



Asia-Pacific Center for Security Studies
Honolulu, Hawaii

The
Interface of **Science,
Technology
& Security:**
Areas of Most Concern,
Now and Ahead



W O R K S H O P P R O C E E D I N G S

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F O R E W O R D

A complete assessment of the challenges and opportunities that will define the future of the Asia-Pacific region requires a careful examination of the linkage between science and technology (S&T) and security. The region's growing international technoscientific footprint is matched by its increasing importance in shaping the evolving global security architecture, and exploring this dynamic relationship will allow us to suggest key features of the future international strategic landscape.

The workshop that the Asia-Pacific Center for Security Studies hosted in October 2010 addressed this issue. Specifically, its aim was to examine scientific and technological phenomena that will generate significant security concerns in the Asia-Pacific region in the next 20 years and beyond. The workshop brought into sharp relief the need to adopt an integrated, synergistic approach to frame our analysis of the emerging risks and opportunities that lie ahead. The 31 participants from 12 countries of the region represented a broad array of disciplines and professions from senior levels of the S&T and security communities. This diverse composition produced a cross-cutting dialogue on issues of mutual and divergent interests that established a common framework for understanding the S&T-security nexus. APCSS places a high value on collective and multidimensional processes of learning and knowledge-sharing, and utilizing these during the workshop discussions proved useful in breaking down silos and creating an open environment for discourse.

This publication comprises more than traditional workshop proceedings. Most of the contributions were written within eighteen months after the event, reflecting the authors' commitment to develop their own ideas in greater detail based on the insights acquired through their participation. The twenty papers and briefs document the multidisciplinary and transinstitutional requirements of strategic interventions and decisions for the future. They provide a deeper understanding of the complex forces that will accelerate or inhibit regional cooperation residing in the intersection of S&T and security issues.

We live in a hyperconnected, complex and rapidly changing world. This publication represents an effort to support a collective thread of dialogue about our future.

Dan Leaf
Director

A C K N O W L E D G E M E N T S

This workshop publication is a result of the unity of committed effort. It would not have been possible without the vision of Dr. William J. Perry, former U.S. Secretary of Defense, and the leadership and guidance of then APCSS Director Lt. Gen. Edwin P. Smith (Ret.) and Deputy Director Brig. Gen. James T. Hirai (Ret.). Thank you to all the workshop participants, whose submissions and discussions made this publication possible. And last but not least, special thanks to Ms. Mary Markovinovic, Ms. Samantha Chung, Ms. Florence Rapozo, and the exceptional Ms. Debra Castro.

EXECUTIVE SUMMARY

Overview of the Workshop

Purpose On October 4-10, 2010, the Asia-Pacific Center for Security Studies held a workshop in Honolulu, Hawaii to identify and assess the most significant current and emerging scientific and technological developments, evaluate their impact on international security, and recommend priority science and technology (S&T) and security policy agenda items based on Asia-Pacific perspectives. Furthermore, it aimed to bring together members of the S&T and security communities from the Asia-Pacific region to engage in a dialogue on current issues of mutual and divergent interests while establishing a common framework to identify the region's challenges defining the S&T-security nexus in the next twenty years.

Attendance Profile APCSS invited 31 participants from 12 countries of the Asia-Pacific region, namely: Australia, Canada, India, Japan, Malaysia, Mongolia, the People's Republic of China, the Republic of the Philippines, the Republic of Korea, Russia, Thailand and the United States. The composition was as follows: 35 percent academics (scientists, engineers, S&T policy professors), 30 percent S&T practitioners (S&T agency/lab directors, consultants), 25 percent security practitioners (military, policy), and 10 percent think tank fellows.

Framing the Issue

- Methodology
 - Subject matter experts (SMEs) provide focused presentations in plenary sessions;
 - Two daily break-out working sessions framed around discussion objectives;
 - Daily plenary participant briefbacks and discussions; and
 - Final group presentations to Dr. William Perry, former U.S. Secretary of Defense and co-director of Stanford University's Center for International Security and Cooperation (CISCA), and Dr. Siegfried Hecker, co-director of CISCA.

- Content Structure

- SME presentations of scene-setters provide overviews of the Asia-Pacific region's security and S&T landscapes, current and future developments in each of the four S&T areas (information technology, biotechnology, energy and environment), their future security implications and areas for international collaboration.

- In break-out sessions, participants tasked to develop the framework of the S&T-security nexus; to identify, prioritize and rationalize the selection of the top S&T phenomena from the four S&T areas that will define the challenges in the S&T-security nexus; and to identify opportunities and challenges for interagency, regional and global cooperation among these phenomena in the next 20 years.

Key Observations and Recommendations

1. Observation There is an obvious gap that exists between the S&T and security communities, with their engagements limited to an “as needed, on demand” basis. Differences in their institutional cultures, an existing knowledge divide and an absence of consensus on the definition of “security” explain the lack of an institutionalized and strategic linkage between these two communities.

1.1 Recommendation Closing the distance between the communities is a key ingredient to collaboratively prepare for the S&T initiatives and phenomena that will most likely have significant global implications in the next 20 years. Bridging this “valley of disconnection” requires a *multi-stakeholder, interdisciplinary* frame applied to the discourse on S&T and security issues and concerns. The expanded community should include “*knowledge translators*” who can effectively navigate the S&T and security worlds.

1.2 Recommendation Institutionalize efforts that enable the development of “*interface institutions*” that enable both direct and indirect S&T-security dialogues across countries and organizations, and provide sustainable opportunities for the up-skilling of stakeholders on S&T and security issues.

2. Observation The S&T-related phenomena that are likely to have the most significant global impact and pose significant challenges and opportunities for cooperation in the next years are: *cybersecurity, energy demand and resources and water issues*. The selection criteria for these choices are *impact, technology development, institutions and infrastructure*.

2.1 Recommendation *Information Technology* is driving fundamental changes in human society. The overwhelming reliance of critical systems on network connectivity is creating new forms of security threats and exploitable instabilities. There is a need to develop secure software to reduce vulnerabilities, as well as to create network architectures that are intelligent and regenerative. Increasing public-private partnerships will provide significant options to address cyberspace concerns.

2.2 Recommendation *Growing energy demands and the need for diversified energy sources* have broad security implications in the light of global population growth, industrialization and limited fossil fuel supplies. The continued improvement of generation, storage and distribution technologies, alongside the development of modeling capabilities that will enable the optimal match of national needs and resources with technologies, must become a national and regional priority.

2.3 Recommendation *The need for, and access to, clean water* is a critical security issue now and moreso in the future. At least two technical challenges related to another security issue – climate change – provide opportunities for collaboration. The first challenge is the need to explore technologies that can check global warming and comprehensively address the unpredictability of water supply. The second challenge pertains to the improvement of global modeling technologies

that predict climate change through the integration of components that will enhance our understanding of future changes in water.

3. Observation The deepening interface of S&T and comprehensive security developments in a globalized context prompts a reexamination of established approaches to both S&T and security management.

3.1 Recommendation Revisit baseline understanding and formulations of “big” concepts such as risk, vulnerability, adaptability, resilience and disruptive innovation.

3.2 Recommendation Intensify studies of the global/regional spill-over effects of S&T developments on the security environment and vice-versa.

3.3 Recommendation Develop advanced global integrated assessment tools and models to capture the intersection of S&T and security developments and to address the interconnectedness of energy, water, agriculture, global health and climate change.

3.4 Recommendation Enhance and sustain international modes of cooperation and collaboration by leveraging international S&T diplomacy; developing more robust and sustainable private public partnerships; and capturing, institutionalizing and sharing successful collaboration efforts.

INTRODUCTION

Two simultaneous, major developments are shaping the future of the Asia-Pacific region. The first is the increasing contribution of countries in the region to the next generation of global technoscientific discoveries and innovation environments. The second is the presence of a growing array of comprehensive security¹ challenges in such issues as water, energy, health and the ubiquity of the internet. Integrating science and technology (S&T) as a core component of national security policy has produced significant benefits for the peoples of the region. But what generates greater regional and national strategic concern is when the S&T-security nexus creates opportunities for misunderstanding. These opportunities assume two forms, rooted in distinct theoretical traditions. First, the possibility for conflict exists where, as proponents of Realism argue, S&T is viewed as a by-product of intense interstate competition for power and influence.² The pursuit of Asia's rising giants, India and China, for global S&T and innovation leadership alongside the U.S. will animate international cooperation, competition and conflict that will have a direct bearing on interstate dynamics and the future world order. An examination of the S&T-security linkage provides a better understanding of the parameters, conditions and forms of state-to-state competition and conflict within the context of the Asia-Pacific region.

In contrast to the Realist thinking, the second cause for concern is premised precisely on the erosion of sovereignty: the study of the S&T-security linkage presents a challenge of global governance that entertains the possibility of non-state entities such as private companies, civil society organizations and individuals as additional, if not competing, sources of legitimacy and authority.³ An analysis of the linkage within this frame will shed light on the paradigm of a reconstituted world order of the future. In this frame, S&T and security as policy subjects share distinct qualities that expose the limitations of state-centric approaches to resolve global challenges and threats. Both generate impacts, associated risks and uncertainties that are borderless, have subsets of policy communities that are specialized and fragmented, and have an increasingly network character in terms of their politicization that demonstrate the need for global governance. In this context, an analysis of the S&T-security relationship achieves two objectives: first, it provides a setting for understanding new approaches to address borderless issues; and second, it leads to the exploration of creative responses to the challenges posed by the intersection of S&T and security issues.

This volume comes out of a workshop held in October 2010. A majority of the contributions were written after the event, reflecting the authors' commitment to document in greater detail the analysis and insights derived from the actual deliberations. The logic of the workshop design flowed from the theoretical considerations discussed above, but the discourse and presentations attended more to the practical issues and challenges of operationalizing the S&T-security interface and did not dwell on the conceptual ramifications of the linkage. Hence, the identification and analysis of the possible S&T areas where insecurities, challenges, opportunities and conflict can proliferate in the Asia-Pacific region in the next 20 years is the centerpiece of the contributions in this volume.

The selection of information technology, biotechnology, energy and the environment as the focus of the workshop illustrate the explanatory power and challenges of both the global governance approach and Realist thinking. They provide the empirical settings for understanding different frameworks to address borderless issues but also illuminate the role of the state and the importance of sovereignty in shaping national S&T trajectories and security strategies in the Asia-Pacific. The region has over half of the world's growing population, is home to the world's rising giants, India and China, and is a major site for the world's increasing security challenges, including energy scarcity and climate change. It would have its fair share of the attendant impacts derived from a worldwide global pandemics should this occur, as well as from the ramifications of the cyberrevolution.

The workshop participants' selection of cybersecurity, energy demand and resources, and water issues as the top three S&T-related phenomena that will have the most significant regional security implications in the next two decades bears out key features of the region's future strategic environment: the presence of an existential cluster of challenges strongly favoring international and collective solutions, the likelihood of needs-driven disruptive innovations and the increasing strategic importance of non-military threat structures. On a broader level, the imperative for a transdisciplinary, transinstitutional and transnational dialogue was made evident in the course of the workshop discussions and presentations. The differentiation of knowledge, institutional/professional experiences and nationality among the participants paved the way for the development of multiple options and considerations critical to understanding the relationship of technoscientific developments and security.

The 20 contributors to this publication come from different countries in the Asia-Pacific region (Australia, Canada, China, India, Russia, South Korea and the U.S.). They are scholars from different disciplines, scientists, policymakers, government officials and security practitioners operating at the interface of S&T and security. Together, they offer a comprehensive overview of the issues and challenges that animate the S&T-security nexus – a valuable contribution to ongoing discussions in the fields of security and strategic studies, international relations, and science and technology studies.

The remainder of this publication is divided into seven sections. A summary of Arun Majumdar's opening keynote speech precedes the first two sections composed of six papers that provide analysis of key features of the security and S&T landscapes of the Asia-Pacific region. The 12 contributors in the next four sections present an overview of trends and challenges in the four S&T areas that were the main focus of the panel presentations. Siegfried Hecker's closing keynote address concludes this section. The final portion provides a summary of the workshop discussions.

In his keynote address, Arun Majumdar discusses the likely sources of the most serious global challenges in the next 40 years. The linkages among these issues provide tremendous opportunities for institutionalizing cooperation and collaboration across countries. Section One provides an overview of some of the dominant security features of the Asia-Pacific region. Ralph Cossa

examines the role of growing numbers of multilateral organizations in the region, exploring both the extent of their effectiveness and their ability to evolve in light of the accelerating complexity marked by a rising China and the U.S. current “re-balancing” towards the Pacific. Mohan Malik argues that technopolitics will shape regional dynamics. The geo-strategic actions of the U.S. and Asia’s rising behemoths, China and India, coupled with an array of serious security challenges such as energy and the environment, will underpin techno-competition. Kerry Nankivell’s paper posits that the maritime domain and modern sea power will be crucial determinants in the geo-political shape of Asia and the world in the future. East Asia’s rise is best understood as a shift in sea power, and she utilizes a maritime frame to examine the ascendance of China as a regional power.

Section Two presents an overview of the critical issues defining the S&T landscape of the Asia-Pacific region. My own contribution examines approaches to the growing concern over resource scarcity and their linkage with the technoscientific discourse in Asia. Scott Hauger provides an overview of the state of climate change and environmental security in the region and examines the challenges and opportunities for collaboration between the S&T and security sectors in Asia. William Wieninger presents a survey of themes attendant to the nuclear issue in the region.

In Section Three, the contributors for the workshop’s information technology panel focus on the themes that underpin the increasing strategic relevance of cyberspace and the imperative for borderless cooperation. Richard Schaeffer, Jr. argues that the high level of complexity of the cyberworld also translates into growing and equally complex risks. Robert Childs calls for urgent and strengthened regional collaboration in cybersecurity. Igor Kotenko provides a broad survey of the current and future state of information and communication technologies (ICT) as well as the current and emerging security issues related to ICT.

The security ramifications of biotechnology serve as the focus of the contributors for Section Four. The paper of Lynn Jelinski outlines a trajectory of biotechnology development in the next 20 years. Ashley Dombkowski’s brief provides a description and analysis of current developments in biotechnology and the role of the private sector. Cong Cao uses a national perspective to analyze biotechnology development in China.

The theme for Section Five is energy. The authors address the challenges and responses to energy insecurity. Lydia Powell embeds her analysis of India’s energy challenges in a comprehensive security setting, identifying linkages between national energy demand and supply, population growth, poverty, the role of women and alternative sources of energy. Kim In-ho looks into South Korea’s direct linkage between national security and its defense R&D agenda. Elizabeth Cantwell frames her presentation of understanding the issues and potential security impacts of emerging energy S&T by examining the current global energy resource systems.

Section Six covers the environment. The papers in this section examine two big themes – climate change and the environment-security nexus. Benjamin Santer offers his perspective on recent developments in the field of detection and attribution (D&A) research. David Brunckhorst’s paper addresses human-environmental, non-traditional security issues, paying particular attention

to disaster situations and their ramifications for traditional security institutions. Sumeet Saksena looks into the environmental risk transition in Southeast Asia and the role of peri-urbanization in health security. In his closing keynote address, Siegfried Hecker shares his experiences and perspectives on reducing global nuclear risks as well as on the role of science diplomacy in mitigating the risks of nuclear weapons and the spread of weapon-usable nuclear material.

Finally, Section Seven provides a summary of the workshop discussions. The two areas of focus include: first, an assessment of the current environment of the S&T-security nexus; second, the development of the selection criteria for identifying – from the four areas of cybersecurity, biotechnology, energy, and the environment – the top three S&T initiatives or phenomena of most concern to the Asia-Pacific region in the next 20 years; and third a summary of the impact, challenges, opportunities for collaboration and policy implications of these three S&T initiatives. The concluding session, led by William Perry, focuses on the broad considerations for formulating responses to manage the S&T-security interface in the future.

September 2012
Honolulu, Hawaii

-- Virginia Bacay Watson

Notes

1. The understanding of “comprehensive security” is strongly linked to the reality of an increasingly interdependent world that necessitates cooperation across national borders. Per Barry Buzan: “Security is taken to be about the pursuit of freedom from threat and the ability of states and societies to maintain their independent identity and their functional integrity against forces of change, which they see as hostile. The bottom line of security is survival but it also reasonably includes a substantial range of concerns about the conditions of existence.” Barry Buzan, “New patterns of global security in the twenty-first century,” *International Affairs* 67, No. 3 (Royal Institute of International Affairs, July 1991): 432-433.
2. Hans Morgenthau, *Politics among Nations: The Struggle for Power and Peace* (New York: Alfred Knopf, 1948).
3. Ann Florini, “Rising Asian Powers and Changing Global Governance,” *International Studies Review* 13, No. 1 (March 2011): 24-33.

Summary of Opening Keynote Address
***“The Interface of Science, Technology and Security:
Energy and Environment”***

Arun Majumdar, Ph.D.

According to Dr. Majumdar, the intersection of population, energy, climate change, resources and infrastructure are the likely sources of the most serious global challenges in the next 40 years. Demographic forecasts show that global population will increase by 47 percent from now until 2050, with less developed countries accounting for 99 percent of the increment. This translates into a population-energy equation that indicates a significant increase in global energy consumption and carbon emissions. At the same time, the velocity of climate change is accelerating – a key input that will need to be mapped into future global security landscape scenarios. The intersection of a growing global population and rising energy demands with climate change variabilities will pose serious challenges for the world’s existing resource and infrastructure base – in particular, the high demand for, and low supply of, rare earth elements and the vulnerabilities of the global cyberinfrastructure. Rare earth materials are key enablers for energy technology in magnetics and are found in many high-tech products. However, Dr. Majumdar points out that most of the global production of rare earth metals is concentrated in China, which has a share of at least 90 percent. This situation poses a potentially serious security crisis, the likes of which were demonstrated when China blocked rare metal exports to Japan in light of Japanese detention of a Chinese fishing trawler captain in 2010. This incident illustrates the growing linkage between various seemingly unrelated security issues, an intersection created in this case by the imbalance of supply and demand for a technology resource.

Dr. Majumdar also highlights the world’s increasing dependence on information and communications technologies (ICTs) coupled with growing cybervulnerabilities as an infrastructure challenge in global energy systems. He notes that cyberattacks continue to improve in their sophistication and ease of implementation, and these dynamic, fast-moving attacks carry serious implications for electric grid management. He stresses the urgency for cybersecurity as a policy priority for advanced SmartGrid research, pointing out that traditional IT cybersecurity tools are proving inadequate for SCADA, while existing SmartGrid interconnectivity is giving rise to new cybervulnerabilities. This phenomenon illustrates how technology is a driver of insecurity, and Dr. Majumdar urges increased international cooperation as a way to improve the security of energy grids worldwide. He cites the Lawrence Livermore National Laboratory’s Vulnerability and Risk Assessment Program (VRAP) that provides assessments both in the U.S. and abroad as an illustration of a successful international collaborative effort that can – and should be – duplicated across the world.

The U.S. imports 60 percent of its oil, and Dr. Majumdar proposes that “we need to make this zero percent.” The BP Oil Spill at the Gulf of Mexico in April 2010 serves as a wake-up call for the nation, a dramatic illustration of the costs of oil dependence. One of the key strategic take-aways from this incident is that energy innovation lies at the core of intersecting national, economic and environmental security. In this context, Dr. Majumdar provides a brief overview of the U.S. Department of Energy’s Advanced Projects Research Agency-Energy (ARPA-E) as an illustration of the U.S. response to the energy challenge. It is an organization designed to fill in the technological gaps of the U.S. energy innovation hubs, initially conceived by the National Academies report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, as an institutional response to reduce foreign dependence on energy sources, stimulate innovation to keep the U.S. as a global technology leader, and develop technological answers for clean, affordable and reliable energy. ARPA-E was officially created in 2007 by the America COMPETES Act. Dr. Majumdar provides a brief description of some of ARPA-E’s ongoing programs that focus on areas of energy storage, energy efficiency, power electronics and electrofuels. In an effort to institutionalize a policy dialogue across the relevant energy communities, ARPA-E also holds events such as the Energy Innovation Summit in 2010. The participants of the Summit included representatives not only from S&T community, but also from the private sector, other DOE offices and federal agencies, investors, state and regional clean technology incubators, policy-makers, the White House and Congress, and international representatives.

Dr. Majumdar concludes his speech by pointing out that the pace and scale of innovations needed in energy technologies is accelerating: while the scientific and technological game changers of the 20th century were spread out across 100 years, it is more than likely that globalization, the enabling medium of information technology, and increasing international R&D cooperation will shorten the time line to 20 years. He is optimistic that continuous progress in energy technology R&D today will provide the world with a game changer in the near future.

P L E N A R Y S E S S I O N 1 :

The Current Security Landscape

The Current State of Regional Organizations in the Asia-Pacific Region

Ralph A. Cossa

There has been a proliferation of regional organizations in the Asia-Pacific region in recent years as multilateral cooperation has seemed a natural fit in a region inhabited by rising powers. The most recent institutions of significance have been the East Asia Summit (EAS) and the ASEAN Defense Ministers Meeting (ADMM) and ADMM Plus (which now mirrors the EAS membership). They both build upon the grandfather of East Asian multilateral institutions, the Association of Southeast Asian Nations (ASEAN) and its regional security extension, the ASEAN Regional Forum (ARF). The three ASEAN offshoots – EAS, ADMM+, ARF – can all be viewed as efforts to promote regional stability by keeping the U.S. (among others) engaged while integrating a rising China. This paper will focus on these ASEAN-driven organizations. Other multilateral initiatives, such as ASEAN Plus Three (involving South Korea, Japan, and China) and the more broadly based Asia-Pacific Economic Cooperation (APEC) “gathering of economies” will not be addressed since their focus is more economic than security-oriented.

ASEAN Coming of Age?

While ASEAN – which links the 10 nations of Southeast Asia – has been around for more than 40 years, it has only recently instituted a charter and begun work on developing a true security community.¹ Under Indonesia’s leadership this year, it tried to be a bit more proactive, getting involved directly in trying (without much success) to mediate the Thai-Cambodia border dispute and also putting pressure on Burma to take significant steps along its self-proclaimed “Seven Step Roadmap to Democracy.”

ASEAN’s main contribution to regional stability, current South China Sea and Thai-Cambodia difficulties notwithstanding, has been to keep traditional tensions and disputes among its member countries swept under the rug. This has helped ASEAN, or at least its key members, to rise economically and helped foster political development among most of its members (Burma, Laos, and Cambodia in particular still have a long way to go). In terms of regional security, ASEAN’s primary contribution to regional security has been through the afore-mentioned regional institutions that it has helped create and continues to manage from its position in the “driver’s seat” for ARF and EAS. In truth, ASEAN is allowed to lead in this area since the major powers in and around the region – China, Japan, India, even South Korea – do not sufficiently trust one another to take the lead, allowing ASEAN to play this role by default. Given the rules of consensus that govern ASEAN and its by-products, these organizations play a confidence building and conflict avoidance role more than a conflict resolution or intervention role.

ASEAN Regional Forum: Moving Beyond CBMs?

The 26-member ARF brings together foreign ministers from throughout and beyond the Asia-Pacific region for annual security-oriented discussions.² While initially focused exclusively on East Asia, the introduction of more South Asian members in recent years should be ringing warning bells about ARF's future focus and effectiveness. Broadening its membership reduces ARF's attractiveness as a framework for East Asian or Asia-Pacific community building, although the presence of all key Northeast Asian players (except Taiwan) does permit occasional six-party (and more) side discussions on Northeast Asia security issues. The 2011 ARF meeting in Bali, for example, provided a venue for nuclear negotiators from South and North Korea to meet in what could be the first step toward a resumption of Six-Party Talks aimed at Korean Peninsula denuclearization.

Generally speaking, ARF seems well-suited to serve as the consolidating and validating instrument behind many security initiatives proposed by governments and at non-official gatherings. Various ARF study groups have provided a vehicle to move multilateral security cooperation forward in areas such as preventive diplomacy, enhanced confidence-building, counterproliferation, counterterrorism, and maritime (including search and rescue) cooperation, all of which help promote greater transparency and military-to-military cooperation. But its contribution to the regional security order remains somewhat constrained.

Few expect ARF to solve the region's problems or even to move rapidly or pro-actively to undertake that mission. The agreement to "move at a pace comfortable to all participants" seems aimed at tempering the desire of more Western-oriented members for immediate results in favor of the "evolutionary" approach preferred by the ASEAN states, which sees the process as being as important (or more) as its eventual substantive products. The Asian preference for "noninterference in internal affairs" also has traditionally placed some important topics essentially off limits, although this may be changing (witness ASEAN's increased willingness to comment on Myanmar's domestic politics). Nonetheless, the evolution of ARF from a confidence-building measures "talk shop" to a true preventive diplomacy mechanism (as called for in its 1995 Concept Paper) promises to be a long and difficult one.

East Asia Summit: will Washington's participation make a difference?

In December 2005, in an effort to further promote East Asia community building, Malaysia convened the first East Asia Summit involving the 10 ASEAN leaders, their Plus Three partners (China, Japan, and South Korea), and Australia, New Zealand and India. Still undefined seven years later is how EAS will interact with broader regional organizations such as APEC or ARF. To its credit, the Chairman's Statement from the second EAS confirmed views that EAS complements other existing regional mechanisms, including the ASEAN dialogue process, the ASEAN Plus Three process, ARF and APEC in community-building efforts. However, details as to how these various efforts will mesh or work together are still lacking.

The big question today is, how (if at all) the organization will change now that the U.S. and Russia have become members – both were officially invited in 2010 and Presidents Obama and Medvedev attended their first EAS meetings in November 2011 in Indonesia. Stay tuned on this one, but the odds are that both new members will continue to quietly blend in and let ASEAN continue to lead, even though President Obama clearly signaled his preference for the EAS to dig more deeply into regional maritime security issues.

ADMM+: the beginning of real security cooperation?

The advent of the ADMM+ opens the door for closer security cooperation since, unlike ARF, it is comprised primarily of defense rather than foreign ministry officials. The first meeting was held in Hanoi in the fall of 2010, during Vietnam’s tenure as ASEAN Chair. It was the first official defense forum involving ASEAN defense officials and the EAS dialogue partners. While applauding the contributions of the “plus” nations to regional peace, security and development, the group reaffirmed ASEAN’s central role in any institutional initiative and stressed that any mechanism should abide by “ASEAN principles of respect for independence and sovereignty, non-interference in internal affairs of member states, consultation and consensus, and moving at a pace comfortable to all parties.”

Drawing from the discussion paper “Potential Prospects and Direction of Practical Cooperation within the Framework of the ADMM-Plus” that was tabled at the meeting, the group agreed to set up five expert working groups (EWG) on humanitarian assistance and disaster relief (HA/DR), maritime security, military medicine, counter-terrorism, and peacekeeping operations (PKO). Vietnam and China offered to co-chair the EWG on HA/DR; Malaysia and Australia took up the EWG on maritime security, and the Philippines will work with New Zealand on PKOs. The ADMM+ set up an ASEAN Defense Senior Officials Meeting Plus (ADSOM+) to monitor progress. Brunei will host the next ADMM+ in 2013.

The ADMM+ initiative seems long overdue. Foreign ministries have traditionally monopolized regional security gatherings. For some critics, that explains their (lack of) effectiveness and their attention to style over substance. Others counter that militaries should be subordinated to bureaucracies and a little pomp is a small price to pay for civilian control over the military. Others worry that a one-day meeting every three years is unlikely to yield much in the way of substance; more astute commentators counter that a lot can get done under the radar if militaries are given the chance to cooperate out of public view. Finally, there is the view among some that the forum is ASEAN’s attempt to regain the initiative on regional security initiatives, and to parry the growing importance of the non-governmental Shangri-la Dialogue which has brought defense officials from the region and beyond together for informal discussions under the leadership of the London-based International Institute for Strategic Studies. Clearly Southeast Asians prefer an organization that is ASEAN-driven over one arranged by a British think tank.

Engaging a rising China

Finally, a few words about engaging a rising China and the role of regional organizations like those mentioned above in this process. When one looks at China's current and potential future role in the international community there is cause for both cautious optimism and for serious concern. In many respects, China is becoming the "responsible stakeholder" that it claims to seek to be, especially in a regional context, helping to drive economic growth in East Asia and beyond, and cooperating both with its ASEAN colleagues and its Plus Three partners both politically and economically. Chinese leaders constantly profess their commitment to peace and stability globally, regionally, across the Taiwan Straits, and on the Korean Peninsula, and there are many statements and even some actions to back up these claims.

