11.1 PRIMARY DRIVERS FOR FUTURE WEATHER AND CLIMATE INFORMATION ARCHITECTURE

Gerald J. Dittberner
NOAA/NESDIS Office of Systems Development, Silver Spring, Maryland

E. Lee Tilton, III *
The MITRE Corporation, Center for Integrated Intelligence Systems, McLean, Virginia

1. INTRODUCTION

This paper offers a rationale for NOAA's role in a cultural paradigm shift in national data collection and information generation. The shift is demanded by environmental concerns, global political and stability issues, and the need for NOAA to contribute information to many US national priorities, some recently heightened by national security concerns.

Projections of alternate futures for the globe and for the United States indicate that there are national priorities that require weather and climate information as key inputs. In the past it has been the responsibility of the National Oceanographic and Atmospheric Administration (NOAA) to produce weather and climate information derived primarily from sources managed by NOAA. However, in the future, it is imperative that NOAA's data be an integral part of a national or global system of systems that collect, manage and disseminate information for use in securing our national interests. The information may be partly or wholly derived from space, aircraft, in-situ, human, and cyber data collection systems operated by the US and other global entities.

2. FUNDAMENTAL THEMES

In the last several decades, major improvements in collection techniques, technologies, and computational processes have greatly improved the forecasting of weather. In addition, the development of climate information production techniques, that are more than just experimental modeling, have been initiated. At the same time, concerns about global problems generally involving the environment have put increased pressure on improved weather and climate information and have grown to critical levels in some areas. Many of these concerns were highlighted in two recent reports published by the National Intelligence Council, titled "The Global Infectious Disease Threat and Its Implications for the United States," (http://www.odci.gov/nic/pubs/other_products/inf_diseases_paper.html) and "Global Trends 2015: A Dialogue About the Future With Nongovernment Experts," (http://www.odci.gov/nic/pubs/2015_files/2015.htm). These and other studies have collectively suggested that the concerns could be focused in five major themes that are fundamental to preserving the national security of the United States: Economy, Health, Energy, Water, and Well-being.

Each of these themes involve problems in which the understanding of related issues, threats, and consequence management are dependent on increasingly improved knowledge of the status and changes in our atmosphere and oceans. The following paragraphs give examples of weather and climate information requirements for each of the five themes.

2.1 *Economy*

The US economy is heavily influenced by foreign and domestic trade in agriculture and by societal instabilities driven by disaster. Balance of trade in agricultural crops is subject to drought, excess rain, availability of adequate irrigation, storms, and weather in general. Since knowledge of climate plays a major role in long term productivity trends, it affects economic performance as well as humanitarian issues. Further, atmospheric characteristics, such as greenhouse gases, can have severe impacts on productivity. Recently, crop production in a large area of China was significantly reduced due to the presence of atmospheric sulfur from burning fossil fuels and other atmospheric pollutants. If the US is

* *Corresponding author address*: E. Lee Tilton, III, The MITRE Corporation, CIIS, 1820 Dolley Madison Boulevard, Mail Stop W940, McLean, Virginia 22102-3401; e-mail: ltilton@mitre.org

called upon to provide assistance, to referee, or otherwise react to foreign needs or transnational conflict caused by weather or climate induced crop issues, the US economy can be greatly affected.

Weather and climate induced disasters such as tornadoes, hurricanes, floods, snow, and ice impact the economy through business and personal loss (property and life) and the resulting pay-out of insurance. Hurricane Andrew, for example, caused serious financial difficulty to State Farm, one of our largest national disaster insurers. Climate trends may also have long term economic impact on the re-insurance business. As long as the national economy is healthy, these impacts can be mitigated; but if the economy is weak, these kinds of influences can be highly leveraged in the economic margin with serious domestic and international consequences.

With regard to man-made threats and disasters, we need only witness the effects of the 9/11 event on the US economy. Although the basic event was not weather or climate related, the associated anthrax threat and other biological threats could be heavily influenced by weather and climate. The spread of West Nile Virus over almost the entire US in two years is an excellent example. What if this was a terrorist experiment to test the US spread of mosquito borne pathogens? We must understand the weather/climate influences on this and other threats.

We must also understand the influence on threats against plants and animals as well as humans. These could heavily influence the economy through agriculture. This points us to our second theme, our concerns for the nation's human, plant and animal health.

