. So we not only need a vaccine bank with at least 500 million doses of those 23 strains, we also need a diagnostic laboratory network that has got surge capacity to be able to diagnose not only infected animals but we have to be able to diagnose that animals are not infected and are safe to move to slaughter or to move to other facilities. We need to have foreign animal disease diagnosticians on the ground and trained to be able to diagnose those animals. We have a—we'd love to have a pen-side test but the consequences of having a wrong diagnosis on a potential economic devastation if we say this animal's infected with foot and mouth disease and it's not would be devastating. So having a 100 percent accurate test on a pen-side test is very difficult. So we need—in addition to that as a preliminary screen, we need our diagnostic labs to be able to communicate with our state veterinarians not only in their state but also the states surrounding them where animals may move. We need to have seamless information that state veterinarians can look at from the farm through the diagnostic lab into the federal system of data collection so that they can make decisions on if an animal's safe to move, if a quarantine zone needs to be connected.

Our system of data collection and transfer from private farms, diagnostic labs, state veterinarians, and federal veterinarians is broken. The National Pork Board is investing almost $1 million with the DHS Center in Texas A&M to try to help put together systems to visualize data that will help us out in an outbreak. That's privately funded. We also need public funding to fix those data systems.

Mr. LUCAS. Tolerate me for just a moment, Mr. Chairman, because agriculture, we produce almost everything everywhere in the country in some quantity. We're not just talking about one central vaccine stockpile. This has to be regionally placed for whatever particular disease we're trying to protect ourselves from to be available instantaneously, and I assume my other friends over here would

note that viruses change subtly, constantly in the wild so the stockpile has to be adjusted to reflect what's virulent and available out there. It's not a sexy topic, Mr. Chairman, but it would be of critical nature. Would my friends on the panel agree briefly? I guess they all agree.

Dr. WAGSTROM. We all agree. One thought just to put it in perspective, there are a million pigs a day that are on wheels moving in a truck somewhere across this country, about half a million cattle on wheels every day. So we don't have the likelihood of having a small outbreak on one farm in a remote area of the country. It's going to be a nationwide outbreak.

Mr. LUCAS. I appreciate your indulgence, Mr. Chairman.

Mr. MARSHALL. Let the record show that Mr. Lucas and the Chairman of this Committee hearing thinks that biochemistry is sexy, so I'm all in.

Okay. Next we recognize Ms. Bonamici for questions.

Ms. BONAMICI. Thank you very much, Mr. Chairman, and thank you to our panel. The district I represent out in the great State of Oregon has quite a bit of agriculture, mostly specialty crops, and this hearing is about the importance of agricultural research. Sometimes we have to take a step up and talk about the importance of agriculture. I think a lot of people in this country are still very detached from the source of their food. I think efforts like Farm to Table help with that so that people in urban areas understand that farms are important and agriculture is important for their food.

I wanted to ask you, recent articles have discussed an alarming decline in insect populations and also pollinators. This obviously affects agriculture. Are any of you looking at this, and if so, what are you finding? Dr. Moose, it looks like you want to say something.

Dr. MOOSE. My experience with pollinators is, growing up on the farm, we had bees. We raised bees. We raised honey. So I know about the issue that you speak. It's one where science has yet to quite figure out exactly what the cause of the decline is. There are a number of possibilities, and it's probably a combination of factors. That said, in the last few years there's been a rebound, if you will, and we also don't understand how that has happened either other than I think as spoke to earlier about the cows and pigs on wheels, bees are on wheels as well, and some of that practice may have contributed to the colony collapse, et cetera, again, not definitive but there have been changes in that to some extent because of the concerns around that, and maybe it's just correlation but the fact that there's been a reduction in the movement and then less of an issue with the pollinators may be connected.

Ms. BONAMICI. Thank you. Climate change affects food security. How does that shape your research agenda? How are you looking at with increasing temperatures, increase in severity of weather events? Dr. Moose again?

Dr. MOOSE. Yeah. So clearly if you're a farmer, you're paying attention to climate both daily and seasonally, and so I think where the opportunity lies is that with the new technologies—it was mentioned earlier about NASA and their satellites. That technology and others like it that weren't even from agriculture necessarily have a big impact on our ability to monitor at a level unprece-

dented previously where all farms can become a research entity, if you wish. And so being able to track the variation in climate, to track to performance and the productivity in farms including the different systems—we have very different kinds of production systems and sometimes you will hear this system is better than that system. We had a question about perennial and annual.

Ms. BONAMICI. Right, right.

Dr. MOOSE. The ability to monitor those allows us to actually gather data to really say here are the benefits to that system both economically in the short term, environmentally in the long term, and this is an area—it's only starting to begin now but there's a tremendous opportunity with our, we'll call it the Big Data revolution that every combine is instrumented with a GPS and is tracking, and many others of this area.

I know in our own department we've recently hired a faculty member specifically to look into this question because we want to make sure again connecting farmers to the science to society that everyone who would be a partner in this is a partner.

Ms. BONAMICI. Terrific. And I wanted to also talk a little bit about the workforce issue. I serve on the Education and Workforce Committee, and out in my state we have Oregon State University, our land grant university, which has extension services in every one of our 36 counties. They run a great 4H youth development program. Of course, we have our Future Farmers of America program. But I know, again, staying with Dr. Moose for now, you talked about you and your wife growing up on your family farms. How do we encourage the next generation to go into agriculture, even if they don't have that family history that you have? And I'll ask you quickly but then I'll ask the other panelists as well. How do we make sure we have a workforce to address these issues?

Dr. MOOSE. Yeah, so I can speak to that. In the University of Illinois, most of our students come from Chicagoland so we really do have this urban population, and I guess the way to convince them is that this type of research is exciting, and this is what I try to do on a daily basis, but I think when you see the advances in science, you know, a lot of students might think, you know, the doctor or the medicine is where the action is. When I was, you know, younger, certainly that was the case. I think that agriculture research, it has that connection that it could be the next big thing, and that is the kind of message that we try to convey to students.

Ms. BONAMICI. I appreciate that. We will certainly need that workforce. Thank you.

My time is expired. I yield back. Thank you, Mr. Chairman.

Mr. MARSHALL. I now recognize myself for questions as well.

I'd like to, without objection, submit the Blue Ribbon Study Panel for the record, which several of our witnesses have referenced, and salute Senator Tom Daschle and his great work on this project as well. It's been a joy to get to work with him.

[The information appears in Appendix II]

Mr. MARSHALL. I'll start with my first question with Mr. Higgs. You discussed in the process of the Biosecurity Research Institute where you work has taken to ensure a smooth transition for NBAF. As you know, NBAF has the full support of the surrounding community as well as the support of Kansas State President General

Richard Meyers, who's the former Chairman of the Joint Chiefs of Staff. He brings a very unique perspective to this and the value of NBAF when it comes to national security. Can you discuss how quickly, specifically, how quickly can NBAF start their critical research once it becomes operational?

Dr. HIGGS. Thank you, Congressman, for that question. So NBAF will become operational, fully operational, probably in 2022, 2023, and it will become operational with dependency on an appropriate workforce. It will take approximately 350 or 400 people to work at NBAF, and part of our mission at Kansas State is to help develop that workforce. We're in constant conversation with Homeland Security, with the U.S. Department of Agriculture and so forth. We have to align the training with the needs of NBAF towards 2023. Obviously there will be sequential employment of people at that facility, but it can't become fully operational until it has all of the staff necessary. Both DHS and USDA are already in those conversations and thinking ahead, but we obviously need a solid plan to know what type of people we need and when, in order to enable that.

Mr. MARSHALL. Okay. I'll go to Dr. Gerstein next. The Blue Ribbon Panel report mentioned several strategies to ensure NBAF is fully utilized including the private-public relationships. Earlier this year DHS proposed the closure of the National Biodefense Analysis and Countermeasures Center located at Fort Detrick in Maryland and still remains underutilized despite being brought online seven years ago. How can we ensure NBAF's space and capabilities are fully utilized to their fullest extent?

Dr. GERSTEIN. Well, thanks for that question. Let me start at the beginning and say I think it's critically important that we not only fund the development of these facilities but we think about the long-term viability. In the case of NBACC, I think we're losing a critical capability for bioforensics and for threat awareness that could put our country at risk.

Now, turning specifically to NBAF, I like the idea of developing a strategy, that is, a public-private partnership, and I would just compliment Kansas for the tremendous support that they had given when I was in the Department. Just recognize that they had put forward approximately 25 percent of the cost to put that facility in—you know, to build it. And so I think that's really a tremendous commitment but we have to continue that commitment into the lifecycle, and we have to ensure that, you know, we bring along industry, the biopharmaceutical industry as well, the pork producers and the livestock, cattlemen's associations. These are all very important that they are part of working together to develop solutions for this industry.

Mr. MARSHALL. Dr. Gerstein, are you familiar with the Fusion Center as well? Are you allowed to talk about how integral that can be with this process as well? It's quite an amazing facility. I got to visit recently.

Dr. GERSTEIN. Well, yeah, absolutely. Look, any time that you bring information and you fuse different capabilities, you bring different stakeholders to the table is extraordinarily important, and in this particular area, the $1 trillion, over five percent of the U.S.

economy, when we can bring that kind of throw weight into the dialog, it's going to be beneficial.

Mr. MARSHALL. I'll finish up with Dr. Higgs. The BRI research also encompasses plant diseases with a focus on diseases like the fungus wheat blast. Wheat accounts for 20 percent of all calories consumed globally, making ag research a matter of food security. What kind of impact would wheat blast have on our ability to produce and export wheat, and what does BRI and Kansas State do to combat this deadly plant disease and others? And again, so proud of the Wheat Institute is doing there as well.

Dr. HIGGS. Well, to answer the question briefly, it would devastate our wheat production. This is a pathogen from South America that can cause 100 percent crop losses. We've been conducting research in the BRI since 2009 to study wheat blast and look at wheat varieties that are resistant to that. We've done research for the Australian government, for example, who won't allow that pathogen in the country. We've now seen wheat blast for the first time get into, Bangladesh and, India, and it is devastating their crops. So that research is critical and run by colleagues in the College of Agriculture.

Mr. MARSHALL. Okay. Thank you, everyone, for answering my questions.

I'll now recognize Mr. LaHood for questions.

Mr. LAHOOD. Well, thank you, Mr. Chairman, and thank you for having this important hearing today on agriculture research, and I want to thank the witnesses for being here today and for your valuable testimony.

The district that I represent in central and west central Illinois has two distinctions related to agriculture. First, it's the eighth largest in the country in terms of corn and soybean production, and also our district produces 96 percent of the pumpkins produced in the entire world in our district, and we're awful proud of both those. I like to tell people we've got some of the most fertile farmland in the entire world in central and west central Illinois. People are also surprised to learn that in the State of Illinois, the number one industry is agriculture. It's not any industry in Chicago or other places, it's agriculture, and we're awful proud of that in Illinois.

In my time in office, I've put together an Ag Advisory Committee that I meet with on a quarterly basis, and we talk about issues related to agriculture, and I'm amazed at the technology and the modernization of agriculture in all different sectors, whether it's drought-resistant seeds or nutrients that are put on our farm fields or the technology that goes into our tractors and equipment. It continues to amaze me what goes on sometimes in a quiet way in agriculture, and obviously all of that work and the research that has been done has resulted in yields that continue to get stronger and stronger. Now, we've got to do some work on prices, but obviously the work that's gone on has helped with our yields and really bountiful harvests that we've had.

Before my questions, I want to highlight a unique agriculture research facility located in Peoria, Illinois, that I represent, and that's the National Center for Agriculture Utilization Research in Peoria, also known as the Peoria Ag Lab. The Ag Lab is run as

part of the Agriculture Research Service (ARS), which has been a vital agency within the Department of Agriculture. For over a half-century, this agency has done work to improve the lives of countless Americans and includes research on corn, wheat and soybeans as well as the distinction of developing the mass production of penicillin in the 1940s by Nobel Prize-winning scientists at the Peoria Ag Lab. Currently, the Peoria Ag Lab is designated to lead technology transfer for the USDA and focuses on bioenergy, renewable resources, and research for safe and healthy foods. To list all the examples of the impactful research done at the Ag Lab would take more than my allotted time but I would like to talk about a few and highlight the valuable research that goes on there.

First, ARS scientists in Peoria developed the first American Petroleum Institute-certified bio-based motor oil from a seed crop, providing for growth in the agriculture and manufacturing sectors of the economy. Second, toxins produced by fungi during grain production and storage cause billions of dollars in annual losses to the U.S. economy and have had significantly negative impact on farmers and rural communities. The toxin detection technologies developed by ARS in Peoria were transferred to the private sector via licensing agreements to more than 30 companies and their widespread use has helped to ensure the safety of the food supply and help to promote job growth in the biotechnology area. Third, new biodegradable products that are nontoxic and inexpensive to produce have been prepared from renewable materials using a process that can easily be scaled by small or large businesses in any location. These products developed by ARS in Peoria can be used to control a wide variety of pests and pathogens, and combined with their low production cost will make this discovery a valuable new tool to help farmers and improve yield and promote economic development.

Building off that discussion on agriculture research, Dr. Moose, I wanted to ask you, how can federal support of agriculture research, which our Peoria Ag Lab relies on federal research, ensure that America is prepared to lead in emerging science to continue to benefit our farmers and the U.S. economy?

Dr. MOOSE. Yes. So the Peoria Lab's a great example of this—the research that goes on there, the technology transfer, the impact that it has on the farm or through society, and so I would say I guess more examples like that would be beneficial, and the mechanisms, there are a variety of ways to do it. The USDA ARS runs that facility. There are others like it that are partnerships with either university or industry groups.

But I think another aspect that could be sort of going forward and enhancing this is just convening at the table, having a voice, an opportunity for industry, government and society or the end users, we'll call them, sitting down at the table, and those things happen just in our own—recently the people from the Peoria Lab are partners in our new Bioenergy Center that's actually a Department of Energy-funded project with the University of Illinois and partners all over the country, and so through that center, we will be having this conversation and specifically around renewable energy from biomass and renewable products, and so the group at Peoria Lab that are partners, they're a critical piece of that trans-

lation from—we have plants that are valuable on the farm, they have unique properties, how can they be processed and added value. And the Peoria Lab is well positioned for that because industry, it might be too risky for them to do that type of work right now, but if we can transition that into a less risky and commercially viable option, then that would—the benefits will come.

Mr. LAHOOD. Thank you. I look forward to working with you, Dr. Moose.

Mr. MARSHALL. I now recognize Mr. Hultgren for questions.

Mr. HULTGREN. Thank you, Chairman. Thank you so much for being here. This is a very important discussion and I want to just say thank you for your time and your expertise. Also, I have to recognize this is the second day in a row that we've had someone representing one of our great universities from Illinois, so I want to keep the streak going. I'm looking forward to tomorrow. I'm not sure who our witness will be then but we're so proud of University of Illinois and all of our great universities. So thank you.

As my colleagues have said, agriculture is so important, and certainly in Illinois, agriculture drives exports. I had the great opportunity last year to be in Taiwan, meet with the president of Taiwan, and also foreign and agricultural ministers there just to discuss how important and mutual importance of agriculture exports and specifically from Illinois.

I also serve as Co-Chairman of the Tom Lantos Human Rights Commission and see that agriculture and food security as an ever-present force that compounds and exacerbates the basic lack of legal and human rights in conflict regions around the world. So we have to continue to recognize what we can do to make sure that food is available to every single person.

Dr. Moose, I wonder if I could address my first question to you. Can you talk a little bit about how federal support for agricultural research can encourage stronger connections between farmers, scientists and society, and how specifically Illinois is helping to build those connections?

Dr. MOOSE. Yes. So as I alluded to in the testimony that I gave and then in my written testimony, I think the federal government has this role of bringing the community together, the community of scientists, the interaction with society, and then because agriculture is so important to many districts around the country, it is why it's a national issue. Every region of the country has their own climate, their own agricultural systems that operate there, yet we can learn from all of them. What a corn farmer does in Illinois he may learn from the farmer elsewhere in the country. So that's one.

Also, it was alluded to earlier, building the pipeline where through education, you're not only educating the knowledge, there's the networking, the interaction of people that I know certainly in my career at North Carolina State, it was the early days of biotechnology research, and it was recognized a workforce needed to be developed, and North Carolina State was one of the first to do that, and now my peers that I went through that program with are leaders in the industry, they're leaders in government, they're leaders in academia. We need to have that next generation also. And I think the unique aspect of that program and others like we have at Illinois, for example, our Illinois Plant Reading Center, industry

supports the graduate training. They don't expect a research outcome. All they expect is, maybe we'll have some good employees, you know, to hire down the road, and so I think that educational piece is really important, and it was integral to Lincoln's vision. He considered education foremost to drive the research.

Mr. HULTGREN. I agree. Let me open this up to everyone.

Coming from Illinois, I see our National Laboratories as vital to our research ecosystem, building the large research facilities and unique one-off machines that no one institution or federal agency has the ability to manage, so again, these laboratories are so important to bring people together. The Advanced Photon Source at Argonne has nearly 2,000 users in the biological and life sciences. I toured Lawrence Berkeley this year and saw the great benefits of the Joint Genome Institute to multiple areas of research. Facilities like the Molecular Science Lab at PNNL also come to mind.

Do you think that USDA is properly leveraging these facilities and other investments in our lab, and how can we better facilitate a more collaborative approach between different agencies so that we're doing the best science and not duplicating efforts and facilities? I'd open it up to anybody.

Dr. GERSTEIN. Well, I wouldn't mind starting just to talk a little bit about Plum Island and the work that was done there. I was in charge of Plum Island. It was part of the Science and Technology Directorate when I was acting Under and then Deputy Under Secretary. So I worked with them very closely, and I always felt like Plum Island was really very much of a joint facility. I had Department of Homeland Security people and I had people from USDA, Department of Agriculture, and every time I'd go up there, I couldn't keep straight who was from which organization, and they were literally working on the bench side by side. One of the outputs of this collaboration was the first ever what we call a diva vaccine for foot and mouth disease, and so that's a great representation of where there is good collaboration. I felt the same with other agencies, for example, EPA and Department of Ag and Health and Human Services as well as Homeland Security. We all collaborated on difficult questions about how would one handle a foot and mouth disease event. For example, think about the large amount of just waste that would be generated if you had to depopulate a number of livestock across several different farms. You know, we were thinking about numbers in excess of 50,000 animals at a time that would—you know, you'd have to do something with all that waste. So, I mean, we worked very closely to try to collaborate, and there's a lot of—believe it or not, even on the depopulation question, there's a lot of research and development that goes into answering how clean is clean enough and how do you dispose of what could be very dangerous pathogenic material.

Mr. HULTGREN. Thank you. Five minutes, now six minutes, goes by way too fast. So we'll follow up because I think this is an important issue of again how we can be continuing to build collaboration. Thank you all.

I yield back.

Mr. MARSHALL. I do want to add my thanks to all the witnesses for coming today. It was an excellent education for me. Thanks for

your testimony and the Members for their questions and participation.

The record will remain open for two weeks for additional written comments and written questions from Members.

This hearing is adjourned.

[Whereupon, at 12:02 p.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Daniel Gerstein

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Putting Food on the Table – A Review of the Importance of Agriculture Research"

Dr. Daniel Gerstein, Senior Policy Researcher, RAND Corporation

Questions submitted by Chairwoman Barbara Comstock, House Committee on Science, Space, and Technology

1. How are the results of federally-supported agriculture research transferred to U.S. farmers? Is the transfer efficient and effective? What improvements might be needed?

   Answer: Research and development must be thought of as a system that includes federal, state, and local governments in collaboration with private industry to identify requirements for federally supported research and development (R&D), fund the highest priority programs, and transition the R&D products to the user community. During my tenure in the Department of Homeland Security (DHS), where our focus was on agricultural biodefense, the R&D products included a wide range of prophylaxis, diagnostics, and knowledge products that support the development of policies, programs, and activities to support and protect a healthy and vibrant agricultural sector.

   This implies that government and industry stakeholders must be in close coordination and have a free flow of information about the biological threats, vulnerabilities, concerns, and requirements to ensure that federally funded R&D is focused on the highest priority issues. It also implies that federal support for key R&D programs and facilities is available. Key to ensuring the successful transfer of federal R&D are unique facilities, such as the National Bio and Agro-Defense Facility (NBAF) in Manhattan, Kansas, or federally led efforts, such as the National Animal Health Laboratory Network, which has its roots in the Homeland Security Act of 2002 and Homeland Security Presidential Directive 9.

   The transfer of federally-funded R&D has had demonstrated success. One such example is the federal funding and support for early R&D for development of a foot-and-mouth disease (FMD) vaccine. The U.S. Department of Agriculture (USDA) and the DHS initially led efforts to develop a vaccine. Government and industry identified the requirement; academia provided some of the early science; and a vaccine developer, through a cooperative R&D agreement with DHS, licensed and manufactured the vaccine. The result was an approved vaccine that is now commercially available.

   While the FMD vaccine example demonstrates how the system can work, more collaborative efforts such as this are needed. Continued cross-talk will be required across the agricultural biodefense stakeholder community to ensure an alignment between

community requirements and funded programs. In this regard, consistent funding for agro-biodefense is also essential to ensure that the highest-priority R&D is appropriately funded.