On the other hand, one can also point to a number of Chinese actions that are considerably more troublesome and point to an even more worrisome future once China has risen. While Chinese colleagues tend to dismiss it or claim that it has been over-exaggerated (or is the product of increased U.S. sensitivity), most China-watchers in America and in Asia are firmly convinced that 2010 marked the beginning of China's increased aggressiveness both in word and in deed. Some have warned then that what we saw in 2010 was a "sneak preview" of what China will look like, and how Beijing will behave, once China has risen. While such concerns should not be overstated – and Beijing has clearly taken a step back as it has seen how counterproductive this increased assertiveness has been – they likewise cannot and should not be dismissed.

It is not clear today what direction Chinese leaders will take the country as its share of political, economic, and military power continues to rise; perhaps even China's current and future leaders do not know for sure. One suspects that there are "internationalists" within the Beijing leadership who see cooperation and compromise as the best way forward. We have even heard leaders like departing Premier Wen Jiabao speaking out about the need for greater domestic reform. On the other hand, clearly there are others who see China's rise as evidence of a "new reality" in Asia and demand respect, even before it is fully earned. They seem increasingly impatient when things do not go their way – the embarrassing berating the Chinese foreign minister reportedly gave his ASEAN colleagues at the 2010 ARF meeting being one case in point. Which camp will prevail or at least become the predominant view is uncertain.

China's International Role As a veto-wielding member of the United Nations Security Council (UNSC), China has a global leadership role whether it seeks one or not. From an American perspective – and clearly not from a Chinese perspective – China has not only not exercised this role responsibly but has taken steps in the past two years that have rendered that body ineffective almost to the point of irrelevance especially when it comes to security on the Korean Peninsula. Their actions provide considerable insight into China's international role and Beijing's perception of international priorities.

In the constant struggle between the principle of non-interference in another country's sovereign affairs and the equally compelling (at least in my view and, I would argue, that of most governments of the world) responsibility to protect, there is little question what side of the debate China comes down on. With the exception of the UNSC vote on Libya, where even the Arab League was demanding action, China has consistently blocked the protection of human rights, using the non-interference principle as the justification or excuse.³ Even Chinese scholars admit the Libya vote was a "one off" and not a signal of a change in Chinese attitude regarding responsibility to protect.

More relevant has been Beijing's clearly one-sided protection of North Korea at the UNSC in the face of clear and continued violations of resolutions that China claims – and is legally bound – to support. Beijing has refused to allow debate on the Yeonpyeong Island shelling despite it being an obviously violation of the UN Armistice Agreement. It likewise refuses to discuss Pyongyang's clearly illegal (under UNSC resolutions) uranium enrichment activities, which Pyongyang has chosen to flaunt. It has consistently blocked the release of reports from expert groups that have pointed out North Korea violations of UNSC resolutions and sanctions (especially those that indicate that violations have occurred via "third countries"). And it significantly watered down a UNSC statement on the Cheonan attack to the point that Pyongyang declared the outcome "a great diplomatic victory." I fear that Beijing's defense of Pyongyang at all costs and under all circumstances has empowered and emboldened the North and has thus contributed to Pyongyang's unacceptable behavior. But this type of Chinese behavior is also having a negative impact on the credibility and utility of the UNSC.

Beijing cannot have it both ways. It cannot (as it does) criticize the U.S. and ROK for employing military "show of force" or "demonstration of resolve" tactics to send Pyongyang a message that future aggression will not be tolerated, when it almost single-handedly blocks U.S. and ROK attempts to deal with the matter politically or economically. Continued Chinese protection of North Korea, Iran, Burma and others at the UNSC will help ensure that future ad hoc "coalitions of the willing" are formed to deal with serious world problems, if the UNSC continues to abrogate its responsibilities as a result of a China veto (actual or threatened). It is a sad commentary about China's current international role, and perhaps an equally bad sign about China's future, that the world's greatest tyrants all have the same best friend in common. Nations, like people, can and should be judged by the company they keep, and the list of countries that claim China as one of its closest (perhaps only) friend should be a cause for shame in China.

China's Role and Behavior Regionally As noted earlier, China has played a generally positive role in regional organizations like the EAS, ARF, ADDM+, etc. It also plays a commendable leadership role in the Shanghai Cooperation Organization with Russia and the nations of Central Asia. But despite this broad-based cooperation, individual actions, especially these past two years, have raised concern. Chinese claims, no longer repeated but never denounced, that the South China Sea represents a Chinese "core interest" sufficient raised concerns among the ASEAN Nations (and in Washington). Tensions with the Philippines over areas of the disputed territories have reached a new high, and its approach to managing this regional flashpoint will provide a solid indicator of the nature of its regional leadership in the decades ahead.

Then there was the incident in the Senkakus, where the Chinese reacted strongly to the Japanese Coast Guard arresting a drunken Chinese fishing boat captain after he repeatedly rammed a Coast Guard cutter with his boat. What should have been a simple legal issue – such behavior cannot and should not be tolerated – became an international incident, with China reportedly arresting Japanese citizens and cutting off rare earth exports in retaliation, in addition to diplomatic threats and insults which continued, even after the captain was released. Japanese are referring to the incident as their “Sputnik moment,” a wake-up call to the real threat a rising/risen China will pose. This incident informs the context of the latest and dangerous stand-off with Japan over the Diaoyu/Senkaku Islands that is making the region nervous; this is a territorial dispute that has the potential to transform the regional security environment, and as one of the claimants yet again, China’s response will provide insights on how it balances its core interests with its regional leadership.

Added to this were repeated Chinese protests and warnings to the United States not to send an aircraft carrier into the Yellow Sea for combined ROK-US exercises aimed at sending a sobering message to the North, on the grounds that the Yellow Sea constituted Chinese territorial waters, a claim so preposterous that it compelled the US Navy, which had originally not planned on sending a carrier there (since they had conducted carrier operations in the Yellow Sea within the past year), to redeploy the USS George Washington Battle Group, not only to remind North Korea that future acts of aggression would not be tolerated, but also to remind Beijing what the meaning of “international waters” actually is.

Following US push-back – at the ARF, in the Yellow Sea, and through a reaffirmation of the US defense commitment to Japan (including the Senkakus) – China has taken a kinder, gentler approach and we have seen an upswing in Sino-US cooperation, just before, during, and since the Hu Jintao visit to Washington in January 2011. Clearly someone in Beijing remembered Deng Xiaoping’s dictum about maintaining a low profile, but the damage has already been done and serious questions have been raised about whether this increased Chinese assertiveness was a sneak preview of things to come. One hopes not, and I am not predicting that it is. But there is no denying that recent Chinese assertiveness has raised US and regional concerns about Chinese future intentions and the implications of a fully risen and more militarily-capable China.

One side note here. There has been much written about China’s development of an aircraft carrier, which made its sea trials this past year. Most of it has been wrong or misguided, especially as regards claims that this will significantly shift the power balance in Asia. If and when China’s first carrier actually becomes fully operational (which is still years away), it will bring China up to the level of where the Soviet (or Ukrainian) Navy was circa 1984. It will still give China only the second best navy in Asia (in terms of capability and professionalism) behind Japan. China may quickly become the 800-pound gorilla in Asia, but the US remains a 1600-pound gorilla and a significant qualitative and capabilities gap will remain for decades to come.

Despite the above-mentioned concerns and challenges, I remain generally optimistic about the future of US-China relations and thus about the prospects for regional and global stability. For better and for worse, the U.S.-China relationship remains one of the most important bilateral

relationships in the world. Today, the two nations face a growing number of political, economic, and security concerns which can best, perhaps only, be solved if there is cooperation between Beijing and Washington. In instances where our core interests, objectives, and tactics or approaches coincide or are complementary, continued cooperation can and should be expected. Since Washington still respects China's core interests when it comes to Tibet and Taiwan – recognizing Tibet as part of China and rejecting any unilateral change in the cross-Strait status quo – these issues can be managed. The area of greatest concern, when it comes to Sino-US relations and to regional stability, deals with Beijing's policies toward North Korea, which makes it increasingly more difficult to build a “positive, cooperative, and comprehensive U.S.-China relationship for the 21st century.”

Meanwhile, Washington and Beijing both remain committed to supporting ASEAN-driven multilateral cooperation in East Asia and the existing forums which provide venues to promote greater cooperation and give China added incentive for integrating peacefully in the region. At the last Shangri-La Dialogue in Singapore in June 2011, we saw first-hand the extra effort made by senior defense officials on both sides to put on a cooperative face. Likewise, along the sidelines of last year's ARF meeting, we saw progress on the development of guidelines to govern conduct in the South China Sea. These are all positive developments both for China's peaceful rise and for the role multilateral organizations can play in bringing this about.

Notes

1. The ASEAN member states are: Brunei, Burma (Myanmar), Cambodia, Indonesia, Laos, Malaysia, the Philippines, Singapore, Thailand and Vietnam.
2. The 10 ASEAN states plus Australia, Canada, China, the European Union, India, Japan, Mongolia, Papua New Guinea, Russia, South Korea, North Korea, New Zealand, and the U.S., plus more recently Pakistan, Timor-Leste, Bangladesh and Sri Lanka.
3. One cannot help but think that at least part of China's motivation is not to set any precedents that might come back to haunt China vis-a-vis Tibet or other areas where China's treatment of its own citizens is less than ideal.

Technopolitics: How Technology Shapes Relations Among Nations

Mohan Malik, Ph.D.

Great power politics is very dynamic. But what are the dynamics of great power politics? What is the key driver of great power politics, especially in the 21st century? This paper contends that advances in science and technology (S&T) have long influenced the course of international politics. Technology, in fact, is one of the key determinants in shaping relations among nations, alongside wars and economic shifts. It remains the key tool for promoting economic development and national security. In the past, developments in technology gave us the industrial revolution that created the modern international system. Technologically advanced industrialized nations accumulated and exercised their vast economic and military powers in order to establish their supremacy over less advanced parts of the world, in effect creating a hierarchy among nations.

Historically speaking, tectonic shifts in global politics have occurred rapidly due to three factors: wars, economic shifts and technological developments. In 1935, with no armed forces to speak of and an economy in decline, the United States wanted to be left alone. However, only 10 years later, armed with nuclear weapons and flush with victory in World War II, an economically prosperous United States took over from Pax Britannica. By making war more destructive, technology has made war an unreliable means of conducting great power relations, thereby fostering co-operation among states. Twenty-two years ago in 1990, China was in the international doghouse post-Tiananmen massacre and India seemed to be at war with itself. Japan was then Number One in Asia. But long cycles of economic growth in China and India and stagnation in Japan have led to a tectonic shift in the global power structure and changed these countries' ranking and status in the pecking order. One of the key factors in the rise of China and India has been rapid technological adoption and advancement.

Information and communication technologies (ICT) in particular have cast a pervasive impact in the dynamics of international relations. According to Charles Weiss, the impact of ICT “may be classified as operating through one of four main mechanisms:

- 1 changing the architecture of the international system: its structure, its key organizing concepts and the relations among its actors;
- 2 changing the processes by which the international system operates, including diplomacy, war, administration, policy formation, commerce, trade, finance, communications, and the gathering of intelligence;

- 3 creating new issue areas, new constraints and trade-offs in the operational environment of foreign policy, a term which includes not only political constraints on international action, but also constraints imposed by the laws of natural and social science; and
- 4 providing a source of changed security perceptions, of information and transparency for the operation of the international system, and of new concepts and ideas for international relations theory.”¹

The Global Diffusion of Technology

The dynamics of globalization unleashed by technology is transforming relations amongst nations. Technological advances have emerged as the principal agents of social, economic and political change, drawing the world closer whilst also dividing it. The “revolution in dual-use technologies” for instance, is generating fundamental transformations both in the way wealth and power is created and wars are fought because technology diffusion is now virtually instantaneous and unstoppable. Unlike in the past, technology diffusion now takes place at its most advanced level. Commercial satellites, GPS readings, space-based imagery, weather data, and Internet data – they all have potential military applications in communications, navigation, intelligence and operation support. The “equalizing” feature of ICT has also lent non-state entities more power to initiate societal change and to address the broadest audience possible in virtual time, undermining in some cases the monopoly of the modern state to govern and rule. Using suicide bombers and improvised explosive devices as their technologies of choice, terrorist groups – considered non-state players in the international arena – have exposed the shortcomings of traditional war-fighting responses and created new vulnerabilities for states.

Developments in advanced technologies – such as the next generation microelectronics, nanotechnology, biotechnology, robotics and artificial intelligence – will upset existing balances of power and shape military capabilities for future conflicts. Forecasts indicate that S&T advancements will transform the battlefield in the decades ahead. By the year 2030, several states will acquire formidable power-projection military capabilities with weapons of increasing range, accuracy and destructiveness for the conduct of high-intensity conflict. Doctrines of flexible response for multiple missions based on high-technology weapons and a diversified, yet integrated, force structure will be the key principles of defense policies of major powers. The “front” will disappear as the whole country will become the battlefield. Since the front will no longer be the main battlefield, long-range force projection weaponry for deep strikes, like ballistic and cruise missiles and amphibious capabilities, will assume significance in the frontless wars of the future. No arms control agreement or non-proliferation regime or technology control mechanism can prevent the proliferation of the technological means of war.

But global technological diffusion will continue to be uneven, and will allow some nations who have the technological edge to gain strategic advantage over others. The changes in geopolitical systems of trade, offshore production by multinational corporations, and intellectual property protection, coupled with advances in ICT, have helped globalize research and development (R&D)

activities. While the United States, Japan and the countries in Western Europe have been the traditional focus of R&D, China and India have emerged as the new destinations for R&D, a trend that will enhance their ability to attain global scientific and technological leadership. China has the potential to leapfrog in cyber and space technologies and concepts. Chinese strategists have long called for a high-tech upgrade of its military to prepare to fight a future war in which software beats manpower.² As early as in 1997, three members of the People's Liberation Army's (PLA) Academy of Electronic Technology wrote an essay in *China Computer World* that called upon China to abandon the "traditional concepts of war-making...which emphasized the destruction of hardware, attacking cities, seizing territory and inflicting casualties. Now, the struggle to control information is the focus of weapon systems and the countermeasures taken against these systems... Conducting warfare with computer viruses is more effective than using nuclear weapons."³ The PLA has identified a number of "focus areas": modern command-and-control communications systems, cyber, space and long-range ballistic and cruise missiles for deep strikes, stealth platforms, and improved air defenses. Indeed, outer space, cyberspace and ocean beds are emerging as the new arenas of strategic competition. Countries that dominate in key technologies in these domains will have an edge over others. It is not a coincidence that a great power shift now under way coincides with the search and development of new weapons technologies of the future. Whichever country invents a new weapon system ("the assassin's mace" as the Chinese call it) would shift the overall balance of power (as nuclear weapons did in 1945) in its favor.

The New Great Game: "Techno-Resource Nationalism"

Every international order is based on an energy resource. Resource politics generates both competition and cooperation between nations. Great power contests are essentially struggles for resources. We moved from the Age of Sail to Coal and Steam, both of which were the basis of Pax Britannica. When the British ran out of steam, literally speaking, the U.S.-led order came into being, based on oil and nuclear energy. Is it a coincidence that the U.S. is seen as a declining power just when the world seems to be running out of oil?

Most wars of the 20th century were energy wars. Stating the obvious, much like humans, nations need energy to revitalize and re-energize in order to defend core interests. In this context, technology for rising powers such as China and India is central to any discussion of their resource base, certainly a key variable in their "comprehensive national power" strategies and politics. To understand the great power play under way in Asia of the early 21st century, strategists contend that we need to brush up our knowledge of the classic works on geopolitics by Halford Mackinder and Nicholas J. Spykman. The role of transportation technology, in particular, deserves special attention as it is changing the geopolitics of the Eurasian landmass. To illustrate, much like Britain and Russia before it, China is now employing modern transportation technology to re-draw the map of Eurasia via high-speed railways, highways and pipelines. Beijing is spending billions to create its alternative hub-and-spokes economic system whereby the various pipelines, railroads and highway transportation networks linking China with Central, Southwest and Southeast Asia will serve as the spokes or arteries that will bring in raw materials and energy resources while exporting Chinese

manufactured goods to those regions and beyond. One can argue that the two most important determinants of China's foreign policy today is oil and technology (specifically energy technology) – not Taiwan, not the U.S., or any other issue.

In the absence of a major scientific discovery or technological breakthrough, the *oilpolitik* will continue to shape power capabilities and culminate in the emergence of new coalitions and geopolitical alliances in the decades ahead. The energy competition is also heightening tensions over the ongoing territorial/maritime disputes, and shaping defense modernization plans and forging new military alliances. Within the next decade or so, the Arctic Ocean is likely to become another area of energy competition.

Not surprisingly, the foreign policies of major economies are being transformed as much by the energy imperative as by the technological imperative. We are seeing the rise of “petro-superpowers”– nations that wield disproportionate power in the international system by virtue of their superior energy reserves. A new energy architecture is emerging. New alliances between consumers and producers are emerging. Saudi Arabia is now looking for new partners in the East. Russia is using energy to stage a comeback on the world stage. We are witnessing a mad rush – a sort of treasure hunt – to gain control of energy resources by China, India and Japan, especially in those countries which are outside the control of major western companies for political reasons. The quest for resource technology is providing a new thrust to China, U.S., Russia and India's diplomacy. While pursuing a mercantilist foreign policy over oil, gas, and minerals, Beijing is also investing heavily in green energy technologies (renewable energy resources such as solar, wind and nuclear technologies) that could help China leapfrog over other major economies in the future.⁴

The creation or discovery of a new clean, cheap energy source could be a technological surprise that has the potential to usher in a new world order. For the first time in history, major economic powers, while still desperately searching for oil, seem serious about finding a substitute for oil. This quest for energy technology explains the mad rush to plant flags on the moon and on ocean beds. Indeed, the race is on for green energy. The new global order may well be based on a mix of solar, hydrogen, lithium and thorium. New energy resources and technologies have the potential to reshape major power relations and bury once and for all the talk of embargoes, containment and blockades. Imagine a scenario where we wake up one fine morning to the news that a real, cheap substitute for oil has been found and we don't need the Middle East as much we do today. What would that mean for geopolitical alliances? Hence, it is argued that “resource & technological nationalism” lie at the root of the new Great Game.

Technology Determines Hierarchy in International Relations

There is a direct correlation between a country's place in the global hierarchy and S&T capabilities. Modern technology is central to the pursuit of national goals for all nations-big or small. However, the pace of technological change across continents and countries is never uniform. Early adoption of new technologies bestows advantages on newcomers. In a globalized world,

technology access and technology denial play key roles in determining the fate of nations. Nations compete either by raising themselves to higher levels of techno-economic performance or by keeping others down, technologically and economically. Technologically advanced nations also enjoy the power to set the norms and standards of behavior in international politics. Great powers, in particular, compete ferociously to maintain their top dog status through their edge in technology. Most high-tech developments are driven by the competitive national quest to maintain the technological superiority over others.⁵ Military strategists, in particular, see superior technology as the key to remaining ahead of enemies and competitors. Technological advances invariably upset existing power balances and shape military capabilities for future conflicts. The restrictions on the transfer of high technology have long been a bone of contention in Washington's relations with both New Delhi and Beijing.

In the 21st century, China is determined to become globally competitive in technology innovation. Interestingly, the Chinese do not subscribe to the "Global Commons" perspective. They call cyber, space, environment and maritime domains as China's "strategic frontiers" where Beijing must have technological edge over others. Releasing the 2006-2020 Science and Technological Development Plan on January 9, 2006, former Chinese President Hu Jintao said: "By the end of 2020, China's science and technological innovation ability will be greatly improved...By that time, China will achieve more science and technological breakthroughs of great world influence, qualifying it to join the ranks of the world's most innovative countries."⁶

Both the current global S&T leader, the U.S. and rising India are also on the innovation offensive. In "A Strategy for American Innovation" in 2009, Barack Obama said: "The United States led the world's economies in the 20th century because we led the world in innovation. Today, the competition is keener; the challenge is tougher; and that is why innovation is more important than ever." His administration continues to provide support on a wide array of civilian and military technological platforms designed to keep the U.S. on the leading edge of S&T innovation. For his part, while announcing the creation of India's National Innovation Council in 2010, Indian Prime Minister Manmohan Singh stated that the Government of India has declared the next decade (2011-20) to be the "Decade of Innovation."⁷ Though India has a long way to go, the institutional and policy foundations for sustained S&T innovation are taking shape. Geopolitical alliances are as much about technology as about shared interests and values. After Israel, India is now poised to become a global hub for high-tech R&D, especially defense R&D, mainly because major American and European defense manufacturers are more comfortable with India than China. And this has implications for great power alignments and Asian balance of power. Aspects of techno-nationalism are reflected in a range of trophy projects, including in efforts to set new technological standards and Chinese and Indian ambitions in space and the oceans.

China's R&D expenditure increased to 1.5 percent of GDP in 2010 from 1.1 percent in 2002, and should reach 2.5 percent by 2020. Its share of the world's total R&D expenditure grew to 12.3 percent in 2010 from 5.0 percent in 2002, placing it second only to the U.S., whose share remain steady at 34 to 35 percent. According to UNESCO, China now employs more people in science and technology R&D than any other country.⁸ Innovation and idea generation remain strong in

Japan and South Korea and have been picking up in China and India due to improving education and a reverse diaspora brain gain. Reverse brain gain is seeing tens of thousands of skilled Chinese and Indian workers from the West returning home and fueling economic growth. This flood of Western-educated and skilled talent will boost their countries' economic competitiveness. From Beijing to Bangalore, from Seattle to Sao Paulo, new industries and innovations are flourishing. China and India produce five times as many engineers as the U.S. Some estimates show that 90 percent of engineers will hail from Asia by 2030. Nearly 25 percent of patent applications in the U.S. have foreign nationals as inventors or co-inventors.

For the time being, the U.S. leads in R&D worldwide with 35 percent of the total output. China comes in second with 16 percent, and Japan in third with 13 percent – but both are catching up fast. According to the Thomson Reuters National Science Indicators, Asia increased its global share of published science articles from 13 percent in the early 1980s to 30 percent in 2009. China is leading the way, having increased its share of articles to 11 percent in 2009 from just 0.4 percent in the early 1980s. Japan is next, accounting for 6.7 percent, followed by India with 3.4 percent. Studies show that in 15 years, China and India are expected to achieve near parity with the U.S. in two very different areas: scientific and human capital (India) and government receptivity to business innovation (China). China and India will narrow significantly – but not close – the gap in all remaining factors. The U.S. is expected to remain dominant in three areas: protection for intellectual property rights, business sophistication in maturing innovations and encouragement of creativity.

Many projections say China's and India's gross domestic product (GDP) could overtake that of the U.S. and Japan respectively by 2025. However, size alone may not matter as long as the U.S. and Japan retain their technological edge. The culture of creativity and entrepreneurship could give the U.S. and Japan the boost they need. Major economies recognize the critical importance of innovation – the application of new inventions and technologies to solve old problems, address new challenges and generate economic growth. When it comes to technological innovation, open societies seem to have an edge over closed societies as open minds generate innovative ideas. And innovation is the engine of economic growth. That is why it would be unwise to write off Japan. Japan could yet spring a technological surprise. Some Chinese economists calculate that within a decade or so India could come close to “spoiling Beijing's party of the century” by outpacing China in economic growth. From Beijing's perspective, India's economic rise coupled with the U.S.' S&T edge would prolong American hegemony in Asia, thereby hindering the establishment of a post-American Sino-centric hierarchical regional order in the Asia-Pacific. That is one reason for the deterioration in China's relations with India.⁹

Given their rapid pace of economic development and large domestic market size, China, India and other emerging economies have the potential to be the sources of new revolutionary technologies, e.g., the development of new clean water and energy sources, the next generation of Internet, power generation, and so on. Future technological breakthroughs will transform our world in a similar way as the Internet did, leading to a rebalancing of the global economy and a rebalancing of the power within it. In short, technologies of the future will once again determine the fate of nations. Technological innovations of the future could turn today's losers into tomorrow's winners.

Techno-economic competition will remain the most effective tool for perpetuating hegemony and for neutralizing or keeping a political and military adversary at bay.¹⁰

To sum up: as in the past, so in the future, technology will play a role greater than any other factor in shaping relations among nations. Geopolitical alliances of the future will continue to be underpinned by the varying levels of technological development among nations. In a globalized world economy, countries will take advantage of their comparative technological advantage over others. Access to technology (or the lack of it) will determine a country's place on the pecking order in the regional and global hierarchy. Let me end by paraphrasing the famous naval theorist Alfred Thayer Mahan: in a globalized world economy, whoever has the technological edge will dominate the world. In the 21st century, the destiny of the world would be decided in the S&T field. Short of wars, major power rivalries and alliances will revolve around technology, resources and trade. Technology could help moderate great power competition and hopefully, prevent wars as nuclear weapons technology did after the Second World War. Advancements in technology will not only change the way we live and fight, but also the way our world is organized. So a great deal of thought needs to be given not just to how technology will change battlefields of the future, but to geopolitical shifts and marketplace dynamics as well. At every level of inter-state interaction, technology remains the fundamental explanatory variable in understanding the international system.

Notes

1. Charles Weiss, "Science, Technology and International Relations," *Technology in Society* 27, no. 3 (2005): 295-313.
2. A book published by two Chinese air force colonels in the 1990s listed 24 formulations in which China could use tactics outside the conventional handbook of war to infiltrate and weaken an opposing country. Political and economic chaos could be created by hacking into or destroying computer systems with viruses, with terrorist acts or through biochemical warfare, the PLA colonels said. See Lynne O'Donnell, "China gears army for cyber-war," *The Australian*, November 10, 1999, 11.
3. Quoted in *China: Will It Become the West's Next Great Adversary?*, Publication of the Center for Security Policy, No. 98-D 21 Decision Brief, February 4, 1998; See also Ivo Dawney, "Beijing Launches Computer Virus War on the West," *The Age*, June 16, 1997, A8.
4. Commentary, "China's Global Arrangement and Diplomatic Focus for Its Strategic Resources," *Chinese Cadres Tribune*, July 30, 2011, trans. <http://chinascoppe.org/main/content/view/3776/92/>.
5. Amitav Mallik, *Technology and Security in the 21st Century* (SIPRI: Oxford University Press, 2004), ix-x.
6. Quoted in James Wilsdon and James Keeley, "China: The next science superpower?," http://www.naider.com/upload/82_China_Final.pdf.
7. Amb. Karl F. Inderfurth and Persis Khambatta, "A U.S.-India Innovation Partnership," *U.S.-India Insight* 1, no. 5 (2011).
8. Anil K. Gupta and Haiyan Wang, "China as an Innovation Center? Not So Fast," *Wall Street Journal*, July 28, 2011. See also Robert J. Herbold, "China vs. America: Which Is the Developing Country?," *Wall Street Journal*, July 9, 2011.
9. For details, see Mohan Malik, *China and India: Great Power Rivals* (Boulder and London: Lynne Rienner Publishers/First Forum Press, 2011).
10. Mallik, *Technology and Security in the 21st Century*, 102.

Rising From and To the Sea: China, Technology and the Future of Maritime Power

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Maritime historian Felipe Fernandez-Armesto notes that “[o]nly miracles of simplicity or complexity” can make it possible to build a society centrally organized around the sea.¹ The sheer hostility of the maritime environment, lack of fresh water or reliable food supply and constant threat of exposure, can only bear either modest, primitive sea-based civilizations, like the Orang Laut of the Malayan peninsula or the Uros of Lake Titicaca in the Andes mountains, or intricately complex ones, like the European empires of the enlightenment or the United States of today. Study of either civilizational phenomenon tempts us to conclude, as Fernandez-Armesto claims we too often do, that “man is not made for the sea, nor the sea for man.”² Indeed, even from within great sea-faring cultures, the predominant cultural narrative of the sea is one of disorientation, longing, madness and ultimately death. These themes provide a thread from Homer to Shakespeare, through the timelessness of Melville to the contemporary narratives of Yann Martel.

But the truth is that the land is not only marginal to the sea geographically, but also socially. Successful and sustained exploitation of the sea, whether for trade, migration or war, has been a consistent hallmark of high civilization. This was so for the rich civilizations of the Indian Ocean more than 6,000 years ago, their followers in the Mediterranean, and certainly the European empires whose rise, for better or worse, marked the opening of modern age.