2.2 *Health*

Health has always been a US and global concern. The concern has been exacerbated by the mobility of the human race and the urban density that exists in many of the highly populated areas. Adding to this is the threat of terrorism and the emergence and re-emergence of many infectious diseases (no less than 30 in as many years). It has been shown that climate can potentially play a significant role in the presence and spread of infectious disease. Recently studied examples include ebola, dengue fever, Riff Valley Fever, hemorrhagic fever, West Nile Virus, cholera, malaria, and tuberculosis. Each of these may have weather, climate, or ocean variables as components of their dynamic behavior. Although we may not be able to respond in some cases, we may be able to take preemptive action if we know that environmental conditions will favor the spread (or reduction) of disease. In other examples, weather or climate changes may be leveraged and weaponized pathogens used as threats or weapons of mass destruction. In some cases, the long-term geographic spread of insect borne diseases, such as West Nile Virus, may be totally dependent on insect distribution responding to changes in climate. Until now we have been satisfied to monitor climate so we can understand its relationship to infectious disease dynamics. In the future, we must improve our ability to predict climate and climate changes, both seasonal and long term, to take both short and long term preventive measures in disease control. We must make our first strategy the elimination or reduction of threats when possible, but be prepared to identify and warn of impending threats when a threat reduction strategy fails.

2.3 *Energy*

Energy is an area of increasing concern because of its present limited availability in some forms, its effect on the economy, and its use as an international bargaining chip. Its impact on the environment in some of its utilized forms and its dependence on technology and knowledge for optimum utilization are also of concern. Our ability to understand the weather, the climate of the atmosphere and the oceans, and their influence on energy cycles of the earth may ultimately determine our ability to positively influence man's impact on the environment.

The way that we use energy determines both how it affects the environment (burning of fossil fuels) and how the environment affects energy in some of its forms (wind, geothermal). The efficiency with which we use energy (usually a technological influence) and the hazards associated with its use (oil spills) can interact significantly with weather and climate of both atmosphere and ocean. In most cases, the extent to which we can monitor, analyze, model, and predict weather and climate are important factors in the economy and the effectiveness of energy use.

In our most recent financial markets, the buying, selling and trading of energy units, such as degree days, has grown from no market to 20 billion dollars a year in just six years. However,

current seasonal prediction techniques are not accurate enough to be useful to the energy markets. The Kyoto protocol is investigating the international trading of carbon credits to ease man's impact on the atmosphere. The impacts are largely influenced by release of greenhouse gases. It is difficult, if not impossible, to design a fair regulatory and verification scheme if we do not fully understand the global energy processes. Our understanding of weather and climate is critical to our ability to understand and reliably predict even short-term seasonal variations and extremes. This in turn is critical to our ability to manage the utilization and regulation of energy.

2.4 *Water*

Water, particularly clean, fresh water, is becoming a scarce commodity in many areas on the globe. Its availability and access is the subject of much negotiation between nations and is at the root of many transnational and internal conflicts. Often, the availability of fresh ground water is not replaceable in the short term once it is pumped out of the ground. The production of fresh water from seawater is still an infant and expensive technology. It is projected over the next few decades that fresh, clean water will become a critical commodity in many nations for health, nutrition, and political reasons. It is imperative that we learn to manage this frail resource; we must understand its availability and changes in its availability on a geographic basis, meaning that we must know the nature and the rate of its replenishment and depletion. Both of these are functions of the short and long-term water cycles of the earth as functions of the weather and climate of both ocean and atmosphere.

In addition to water quantity, we must know water quality if it is to be useful for agriculture and human utility. Utility includes consumption, bathing, recreation, and power in addition to agriculture, aquaculture and many types of manufacture and industry. Fresh, clean water is critical to good health. It is reported that 85 percent of the fresh water in India (soon to be our most populous nation) is polluted. This is closely tied to India's coastal cholera outbreaks, which in turn is influenced by water dynamics in the coastal regions. (Reference NASA's CHAART Remote Sensing of Cholera Outbreaks, http://geo.arc.nasa.gov/sge/health/projects/cholera/cholera.html) All of these facets of water are key elements of NOAA's, and its land counterpart, the United States Geological Survey's missions and objectives.