2. What areas of research and development would be most important to strengthen the nation's position in global food exports and to help provide U.S. farmers a competitive edge in meeting future food needs and market demands?

Answer: Increased demands for food, coupled with climate change stresses, will translate to greater requirements for R&D to produce generations of crops and livestock that produce more per unit area under more-extreme climate conditions and in harsher environments. It will also require R&D to support important agricultural biodefense capabilities.

No single technology or R&D area is sufficient to protect the $1 trillion-per-year agricultural sector. We need a combination of capabilities for preventing, mitigating, protecting from, responding to, and recovering from an agriculture biodefense event (either naturally occurring or deliberate) to support and protect the U.S. agriculture sector. This combination not only protects the food supply for U.S. producers and consumers but also supports a healthy and vibrant U.S. food export capability.

Threat awareness remains essential for protecting the nation's agricultural sector. Understanding the range of threats—from naturally occurring disease to the deliberate use of biological pathogens—allows tailoring R&D towards the highest-priority concerns. Prevention and protection programs, such as vaccine programs and international efforts to halt the spread of disease (through a variety of programs, including biosurveillanee and reporting, arms control, and export controls), should receive high priority in R&D. Surveillance and detection remains essential for monitoring the agricultural sector. Improved bioassays, pen-side diagnostics, agricultural screening tools, and surveillance and reporting capabilities and the associated R&D are essential as well. Response and recovery R&D, including response planning, development of rapid response capabilities, and depopulation protocols would be essential in the event of an outbreak or an attack.

In looking to the future, biotechnology is continuing to increase at unprecedented rates. New tools and technologies are continuing to be introduced. Gene editing, genomic selection, deployment of transgenes, and high throughput sequencing—to name a few areas—have the potential to significantly alter agricultural yields and reduce susceptibility to a wide range of natural threats (including climate change) and deliberate threats. R&D must continue to ensure that the United States maintains a competitive edge for meeting market demands and in agricultural exports.

3. What areas of research and development would you suggest be prioritized in the next farm bill?

   Answer: While agricultural R&D is a broad area with many requirements, activities that support the U.S. agricultural industry's capacity to deal with importation of new diseases, changing climate, and increasing global demand should receive priority. Growth in global trade and travel means that humans, animals, plants, and microbes are more likely to be introduced into the United States. Protecting the U.S. agricultural system means developing threat awareness and surveillance and detection systems to support rapid response and recovery systems.

   Changing climate and increasing demand (particularly for protein) will require being able to increase yields using less water and land. By 2050, the requirement for food production will increase by an estimated 70 percent. R&D has a pivotal role in delivering these requirements.

4. Lots of remarkable new technology is right around the corner and seems bound to change farming: drones equipped with advanced sensors; autonomous planting and harvesting equipment; computers and smart machines to calculate when and how to plant, irrigate, fertilize and harvest. What do you foresee as technologically advanced farming?

   Answer: The increased demands for food, coupled with climate change stresses, will translate to greater requirements for R&D to produce generations of crops and livestock that produce more per unit area than current varieties, under more extreme climate conditions and harsher environments.

   Genetically modified organism (GMO) technologies and the associated R&D offer important opportunities for improving yields in harsher climates. However, the current debate about GMOs unnecessarily focuses on the technology, rather than on the products that it supports. Regulations should focus on promoting ethical and scientifically based improvements that are carefully managed to avoid potentially dangerous outcomes.

   New modes for enhancing agricultural output and protecting the environment will continue to be incorporated. Substitution of biological materials for chemical fertilizers and vector control is occurring with increased regularity, and these uses will continue to expand. Reducing the use of antibiotics in agriculture will also be important for reducing antimicrobial resistance in animals and humans.

5. What role should the federal government, states, academia, and private sector play in agricultural research? Is one entity better suited to conduct certain types of research (for example basic research versus applied research)?

Answer: The federal government, states, academia, and private sector each play important roles in agricultural research. The point is to develop a collaboration between the various actors to ensure that all critical R&D is being conducted to the betterment of the U.S. population and agricultural sector. Such collaboration also strongly implies close collaboration across the globe in the monitoring of disease and the conduct of R&D activities.

Allocating roles to each of the entities in an absolute sense is not possible. Government, academia, and the private sector conduct R&D across a broad spectrum of activities. Private industry, academia, and federal laboratories (such as NBAF and the Department of Energy labs) conduct basic and applied R&D, from early research to increase fundamental understanding of certain phenomena to developmental activities to monetize their work and improve outcomes. The government has a primary role in coordinating activities in particular areas, such as agricultural biodefense; developing policies and regulations; developing codes of ethical behavior, biosafety and biosecurity; and monitoring compliance.

However, in certain circumstances, such as the development of the FMD vaccine, government, academia, and industry work together to develop a needed capability. Government and academia provided much of the early research and development. Private industry, through a cooperative R&D agreement, collaborated with government to bring the vaccine to market.

In cases involving genetically modified organisms, industry is working to develop drought-resistant crops and livestock that yield more protein. Industry routinely partners with academia on these efforts.

The government (at all levels) has unique roles in disaster management and emergency situations. For example, in the event of an FMD outbreak in the United States, the government would have an active role in monitoring the response, particularly in areas such as depopulation and disposal of the infected remains.

The difficulty in establishing discrete roles for each of the entities involved in agricultural biodefense provides indication of why close collaboration of R&D efforts is essential. Through this collaboration, the highest-priority issues can be examined and gaps in agricultural biodefense R&D addressed.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Putting Food on the Table – A Review of the Importance of Agriculture Research"

Dr. Daniel Gerstein, Senior Policy Researcher, RAND Corporation

Questions submitted by Representative Randy Hultgren, House Committee on Science, Space, and Technology

1. Do you think USDA is properly leveraging DOE Office of Science facilities and other investments at our national labs? How can we better facilitate a more collaborative approach between different agencies so we are doing the best science and not duplicating efforts and facilities?

   Answer: The agricultural biodefense stakeholder community consists of government, the federally funded R&D centers (FFRDCs), academia, and private sector. The DOE laboratories are FFRDCs that provide a broad range of R&D activities, from basic research to development.

   Each of the stakeholders play important roles in agricultural biodefense research. The point is to develop collaboration between the various actors to ensure that all critical R&D is being conducted to the betterment of the U.S. population and agricultural sector. Such collaboration also strongly implies close collaboration across the globe in the monitoring of disease and the conduct of R&D activities. Through this collaboration, the highest-priority R&D issues can be examined and gaps in agricultural biodefense addressed.

   While the stakeholder community works with the DOE national labs in agro-biodefense R&D, I do not have specific knowledge of ongoing programs between USDA and the national labs. However, during my time in DHS, we maintained close relationships with the labs to ensure we were doing the best science and minimizing or eliminating duplication of efforts and facilities.

2. With regard to research on microbial communities in soil, plants and animals, does the U.S. Department of Agriculture have any plan to focus on the use of engineered microbial communities for soil and seeds to increase drought resistance or lower inputs?

   Answer: I have no information regarding specific USDA programs for development or use of engineered microbial communities for soil and seeds to increase drought resistance or lower inputs.

However, the increased demands for food, coupled with climate change stresses, will translate to greater requirements for R&D to produce generations of crops and livestock that produce more per unit area under more extreme climate conditions and in harsher environments.

GMO technologies and associated R&D offer important opportunities for improving yields in harsher climates. The search for identifying opportunities for enhancing agricultural output and protecting the environment will continue, and USDA has a central role in these efforts.

Responses by Dr. Stephen Higgs

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Putting Food on the Table – A Review of the Importance of Agriculture Research"

Dr. Stephen Higgs, Associate Vice President for Research, and Director, Biosecurity Research Institute

Questions submitted by Chairwoman Barbara Comstock, House Committee on Science, Space, and Technology

1. How are the results of federally-supported agriculture research transferred to U.S. farmers? Is the transfer efficient and effective? What improvements might be needed?

   Answer: Results from federally funded agricultural research are transferred to interested and invested parties, including farmers in a number of ways. Academic researchers distribute their data in peer-reviewed scientific publications, in abstracts and posters at conferences and in oral presentations at meetings. Additionally, scientific advancements are brought directly to farmers and the consultants that support agriculture by extension personnel from land grant institutions. These are universally recognized platforms by which progress in the field is made, but is also a criterion by which personal careers are advanced. Via these types of communication, scientists can identify potential collaborators. Collaborative research is particularly important since it can bring together scientists with complementary expertise so that a problem can be studied from different perspectives. On-farm research is another way that scientists engage farmers in the research process to speed the delivery of science-based information.

   Personally, I give PowerPoint presentations describing the agricultural research and related training conducted at the Biosecurity Research Institute, many times a year to a wide range of audiences. Farmers are often present in these audiences, and they frequently ask questions about the pathogens that we study. As the first land grant university, Kansas State has multiple departments and colleges that have been involved in agricultural research for over 150 years. The activities include Research and Extension work that is a direct link between researchers, farmers and the agricultural community. One important improvement would be to reverse the decline in federal research funding that underpins the science upon which modern agriculture depends. There is a direct inverse relationship between investment in agricultural research and the cost of food which impacts poverty and public health.

   I assume federal agencies that support agricultural research have a mechanism by which they can themselves promote the results of the research that they support to farmers. The Department of Homeland Security for example, has a website dedicated to the Plum

Island Animal Diseases Center https://www.dhs.gov/science-and-technology/plum-island-animal-disease-center.

This has drop-down links to describe the facility, what is (and is not) done there and how the work protects our agriculture and food industries. The site also links to the USDA's Agricultural Research Service (ARS), the Animal Plant Health Inspection Service (APHIS) and the Foreign Animal Diseases Diagnostic Laboratory (FADDL). All of these would allow farmers to have access to research results, but knowledge of those websites might need to be communicated to farmers more effectively.

Beyond that, I cannot really judge how efficient and effective this type of information transfer from federal agencies is and what improvements are needed.

If one interprets the question in its broadest terms to mean transfer of actual products that result from federally funded agricultural research, that is also difficult for me to judge. This type of research is often not "product-driven". For example, if research is focusing on diagnostics and vaccines, advancing these to an application is not really possible in most academic settings. The application depends on product development beyond concept and laboratory testing. It requires evaluation though prolonged and strictly regulated procedures and then successful commercialization and marketing. These expensive paths from concept to market are typically performed by private sector companies.

The National Bio and Agro-Defense facility (NBAF) being built in Manhattan, Kansas actually has a Biotechnology Development Module (BDM) that is intended to perform this product development and commercialization function by engaging animal health companies. DHS and Kansas State University personnel are already active in developing these relationships, even though NBAF will not be operational until 2022.

2. What areas of research and development would be most important to strengthen the nation's position in global food exports and to help provide U.S. farmers a competitive edge in meeting future food needs and market demands?

Answer: To strengthen the Nation's position in global food exports and to help provide U.S. farmers a competitive edge in meeting future food needs and market demands, there are perhaps several areas of research and development that should be strengthened. Obviously, we need to understand and be able to accurately predict what future demands will be and who we are/will be competing with. With this knowledge, we should be able to align research and development priorities to meet the predicted needs. In simple terms, we need to increase agricultural productivity and grow export capacity. This may involve research to develop high yield plants and animals, strains that can thrive under

environmentally diverse conditions (for example drought tolerant plants), and strains that are resistant to pests and pathogens. Other genetic traits and technologies that may be needed would include increased shelf life to reduce wastage.

An important research focus at the BRI, and one that has been highlighted in the Blue Ribbon study panel discussions, is the area of food security. As it exists, our agricultural industry faces many potential threats that could be devastating to both our National needs and our international trade of agricultural products. Our crops and our livestock are highly vulnerable to a broad range of foreign pathogens and pests. These could be introduced into the U.S. either via, for example, insufficiently scrutinized imports or deliberately. Planning to increase exports as discussed above is necessary, but we must have in place strategies and technologies to protect our existing agricultural system.

We need to support research that will allow us to better understand the threats, know where they are, know how they may be introduced, be able to detect them rapidly through effective surveillance, be able to respond to control the damage, and if necessary recover quickly from an outbreak. The Kansas Intelligence Fusion Center has a Biothreat Team, of which I am a member, and the team focus is on identifying biological threats to plants, animals, and people prior to them reaching the U.S. Protecting agriculture should start by knowing what threats are over the horizon.

In the last 20 years, foreign animal diseases such as West Nile virus (WNV) and Porcine epidemic diarrhea virus have been introduced and become established in the U.S. Zoonotic diseases such as WNV are particularly difficult to eradicate because of the wildlife component of the transmission cycle, and yet are particularly worrisome because they threaten humans as well as livestock. Foreign plant diseases such as wheat blast could enter the U.S. in shipments of grain from South America; the same way it got to Bangladesh in 2016 devastating wheat production in portions of that country. Research has been going on in the BRI since 2009 to develop varieties of wheat resistant to wheat blast.

Investments in the fundamental and applied research that supports agriculture and the technologies that support biological research (e.g., CRISPR technologies) are essential to maintain competitiveness in the global marketplace.

3. What areas of research and development would you suggest be prioritized in the next farm bill?

   Answer: The areas of research and development that should be prioritized in the farm bill, are basically those discussed above. Biodefense of U.S. agriculture is far from where it needs to be.

   Research to protect and sustain what we have is essential. Through the types of multidisciplinary research conducted at the BRI and in several K-State colleges and departments, we are building capacity to identify agricultural threats (diagnostics, surveillance), develop resistant plants and animals and treat effected animals (vaccines). The Blue Ribbon Study Panel on Biodefence has concluded that the U.S. lacks leadership, a strategic plan and a budget for biodefence. Defense against biological threats is not just an issue to protect people but is also vital for agriculture. The most recent publication of the panel highlights this need for "Defense of Animal Agriculture". This does not address biological threats to food crops, but I believe that the Blue Ribbon Panel are planning to address that concern as well.

   An important component to complement research is training not only of researchers, but also of personnel that may be involved in responding to an outbreak. At the BRI in Pat Roberts Hall, staff of the National Agricultural Biosecurity Center are working with DHS and FEMA funding to train first responders and have received DHS funding to work on a National Readiness Program. DHS has had an important role in supporting and overseeing research related to protecting U.S. agriculture and this responsibility should be further clarified and financially supported.

4. Lots of remarkable new technology is right around the corner and seems bound to change farming: drones equipped with advanced sensors; autonomous planting and harvesting equipment; computers and smart machines to calculate when and how to plant, irrigate, fertilize and harvest. What do you foresee as technologically advanced farming?

   Answer: My view of technologically advanced farming relates to maximizing yield in all production areas, with use of, for example varieties of cereals, vegetables and fruit that are optimally suited to each situation. These high yield varieties should grow with minimal irrigation, be monitored for diseases using modern technology (high resolution imaging from drones?), harvested and processed efficiently and be suited for long-term storage prior to distribution.

   These technologies are and will continue to improve efficiencies in agricultural production and protection. Although important, alone these technologies will not replace the very real need for identifying and understanding the increasing and evolving challenges to agriculture posed by a changing climate, changing landscapes, and

increasing food demand. History suggests that as agriculture becomes more sophisticated technologically, their vulnerabilities to external threats also increases; e.g., emerging pathogens of animals and plants. We must invest in the science and technologies that address plant and animal health, not just production. Exotic pathogens threaten our production systems should they be introduced and emerging pathogens threaten our ability to export what we produce.

5. What role should the federal government, states, academia, and private sector play in agricultural research? Is one entity better suited to conduct certain types of research (for example basic research versus applied research)?

Answer: In the context of agricultural research, federal, state, academic and private sector entities have specific roles but they also have complementary activities and roles. The federal government is a primary funder of agricultural research, but feeding the world will require increased resources to keep up. The federal government also needs to develop and enforce fact-based regulations to protect our agriculture from threats and ensure compliance. As mentioned above, the research should be aligned with U.S. needs and objectives. These must include input from private sector producers and also consumers. This involves market research to ensure that we do not perform research to develop something that we do not need and will not be used. A genetically modified crop or a vaccine that is not acceptable in the marketplace is a waste of taxpayer money. The government and multinational private sector companies should understand needs and tolerances in the national and international markets. Together they should provide input to direct agricultural research. Academia is particularly good at basic research and through links with industry can facilitate developing applications for their discoveries. To some people/groups so–called basic research does not have value because it may not be innovative or hypothesis driven. However, the knowledge gained from basic research provides the essential platform on which applied research can be built.

In general, industry no longer funds the fundamental research that leads to transformational change. Private sector research is focused on the narrow array of issues impacting that industry and the solutions relevant to that industry. Federal support for research is essential to address current challenges and anticipate and prepare for future challenges. With increasing global pressures on food production systems, this would be a poor time to retreat from supporting the research necessary to address these pressures.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Putting Food on the Table – A Review of the Importance of Agriculture Research"

Dr. Stephen Higgs, Associate Vice President for Research, and Director, Biosecurity Research Institute

Questions submitted by Representative Randy Hultgren, House Committee on Science, Space, and Technology

1. Do you think USDA is properly leveraging DOE Office of Science facilities and other investments at our national labs? How can we better facilitate a more collaborative approach between different agencies so we are doing the best science and not duplicating efforts and facilities?

   Answer: I am not in a position to judge whether or not the USDA leverages DOE resources properly.

   DOE-sponsored genome sequencing has been of great benefit to USDA research programs by providing fundamental information on the organisms important to agriculture, including, plants, arthropods, and pathogens.

   I do, however, firmly believe that collaborative research is essential and it is the most effective approach in advancing knowledge and understanding to tackle problems. You cannot make people, different divisions within agencies and different agencies work together. Interagency agreements may help if they have clearly defined roles and objectives, but they must evolve with the needs and the capabilities. I was surprised to learn recently that the interagency agreement between the USDA and Defense Threat Reduction Agency (DTRA) had not been renewed even though they have some important shared interests. I think that for historical reasons some groups do not work well together, perhaps because they are competing for funds. These issues must be addressed by developing a culture of collaboration. With NBAF on the horizon, one hopes that the culture with the many new scientists that will be employed will be one that promotes collaborative research.

   This might be an area for collaboration with DARPA; e.g., DARPA's Insect Allies Program. Perhaps a collaborative program analogous to the USDA-NSF food-water-energy Nexus program.

2. With regard to research on microbial communities in soil, plants and animals, does the U.S. Department of Agriculture have any plan to focus on the use of engineered microbial communities for soil and seeds to increase drought resistance or lower inputs?

Answer: I really do not know about the USDA's plans for research on microbial communities in soil, plants and animals. In my field of infectious diseases, there is a current emphasis on the use of microbially infected mosquitoes that are being released on a large scale in several countries, to reduce mosquito populations. With suppressed populations, one would anticipate a lower transmission rate of human pathogens. A similar approach to reduce the capacity of mosquitoes to actually transmit pathogens has potential as well. I can provide further details and pertinent publications, for example: Higgs, S. (2013). Alternative approaches to control dengue and chikungunya: transgenic mosquitoes. Public Health. 24: 35-42.

The relatively recent and rapid development of CRISPR gene-drive technology, has potential applications to agriculture that could include drought resistant traits. I was a member of a National Academy study group to evaluate the applications of the technology, and contributed to the publication: "Gene drives on the horizon: Advancing science, navigating uncertainty and aligning research with public values" Further details are available at http://nas-sites.org/gene-drives/.

One great deficiency in the area of engineering communities is the lack of foundational databases by which to analyze datasets. The magnitude of this effort would almost certainly require multi-agency support. Without these foundation databases, progress will be very slow with a lot of false starts.

My thanks to Dr. James Stack (K-State Department of Plant Pathology, College of Agriculture and Dr. Ron Trewyn, (K-State President's Office), for their comments and contributions to these responses.

Responses by Dr. Stephen P. Moose

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Putting Food on the Table – A Review of the Importance of Agriculture Research"

Dr. Stephen P. Moose, Denton and Elizabeth Alexander Professor, Maize Breeding and Genetics, Department of Crop Sciences, University of Illinois at Urbana Champaign

Questions submitted by Chairwoman Barbara Comstock, House Committee on Science, Space, and Technology

1. How are the results of federally-supported agriculture research transferred to U.S. farmers? Is the transfer efficient and effective? What improvements might be needed?

   Answer: There are many routes for outcomes of federally-supported research to reach U.S. farmers. Some of these are direct, through agencies housed within the USDA such as the Agricultural Marketing Service, the National Agricultural Statistics Service, and the Economic Research Service. Research that improves the monitoring functions of APHIS or GIPSA directly touches farmers that interact with these important agencies. The knowledge and products from applied research conducted by USDA-ARS or university scientists supported by federal funding are often the first responses to emerging issues such as new disease outbreaks in farmers' fields or livestock barns. Furthermore, Extension activities at every land-grant university engage farmers in information exchange and technology demonstration. Research results are also transferred to farmers through a variety of indirect means. Scientific breakthroughs are first communicated through journal publications, which are then more broadly disseminated by media outlets to farmer audiences and the greater public. Perhaps most frequently, farmers experience the outcomes from federally-supported research through commercial products developed from new knowledge and technologies.