Today, U.S.-led globalization, under challenge by a quickly rising Asia led by China, is also underpinned by a sophisticated sea-based trading system. This system – enabled by global mega-ports, standardized containers and stories-high gantry cranes, a worldwide break-neck pace in shipbuilding, satellite communication and modern, global finance – has allowed us to experience the single largest accumulation of wealth that mankind has yet achieved.³ And as was the case with Indian Ocean cultures witness to booming monsoon-powered trade in the fifth century B.C.E., so today, those nations who have successfully leveraged the sea for economic advantage have become wealthy the fastest, interacted with the world the most frequently, projected power the farthest, and thereby given their cultures, languages, religions, and political systems a large advantage in survivability.

What has changed in relative civilizational successes from the Indian Ocean thousands of years ago to today? Only technological innovation in sea power, and the number of players pursuing it. Today’s widely perceived shift in the balance of power is underpinned by just that. East Asia’s rise is best understood as a shift in sea power, primarily commercial and (to some extent) military. Led by Japan, South Korea, Singapore and Taiwan, new players like Malaysia, China, Vietnam and, increasingly, India are looking to sea power as pre-requisites for overall national success. These major successes in increasing sea power have come hand-in hand with major new geo-political

burdens, some of them urgent and intense. The 21st century, as so many before, will be shaped by national successes and failures in meeting these challenges and continuing the safe and reliable use of the sea.

An exhaustive analysis of the regional causes and consequences of the rise of maritime Asia is beyond the scope of this work. Such an investigation would be nothing less than a maritime interpretation of a vast and deep civilizational shift that is changing the global center of gravity from the Atlantic to the Pacific Ocean. However, this work can and does take on a re-description of the rise of China in particular from a maritime perspective. The case of China is taken as a special one for three primary reasons. First, it is the rise of China that will have and is already having the most widely-felt regional impact. Second, the rise of China, unlike the rise of some other players, is the most accessible and clear example of a successful, maritime-based broad national strategy. And third, the success of this maritime-based national strategy in China is prompting a re-evaluation, even among established maritime players, about the very fundamentals of the maritime domain and modern sea power. For these three reasons, the impact of maritime power on overall national development, and the role of technology in enabling that rise will be examined here in terms of China primarily. Applying these insights to Singapore, South Korea, Vietnam, Malaysia, and other powers will remain outside the scope of this paper.

Beginning from that premise, this overview will follow this logic to examine the rise of China and the strategic future of the Asia-Pacific through a maritime lens, with a view to the role of technology and development in the achievement of sea power. Analysis will be undertaken in three broad parts: it will begin with a consideration of China's two kinds of sea power, both commercial and military. It will be argued that the first is the foundation of modern China, and that the second only a natural out-growth of a maritime-based economy. Discussion will go on to explore the impressive growth in maritime capabilities, particularly sub-surface, in the wider Indo-Pacific context, considering the impact on the regional strategic outlook. Finally, it will conclude with a discussion of the policy burdens of Asia's maritime success.

TWO KINDS OF SEA POWER

China as a Commercial Sea Power

The maritime security field in the Asia-Pacific is dominated by discussions about the rise of Asian sea power translated as the rise of Asian navies. Too often, scholars and security practitioners alike assume that sea power is a single-dimensional characteristic, measured in 'gray hulls' and naval tonnage. While it is undoubtedly true that Asian power is increasingly employed not just on the continent itself, but on the world's oceans, focusing on this development alone puts the cart before the horse. Asia's naval expansion, while itself a strategic game-changer in the region's security outlook, needs to be understood as a necessary result of a dramatic rise in Asia's commercial sea power. It is this commercial sea power that is the foundation supporting, if not necessitating, Asia's turn to the sea in naval terms.

In 1998, senior Chinese military officials, evaluating China's military position in Asia, argued that China needed to "foster a maritime consciousness among its citizens, develop a maritime economy, and develop its naval security forces."⁴ While the first and third recommendations were well-taken at that time, arguably, by 1998 China had already begun to cement formidable commercial sea power. In the aggregate, the economic revolution that has lifted billions out of poverty in China and transformed China's global position has been profoundly maritime in nature. When China embarked on economic reforms in the early 1980s, its manufacturing exports as a percentage of global exports was less than 1 percent.⁵ Two decades later, spurred by massive investment in the nation's manufacturing sector and coastal infrastructure, China accounted for more than 8 percent of all global exports in the manufacturing sector by the first half-decade of this century,⁶ and after a brief period of negative growth following the global financial crisis in 2008, was again increasing its manufactured exports, both in absolute and relative terms, by early 2011.⁷ While this impressive growth has often been registered as a success of national investment in manufacturing alone, it has been importantly predicated on the ability of Chinese manufacturers to get products to far-off markets via seaborne trade. This has meant that Beijing's development strategies needed to be laid out with reference to the sea: early investments, from infrastructure to capital support of identified industries, were almost exclusively focused on those coastal areas of China with easiest and cheapest access to sea-lanes. Inspired by the example of neighboring Singapore,⁸ China's leadership in the early 1980s deliberately set out to ride the steady tide of ocean-going trade sailing past China's coast. Rather than pursue indigenous 'balanced growth' or domestically-focused industrialization, Beijing instead chose to throw its weight behind the development of a manufacturing sector plugged into the global maritime economy as an easy and accessible fulcrum for national economic development.

In 1995, three years before General Mi exhorted China to develop a maritime economy, with China's manufacturing sector already demonstrating impressive growth, steps were undertaken to ensure increased reliable maritime access for Chinese manufacturers to their customers overseas. In that year, the Shanghai Municipal Government was authorized by Beijing to develop its maritime economy with a view to leveraging the international trading system; Shanghai took this direction with a degree of energy and enthusiasm that no one could have foreseen. In 1990, Shanghai port handled less than half-a-million 20-foot equivalent units (TEUs) of containerized trade, despite its favorable geographic position at the mouth of the Yangtze River on the Pacific basin. By 1998, Shanghai's throughput had risen to 3 million TEUs, averaging almost 27 percent growth year-on-year.⁹ By 2010, Shanghai had narrowly edged out Singapore to become the world's largest container port, a singularly magnificent and unforeseen achievement.¹⁰ It was premised not only on the exploitation of natural and structural economic advantages, including Shanghai's deep-water harbor and China's competitive labor market, but also on planning, foresight and feats of engineering undertaken by the Chinese leadership. Massive infrastructure projects became the hallmark of Chinese national development, including the dredging of Shanghai harbor to make way for ever-bigger container vessels, the construction of subsidiary ports to provide excess capacity, and the building of the large-scale supporting infrastructure to connect it smoothly together, such as the impressive 32.5 km Donghai Bridge, the second-largest ocean bridge in the world. As a single national asset, the port at Shanghai is impressive enough. Consideration, however, that Shanghai

is only the largest of China's mega-ports, eight of which rank as among the world's 20 largest container thoroughfares,¹¹ and one begins to appreciate the magnitude and global relevance of China's maritime economic revolution.

But even before the emergence of Shanghai as the focal point of China's maritime economic strategy, by 1998, China had already scored notable successes in the development of credible sea power as a leading player in the global shipbuilding industry. Though in the 1980s, China was described as a "technologically backward, poor-quality manufacturer of basic ships,"¹² as early as 1992, China ranked as the third largest shipbuilder in the world, standing astride long-established European industry players like Germany and the Netherlands, and already eclipsing traditional maritime powers like the United Kingdom.¹³ Today, China is the world's second largest commercial shipbuilder, second only to industry powerhouse, South Korea and second to none in terms of raw aggregate new orders (Chinese firms grabbed 61.6 percent of all new vessel orders in 2010).¹⁴ While Chinese firms are preferred for low-tech bulk carriers (in contrast to South Korea's high-end ships), China has developed a sophisticated manufacturing capability that widens its maritime base, raises its indigenous technological and engineering capacity, and more deeply entrenches its economy and overall national interests in the global maritime market-place.

Moving up the value chain of commercial shipbuilding is not the only challenge facing Chinese commercial sea power in the coming decades. The most pressing challenge, already identified by Chinese planners, will be to ensure that Chinese ports continue to thrive without becoming their own worst competition. Chinese planners are acutely aware that, given China's unquestioned dominance of container trade in the East Asian region and globally, future competitive threat is likely to come from within, rather than from abroad. That is, the primary challenge to China's continued success is the very real prospect that the successes of Shenzhen and Guangzhou may come at the expense of Shanghai or Hong Kong, creating an effective ceiling to China's national commercial seapower. Already, analysts of port development strategies in this region have noted the problem of "mutually destructive competition"¹⁵ among a group of all-Chinese ports and port operators.

However, adaptive behaviors premised on "co-opetition" rather than direct competition already characterize developments in business strategy in southern China and Hong Kong. Port operators, facing increasing competition, have formed "strategic alliances" with their competitors as a means of maintaining market share, increasing bargaining power with global shipping lines, and ensuring long-term market relevance through the development of complementary business strategies, as opposed to directly competitive ones.¹⁶ Though this development was primarily observable at the firm level in southern China (that is, between companies, either private or state-owned), there is evidence that this strategy has been adopted at the level of governmental port authorities. In June 2011, Chinese media sources confirmed that a "strategic alliance" between four Chinese ports – Qingdao, Yantai, Rizhao and Weihai – signed a cooperative framework agreement with South Korea's Port of Busan to establish an integrated "shipping and logistics center in Northeast Asia."¹⁷ This "port cluster" approach, in which closely sited ports may consolidate market share by taking on specialized roles within the cluster to form an integrated logistics region, is clearly aimed at taking Chinese competitiveness in the maritime logistics sector to a new level for the next century.

Whether or not such “co-opetition” is feasible, what the balance of short-term costs and long-term gains will be, and how it will affect overall port operations worldwide remain to be determined. However, China has already proven its weight in commercial sea power, suggesting that any significant organizational development there should be taken as a potential leading trend in the overall global industry.

And so, China’s fast-developing strength at sea has been several decades in the making, though its military modernization has only gained wide-spread global attention since the turn of the century. When General Mi advocated in 1998 for a Chinese “maritime consciousness” and “maritime economy” as a precursor to establishing China’s global power, he was already well-behind the times. By design, Deng Xiaoping’s opening of China to the world in 1978 firmly oriented the country to its coasts. Value-added exports in the manufacturing sector was a single plank of national development strategy, further enabled by the design and construction of major world-class infrastructure projects at Chinese ports, and by a government-led explosion in Chinese shipbuilding. Today, China’s economic miracle continues to be profoundly maritime. Chinese people are emerging from a century of poverty by making rudimentary (but increasingly modern) manufactured products, funneling them through new Chinese mega-ports at ever-increasing speed and volume, to be circulated around the globe by Chinese-built ships.

As a result, China, more so than most of the world’s littoral states, has entangled its continued prosperity and well-being with safe and reliable access to the world’s oceans. On that basis, in the widely read *Zhongguo Junshi Kexue*, a senior officer of the People’s Liberation Army uses U.S. naval theorist Alfred Thayer Mahan to underscore China’s need to control Asian sea lanes of communication (SLOCs), especially the “strategic passages” through which Chinese-traded goods and materials traverse: “In modern times, efforts aimed at securing the absolute control of [maritime] communications are turning with each passing day into an indispensable essential factor in ensuring the realization of national interests.”¹⁸ Its maritime-based economy impels Beijing to direct national security policy toward safeguarding its fundamentally domestic economic interests.

China as a Military Sea Power

Thus, even before the dawn of the new millennium, China had fostered the development of credible, indigenous sea power with commercial, rather than military roots. Of course, these commercial successes, particularly with respect to China’s ever-busier shipyards, had important repercussions in the realm of military policy. If scholars in China are increasingly turning to U.S. naval theorists to understand and assess China’s strategic position in the Asia-Pacific, it is because China’s new and intense vulnerability to naval blockade is causing a deep re-assessment in Beijing of the Pacific Ocean and the posture of China’s neighbors. This re-assessment has emphasized two primary constraints on China’s geo-strategic position.

The first is China’s “Malacca dilemma.” In 2003, Chinese President Hu Jintao asserted that “certain major powers” are interested in controlling the Straits of Malacca to China’s great disadvantage.¹⁹ As the primary conduit for China’s increasingly large foreign energy supplies, as

well as a conduit for Chinese exports, the strategic chokepoints through maritime Southeast Asia (including the Malacca, Lombok and Makassar straits) are a major source of anxiety among China's military planners. While steps to mitigate China's dependence on seaborne energy have been undertaken (primarily via the construction of pipelines), the economic reality remains that China will continue to be dependent on sea-borne energy cargos for the long term. Moreover, Chinese exports of manufactured goods to markets in the Middle East, Eastern Africa and the Mediterranean necessarily require transport through the narrow straits of maritime Southeast Asia. As a result, much strategic weight is placed on Beijing's ability to, if not control, then guarantee free access to these waterways.

The second primary constraint on modern China's geo-strategic position, given its maritime-focused economy, has been identified by Chinese military leaders as the problem of the 'first island chain.' Writing in 2003, Chinese scholars Hou Songling and Chi Diantang explain:

[A]lthough China's geographic position causes China to face the sea, it does not border the ocean. Between the nearby seas and the greater ocean is an island chain composed of the Japanese archipelago, the Ryukyu Islands, Taiwan, and numerous Southeast Asian archipelagos. This is the "first island chain." To pass through the nearby seas and enter the larger ocean, China must pass through this island chain. The northern part of this island chain is currently controlled by the U.S.-Japan alliance. These areas can easily be blockaded during times of war since they are isolated frontally by Taiwan, which has still not been reunified with the motherland.²⁰

Thus, the vulnerability of China's coastal economic centers to blockade, disruption or destruction by the United States and its allies has put a new imperative on controlling all of the waters within the 'first island chain.' Beijing seems to believe that controlling these coastal seas is the only means of guaranteeing free and reliable access to the open ocean in the event of regional hostilities. This control of the sea includes, of course, regaining control of Taiwan, the largest single island in the chain, strategically located at its center. Seen in this light, China's naval modernization and strategic focus to regain control of Taiwan can be understood as an inevitable structural corollary to its economic miracle.²¹

Just as its commercial success in the maritime realm has had important effects on military policy, it also has had important benefits for the military modernization that it necessitates. That is to say, that not only does China's maritime economy create a new strategic imperative at sea, it also makes it easier to meet that imperative. In contrast to many in the developing world, China is increasingly employing a defense-sector innovation model perfected in the United States that leverages the global marketplace through the commercial sector as a means to spur sustainable, indigenous technological growth directed at long-term defense priorities. This has paid big dividends in China's shipbuilding sector, in which commercial and naval shipbuilding projects are undertaken literally alongside one another, sometimes in the same shipyard by the same state-owned enterprise.²² While technology is not uniformly applicable to military and commercial shipbuilding, there are enough areas of overlap that the sectors have mutually benefited one another.²³ Both

commercial and naval shipbuilding in China have seen a veritable explosion: just as China moved surely up the ladder of commercial shipbuilding nations, so the People's Liberation Army (Navy) has ratcheted up the pace of its shipbuilding programs. China's PLA(N) unveiled two classes of nuclear-powered submarines over the last decade and looks on track to launch another by 2015, an unanticipated achievement in a remarkably short period of time. The aggregate result is that China is positioning itself to be a maritime superpower with not only far-reaching strategic interests, but strategic advantages that are deeply intertwined with its commercial success.

Of course, China is not alone in discovering the high-value return on investment in linking commercial industrial capability to military sea power. Other countries have recognized and, to varying degrees, employed this logic as well. South Korea, for example, spent much of the last decades of the 20th century nurturing the development of industry giants – Daewoo, Hyundai and Samsung – and eventually succeeded in all but cornering the global market on ship construction. Like China today, South Korea quickly leveraged this industrial high-technology capacity to fast-track the development of modern naval shipbuilding of high-quality platforms enabled by foreign-produced accompaniments. Most recently, the much-envied KDX programme, in which the Republic of Korea Navy will take delivery of three classes of vessels in less than a decade, brought the second of three planned Aegis-capable destroyers online in June 2011.²⁴ The ROK Navy describes the new platform as a “the world's top class anti-ship, anti-aircraft and anti-submarine” asset, noting that it carries a wide array of American, European and Korean weapons, including the Aegis Combat System produced by Lockheed Martin.²⁵

It is this kind of natural strategic synergy that the then Chief of Naval Operations Admiral Gary Roughead was eyeing when he told the Senate Armed Services Committee that the United States Navy requires a “stable shipbuilding program” not only to maintain the Fleet's capability and access in the world's oceans, but to safeguard the American commercial industrial base in the shipbuilding sector as an easily-eroded, but not easily rebuilt national strategic asset.²⁶ Perhaps under pressure of shrinking budgets, some underperforming shipbuilding contracts or empowered organized labor, there is palpable consternation among U.S. Navy professionals about the state of U.S. shipbuilding and its eventual impact on both commercial and military sea power.

China's Collapsing Domains

As noted above, China is innovating to send a fleet to sea, boasting greater size and exhibiting greater technological sophistication. This trend was most prominently in evidence to everyone in the strategic community, and not limited to maritime professionals only, with the long-overdue confirmation in June 2011 by China's PLA Chief of General Staff General Chen Bingde that China was indeed preparing to sail its first aircraft carrier.²⁷ The confirmation was quickly acted upon: the refurbished ex-Soviet carrier, *Varyag* completed its maiden voyage on August 17, 2011, uncomfortably coincident with a visit from U.S. Vice President Biden.²⁸ Follow-on commentary offered to the *Hong Kong Commercial Daily* by Lt. Gen. Qi Jianguo, Assistant Chief of the General Staff, noted that aircraft carriers are “symbols of a great nation” that are deployed by all of the

world's great nations.²⁹ While strategic commentators outside China are generally cautious in their overall assessment of the immediate strategic impact of this new development vis-à-vis the United States,³⁰ there is no doubt that China's emergence as a maritime power of significant size and scope is irreversible and of great portent in the long term.

In addition to its impressive feats of relatively short-fuse shipbuilding, China's efforts to meet new strategic imperatives at sea have come in unconventional forms as well. It is likely with these unconventional, asymmetric capabilities, and not through the development of traditional capabilities like aircraft carriers, that China will seek to gain advantage over established naval powers. Facing overwhelming U.S. regional superiority, combined with the clear technological superiority of U.S. allies Japan and South Korea's maritime forces, China has sought to leapfrog and innovate its way to an asymmetric balancing of those maritime powers of which it is most suspicious. Through technological innovation, China's military today aims to not only add assets to the maritime domain, but fundamentally change its character by collapsing it with land and space. The most obvious example of this is the development of the Anti-Ship Ballistic Missile (ABSM), Dong-Feng 21D (DF-21D) by the Chinese People's Liberation Army, which might one day be able to accurately target an aircraft carrier strike group sailing as far as 2,700 kilometers away from the Chinese coastline. As leading analysts note, the DF-21D could be stationed on the coast to fully exploit the range of the technology, or it could be embedded so deeply within Chinese territory so as to make any retaliation or pre-emptive measure against it an attack on the heart of China, and therefore "extremely escalatory."³¹ For this reason, many analysts agree that the DF-21D is not just another in a string of technological milestones marked by the PLA, but is a potentially paradigm-shifting development that will uncomfortably blur long-held distinctions between the maritime realm and the territorial one. Historically, the former has been exploited as a realm offering a lot of political and strategic maneuverability: nations could put pressure on rivals at sea that they could not realistically get away with on land, engaging in everything from gunboat diplomacy to minor provocations with little escalatory effect. Blurring the line between the land and the sea will mean that this valuable maneuverability will be importantly and significantly reduced.

Not only is China's modern technological environment fusing seapower with conventional land-based power, it is also blurring the distinction between sea power and dominance of both outer space and cyberspace. Modern navies, led by the U.S., increasingly found power projection capability on information technologies and enabling assets in the sky, rather than at sea. Such information and communications technologies allow forces to employ global positioning systems, precision-guided munitions, and other networked & digitized information-based capabilities necessary for modern fighting forces operating far from home ports. In important ways, seapower in the 21st century will also require deep reliance and control of space and space-based assets.³² Further down the chain, ensuring the integrity of information and the reliability of communications channels in cyberspace is vital to ensuring the operational viability of a far-flung fleet sailing in the vast oceanic region of the Pacific. Though not specifically or overtly directed at one another, both the United States and China are clearly aware of the deepening multi-dimensionality of modern sea power in terms of expanding spatial domains. As a result, both organizations continue to

innovate to further project their power along all dimensional axes, and hedge against vulnerability through innovated defensive technologies and postures.

Certainly, this is the message that senior U.S. military officials are delivering to Washington. Challenged by political leaders to demonstrate that the formidable U.S. Navy and U.S. Pacific Command (PACOM) would have a response to missile developments achieved in China, comments made by senior officials including Admiral Gary Roughead and Admiral Patrick Walsh (Pacific Fleet Commander) suggest that the appropriate response to China's DF-21D announcement will be multi-tiered. As early as 2009, Admiral Roughead told U.S. Senator John McCain at a hearing of the U.S. Armed Services Committee that the best innovation to maintain the credibility and influence of U.S. sea power is not technological *per se*, but organizational. He argued that, as the U.S. already deploys a technologically unmatched fleet, the U.S. Navy should adapt to changing strategic conditions by thinking about new paradigms for the maritime domain. This will include, among other adaptations, thinking in new ways about how to arrange and structure the use of its already-established assets. A new paradigm might privilege, for example a "Blue Water Antisubmarine Warfare" premised on "integrated air and missile defense." The new paradigm might also require focusing shipbuilding efforts not on large, targetable platforms like aircraft carriers, but on more agile, dispersible littoral-capable vessels instead.³³ In 2011, responding to Congressional concerns about the DF-21D innovation in particular, Admiral Walsh implied in an interview with Japanese media that Chinese missile development put a new premium on the missile defense program, including the cooperation of U.S. allies in Asia in that program, as "essential to [U.S.] ability to operate freely" in the Pacific.³⁴

None of these answers represent a fully satisfying American answer to the challenge of Chinese missile innovation. As more and more unclassified sources become available, it is likely we will see that the overall U.S. response to the Dong Feng 21D will involve a myriad of actions, including the ones discussed above alongside many others. The United States, with a considerable indigenous and sustainable technological capability of its own, will nonetheless be unlikely to directly out-innovate China on this measure with a single counter-platform, but will adapt in a multi-dimensional fashion to new strategic realities.³⁵

THE PROLIFERATION OF SEA POWER: MODERN MULTI-POLARITY AT SEA

Though the People's Republic of China's emergence as a firmly founded seapower is pre-eminent to understanding the modern Asia-Pacific, it is contextually important to note the overall proliferation of new maritime players throughout the region. In 2011, there is no doubt that technological innovation is changing the seascape of the Indo-Pacific region in military terms. While the development of commercial sea power is inarguably more important in terms of the impact it has on the day to day lives of the region's inhabitants and its broad security outlook, advances in military power are important corollaries to understanding the strategic future of the Asia-Pacific. Whether in Japan, South Korea or Singapore, or Vietnam, Malaysia or India, the economic structure of the Asia-Pacific is generating a new or reinforced interest in the oceans in

virtually every major capital on the continent. In these countries – just as in China – as commercial interests in seaborne trade become more sophisticated and profitable, so the imperative to secure the nation’s interests through military credibility will sharpen. In the modern Indo-Pacific, this logic has been borne out: today, the flag follows trade, that is to say that the natural result of increasingly trade-dependent economies is the concurrent development of sophisticated sea power to protect those interests wherever they may be threatened.

There are many places to find evidence of this trend across the region, but the single most instructive area for investigation is the explosion in naval capability across the theater. Though the U.S. Navy remains the preponderant power at sea and will for some time,³⁶ there is increasing erosion of the Navy’s strategic advantage by an array of increasingly credible players on the ocean. Not only China’s People’s Liberation Army (Navy) and the Indian Navy, but also the Japanese Maritime Self Defense Forces (JMSDF), the Republic of Korea Navy (ROKN), the Republic of Singapore Navy (RSN), and the Royal Australian Navy (RAN) are sending increasingly capable platforms to sea with increasing frequency, in service of an ever-widening sphere of strategic missions for the governments that they serve. Whether fisheries patrol, customs enforcement, anti-piracy operations, disaster management and humanitarian assistance, or old-fashioned naval exercise, patrol and port visits, the Indo-Pacific oceans complex is now more than ever a high-traffic area for regional navies.

In no single indicator is this explosion in capability more stark than in the proliferation of submarines. At least one private market consultancy, Forecast International, predicts that 111 submarines will be built globally between 2011 and 2020, nurturing a market worth \$106 billion.³⁷ Though the estimate is, especially in the out-years, highly speculative, we can say for sure that more than 50 submarines have been acquired or announced by Indo-Pacific nations in the last five years alone.³⁸ A straight-line extrapolation of this regional trend would suggest that a global projection of 111 submarines built is perhaps an under-estimation of the true rate of proliferation of submarines in the new Indo-Pacific.

While there are a number of ways to measure naval strength and ambition, aggregate number of submarines is an interesting barometer for two reasons. First, submarines are oftentimes the first acquisition of a newly ambitious naval power because they are an asymmetric weapon of maritime warfare. A single, relatively pedestrian submarine can inflict tremendous damage on an unsuspecting adversary, and even the possibility that a submarine is nearby can keep a well-trained, well-resourced surface fleet on the defensive and reluctant to maneuver. In confrontational circumstances, a submarine is a uniquely cost-effective platform for a modest power facing a more capable adversary. The tragic sinking of ROKS *Cheonan* in March 2010 is evidence of that truth: in that instance, an unsophisticated North Korean coastal submarine broke a state-of-the-art South Korean corvette in two and killed 46 sailors. For that reason, submarine acquisition can be understood as the first sign of an emerging naval power gaining a foothold in strategic context. In the Indo-Pacific today, we are seeing a number of first-time submarine acquisitions, suggesting a number of strategic transformations underway at the same time across the region.

The second reason that it is an interesting metric is that submarines, though cost-effective, are incredibly technologically daunting. Save for outer space, there is no more hostile operating environment for human beings than under the ocean's surface. As a result, the operation of submarines require a lot of professional training for personnel, a time-intensive and laborious effort to operate and maintain, and even greater effort and skill to safely design, build or modify submarines indigenously. Whether newly emerging navies are building their own submarines (like China and India) or whether they are acquiring them from abroad (like Vietnam and Malaysia), the inclusion of submarines in substantial numbers in the region is evidence that navies are increasingly capable, or at least, increasingly ambitious in technological terms. The fact that the Asian continent is today not just an active buyer of submarines, but also a designer and merchant,³⁹ speaks to the truly remarkable technological revolution that the continent has undergone in recent decades. The upfront investment in technology, training and professionalization can and will pay dividends to investing nations in terms of the strategic advantage that submarines can provide. Moreover, this strategic advantage will have immediate impact, creating a new multi-polar Asia in which multiple credible players will be operating in the ocean at any given time.

THE BURDEN OF ASIA'S MARITIME SUCCESS

Of course, the proliferation of submarines in particular, and of naval assets more generally in a heterogeneous strategic environment greatly increases geo-strategic uncertainty. Couple this with the growing reliance on maritime-based trade by virtually all of the countries of the region, and it is easy to see that the stakes of maritime security are rising. The increase in interests and acquisition of capabilities does not foreordain military conflict, but does make such conflict easier to stumble into over relatively minor political flashpoints. In this context, the continued proliferation of maritime boundary disputes in both East and South Asia lends particular cause for concern. As military credibility and technological capabilities continue to rise in Asia, the crisis events at sea of 2010, including the sinking of ROKS *Cheonan* in March and the confrontation of Japanese Coast Guard vessels and a Chinese fishing trawler in September, will likely become more numerous and perhaps more deadly than in times past. In this sense, the burden of economic and military successes in China and in the wider Asia-Pacific will be the need to sharpen both conflict resolution and crisis management skills throughout the civilian bureaucracies of the region. Without an evolution in policy and diplomatic innovation in skill commensurate with innovation clearly on display in the realm of maritime power, the burden of Asia's success may also be its Achilles heel.

Notes

1. Felipe Fernandez-Armesto, "Maritime History and World History," in *Maritime History as World History*, ed. Daniel Finamore (Gainesville, FL: University Press of Florida, 2004), 8.

2. Ibid.

3. For a great historical overview of containerized trade and the "world the box made" see Marc Levinson, *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger* (Princeton, NJ: Princeton University Press, 2006).