The responsibility for the management of the earth's fresh, clean water in the next 50 years will become as important an issue as the economy, health and energy. It will be an international political issue and its availability may dominate many transnational relationships. In order to understand the global nature of fresh water, it will take all the international cooperation and technology we can muster over the next decades. Water may well become as important an international commodity as energy is today. Information on global water availability may become highly leveraged in our quest for national security and well being. The spotlight will be on NOAA as a key player.

2.5 *Well-Being*

Well-being may be defined as the ability of a people to live a safe, happy, prosperous, and long life. It is influenced by a range of issues from the monitoring and prediction of weather to the forecasting of glacial melt. It includes a healthy population, a robust economy, all of the freedoms, and our ability to maintain those aspects of our society. To maintain means to defend, at home and abroad, and to offend as necessary while keeping our society and its people safe, secure, and free. This process is continually changing and challenged as the human race becomes more mobile and its societies and laws (or lack thereof) become more complex and globally interactive. Well-being may be as simple as knowing that it will not rain on our picnic, or as complex as knowing that certain disease vectors will not threaten the population because of climate changes. It can be as simple as being able to predict the extremes of the next heating season so that citizens do not go without heat, or as complex as making the proper agricultural decisions based on El Nino predictions during the next decade. It could mean collecting and/or predicting the status of the elements (water and air) to prepare our troops abroad for disease or environmental extremes. National security is not just keeping the enemy "out" if it means keeping our people "in".

Well-being is a collective attribute of our society that allows us to be happy - happy to be alive, happy to be American, and happy to be contributing to human progress. Environmental and man-made threats are stressing and not

conducive to happiness and well being. The threatened aspects of the economy, health, energy, and water can add up to a very unhappy and threatened society with weather and climate as common elements. We can envision a man-made or natural bio calamity affecting our health and water and, in turn, our economy and energy supply. This could produce global consequences such that our national security and well-being are seriously, and maybe permanently, affected. We can also envision that weather and climate information and predictions could be critical to social stability in this scenario. We simply cannot afford to treat better knowledge and understanding of weather and climate of the atmosphere and oceans as "scientifically interesting and nice to know"; they are too much of an integral part of our security and well being.

3. OBSERVATIONS

Once upon a time we were content to observe the atmosphere and ocean weather. Our desire to have continuous observations led to a desire to measure and monitor. The monitoring led to an interest in understanding what we were observing. Understanding more and more made us desire to look farther and deeper. As we acquired more knowledge and understanding, and as the world got more complicated, we realized that weather and climate of atmosphere and ocean were often an integral part of the reason for events being what they are.