   The current system for transfer of research outputs and innovations in agriculture is efficient and effective, as measured by both historic and current high rates of technology adoption by U.S. farmers compared to other countries. U.S. farmers are becoming even more technology savvy, and are increasingly able to identify novel applications from research results that may not have even been apparent to the researchers. Regarding improvements, the massive volume of information that is already available and continues to grow at an exponential pace presents challenges in both accessing information and applying it on the farm. A greater emphasis in Extension on information science and delivery in formats easily accessible to working farmers would be a valuable addition to an already strong technology transfer system. As an academic scientist, my productivity is often judged by numbers of publications and citations by other scientists. Although useful, these metrics do not assess impact to users beyond the scientific community. Systems for granting agencies to track research that is eventually adopted on farm would

be a welcome additional metric to not only convey to farmers and the public the value of such research, but also offer incentive and credit to researchers who contribute real innovation, instead of just padding their curriculum vitae.

2. What areas of research and development would be most important to strengthen the nation's position in global food exports and to help provide U.S. farmers a competitive edge in meeting future food needs and market demands?

   Answer: The U.S. has historically competed in global food markets on the basis of greater production, via increasing acreage or herd sizes, coupled with higher yields or feed efficiencies. Accordingly, substantial research efforts are directed at improving production capacity or efficiency. Continuing such investments is one way to maintain the global competitiveness of U.S. farmers, although other countries can be expected to do the same. However, consumers at both home and abroad increasingly value food attributes such as nutritional quality, methods of production (locally-grown or organic), and environmental impacts. Thus research and development aimed at enhancing nutritional quality of food products, energy conservation, and reducing environmental pollution from agricultural practices will help U.S. farmers meet these consumer demands. Finally, agricultural systems that are more robust to the challenges of changing weather patterns, both within season and across longer time scales, will be essential to meeting both domestic needs and producing surpluses for export. Thus, research that fosters better understanding and management of responses to environmental factors will be critical to the resiliency that is necessary to be a major global exporter of food.

3. What areas of research and development would you suggest be prioritized in the next farm bill?

   Answer: Your question here has good timing, because on November 22, the American Society of Agronomy, Crop Science Society of America (of which I am a member), and the Soil Science Society of America sent a joint letter to the leadership of the House Committee on Agriculture recommending research priorities for the next Farm Bill (https://www.soils.org/files/science-policy/letters/2017-11-22-house-farm-bill-recs.pdf). I certainly concur with their suggestions of increasing support for research equipment, a prestigious graduate student fellowship program for agriculture similar to that at NSF, and continued support of the Foundation for Food and Agriculture Research that matches federal research investments with non-federal funds. Another key request is to allocate some NIFA funding to both longer-term research projects and high-risk, high-reward projects, in addition to the typical three or four year grants that prioritize conservative, short-term work. These changes will positively impact the pace of innovation and the alignment of research with delivering solutions to challenges in agriculture.

I will go beyond the above recommendations to suggest three high priority research areas, each of which were chosen because their significant potential impact will be greatest if also coupled with effective national policies to implement best practices throughout U.S. agriculture. These dual goals are more easily achieved through the Farm Bill, rather than spending bills for individual granting agencies. The first priority is to invest in research and development that addresses the distortion of local, regional, and global nutrient cycling by agricultural systems, particularly nitrogen and phosphorous. Past research has done much to document the extent of nutrient imbalances, practices that intensify these imbalances, and the environmental consequences of nutrient pollution. Although many solutions have been proposed and some are being used, research now needs to support greater adoption of best practices, or discovery of even better ones.

The second high priority research area was mentioned in my prior testimony, and that is to support research and development that further leverages the digital data revolution already happening in all sectors of agriculture. Specifically, research that leverages new capabilities to include operating farms of any type as "research centers" for data collection, data processing, and testing of data-driven solutions, which could enable dramatic gains in productivity, efficiency and resiliency of U.S. agriculture. Finally, and as was discussed with Representative Abraham at the hearing, new advances in precision genome modification such as CRISPR hold both tremendous promise and reason for caution. Research investments are needed to ensure the U.S. is at the leading edge of genome editing applications to agriculture, and also to assure the public this new technology will be used responsibly.

4. Lots of remarkable new technology is right around the corner and seems bound to change farming: drones equipped with advanced sensors; autonomous planting and harvesting equipment; computers and smart machines to calculate when and how to plant, irrigate, fertilize and harvest. What do you foresee as technologically advanced farming?

Answer: Farming is hard labor, which has always been a powerful incentive to develop technologies that reduce the labor requirements. We have been amazingly successful, such that one US farmer today can now feed 150 people, compared to 25 just 50 years ago. As your question suggests, it is feasible to envision that even with current technology, nearly full automation of the entire cropping cycle is possible, particularly for small farms. As with many other industries and occupations, this automation and reduction of labor force will be accompanied by gains in efficiency, but also sociological consequences.

Another major driver of past agricultural innovations has been the desire to manage the environmental factors that most influence crop productivity, such as soil fertility, water availability, competition from weeds, and damage from pests or disease. Automation is

not only increasing the efficiency by which these factors are managed using current methods, but could potentially replace them with new "green" technologies, such as robotic removal of weeds instead of spraying chemical herbicides. As our knowledge of crop genomes grows and genome editing technologies improve, it will be possible to design high-yielding "tunable" plants that perform well in a wide range of environments, instead of the current approach to breed for varieties tailored to specific conditions.

Finally, I foresee tremendous potential for urban agriculture, where either repurposed buildings or new construction is dedicated to food production. Bringing some aspects of food production into urban communities offers many benefits, provided that it can be achieved in a manner that is at least energy-neutral, and preferably like today's farming, energy-positive.

5. What role should the federal government, states, academia, and private sector play in agricultural research? Is one entity better suited to conduct certain types of research (for example basic research versus applied research)?

Answer: Currently, the federal government, states, academia, and private sector each participate in agricultural research at scales that vary by both scope and time, and the intended end users. The federal government is appropriately the major contributor to research programs and infrastructure that is national or international in scope, or where there is a recognized public good from long-term research. However, within federal agencies that provide this support, there is a continuum from small to large projects, directed at investigators in both academia and the private sector. The federal government support is essential for investments in infrastructure that are too large or risky for others to build. States, through their land-grant universities and other entities, are frequent partners with the federal government in supporting research. States often emphasize research that meets needs or leverages strategic advantages specific to their region. States support both short-term and long-term research and pursue the full range of investigations from basic inquiry to commercialization. The private sector includes small start-ups and large multi-national corporations. Driven by return-on-investment and demands of their customers, they most frequently engage in short-term and applied research.

Beyond the above general trends, the roles of different entities in supporting research are probably best determined by the goals of the research project, the capacity and resources available, and expertise of the people in those entities. For some projects, a lead role for the federal government with partners from academia may be appropriate, whereas in others the research might best succeed if conducted by the private sector.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Putting Food on the Table – A Review of the Importance of Agriculture Research"

Dr. Stephen P. Moose, Denton and Elizabeth Alexander Professor, Maize Breeding and Genetics, Department of Crop Sciences, University of Illinois at Urbana Champaign

Questions submitted by Representative Randy Hultgren, House Committee on Science, Space, and Technology

1. Do you think USDA is properly leveraging DOE Office of Science facilities and other investments at our national labs? How can we better facilitate a more collaborative approach between different agencies so we are doing the best science and not duplicating efforts and facilities?

   Answer: From my perspective, given that both USDA and DOE support a broad scientific portfolio with distinctive missions, the answer to this question depends on which disciplines are considered. My impression is that for those areas where USDA science has little apparent overlap with DOE, such as food safety, there is probably little leveraging of DOE capabilities. However, in the area of bioenergy, where there is obvious mutual interest in crop production and bioprocessing, there are many strong and productive interactions between USDA and DOE Office of Science. My research group was previously supported by a grant from a joint DOE-USDA funding program, which also involved work at the DOE Joint Genome Institute (JGI). In addition, our newly awarded DOE bioenergy research center headquartered at the University of Illinois includes six USDA scientists as co-investigators, and this project will make extensive use services from both EMSL and JGI.

   Despite these positives, I have also noticed that due to the much larger budget available to DOE compared to USDA, when there are collaborations between the two agencies, DOE often contributes a greater portion of the budget and thus exerts more influence on the project, even though there is stronger domain expertise on the USDA side. One easy remedy for this issue is for the USDA and DOE contributions to be equal when they conduct joint programs. In addition, since the passage of the Energy Independence and Security Act in 2007, a significant influx of funding was provided to DOE for bioenergy research. DOE then began supporting research in domains such as crop production, genetic improvement, and bioprocessing that were already being supported by USDA, albeit at smaller funding levels. Because agriculture is at the front end of the bioeconomy, I believe that if this funding had come to USDA NIFA instead of DOE, the funds would have been better spent and our country would be further along the path to an economically viable bioenergy industry.

2. With regard to research on microbial communities in soil, plants and animals, does the U.S. Department of Agriculture have any plan to focus on the use of engineered microbial communities for soil and seeds to increase drought resistance or lower inputs?

Answer: An emerging area of science is focused on understanding the contributions of microbial communities to not only our own health, but also that of the soil, livestock, and crop productivity. Although it has been long recognized that microbial communities influence the ability of plants to acquire soil nutrients, and in some cases likely promote growth, the ability to manipulate or "program" these microbial communities to increase crop yields or yield efficiency has been challenging. However, both new startups and large agricultural biotechnology companies are making substantial investments in developing such products, and this has also stimulated federal funding for microbiome research. The USDA is a partner in the National Microbiome Initiative that began in 2016 as an interagency effort to coordinate funding and other resources to realize the promise of microbiome science. I am also aware of new project at the USDA-ARS laboratory in Albany, California that is studying crop growth responses to microbial communities, and recent USDA-NIFA awards to support a number of projects investigating how the microbiome can further enhance nutrient uptake. I also know that the day after our hearing, the Interagency Microbiome Strategic Plan was announced, which aims to support interdisciplinary research, develop platform technologies, and expand the microbiome workforce.

Responses by Dr. Elizabeth Wagstrom

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Putting Food on the Table – A Review of the Importance of Agriculture Research"

Dr. Elizabeth Wagstrom, Chief Veterinarian, National Pork Producers Council

Questions submitted by Chairwoman Barbara Comstock, House Committee on Science, Space, and Technology

1. How are the results of federally-supported agriculture research transferred to U.S. farmers? Is the transfer efficient and effective? What improvements might be needed?

   Answer: Scientific information, agricultural products, and interventions to control and prevent pests and diseases are transferred to U.S farmers and consumers of agricultural products by the most effective mechanism for the purpose intended. For example, scientific information to prevent the spread of diseases, including increasing on farm biosecurity measures is transferred to federal and state action and regulatory agencies who have within their mission space the responsibility for responding to disease outbreaks; scientific information is also transferred to trade journals, which may be a primary source of information for U.S farmers; novel veterinary medical countermeasures designed for preventing and controlling the spread of pests and diseases are transferred to businesses supporting the agriculture sector (e.g., pharmaceutical and vaccine manufacturers) who will then further develop for commercial use and obtain regulatory approval for sale and distribution to veterinarians and farmers. Although the majority of technology transfer of ARS research is for vaccines and novel control measures for food safety concerns and endemic diseases of livestock, this would also include contracts for the National Veterinary Stockpile for foreign animal diseases. All research is reported in scientific journals and undergoes rigorous peer-review before publishing, in addition results are presented at all applicable scientific and professional veterinary and producer group meetings. Results are disseminated to various popular press magazines that serve the livestock and poultry sectors. Some information is provided via webinars and web sites.

   The process for transferring research information and tools is effective and is only encumbered by the lack of available resources to support research programs and support functions such as communication staff, facility operations and maintenance staff, and technology transfer specialists. The travel restrictions enforced a few years ago were quite devastating to many scientific meetings and particularly damaging to the ability of federal laboratories to retain and recruit world-class scientific talent. Scientific meetings are often places where new collaborations and research approaches emerge as a result of seeing the most current cutting-edge research presented by peers. Lifting the travel restrictions would be a significant improvement for federal scientists.

Additionally, for years research was transferred to producers through the Cooperative Extension Service but budget reductions have diminished the agency's ability to fulfill that role. Industry voluntary funded associations and "check off" programs have now taken on that role and have done an excellent job with limited resources. However there are many small agriculture producers who do not have participate in an association or "check off" and thus are unable to share in the latest technology. There is still a need for an effective Cooperative Extension program to reach these producers and funding these programs needs to be a priority.

2. What areas of research and development would be most important to strengthen the nation's position in global food exports and to help provide U.S. farmers a competitive edge in meeting future food needs and market demands?

   Answer: Animal diseases are still the most important area of research. There needs to be a focus on emerging diseases, particularly zoonotic diseases that threaten both human and animal health. We need research and development of tools for disease detection, prevention, and control. This is limited by available resources to employ and sustain a critical mass of highly-skilled scientific staff and support personnel that conduct research on a wide range of animal diseases. When ARS has such a critical mass of scientists, it is uniquely positioned to "turn on a dime" to conduct critical research to address emerging disease issues that impact the health of our Nation's livestock and poultry sectors. Having adequate human capital when a new disease emerges is not something that can be acquired overnight and requires long-term investment to develop and sustain our capacity to conduct the research required. Succession planning for normal personnel turnover at the end of long and successful scientific careers is nearly impossible given current funding levels.

3. What areas of research and development would you suggest be prioritized in the next farm bill?

   Answer: Animal diseases should have the highest priority for farm bill funding. The economic losses from animal diseases are a significant burden on the overall agriculture economy due to the high value of livestock and poultry. The large scale movement of livestock makes the entire industry vulnerable to wide spread outbreaks. It is estimated that each day 1 million pigs and 500,000 cattle are moved and when added to livestock concentration points such as fairs, exhibits and auction markets the risk grows exponentially. As an example, an outbreak of Foot and Mouth Disease in the U.S. is estimated to produce a $200 billion loss to the agriculture economy. Research that allows for better understanding the biology of a particular disease and development of control methods is critical to maintaining the health of the U.S. livestock herd.

Intramural research programs to advance the development of agricultural countermeasures to disease, similar to BARDA at HHS would be helpful. This requires a long-term federal research funding commitment to developing, hiring and retaining a skilled workforce with diverse scientific knowledge and research skills in veterinary medicine, pathology, microbiology, virology, immunology, molecular biology, parasitology, genetics, bioinformatics and computational biology (to name a few fields that we severely lack adequate numbers of scientists). In addition, the Presidential Advisory Committee on Combatting Antibiotic Resistant Bacteria recommended funding an Innovation Institute within the USDA that would facilitate development of start-up projects for animal health products that would allow us to reduce the need to use antibiotics.

4. Lots of remarkable new technology is right around the corner and seems bound to change farming: drones equipped with advanced sensors; autonomous planting and harvesting equipment; computers and smart machines to calculate when and how to plant, irrigate, fertilize and harvest. What do you foresee as technologically advanced farming?

   Answer: Precision farming for livestock, including sensors that detect diseases and general health parameters is the next new technology in livestock production. Use of CRISPR technology to rapidly advance the genetic improvement of livestock and poultry for efficient production of a healthy, safe and nutritious food supply to feed our Nation and the World. Some of these technologies need to be developed with foreign animal diseases in mind and a long-term goal of attacking and eradicating those foreign animal diseases in foreign countries where they are endemic. We have only scratched the surface in this area of technology but it will continue to grow with great debate about the social implications and ethical concerns. But it must move forward if we are to remain competitive in U.S. agriculture. It will be important that the regulatory structure allows reasonable pathways to approval of these technologies while protecting public and animal health.

5. What role should the federal government, states, academia, and private sector play in agricultural research? Is one entity better suited to conduct certain types of research (for example basic research versus applied research)?

   Answer: Federal funds should be directed toward basic research which, in addition to Federal agencies, is often funneled to academia. Other than through their land grant institutions, state agencies rarely contribute to research. ARS research has contributed immeasurably to agriculture over the years but their contribution has been diminished in the last few years due to budget reductions. At a time when we are facing a worldwide food crisis in the coming years, I believe we must reinvest in ARS' research in addition to support of the extramural research funded by the Agriculture and Food Research Initiative.

Agricultural Research Service (ARS) at the USDA is a mission-oriented, problem-solving agency. Solving the problem may require basic research, applied research, or a combination of each. Importantly, the availability of base funds appropriated by Congress allows ARS to tackle higher risk and longer-term research projects that are critical to innovation and cutting-edge research that eventually feeds the research pipeline. States are especially adept at focusing on applied research to meet local and regional needs. Academic institutions that conduct agricultural research are dependent on competitive research grants from the National Institute of Food and Agriculture, which are usually three years duration (relatively short term), and other public-private institutions (such as the National Pork Board) with very focused needs. As such, academic institutions usually excel in basic research but Land Grant Universities that are directly linked to agriculture also make significant investments in applied research. The private sector is especially adept at very applied research (such as the pharmaceutical industry) but tremendous accomplishments and impact have been achieved when core competencies and resources between federal, academic, and/or the private sector are aligned to solve problems of high national priority. The private sector is not able to invest in long-term basic research and they rarely have high biocontainment animal health research facilities available to them. However, the private sector is fully capable of obtaining the necessary regulatory approvals for next generation products.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Putting Food on the Table – A Review of the Importance of Agriculture Research"

Dr. Elizabeth Wagstrom, Chief Veterinarian, National Pork Producers Council

Questions submitted by Representative Randy Hultgren, House Committee on Science, Space, and Technology

1. Do you think USDA is properly leveraging DOE Office of Science facilities and other investments at our national labs? How can we better facilitate a more collaborative approach between different agencies so we are doing the best science and not duplicating efforts and facilities?

   Answer: The respective research missions of the USDA and DOE are very different and with some rare exceptions, the types of research facilities needed to achieve the needs of the USDA and DOE are very different. Importantly, USDA requires very specialized high biocontainment laboratories to work on especially dangerous and sometimes zoonotic pathogens of animals and plants, which cannot be accommodated by the facilities that administer the DOE mission. Accordingly, there is little overlap between the type of research conducted by the USDA and DOE. To better leverage the existing USDA biocontainment research facilities, the Congress should develop sustainable budget strategies that adequately fund the research at existing ARS animal health research locations, as well as, maintenance and operation of their existing biocontainment facilities that support the research missions of ARS. Moreover, Congress should increase funding for livestock and poultry research at its existing facilities to take advantage of economies of scale at the current biocontainment research locations by increasing their operational and research budgets to return our critical mass of scientists back to numbers of animal health research scientists seen 30-40 years ago. The ARS animal health research locations have suffered by a multi-decades-long failure of Congress to adjust ARS research budgets for inflation costs that impact their ability to conduct biomedical research in the animal health sector (the budget model in use by Congress for the NIH should be applied similarly to ARS biocontainment facilities research budgets: https://officeofbudget.od.nih.gov/gbipriceindexes.html). In addition, the cost of living adjustments to federal salaries is not always funded by Congress and they are then funded out of available research budgets which in turn reduces the amount of research that is done. For ARS animal health research, this equates to the loss of funding to support 2-3 scientists per year and continually erodes the research capacity for our Nation.

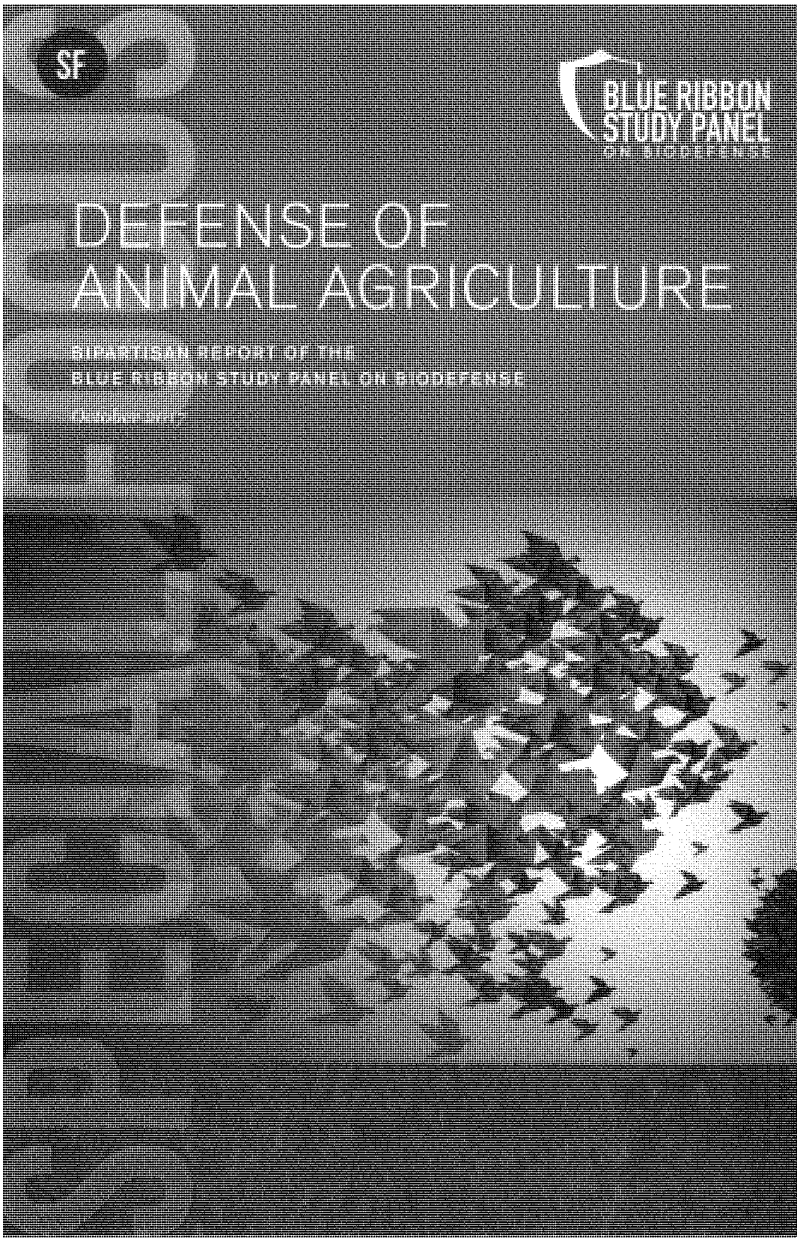
2. With regard to research on microbial communities in soil, plants and animals, does the U.S. Department of Agriculture have any plan to focus on the use of engineered microbial communities for soil and seeds to increase drought resistance or lower inputs?