4. Lt Gen Mi Zhenyu, "A Reflection on Geographic Strategy," quoted in James R. Holmes and Toshi Yoshihara, "The Influence of Mahan on China's Maritime Strategy," *Comparative Strategy* 24, no. 1 (2005): 30.
5. Renfeng Zhao, "China and India: A comparison of trade, investment and expansion strategies," Chatham House Short Report, June 1, 2007, <http://www.chathamhouse.org/sites/default/files/public/Research/International%20Economics/010607workshop.pdf>.
6. Ibid.
7. "China Manufacturing Growth is Accelerating on Export Orders, Survey Shows," *Bloomberg News*, March 23, 2011, <http://www.bloomberg.com/news/2011-03-24/china-manufacturing-growth-is-accelerating-on-export-orders-survey-shows.html>.
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P L E N A R Y S E S S I O N 2 :

The Current Science & Technology Landscape

Issues in Science, Technology and Resource Security in Asia

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Contemporary scientific and technological developments in Asia provide an important context with which to understand the ongoing intellectual and policy debates defining the global security environment and the institutional and structural future of global politics.¹

One primary node of the discourse revolves around the modern state and its ability to provide security and prosperity for its citizens in a hyperconnected world burdened with growing transsovereign concerns. There is growing consensus in the literature that the state is undergoing transformation as it responds to challenges that are specifically global in scope. One such concern is resource scarcity. The combined pressures of globalization, economic growth, population increase, urbanization and climate change are driving the enormous demand for water, energy and food, but supplies of these resources are rapidly dwindling. Three conditions underpin resource scarcity as a national strategic priority. First, most of these resources are existential in nature – water, energy and food are essential to life and therefore directly impact human security. State provision of these resources to its citizenry is a core national interest. Second, resource scarcity is interwoven with environmental concerns derived from climate change, itself an emerging global security issue because of its potentially catastrophic impact on the planet. And third, existing solutions to resource scarcity (political, economic, environmental, technoscientific) do not preclude local and/or global conflicts from happening in the future.

Asia animates in full relief the landscape of scarcity. It is at the forefront of the ongoing transformations in international order of type, not degree – towards what India's former Foreign Secretary posits is a “more pluralistic, non-European, non-Western world” where its dynamic economies have “retaken control of vast resources, huge assets, big markets, are generating surplus capital, and are less dependent on imported innovation, capital inflows, development aid and technology.”² The state is overwhelmed by the number of challenges it will need to manage. As the world's fastest growing region, demand for water for energy and industrial use is projected to rise the highest among the world's regions at 78% between 2000 and 2030.³ The region is also the world's most populous and hyper-urbanizing, with a rapidly expanding affluent middle class that tripled in size between 1990 and 2005⁴ and is still expected to grow in the decades to come: this means a shift in consumption patterns, diets and resource use of its population that will only increase food and energy requirements. Fulfilling these enormous demands will further aggravate pressures on the degrading ecosystem. Lastly, the region is heavy on geopolitics, rife with traditional security dilemmas and the location of the world's rising regional/global powers, India and China. The strategic picture of Asia will not be complete without taking full measure of the linkage between resources and the region's geopolitical giants.

As a core component of national security, science and technology (S&T) is an essential element of state responses to the growing challenge of resource scarcity. Among Asia's emerging and

developed economies, these responses derive from two major strategies – extraction and adaptation – that Michael T. Klare discusses in his most recent book.⁵ Klare maintains that the world economy is now entering into a period of what he calls the “tough” extraction for increasingly scarce natural resources, and that this scramble for what is left will be “one of the defining political and environmental realities of the 21st century.”⁶ He suggests that the “race to adapt” to develop efficient, environmentally industrial processes and transportation systems presents a better alternative⁷ to resource scarcity management.

I build upon these two constructs in this paper and examine their technoscientific articulations in the Asian setting. The purpose is two-fold: first, to identify and examine the S&T dimensions of the current security environment in Asia; and second, to provide empirical substantiation to the assertion that the nature of global affairs is evolving. Yes, state sovereignty continues to structure international dynamics and great power politics still matter. But the growing list of transnational security problems, the emergence of non-state entities as key actors in tackling global problems and the transformative power of technologies are major variables changing the global landscape. Within this context, scientific and technological developments simultaneously shape, are shaped by, and co-produced with, the dynamics of interactions defining the global environment.

This paper is an exploratory effort to acquire a better understanding of the interface of S&T, security and the dynamics of global politics. The actions and decisions of the state in a changing operating environment articulate key parameters of the future, and knowledge and understanding of these variables is valuable towards identifying critical inputs that will shape global dynamics. This inquiry also allows for identifying conceptual trends in Asia. As the region’s global position becomes more pronounced, so will the ideas that come out of it carry more strategic weight. These can provide us with contours of the where, why and how of conflict and cooperation in the future. From a theoretical standpoint, the objective of this paper is to substantiate the growing consensus among scholars of international relations and security theorists for the need to revisit existing conceptual approaches and sustain the ongoing dialogue that aims to draw out new constructs to analyze and understand the empirical realities of global politics.

MANAGING RESOURCE SCARCITY

Extracting in a world of resource scarcity

Countries and multinational resource companies – jointly or independently – are leading the way to extract water, energy, minerals and buying up or leasing land for agricultural projects – “global land grabs,” as Klare puts it.⁸ No place on earth is left unexplored, from the deep oceans, the Arctic, war zones such as Afghanistan, to the ‘last frontiers’ of Asia and Africa. In Asia – China, India and the smaller, developed economies of South Korea and Japan are leading the region in global extraction activities, particularly in the acquisition of energy resources (oil and gas). Oil and gas extraction is underpinned by national energy security strategies containing the following features: the expansion of oil and gas pipeline diplomacy, increasing competition for potential

offshore supplies, governmental support for foreign investments by their own national oil companies (NOCs) and concern over the security of sea lanes.⁹ For China and India, energy security is a strategic requirement inherent in their growing geopolitical status, and oil and gas pipeline diplomacy is a critical strategy to enhance their positions vis-à-vis their power rivals, neighbors and the rest of the region. The strategic point of departure is that, as Malik points out, “every international order is based on an energy resource,” making great power rivalries as “essentially struggles for resources.”¹⁰ China’s plans to create a hub-and-spokes economic system linking itself via a network of pipelines, railroads and highway transportation systems to Central, Southwest and Southeast Asia is a strategy designed to bring in raw materials and energy resources to China and as a conduit to export Chinese manufactured goods to those regions and beyond.¹¹ In May 2012, perhaps lesser in scope but carrying the same intention, the national oil companies (NOCs) of India, Pakistan, Afghanistan and Turkmenistan signed the historic gas sale purchase agreement (GSPA) through the so-called “peace pipeline” – the \$7.6-billion Turkmenistan-Afghanistan-Pakistan-India (TAPI) gas pipeline that regional observers say will not only reshape regional energy cooperation but will transform regional political dynamics as well. The over-all effect of these Chinese and Indian regional energy engagements can only enhance their status as power center of the region.

The scientific and technological dimension of resource extraction bears out the interplay of geopolitics, resource competition, the role of the NOCs, and sea lane security in two ways: as critical tools in energy resource extraction and appropriation, and as component of the country’s capabilities to protect the resources themselves. Innovations in extraction technologies, such as those used in deriving oil from tar sands and deep-water explorations, are emerging as major requirements for securing energy sources. For instance, China intends to further develop deep-water exploration capabilities within the context of its territorial claims in the South China Sea (SCS).¹² As relative newcomers in deep-water exploration, China’s powerful quasi-governmental NOCs are taking the lead to improve Chinese capabilities in this area. Thus far, only the Chinese National Offshore Oil Corporation (CNOOC) possesses deep-sea drilling technology capacity, but this monopoly is expected to be short-lived. Because foreign private companies are the primary source of global expertise on deep-sea drilling, the NOCs have taken to either buying out or partnering with these foreign firms to acquire and build technological capabilities. CNOOC has provided a great precedent – it produced what is considered as a significant advancement in China’s deep-water exploration capabilities – the “981” drilling platform that it completed in 2011. Insiders have sighted technological barriers as one of the reasons why China has not fully engaged in the SCS, so one can posit that as its NOCs develop their exploration and extraction technology base, it is highly likely that Chinese presence in the SCS will become more pronounced. China’s development of its technology base via foreign acquisition speaks to a trend that will become more pronounced in other countries as competition for resources intensify. For instance, India’s Oil & Gas National Corp. (ONGC) partnered with ConocoPhillips this year for deep-water and shale gas exploration off of India’s coast. ONGC will provide the local knowledge about the basins, while ConocoPhillips will share its knowledge to “unlock that potential and bring it to production,” according to ConocoPhillips’ global geosciences chief.¹³

The ongoing SCS disputes bring to the fore how a country's military can be involved in resource extraction activities: protecting resources by providing the necessary assets for a safe and secure operating environment. Having moved to the top of Asia's security agenda, scholars of the region argue that tensions in the disputed territories are likely to escalate as competition for oil and gas intensifies.²⁰ This dispute is seen as one of the drivers of the technological development and acquisitions of the claimants and their allies as the "militarization of the dispute continues apace."²¹ Indeed, the ASEAN nations' ramp-up of military modernization activities of late has partly been attributed to the combination of competing territorial/EEZ claims and China's increasing presence in the SCS.²²

There is also an emerging race in deep-sea mining for rare earth elements (REEs), which are key ingredients used in high technology manufacturing, e.g., hybrid cars, lasers, aviation, smart phones, clean-energy technologies and defense technologies. China controls about 95% of the world's output of these minerals, and in 2009 and 2010 made a series of policy decisions that tightened its exports of these elements, citing protection of its natural resources, environmental concerns, excessive exploitation and illegal mining as reasons for their REE strategy.¹⁴ Seriously concerned about this development, the U.S., Japan and the European Union (EU) filed a complaint to the World Trade Organization (WTO) in March alleging that China was using the exports restrictions on REEs as an economic and political weapon, i.e., to protect domestic manufacturing and as a retaliatory measure against Japan for the latter's detention of a Chinese fishing boat captain when his boat collided with two Japanese Coast Guard vessels near the contested Diaoyu/Senkaku Islands in 2010.

China's REE strategy served as a wake-up call for other countries whose response was multi-pronged: Japan, India and the U.S. established R&D programs on deep-sea prospecting, initiated searches for alternative deep-sea deposits in the region and started programs that developed technologies to improve prospects for mining undersea metals. In June 2012, Japan announced its discovery of a large deposit of REEs in its Pacific seabed, estimated at 6.8 million tons, enough to supply Japan's high-tech industries for at least 200 years.¹⁵ Concerned about having China suspend their REE supplies yet again in light of the ongoing island disputes, Japanese companies are resorting to innovation to lessen their dependence on China: according to the *Asahi Shimbun*, Japan's largest newspaper, Honda Motor Corp. is planning to "start extracting rare earths from nickel-metal hydride (NiMH) batteries used in hybrid vehicles," i.e., to recycle rare earths from its existing products.¹⁶ The establishment of mining companies in several countries has also facilitated technology transfer and diffusion. For instance, when Colorado-based Molycorp acquired China-based Neo Materials, the purchase included the company's technology needed to provide the more purely refined rare earth oxides used in computer, defense and telecommunications equipment.

Given the level of deep-sea mining technology right now, commercialization of any recently-discovered deposits will take years. Innovations will be critical: the minerals are found deep beneath the seabed (5,600 m) and difficult to find in profitable concentrations.¹⁷ Petroleum extraction technologies are currently used, but they are not optimal. Leading-edge advantage will accrue to countries or firms who are able to develop technological innovations that can accelerate

deep-sea mineral extraction while doing this safely and cheaply. This is one node of the REE technology race in the next decades. Already, India's recent decision to enter into the REE race in the deep sea includes a plan to bring together marine science experts and engineers in nuclear energy, space research and defense to help expedite the innovation process for REE extraction. Its marine science programs are leading the study of the seabed as well as test mining that has already reached depths of 6,000 m. Another node of the technology race will be the capacity to master, integrate and innovate upon large technological systems that will allow a country to maintain or enhance its relative power position in the international system. To illustrate: China's state-owned venture Ship Scientific Research Centre unveiled what could be an initial foray into large-scale underwater mining with the development of a deep-sea station. Earlier this year it announced plans for a nuclear powered mobile deep-sea station; its *Jiaolong* manned submersible already reached depths of 7,000 m.¹⁸ The creation of a deep-sea station embodies advanced technological capabilities in numerous fields, e.g., maritime, space, nuclear, materials, extraction, defense.¹⁹ On a strategic level, this plan, if realized, is not only a material manifestation of S&T leadership; it also adds another dimension for geopolitical engagement in the maritime domain.

Adapting to Resource Scarcity: Clean-energy on the Rise

Alongside the increasing urgency to extract and appropriate scarce resources, countries are also pursuing the adoption of “new materials, methods, and devices” that would “free the world from its dependence on finite resource supplies.”²³ One major policy initiative among countries is the prioritization of green or clean-energy innovation²⁴ as a strategic component of national economic, environmental, and science and technology (S&T) development plans. Worldwide, clean-energy has come into its own only in the last decade or so and continues to experience growth in the face of daunting challenges²⁵ in the form of high costs and inadequate global investment. Nevertheless, Asian countries are beginning to institutionalize their commitments to clean-energy, with China leading the effort in terms of total investment and technological development. Southeast Asia nations such as Indonesia, Vietnam, Thailand and Malaysia have started to put green policies in place.²⁶ In India, the government's annual Economic Survey 2011-2012 included, for the first time, a chapter on sustainable development and climate change that contains a proposal for lower-carbon sustainable growth as a central element of India's 12th five-year-plan.²⁷ Its investment in green industries is expected to increase to \$70B in 2015 from a projected \$45B in 2012.²⁸

In 2008, South Korea's government declared green growth as a national development model and is focusing on synergizing the country's economic development and environmental protection by striving for a low-carbon green economy that promotes investments in resource savings and other environmental growth sectors. Japan's New Growth Strategy, first approved in December 2009 and revised in June 2010, is the government's guiding policy underpinning its current economic recovery plan that puts increased focus on fast-growth sectors, including renewable energy, green vehicles, farming and healthcare. The Fukushima triple catastrophe also paved the way for the Noda cabinet to endorse the 2012 white book on the environment that specifically calls for power generation in the Tohoku region through renewable energy sources using wind and solar power.

China spent \$54B in low carbon energy technology in 2011, making it the world's largest investor, surpassing the \$34B investment of the U.S.²⁹ Of its seven strategic emerging industries identified in its "12th Five-Year Development Plan for National Strategic Emerging Industries (2011-2015), three – alternative energy automotive, energy-saving/environmental protection and new energy – are in the green energy sector.³⁰ Its increasing investments in clean technology in recent years have started to pay off: China is now either more advanced than, or provides serious competition to, American technologies in its low-emission coal energy plants, third and fourth generation nuclear reactors, high-voltage transmission lines, alternative-energy vehicles, solar and wind energy devices.³¹

Adopting green or clean-energy innovation draws out a distinct S&T profile. First, in contrast to non-renewable, finite energy resources (oil and gas) that are concentrated in specific geographic areas and thus found only in a limited number of countries, renewable sources and significant potentials for energy efficiency exist virtually everywhere, so a country's renewable source and capacity are significantly determined by its natural resource endowments.³² Reduced energy intensity and the geographical and technological diversification of renewable, sustainable energy sources³³ thus offer great opportunities for enhancing national energy security, government capacity to support local business endeavors and the delivery of public services to local communities. For instance, South Asia's high insolation and dense populations make solar power an ideal renewable energy option and allow government companies such as India's National Solar Mission to support large-scale deployments of solar power³⁴. This natural solar power advantage and falling solar panel/LED costs also make it profitable for local companies to build and operate low-cost solar-powered microgrids that provide clean light and charge phones to rural villagers³⁵. The use of indigenous renewable resources in concert with grassroots technopreneurship that deliver accessible and low-cost solutions to the base-of-the-pyramid population articulate an emergent paradigm of innovation in Asia, the site of significant green growth as global leadership in renewable markets shifts towards the region's developing economies. In contrast to the dominant model of innovation that uses indicators such as numbers of scientists and engineers, amount of R&D investment and numbers of scientific publications and patents produced to measure the innovation capability of countries, the emerging "grassroots" paradigm offers alternative indices of innovation capability. This include the production of indigenous solutions to serve the needs of the majority lower-income populations, the extent of outside-the-lab innovations, and the presence of institutional and organization innovations that enable co-creation and cooperation to create reach, reduce costs and deliver products and services to the majority of the people.³⁶ The focus is on simplicity and frugality in the process of innovation as opposed to the expensive innovation in the conventional paradigm that features, among others, large resource and facility investments and highly qualified and educated personnel.³⁷ Recognizing the growing importance of the green growth-innovation nexus, the annual Global Innovation Index (2012) included, for the first time, "ecological sustainability" as a key pillar of innovation input.³⁸ This indicator will be a defining feature of evolving S&T systems in the future, effectively housing notions of grass-roots innovation and renewable energy adoption.

Second, clean-energy is increasingly socialized and politicized as a critical component of

climate change, food and water security. The borderless and existential nature of these issues has stepped up transnational commitments, marked by the growing presence of non-state stakeholders in the ‘green’ discourse. The interactions of state and non-state actors are giving rise to a complex network of institutions facilitating S&T transfer and diffusion that are helping to spur innovations in clean-energy. While these interfaces and the security issues mentioned above are not new features of international engagement, using the water-energy-food-climate change “nexus approach”³⁹ to frame sustainability is a relatively new approach, especially in terms of developing ‘nexus S&T’ solutions that harmonize innovation efforts across the security issues. In this respect, clean-energy innovation will most likely be a part of integrated technological solutions to address resource scarcity and sustainability.

Finally, states do matter. In Asia, the state is the main driver for clean-energy development. It is crucial in promoting international S&T cooperation and sustaining the momentum for innovation particularly the central role it plays in the protection of intellectual property rights (IPR). Among Asia’s emerging economies, IPR is still a maturing regime. Even China, poised to become a global leader in various S&T areas including clean-energy, is challenged by a weak culture of IP protection. Asia’s expected lead role in global green growth and innovation will need to be matched by the parallel development of a more effective IPR regime, and the state will be pivotal towards this end.

In the Skyline

This paper set out to examine the scientific and technological dimensions of state responses to the growing challenge of resource scarcity as a way to derive currents filling up the regional and global landscape. The preceding analysis that focused on extraction and adaptation strategies as major ways of enhancing national resource security among Asia’s emerging and developed economies bears out the analytic point of this paper that the emergence of transnational security problems, non-state actors and S&T developments are key drivers of change in global affairs. From their dynamic linkage we derive several propositions:

- Interstate competition for scarce resources will continue to create tensions between countries and will be a long-standing feature of the region’s security landscape. The converging triad of ever-increasing domestic energy demand, the NOCs’ improved extraction technology capabilities and geopolitical/sovereignty considerations will heighten maritime tensions in the region;
- The quasi-governmental NOCs will likely play a greater, more independent role not only in territorial disputes but in shaping national energy policy;
- A strategic alliance coalescing around scarce resources is distinct from a strategic alliance based on S&T capabilities. In the long run, and within the context of climate change, power and wealth will accrue not from control over dwindling resource supplies, but from the mastery of new S&T areas embedded in effective S&T alliances;
- Global S&T leadership will critically depend not just on success with individual technologies or particular scientific fields, Deep-sea mining and clean-energy innovations

highlight the trend for technological systems integration – this converges with the growth of S&T interdisciplinary fields underpinned by the continuous development of IT.

- With their strategic focus on advancing green capabilities, the emerging economies of Asia will become major sources of indigenous, clean-technology innovations, among others; in this context, the region will be a major source of game-changing developments, disruptive innovations and technological surprises;
- The ‘vulnerability and risk’ construct of a green economy is yet to be fully examined; green technologies for one will most likely generate dual-use concerns;
- National core interest management is increasingly dependent on the cumulative activities of multiple non-state actors, so public-private partnerships will continue to flourish. It is possible that this relationship will provide the nucleus for new forms of governance structures. While the state’s power and authority are bounded by territory, the power and authority of transnational entities who operate beyond the state’s control lie in their networked capacity to move people, ideas, beliefs, money, technology and other resources in and out of the state’s territory;
- The nexus of energy-environment-economic security suggest that a systemic approach to transnational security issues will provide more comprehensive and optimal solutions.

Globalization is a permissive environment, engendering the creation and re-invention of actors, institutions, processes and issues. The dynamics around resource security and the role of science and technology in managing resource scarcity illustrate tight and explicit linkages between geopolitics, S&T and economics that produce new settings and conditions with significant implications for global affairs. While it is clear that the state and the international system are undergoing transformations, there is no consensus on what the shape of the future global landscape will look like, but the issue of resource scarcity does sketch out some important variables and developments that will matter in the decades ahead.

Notes

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Climate Change and Environmental Security in the Asia-Pacific Region

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Introduction: Climate Change and Environmental Security in the Asia-Pacific Region

Increasingly over the last five years, national and international security organizations in the Asia-Pacific region are recognizing global warming as a potential threat to environmental security – and thus as a challenge to national and regional security. Some island nations, including the Maldives¹ and Kiribati,² have concluded that climate change poses an existential threat, as rising sea levels could submerge their low-lying islands. Some larger nations, including Australia³ and the U.S.,⁴ are incorporating issues of climate change in their strategic defense planning in anticipation of a higher rate of humanitarian assistance and disaster relief missions. Their concerns center on forecasts of a growing incidence and severity of climate-related natural disasters such as flooding, tropical cyclones and drought, and the consequent impacts on food, fresh water and infrastructure. Such events, together with their potential impacts on human disease and migration, could pose significant stresses on vulnerable nations with limited abilities and resources to respond to environmental strains.

The likelihood of such events is uncertain. Over the next 20 years (2010-2030), best-case and worst-case scenarios based on projected levels of greenhouse gas (GHG) emissions do not diverge greatly. Current projections, extrapolated from historical observations, suggest a rise in average global temperature of about 1 degree C (2 degrees F) by 2030⁵ and a rise in sea level of about 6 cm (about 2.5 in).⁶ Because of the complexity of the climate system, however, scientists cannot unambiguously or precisely associate these phenomena with future environmental impacts and their human consequences. Moreover, linear extrapolations may not fully account for these phenomena as they will be experienced. Nonetheless, there is broad scientific agreement on the general trend: the extra energy input to the Earth's climate system as a result of global warming is resulting in more extreme weather events, and the impact will increase over time. Because the Earth's atmosphere acts as a reservoir for GHGs, there will be a substantial lag time between effective mitigation and any cooling effect at the Earth's surface, so that present trends and their security implications will continue over the next 20 years and more.

Longer-term impacts of climate change are difficult to predict, and will depend in part on the results of international cooperation to reduce GHG emissions in the interim.⁷ The Intergovernmental Panel on Climate Change (IPCC) working group on impacts, adaptation and vulnerability identifies some specific threats to the Asia-Pacific region. These include increased flooding and declining overall water resources in Asian rivers, coastal and river flooding in heavily-populated mega-delta areas, and reduced food production in central and south Asia. Water security problems will increase in southern and eastern Australia, while sea level rise will threaten small

islands in the Pacific and Indian Oceans.⁸ The working group report concludes that “adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions.” They further state that, although many options for adaptation are available, “... more extensive adaptation than is currently occurring is required to reduce vulnerability to future climate change. Existing barriers, limits and costs are not fully understood because they depend on specific, geographical and climate risk factors as well as particular institutional, political and financial constraints.”⁹

Climate Science, Environmental Science and the Security Sector

Climate and environmental scientists are sounding a clear alarm: climate change is likely to pose transnational threats to the security of nations in the Asia-Pacific region and worldwide. Leaders and security organizations across the region are considering and planning to address those threats with a strategic blend of policy initiatives. These include mitigation to reduce the scale of warming, adaptation to cope with the unavoidable impacts of a changing environment, and capacity-building for response to crises that may occur.

Mitigation is largely the concern of the industrial, energy, and transportation sectors. It is the subject of high-profile international negotiations to reduce GHG emissions and the carbon load in the atmosphere. Security organizations with a large carbon footprint can contribute to GHG mitigation. For example, the U.S. Department of Defense has set a goal of 34 percent reduction in facilities’ emissions between 2008 and 2020.¹⁰

Like other sectors, the security sector will have to adapt to emerging climate trends. Changes in polar ice, for instance, will likely impact naval operations. Rising sea levels may pose challenges to coastal area facilities. New patterns of rainfall, flooding, or desertification may impact agricultural systems and could result in long-term demographic changes in some Asia-Pacific nations. The IPCC *Synthesis Report* finds that as a result of climate change, freshwater availability in Asia will decrease in large river basins, while heavily populated, coastal “mega-delta” regions will be at risk from flooding. At the same time, climate change will “... compound the pressures on natural resources and the environment associated with rapid urbanization, industrialisation and economic development.”¹¹ These phenomena will challenge governments in the region and require a whole-of-government approach. As the U.S. Quadrennial Defense Review Report put it, “...climate change will shape the operating environment, roles and missions that we undertake.”¹² It is an assessment that applies to security organizations across the region.

Security organizations typically have major responsibilities in responding to the kinds of natural disasters and humanitarian crises that climate change is expected to exacerbate. In some countries, the military is the only institution with the capacity to respond to a major disaster. Humanitarian assistance and disaster relief (HA/DR) operations are a significant part of the defense mission of

Asia-Pacific nations including the U.S., China, Australia, Japan and the Republic of Korea. An important rationale for such operations is their contribution to security and stability in the affected regions. In the absence of effective planning and action to provide assistance to nations affected by the direct impacts of climate change, it is security organizations that will have the responsibility for coping with the potential social, economic and political consequences of these events to include internal or external migration of climate refugees, disputes over access to water resources, rising food prices, or political instability in nations with inadequate resources to address the additional stresses imposed by climate change.

Meeting the challenges of climate change and security in the 21st century will require leaders and professionals in the security sector to work together with climate scientists, environmental scientists and engineers to develop a high level of understanding of climate change and its impacts over time. Policymakers must be able to pose the right questions to researchers and make good decisions about research funding. The science and technology (S&T) community must learn to communicate their findings to policymakers in a way they can understand and act upon. In the Asia-Pacific region however, networking and knowledge transfer between the S&T and security sectors are still in their early stages of development, especially regarding local knowledge that can support security sector planning for adaptation and response to climate change.

Collaboration Between the S&T and Security Sectors: Global Issues

Research is problem-driven. Issues of climate change, its environmental impacts and their societal impacts present a highly complex and multidisciplinary set of problems that depend in many ways on the needs, the missions and the perspectives of those who articulate the problem. A simplified schematic hierarchy of problems is presented in figure 1 (p. 58). The hierarchy of research questions provides a conceptual framework for understanding the ways in which different knowledge communities approach the problems of climate change. It also provides policy points of departure in terms of where those different communities must interact to frame questions and to share knowledge across professional boundaries.

Scientific communities typically ask the higher level questions in figure 1 and may be associated with the concept of fundamental or basic research. An important stimulus to climate change research, for example, was the work of a chemist, Dr. David Keeling, who developed a device that could accurately measure the atmospheric content of carbon dioxide and, in 1957, installed it at an observatory on top of Mauna Loa in Hawaii. The resulting data, released in 1984, showed that atmospheric carbon was increasing over time, and alerted the scientific world to the threat of global warming.^{13, 14}

Figure 1. A Hierarchy of Climate Change-Related Research Questions

1. What is happening to the Earth's climate and why?
2. What is likely to happen to the climate in the future?
3. What will climatic changes mean for the environment (biosphere)?
4. How will environmental impacts affect the human environment or social order?
5. What can we do to mitigate or adapt to those environmental impacts?
6. What do security organizations need to know to prepare to adapt and respond to those changes?

Global collaboration across S&T communities, with the intention of informing policymaking, was institutionalized four years later in 1988, when the United Nations Environment Program (UNEP) and the World Meteorological Organization established the IPCC. Since 1990, IPCC has issued four reports that synthesize the results of global research related to the physical science aspects of the climate system (Working Group I or WG I), the likely impacts of climate change on natural and socio-economic systems (WG II), and the technological options for mitigating climate change (WG III). Early reports focused on establishing the existence and causes of climate change, and establishing the need for better data to address its impacts. The third report (2001) provided a lengthier consideration of future climate scenarios as climate models improved. The fourth report (2007) continued this trend and provided more substantial consideration of future impacts of climate change on the environment.