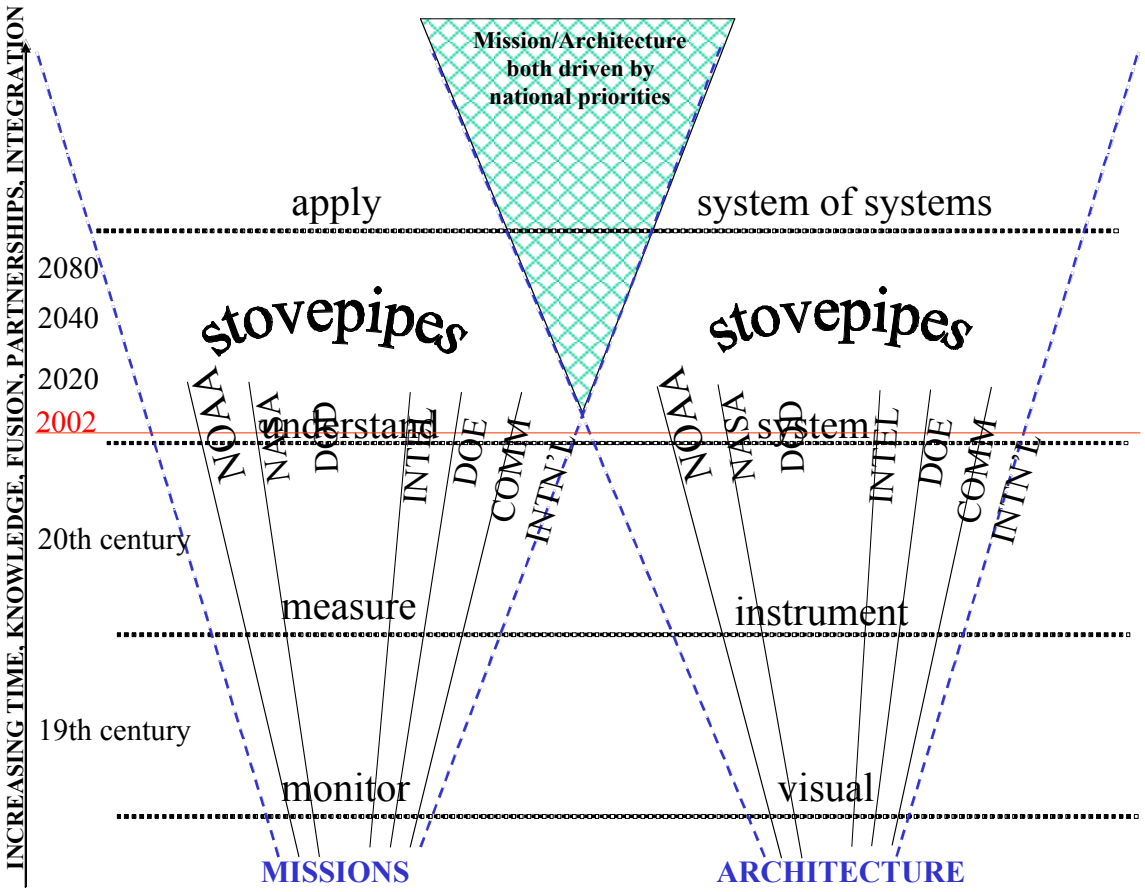

Figure 1. Notional Depiction of National Agency Missions and Architecture Versus Time

Now we must start applying what we know. This suggests a continuing need for more information, more understanding, and more application methodologies. It also suggests that we eliminate our governmental stovepipes and that we spend our national resources wisely to avoid replication and redundancy without sacrificing reliability and continuity. We need to build a complementary national system of systems that provide all of our information needs to assure our national well-being. The system of systems must encompass our space, aircraft, insitu, human, and cyber data gathering capabilities with appropriate interoperability and queuing between systems. This is going to require a change in our collection and collective national culture. The progress made toward satisfying the data collection needs in the five theme areas should provide the metrics framework for national information collection success.

The key is to have our national priorities be the primary driver of our federal missions and our information production infrastructure.

Figure 1 gives a notional depiction of our national agency stovepipes for missions and infrastructure associated with each agency. It suggests that our organizational missions have been driven by individual functional mandates and not by collective national priorities. This is true also for the associated infrastructures aimed primarily at information production. When the two processes come together in time (vertical dimension) we will start to enjoy the progress of attacking our national concerns at the problem level. We must use our national priorities as the primary driver of our national missions to include the implied interoperability and the necessary re-evaluation and revamping of policies.