Answer: Yes. Genetically engineered microorganisms designed to address priority agricultural needs will offer significant enhancements in agricultural outputs and productivity. However, a significant amount of basic research is still needed to rationally design microorganisms that are effective and safe. Although high efficiency whole genome sequencing technologies are now available, significant gaps remain in our understanding of the function of genes and how they contribute to health and disease function. This is a good example for the need to increase our investment in agricultural research so that the U.S can fully materialize on the competitive advantages that U.S agriculture brings to our economy and the welfare of our citizens. We also need to increase our research into microbiomes of animals as a way to fully understand how pathogens colonize animals and to investigate methods to prevent or reduce their colonization.

Appendix II

Additional Material for the Record

REPORT SUBMITTED BY
REPRESENTATIVE ROGER W. MARSHALL



SPECIAL FOCUS

DEFENSE OF ANIMAL AGRICULTURE

BIPARTISAN REPORT OF THE
BLUE RIBBON STUDY PANEL ON BIODEFENSE

October 2017

BLUE RIBBON
STUDY PANEL
ON BIODEFENSE

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PANEL MEMBERS

Joseph I. Lieberman, Chair
Thomas J. Ridge, Chair
Donna E. Shalala
Thomas A. Daschle
James C. Greenwood
Kenneth L. Wainstein

PANEL EX OFFICIO MEMBERS

Yonah Alexander, PhD
William B. Karesh, DVM
Rachel Levinson, MA
I. Lewis Libby, JD
Gerald W. Parker, DVM, PhD
George Poste, DVM, PhD, DSc
Tevi Troy, PhD

PANEL STAFF

Ellen P. Carlin, DVM, Co-Director
Asha M. George, DrPH, Co-Director
Robert H. Bradley, Policy Associate
Patricia Prasada-Rao, MPH, Panel Coordinator
Patricia de la Sota, Meeting Coordinator
Katherine P. Royce, EcoHealth Alliance Intern

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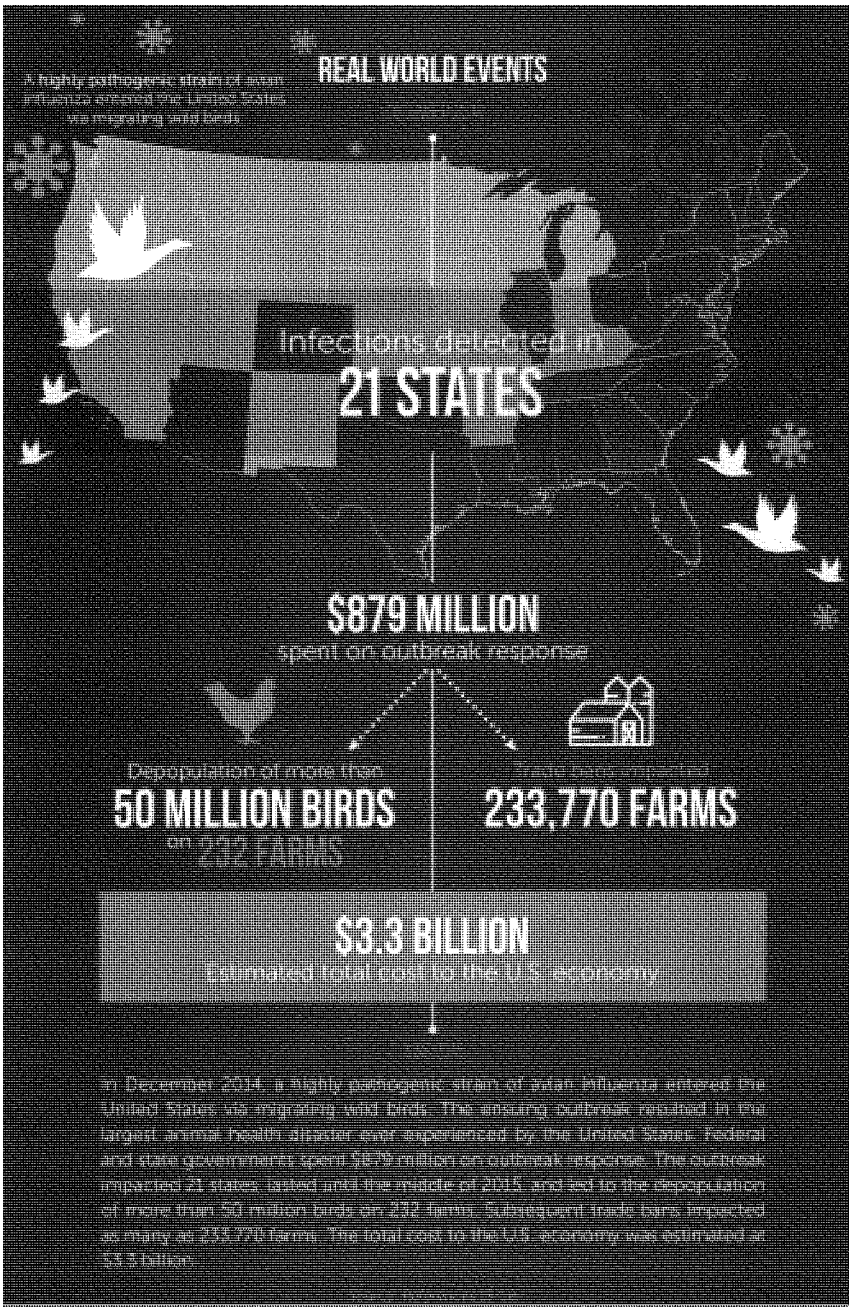

REAL WORLD EVENTS
A highly pathogenic strain of avian influenza entered the United States via migrating wild birds
Infections detected in
21 STATES
$879 MILLION
spent on outbreak response
Depopulation of more than
50 MILLION BIRDS
on 232 FARMS
Trade bans impacted
233,770 FARMS
$3.3 BILLION
Estimated total cost to the U.S. economy
In December 2014, a highly pathogenic strain of avian influenza entered the United States via migrating wild birds. The ensuing outbreak resulted in the largest animal health disaster ever experienced by the United States. Federal and state governments spent $879 million on outbreak response. The outbreak impacted 21 states, lasted until the middle of 2015, and led to the depopulation of more than 50 million birds on 232 farms. Subsequent trade bans impacted as many as 233,770 farms. The total cost to the U.S. economy was estimated at $3.3 billion.

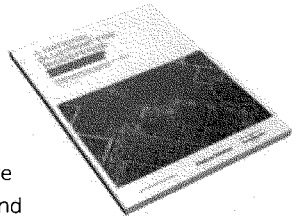
EXECUTIVE SUMMARY

The increasing rate of emerging and reemerging zoonotic disease, along with threats and attempts by those with nefarious intent to attack food and agriculture, point to the need to exert more effort to eliminate vulnerabilities and reduce consequences associated with America's agricultural sector. The Food and Agriculture (F&A) critical infrastructure sector produces, processes, and delivers the systems and commodities that feed billions of people and animals throughout the United States and globally. In 2015, the agriculture, food, and related industries contributed $992 billion (5.5%) to U.S. gross domestic product (GDP), making it one of the largest sectors of the U.S. economy. Given its critical importance to food safety and availability in the United States and around the world, protecting this sector is a matter of national security. Federal agencies; state, local, tribal, and territorial (SLTT) governments; academic institutions; and industry partners all contribute to and are responsible for this vast enterprise. Our lives, culture, economy, and livelihood depend on their efforts.

In its 2015 *A National Blueprint for Biodefense: Leadership and Major Reform Needed to Optimize Efforts*, the Blue Ribbon Study Panel on Biodefense determined that national biodefense lacked centralized leadership, interagency coordination and accountability, collaboration with non-federal stakeholders, and incentives for innovation sufficient to achieve needed capabilities and maximize mission effectiveness. With its series of special focus reports, the Panel undertakes in-depth examinations of particular biodefense topics of concern, considers how the recommendations it made in the *Blueprint for Biodefense* apply to these topics, and adds detail and new action items in keeping with its existing recommendations. This special focus report is the first in the series, and reflects the Panel's evaluation of threats to animal agriculture, a critical infrastructure component central to the health and well-being of the population and the security of a major element of the national economy.

The Panel views protection of agriculture – the cultivation and breeding of animals and plants for food, fiber, and other products used to sustain human life – as a critical part of the overall biodefense mission space. While nearly all the Panel's *Blueprint for Biodefense* recommendations apply to agrodefense, some are especially important for the mission and deserve particular attention at this time. The goal of this report is to elucidate a few key, persistent challenges and to propose solutions. This report does not address every challenge in agrodefense. It emphasizes that intersection of issues which reflect the underlying principles of the *Blueprint for Biodefense*, and which have been inadequately evaluated or discussed in other

fora. This report does not directly assess threats to food (including food safety issues) or to plant agriculture, two areas of great import that rightfully deserve their own substantive analyses. Neither does it address food security (access to food), another important topic. These topics were beyond the scope defined for this special focus report. Additional areas for oversight consideration are included at the end as proposed congressional hearings.



The findings and recommendations herein are structured along the same thematic lines as the *Blueprint for Biodefense*: Leadership, Coordination, Collaboration, and Innovation. Recommended actions are listed in the Summary of Proposals for the Executive Branch and the Summary of Proposals for Congress, and are designed to align directly to recommendations in the *Blueprint for Biodefense*.

LEADERSHIP

As assessed in our previous report, White House-level political leadership is necessary to elevate biodefense as a critical national and federal imperative. As recommended, the Vice President, in conjunction with strong congressional champions, could better drive priorities and activity across the large, unwieldy enterprise of agricultural defense.

Agricultural defense is a broad and complex mission space that necessitates the significant involvement of most federal departments and agencies. Presidential Policy Directive 21 places the Department of Agriculture (USDA) and the Department of Health and Human Services (HHS) as the federal leads for the F&A critical infrastructure sector. Roles and responsibilities under the U.S. Code and other authorities are not necessarily coordinated, however, nor are authorities necessarily exercised in a way that has prioritized needed activity.

The ultimate ownership of F&A by the private sector, and its significant contribution to SLTT and international economies, necessitates substantial federal collaboration with non-federal stakeholders. White House-level leadership is critical to minimize overlap, identify mission gaps, and coordinate effort. The White House should ensure that the National Biodefense Strategy addresses threats to food and agriculture. The President and Congress should ensure that detailed agrodefense expenditures are incorporated into a cross-cutting biodefense budget analysis.

COORDINATION

Agricultural outbreaks may result from natural events or from deliberate actions. Coordination between animal health (a USDA mission), and law enforcement (a Federal Bureau of Investigation, or FBI, responsibility), is critical. Sharing information among these and other interagency entities as well as non-federal stakeholders is necessary to focus attention on the most relevant threats and ensure that prevention and response measures are aligned with those threats.

The Panel recommends increased coordination between the USDA and FBI. Further, since the FBI deems all domestic incidents of foreign animal diseases suspicious, law enforcement and health officials should conduct joint investigations of all such outbreaks. The development of an updated Food and Agriculture Incident Annex (FAIA) will be a critical step toward improving preparedness for agricultural outbreaks. Any revision must prioritize planning for both natural and intentional events.

The Federal Emergency Management Agency, the USDA Animal and Plant Health Inspection Service, and the FBI should ensure that any update to the FAIA recognizes and addresses the investigative mission of the FBI, and clearly directs other federal departments and agencies to support inquiries into suspected acts of agricultural crime and terrorism.

COLLABORATION

Effective overall homeland security depends on successful collaboration among federal and non-federal stakeholders. The same is true for agrodefense, especially regarding early detection and surveillance efforts to characterize and prevent further spread of disease. The early detection of infectious disease outbreaks is one of the most important means we have for mitigating their impacts and shortening the duration of response. This detection should occur at the level of livestock production, but also in wildlife.

Although the nation has made great strides, it still falls critically short in rapid biodetection, diagnosis, and integrated biosurveillance of outbreaks. Biodetection is hampered by an insufficient focus on rapid pen-side diagnostics, and insufficient investment to develop new wildlife disease detection technologies and validate existing tests. Although improving, biosurveillance remains perpetually challenged by information sharing problems. Much of the data are owned by the private sector, thus requiring protected information policies that incentivize sharing. Success also depends on the cooperation of federal and state agencies. White House leadership

could provide the basis for the coordination and collaboration necessary to optimize the needed functions of biosurveillance collection, integration, and analysis. The White House should consider the full scope of wildlife surveillance activity that would benefit wildlife, livestock, and human health, and direct relevant departments to develop a commensurate budget request. The National Security Council should direct interagency partners to develop a standard of quality by which the value of investment in biosurveillance can be measured. Congress should fund and facilitate enhanced opportunities for data collection from livestock and wildlife, including through increased appropriations to the USDA National Wildlife Disease Program.

INNOVATION

Ultimately, the current paradigm for disease response is insufficient to protect the sector. The nation needs new ideas and scientific solutions to drive agrodefense approaches beyond their current limitations. One example would be to increase funding to the National Veterinary Stockpile to demonstrate a market commitment to procurement the way the BioShield Special Reserve Fund was designed to do for human medical countermeasures.

To meet the requirements of Homeland Security Presidential Directive 9, far greater investment in advanced research and development is also necessary. The nation requires focused investment in pen-side, innovative diagnostic technology, and in better laboratory-based technology to enable rapid assessment for SLTT animal health officials, enabling earlier decision-making. The USDA should further develop its vaccine use policy for avian influenza and other high-consequence diseases, basing these policies on the use of platform technologies for rapid diagnostics and vaccines in response to outbreaks.

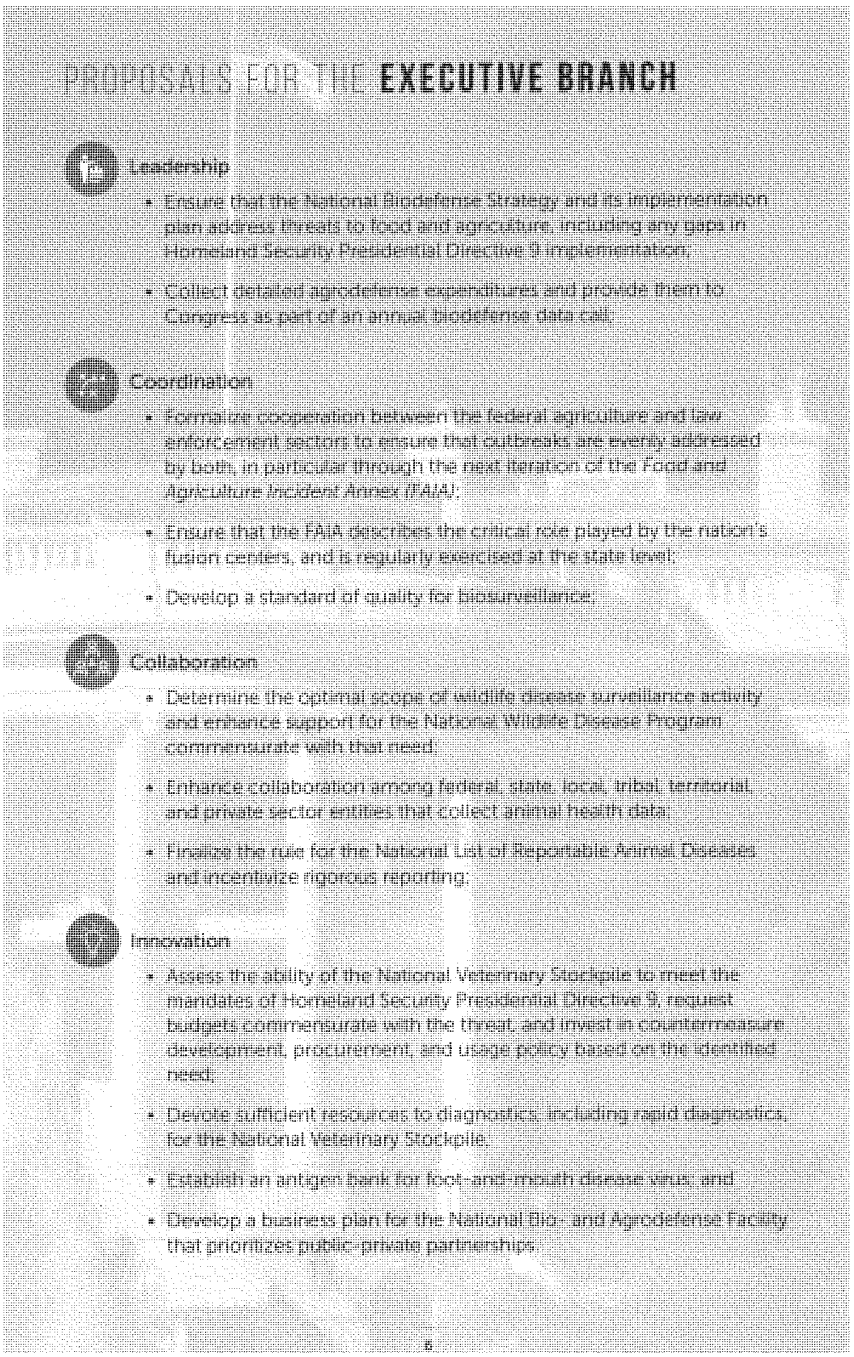
Additionally, DHS and USDA should develop a business plan for the operation of the National Bio- and Agrodefense Facility. This plan should engage the public and private sectors; consider domestic and global markets for agrodefense research and development; and identify a dollar figure that defines both need and opportunity.

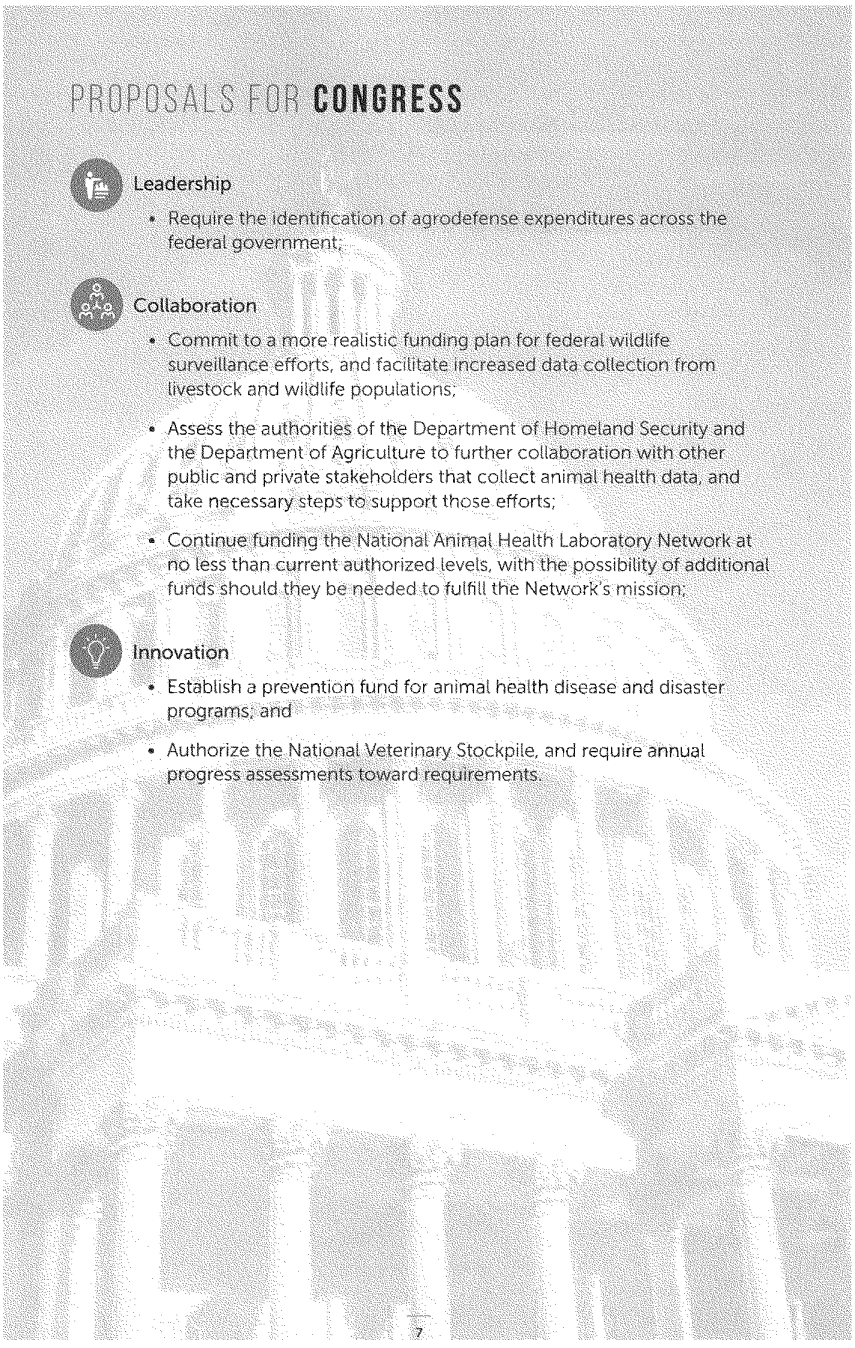
The President's Fiscal Year 2018 budget request would eliminate all agriculture and animal-specific research by the DHS Science and Technology Directorate.