IPCC was awarded a share of the Nobel Peace Prize in 2007 after the release of its fourth report. The fifth report is scheduled for release in 2013-2014. Scientists from 22 Asia-Pacific nations are named as lead authors and review editors of this upcoming report, with major representation from China, India, Australia, Japan, Canada, the U.S. and the Russian Federation. All three initial meetings of the global working groups will be held in Asia – China, Japan and the Republic of Korea.¹⁵

In the case of climate change, science has been the spur to policy. The first IPCC report in 1990 led to the creation of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. Although the convention that took effect in 1994 addressed the mitigation of, and adaptation to, climate change, its activities were largely centered on issues of mitigation. This emphasis was continued in the 1997 Kyoto Protocol that was based on the second IPCC report issued in 1995. The third report, in 2001, informed the seventh Conference of the Parties (to the UNFCCC) in Marrakesh, which supported the world's 49 least developed countries in the preparation of a National Adaptation Programme of Action (NAPA).¹⁶ Between 2005 and 2011, 13 eligible Asia-Pacific nations completed NAPAs, with one still in progress.¹⁷ The fourth report, with its increasing emphasis on the inevitability of global warming and greater confidence in projecting its impacts on the human environment, influenced the 2009 Copenhagen meeting. While failing to establish a mitigation treaty, the meeting nonetheless agreed to develop an adaptation framework.

The 2010 meeting saw the adoption by the parties of the Cancun Adaptation Framework and their commitment to establish a UNFCCC Adaptation Committee to help developing countries formulate their national adaptation strategies and gain access to funds for their implementation, work that was advanced at the 2011 meeting in Durban, South Africa, through the establishment of a Green Climate Fund.

The last 20 years, then, have seen the development of global-level institutions for the synthesis and reporting of climate and environmental research in support of policymaking – first with regards to understanding the phenomenon of global warming and then to mitigating the problem through the reduction or capture of greenhouse gases. More recently, the scope of interest has broadened to include issues of adaptation to the phenomenon of global warming which is thought to be inevitable. This interest in adaptation to climate change at the global level as expressed in Marrakesh, Copenhagen, Cancun and Durban, is helping to promote collaboration between scientists and policy professionals working in the arena of international development in both governmental and non-governmental agencies. Much of the focus of these emerging programs is on improving the resilience of national infrastructures to respond to an anticipated increase in climate-induced natural disasters.

However, progress in adaptation planning and implementation at the national level remains a lagging indicator. As of 2010, total funding of NAPA projects through the Least Developed Countries Fund (LDCF) established in 2001 amounts to \$113 million, with less than \$25 million going to Asia-Pacific countries. As a consequence, the Cancun COP instituted measures to improve the ability of nations to design NAPA strategies and to access the fund.¹⁸ Moreover, nations that are challenged by climate change but are not categorized among the least developed, e.g., Vietnam, Indonesia, Pakistan and the Philippines, must rely more heavily on their own initiative and resourcefulness to develop adaptation strategies.

Collaboration Between the S&T and Security Sectors: National and Regional Issues

Policy communities who have need of science-based information to address an issue (possibly associated with applied research) typically ask the lower level questions in figure 1. Since 2005, a growing number of government agencies and non-governmental organizations (NGOs) concerned with environmentally sustainable economic development are asking questions regarding the potential impacts of climate change in their areas of responsibility. In 2007, for example, drawing on the work of academic researchers, consultants and technical staff, the U.S. Agency for International Development (USAID) published *Adapting to Climate Variability & Change: A Guidance Manual for Development Planners*. The agency identified the manual as the “first of several tools” it is developing to “assist planners and stakeholders as they cope with a changing climate.”¹⁹ That same year, the United Kingdom’s Department for International Development (DFID) and Canada’s International Development Research Center (IDRC) co-funded an Asia-wide review of climate change adaptation research.^{20,21,22}

Various reports acknowledge the novelty of these efforts in adaptation research. For instance, the Chinese Academy of Sciences reports that:

“Scientific research capacity in China is strong. Most research attention continues to be devoted to the effects of climate change, including issues of data collection, modeling and climate forecasting. There is also growing attention to the impacts of forecast changes on ecosystems and biodiversity, and to assessments of aggregate costs of climate change impacts and adaptation. However, adaptation as a specific domain of research effort in China is a new concept.”²³

DFID and IDRC are following up on these recent initiatives. DFID, for example, is including climate change research as one of six agency research areas for the five-year period 2008-2013.²⁴ USAID commissioned a feasibility study for the establishment of an Asian regional Center of Excellence on Climate Change and Development.²⁵ The Japan International Cooperation Agency (JICA), in collaboration with the World Bank and the Asian Development Bank, undertook a study of the impacts of climate change on Asian coastal areas. In December 2010, it published *Climate Change Adaptation and International Development*, which presents case studies of climate change and adaptation in Asia and Africa and considers improvements to the international architecture for climate change adaptation assistance.²⁶

Non-governmental organizations (NGOs) concerned with international development, environmental conservation or humanitarian assistance are playing a seminal role in applied research and synthesis to address issues of environmental and human impacts of climate change and to bring the results to the attention of policymakers and other stakeholders. For example, the Woodrow Wilson Center established its Environmental Change and Security Program in 1994, and since 1997 has managed a China Environment Forum to encourage dialogue on environmental and energy challenges in China. The early work of the Pew Center on Global Climate Change established in 1997 was largely concerned with mitigation and its political and economic impacts. However, since 2004, it has increasingly sponsored projects that consider adaptation.^{27,28}

In some Asia-Pacific nations, NGOs are taking a lead in addressing adaptation and security issues related to climate change. For instance, beginning in 2007, Leadership for Environment and Development (LEAD) Pakistan became the first organization in the country to build a database on climate change and in 2008 partnered with the British High Commission to conduct a scoping study on options for adaptation to and mitigation of climate change. In 2009, LEAD established a Climate Action Program, bringing together senior scientists and policymakers to increase the level of awareness of decision makers in Pakistan, to enhance the national capacity and resources to respond to climate change, and to encourage unified government policy responses to the threat.^{29,30}

Major international foundations have also instituted programs for climate change adaptation. The International Organization for Migration, for example, recognizes migration as a legitimate adaptation strategy to climate change.³¹ In 2008, the Rockefeller Foundation established an Asian Cities Climate Change Resilience Network.³² In 2009, the MacArthur Foundation created a

research program on Climate Change, Environmental Security and Natural Disasters³³ and provided funding to develop an Ecosystems and Livelihoods Adaptation Network, explaining that, “mitigation is a necessary but insufficient response. We can no longer afford to dismiss adaptation as ‘giving in’ or worry that it will reduce incentives for addressing the root causes of climate changes. This creative new network will nurture the emerging field of adaptation science, helping to build knowledge and catalyze new ideas.”³⁴

NGOs, think tanks and quasi-governmental institutions operating in the defense and security sectors are also beginning to synthesize climate change research and apply findings to inform policymakers in the security sector. Notable examples include the influential 2007 report by the Center for Naval Analyses (CNA), *National Security and the Threat of Climate Change*,³⁵ and the German Advisory Council on Global Change (WBGU) 2008 report to the German Federal Government, *Climate Change as a Security Risk*.³⁶ These much-cited reports drew upon the fourth IPCC report and social science research on topics related to environment and conflict to provide the first extensive considerations of climate change and its implications for the security sector.

Organizations in the Asia-Pacific region have followed suit: Drawing upon the German report, the Bangladesh Institute of Peace and Security Studies in 2009 published an issue brief on climate change and security, and in 2010, with support from the MacArthur Foundation, launched a research project on the security impacts of climate change on Bangladesh and South Asia.^{37,38} In 2009, New Delhi’s Institute for Defence Studies and Analyses published a report, *Security Implications of Climate Change for India*, addressing issues of adaptation as well as the impact of climate change on warfighting and on India’s bilateral relations with neighboring countries.³⁹ In 2010, Singapore’s Institute of International Affairs published a conference paper on “Climate Change and Security in the Asia-Pacific for presentation at the 2nd Tokyo Seminar on Common Security Challenges.”⁴⁰

These examples illustrate the point that over the last five years, policy-oriented think tanks and NGOs around the region have increasingly come to play an intermediary role between S&T communities and policy communities on topics related to climate change adaptation. Most of that work has been within the development community with a focus on sustainable development and resilient infrastructure in the face of anticipated climate change. This past five years, however, have seen security organizations in the developed nations framing and posing questions about adaptation and response to climate change.

Collaboration Between the S&T and Security Sectors: Security Organizations

In 2010, both the U.S. Department of Defense and the Department of State issued major policy documents recognizing climate change as a transnational threat. The U.S. State Department’s first *Quadrennial Diplomacy and Development Review* identified climate change as one of six focus areas for U.S. development efforts.⁴¹ These policy documents drew upon a growing body of agency and agency-sponsored research and analysis as well as that of academia, international organizations and NGOs. For instance, in 2007, the U.S. Army War College’s Strategic Studies Institute

conducted a colloquium on national security implications of climate change. The proceedings of the conference include 21 essays that tackle issues of climate science, environmental and human impacts, and military planning in the context of climate change.⁴² In 2009, the U.S. Navy established Task Force Climate Change (reporting to the Chief of Naval Operations), and in 2010, published the first “U.S. Navy Climate Change Roadmap” that focused on the identification of S&T needs to inform naval operations in the context of a changing climate.⁴³ As noted above, in 2009, the Australian national defense strategy addressed issues of climate change and its threat to security in the Asia-Pacific region.⁴⁴ These national level policies are only beginning to show up in planning agendas at lower echelons.

The Chinese government is also responding to climate change issues at the intersection of science and policy. English language resources include a major policy document “China’s National Climate Change Programme” approved by the State Council in June 2007. The program focuses on mitigation but also addresses adaptation, with considerations of agriculture, forestry, water resources, and the threat to coastal zones.⁴⁵ Chinese policy for adaptation to climate change is framed by an economic development perspective, and emphasizes the need for sustainability in development activities. Duncan Freeman argues that climate change has only a marginal position in Chinese security policy, and that China resists the notion that security and climate change are linked.⁴⁶ However, according to a report by China scholar Michael Davison, the Chinese People’s Liberation Army (PLA) created a Military Climate Change Expert Committee in November 2008 to discuss the threat of climate change to military capabilities. The committee suggested strategies for disaster relief missions, and the PLA National Defense University has conducted a preliminary study.⁴⁷

The security dimension of climate change in other Asia-Pacific nations is often less developed and not as readily transparent. For instance, the Bangladesh Climate Change Strategy and Action Plan managed by the Ministry of Environment and Forestries identifies the National Disaster Management Council as a lead agency for responding to climate change. It also identifies a role for the Meteorological Department as well as the National Space Agency that falls under the jurisdiction of the Ministry of Defence.⁴⁸ In Indonesia, an observer with the Centre for Strategic and International Studies notes that the country’s Ministry of Defence had no specific national security agenda for climate change as recently as 2008. After the election of a new president in 2009, however, a strategic defense review and a “Minimum Essential Force” document identified climate change as a potential threat for consideration in developing Indonesia’s strategic security requirements.^{49, 50}

Regional security organizations and conferences are also beginning to serve as forums for knowledge exchange on climate change. In March 2010, for example, the Tokyo-Seminar on Common Security Challenges included a session on “Climate Change and the Role of the Armed Forces.”⁵¹ In April 2010, the leaders of ASEAN issued a statement on climate change in response to the Copenhagen Accord. The statement was in two sections. The first articulated a set of common policies toward GHG mitigation. The second called for regional cooperation in addressing resilience (adaptation) to climate change, including scientific collaboration to determine local

impacts, and cooperative research for food security. The joint statement is written from a sustainable development perspective, and does not address traditional security issues such as humanitarian assistance or disaster relief.⁵² In April 2010, the South Asian Association for Regional Cooperation (SAARC) issued the Thimphu Statement on Climate Change by which its members agreed to a set of 16 actions to cooperate on climate change issues of mitigation and adaptation. It also exhibits a development-focused conceptual framework. Only one of its 16 articles addresses security sector issues: Section (xiv) calls for the establishment of a SAARC Inter-governmental initiative on climate-related disasters to be supported by a SAARC Disaster Management Center.⁵³

One can argue that the securitization of climate change is an emergent issue in the region. Government ministries in the U.S. and Australia and non-governmental or quasi-governmental think tanks in nations including Japan, India and Bangladesh are starting to consider the role of the security sector in adaptation and response to the impacts of climate change. Most documents recognize a need for better science-based knowledge of local impacts to guide policy for climate change adaptation. However, robust institutions for a science-security dialogue are largely notable for their absence.

Collaboration Between the S&T and Security Sectors: Interagency Collaboration

The interface of science and policy at the national level implies an effective mechanism for interagency cooperation that brings together scientific and security agencies. China, for instance, established a National Working Group for Dealing with Climate Change in 1990 and a National Coordination Committee on Climate Change in 1998. The 2007 national climate change program drew upon the committee's *National Assessment Report on Climate Change* (2006), a collaborative effort of nine government departments including the Ministry of Science and Technology, the China Meteorological Administration, the Chinese Academy of Sciences, the State Environmental Protection Administration, the National Development and Reform Commission and the Ministry of Foreign Affairs. The new national policy in turn upgraded the working group to a National Leading Group headed by Premier Wen Jiabao under the jurisdiction of the National Development and Reform Commission.^{54,55,56}

In the U.S., Congress created a U.S. Global Change Research Program in 1990 under the White House Office of Science and Technology Policy. The program coordinates and integrates federal research on changes in the global environment across 13 federal agencies including the Departments of State and Defense. Until recently, the program focused on the fundamental questions of climate science and environmental science at the top of figure 1. But in 2008, the program revised its strategic plan to consider the associated issues of climate change impacts, adaptation, vulnerability and sustainability, as well as decision support to stakeholders.⁵⁷ Interagency consideration of science and policy for adaptation to climate change assumed higher visibility with the establishment of an Interagency Climate Change Adaptation Task Force in 2009, and its charge by the President that agencies should participate actively to develop a domestic and international strategy for adaptation to climate change.⁵⁸ A year later, in its first progress report, the task force established a set of five goals

that included improving the integration of science into decision-making to support adaptation and enhancing efforts to lead and support international adaptation. This goal specifically addressed a need for collaboration among international development, national security and technical support agencies.⁵⁹

The importance of such interagency coordination is underlined by a May 2010 report from the French Institute of International Relations, an NGO, which recommended that Japan should “improve the governance on climate change by enhancing governmental coordination. Lack of intra-governmental communication and cooperation prevents the elaboration of a consistent and coordinated approach to tackle the issue of climate change. A supra-bureaucratic organ should coordinate the different administrations.”⁶⁰

Other Asia-Pacific nations have formed interagency groups to link science and policy. In 2010, Singapore’s Inter-Ministerial Council on Climate Change, established in 2007, was reconstituted as the National Climate Change Secretariat and assigned to the Prime Minister’s Office.⁶¹ Australia took a different approach, creating a cabinet-level Department of Climate Change in 2007 that was recently reorganized as the Department of Climate Change and Energy Efficiency.

Climate change issues are a concern for the whole of society. They engage the energy and transportations sectors on issues of mitigation. They inform economic development as well as the security sectors on issues of adaptation and response. They require the engagement of the research and development sectors for their understanding and solution. Interagency coordination and collaboration will be necessary to effectively address these complex problems. Transnational interagency collaboration through multilateral and bilateral relationships must also be developed to address transnational problems. Sharing of best practices among nations and the development of better practices within and among nations will be an important part of the agenda for the future.

Summary Observations and Conclusions

There can be little doubt that the threat to environmental security of global warming is real and of central interest to security organizations in the Asia-Pacific region and the world. Scientific understanding of the cause and the process of climate change is extensive and growing and provides a knowledge base for national and international efforts to mitigate GHG emissions. Many Asia-Pacific nations are active in fundamental climate and environmental research and participate in the IPCC system. All are engaged in the UNFCCC process. Knowledge sharing on mitigation issues is institutionalized, and security agencies are engaged in meeting national goals for GHG mitigation.

In recent years, especially since the fourth IPCC report in 2007, policymakers across the region are increasingly concerned with problems of adaptation to climate change. NGOs concerned with sustainable development are playing an important role in framing the problems of adaptation to climate change and have an intermediary role in linking the S&T and policy communities. Increasingly, security organizations – at this time primarily defense and foreign ministries in the major developed nations – are starting to anticipate the need to adapt to the impacts of climate

change on human and environmental security and thus on national security and regional stability.

Perhaps most importantly, Asia-Pacific nations are building their capacity to address the security problems associated with climate change. Interagency task forces are bringing together scientists and security professionals at senior levels to foster a whole-of-government approach to the problems of climate change. Multilateral security organizations and conferences are considering issues of adaptation as well as mitigation. Agencies and organizations at the national, regional, and global levels are cognizant of the need for better scientific knowledge of the local impacts of climate change on the physical and social environments.

At this time, the emerging linkages between S&T communities and security communities are most apparent in developed nations at the national agency level, with a focus on issues of adaptation. Many less developed countries do not appear to be well-engaged in research and planning for adaptation to climate change. Sub-national-level actors who will typically be tasked with responding to chronic or acute security impacts of climate change are not transparently engaged in formulating the questions for research. Nor are the pathways for knowledge transfer fully developed.

As the security sector develops plans for adaptation and considers planning for response to the impacts of climate change, there is an emerging need for more robust institutions to support a broader and deeper dialogue between S&T and security communities. Security practitioners should develop questions to task research communities and then work together to develop requirements and approaches to respond to the stresses imposed by climate change. Multinational forums should seek to develop common frameworks for addressing security problems in response to climate change. A corresponding need exists for sharing research, knowledge transfer, and problem assessment between developed and developing nations.

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Nuclear Energy, Nuclear Weapons and Security in the Asia-Pacific Region

Presentation Summary

Bill Wieninger, Ph.D.

Dr. Wieninger opens his talk by pointing out how the energy derived from splitting the atom continues to vex mankind with its great potential for both prosperity and destruction. He then proceeds to discuss how this plays out in the Asia-Pacific to date, highlighting important trend lines for the immediate future and identifying areas for regional cooperation and conflict.

Almost 70 years after the Chicago pile started operations, the International Atomic Energy Agency (IAEA) identifies 441 power reactors worldwide providing some 374,692 megawatts of electricity, with 251 of these operating in Asia (including 104 in the U.S.). Dr. Wieninger points out that if the U.S. and Russia are dropped from the count, Asia accounts for 116 reactors or 26 percent of the world's reactors. But with 60 percent of the world's population, Asia is still lagging in nuclear power generation.

Sixty-five years after the detonation of the first atomic bomb, Asia is unfortunately the site of a more proportionate number of the world's nuclear weapon states, with 45% of known weapons states (China, India, Pakistan, and North Korea) found in the region. Moreover, it contains two of the world's most dangerous flash-points (India-Pakistan and the Korean Peninsula), the sensitive issue of Taiwan, as well as being the global sub-region with the highest number of terrorist attacks (South Asia). In terms of numbers, estimates vary, but the Center for Defense Information states China, India, and Pakistan have 250-320, 50+, and 40-70 nuclear weapons, respectively, with North Korea estimated to possess 4-8 weapons. Thus, Asia is currently in the unenviable situation of maximum danger and minimum opportunity with regard to nuclear technology. Dr. Wieninger argues that this needs to change. He adds that the good news is that least in terms of nuclear energy, there are some positive developments. Prior to the catastrophe at the Fukushima nuclear power plant in Japan in March 2011, the International Atomic Energy Agency (IAEA) reported that 49 of the 60 reactors under construction worldwide were in Asia, although the region still has relatively fewer of current operational power reactors. He provides a breakdown of the state of nuclear reactors in the region as follows:

- China is without question the most ambitious and furthest along with 13 operating reactors and 23 currently under construction;
- Russia has the second most ambitious plan, with 32 operating reactors and 11 reactors in the works;
- South Korea, whose 21 nuclear power plants generate 40 percent of her electricity, has five reactors under construction;

- India has 20 nuclear power plants supplying 3 percent of the nation's electricity and has 4 reactors under construction (notably, one report indicates that India could import up to 40 reactors by 2020);
- Taiwan has 6 operating reactors supplying 17 percent of electricity and two under construction; and
- Vietnam is pursuing power reactors and has signed initial agreements with the U.S. to do so, although the timeline for construction remains uncertain.

Unfortunately, experts also foresee a growth in nuclear weapons in the coming decade. Dr. Wieninger points out that:

- Although North Korea's plutonium production facilities at Yongbyon have not been restarted since 2008, it is quite possible that they are growing a hidden uranium enrichment program;
- Pakistan continues to grow its arsenal, with an ongoing uranium enrichment program and a growing plutonium production capability; and
- India's access to fertile material dramatically increased subsequent to the 2008 nuclear agreement with the U.S. (although to date there is no indication this has led to an increase in fissile material production).

Despite the suboptimal situation with regards to weapons proliferation (which is mostly vertical proliferation), there are a number of areas for international cooperation, notably in the terms of safety, security and fuel supplies. For instance, there was robust cooperation among various stakeholders in safe reactor design, construction, and operation even prior to the incident at Fukushima, as demonstrated by the continuing cooperation between Westinghouse, Southern Power and China on construction and the eventual operation of AP1000 reactors in the U.S. and China. With good leadership, the tragedy at Fukushima could lead to much greater regional and international collaboration on safety as it did in the U.S. in the wake of the Three-Mile Island accident in 1979 that led to the subsequent creation of the Institute of Nuclear Power Operations.

Dr. Wieninger also suggests that a regional nuclear society to foster information exchanges and expert knowledge could be another form of collaboration, pointing out that Europe has such an agency called the European Nuclear Society that includes 27 national members and many corporate members. Scientific exchanges between technical experts have proven beneficial in promoting better international relations in the past, so this could be a powerful tool for enhanced regional cooperation.

Finally, a third area for potential cooperation among countries could be in the process of nuclear fuel cycle itself. Countries in the region either have nuclear-related requirements or resources and capabilities that animate the cycle at different phases, while some states have uranium supplies (Mongolia) or possess robust fuel production capabilities (Russia), others have a growing demand for clean energy (China, Vietnam). There will be political obstacles that could temper fuel cycle cooperation, but regional energy leaders should regard it an important avenue for consideration.

Dr. Wieninger concludes with a discussion of issues that will shape the nuclear landscape. First are technological advances that could allow for the enrichment of uranium using lasers. Experts have investigated laser isotope separation for years, but have yet to be commercially viable. Were the technical and engineering challenges to be mastered, it would likely reduce the cost of fuel for power reactors. Given that the cost of fuel is not a major impact on the economics of nuclear energy, this would not heavily impact the attraction to nuclear power. However, such technology would also greatly increase the risks of weapons proliferation as it would theoretically be easier to operate clandestine facilities for the illicit production of fissile material for weapons.

Second, he argues that the risk of major accidents can never be completely eliminated. Historically, accidents such as the Three Mile Island and Chernobyl have prompted dramatic shifts in the use of nuclear power in much of the world. However, this need not always be the case. For example, France maintained its course on nuclear power despite the two major accidents. Additionally, the U.S. Navy's long history of safe reactor operations demonstrates that with the proper human systems in place, the risk of accidents will be extremely low. For all the horrors of a major accident, the simple truth is that mortality risks from nuclear power are dwarfed by those posed by fossil fuels, whether one considers particulate pollution, carbon emissions, supply stability, extraction pollution or transportation accidents. Ultimately, it will be incumbent upon leaders in the energy security arena to highlight the relative risks of different sources of energy generation.

Finally, nuclear power remains problematic due to proliferation concerns. For this reason, government policy will need to play a key role in all things nuclear, particularly in the establishment of a strong and effective regulatory framework that reduces the dangers of nuclear weapons proliferation, nuclear facility incidents and waste management. Moreover, states should also enhance international cooperation to optimize the use of nuclear energy, given its potential to mitigate pollution and climate change.

P L E N A R Y S E S S I O N 3 :

U P D A T E O N S C I E N C E
& T E C H N O L O G Y
D E V E L O P M E N T S W I T H
S I G N I F I C A N T S E C U R I T Y
I M P L I C A T I O N S

Category #1:
Information Technology

The Cybersecurity Landscape

Presentation Summary

Richard C. Schaeffer, Jr.

Mr. Schaeffer characterized the cyberenvironment as continuously accelerating, evolving and expanding. He points out that from December 1995 to March 2001, the number of Internet users grew from 16 million to 458 million, and by January 2009, there were over 1.5 billion Internet users. A projection of this trend indicates that the number of Internet hosts is expected to exceed human population around 2015: as the world's population tops seven billion, the number of internet hosts is estimated to exceed 10 billion.

Key to better understanding the threat environment of cyberspace is to know that it is a highly complex space that consists of numerous layers of networking systems. What we actually see forms only part of this environment, as most of cyberspace remains invisible to Internet users. Mr. Schaeffer notes that there are at least five layers operating in the computer network: the geographic layer, physical network, logical network, cyberpersona and the persona layer. It is the dynamic operation of this complex network of systems that has created both security and insecurity to its



FIGURE 1 Threat Environment – Steady State

users. According to Mr. Schaeffer, cyberuse immensely informs the “steady state” of the threat environment worldwide, as shown in Figure 1 (page 75). In order to manage the growing and equally complex risks related to cyberspace, Mr. Schaeffer suggests four ‘must-have’ drivers of Information Assurance (IA) capabilities:

- the rapid introduction of new technology and services: vulnerability discovery capabilities must keep pace, and IA solutions must be available at the speed of the IT business and customer cycles;
- leverage and influence commercial activity: this is vital because commercial IT dominates most systems, and commercial IA is growing;
- continuously strengthen weakest links (people and systems) because global communication and connectivity continue to expand; and
- pay close attention to the impact and implications of Facebook, My Space, Twitter, and other yet-to-be discovered social networking capabilities.

What it will take to be secure, according to Mr. Schaeffer, is a “coalition of the connected” because cyberspace is global, interconnected, belongs to no one, and will take the combined talents, efforts, and capabilities of government, private industry and allies to secure it.

Regional Collaboration in Cybersecurity

Presentation Summary

Robert D. Childs, Ph.D.

In his presentation, Dr. Childs argues for urgent and strengthened regional collaboration in cybersecurity. He opens with a 10-minute video of a possible scenario where former U.S. officials are playing the role of top government leaders who are gathered to discuss possible responses to an as yet unconfirmed cyberattack on U.S. critical infrastructure. Results of the emergency meeting will directly be briefed to the President. Dr. Childs believes that this simulation reveals the reality of cyberattacks and cyberwar, and nations must act in concert to find and implement appropriate responses. He provides a rundown of the strategic ramifications and issues of cyberattacks as follows:

- Estonia is one of the few countries to experience an open act of cyberterrorism and cyberwar; its experience is not an isolated one – it will be repeated in the future;
- the more advanced a country is in using technology, the greater the effects of a cyberattack or network denial of service will be;
- there is a need for a global perspective on how to deal with the effects of cyberisolation instigated by a determined enemy;
- the Internet is part of our lives now – we cannot simply disconnect from it, but we must determine how we are to live in it; cyber is virtual but has become the “fifth domain,” (and the fourth commons) that is as real as any physical domain (land, sea, air and space); and
- the ability to assign attribution is key to dealing with the strategic impact of cyberattacks; with attribution, nations must build trust: trust in one another’s desire for national security and trust to share information on cyberthreat warnings and indications; without trust, there can be no appropriate response or retaliation to a cyberevent.

Gross Domestic Product (GDP) leaders like the U.S. depend on the Internet to maintain positive GDP growth, but Dr. Childs cites that China and India have surpassed the rest of the world in numbers of Internet users with Vietnam coming up fast. The implication is that the ability to influence the governance of the Internet will be the countries with the most users, and it is thus incumbent upon all nations to seek collaboration to collectively improve cybersecurity.

Moreover, the techtronic forces driving global change on all aspects of human society are IT-based. Dr. Childs mentions two factors in particular: economic virtualization and margin expenses, and the technology itself. He points out that the explosion of online economic activity has gone hand-in-hand with the notion of borderless networks and now enhanced by cloud computing. Furthermore, economic virtualization has engendered technology expectations that are now “trickling up” from home use to work. Three technology-related trends will define change in the

future: the continued proliferation of commercial devices, the shift to Internet Protocol version 6 (IPv6) that will provide a massive increase in IP addresses from 2³² to 2¹²⁸, and the unabated growth and spread of social media and the “New Millennial” users. Dr. Childs notes that cloud computing will pose the next security challenge in four areas: trust (in turning over data to others), control (location of the servers), information assurance, and supply and demand.

Existing challenges continue to be daunting. Operationalizing the definition of ‘cybersecurity’ is a major and global issue. In the U.S., competing frames of what cybersecurity is revolves around four areas: economic prosperity, privacy rights and civil liberties, public safety and law enforcement, and national security.