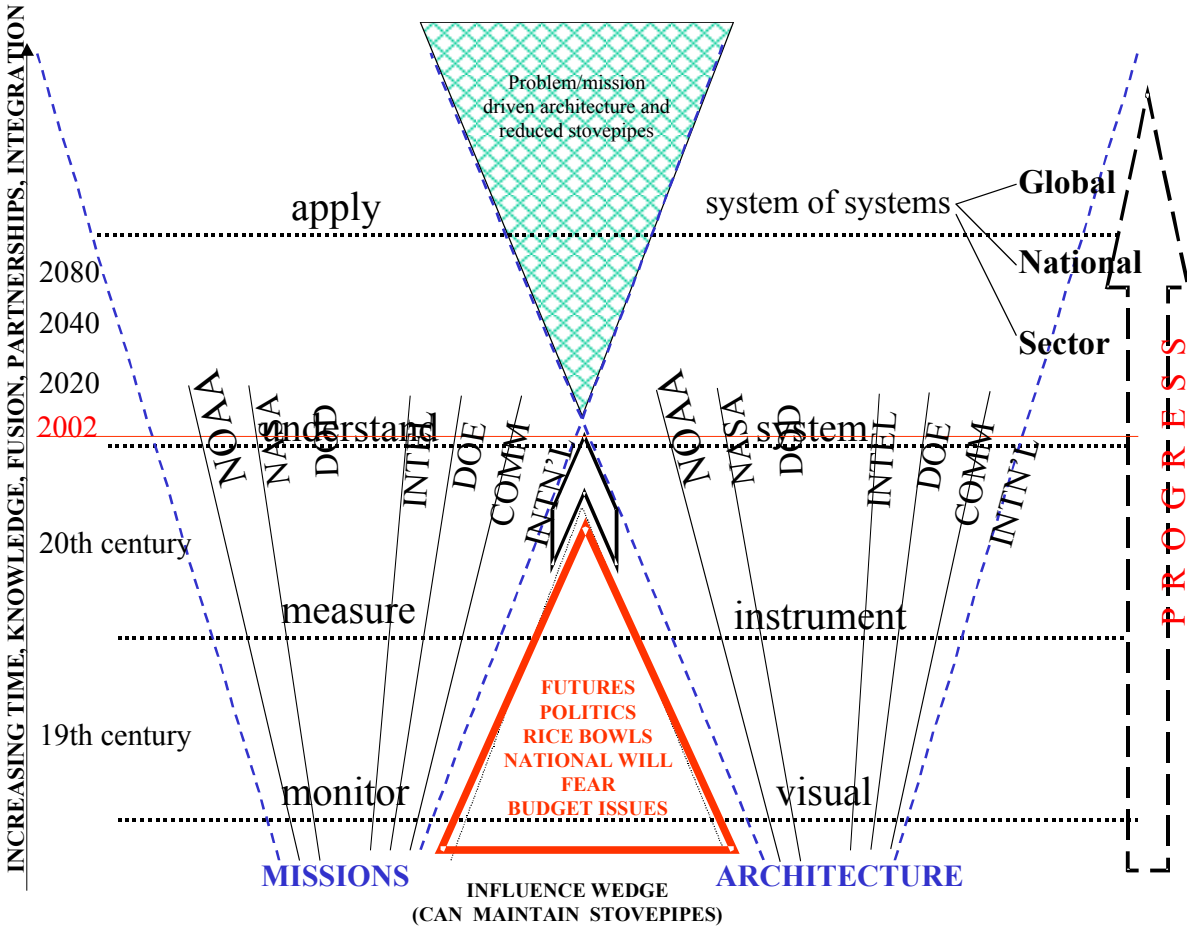

Figure 2. Timeline for Influence of National Will and Politics on Achievement of Goals

In addition, the individual stovepipes between organizations in both missions and architecture must start to disappear. This should produce efficiencies, but at the expense of agency autonomy. However, the most important aspect will be focusing on national problems and priorities and putting our individual organizational interests in a lower priority.

Figures 2 and 3 illustrate how our national will and politics can influence how soon we will be able to achieve this goal. Note that futures, politics, rice bowls, national will, fear, and budget issues can drive a wedge (in time) between our traditional missions and system architectures. This results in maintaining our traditional stovepipes rather than bringing the two together in a problem driven architecture based on national priorities. Even though each national element may be making progress in its individual mission responsibility, the result may not be addressing the national priorities in the most effective manner. The green crosshatch is where the individual stovepipe missions and stovepipe architecture start to overlap in a national system of systems commonly driven by national priorities.