This signals a substantive diminishment of support from the Executive Branch for agriculture and agrodefense research.

The Administration must improve agrodefense efforts to prevent or combat a major agro-disease outbreak. Although accounting for only 5% of GDP, food safety and food access affects 100% of the population. F&A are increasingly vulnerable to large-scale disease outbreaks that could significantly impact the economy, and which could also threaten the security of the population. The Panel believes that current government efforts should be assessed and redirected as outlined in this report per the forthcoming National Biodefense Strategy. Federal investment in agrodefense must focus on prevention and early identification to reduce or prevent the incursion of major costs and losses.

Like homeland security in general and biodefense in particular, the interagency nature of agrodefense means that many congressional committees oversee agrodefense efforts. These committees should both continue and expand previous efforts and increase their direction to the Executive Branch. The Farm Bill provides a significant opportunity every five years to accomplish this legislatively.


PROPOSALS FOR THE EXECUTIVE BRANCH
Leadership
• Ensure that the National Biodefense Strategy and its implementation plan address threats to food and agriculture, including any gaps in Homeland Security Presidential Directive 9 implementation;
• Collect detailed agrodefense expenditures and provide them to Congress as part of an annual biodefense data call;
Coordination
• Formalize cooperation between the federal agriculture and law enforcement sectors to ensure that outbreaks are evenly addressed by both, in particular through the next iteration of the Food and Agriculture Incident Annex (FAIA);
• Ensure that the FAIA describes the critical role played by the nation's fusion centers, and is regularly exercised at the state level;
• Develop a standard of quality for biosurveillance;
Collaboration
• Determine the optimal scope of wildlife disease surveillance activity and enhance support for the National Wildlife Disease Program commensurate with that need;
• Enhance collaboration among federal, state, local, tribal, territorial, and private sector entities that collect animal health data;
• Finalize the rule for the National List of Reportable Animal Diseases and incentivize rigorous reporting;
Innovation
• Assess the ability of the National Veterinary Stockpile to meet the mandates of Homeland Security Presidential Directive 9, request budgets commensurate with the threat, and invest in countermeasure development, procurement, and usage policy based on the identified need;
• Devote sufficient resources to diagnostics, including rapid diagnostics, for the National Veterinary Stockpile;
• Establish an antigen bank for foot-and-mouth disease virus; and
• Develop a business plan for the National Bio- and Agrodefense Facility that prioritizes public-private partnerships.
6



PROPOSALS FOR **CONGRESS**

Leadership

- Require the identification of agrodefense expenditures across the federal government;

Collaboration

- Commit to a more realistic funding plan for federal wildlife surveillance efforts, and facilitate increased data collection from livestock and wildlife populations;
- Assess the authorities of the Department of Homeland Security and the Department of Agriculture to further collaboration with other public and private stakeholders that collect animal health data, and take necessary steps to support those efforts;
- Continue funding the National Animal Health Laboratory Network at no less than current authorized levels, with the possibility of additional funds should they be needed to fulfill the Network's mission;

Innovation

- Establish a prevention fund for animal health disease and disaster programs; and
- Authorize the National Veterinary Stockpile, and require annual progress assessments toward requirements.

INTRODUCTION

THE THREAT TO FOOD AND AGRICULTURE

The Food and Agriculture (F&A) critical infrastructure sector produces, processes, and delivers the systems and commodities that feed billions of people and animals throughout the United States and overseas.[1] In 2015, agriculture, food, and related industries contributed $992 billion (5.5%) to the U.S. gross domestic product (GDP).[2] As one of the largest sectors of the U.S. economy, protecting this infrastructure is a matter of national security.

Agriculture, the cultivation and breeding of animals and plants for food, fiber, and other products, is central to American culture, economy, wellbeing, and livelihood. Because of its importance, agriculture is a target for terrorism, warfare, and criminal activity.[3,4] The geographically dispersed yet industrially-concentrated nature of the sector makes it an especially vulnerable target. Farms dot the landscape in every state; livestock are often concentrated in specific locations; and lethal and contagious biological agents that impact plants and animals are more numerous even than those that directly impact human beings.[5]

As with other critical infrastructure sectors, criminals, terrorists, and enemy combatants may target F&A because disruption of this sector can lead to significant negative effects on the populations it serves. Al Qaeda has stated on numerous occasions that it seeks to impact the economies of those it considers to be its enemies, including with agricultural attacks. Targeted destruction of F&A critical infrastructure is a standard, long-standing, and effective element of warfare, with records of chemical and pathogenic attacks dating back to World War I.[6] An outbreak in 2011 of a rare strain of *E. coli* O104:H4, first identified in northern Germany, spread to 16 countries including the United States, resulting in 4,321 cases of illness and 53 deaths.[7] Although initially assumed to have a natural origin, epidemiological evaluation later concluded that an accidental or intentional introduction of contaminant into fenugreek seeds was plausibly responsible.[8] The use of biological weapons to attack agriculture could result in billions of dollars in losses. Naturally occurring outbreaks in the United Kingdom of foot-and-mouth disease (FMD) in 2001 and bovine spongiform encephalopathy (BSE) in 1996-7 cost the United Kingdom £8.6 billion (about $14 billion)[9] and £2.5 billion (about $3.2 billion), respectively.[10] Bioterrorism could easily do the same.

Criminals also target the F&A sector. Documented criminal activity has included theft of expensive foods, hybrid seeds, and hay; growth of poppies for opium; murder of farmers; rustling of cattle and other animals (e.g., bees); burglary of valuable metals; and stealing fertilizer elements (e.g., anhydrous ammonia, ammonium nitrate) that can be used to produce methamphetamines and explosives.[11]

Naturally occurring disease outbreaks remain a persistent challenge. Outbreaks of highly pathogenic avian influenza (HPAI) have led to the deaths of more than 67 million birds in the United States since 1983.[12] In December 2014, a highly pathogenic strain of avian influenza entered the United States via migrating wild birds. (Wild birds play a key role in spreading these influenza viruses, such as when they move from northeast Asia into the west coast of North America on their long-distance migration routes.[13]) The ensuing outbreak resulted in the largest animal health disaster ever experienced by the United States.[14] The outbreak lasted until the middle of 2015, ultimately affected 21 states, and led to the depopulation of more than 50 million birds on 232 farms.[15] Subsequent trade bans impacted as many as 233,770 farms.[16] The total cost to the U.S. economy was estimated at $3.3 billion, with the turkey sector losing $1.1 billion and the egg sector $2.2 billion.[17] Federal and state governments spent $879 million on outbreak response.[18]

HPAI strains can also place humans at significant risk if the strains develop the capacity to spread from poultry to people. The public health community is concerned about possible mutations that would allow these viruses to spread in this fashion. Each case of animal infection during a large-scale outbreak is another opportunity for such a mutation to occur. Further, all avian influenzas can threaten egg production, thereby endangering the supply of human influenza vaccine and other vaccines that depend predominantly upon egg-based culture methods.

The genetic code of the 2009 H1N1 influenza pandemic arose in part from other influenza strains circulating in wild birds and commercial pigs. Media use of the misnomer "swine flu" created misplaced concern among the public over food safety. While human health was never at risk from pork consumption, the pork industry was negatively impacted: consumption declined, sales dropped, hog prices fell, futures prices on the Chicago Mercantile Exchange plunged, and several countries banned U.S. pork imports.[19] Inaccurate media linkage of H1N1 to swine cost the U.S. pork industry $200 million.[20]

Porcine epidemic diarrhea virus (PEDv) and porcine deltacoronavirus (PDCV) emerged for the first time in the U.S. domestic swine population with lethality and ferocity in 2013 and 2014. These swine enteric coronavirus diseases (SECD) cause acute and rapidly spreading diarrhea that does not affect humans, but which can result in 50-80% mortality in piglets.[21] PEDv, in particular, results in diarrhea,

vomiting, and high morbidity in a herd, and high mortality (90-95%) in piglets. In 2013, PEDv cost the U.S. pork industry returns of $481 to $929 million.[22] Although U.S. Department of Agriculture (USDA) guidelines should have been sufficient to control these outbreaks, the USDA did not take regulatory action against SECD immediately. As a result of this, the USDA cannot conclusively determine where or how either virus entered the United States.[23] The Federal Bureau of Investigation (FBI) was not contacted to conduct an evaluation of the potential for an intentional (criminal or terrorist) origin for the outbreak.

THE THREAT OF ZOONOSES

Among the biological threats for which the U.S. Department of Homeland Security (DHS) has issued a Material Threat Determination, all but one (smallpox) are zoonotic, meaning the disease can move between animals and people. Many major infectious disease outbreaks over the last 10 years (e.g., Ebola, Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome (MERS)) have originated in animals. Three-quarters of emerging infectious diseases are, in fact, zoonotic in nature. While most of these originate in wildlife, livestock can also act as conduits for infection. The recent U.S. avian influenza outbreaks did not affect humans, but other avian influenza strains in Asia have infected thousands of people; the H7N9 strain alone has infected more than 1,300 people since 2013.[25]

While influenza is the most likely virus to cause a pandemic, myriad other viruses cross over from wild animals into human populations. These viruses will continue to create pandemics. In 2003, the emergence of a previously unknown and virulent coronavirus, termed SARS, caused a rapid outbreak in Asia. It is believed to have jumped from bats to an intermediate animal and then to people. SARS quickly incapacitated tourism and trade as the outbreak spread as far as Canada. The economies of China, Hong Kong, Singapore, and Taiwan lost approximately $13 billion in GDP collectively, despite the relative paucity of cases (7,000) and fatalities (700).[26] Other global economic costs were as high as $40 billion.[27] The cost of patient treatment is not the predominant element in these estimates; the actual costs of SARS were the economic shocks resulting from shifts in human behavior. Ultimately, the infection spread to 29 countries.[28] Authorities were finally able to contain its spread, but the rapidity with which the virus breached hemispheres revealed the extreme interconnectedness of human health in the modern era. The more recent Ebola and Zika outbreaks reinforce this fact. According to Dr. Ali Khan, former director of the Office of Public Health Preparedness and Response at the Centers for Disease Control and Prevention (CDC), the primary threat to the health security of this nation remains a zoonotic disease.[29]

U.S. AGRODEFENSE TODAY

In 2004, Dr. Roger Breeze, former director of the USDA biosafety level 3 laboratory at the Plum Island Animal Disease Center (PIADC) wrote:

> *Our national policy for inadvertent and deliberate foreign animal disease introductions should be simple: we will minimize direct and indirect economic impacts, and we will not engage in mass slaughter. Fortunately, most of the tools and technologies to permit such a policy already exist. We now have rapid, on-farm tests for these diseases; effective vaccination strategies; Internet-based command, control, and communication systems; and the means to track animal products from farm to table, even internationally... If we choose this way forward, there will be little point in deliberate attacks, because the outcomes terrorists want to see will not be possible and inadvertent introductions will be eliminated with scarcely a footprint.*[30]

Thirteen years later, the U.S. government has made some notable commitments to countering the threat to animals. For example, the National Animal Health Laboratory Network (NAHLN) works to detect biological threats to food animals, although its funding is not as robust as its human-health counterpart, the Laboratory Response Network for Bioterrorism. DHS is spending $1.25 billion dollars to build a modern animal disease laboratory in Manhattan, Kansas (to replace PIADC). At the border, U.S. Customs and Border Protection agricultural inspectors work daily to prevent the import of food and agricultural products that could harm human health, animal health, and the economy. USDA inspectors and veterinarians similarly safeguard the food supply through border-based health inspection and quarantine of incoming animals, and the USDA Food Safety and Inspection Service and the U.S. Food and Drug Administration (FDA) safeguard food safety at processing plants throughout the United States and globally. USDA also accredits and trains private-sector veterinarians to detect and respond to disease outbreaks. These and other efforts account for a large portion of the federal investment in defending U.S. food and agriculture.

Yet in context, the F&A sector receives far less attention than many other critical infrastructure sectors. This sector continues to be highly vulnerable, and many of the tools and technologies described by Breeze remain poorly developed and integrated into suitable plans and proper response operations.

Further, many farms are open systems, and biosecurity varies from one farm to the next, a point clearly illustrated during the 2015 HPAI outbreak. As the Government Accountability Office (GAO) found in an analysis of USDA efforts to combat avian

influenza, poultry producers and growers oftentimes did not adhere to basic biosecurity practices before and during the outbreak, which resulted in further infection. The USDA relies on poultry producers and contractors to voluntarily take preventive steps to protect their flocks from disease.[31] In early 2016, USDA took the first steps to address this issue by publishing an interim rule making indemnity payments contingent on poultry and egg producers and growers certifying their adherence to a biosecurity plan. The rule is limited to large-scale operations for certain animals, and is particularly focused on HPAI. Biosecurity provisions have also been added to the National Poultry Improvement Plan, a voluntary program under which producers can be certified as disease-free for trade purposes.

Thus, the production of food presents what amounts to a chain of vulnerabilities. The intentional disruption of any of the goods and services that comprise F&A could occur at myriad nodes along this chain. Weaknesses of these types put human health, animal health, and the entire agricultural-based economy at risk.

According to GAO, the President's Fiscal Year (FY) 2015 $23 billion budget request for USDA included only $287 million for animal health efforts – that is, 1.2%.[32] While this figure does not include use of the Commodity Credit Corporation (CCC) for response efforts, the dollar value of which can be substantial, the annually appropriated level is simply too low to preventively safeguard animal health to optimal levels. This is a department whose earliest and groundbreaking successes in the nineteenth century were for the proactive protection of animal health. Notable priorities for that nascent department, established by President Abraham Lincoln, included funding the study, control, and eradication of infectious diseases like contagious bovine pleuropneumonia and Texas cattle fever. DHS has invested research dollars at PIADC for FMD vaccines, and construction dollars for the new National Bio- and Agrodefense Facility (NBAF). Yet the President's FY 2018 request disregards agriculture research and development funding support at DHS, eliminating all of its research programs at PIADC.

Many of the activities in which DHS, USDA, and interagency partners engage are indispensable elements for the development of effective biosurveillance, medical countermeasures (MCM), response capacity, and all other features of effective agrodefense. It is difficult to account for the ways in which these and other expenditures work together to reduce the threat to agriculture and to determine the areas where resources are most necessary. While the forthcoming National Biodefense Strategy should partially solve this problem, an Office of Management and Budget (OMB) assessment of program productivity and return on investment – and one made publicly available – is still needed.

LEADERSHIP

The ownership of F&A by the private sector and the significant contribution it makes to SLTT economies necessitates significant federal interaction and collaboration with non-federal stakeholders. Presidential Policy Directive 21 designated the USDA and the Department of Health and Human Services (HHS, delegated to the FDA) as the federal agencies to lead the infrastructure protection components of the F&A sector.[33] Like many of its critical infrastructure counterparts, the complexity of facilitating resilience within this sector necessitates significant involvement by other federal departments and agencies, as well as with the non-federal parties that own and operate it. The Panel has previously stated that political-level leadership at the White House is needed to drive priorities for biodefense, and this by extension includes agrodefense, particularly in light of policy and political divisions outlined in this report.

FEDERAL STRUCTURAL ORGANIZATION

The defense of U.S. agriculture is a broad and intricate mission space, its complexity reflected in the biodefense enterprise writ large. USDA and FDA have primary federal responsibility for encouraging the national security of agriculture. The USDA Office of Homeland Security and Emergency Coordination provides the primary means of communication between USDA and other departments at a policy level. Most other federal departments and agencies also help to protect this sector, with DHS serving a leading role in addressing national security related incidents.

The functions necessary to do this include intelligence analysis, law enforcement, animal health, plant health, public health, environmental remediation, and outbreak response and recovery. The 2008 *Food and Agriculture Incident Annex (FAIA)* to the *National Response Framework*, which addresses only the response and recovery element of agrodefense, lists USDA and HHS as Coordinating Agencies, and the Department of Commerce (DOC), the Department of Defense (DOD), the Department of Energy, DHS, the Department of Interior (DOI), the Department of Justice (DOJ), the Department of Labor, the Department of State, the Department of Transportation, the Environmental Protection Agency (EPA), the General Services Administration, the U.S. Agency for International Development (USAID), the U.S. Postal Service, and the American Red Cross as Cooperating Agencies.[34] The forthcoming update to the *FAIA* (expected in 2017) will provide further specificity, naming subordinate agencies and offices within many of these departments, and detailing how agencies should coordinate with one another.

Ultimately, the United States Code (7 USC 8310(e)(2)) designates the USDA as the lead agency with respect to issues related to pests and diseases of livestock; 7 USC 7652 likewise designates the Secretary of Agriculture as the principal federal official responsible for coordinating all federal research and extension activities related to food and agricultural sciences. However, like other areas of biodefense, federal responsibilities for agrodefense are by necessity spread broadly across the interagency. Roles and responsibilities under the U.S. Code and other authorities are not necessarily coordinated, nor are the authorities always exercised in a way that has prioritized needed activity. White House-level leadership is, therefore, critical to minimize overlap, identify mission gaps, and coordinate effort. The Panel has recommended previously that the Vice President serve in this role.

SLTT leadership at the political level is no less fundamental to all phases of protecting animal agriculture. In January 2016, when avian influenza appeared in Indiana, then-Governor Michael R. Pence was the first high-level state official to arrive at the emergency command post in Jasper, Indiana. Governor Pence's appearance motivated both officials and producers to act quickly and prevent this outbreak from spreading as far as it had during the national outbreak in 2015. According to Dr. Bret Marsh, Indiana State Veterinarian:

> *He was there ☒rst. And it frustrated some of the press because they didn't know he was coming. But he didn't want to be the event. He wanted the people to complete the event and keep their work moving forward. And I would get these text messages from some guy named Mike... I've worked for several governors, but I've never had text messages... So I think, from the Vice President's o☒ ce, clearly he has an understanding and understands the importance of these issues, in our state, and, therefore, across the country.*[35]

Dr. Marsh also believes that without local collaboration, the outbreak would have spread farther. Producers, not officials, culled poultry at affected farms, realizing that it was "the right thing to do." Additional SLTT interventions are needed to strengthen government partnerships with industry, build expertise, and develop response plans before outbreaks occur.

While the Panel emphasizes in this and in prior reports that two high levels of leadership are necessary to identify appropriate political direction and policy development and coordination, the Panel also reinforces the need for operational leadership during crises as the third critical piece. Congress should consider evaluating the response planning and recovery elements of Homeland Security Presidential Directive 9 (HSPD-9), particularly those areas that pertain to response capabilities and F&A-specific response plans to ensure that they meet National

Preparedness System requirements. The forthcoming issuance of an updated *National Food and Agricultural Incident Annex* (see Coordination chapter) provides a timely opportunity to do so.

ARTIFICIAL POLICY DIVISIONS HAMPER PROGRESS

A complex web of ecological interactions governs the spread of infectious disease. All efforts to prevent and plan for biological events impacting humans must therefore integrate with animal and environmental health initiatives. Animals can be susceptible to many of the same threats as humans and they can also act as conduits for human infection. Further, animals can be terrorist targets in their own right. All agrodefense efforts must integrate human, animal, plant, and environmental health elements into decision-making, budgeting, and operations.

Assessment and reduction of risk to the F&A sector have been led primarily by DHS, USDA, and FDA. HSPD-9 and the F&A Sector-Specific Plan (part of the National Infrastructure Protection Plan) provide a foundation for the protection of this sector.[36] However, associated efforts to prevent, deter, prepare, detect, attribute, decontaminate, remediate, and mitigate agricultural events are not well integrated. Additionally, medical and other countermeasures to protect animals and plants are unavailable for most emerging pathogens. Further, the Bioterrorism Risk Assessment process conducted by DHS appears to be insufficiently linked to follow-on investments that could mitigate this problem via risk management activities.