Finally, he points out that if regional collaboration in cybersecurity is going to improve, nations have to address some key issues, namely information sharing, attribution and mitigation steps, rules of engagement, and the borderless nature of cyberspace (this is an important consideration if potential partners collaborate to organize a cyberspace joint area of operations that allows collaboration in a timely fashion).

The Current State and Future Landscape of Cybersecurity: A View from Russia

Presentation Summary

Igor Kotenko, Ph.D.

The first part of Dr. Kotenko's presentation provides a broad survey of the current and future state of information and communication technologies (ICT) as well as the current and emerging security issues related to ICT. The second area of his discussion outlines Russia's policy response to IT security. In the final section, he shares some of his thoughts on international collaboration in the area of cyberspace security.

In the first part of his talk, Dr. Kotenko discusses the trends defining the future of ICT as follows:

- a worldwide broadband network based on fiber optics, communication satellites, cellular and microwave communication;
- increasing availability and accessibility of "anytime, anywhere" face-to-face, voice-to-voice, person-to-data and data-to-data communication systems;
- the 'Internet of things': the ubiquitous availability of computers will facilitate automated control and make continuous performance monitoring and evaluation of physical systems routine; and
- a rapid increase in the number of homes with integrated systems (and a consequent rise in smart and smarter integrated homes) with the ability to plug into the global communications network at increased speeds.

He also briefly outlines some of the common computer attack trends:

- increasing level of automation and penetration speed of attack tools;
- increasing sophistication of attacks;
- increasing speed of 'vulnerabilities discovery';
- exploitation of global internet security policy gaps; and
- increasing number of entities (countries included) with the capacity to develop cyberweapons.

Dr. Kotenko points out that modern and future malicious software have what he calls "key peculiarities" that pose serious challenges for crafting appropriate cybersecurity policy strategies and responses. Among those malicious software features are:

- a flexible control system – minimizes the risks of successful detection and disinfection;
- a stage-by-stage infection scheme – allows the maximum extent of invisibility up to the final destructive stages (e.g., up to the execution of the module implementing a viral functionality);
- a module-based scheme of the update process – provides functional and structural variability to the forming mixed (mashup) malicious software;
- effective mechanisms of concealing presence from the attacked host (these include mechanisms focused on the active stage of the malware life cycle);
- presence of active mechanisms for counteracting against the host's anti-malware software;
- use of cryptographic algorithms; and
- use of cloud computing.

The ICT revolution continues to pose challenges because the Internet was not initially designed to be a critical part of the economic infrastructure. The current and emerging problems and concerns stemming from its pervasive use arose from the unanticipated trajectory of ICT development on a global basis. Dr.Kotenko raises some of these issues, emphasizing that these have serious implications for national security:

- the Internet will triple the number of people now connected, from one billion to three billion in the next 3-5 years;
- there will be additions of billions – perhaps even hundreds of billions – of devices in the virtual globe (e.g., sensors, tags, micro-controllers);
- net-delivered services will continue to reshape the world;
- user-generated content is leading to a massive increase in the creative flow of content and processes;
- there will be increasing pressure to address the need to balance between the perceived need for control with the creativity that spawns innovation (and profit);
- there is a need to examine the question of whether the future is going the way of tethered appliances or generative technology;
- current architectures are open to security breaches, privacy invasion and identity theft; and
- criminals and terrorists will have at least the same access to the Internet as most people, and in the future they will be better educated, more insidious and will use the newest technologies.

The future of the Internet is one of great complexity in information technologies and systems. The key is to have collaborative end-to-end security and trust in highly complex networks and services. Dr. Kotenko asserts that non-functional requirements such as trustworthiness should be a part of the design and construction of future systems. He defines trustworthy ICT as technologies that are secure, reliable and resilient, can survive attacks, guarantee a desired level of service, protect user data and privacy, and provide usable and trusted tools to support the user.

In ending the first part of his presentation, Dr. Kotenko briefly mentions what he considers to be one of the most important and intriguing direction of current research in the area of cybersecurity:

the creation of auto-adaptive, survivable, self-generative systems. These systems have at least three key features: provide 100 percent critical functions at all times in spite of attacks; able to learn own vulnerabilities to improve survivability over time; and able to regenerate service after attack.

His discussion of Russia's response to growing cybersecurity concerns focuses on two official documents: the "National Security Strategy of the Russian Federation to 2020" (Presidential Decree No. 537, issued in May 12, 2009), and the "Strategy for Developing an Information Society in Russia" (authorized on February 7, 2008). The first document is a provision in the "Organizational" section (Section V) of the national security strategy subtitled "Legal-normative and informational foundations of the realization of the given strategy." It decrees that in order for Russia to develop a "system of Situational Centres" in the intermediate term, "it will be necessary to overcome technological lag in the most important areas of IT, telecommunications, and interconnectivity, which determine the state of national security." The provision also calls for Russia to "develop and introduce technologies of information security into systems of government and military administration, systems of management of ecologically dangerous products and critically important sites, and to create conditions for the harmonization of the national information infrastructure with global information networks and systems."

The second document outlines the steps for Russia to transform itself into one of the world's leaders in "post-industrial development and significantly bolster its information security" and aims to see Russia's share of ICT-based production increase to at least eight percent of total national exports by 2015. This is in part Russia's initiative that articulates its support for the two phases of the World Summit on the Information Society (WSIS) in Geneva (2003) and Tunis (2005), as well as its approval of the Okinawa Charter on Global Information Society that was signed by the G8 leaders on the occasion of the G8 Summit in Kyushu-Okinawa in 2000. The charter aims at "integrating efforts to bridge the digital divide into a broader international approach."¹ Special attention is given to the international negotiating processes revolving around three aspects: military-political (including informational and psychological) security, cybercrime and cyberterrorism.

In the third and final part of his presentation, Dr. Kotenko shares his thoughts on cyberspace security as an emerging area for international collaborative research. He stresses that in response to the economic loss and destabilization on the global scale caused by growing cyberattacks, governments and the professional communities must increase collaborative efforts now and in the future. According to him, the bottom line of these efforts must be the development of mutual trust between specialists that he hopes will lead to the development of mutual trust between governments around the world.

Notes

1. Alfredo M. Ronchi, *ECulture: Cultural Content in the Digital Age* (Google eBook, 2009): xvi.

P L E N A R Y S E S S I O N 4 :

U P D A T E O N S C I E N C E
& T E C H N O L O G Y
D E V E L O P M E N T S W I T H
S I G N I F I C A N T S E C U R I T Y
I M P L I C A T I O N S

Category #2:
Biotechnology

Biotechnology and its Potential Impact on Global Security

Lynn W. Jelinski, Ph.D.

Biotechnology – the ability to understand and manipulate biology at the molecular level – is likely to continue to have a profoundly positive impact on the human condition. For example, we have already seen great advances in the treatment of complex viral diseases such as AIDS, in our understanding of the genetic basis for diseases such as breast cancer, and are beginning to unravel the genetic, molecular and environmental underpinnings of autism and Alzheimer’s disease. This trajectory is likely to accelerate in the years to come. In addition to its application to human health care, biotechnology has already had a substantial impact on agriculture. For instance, DNA markers are used to guide the conventional breeding of plants for greater yield and nutritional value, and we have genetically modified corn that is resistant to plant pests.

Biotechnology can also provide the basis for exquisitely sensitive sensors that are already used in diagnostic kits, including those for the measurement of glucose for diabetics and for a wide range of food safety applications. When coupled with nanotechnology and microelectronics, one can imagine ever more accurate insulin pumps, crop management tools and water safety monitors.

Its benefits notwithstanding, biotechnology comes with its own set of complex ethical issues, including cloning, use of fetal stem cells, whether individuals and insurance companies should have access to the knowledge about cancer markers, and the consumers’ right to have foods derived from genetically modified organisms so labeled. We must address these ethical issues in a globally responsible way to reap the full promise of biotechnology.

Trajectory of Biotechnology in the Next 20 Years

Many of the intellectual underpinnings of biotechnology are already in place to safely predict that biotechnology will continue to have a very positive global impact over the next 20 years. For example, molecular tools, rapid sequencing technologies, partial libraries of genomes and high speed computational algorithms to mine these libraries are in place. Projection of the future is difficult because discontinuous innovations are required to change the world as we now know it. For instance, it is hard to believe that less than 20 years ago CERN (the European Organization for Nuclear Research) published what is considered the first public face of the world wide web project, which grew out of private, defense and research investments in networks starting in the 1960s. The innovation that gained enormous acceptance was when TCP/IP protocols could adapt to existing communications protocols. Today, it is hard to imagine life without the internet. We now have an entirely new vocabulary including terms such as google, URL, Facebook, Skype, Wikipedia and eBay. We have instant access to information and new means of communicating and performing everyday activities such as buying airline tickets, paying bills and researching our ancestors. It is also hard to believe that Motorola made commercially available the first portable cellular phone

only in 1983. Now nearly everyone has one or two, with functionality that includes access to the internet, voice and text communications, GPS, and digital cameras.

As is the case for information technology, discontinuous innovations in biotechnology have changed the world as we know it. For example, DNA fingerprinting was first used in a criminal investigation in 1986. The human genome project officially began in 1990 and a working draft was available by 2000 (five years earlier than projected), spurred by advances in sequencing and computation. Dolly, the cloned sheep, was born in 1996 and introduced to the world in 1997. And in 1996, Roundup Ready soybeans were commercially available; by 2005, 87 percent of the U.S. soybean fields were planted with them.

These examples from the past illustrate two points. First, discontinuous innovations rest on the shoulders of visionary people and take advantage of a strong underpinning of basic knowledge and applied research. Second, the future holds great promise for additional discontinuous innovations in biotechnology if we continue to nurture the underlying intellectual base and build the human capital capable of challenging the status quo.

In this paper we define six global security issues that could benefit greatly from biotechnology approaches over the next 20 years, coupled of course, with informed policy. We set forth challenges in each of these six areas with the goal of changing the world as we now know it. Our goal is a New Secure World.

Applications of Biotechnology to Security Issues



FIGURE 1 Six areas of global security in which biotechnology could have a major impact over the next 20 years

How Biotechnology Might Affect Global Security Issues

Although global security issues are legion, we will focus here on six areas in which biotechnology could have a major impact. These are energy security, security to extremes in climate, health security, security from acts of terrorism, water security, and food security (figure 1, p. 86). Although we will discuss each of these in turn, we show at the conclusion of this paper that these areas are largely interrelated and we advocate a systems approach to them.

Energy Security The world's supply of oil, gas and other fossil fuels is limited, and furthermore, burning of fossil fuels contributes to global greenhouse gas emissions. Although new fossil fuel discoveries continue to be made, considerable uncertainty exists in the amount of reserves and the rate in which they are being depleted. Figure 2 depicts the percent of known oil reserves in 2009 by geographic area. Most would agree that because our supply of fossil fuels is finite, we must do something, whether nuclear energy, alternative fuels, hydrogen fuel cells, or conservation, to continue a sustainable trajectory of global population and economic growth.

In this section we briefly discuss various options for producing biofuels and how advances in biotechnology might accelerate their production in an economically and environmentally responsible way.

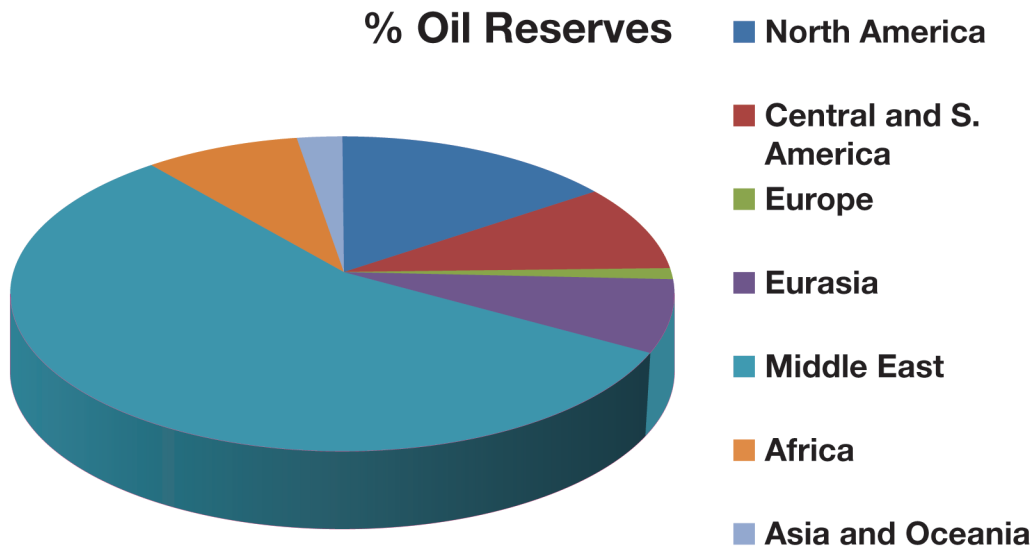


FIGURE 2 Percent of world's known oil reserves, 2009. **SOURCE:** Compiled from data obtained from <http://www.eia.doe.gov/emeu/international/reserves.html>

- *Ethanol as a Biofuel* Biotechnology offers the promise of producing sustainable biofuels and biodiesel from plant feedstocks.¹ In Brazil, for example, the fermentation of cane sugar to ethanol, coupled with new infrastructure and policies for cars capable of running on “flex” fuel, has shown that biofuels can be produced in a sustainable way. In 2009, Brazil produced 29.4 billion gallons of ethanol for fuel, or 37.7 percent of the world's supply.² Ethanol can be

fermented directly from sugar in the sugar cane feedstock, making the process economically viable when the price of gasoline is sufficiently high. Because in the U.S. sugar cane grows only in Texas, Louisiana, Florida and Hawaii, this route to ethanol is less attractive in the U.S. than it is in Brazil or Central America.

To produce ethanol from corn, the cornstarch must be converted into sugars before fermentation. This conversion is expensive and furthermore, the process of making ethanol directly from corn is environmentally less desirable and competes with corn as a source of food. In the absence of an inexpensive source of sugar, the conversion of cellulosic feedstocks into ethanol or biodiesel is more likely, ultimately, to be an economically viable and sustainable route to biofuels.

- *Cellulosic Feedstocks for Fuel* Cellulosic feedstocks such as switchgrass and corn stover can be converted into sugars and lignins and then fermented into ethanol, or converted via pyrolysis into biofuels. Biotechnology is being used to optimize both scenarios. For example, lignins interfere with the fermentation process and scientists are examining ways to remove them. In addition, cultivars of perennial grasses are being improved, just as turf grasses were, by selective breeding using genetic markers. Finally, one could imagine learning about new processing enzymes from termites, whose guts are capable of digesting cellulose.
- *Algae to Create Biodiesel* Biodiesel is produced in the U.S. from soybeans and in Europe from canola oil. Both are expensive propositions. An alternative approach is to harvest biodiesel from algae grown in high density.³ This has been pioneered by a number of demonstration projects, among them the Redhawk power plant near Phoenix, Arizona, in which algae were maintained in plastic bag-like containers.

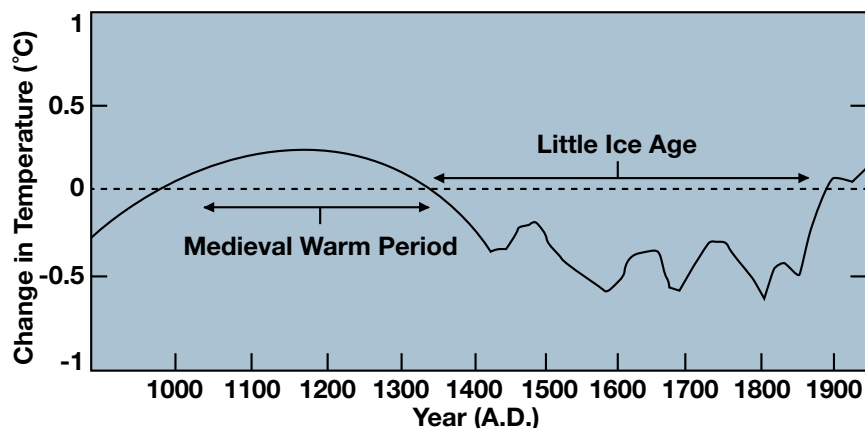


FIGURE 3 Smoothed and averaged regional proxy data illustrating the Medieval Warm Period and the Little Ice Age.
SOURCE: http://www.geocraft.com/WVFossils/ice_ages.html

Security to Extremes in Climate Although the exact predictions about global warming have recently been called into question⁴ and debate continues over the degree to which anthropogenic activity has influenced global climate,⁵ several issues are clear. First, the earth's climate has previously undergone warming and cooling periods (figure 3), although the global extent of these temperature swings is unclear, as historical records and proxy measurements were used to construct the analyses.⁶ Nevertheless, the Medieval Warm Period (ca. AD 950 - 1250) is one in which Europe was balmy and grapes grew in England. During the subsequent Little Ice Age the Thames repeatedly froze over. In addition, between 1900 and 2005, where actual temperature measurements were recorded, temperatures at Earth's surface increased about 0.8 degrees Celsius.⁷

Potential impacts of global climate change include weather extremes, changes in sea level, ocean warming, flooding, new regional rainfall patterns, new temperature extremes, threats to human health and reduced crop yields. It is appropriate and timely that we develop contingency plans for the global security issues described here, should recent climate change predictions come to fruition. Failure to adapt to these changes could be a source of national and international instability particularly in climates and geographical areas most affected by climate extremes.

Biotechnology can address many of the uncertainties predicted by climate change including: the development of plants either bred or engineered to adapt to extremes in temperature, crops that can withstand stress and are tolerant to drought or saline. Adaptive strategies could also involve developing agricultural cropping systems that require reduced water and nitrogen inputs and sequester more carbon than is currently the case.

Over the past several decades biotechnology and plant breeding approaches to drought tolerance have been the subject of intense investigation. We now have a better understanding of the roles of regulatory networks, gene expression and signal transduction.⁸ Nevertheless, the commercial production of drought resistant plants is in its infancy and we may well need a discontinuous innovation to bring it to reality.

Health Security The future of biotechnology is bright when it comes to predicting its impact on human health.⁹ We are likely to see advances in areas such as personalized medicine, drug delivery, gene therapy, vaccines and regenerative medicine. Many of these advances will stem from molecular diagnostic tests now capable of interrogating specific points in the chain: "DNA makes RNA makes protein" as markers relate to disease progression and personal response to treatment.

While these advances in healthcare will greatly improve quality of life, some are also directly applicable to global health security issues. For example, outbreaks of pandemic diseases and chronic debilitating diseases create economic disruption and place heavy demands on medical and social services. In this section we focus on three areas in which medical biotechnology, both diagnostic and therapeutic, can have a large impact on global security. The ultimate goal is to use biotechnology to move from treatment of disease to prevention of disease.

- *End to Chronic Debilitating Diseases* Many countries, particularly ones in tropical zones, face the security threat that chronic debilitating diseases impact people of working age, creating a population of non-working and medically needy people. Diseases include chronic conditions such as schistosomiasis, Chagas disease, AIDS, dengue, and West Nile virus.

A similar situation, but ethically difficult to discuss, pertains to countries that face a rapidly aging population. As our average lifespan continues to increase, so too will the number of people requiring advanced care for conditions such as Alzheimer's disease, dementia, hip replacements and artificial heart valves. Unless properly managed, this situation, coupled with new and expensive medical procedures, costly diagnostic tools and heroic treatments, conspires to create an unstable economic situation. We anticipate that biotechnology will contribute diagnostic and preventative tools to ease the security burden of chronic debilitating diseases.

- *Regenerative Medicine* Replacement tissues and organs derived from stem cells may one day make it possible to replace organs such as kidneys and livers and to treat diseases such as muscular dystrophy and Parkinson's disease. Research at the interface between biotechnology and materials science is now making it possible to grow cells on artificial scaffolds.
- *Shift from Treatment of Disease to Prevention* Ultimately biotechnology will make it possible to shift to disease prediction and prevention from our current modality of treating diseases after they have occurred. Microarray technology of increasing sophistication will make it possible to shift from the treatment of disease to its prevention. For example, over 10 million single nucleotide polymorphisms (SNPs) have been identified in the human genome. SNPs can predict genetic disease, which can be treated or prevented.

Water Security Access to clean water is a major issue, particularly in developing countries. Waterborne diseases are the second most frequent cause of death in children under five years of age.¹⁰ Dr. Rita Colwell summed up the national security issues surrounding access to clean water when she discussed her life-long work on the waterborne disease cholera leading to receipt of the 2010 Stockholm Water Prize: "*Infection by waterborne diseases, parasites, bacteria and viruses causes a reduced capacity for work and daily functions, which creates economic and social disruption and a reduction of capacity of a country. Safe drinking water is critical to economic stability, social stability and even national security.*"¹¹

Colwell, whose lifelong work has used molecular and other techniques to understand the transmission of waterborne diseases, advocates simple improvements in water treatment in developing countries. She also warns that climate change could increase water temperatures, perhaps leading to increased geographical distribution and seasonality of waterborne pathogens.

Security from Acts of Terrorism Although the absolute number of deaths from terrorist incidences is small (figure 4) compared to deaths from hunger or waterborne diseases, terrorist activities introduce a high level of uncertainty and chaos. The disruption from terrorism is encumbering in its disruption of travel and its requirement for resources. Furthermore, in the wrong hands and weaponized, biological agents such as ricin, aflatoxin, botulism toxin, saxitoxin, smallpox, anthrax, ebola, Marburg virus, plague and Rift Valley fever could generate enormous damage. Although treaties are in place prohibiting the use of biological agents, it is nevertheless prudent to be prepared to detect and prevent such an attack. Terrorists are not bound by treaties and rogue scientists could provide access to biological agents.

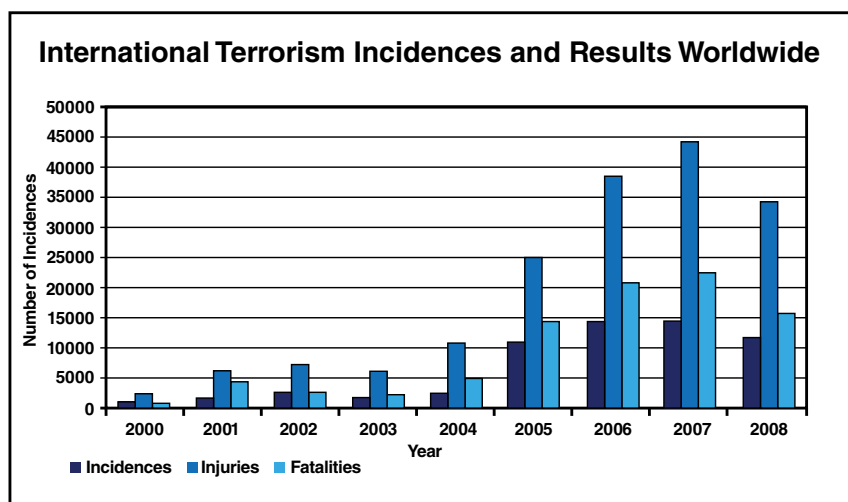


FIGURE 4 International terrorism between the years 2000 and 2008.
SOURCE: U.S. Department of Defense, <http://www.project.org/info.php?recordID=178>

Biotechnology offers the advantage of producing exquisitely sensitive sensors for detection of both biological and non-biological threats. One could imagine sensors for airborne threats, multi-array sniffers at airports and public buildings, and perhaps routine screening in hospital emergency rooms to detect early victims.

hunger.¹² As figure 5 (p. 92) shows, most of the world’s hunger is concentrated in Africa, India, Mongolia, Bolivia and Central America. Biotechnology, either as a guide to conventional breeding programs or via genetic engineering, can be used to enhance the production of foods, both plant and animal. Goals include higher yields, shorter time to market, resistance to pests and pathogens, and greater nutrition.

Food Security According to the World Food Programme, about one person in six or seven regularly suffers from

While the goal of eliminating world hunger is noble, not everyone is willing to embrace a solution that involves genetically modified organisms (GMOs). For example, the European Union has not been widely accepting of GMO crops and requires labeling for foods and food products that still contain the DNA or protein derived from GMOs. Similarly, in September 2010 the U.S. Food and Drug Administration was unable to reach a decision on whether to allow genetically engineered Atlantic salmon to be used for human consumption.¹³ The salmon, AquaAdvantage, was raised from eggs injected with DNA from the Pacific salmon and genetic material from the ocean pout eel. If approved, this would have been the first genetically modified animal in the food supply.

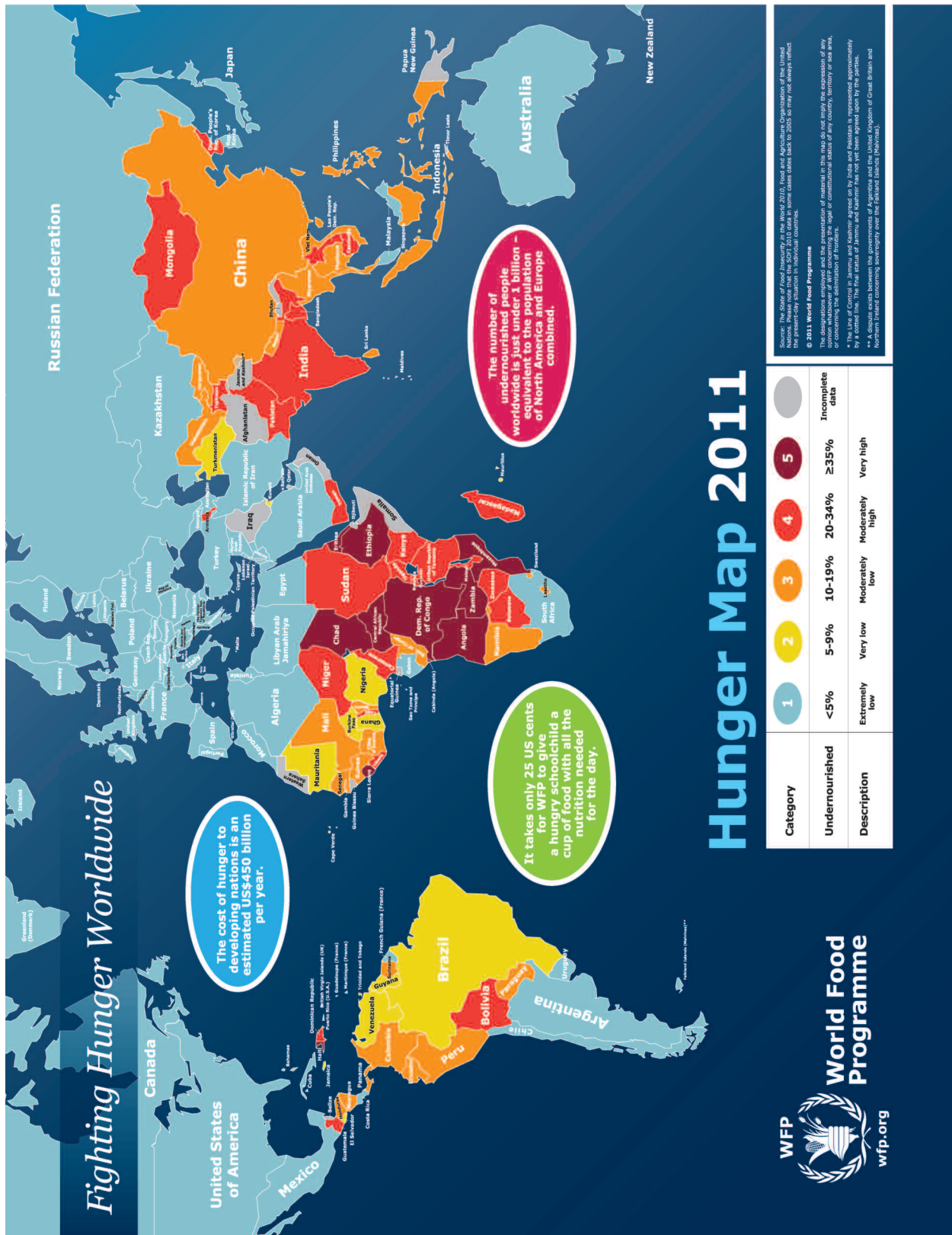


FIGURE 5 World Hunger Map. **SOURCE:** World Food Programme, <http://www.wfp.org/>
©World Food Programme, 2011

How are we adapting/responding to these global security issues?