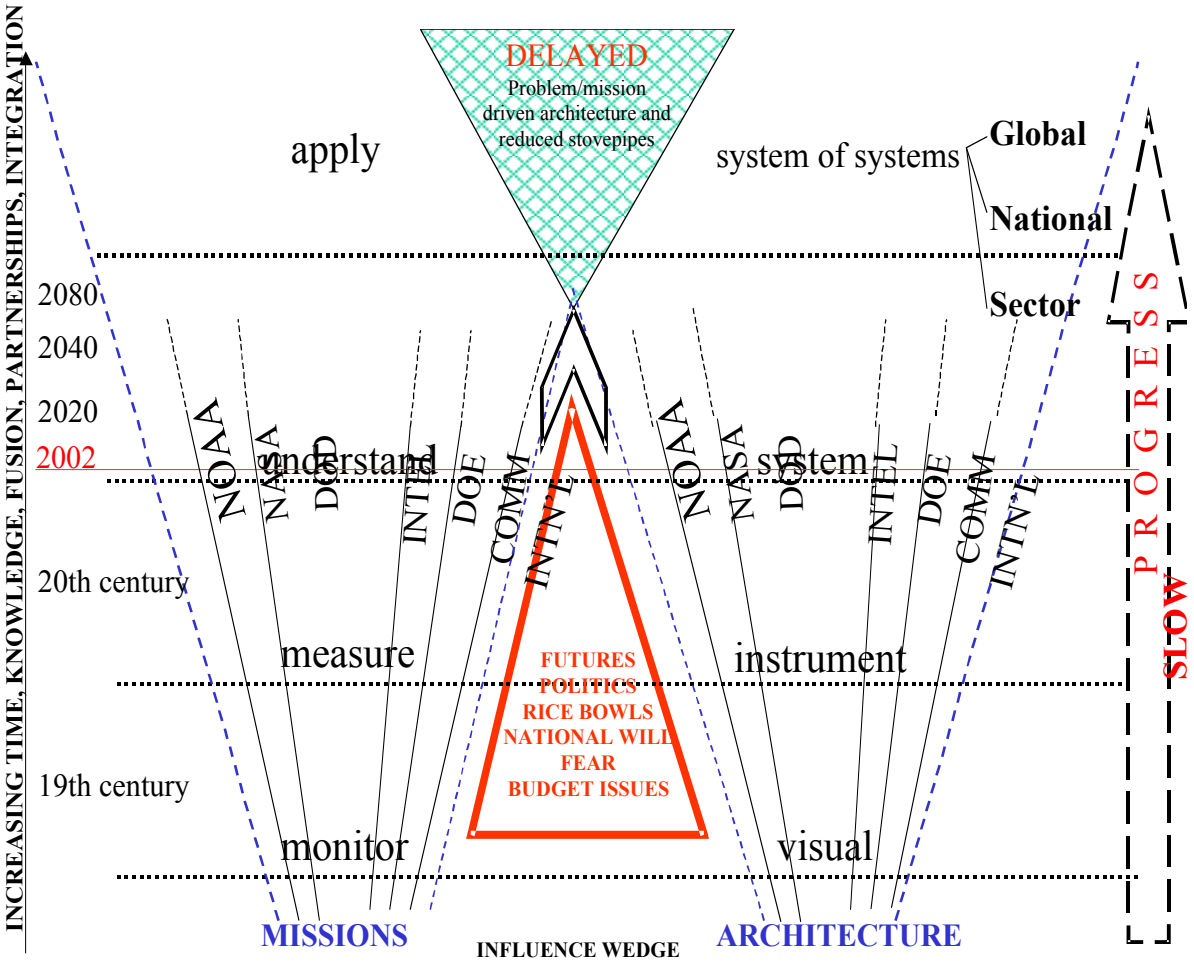

Figure 3. Delayed Achievement of Mission Goals Due to Influence of National Will and Politics.

Figure 4 illustrates a way to envision the national system of systems. NOAA's responsibility is to lead the fulfillment of the national need for producing weather and climate information for oceans, atmosphere, and space. The data required to do this must be acquired from the national information gathering infrastructure.

Partnerships must be formed to assure accessibility to the full data suite and to collaborate in the development of an interoperable infrastructure. Each federal element must do this as a full partner in our national system of systems rather than operating within its own stovepipe.

Figure 4. A Vision of Our National Collection of System of Systems.

4. CONCLUSIONS

Weather and climate are major influences on areas that have serious impacts on national concerns. The future of our ability to forecast and predict weather and climate, near-term variations and long-term trends can be of critical importance. We must work smart now to gain the lead-time to put the infrastructure into operation because the need will not wait. The alternate US futures that could await us in the areas of economy, health, energy, water, and well-being suggest where we should place significant investments in weather and climate knowledge (See NRO Alternate Futures Study, “Proteus”). Because of the need to treat our national information collection and production infrastructure as a system of systems, the responsibility role for weather and climate information must consider our national priorities as major investment drivers. Weather and climate related information systems must be operated as critical and complementary components of the total, national information generation infrastructure. Barring any significant changes in federal roles and missions, that responsibility belongs to NOAA.

Since the earth’s atmosphere and oceans operate as global dynamic systems, our observations must be global. If we are to reach global understanding and global application, complex and expensive observation systems, as well as national and global cooperation through partnerships must be built. This system must be interoperable, a system of systems, to make optimum use of limited resources. Each piece of infrastructure must be tailored toward a specific aspect of the national problem set with the best developmental approach being assigned to the appropriate agency. We must find a way for politics, budgets, rice bowls, funding cultures and federal missions to reinforce each other to meet this challenge. This is not a choice. This is an imperative.