Optimal biodefense can only be achieved when grounded in an ecological understanding of the entire health picture. The distributed nature of health-related responsibilities across the federal government creates bureaucratic silos that often fail to recognize the interrelatedness of human, animal, plant, and environmental health. A designated leader at the White House who recognizes this interconnectedness could drive integration across federal efforts.

RECOGNITION OF THE THREAT BY HIGH-LEVEL LEADERSHIP

In 1999, Congress established the Advisory Panel to Assess Domestic Response Capabilities for Terrorism Involving Weapons of Mass Destruction, also known as the Gilmore Commission. This Commission produced several reports for the President and Congress, the first of which noted that agriculture was a highly vulnerable sector and that the biological threat to it deserved more attention than it was getting at the time.[37]

Since then, White House councils (e.g., Domestic Policy Council (DPC), National Economic Council (NEC), Homeland Security Council (HSC), and the National Security Council (NSC)) and the Office of Science and Technology Policy (OSTP) have taken up the issue of agrodefense in various ways. Under the direction of President George W. Bush, White House staff evaluated the extent to which the nation had secured F&A critical infrastructure sector and related sectors and activities. President Bush's HSC identified agrodefense as a pressing concern, and began developing a presidential directive to address it as a part of biodefense. However, the enormity of the risk to agriculture, as well as the precedence of deep-seated and long-standing turf protection among the departments and agencies, drove the Bush Administration to separate agrodefense from other biodefense efforts. The White House subsequently produced two directives in 2004: HSPD-9, *Defense of United States Agriculture and Food*[38] and HSPD-10, *Biodefense for the 21st Century*.[39] These were written separately, although the staffs were the same, and there was cross-over of ideas and an acknowledgement of the realities of One Health. But there were also deep-rooted turf issues that manifested during the process, reflecting the same territoriality seen throughout the federal government today.

Congress also recognized the threat to the sector and sought to address it through oversight and legislation. Senator Pat Roberts convened the first congressional agroterrorism hearing in 1999.[40] More oversight followed. The decision to build the NBAF resulted in hearings and legislation about the national need for agrodefense research and response capability and capacity. The 2014–15 avian influenza outbreak drew attention to the flaws in agrosecurity, and both the House Committee on Agriculture and the Senate Committee on Agriculture, Nutrition, and Forestry held hearings to identify systemic shortcomings in the response to that outbreak.[41] Both chambers of Congress heard from witnesses who identified biosecurity measures that could be legislated, including a mandatory disease prevention program and an FMD vaccine bank.[42] In addition, the House Committee on Agriculture held a hearing on the FMD threat,[43] and the House Committee on Homeland Security held hearings on agrodefense more broadly.[44] Congress tasked GAO in the first decade of the 2000s to conduct a variety of studies regarding protection of the F&A sector; since 2010, congressional requests have been few and usually in response to – not in advance of – outbreaks affecting agriculture.

As a reflection of federal interest in agrodefense, the NBAF deserves special mention. The NBAF is part of the USDA and DHS "plan to provide safe, secure, and state-of-the-art agricultural biocontainment laboratories that research and develop diagnostic capabilities for foreign animal and zoonotic diseases" called for by HSPD-9.[45] The Executive and Legislative Branches have supported the creation of the NBAF, if haltingly, while working through controversies. The overall trajectory

of support to build this laboratory has demonstrated a federal commitment to agrodefense research and response. DHS, with substantial contributions from the state of Kansas and the city of Manhattan, Kansas, will spend well over $1 billion to develop it.

All of this oversight and commitment, and the areas that have lagged or been omitted from it as described in this report, are occurring in the absence of a national strategy and corresponding implementation plan. As described in the *Blueprint for Biodefense*, the nation requires a comprehensive National Biodefense Strategy that integrates the input of all non-federal stakeholder groups. Congress has acted upon the Panel's recommendation and required the development of this Strategy per Section 1086 of the National Defense Authorization Act for FY 2017 (Public Law 114-328). While the Panel recommended that the Vice President take charge of producing this Strategy, Congress directed four departments, DOD, DHS, HHS, and USDA, to work together to do so. The drafters in the House and Senate Committees on Armed Services included USDA because they recognized the integral role of agriculture in our biological security and the serious threats to this sector.

In accordance with Recommendation 3 of the *Blueprint for Biodefense* to develop, implement, and update a comprehensive National Biodefense Strategy:

The White House must ensure that the National Biodefense Strategy (Strategy) and implementation plan address threats to food and agriculture. As part of this process, the National Security Council, Domestic Policy Council, and National Economic Council, in consultation with the Secretaries of Agriculture, Defense, Health and Human Services, and Homeland Security, should jointly review Homeland Security Presidential Directive 9, *Defense of United States Agriculture and Food*, determine where it falls short in addressing today's agrodefense needs, and incorporate updates into the Strategy and its implementation plan. While leadership and policy coordination of interagency federal activity should be centralized, responsibilities for agrodefense will continue to be distributed nationally. The Strategy must recognize this decentralized nature of the U.S. food and agriculture critical infrastructure sector.

USDA has made some critical investments in agrodefense, such as directing research efforts at PIADC with significant emphasis on FMD vaccine, providing food and agrodefense grants through the National Institute of Food and Agriculture, and working with the FBI, FDA, and other agencies to conduct law enforcement and public health investigations. USDA, with some White House direction, also produced a number of policy documents. In addition to USDA, the DOC, DOI, and various HHS agencies (e.g., CDC, FDA), have generated relevant F&A policy documents. While these departments and agencies all take some responsibility for agrodefense, USDA and FDA are ultimately responsible. In addition to DHS input, USDA leadership and FDA leadership must make National Biodefense Strategy contributions a top priority.

While policies and plans are important, they will mean little without an agency to own them and dollars to implement and exercise them. And yet, a federal fiscal commitment to agrodefense is not entirely apparent. The Homeland Security Act of 2002 (HSA) required that the President's budget request incorporate a homeland security funding analysis – in essence, a kind of budgetary cross-cut. According to the FY 2017 analysis, 29 agency budgets included federal homeland security funding across 17 functional areas. The agriculture function accounted for only 0.76% of the total.[46]

Published not long after the HSA, HSPD-9 also acknowledged the pressing need for budget coordination: "For all future budgets, the Secretaries of Agriculture, Health and Human Services, and Homeland Security shall submit to the Director of the Office of Management and Budget, concurrent with their budget submissions, an integrated budget plan for defense of the United States food system."[47] OMB did collect this information and included it in the annual homeland security analysis in accordance with the HSA, but this analysis was high level and did not provide any detail regarding the expenditures in the functional areas. Furthermore, Congress eliminated the reporting requirement altogether in its FY 2017 appropriations law. The Panel strongly recommends statutory reinstatement of the analysis and continued collection of this information on the part of OMB.

In accordance with Recommendation 4 of the *Blueprint for Biodefense* to develop a unified biodefense budget aligned with the national biodefense strategy, the Panel proposes the following:

The President and congressional appropriators should ensure that detailed agrodefense expenditures are identified and included in the recommended data call for and development of a crosscutting biodefense budget analysis. These requested expenditures should be accompanied by impact evaluations. Any gaps recognized as a result should be addressed in the National Biodefense Strategy.

COORDINATION

Many federal departments and agencies share responsibility for agrodefense. Coordination of these efforts is paramount. Because agricultural outbreaks may result from natural events or from deliberate actions, coordination between animal health and law enforcement is particularly critical. The health mission of the USDA and the investigative mission of the FBI must be jointly acknowledged, exercised, and implemented.

LAW ENFORCEMENT AND ATTRIBUTION OF ATTACKS

According to the FBI, the intentional introduction of disease is difficult to differentiate from accidental or naturally occurring outbreaks.[48] Authorities for animal health, plant health, and law enforcement must work with one another from the earliest stages of an outbreak to attribute its source. Some of the most important elements of this joint cooperation include rapid notification of agreed-upon triggers, early threat reports, and unusual disease events, as well as efficient criminal-epidemiological investigation and response. Yet there has been an inconsistent recognition that agriculture is a target of domestic and international terrorist elements, and that intentional means of introduction should be equally considered when suspicious or unusual animal-plant disease events and other recognized triggers are initially detected. Continued training such as that provided by the FBI through its Criminal and Epidemiological Investigation course will help support better understanding between the agriculture and law enforcement communities, help the investigation of threats to animals and plants, facilitate threat and operational awareness, develop information sharing protocols, and foster SLTT health-law enforcement contact networks. Additionally, broad distribution throughout the food and agricultural community of resources developed jointly by USDA, FBI, and FDA, such as the *Criminal Investigation Handbook for Agroterrorism*, will help increase awareness of the threats to F&A and how these communities can work together to investigate outbreaks in, and suspected acts of terrorism against, this sector.

When this report went to press, federal partners were drafting a revised FAIA that would provide updated and more comprehensive guidance for federal interagency planning efforts involving food and agricultural incidents. The development of an updated annex is a critical step toward improved agricultural event preparedness, and ideally the final version will contain more in-depth detail on the roles and

responsibilities assigned to the federal interagency than the 2008 version. Challenges in developing the revision in a way that prioritizes both natural and intentional events may reflect a central issue about the perception of agricultural terrorism. Law enforcement investigation of terrorism is well within the scope of the FAIA's purpose – interagency planning and coordination for response and recovery. Much as the recently-updated *Nuclear/Radiological Incident Annex* establishes a clearly-defined role for the Bureau's investigatory responsibilities in the aftermath of weapons of mass destruction (WMD) terrorist acts,[49] discussion of the details and parameters of FBI and other law enforcement response must be included in the response to F&A events.

Scenarios detailed in any new FAIA should include intentional introductions of food and agricultural pests or contaminants, and should address the source and means of those introductions. The FBI considers any foreign animal disease outbreak suspicious until proven otherwise, and seamless coordination in the early stages of investigation among law enforcement, animal health, and public health is therefore critical. Mitigating animal health impacts indeed must be the priority, but there is no reason that protocols developed by the FBI cannot be leveraged to ensure a concomitant investigation to determine the source of the outbreak which, if intentional, must be known quickly to then disrupt follow-on acts of terror or crime.

In accordance with Recommendation 9 of the *Blueprint for Biodefense* to better support and inform decisions based on attribution of biological events, the Panel proposes the following:

The Administrator of the Federal Emergency Management Agency should coordinate with the Administrator of the Animal and Plant Health Inspection Service (APHIS) and the Director of the Federal Bureau of Investigation to ensure that any update of the *Food and Agriculture Incident Annex* (Annex) recognizes and addresses the investigative mission of the Federal Bureau of Investigation (FBI), and clearly directs other federal departments and agencies to support inquiries into suspected acts of agricultural crime and terrorism. The next iteration of the Annex should incorporate concepts of initial consideration of intentional threats in unusual or suspicious disease events; the roles and responsibilities of the FBI, USDA Office of Inspector General, and FDA Office of Criminal Investigations; and subsequent joint criminal-epidemiological investigations. The Annex should also enumerate the role played by the nation's fusion centers in coordinating and disseminating information.

Further, the aforementioned officials should ensure that, to the greatest extent possible, responsibilities in this Annex related to law enforcement inquiries or investigations of acts of agricultural terrorism align with similar activities in the *Nuclear/Radiological Incident Annex*, the *Biological Incident Annex*, and any other incident annex to the *Response and Recovery Federal Interagency Operational Plans*.

The Administrator of the Federal Emergency Management Agency should coordinate with the Administrator of APHIS and the Director of the FBI to ensure that Annex updates would be required to be regularly exercised at least at the state level, as is done with other areas of national security. These exercises should provide a means for the named agencies, as well as other federal and non-federal partners, to develop measurements of the capabilities needed for adequate and economically justifiable response and recovery efforts. They should also be used to gauge the value of funding programs to enhance the capabilities described within the Annex.

COLLABORATION

Collaborative effort within the interagency and among non-federal stakeholders has been a cornerstone of homeland security efforts since September 11, 2001. That same collaborative effort is necessary within agrodefense. This section of the report focuses on challenges in two areas: biosurveillance and reporting/ information sharing. Avian influenza and other outbreaks have demonstrated the critical importance of timely and accurate biosurveillance. Early detection is one of the best methods available to prevent the spread of infectious disease. The emergence of infections not just in rural but also in urban areas, as evidenced by a rare avian influenza strain that infected 500 cats (and at least one human) in a New York City animal shelter in late 2016, demonstrates a requirement for vigilance and an acknowledgement that all areas, rural and urban, and many species, wild and otherwise, must be part of any surveillance framework. Adequately funding data collection and establishing a nationally notifiable animal disease list are critical to the success of this system, as is reporting and information sharing among federal, SLTT, and private sector stakeholders. Ultimately, leadership over federal biosurveillance efforts and, in particular, the integration of these efforts is still needed.

BIOSURVEILLANCE

The early detection of infectious disease outbreaks is one of the most important means available to mitigate their impacts and shorten the duration of response. This detection should occur at the level of livestock production and in wildlife. Stakeholders in this area span from government agencies at all levels to local farmers, veterinary hospitals, and even poison control centers. Although the *control* of many diseases is not possible in wildlife, early *detection* is one of the best defenses against catastrophic impacts of agricultural and zoonotic disease threats.

The drafters of HSPD-9 understood this concept. HSPD-9 tasks DOI, USDA, and EPA to operate surveillance and monitoring systems (section 8); DOJ, DHS, and the intelligence community (IC) with intelligence collection and analysis (section 9); and DHS with integration of this information (section 10). Each of these elements exists in various stages of maturity and interagency integration. An important missing element is a standard of expectation or quality by which the value of investment in biosurveillance can be measured. Such a standard could include: the

key area of characterization; risk determination; potential course of action; and a means of assessing the value of the contribution these measures have on health. Such a standard does not currently exist in biosurveillance, and without it, funding will continue to be inhibited and uninformed.

In December 2014, the USDA identified HPAI in poultry in Oregon and Washington in an outbreak that ultimately reached 232 farms across 21 states before federal and state officials and industry partners eradicated it.[50] The federal government spent $879 million to contain the outbreak,[51] a figure that includes $610 million toward response activities, $200 million in indemnity payments, $34 million in planning costs for the coming autumn, and $35 million in overtime, travel, and supplies for USDA employees.[52] While the costly response prevented a larger disaster, the 2014–15 outbreak still cost the U.S. economy $3.3 billion.[53] Nearly 7.5 million turkeys, 43 million layer hens, and 3.5 million replacement pullets (young female hens) were destroyed,[54,55] and an estimated 15,000 jobs were lost in the egg industry.[56] Indirect costs included higher prices for eggs;[57] non-indemnified losses to producers (estimated at more than $1 billion);[58] and bans placed by 15 countries on poultry imports from the United States, with many other countries placing targeted bans on particular U.S. states or regions.[59]

In January 2016, an unrelated HPAI strain appeared in a commercial turkey flock in Indiana, and a low pathogenic strain was confirmed at eight nearby farms; approximately 414,000 birds were depopulated to control this outbreak which lasted until May of that year.[60]

Combined, these avian influenza outbreaks resulted in the death or culling (selective slaughter) of 50.6 million animals, cost the federal government $930 million, and cost the U.S. turkey and egg sectors $1.6 billion.[61] Indirect impacts on the U.S. economy were even higher. We can expect more events of this nature in the years to come. As recently as March 2017, another HPAI outbreak occurred, this time in Tennessee.

The 2014–17 U.S. avian influenza outbreaks exemplify a partially effective detection and surveillance capacity linked to a response capacity fraught with significant challenges. The GAO reported that USDA evaluated response weaknesses revealed by the first two outbreaks (2014–15 and 2016).[62] USDA identified challenges in biosecurity, continuity of business planning, diagnostic testing, epidemiological investigation, incident management, mass depopulation and euthanasia, biosurveillance, and vaccination, among other categories. While response capacity is clearly of significant importance given the inherent difficulty of preventing pathogens like HPAI from entering U.S. borders via wild birds, some increased emphasis on biodetection and biosurveillance in wildlife and livestock

could improve mitigation efforts toward avian influenza and other diseases. This is particularly true for wild bird surveillance, which requires steady funding in advance of outbreaks.

Rapid biodetection, diagnosis, and integrated biosurveillance remain critical functions toward which the nation has made great strides, yet which still lag behind the need. Biodetection is hampered by an insufficient focus on rapid pen-side diagnostics, and insufficient investment to develop new wildlife disease detection technologies and validate existing tests (e.g., PCR assays for avian influenza and other pathogens). Biosurveillance is perpetually challenged by information sharing problems. HSPD-10 described the need for "an integrated and comprehensive attack warning system to rapidly recognize and characterize the dispersal of biological agents in human and animal populations, food, water, agriculture, and the environment."[63] However, animal health surveillance remains somewhat segregated from the model of comprehensive biosurveillance described. Livestock health surveillance is currently performed for the benefit of agriculture and food animal production. These data are typically unavailable on a regular basis to federal agencies with surveillance responsibilities outside of the USDA, although reportable zoonoses do make their way to state and federal public health authorities. Some argue anecdotally that animal and human health surveillance data are insufficiently integrated; while this may be the case, the Panel has to-date identified few examples that any such lack of integration has directly caused negative health impacts in animals or people. A deep evaluation of the nodes of connectedness, the lack thereof, and case studies of where failures have occurred could help guide further biosurveillance policy.

Spurred by outbreaks of FMD and BSE in the United Kingdom, along with the spread of West Nile virus in the United States, the USDA established the National Wildlife Disease Program (NWDP) in FY 2003 to provide wildlife disease surveillance and management at a national level. Because state wildlife agency efforts tend toward wildlife management rather than disease diagnosis, understanding of the wildlife disease surveillance picture, particularly in the context of the broader animal and human health picture, has fallen to the federal government. The NWDP program is designed to reveal key features of infectious diseases, such as prevalence, species predilections, species reservoirs, predominant strains, and geographic scope of given pathogens. The program accomplishes a great deal despite its low level of appropriated funding. For instance, NWDP instituted national disease monitoring programs for swine brucellosis, pseudorabies, and classical swine fever.[64] The program also undertook a pilot study examining feral swine as sentinels for anthrax.[65] Anthrax and other material threats are targets of other NWDP initiatives, such as its efforts to sample wildlife species for the presence of tularemia and plague. The monitoring was put to use in Indiana after the 2016 avian influenza

outbreaks to sample mice, starlings, gulls, and other animals that might be harboring the offending virus.[66] USDA also funded wild bird surveillance through its CCC funds; the USDA funding allotments toward surveillance are shared with partner agencies, an important example of collaboration.

Initially funded at approximately $6.2 million, NWDP has not seen an increase since its inception and operates now at just under $4 million. This fact illustrates that each year for the last decade-and-a-half the operational side of the program has ended up with about $3 million to surveil for more than 75 pathogens, toxins, and syndromes, at multiple scales ranging from state to national, continental, or even international.

This figure is surprisingly low when placed in context. USAID's EPT PREDICT, a critical global wild animal surveillance program, receives roughly $20 million annually; yet the core domestic program designed for wildlife sampling receives one-fifth of that. While the United States is not considered a hotspot for emerging infectious disease, its land mass, biodiversity, and commercial agricultural sector create a trifecta of risk for pathogen introduction. The surveillance effort should be commensurate with that risk. Much of the international biosurveillance work undertaken by USAID, particularly in predictive efforts, may serve as a model for future surveillance programs, and its work to build capacity abroad should be reflected as an element in the National Biodefense Strategy.

Current funding levels present limitations to our situational awareness and accumulation of scientific knowledge. As stated by Bevins et al., "Large-scale surveillance programs such as this... are important for providing ecological data on infections at politically and biologically relevant scales."[67]

Congress continues to appropriate funding as particular events occur. From 2006–11, USDA, DOI, and SLTT agencies implemented an NSC-requested plan for a nationally coordinated avian influenza surveillance effort in wild birds.[68,69,70] Their funding came from separate appropriations to the two federal departments as per the standard congressional approach, one that does not incentivize inter-departmental cooperation unless the subcommittees jointly build such partnering into the law. White House direction was likely, therefore, an important element of the program's ultimate success. Efforts ceased in 2011, and were not renewed until 2014 when HPAI reappeared in U.S. commercial poultry flocks. If history repeats itself, USDA or Congress may discontinue the program once again when a lull in avian influenza outbreaks tempts them to turn their funding elsewhere.