It is important to note that none of the six security issues we have identified exists in isolation. For instance, access to plentiful and clean water is directly related to health security, to security from terrorism, to food security, or to security to extremes in climate, and indirectly to energy security. Consequently, a systems approach seems appropriate.

The U.S. is currently engaged in a number of activities to address these global security issues – issues even more important in the context of a growing world population. In 2010 the world's population is estimated at 6.87 billion people (U.S. Census Bureau). While population growth has slowed to about 1.1 percent in many developed countries, the world's population is not expected to peak for at least 20 more years, at which time estimates range from an additional 0.63 – 2.13 billion more people (figure 6). It is likely that this population growth will add additional stress to the system.

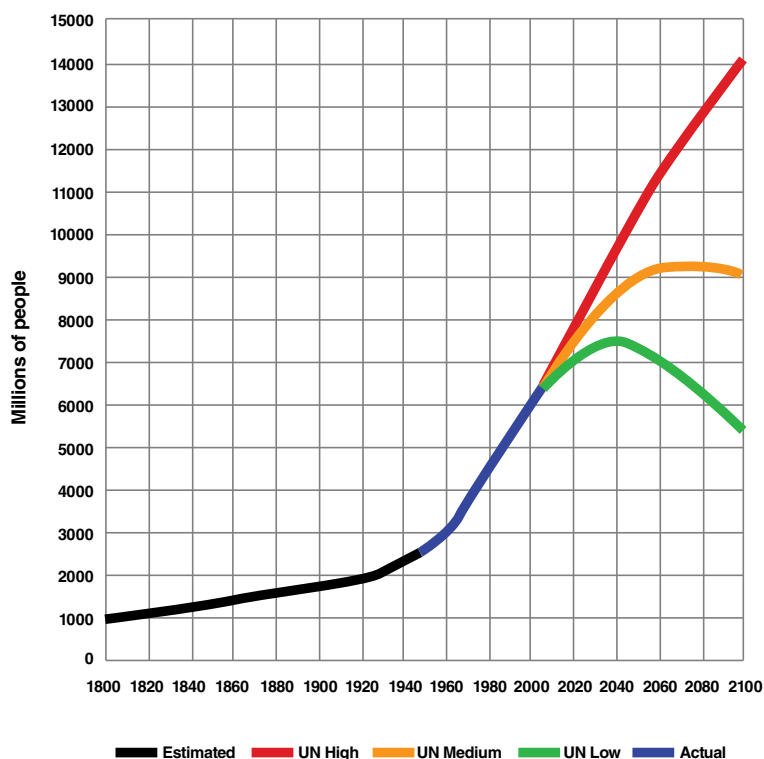


FIGURE 6 Projections for world population
SOURCE: http://en.wikipedia.org/wiki/World_population

The U.S. is engaged on a number of fronts to address these security issues. For example, Congress recently passed the Energy Independence and Security Act (2007). Its goals are “to move the United States toward greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the Federal Government, and for other purposes.” Among other provisions, it calls for the amount of biofuels added to gasoline to increase to 36 billion gallons by 2022, up from the 4.7 billion gallons in 2007, and that most of this increase comes from non-cornstarch feedstocks such as sugar and cellulose.

In addition, the National Science Foundation, the National Institutes of Health and the Department of Energy commissioned the National Research Council to produce a report “*New Biology for the 21st Century*” which defined four major societal challenges:¹⁴

- generate food plants to adapt and grow sustainably in changing environments;
- understand and sustain ecosystem function and biodiversity in the face of rapid change;
- expand sustainable alternatives to fossil fuels; and
- understand individual health.

These four challenges are now driving part of the biotechnology research agenda. For example, the U.S. Department of Agriculture has issued competitive grants in five broad areas: 1) keep American agriculture competitive while ending world hunger; improve nutrition and end child obesity; 3) improve food safety; 4) secure America’s energy future; and 5) mitigate and adapt to climate change.

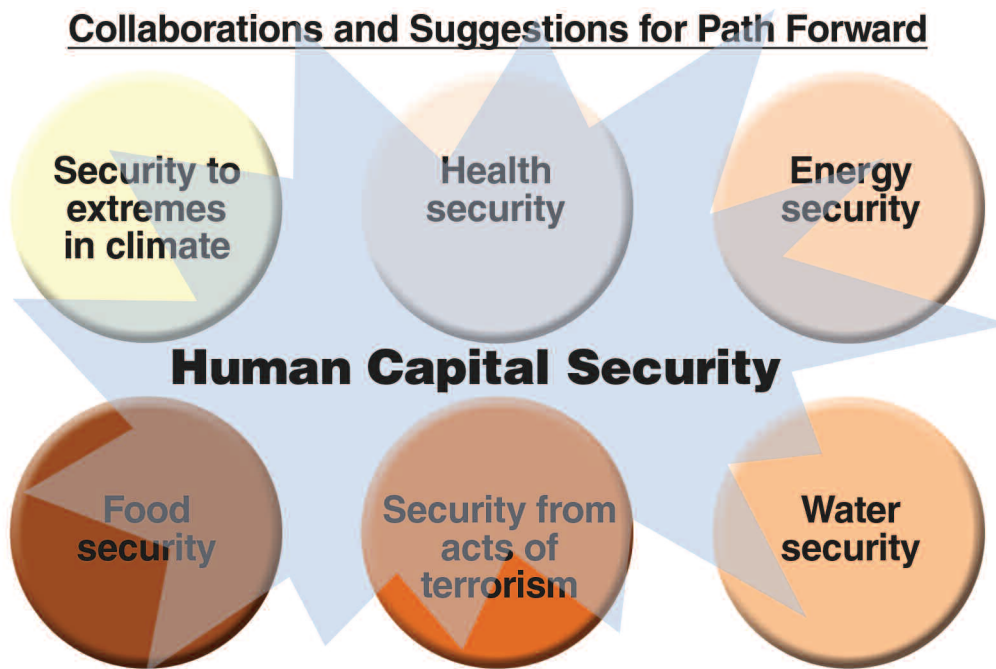


FIGURE 7 Emphasis is on the value of human capital

Way Forward: Recommendations for Strengthening and Improving Global Security

The six biotechnology security issues are not unique to the U.S.; many other nation-states have the same issues. Solutions to these issues will overlap, and cooperative effort will produce superior results.

With our focus on potential applications of biotechnology to security issues we have ignored perhaps one of the most important areas of all: human capital security (figure 7, p. 94). As we go forward to define collaborations and areas of joint interest, it is essential to recognize that our greatest security will ultimately come from a highly educated, technically and scientifically literate population.

To fully utilize our human capital to solve the security issues faced jointly by nations, We set forth the following recommendations to build collaborations around mutual issues of global security:

- for each identified issue selected for multinational effort, face-to-face meetings are important first steps and memoranda of understanding are useful to formalize collaborations;
- leaders should go beyond meetings and discussions and create hands-on opportunities for genuine intellectual exchanges, including visiting professorships, laboratory internships and joint field work;
- leaders should define several focused areas of mutual interest and expect mutual contributions and time commitments from each nation;
- the efforts should include cultural as well as scientific exchanges;
- there must be a substantial effort to follow up on issues identified and to ensure mutual contributions occur as anticipated; and
- to continue to build human capital, it is essential that students are exposed to the value of global teamwork.

Notes

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Biotechnology Developments and Security

Presentation Summary

Ashley Dombkowski, Ph.D.

Dr. Dombkowski provides a brief description and analysis of current developments in the area of biotechnology. In the first part of her presentation, she identifies the top three transformational biotechnology breakthroughs that have security and global health applications. She then proceeds to discuss public-private partnerships as an effective model to improve the innovation environment of the biotechnology sector.

The first major biotechnology breakthrough with security applications is the continuous improvements in DNA sequencing technology. In 1990, it cost \$3 billion to fully sequence the DNA of a human being. Today, with more advanced tools, the cost is approaching \$1,000. At this \$1,000-per-sequence price point, the applications of this breakthrough are much more cost effective. Among the latest applications of DNA sequencing is personal profiling: consumer-focused applications are already using cheaper, albeit less precise, techniques that approximate a complete DNA sequence, allowing an individual to pay \$400 to obtain data about their genetic heritage and understand their predisposition to certain diseases, their ability to respond (or not) to certain drugs, and their carrier status as pertains to certain diseases.

Dr. Dombkowski expects that with fast, sub-\$1,000 DNA sequencing technology, we will be able to increasingly understand the molecular basis of disease that in turn will streamline drug development and prescription. In addition, fast, cheap human DNA sequencing will also enable fast, cheap sequencing of pathogens of infectious agents and determine whether they have drug resistant genes. She points out that the security and global health implications of this capability will be profound. For instance, data that advanced technologies provide such as DNA sequencing can be combined with information management tools that can provide increasingly elegant, accurate, timely information about outbreaks and pandemics that might occur in any part of the world.

The next technological frontier covers breakthroughs in “cellular reprogramming” or “manipulating cell fate,” specifically, the invention of techniques to create the so-called “induced Pluripotent Stem Cells” (iPS cells). Of particular military interest in this breakthrough is the possibility that an iPS-cell enabled drug discovery can be applied to prevent/cure devastating neuro-degenerative diseases such as amyotrophic lateral sclerosis (ALS) diagnosed among Gulf War veterans. In the longer term, Dr. Dombkowski states that iPS technologies are expected to lead to ‘true’ regenerative medicine.

The third and final breakthrough is the breadth of progress being made by the private sector on multiple fronts in vaccines, to include: DNA vaccines, vaccine preparations that do not require refrigeration, and micro-needles that enable vaccine delivery. Of particular security and global health significance is the current progress with new manufacturing techniques that could allow for the rapid development of a vaccine against a pathogen of interest at the kind of scale that is needed to address large populations during, say, a pandemic situation.

It is clear that emerging major scientific breakthroughs have security and global health implications. In this context, Dr. Dombkowski points out that there is greater need to sustain biotech innovation, but the financial costs and resource requirements from discovery to development are increasingly prohibitive. It takes at least \$1 billion and 10-15 years to advance a drug successfully from ‘discovery to pharmacy,’ and only a very small percentage of drugs make it all the way. A major way out of this financial challenge is to increase public-private partnerships (PPP) to sustain biotech innovation. She brings up two case studies to illustrate her point. The first is Parmathene, a publicly-traded company that is a so-called “pure play” enterprise in national defense in that its programs are all bioweapon countermeasures e.g., vaccines and prophylactic treatments for Anthrax and nerve agents. The development of these programs is jointly funded by private sources of capital (venture capital, public market, etc.) and by government capital (the U.S. Department of Defense). The second case, Cleveland Bio Labs, is also a publicly-traded company and is similarly funded by a combination of public and private sources. But unlike Parmathene, it combines the development of programs with military applications alongside the development of traditional therapeutic medicines. So while its Protectans programs are being developed to counteract the detrimental effects of radiation therapy in patients undergoing cancer treatment, they are also developing applications in settings where populations might be exposed to radiation from, say, a nuclear weapon or a nuclear disaster. Dr. Dombowski concludes by saying that PPPs should be more fully utilized as institutional models to deliver the medicines of tomorrow. These types of cooperative or collaborative arrangements are a win-win for the stakeholders involved.

Biotechnology in China

Cong Cao, Ph.D.

Introduction

Biotechnology will be among the emerging science and technology (S&T) fields that will have the most significant global impact in the decades to come. Experts forecast that better drugs, devices and treatments for diseases, advancements in stem cell and genetically modified organisms (GMO) technology, and exciting developments in genome sequencing for personalized medicine will materialize in the next 20 to 30 years. Developing economies are emerging as important players in these fields in part because of advances in information and communication technologies (ICTs), sustained economic growth and strong government support. Governments are increasing their investments in research and development (R&D), providing support for the next generation of life scientists, enabling institutionalized knowledge transfer from academia to industry and encouraging the expansion of the private sector's role in all aspects of development. Moreover, scientists from developed and developing countries are increasing collaborations to tackle global problems, creating deeply-intertwined international networks to create, share and acquire knowledge produced at the frontiers of various S&T areas.

Within the context of these encouraging developments, China is charting a trajectory in the next few decades that casts itself as a major global biotechnology player. This field is one of the government's seven strategic S&T areas identified to provide solutions to some of China's pressing societal problems, underpin long-term economic growth and serve as a pathway for building indigenous innovation ("*zizhu chuangxin*") capability. China's rise in biotechnology seems predictable, but the path is fraught with serious challenges. In this paper, I will provide a brief summary of China's biotechnology development focusing primarily on the pivotal role of the government, and then discuss some of its major challenges that, if left unresolved, could retard China's quest to become a global biotechnology leader.

Understanding the Trajectory

China's interest and significant contributions in biotechnology began decades earlier primarily as part of its S&T efforts to catch up with the West.¹ A glance at some of the country's life science/biotech accomplishments during this time reveals that these initiatives focused on discoveries and innovations with high societal relevance. In the early 1960s, Chinese life scientists successfully synthesized the "world's first" bovine insulin believed to be a major accomplishment that could have earned China a Nobel Prize.² Sustained government R&D support in the subsequent decades led to another milestone at the end of the 1990s when – alongside the U.S., Germany, the United Kingdom, France and Japan – China became part of the international research effort to map the human genes known as the Human Genome Project. Although its contribution amounted to

just one percent of the total sequencing of the human genome, China was the only developing country participating in this consortium. In late 2003, it became the first country to approve a drug license for a recombinant gene therapy to treat head and neck cancers.³ Today, it is one of the leaders in research on genetically modified (GM) food. The government's recent approval of a strain of genetically engineered rice and corn puts the country in position to be first in the world to produce these GM grains on a commercial scale. In China's 12th Five-Year Plan (2011–2015), the R&D focus will be on the growth of the biotechnology industry in such areas as the development of new chemical drugs, biomedical engineering and the modernization of traditional Chinese medicines.

Governance Structure

China's current drive to become a global leader in biotechnology is a microcosm of its effort to meet the growing economic demands of its population as well as to become a major power in science and technology, i.e., to "enter the ranks of innovative countries by 2020" and become a global scientific power by mid-century.⁴ These strategic objectives underpin the central government's major and transformative role in China's national innovation system. As one of seven strategic priorities for scientific and technological development identified in China's 12th Five-Year Plan (2011–2015), biotechnology provides a clear illustration of the dominant role of the government in the development of national S&T capabilities.

At the heart of China's bid to become a leader in global biotechnology is the central government, whose role is reflected in a governance structure that is highly centralized and bureaucratized. At the apex of the organizational structure is the Chinese Communist Party (CCP) Central Committee (figure 1, p. 101). The CCP Central Committee exerts influence and power through a Science, Technology and Education (STE) "Lead Group" that is organized within the State Council, which is composed of all heads of ministries directly involved in China's S&T policy process. The Lead Group is usually chaired by a vice-premier who is also a concurrent member either of the Politburo or the Standing Committee of the CCP Central Committee – China's de facto governing body. However, since the integration of S&T into the national development strategy in the mid-1990s, China's premier has chaired the STE Lead Group. This group is responsible for:

- the study and review of the nation's strategy and key policies for the development of science, technology, and education;
- the identification of major tasks and programs related to science, technology and education;
- leadership appointments; and
- the coordination of important issues of science and education involving agencies under the State Council and regional institutions.

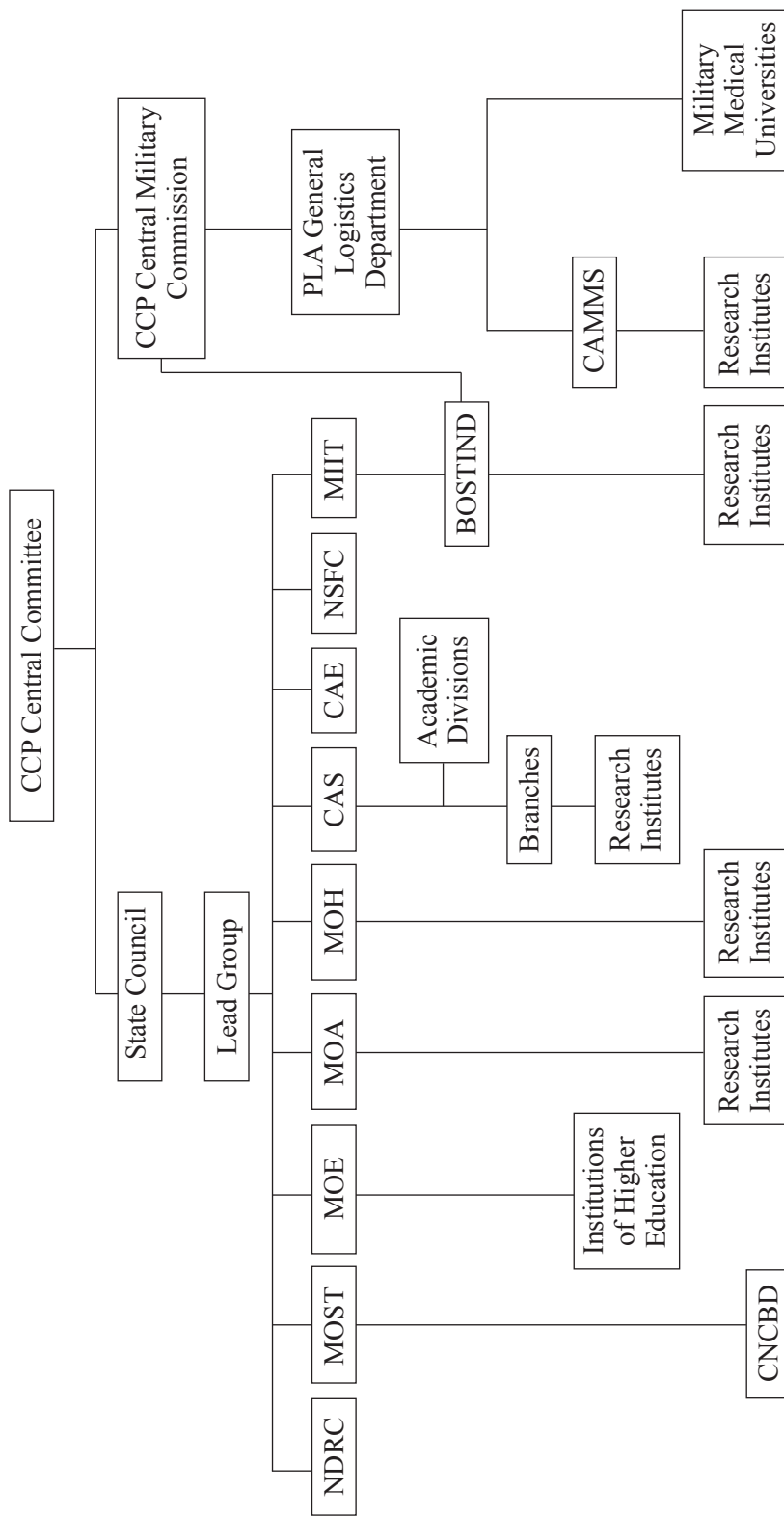


FIGURE 1 China's Organizational Structure for Life Science/Biotechnology. **SOURCE** Author's own.

LEGEND: Lead Group – State Lead Group for Science, Technology, and Education; NDRC – National Development and Reform Commission; MOST – Ministry of Science and Technology; MOE – Ministry of Education; MOA – Ministry of Agriculture; MOH – Ministry of Health; CAS – Chinese Academy of Sciences; CAE – Chinese Academy of Engineering; NSFC – National Natural Science Foundation of China; MIIT – Ministry of Industry and Information Technology; CNCBD – China National Center for Biotechnology Development; BOSTIND – Bureau of Science, Technology, and Industry for National Defense; CAMMS – Chinese Academy of Military Medical Sciences

The Lead Group manages over the nine government ministries that hold S&T portfolios and carry out political functions.⁵ The Ministry of Science and Technology (MOST) and the Chinese Academy of Sciences (CAS) are the prominent players in biotechnology development. MOST is by far the most powerful among the nine organizations. It is the overarching government agency overseeing the nation's S&T affairs, exercising a wide range of functions as follows:

- formulation of S&T development policies, plans, programs;
- creation of the legal framework for S&T;
- institution of reforms in government research institutes;
- management of the S&T budget and resources;
- administration of high technology programs;
- management of China's national science parks;
- establishment of programs to improve the public's scientific literacy; and
- examination of S&T's societal impacts.

The Chinese Academy of Sciences (CAS) manages around 100 research institutes and laboratories, owns at least 400 spin-off companies from its institutes,⁶ and employs some 60,000 research staff – considered the best and brightest of China's S&T and engineering community. It is the premier organization leading China's innovation drive in both the civilian and defense S&T sectors, and its R&D programs are credited with producing approximately 20 percent of China's peer-reviewed scientific papers in the last ten years and around 25 percent of China's citations in scientific journals.⁷

Policy Evolution

China has been investing heavily in biotechnology in 1986 with the State High-Tech R&D Program (also known as “863”), China's first national S&T program that focused on high-technology development. The program's R&D agenda emphasized immediate outcomes and quick results over fundamental R&D. MOST awarded biotechnology the largest amount of the 863 funds. Priority areas included bioengineering technology, gene manipulation technology, bioinformatics and modern agriculture technology. This initiative was followed by the National Basic Research and Development Program (“973”) in 1997. Unlike its predecessor, this program gave policy attention to the basic and mission-oriented basic R&D priorities of China to enable it to occupy an important seat (*yixi zhidi*) in international R&D communities. The 973 program supported projects that meet at least one of the following three criteria: first, provide solutions to major problems associated with China's social, economic, and scientific and technological development; second, have high relevance to major basic research problems with interdisciplinary and comprehensive significance; and third, exploit China's advantages and special characteristics, i.e., its natural, geographic and human resources.

In the last 10 years or so, these programs have evolved to conform to the latest policy guidance – the Medium and Long-Term Plan (MLP) for the Development of Science and Technology

(2006–2020). The MLP provides a roadmap of how the country – through the enhancement of indigenous innovation (*zizhu chuangxin*) capabilities – can become an innovation-oriented nation by 2020 and a world leader in S&T by 2050. It identifies biotechnology as one of the eight areas of “frontier technologies” where China is expected to make a significant global contribution in the next forty years (table 1).⁸ Mega-engineering programs in biotechnology include GMO R&D, drug innovation and R&D for the prevention and control of HIV/AIDS and other major diseases. Of the original four mega-science programs, two are in the life sciences and biotechnology field: protein science, and developmental and reproductive biology.⁹

Key areas (11)	Mega engineering programs (16)
Energy	Core electronic components, high-end generic chips, and basic software
Water and mineral resources	Extra large scale IC manufacturing and technique
Environment	New generation broadband wireless mobile telecommunication
Agriculture	Advanced numeric controlled machinery and basic manufacturing technology
Manufacturing	Large-scale oil and gas exploration
Transportation	Large advanced nuclear reactor
IT industry and modern services	Water pollution control and treatment
Population and health	Genetically modified organism new variety breeding
Urbanization and urban development	Drug innovation and development
Public securities	AIDS, virus hepatitis, and other major diseases control and treatment
National defense	Large aircrafts
	High definition observation system
	Manned aerospace and lunar exploration
Frontier technology (8)	Mega science programs (4)
Biotechnology	Protein science
Information	Quantum research
New materials	Nanotechnology
Advanced manufacturing	Development and reproductive biology
Advanced energy	
Ocean	
Laser	
Aerospace and aeronautics	

TABLE 1 Areas and Programs Identified in China’s Medium and Long-Term Plan (MLP) for the Development of Science and Technology, 2006-2020

SOURCE: Reprinted with permission from C. Cao, P. Suttmeier and F. Simon, “China’s 15-Year Science and Technology Plan,” *Physics Today* (December 2006): 38–43. ©Copyright 2006, American Institute of Physics.

In the wake of the global financial crisis that started in 2007, the State Council promulgated the “Policies for Expediting the Development of Biotech Industry” (2009) requiring government ministries and regional governments to formulate concrete implementation policies for biotechnology. The government identified biotechnology as a new, post-crisis engine for economic growth with a focus in five areas: biomedicine, agricultural biotechnology, energy biotechnology, biotech manufacturing and environmental biotechnology. Currently, the government is preparing to release a plan for the rejuvenation of the (NDRC)-led biomedicine industry that will focus R&D efforts in the areas of gene medicine, protein medicine, monoclonal antibody medicine, therapeutic vaccines and small molecule chemical drugs. A new element to this initiative is NRDC’s calls for unprecedented interagency collaboration with MOST, the Ministry of Health, and the State Food and Drug Administration (SFDA). It is hoped that this institutional innovation will pave the way for more coordination across ministries holding biotechnology portfolios.

Funding

The government continues to invest heavily in biotechnology. It committed over \$238M in life sciences and biotechnology from 1996 to 2000, and significantly increased this amount to \$795M from 2001 to 2005. In the Twelfth Five-Year Plan period (2011–2015), biotechnology is set to receive \$1.7 Trillion in government funding, and at least \$1.5B for new drug development alone.¹⁰ Development priorities will include biopharmacy, bioengineering, bioagriculture and biomanufacturing.¹¹

In terms of biotechnology industrial output value targets, data show that China is well on its way to achieving its Twelfth Five-Year Plan target of \$253.6B by 2015, with a current industrial output value in the areas of gene engineering drugs, vaccines and diagnostic test kits already reaching \$159B.¹² By 2020, the goal is to reach an industrial output value of around \$318B – \$477B, to include the development of new biotechnology industries such as biomedicine and GM plants.^{13, 14} Life sciences and biotechnology now account for about 20% (\$27B) of the total investments in R&D (\$135B). In terms of human resources, China currently has approximately 30,000 scientists employed in around 200 publicly-funded labs in biotechnology, and an estimated 50,000 workers in some 500 biotechnology companies.¹⁵ From 2011 to 2015, biotechnology is expected to create one million jobs, improve life expectancies by one year, reduce infant mortality rate to 12 percent, and reduce carbon emissions of the most common pollutants by 10 percent.¹⁶

Government-Sponsored Science and Industrial Development

Beyond providing the strategic direction and the primary funding source, government support for biotechnology is manifest in other ways. First, it identifies specific sites for biotech industrial development. NDRC granted approval for the establishment of nine national biotechnology bases in Beijing, Shanghai, Guangzhou, Changsha, Chongqing, Qingdao, Chengdu, Kunming and Wuhan, following the construction of three such bases in Shijiazhuang, Shenzhen and Changchun. Selection of these cities were based on the presence of infrastructure suitable for biotechnology development,

a relatively perfect market environment, and the existence of a cluster of related industries that facilitates the integration of large biotechnology groups and the development of small and medium-sized enterprises. In addition, NDRC also approved the creation of ten national biotechnology industrialization bases in Xi'an, Tianjin, Taizhou, Tonghua, Dezhou, Zhengzhou, Nanning, Harbin, Hangzhou and Nanchang. In these cases, the government seeks to promote new clustered areas for biotechnology development, create an industry with regional characteristics and redistribute economic and social resources to other areas of China.

Second, the government is also investing a total of \$1.8B in biotechnology science parks. The development of these parks is orchestrated with its policy to recruit overseas Chinese-born scientists and professionals who are offered generous incentive packages to return to China to establish and lead life science-related business entities in these parks. For instance, the Suzhou Industrial Park launched a “Pioneering Talent Grant” in 2007 that carries a \$158,500 award as start-up capital. This was followed up by an additional investment of up to \$792,500 through the China–Singapore Suzhou Industrial Park Ventures Co. Ltd, supplemented by provisions of free laboratory space and housing subsidies for key talents.¹⁷ The bioBay, as the Suzhou Biotech Science Park is now known, is considered one of the best biotech parks in China.¹⁸

Third, the government’s interests in biotechnology industry are represented in the commercial sector by two types of enterprises. The first are the state-owned enterprises (SOEs). Amidst the backdrop of a favorable policy environment, SOEs are typically monopolies, receive generous government support, are well equipped and have relatively advanced technological capabilities. The second group includes top-tier state-owned research and higher education institutions that have life-science schools or departments. These institutions have institutionalized a “commercial identity,” creating their own spin-off biotech firms and arranging tie-ups with local and foreign companies. In recent years, the Chinese government significantly increased R&D budgets in these institutions, especially among the elite universities and institutes under the Chinese Academy of Sciences. Since 1994, it has established at least 15 national biomedical research key laboratories.¹⁹

Finally, the government provides strong support to the growth of the private sector involved in the biotechnology industry through a combination of reforms and tax and legal incentives. The focus of support consists of two groups. The first are small private enterprises, often set up by returnees and to a lesser extent by former employees of public research institutes. This category also includes a small number of China-based outsourcing service providers – mainly contract research organizations (CROs). CROs provide an array of services including product development, formulation and manufacturing clinical trial management, data management, biostatistics and medical writing services for new drug applications and regulatory affairs support. Given the breadth of their functions, CROs can potentially be the main players in the development of China’s pharmaceutical industry and will be critical in creating increased opportunities for international collaboration.²⁰ The second group – and a more recent actor in China’s biotechnology R&D landscape – consists of the multinational pharmaceutical giants, e.g., Pfizer (Beijing), GlaxoSmithKline (GSK, Shanghai), Novartis (Beijing), AstraZeneca (Shanghai), and Roche (Shanghai). Aside from conducting their own R&D in China, these companies are developing

collaborations with Chinese universities, research institutes and biotechnology enterprises, as well as establishing joint ventures with domestic companies.