The integration of collected surveillance information is an essential component of the process.[71] Yet this piece has been perhaps the one most stymied by bureaucracy. The subject of a national, comprehensive, and integrated human and

animal health surveillance system has been much discussed since the issuance of HSPD-9, which stated:

> *The Secretary of Homeland Security shall coordinate with the Secretaries of Agriculture, Health and Human Services, and the Administrator of the Environmental Protection Agency, and the heads of other appropriate Federal departments and agencies to create a new biological threat awareness capacity that will enhance detection and characterization of an attack. This new capacity will build upon the improved and upgraded surveillance systems described in paragraph 8 and integrate and analyze domestic and international surveillance and monitoring data collected from human health, animal health, plant health, food, and water quality systems.*[72]

Similar to the related requirement in HSPD-10, no such system has ever been implemented. DHS' National Biosurveillance Integration System (NBIS) might have achieved this goal, at least in part, but has not realized the function envisioned for it for reasons described in the *Blueprint for Biodefense*. Acquiring the necessary data has proven to be difficult. Much of the data are owned by the private sector, thus requiring protected information policies that incentivize sharing. Similarly, successful analysis to detect emerging health threats depends on the cooperation of federal and state agencies. Despite such challenges, the Panel has previously concluded that NBIS could have been successful with centralized stewardship; and it remains true that White House leadership could still provide the basis for the coordination and collaboration necessary to optimize the function, if not the NBIS itself. Should NBIS be expected to continue its mission, the White House must get behind and support it. The White House would need to direct interagency sharing of information for the system, and encourage other departments to not just provide information, but to seek information from NBIS through well-formed queries with stated purpose for use. NBIS in turn should be required to evaluate how well its information contributions to DHS and other departments assist in risk reduction and other desired impacts associated with integrated biosurveillance. The approach should be tied to the standards for biosurveillance discussed previously.

The implementing partners of the wild bird surveillance system established an interagency steering committee for surveillance of influenza in wild birds. USDA APHIS (Wildlife Services and Veterinary Services), the U.S. Geologic Survey (DOI), U.S. Fish and Wildlife Service, CDC, state representatives, and the National Flyway Council are members of this Interagency Steering Committee for Surveillance for HPAI in Wild Birds. This committee has produced interagency plans for detection of HPAI in wild birds.[73] The steering committee has been a cohesive unit for designing and implementing large scale surveillance systems. The development of more

interagency steering committees similar to that for HPAI could perhaps provide a platform for this kind of education, information sharing, and relationship building.

The NAHLN, a network of federally-supported partner labs located across has country, also serves a vital function in quickly identifying, confirming, and providing diagnostic surge support for infectious disease outbreaks. In the 2014 Farm Bill, funding was authorized at the level of $15 million annually. The 2018 Farm Bill provides an opportunity for Congress to consider whether the currently authorized level is sufficient to meet the growing need for a national system capable of handling its daily diagnostic demand as well as surge demand for a massive outbreak. Additionally, in the 2008 Farm Bill, Congress authorized the creation of a prevention program for plant diseases and disasters funded by the CCC.[74] Congress should consider establishing a fund to address similar programs for animal health, one that provides more robust support for early detection and surveillance efforts at the state level.

In accordance with Recommendation 14 of the *Blueprint for Biodefense* to improve surveillance of and planning for animal and zoonotic outbreaks, the Panel proposes the following:

The National Security Council should direct interagency partners to develop a standard of expectation or quality by which the value of investment in biosurveillance can be measured. The White House should consider the full scope of wildlife surveillance activity that would benefit wildlife, livestock, and human health, and develop a commensurate budget request. The Administration and Congress should commit to such a plan for the long term. Congress should fund and facilitate enhanced opportunities for data collection from livestock and wildlife by the Department of Agriculture (USDA), Department of Homeland Security (DHS), and Department of Interior, through increased appropriations to the USDA National Wildlife Disease Program. The Secretary of Homeland Security should further DHS collaboration with other federal, state, local, tribal, and territorial, and private sector entities that collect animal health data. Congress should assess whether DHS and the USDA have the needed authorities to ensure the effective sharing of information, and amend statute as necessary.

Congress should continue to fund the National Animal Health Laboratory Network in FY2018 and thereafter at no less than authorized levels, leaving open the possibility that additional funds may be required to fulfill the Network's mission as the need to rapidly diagnose outbreaks grows.

Congress should establish a prevention fund for animal health disease and disaster programs through which capability gaps identified in this report and other relevant agrodefense analysis can be addressed. The Commodity Credit Corporation would be an appropriate vehicle for this funding. This fund could be based on the program created for plant health in Section 10201 of the Food, Conservation and Energy Act of 2008.

REPORTING AND INFORMATION SHARING

The SECD outbreak, perhaps more than any other livestock infectious disease outbreak in recent memory, demonstrated the importance of early reporting, whether for foreign or endemic diseases. APHIS has developed a National List of Reportable Animal Diseases (NLRAD), which has two categories: Notifiable Diseases and Conditions, and Monitored Diseases. The Notifiable Diseases and Conditions consists of foreign animal diseases, emerging disease incidents, and regulated disease incidents. Currently, only accredited veterinarians are required to report specific diseases, such as foreign animal diseases and other diseases not known to exist in the United States.[75]

Monitored diseases do not have a requirement for immediate reporting; they are included only in a monthly reporting requirement by state animal health officials and only when confirmed (not at the suspected or presumptive stage). Furthermore, disease reporting rules for monitored diseases do not require states to report the specific number of cases that have been identified. Last year, only 36 states voluntarily reported diseases on this list to USDA. Furthermore, some states have their own unique reportable disease lists which often differ in terms of which diseases are reported (*e.g.*, the only virus present on all state lists is influenza). Though newly-identified emerging infectious diseases are often placed on the mandatory notifiable reporting list, many known, long-standing diseases that are on the voluntary monitored list have not historically been tracked reliably or consistently.

A systematic and comprehensive animal disease reporting system that codifies reporting requirements and provides for consistent reporting is needed. The 2013 swine coronavirus outbreaks demonstrate the disadvantages apparent from the

lack of such a system. Although USDA was aware of the initial cases, it did not take further regulatory action that would require reporting from affected farms over concerns that it could have negative impacts on the swine industry. Instead, USDA initially supported industry-led efforts to address the outbreaks.[76] A balance between restrictive reporting requirements and the ability of industry and states to manage their own agricultural affairs is needed. The goal should be to allow greater availability of information, coordination of effort, quicker response, and reduced impacts on all stakeholders. The foundation for this eventual outcome is in place: many states are already voluntarily working with USDA to report diseases, and further support through the NAHLN, cooperative agreements, and veterinary accreditation can help strengthen regular reporting of diseases at the state level.

A 2014 concept paper from the USDA on building a reportable disease system has yet to be implemented, although the USDA has since issued a follow-on publication, a framework designed as a pre-cursor to rulemaking. USDA states that, "Regulatory action will officially recognize the NLRAD and codify specific reporting requirements for State animal health officials, laboratory personnel, veterinarians, producers, and others. The U.S. agriculture infrastructure is vulnerable to significant damage from listed as well as emerging diseases."[77] The NLRAD will provide consistent reporting across the United States and help animal health officials protect the U.S. agriculture infrastructure. USDA posted the draft framework for public comment in late 2016; if implemented in regulation, it would make reporting of notifiable diseases mandatory by veterinary practitioners, producers, diagnostic laboratory personnel, and others with knowledge of real or suspected occurrence of these notifiable disease categories. Monitored diseases are to be reported on a monthly mandatory basis by state animal health officials. Additionally, for the first time, private laboratories and entities would be required to report both notifiable and monitored diseases. Notably, the framework would rely on collaboration between federal, state and industry officials to decide the detail of data needed for each disease on the monitored list. At the time this report went to press, the framework was in a review period after receiving public comments.

In accordance with Recommendation 7 of the *Blueprint for Biodefense* to integrate animal health and one health approaches into biodefense strategies, the Panel proposes the following:

The Administrator of the Animal and Plant Health Inspection Service (APHIS) should finalize the rule to establish the National List of Reportable Animal Diseases (NLRAD), in accordance with APHIS' proposed framework and stakeholder comment on that framework. Once finalized, the Administrator of APHIS should ensure that sufficient data systems are in place to properly support the reporting and dissemination of data through the NLRAD. Additionally, the Administrator of APHIS should take appropriate steps to encourage and incentivize rigorous reporting from laboratories, veterinarians, and other stakeholders for cases of diseases on the monitored list, beyond the requirements detailed in the proposed framework.

INNOVATION

Innovative thinking, both in how we govern and in the technological solutions we bring to defense challenges, has been one of the foremost messages of this Panel. The nation needs new ideas and new scientific solutions to push agrodefense approaches beyond their current limitations. Options beyond culling, particularly those that consider animal welfare, must become core tenets of our response; government incentives for innovative research where commercial markets are lacking must become the norm; and academia, producers, and government officials must be encouraged to work together in new ways.

NEXT-GENERATION MEDICAL COUNTERMEASURES

As important as biosurveillance is, the bigger challenges seem to rest with other elements of the system: we have minimal MCM stockpiles or agreements with vendors; we lack the capability to produce MCM on demand; we cull animals because it is deemed to be the only option; and the direct and indirect costs of response are enormous. Reasons for this vary from insufficient federal investment in innovative technologies to the logistical hurdles, cost, and trade ramifications of vaccinate-to-live control strategies.

HSPD-9 requires a coordinated federal effort, led by the Secretary of Homeland Security, to accelerate and expand the development of countermeasures against catastrophic animal, plant, and zoonotic diseases. Relatedly, HSPD-9 requires DHS, HHS, USDA, and EPA to develop a National Veterinary Stockpile (NVS). The White House envisioned the stockpile to contain "sufficient amounts of animal vaccine, antiviral, or therapeutic products to appropriately respond to the most damaging animal diseases affecting human health and the economy and that will be capable of deployment within 24 hours of an outbreak."[78] To date, the NVS has not been authorized in statute.

While the NVS maintains supplies like personal protective equipment and depopulation equipment which have been distributed and used successfully in recent outbreaks, from an MCM standpoint, the NVS is entirely inadequate. For instance, although the stockpile had 9 million doses of vaccine for a North American avian influenza strain (H5N3) at the time of the 2015 HPAI outbreak, it lacked any doses for the strains that actually were infecting poultry during that outbreak. Following the outbreak, APHIS issued a series of Request for Proposals (RFPs) to stockpile avian influenza vaccine for those strains to be used in future

outbreaks. In July 2016, APHIS released its final RFP to acquire an undisclosed number of avian influenza vaccine doses, a purchase that used funding through the CCC. However, without sustained, continued funding, these additional doses will eventually reach the end of their shelf-life and will not be replaced.

Vaccination is generally an effective method of influenza control in poultry.[79] Yet vaccination factors only minimally into USDA HPAI plans[80], and it is unlikely that the NVS has sufficient access to HPAI vaccine for use in combating any large epidemic. Many elements of vaccination indeed make it a complex technical and policy decision: an abundance of viral strains confounds vaccine formulation and stockpiling decisions; vaccinated animals can still shed virus; and vaccination can negatively impact trade status. Yet mass culling is losing favor among the public and should not be the only option. MCM will need to play a more prominent role, and policy and technology will need to catch up to that necessity.

The lack of vaccine available for use during the 2015 outbreak points to larger problems facing the NVS. While USDA APHIS applies a threat-based approach to vaccine procurement, the agency lacks sufficient funding to procure the MCM that threat-based analysis actually reveals. APHIS is unable to support the procurement of MCM for many of the diseases on its *High-Consequence Foreign Animal Disease and Pests* list. There are no therapeutics in the stockpile, and mass procurement of vaccines for outbreaks is frequently a reactionary practice. In recent years, the NVS received on average $4 million per year in congressional appropriations, vastly less than that for the Strategic National Stockpile (SNS) which received $575 million in FY 2017 to serve a similar role for human health. While the precise dollar value of an optimal veterinary stockpile is not publicly known, and may not be the same as for the human stockpile, the magnitude of the difference is striking given that many of the costs for development and stockpiling are expected to be similar. At $4 million annually, USDA is forced to find efficiencies in the NVS supply chain and forge outside partnerships just to provide a limited supply and range of countermeasures. The NVS appears to be little more than a vehicle for MCM distribution, rather than an end-use driver for federal identification, procurement, and stockpiling of priority MCM. It is extremely concerning that a funding level that appears to be based on historical precedent rather than risk-based allocation is driving the contents of the nation's stockpile of veterinary countermeasures. At $4 million, the NVS can only remain on standby and await emergency funding assistance (e.g., borrowing from the CCC), to purchase sufficient amounts of a vaccine during a crisis.

Insufficient federal support for the development of animal vaccines and countermeasures has created an incentive vacuum for the private sector to create them. NVS funding has focused on procuring readily available vaccines, rather

than demonstrating a market commitment to procurement the way the BioShield Special Reserve Fund was designed to do for human MCM. Companies often face difficulties in bringing new animal vaccines, antivirals, and therapeutics to market, and those that would develop agricultural countermeasures that lack a commercial market have minimal advanced R&D support and no procurement commitment in the form of robust NVS funding. In the absence of such support, and without the guarantee of a viable federal market, companies hesitate to commit to developing countermeasures at all. Funding the NVS alone is, therefore, insufficient. If the federal government wants to meet the requirements of HSPD-9, a far greater investment in advanced R&D is also necessary. A system of determining how much funding is worth investing in which diseases is therefore of national interest. To date, APHIS has not approved the use of avian influenza vaccines in commercial poultry, including those it has purchased, and it has not indicated whether or when such a determination will be made. The potential of the stockpile will be significantly enhanced through the acquisition of necessary MCM, and through the establishment of policies for their use.

In accordance with Recommendations 27 and 28 of the *Blueprint for Biodefense* to prioritize innovation and to fully fund and incentivize the medical countermeasure enterprise, the Panel proposes the following:

To meet Homeland Security Presidential Directive 9 (HSPD-9) requirements, the Secretary of Agriculture should assess the ability of the National Veterinary Stockpile to deploy sufficient high-consequence animal disease medical countermeasures within 24 hours. Assessments should prioritize the pathogens identified on the Department of Agriculture's *High-Consequence Foreign Animal Diseases and Pests* list. The Department of Agriculture (USDA) should determine the level of funding needed for these efforts, and request it. USDA should use the findings to: inform its budget request; drive federal priorities for medical countermeasure innovation; and incentivize public-private-partnerships to develop, transition, approve, license, and procure these products. Congress should authorize the National Veterinary Stockpile program. Such authorization should require an annual analysis by the USDA of its progress and an identification of persistent capability gaps and costs associated with achieving the HSPD-9 goal.

The Secretary of Agriculture, in consultation with relevant public and private stakeholders, and in alignment with World Organisation for Animal Health policies, should further develop its vaccine use policy for avian influenza and other high-consequence diseases. Vaccine use policy should be based on an underlying commitment by the federal government to respond to outbreaks with rapid diagnostic and vaccine platform technologies.

The NVS also lacks therapeutics and rapid diagnostics. Rapid diagnostics, including patient-side diagnostics, may arguably be the most important element of an animal disease stockpile. They allow for quick decision-making to minimize the spread of disease before it spreads to larger groups, and to prevent inappropriate uses of vaccine or therapeutics. Absent these tools, diagnosis is dependent on empirical observation by veterinarians, followed by time-consuming laboratory identification. The ability to quickly deploy a user-friendly diagnostics capability to the field would allow for a rapid assessment for SLTT animal health officials, enabling earlier decision-making.

The government does not invest sufficiently in pen-side, innovative diagnostic technology, nor even in today's laboratory-based technology. Diagnostic test kits have short shelf-lives, making them expensive to obtain and maintain. Stockpiling diagnostic test kits would indeed require a sustained financial investment; the need must drive the funding levels, and USDA should determine requirements and request funding in its next budget request to OMB for this purpose.

In accordance with Recommendation 30 of the *Blueprint for Biodefense* to incentivize development of rapid point-of-care diagnostic technology, the Panel proposes the following:

The Secretary of Agriculture should request adequate resources for the National Veterinary Stockpile to maintain a diagnostic test kit for each stockpiled vaccine sufficient to ensure timely delivery of the kits to laboratories. In the Department of Agriculture's budget request, the Secretary should request resources to incentivize the development of rapid point-of-care diagnostic devices for high-consequence pathogens.

Among all livestock infectious diseases, the United States has been singularly focused on the development of vaccines for FMD since the 1950s. Yet today, the USDA's own FMD vaccination strategy states that the United States does not have sufficient vaccine to vaccinate beyond a small focal or moderate regional outbreak.[81] The United States contributes funding to the North American FMD Vaccine Bank, which is a repository for vaccine antigen concentrate (VAC). PIADC holds this supply of antigen. Whereas vaccine production from scratch can take up to 14 weeks, industry can produce 2.5 million doses within 21 days with the antigens contained in the bank.[82] Yet the supplies in the Vaccine Bank are insufficient to handle a major FMD outbreak in this country. Culling herds continues to be the highly unsatisfactory default tool for outbreak control. It will be years before the NVS and industrial capacity can address anything more than a local outbreak. No new and validated FMD technology, whether for diagnostics, vaccines, or therapeutics, is on the horizon that would rescue the United States in an FMD emergency.

The NBAF is intended, in part, to address this problem. DHS, the state of Kansas, and the city of Manhattan, Kansas are building the NBAF to expand capacity for disease research and MCM R&D for foreign animal and other agricultural diseases. With its large-animal capabilities, NBAF will also assist with the diagnosis and study of additional diseases more rapidly than its predecessor does. NBAF, however, will only reach its full potential if the federal government commits to funding the research its planners envisioned for it.

The fate of another DHS laboratory provides a case in point. The National Biodefense Analysis and Countermeasures Center (NBACC) is a new facility built across two presidential administrations and two parties to meet a national security threat. In the FY 2018 budget request, the Administration proposed elimination of NBACC to fund other priorities. If the federal government approaches the NBAF in similar fashion (a big vision to build, but a small vision to implement long-term programmatic activity once that building is erected), the $1 billion investment could be wasted. If the USDA is the only customer of the lab (much like the FBI has been the only customer of NBACC's bioforensics lab), this not only eliminates a large opportunity for public-private partnership, but places the lab at the mercy of USDA's R&D appropriations which are historically a fraction of what is needed.[83] It is also the subject of some debate within DHS, USDA, and Congress as to which federal department will assume oversight and funding of NBAF operations. The President's FY 2018 request would eliminate all agriculture and animal-specific research by the DHS Science and Technology Directorate; this would include agricultural screening and surveillance research and development, as well as foreign animal disease MCM research. The budget request provides no compensatory funding for USDA to take on these missions. As agrodefense is fundamentally a national security concern, it

should continue to be a primary responsibility of DHS. While final appropriations language may reject these proposals, they speak to a diminishment of support from the Executive Branch for agriculture and agrodefense research.

In accordance with Recommendation 27 of the *Blueprint for Biodefense* to prioritize innovation and incrementalism in medical countermeasure development, the Panel proposes the following:

The Secretaries of Agriculture and Homeland Security should establish an antigen bank for foot-and-mouth disease virus. This recommendation is consistent with the Panel's broader recommendation for federal stakeholders to establish a bank of antigen payloads to operationalize a plug-and-play strategy using proven platform technologies for use in emergencies. The Secretaries should ensure that the acquisition of any such antigen bank is tied to a business plan, to establishment of policies for vaccine usage, and to the National Biodefense Strategy. Further, the Secretary of Homeland Security, in coordination with the Secretary of Agriculture, should develop a business plan for the operation of the National Bio- and Agrodefense Facility, one that would engage the public and private sectors; consider domestic and global markets for agrodefense research and development; and identify a dollar figure that defines the need and the opportunity. In the development of this plan, the Secretary of Homeland Security should issue a Request for Information to assess market opportunity for agricultural research in high-containment laboratories. The Secretary should submit the business plan to congressional committees of jurisdiction, including homeland security and agriculture authorizers and appropriators; future Department of Homeland Security and Department of Agriculture budget requests should align with the plan.

CONCLUSION

Nearly all federal departments and a few independent agencies contribute directly or indirectly to the protection of American livestock. So do SLTT governments, and so does industry through the efforts of producers, veterinarians, biotechnology companies, and many others. Finding a way to coordinate them is not an easy charge. While a higher priority has understandably been placed to date on protecting human health from intentionally introduced, accidentally released, and naturally occurring infectious diseases, the increasing rate of emerging and reemerging zoonotic disease accompanied by the overt statements and attempts by those with nefarious intent to attack food and agriculture, indicate the necessity to exert more effort to combat threats, eliminate vulnerabilities, and reduce consequences associated with this sector.

The Administration must improve agrodefense efforts at the departmental level and among the interagency. Departmental efforts should be assessed and redirected per the forthcoming National Biodefense Strategy and along the points outlined in this report. One of the most important elements that could materialize from the Strategy is the emergence of departmental ownership of agrodefense. DHS investments in NBAF development, and USDA's commitment to funding response activities, demonstrate an acknowledgement of the threat. However, current funding levels in areas such as biosurveillance and MCM are insufficient to address mission needs. Furthermore, political leadership and policy coordination, particularly that which acknowledges the intentional dimension of agricultural preparedness, require strengthening. Agrodefense in many ways appears to be an orphan, with long-view funding and policy priority finding a home in neither DHS nor USDA.

Federal investment in the mission space is also temporally lopsided, with more attention and funding brought to bear on the issue when disaster strikes, rather than beforehand. This situation leads inevitably to the incursion of major costs and losses. Such a disparity should be rectified. Budget requests should be submitted and reviewed by OMB and Congress in unified fashion. Beyond the recommendation in this report for such a unified approach to agrodefense budgeting, the Panel will be issuing further analysis of how a more integrated approach can benefit all biodefense efforts. Assessment of capabilities, accountability for these capabilities, and transparency in OMB budget and performance submissions are needed.

The interagency nature of agrodefense means that many congressional committees oversee agrodefense efforts. The House and Senate Committees on Agriculture

and Homeland Security should lead these oversight efforts to ensure that all requirements for securing our agricultural enterprise are met. These Committees should both continue and expand previous efforts and increase their direction to the Executive Branch. The Farm Bill provides a significant opportunity every five years to do this legislatively.

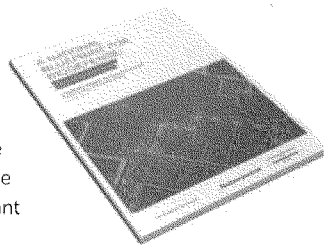
In the 115th Congress, Representative David Young and Senator Pat Roberts introduced legislation that would delineate agrodefense-related responsibilities within the Department of Homeland Security. Signed into law in June 2017,[84] these bills reflect congressional recognition of the need to establish some degree of ownership of the defense of F&A mission within the Executive Branch. The Panel's recommendation for further improvements could be directed via the Farm Bill and other authorization and appropriations vehicles.

While many experts agree that bureaucratic silos of the kind that may inhibit collaboration or information sharing do indeed exist, some silos do appear to be thinning over time. Breaking down all bureaucratic stovepipes may never be possible, so the more apt question may be whether it is possible to make the interaction of those silos more efficient and effective, such as through more joint steering committees. While it is important to put in place policies and even statutes that require collaborative effort, the human beings who implement that effort have to want to do so. Examples of success are often based not on policy and law, but on personnel with long-standing relationships across the interagency and the public/private divide, and who want to drive progress.

With each passing year, new threats are discovered that could have severe, long-lasting impacts on animal agriculture. Some of these threats arise at home, and others come from abroad, necessitating concerted effort not just domestically but also internationally. Even with optimized levels of federal leadership, coordination, and funding in place, a common sense of ownership of the challenge, from governmental and non-governmental stakeholders alike, will be necessary. It is essential that our animals, our lives, and our economy are not left vulnerable. The Panel believes that the implementation of the proposals contained in this report is an important step toward that end.

PROPOSED CONGRESSIONAL OVERSIGHT HEARINGS

Congressional oversight must ensure that federal departments and agencies meet congressional and other mandates, and in a coordinated fashion. The following proposed hearing topics reflect recommendations discussed in this report, and raise additional ideas for consideration. Parentheticals at the end of each description direct the reader to relevant recommendations in the *Blueprint for Biodefense*.



ANIMAL DISEASE REPORTING

A nationally notifiable animal disease system akin to the existing system for human disease would enhance surveillance and detection of biological threats. A proposed National List of Reportable Animal Diseases has been offered by USDA, but not yet finalized. What is the status of implementation? Will the final rule reflect both the mission need as well as stakeholder input? How could the list be integrated into a system by which states and other owners of disease information could willingly and comfortably report disease incidence? (See Recommendations 7, 14)

HOUSE COMMITTEES:

- Agriculture
- Homeland Security
- Natural Resources

SENATE COMMITTEES:

- Agriculture, Nutrition, and Forestry
- Environment and Public Works
- Homeland Security and Governmental Affairs

BIODEFENSE AND AGRODEFENSE STRATEGIES

In what ways is agrodefense being addressed and incorporated into the National Biodefense Strategy? Is it receiving the emphasis that the F&A sector requires as a national asset? (See Recommendation 3)

HOUSE COMMITTEES:

- Agriculture
- Armed Services
- Budget
- Energy and Commerce
- Homeland Security
- Oversight and Government Reform

SENATE COMMITTEES:

- Agriculture, Nutrition, and Forestry
- Armed Services
- Budget
- Health, Education, Labor, and Pensions
- Homeland Security and Governmental Affairs

BIOSURVEILLANCE

The United States lacks a comprehensive biosurveillance and detection standard and capability. An integrated biosurveillance function exists in statute, but has been difficult to realize. The program designed to do this, the National Biosurveillance and Integration System, was eliminated in the President's Budget Request for FY 2018. What would it take to bring agencies with biosurveillance responsibilities, including for animal agriculture and wildlife, together in a trusted, information-sharing environment? What is the needed end-state for a continuous capability to detect, validate, and warn of any biological threat, including agricultural threats, within the United States? Many questions about wildlife zoonoses remain, including the ecology of material threats like *Yersinia pestis*, and how changing climate patterns will affect the disease distribution of pathogens like avian influenza. How can we achieve a comprehensive and effective national surveillance architecture if we do not invest to answer these scientific questions? (See Recommendations 7, 11, 12, 13, 14)

HOUSE COMMITTEES:

- Agriculture
- Energy and Commerce
- Homeland Security
- Natural Resources
- Oversight and Government Reform
- Veterans Affairs

SENATE COMMITTEES:

- Agriculture, Nutrition, and Forestry
- Environment and Public Works
- Energy and Natural Resources
- Health, Education, Labor, and Pensions
- Homeland Security and Governmental Affairs
- Veterans Affairs

FOOD SUPPLY PROTECTION AND RESPONSE

The F&A critical infrastructure sector is a distributed and highly complex system. Many efforts have been made to reduce its vulnerability to terrorism and other insults. HSPD-9 (2004) and the DHS F&A Sector Specific Plan (2010), among other policy documents, guide protection of this sector. Have these and other plans been updated, exercised, and sufficiently funded? Are they integrated with related efforts for biosurveillance, attribution, decontamination, and remediation? How will USDA, FDA, CDC, and other federal agencies respond if a terrorist attack impacts the food supply? How can PPP in this area be improved? What efforts and funding are still required to protect the food supply, including plants? Who and in what state is planning for decontamination and remediation to make food processing plants operational again after an incident? (See Recommendations 3, 9, 10)

HOUSE COMMITTEES:

- Agriculture
- Energy and Commerce
- Homeland Security
- Natural Resources

SENATE COMMITTEES:

- Agriculture, Nutrition, and Forestry
- Environment and Public Works
- Health, Education, Labor, and Pensions
- Homeland Security and Governmental Affairs

FUNDING OF PREPAREDNESS AND RESPONSE EFFORTS

Funding for federal agrodefense programs is spread amongst a number of Departments and their corresponding activities. Although HSPD-9 provides a basic framework of agrodefense roles at each phase of preparedness, much of the federal investment in agricultural defense comes in the response phase, leading to greater costs and damages when calamity strikes. The CCC provides significant support to USDA to react to crises, but is not currently utilized in developing more robust preparedness efforts up front. What steps can departments and agencies take to better coordinate their agrodefense spending? What incentives might there be to encourage more investment in preparedness and prevention efforts in advance of a threat to food and agriculture? Is there an opportunity for CCC funds to be used for USDA prevention and mitigation efforts? (See Recommendations 4, 7)

HOUSE COMMITTEES:

- Agriculture
- Appropriations
- Budget
- Energy and Commerce
- Homeland Security

SENATE COMMITTEES:

- Agriculture, Nutrition, and Forestry
- Appropriations
- Budget
- Health, Education, Labor, and Pensions
- Homeland Security and Governmental Affairs

GLOBAL HEALTH RESPONSE

The world lacks a global health response apparatus that can react quickly and insert public health teams to respond to human, animal, and plant outbreaks. What is the current global response capacity and in what ways is it not meeting needs? How can international efforts be evaluated and better coordinated? What is the status of current global health response programs and how can they show more progress? What level of funding would be necessary? What lessons can be learned from recent outbreaks in animals, such as HPAI in China? (See Recommendation 33)

HOUSE COMMITTEES:

- Agriculture
- Armed Services
- Foreign Affairs
- Energy and Commerce
- Natural Resources

SENATE COMMITTEES:

- Agriculture, Nutrition, and Forestry
- Armed Services
- Foreign Relations
- Health, Education, Labor, and Pensions

OPERATIONAL RESPONSE AND COORDINATION

In the midst of a crisis, operational leadership is critical to successful outcomes. What is the status of response and recovery planning and recovery efforts for high consequence infectious disease scenarios at all levels of government? What further capabilities do responders, particularly those at the local level, require to combat threats to F&A? What can be done to further multi-agency coordination in this area? How can we increase training efforts related to existing plans and protocols? How can we strengthen relationships and communications among the responsible agencies, to ensure operational leadership? (See Recommendations 16, 17)

HOUSE COMMITTEES:

- Agriculture
- Homeland Security

SENATE COMMITTEES:

- Agriculture, Nutrition, and Forestry
- Homeland Security and Governmental Affairs

WORKFORCE

The national veterinary workforce trained to prevent, detect, and respond to livestock outbreaks of foreign animal diseases is limited. Yet it is this profession that is responsible for protecting animal health and welfare and, therefore, all of the elements of this sector important to human health and the economy. The National Veterinary Emergency Response Teams (NVERT) are the core federal response capacity needed for large animal health situations. Are the available NVERTs sufficient to respond to an animal emergency of catastrophic proportions? Is a USAJOBS-based application requirement the best way to invite and incentivize private sector veterinary professionals into the system? Is the Public Service Loan Forgiveness Program a potential vehicle for expanding the workforce? How can the barriers of entry for interested veterinarians be lowered?

HOUSE COMMITTEES:

- Agriculture
- Appropriations

SENATE COMMITTEES:

- Agriculture, Nutrition, and Forestry
- Appropriations

APPENDIX A: METHODOLOGY

Established in 2014, the Blue Ribbon Study Panel on Biodefense informs U.S. biodefense efforts and provides recommendations for needed change. The Panel, supported by seven ex officio members and funds from foundations, industry, and individual donors, assesses where the United States falls short in addressing biological terrorism, warfare, accidents, and emerging, reemerging, and other naturally occurring infectious diseases. Information-gathering is achieved primarily through public and private meetings and literature research, and recommendations are issued in the form of reports. The Panel works to educate all stakeholders and the public about its findings through these reports, public appearances, and other communications platforms.

RESEARCH QUESTIONS

In order to assess gaps in the animal agrodefense enterprise, the Panel developed the following research questions:

1) Are our priorities correct?
2) Are our investments commensurate with the challenge?
3) Can we benefit by rebalancing investments, or is new funding required?
4) What have we done that has brought a significant return on investment?
5) What else should we be doing that we are not?

RESEARCH ACTIVITY

For this special focus report, the Panel reviewed scientific studies; reports by congressional and presidential commissions; presidential directives; statute and proposed legislation; GAO reports; and federal strategies, plans, budgets, organizational constructs, and programs related to defense against deliberately introduced, accidentally released, and naturally occurring biological events with catastrophic potential. This review: 1) informed the Panel's assessment of the comprehensiveness of efforts to address postulated and actual agrodefense challenges; 2) informed the Panel's determination of how the understanding of the threat, knowledge base, and elements of the agrodefense enterprise should change in light of this assessment; and 3) shaped the structure and topics of the agrodefense special focus meeting held by the Panel on January 26, 2017 in Manhattan, Kansas.

AGRODEFENSE SPECIAL FOCUS MEETING

The Panel organized this special focus meeting around the major activities that comprise the biodefense enterprise at large: prevention, deterrence, preparedness, surveillance and detection, response, recovery, attribution, and mitigation. Two Panel Members, former Senate Majority Leader Tom Daschle and former Homeland Security Advisor Ken Wainstein, co-chaired the meeting and received: 1) information regarding national agrodefense policy, departmental and agency programmatic activities, and legislative matters; and 2) statements from a sitting member of Congress, former federal officials, current state officials, academic and private sector representatives, thought leaders, and subject matter experts. After the meeting, Panel staff summarized major insights, areas for improvement, and recommendations articulated by meeting speakers, and conducted preliminary high-level analysis of the meeting. See Appendix C for the meeting agenda and speakers.

ANALYSIS

Panel staff qualitatively analyzed the information gleaned from their research and from the special focus meeting. Staff evaluated facts, findings, and recommendations provided by meeting speakers and through other means, including policy research and interviews with subject matter experts and former high-level officials. Throughout the process, the five research questions above provided the basis for assessment. This approach allowed Panel Members and staff to identify continuing organizational, legal, policy, and programmatic issues, and to recommend solutions. Panel staff did not use statistical and other quantitative methods for this study. The study is not considered pseudo-qualitative/quasi-quantitative.

STUDY LIMITATIONS

Funding and other resource constraints prevented the Panel from performing site visits beyond visiting the Biosecurity Research Institute at Kansas State University. The Panel did not assess challenges in protecting the food supply or the plant sector, as these are extensive enterprises in and of themselves and require their own special focus. In addition, some agrodefense programs and policies; intelligence, raw data, and documents; appropriations and budget documents; and other sensitive pieces of information are classified or otherwise unavailable, and were not reviewed by the Panel as this was a wholly unclassified endeavor.

APPENDIX B: MEETING AGENDA AND SPEAKERS

The following is the agenda for the special focus meeting at Kansas State University, Manhattan, Kansas. Names and affiliations appear here as they did at the time of the meeting.

AGRODEFENSE: CHALLENGES AND SOLUTIONS

JANUARY 26, 2017

Opening Remarks

- Former Senate Majority Leader Thomas A. Daschle, Panel Member, Blue Ribbon Study Panel on Biodefense
- Former Homeland Security Advisor, Kenneth L. Wainstein, Panel Member, Blue Ribbon Study Panel on Biodefense
- President Richard B. Myers, Kansas State University (General, USAF – retired)

Congressional Perspective

- The Honorable Roger Marshall, MD, United States Representative, Kansas

Panel One – Prevention and Deterrence

Challenges and opportunities in reducing risk from agricultural threats. Understanding the challenges of laboratory research in the context of threats to F&A, regulatory regimes, and new technologies. Ways in which outbreaks have demonstrated strengths and weaknesses, with respect to medical countermeasures.

- Stephen Higgs, PhD, Associate Vice President for Research and Director, Biosecurity Research Institute
- Amy Kircher, DrPH, Director, Food Protection and Defense Institute, University of Minnesota
- Steve Parker, MBA, MSCM, Head, North America Veterinary Public Health, Merial

Lunch Keynote - Leadership in Protecting the Agricultural Sector

- Bret D. Marsh, DVM, Indiana State Veterinarian

Panel Two – Surveillance and Detection

Key elements of effective agricultural biosurveillance and detection, and continued challenges in the effectiveness of ongoing efforts. Technological and policy challenges for early and reliable detection of environmentally dispersed biological agents to attack agriculture. Key elements of effective animal and plant surveillance and detection architecture, and impediments and opportunities to increase situational awareness for early and accurate disease detection and clinical diagnoses. Requirements for medical countermeasures, including the need for extremely rapid development, distribution, and dispensing.

- Tammy R. Beckham, DVM, PhD, Dean, College of Veterinary Medicine, Kansas State University
- Ali S. Khan, MD, MPH, Dean, College of Public Health, University of Nebraska Medical Center
- Kelly F. Lechtenberg, DVM, PhD, President, Midwest Veterinary Services/ Central States Research Center/Veterinary and Biomedical Research Center

Panel Three – Preparedness, Response, Recovery, and Mitigation

Pre- and post-event planning, including the challenges faced by the food, agriculture, and public health communities, and the roles of state, local, and federal governments. Challenges of epidemiology and other tools for characterizing the spread of animal, plant, and foodborne diseases in the United States. Recovery and mitigation, including the challenges posed by cutting edge technology, lack of agreement regarding state and federal responsibilities, and implications for future preparedness.

- Jackie McClaskey, PhD, Secretary, Kansas Department of Agriculture
- D. Charles Hunt, MPH, State Epidemiologist and Director, Bureau of Epidemiology and Public Health Informatics, Kansas Department of Health and Environment
- C. J. Mann, DVM, Chief Executive, Empryse Group

Closing Remarks

- President Richard B. Myers, Kansas State University (General, USAF – retired)
- Former Homeland Security Advisor, Kenneth L. Wainstein, Panel Member, Blue Ribbon Study Panel on Biodefense
- Former Senate Majority Leader Thomas A. Daschle, Panel Member, Blue Ribbon Study Panel on Biodefense

APPENDIX C: ACRONYMS

APHIS	Animal and Plant Health Inspection Service
BARDA	Biomedical Advanced Research and Development Authority
BSE	bovine spongiform encephalopathy
CCC	Commodity Credit Corporation
CDC	Centers for Disease Control and Prevention
DHS	U.S. Department of Homeland Security
DOC	U.S. Department of Commerce
DOD	U.S. Department of Defense
DOI	U.S. Department of Interior
DOJ	U.S. Department of Justice
DPC	Domestic Policy Council
EPA	U.S. Environmental Protection Agency
F&A	Food and Agriculture
FAIA	Food and Agriculture Incident Annex
FBI	Federal Bureau of Investigation
FDA	U.S. Food and Drug Administration
FEMA	Federal Emergency Management Agency
FMD	foot-and-mouth disease
FY	fiscal year
GAO	Government Accountability Office
GDP	gross domestic product
HHS	U.S. Department of Health and Human Services
HPAI	highly pathogenic avian influenza
HSA	Homeland Security Act of 2002
HSC	Homeland Security Council
HSPD	Homeland Security Presidential Directive
IC	Intelligence Community
MCM	medical countermeasure(s)
NAHLN	National Animal Health Laboratory Network
NBACC	National Biodefense Analysis and Countermeasures Center
NBAF	National Bio- and Agrodefense Facility
NBIS	National Biosurveillance Integration System

NLRAD ..... National List of Reportable Animal Diseases
NEC ..... National Economic Council
NSC ..... National Security Council
NVS ..... National Veterinary Stockpile
OMB ..... Office of Management and Budget
PEDV ..... porcine epidemic diarrhea virus
PIADC ..... Plum Island Animal Disease Center
PPP ..... public-private partnership(s)
R&D ..... research and development
RFP ..... Request for Proposal
S&T ..... science and technology
SLTT ..... state, local, tribal, and territorial
SNS ..... Strategic National Stockpile
USDA ..... U.S. Department of Agriculture
USAID ..... U.S. Agency for International Development
WMD ..... weapon(s) of mass destruction
VAC ..... vaccine antigen concentrate

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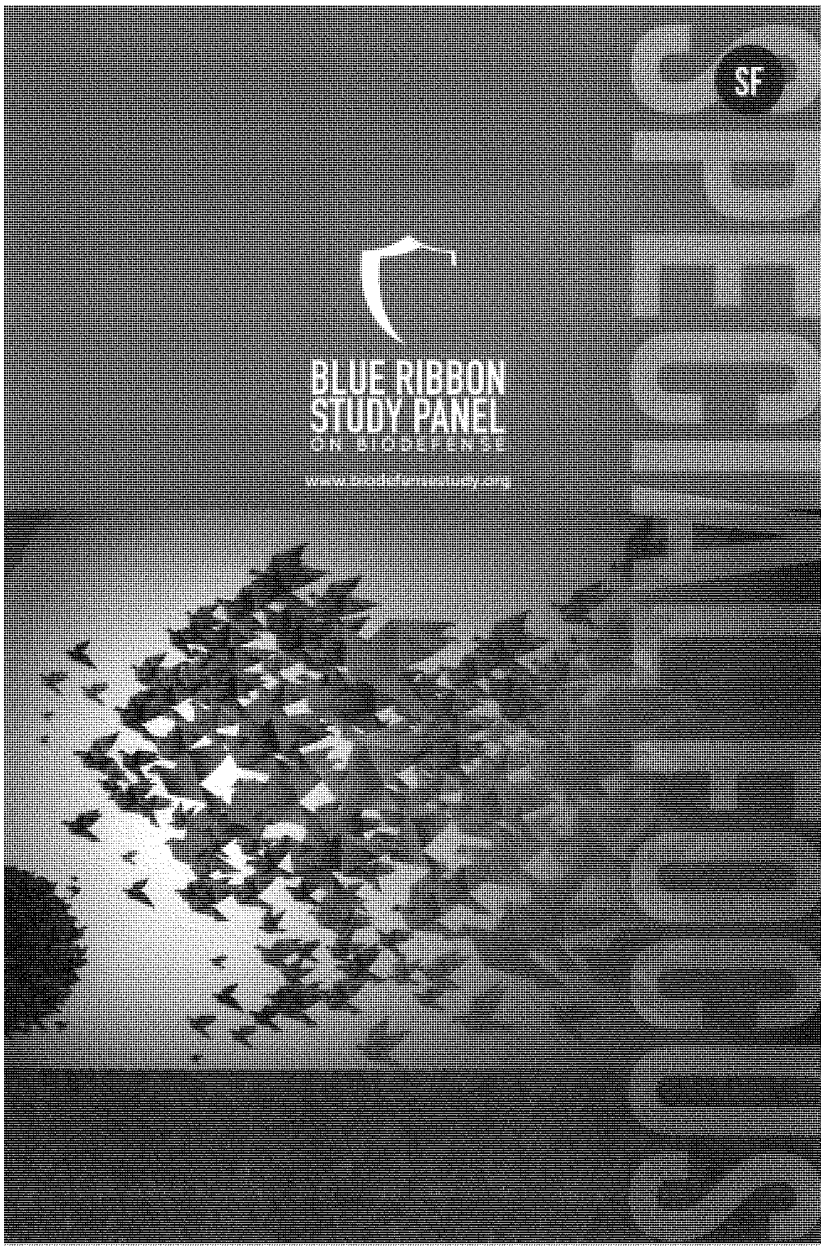
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