Looking Ahead

A confluence of conditions is paving the way for China to make great strides in biotechnology: high economic growth, strong government and elite support that recognizes the strategic role of S&T in the country's rise to power and development, immense demographic, health and agricultural challenges that call for wide-scale and urgent S&T solutions, and the gradual improvement of the quality of its scientific labor force due to the increasing international exchanges and the growing number of returning S&T talent eager to become stakeholders in China's innovation drive. However, China still faces significant difficulties, and the achievement of its goal to become a global leader in biotechnology will largely be a question of the timing and extent to which it can overcome these challenges.

First are the institutional challenges rooted in the governance structure of China's national innovation system. The issue is whether a bureaucracy-centered S&T policy- and decision-making process provides the optimal arrangement for China's quest to become a global S&T leader. While the highly-centralized and bureaucratized set-up allows for extending biotechnology development across various government ministries, turf battles and bureaucratic rivalries have inhibited policy coherence and coordination. In some cases, organizational goals and funding priorities overlap, resulting in wasted resources and duplication of efforts. There have also been concerns of weak accountability with reference to new spending initiatives and monitoring expenditures. In the last decade, government-sponsored S&T institutions and programs have come under fire from some government officials, technocrats, and especially from members of the Chinese S&T community for undermining efforts to strengthen China's innovative capability.²¹ The laundry list of criticisms include a corrupt and politicized process involving some national science projects, favoritism in the awarding of grant money, weak accountability for research results, intellectual property rights violations,²² and inflexible management structures that are not conducive for innovative R&D work. A more recent institutional development – the growing role of local (provincial and municipal) governments in R&D – is yet to be examined in terms of their impact on the centralized S&T policy-making process and their role in the creation of innovative environments and domestic markets.

The second challenge is the need for the biotechnology industry to parlay what has so far been an effective 'scientific and applied research catch-up' system to one that creates a culture of innovation in order to develop and commercialize indigenous products that are internationally competitive. In-house R&D activities among domestic enterprises have not kept pace due to weak research capabilities, low R&D spending, heavy reliance on foreign S&T for its innovation activities and weak academic-industrial enterprise R&D linkages. Chinese firms focus on short-term gains, e.g., from sales of generic products, rather than on the longer-term benefits accruing from innovative research. Most Chinese pharmaceutical companies that invest in R&D only aim to improve upon existing processes and modify existing formulations of drugs. Moreover, government-supported

venture capital firms that experts view as critical in promoting indigenous innovation still have minimal presence in industrial biotechnology, much less private biotechnology startup companies. According to China's State Intellectual Property Office (SIPO), foreign entities filed 51 percent of the biotech patent applications and received 62 percent of the patents granted.²³ Data (table 2) also show that imports far exceed exports in the life sciences and biotechnology sector. This profile of industrial biotechnology for the most part describes the state of China's high-technology sector, and in an effort to bolster China's industrial innovation, the government – articulated through its 2006 MLP and 11th Five-Year Plan (2006–2010) – called for the development of an innovation system that strengthened the 'lab-to-market' process.²⁴ This is a decided shift in government S&T/industrial policy, so the challenges will lie in the implementation phase.

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011
Exports									
Biotechnology	190	219	268	256	265	263	296	355	410
Life science	2,502	3,237	4,563	6,342	8,917	13,394	11,059	13,861	17,840
Imports									
Biotechnology	105	108	142	154	201	322	360	422	450
Life science	3,062	3,793	4,576	5,138	6,464	8,063	9,477	11,683	15,800
Balance									
Biotechnology	-85	-111	-126	-102	-64	59	64	67	40
Life science	560	556	13	-1,204	-2,453	-5,331	-1,582	-2,178	-2,040

TABLE 2 China's Trade in Biotechnology and Life Science (\$ million) **SOURCE:** *www.sts.org.cn*.

The third challenge covers international aspects of China's biotechnology development. Growing numbers of multinational biotechnology and pharmaceutical companies have set up their R&D operations in the country to take advantage of the availability of a large, but as yet relatively underutilized, S&T labor force and undoubtedly transforming the landscape of China's industrial biotechnology. But the joint ventures and partnerships face a steep learning curve. On the one hand, the legal framework that governs international business collaborations still need further reform, and international partners need to educate themselves on the evolving Chinese legal system. China's biotechnology has no overall national industry association, presenting a challenge to new entrants looking for both industry information and partnerships. On the other, home-grown enterprise managements have little experience with the various aspects of the 'discovery and development' value chain. Intellectual property rights (IPR), tax, ownership and other issues often come to the fore when due diligence is conducted by their foreign counterparts. Domestic biotech enterprises that are truly international in orientation remain in the minority, so one key issue facing China will be how and to what extent the industry can be 'internationalized' and be able to stand up to global business standards.

The speed with which China will achieve its goal becoming a global S&T powerhouse will significantly hinge on its ability to defend IPRs, a vital component of the innovation system.²⁵ While it is making great strides in IPR reform,²⁶ the government is yet to create a basic and complete legal framework for IPR protection. For instance, such a framework needs to include initiatives to educate the Chinese public on the importance of intellectual property protection. For the most part, people are still unwilling to support legally copyrighted products, emboldened by the fact that the existing legal system is not effective to serve as a deterrent to commit IPR-related violations. The IPR concerns of international companies entering the China market, e.g., protection of technology that companies bring to the country, lack of legal enforcement, opacity of domestic laws, etc. also expose weaknesses of the current legal regime. Addressing these issues as soon as possible will allow China to bolster its innovation efforts, especially as more of its companies and citizens will become patent holders and key players in Chinese innovation, a trend that will most likely drive the future discourse of IPR protection in China.

As one of seven strategic S&T areas identified in the government's 12th Five-Year Plan (2011–2015), biotechnology is considered a major platform for strengthening China's innovation system and primed to be a leading purveyor of high-value S&T in the future. The challenges it faces are not unique but rather typify those faced by other leading edge S&T areas in China. Because of its central role in shaping the trajectory of China's S&T development, the government is no doubt the driving force behind China's efforts to address these challenges. Competitive and strong national innovation systems however, may not necessarily require a central role for the state. It bears watching how China's government will transform itself as the drive for indigenous innovation gains momentum.

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P L E N A R Y S E S S I O N 5 :

U P D A T E O N S C I E N C E
& T E C H N O L O G Y
D E V E L O P M E N T S W I T H
S I G N I F I C A N T S E C U R I T Y
I M P L I C A T I O N S

Category #3:
Energy

India's Energy Challenges

Lydia Powell

Meeting a Billion Aspirations

Thanks to the revolution in information technology, material aspirations of over one billion Indians have been 'globalized.' Roughly 400 million Indians, classified currently as desperately poor, aspire to be lifted out of poverty and move into proper homes with electricity. The rest seek to educate and entertain themselves with cutting-edge communication devices and move around in motorized personal vehicles. The 'globalized' aspirations of a billion Indians are unfortunately on a collision course with a carbon budget that has been 'nationalized' under multilateral climate forums.

While climate change is defined as a borderless global problem, responsibility for causing – and the liability for addressing – the problem is apportioned strictly according to sovereign borders. Under this supposedly unquestionable premise, while India's size in terms of population numbers gives it a significant economic advantage, it becomes an enormous disadvantage when it comes to climate liability. For the present climate regime, India has the unenviable challenge of steering a billion economic aspirations within a constrained ecological budget. This in essence is India's energy challenge. India has to more than triple its energy supply in the next two decades while halving carbon emissions merely to deliver the very basic energy services such as lighting and heating to the majority of its population.

Factors that contribute to India's low per capita carbon emissions – poverty, low carbon lifestyles characterized by vegetarian or low protein diets, low vehicle ownership, use of non-motorized and public transport – are the very factors that the pursuit of economic aspirations is designed to change. Based on aggregate figures, India is the world's fourth-largest energy consumer with a total primary energy demand of 621 million tons of oil equivalent (Mtoe) in 2008, equivalent to the primary demand of Brazil, Indonesia and Saudi Arabia combined,¹ as well as the fourth-largest polluter emitting accounting for roughly 1.7 billion tons of CO² equivalent in 2007.² As per projections by the International Energy Agency, India is going to become the second-largest contributor to the increase in global energy demand by 2035, accounting for 18 percent of the rise.³ India's energy consumption is estimated to more than double by 2035 growing on average by about three percent per year, a rate of growth significantly higher than in any other region.⁴ Its per-capita consumption is also going to increase rapidly. Yet even by 2035, India's per capita energy consumption at 1.0 toe will be less than one-quarter that of the OECD.⁵

Moving from Carbohydrates to Hydrocarbons

India's per capita carbon emissions are as low as 1.5 tons which is one-third of the global average and less than one-tenth of the largest emitter. This is primarily because of the 400 million

Indians who draw their ‘energy’ only from carbohydrates they consume and the carbon they collect in the form of twigs used to burn ‘subsidized’ hydrocarbon. This perverse inequality in energy consumption is facilitated partly by the supply of female labor in India (fueled only by the meagre food they consume) that is deployed to collect and burn carbohydrate and carbon-based fuels. The economic rationale that sustains this exploitation is that the ‘opportunity cost’ of female labor is negligible as long as the women remain uneducated and unskilled. It is not uncommon to see female labor being used to ferry liquid petroleum gas – among the highest forms of energy available today – in cylinders weighing 16 kilograms to remote regions of India that lack motorable roads or pipelines. This is a net energy deficit system which, by definition, cannot generate energy surpluses that are necessary for ‘wealth generation’ through productive economic activities.

To increase the opportunity cost of female labor, substantial investments must be made in education that in turn requires massive investment in energy supply. Even the provision of basic lighting services that would facilitate the education process in poor households is a huge challenge. To provide roughly 80 million households (in which 400 million people live) with just two 60-watt electric bulbs that can be used for about four hours a day, India will have to increase its current generating capacity by about 10 - 12 percent. In order to meet the goal of increasing the per capita availability of electricity to 1,000 kilo watt hours – the level prescribed by the United Nations as the minimum needed for acceptable quality of life and also the key policy goal of the government – India needs to increase its power generating capacity by 400 to 500 percent.

Even the electricity consumption of those with access to electricity in India is below global average partly because electricity is unavailable and partly because it is unaffordable. Just under one-sixth of electricity users in India consume over 100 kilo watt hours per month, compared to the U.S. average of 900 kilo watt hours per month.⁶ The per capita consumption of electricity in India at less than 500 kilo watt hours is one-fifth of the world average of over 2,500 kilo watt hours.⁷ The energy intensity of households in India is roughly half that of a household in Brazil with a similar income, or one-third that of a household in the U.S. in the same income category.⁸

The absence of modern energy services among the poor is at the heart of economic exclusion of large sections of the population in India. Current reforms and investments in the energy sector are focused on market development and privatization primarily to limit budgetary deficit and to establish macro-economic stability. Economic disparities are likely to widen under such a policy regime, with the economically well-off sections of the population using their access to modern energy services for further economic emancipation while families without energy services remain locked in net-energy deficit subsistence traps.

Offering renewable and green energy technologies as energy solutions to poor rural households has not succeeded to the desired level, as it has predominately been a result of an energy policy which is very much a market-push agenda and not a ‘development’ agenda. Under this agenda, expensive ‘green’ energy is thrust on the poor either to demonstrate India’s commitment to promote green energy or as a test market for new forms of energy technology – not as a means for development of the poor. Implementing any technological change in energy provision will have

meaning only if it helps the poor move towards a system in which they have a substantial share of the power and hence, of society's material wealth.

Sustaining India's Coal-based Energy System

Coal is the main adjustment variable between 'business-as-usual' and 'low-carbon' energy paths for India because its formal energy system is essentially coal-based. Coal accounts for over 38 percent of India's primary basket followed closely by non-commercial energy sources such as firewood and animal dung, which account for over 26 percent. Hydrocarbons (oil & gas) account for 30 percent while hydropower contributes less than five percent. Nuclear power, wind and other renewable energy sources contribute less than one percent of India's primary energy needs.⁹ Over 75 percent of electricity is currently generated in coal-based thermal power plants, and that share is projected to remain the same for the next two decades, with the volume increasing by over 400 to 500 percent.¹⁰

Until very recently, it was widely believed that India's coal reserves would last for over 150 to 200 years. More recent estimates suggest that out of about 98 billion tons of 'proven' reserves of coal, only 56 percent or 55 billion tons are extractable.¹¹ Depending on the rate of extraction of domestic coal, current reserves may last anywhere between 30 - 60 years.¹² For example, if coal production continues to increase at the rate of five percent per annum, proven reserves will be consumed in the next 45 years. Though a number of possibilities exist for technological improvements that can increase coal extraction and lead to new coal reserve discoveries, current trends seem to indicate that coal reserves in India are well on their way to exhaustion.

India is yet to move on to the second stage of its nuclear programme where it plans to use fissile plutonium to convert thorium and uranium into more fissile materials. In the third stage, India plans to develop advanced power systems using fissile uranium obtained from thorium. Despite doubts over the technical and economic viability of the thorium cycle, the Department of Atomic Energy (DAE), a tightly-held autonomous body that controls the Indian nuclear establishment, re-affirms its commitment to the three stage program.

Domestic coal-based power generation may be limited to 300 giga watts if imported coal does not materialize as presumed. India's coal-based system is not a threat to global climate stability as is commonly believed because even if all coal reserves in India are used for power generation, Indian carbon emissions are unlikely to exceed 4.5 giga tons or three tons per person, which is lower than current global average levels. The real problem with India's coal-based system is its inefficiency. Thermal power generators in India perform well below global benchmarks in terms of thermal efficiency with efficiency levels of 27 to 30 percent compared to 37 percent in OECD nations.¹³ Widespread adoption of efficient coal technologies will extend the life of domestic coal, reduce carbon emissions and lower costs of electricity.

An improvement of just one percent in efficiency can reduce coal consumption by three percent which translates into a reduction in annual coal consumption by about 100 million tons. This will lead to a reduction in annual CO₂ emissions of over 170 million tons (equal to the total emissions of the Netherlands). A variety of technical and institutional factors such as poor quality of coal, low Plant Load Factor (PLF), age-related deterioration, lack of maintenance, ineffective regulation, absence of competition and dubious tax policies contribute to India having one of the highest production cost for electricity in the world in Purchasing Power Parity (PPP) terms. To address these challenges, the government of India has launched a number of schemes, e.g., a market-based trading scheme that would facilitate trading energy efficiency certificates, introduction of supercritical technology, modernization of old thermal power stations, retirement of older small size units, comprehensive energy audits and setting-norms for energy usage. The success of these measures is critical because ‘a carbon tax’ cannot be imposed on the average energy consumer in India who is already overburdened with an ‘inefficiency tax.’

Realising Nuclear Energy Ambitions

The recent waiver from the Nuclear Suppliers Group (NSG) that allows India to import nuclear technology has resulted in politically seductive pronouncements such as “40 giga watts of nuclear power by 2020” and “450 giga watts by 2050.” Given that India was able to install only about 4 giga watts of nuclear power generation capacity in 60 years (albeit under severe technological and financial constraints), its ambition of increasing capacity by a hundredfold in the next 40 years can only be described as ‘irrational exuberance.’

India began its nuclear program early in the late 1940s with a three-stage plan that was designed to achieve energy self-reliance. During the first stage, India tested both light water and heavy water technologies and eventually picked pressurized heavy water technology. Heavy water reactors generated more plutonium than light water reactors for the same amount of mined uranium, a decisive criterion for India because it has high plutonium requirements for the second stage of the program and has scarce uranium reserves. Moreover, plutonium for military purposes was easier to obtain by reprocessing spent fuel from heavy water reactors than spent fuel from light water reactors.

India now has 15 operating Pressurized Heavy Water Reactors (PHWRs) and two operating Light Water Reactors (LWRs) with a total operating capacity of 4.12 giga watts. Three PHWRs, two Prototype Fast Breeder Reactors (FBRs) and one more LWR of total capacity 3 giga watts are under construction. There are plans to construct four more 500 mega watts FBRs by 2020, which would add up to a total FBR capacity of roughly 2 giga watts. These FBRs are to set the scene for the third phase of its nuclear program that plans for full utilization of the country’s abundant thorium. Studies indicate that India would need 200 giga watts of FBR capacity to start introducing thorium-based fuel in the FBRs.

DAE argues that by 2050, India would face a power deficit of over 412 giga watts and suggests that it would be wiser to import 40 giga watts of nuclear reactors by 2020 rather than having to import over 1.6 billion tons of coal by 2050. If India manages to commission 40 giga watts by 2020, it would have launched – in 12 years – more than five times the nuclear generation capacity achieved in the previous 40 years. India currently successfully operates a number of nuclear reactors and its industry is able to supply most of the necessary equipment and has its research centers in lead positions in FBRs. Nevertheless, it faces seemingly insurmountable economic, legal, technical, logistical and commercial challenges that need to be overcome to meet its nuclear ambitions. At the very least, the government needs to establish a sound economic framework that would guarantee economic sustainability to its electricity sector.

Conclusion

In studying India's energy sector, it is easy to confuse the whole for its parts. The industrialized world is threatened by the whole or the aggregate level of India's energy consumption, which is comparable to the largest energy consumers of the world; but it often ignores the low per capita energy consumption levels that are comparable to the energy consumption levels of Mozambique. The magnitude of projected energy demand also captivates and engages Indian energy planners to such an extent that they often overlook qualitative aspects such as increasing efficiency in energy production and distribution, offering equity in energy distribution and ensuring compliance with environmental standards. Available technologies can play a critical role in the qualitative aspect of energy production and delivery, yet it is marginalized as it is not as politically attractive as the 'security of supply' framing of the energy problem.

India's energy challenge is threatening, both for India and the rest of the world, precisely because the well-known rhetorical conflict between the message of abundance and the message of scarcity seems to have suddenly become reality. Technology which has traditionally moderated the conflict between abundance and scarcity is once again seen as the savior that would deliver abundance for India and the rest of the developing world. Sophisticated global technological resolutions convey the message that energy technology solutions are automatic and could be confidently awaited. Yet it is unclear at this point whether the optimism is justified, given the scale and scope of India's energy challenge.

Notes

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6. Narasimha Rao, Girish Sant and Sudhir Chella Rajan, *An Overview of Indian Energy Trends: Low Carbon Growth and Development Challenges* (India: Prayas Energy Group, 2009).
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10. Central Electricity Authority, "Long Run Electricity Demand Forecast Using Econometric Model," *Report on Seventeenth Power Survey of India* (Government of India: 2007): 273-289.
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High Explosives and Security Issues in the Republic of Korea

Presentation Summary

Inho Kim, Ph.D.

Dr. Kim opens with a brief explanation of the two principal cornerstones of South Korea's Agency for Defense Development (ADD), where he serves as the Director of its High-Energy Density Technology Directorate. During the agency's creation in 1970, then South Korean president Park Chung-hee designated ADD as the "cornerstone of national defense." Given this guidance, the Directorate focused its efforts in the next 40 years in towards various indigenous high explosives for utilization in conventional weapons and platforms. In 2010, President Lee Myung-bak announced the agency's second cornerstone – the "creativity challenge," calling on ADD to transform itself and broaden its functions in the decades ahead. In this context, the High Energy Density Technology Directorate put forth a roadmap that focuses research and development (R&D) efforts on, among others, "defense green technology" and anti-terrorism technology. Dr. Kim proceeds to discuss details of these two priorities. He first expounds on two areas of research in defense green technology – nitrogen clusters and the development of demilitarization technology, and then goes on to elaborate on ADD's research on anti-terrorism technology.

Recent scientific breakthroughs related to nitrogen clusters derived from nitrogen in the air lends cautious optimism to the possibility that nitrogen clusters could be a next-generation energy material as well as a source of "green fuel." Dr. Kim posits that clusters could replace fossil fuel in the future and will have uses in ammunition and warheads, adding that it might take 20-30 years of R&D before clusters can achieve full utility. ADD houses a research center dedicated to green energy materials, including R&D on nitrogen clusters, but Dr. Kim says that international cooperation can further accelerate research progress. Currently, ADD is involved in two international cooperation projects in high energy density materials. The first is with the U.S. Army's Armament Research, Development and Engineering Center. The focus of this 10-year joint effort is low carbon, nitrogen-rich green explosives research. The second collaborative project on energy materials research is with the Swedish Defence Research Agency (FOI), one of Europe's leading research institutes in defense and security.

The development of demilitarization technology is ADD's answer to the problem of accumulating stockpiles of obsolete munitions (figure 1, p. 120). Dr. Kim points out that storage facilities for these munitions are running out fast. Munitions disposal through open burning or open detonation are increasingly becoming less viable because apart from the danger that obsolete munitions pose, these methods cause environmental pollution (e.g., heavy metal concentration in the soil and the circulation of toxic gases). He also mentions increasing calls for the recycling of resources as an important consideration in finding eco-friendly solutions for obsolete munitions.

Dr. Kim believes that the development of demilitarization technology is one of the best ways to participate in the defense green race while also in accord with the pursuit of a clean environment. He points to South Korea's joint partnership with the U.S. in the construction of a demilitarization facility for convention munitions as an ideal situation that responds to South Korean defense and environmental concerns while engaging in international collaboration. In this case, the U.S. provides the equipment and technology for the melt-out facility, while South Korea provides the buildings, manpower and support facilities.

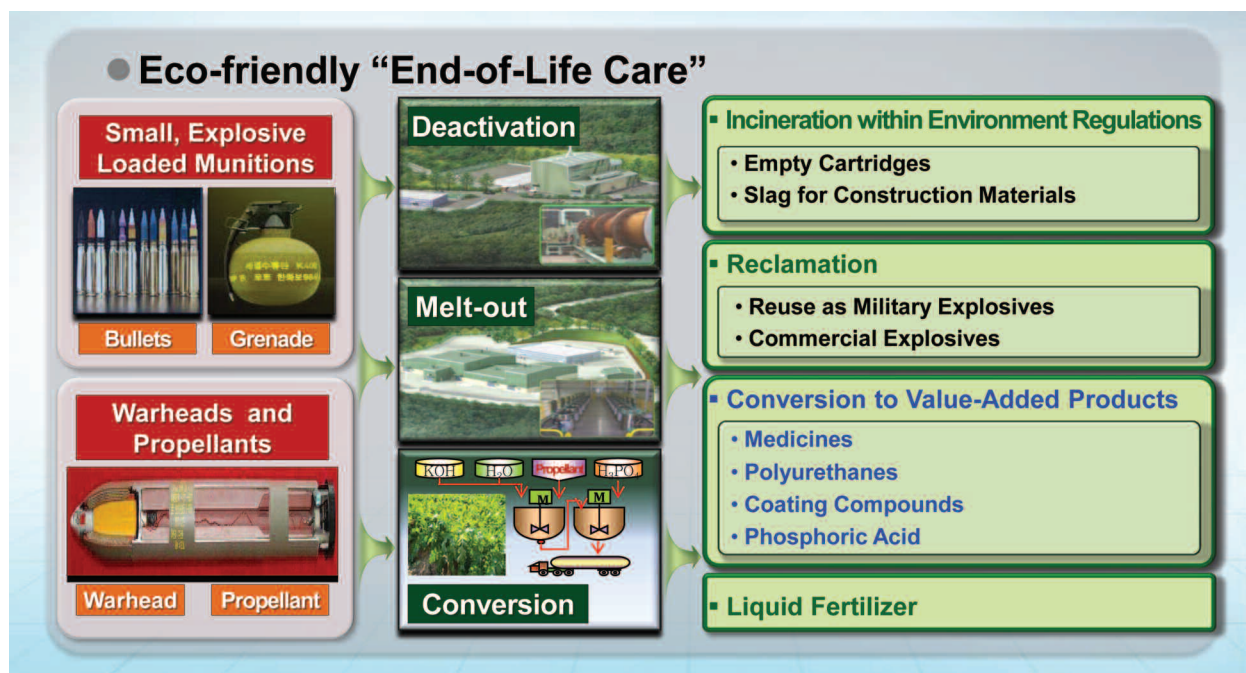


FIGURE 1 Demilitarization of Conventional Munitions

The terrorist groups' use of improvised explosive devices (IEDs) is a serious, worldwide security issue. For this reason, there is a high demand for IED detection and counter-IED technologies. He explains that explosive detection technologies are classified into two large groups – bulk detection and traces detection. Bulk detection technology is a technique to find the image of the bulk explosives utilizing various methods such as neutron techniques, nuclear quadruple resonance, X-ray diffraction imaging, millimeter-wave imaging, terahertz imaging and laser techniques. Trace detection technology is a technique to detect small amounts of vapors or molecules of explosive materials utilizing various methods such as chemiluminescence, mass spectroscopy, ion mobility spectroscopy, electrochemical methods and micro mechanical sensors.

Dr. Kim cites the 2010 sinking of the Cheonan, a South Korean war ship, to illustrate the key points of his presentation. First, it demonstrates how ADD's 40-year R&D efforts in high explosives including underwater explosives prepared them to conduct a thorough scientific analysis of the incident. The investigation's conclusion attributes the sinking to an explosion of 250 kg of

aluminized underwater high explosives that occurred at a point three meters left from the keel in the port side in depths between six to nine meters. Second, the incident underscores the importance of international cooperation in science and technology. The assistance that the multinational team provided to the South Korean team in various aspects of the investigation proved invaluable. Their presence and role also lent objectivity to the findings of the investigation. Dr. Kim points out that reliable analysis of explosion damages requires various test and evaluation technologies and a lot of experience on high explosives-related phenomena. It is also time consuming and very expensive to get the database. So a corollary lesson on international cooperation from the Cheonan sinking is the need for increased information-sharing of the damage analysis database among countries. And third, the sinking via high explosives suggests the strong possibility that future acts of terrorism can utilize new types of high explosives. Thus R&D on detection technologies must keep pace with the emergence of new high energy density materials. In addition, the incident points to the need for stronger international regulations regarding the use of tag materials in high explosives and the creation of an international agreement to control high explosives including its raw materials.

Emerging Energy S&T: Understanding Issues with Potential Security Impacts

Presentation Summary

Elizabeth R. Cantwell, Ph.D.

Advances in science and technology are needed to meet the challenges brought on by the convergence of energy, economies and global futures, especially with increasing global energy use commensurate with economic development. In this context, Dr. Cantwell discusses two considerations. The first is the need for transformational discoveries and disruptive technologies to mitigate climate change, decrease all dependencies on nonrenewable fossil fuels, create localized resource capacities for increased resiliency and manage/understand the increasing complexities of global energy. The second consideration is Dr. Cantwell's belief that leaders in innovation will drive the technology that defines the 21st century. In this respect, she emphasizes that policymakers must stay engaged with global innovations. One of the pressing issues that both these communities need to address is to improve understanding of the impacts of new technologies on global energy and resource 'systems.'

Discussing in more detail her view on global energy resource systems, Dr. Cantwell raises the issue of resource wars. She identifies two systemic features that frame the debate around the possibility of future resource wars. The first is the existence of **interdependencies**. In this early 21st century, access to energy sources depends on:

- global markets;
- the incapacity of most countries to be self-sufficient;
- cross-border pipelines and other strategic transport channels;
- closely-linked financial and energy markets;
- the interdependence between energy, water and land use; and
- existing risks including major supply disruption through political conflict or war, technical system failures, accidents, sabotage, extreme weather or financial market turmoil.

The second feature addresses the vital **networks** of complex energy systems to include:

- supply from upstream to downstream;
- vast infrastructure of offshore platforms, pipelines, tankers, refineries, storage, generation capacity, and transmission and distribution systems; and

- the revolutionary transition of power grids worldwide into so-called ‘smart grids’ that exploit renewable energy sources; as such, distributed power generation requires networked control, making future power systems more exposed to cyberattacks.

Global energy resource systems also contain various energy opportunities. Dr. Cantwell argues that all these opportunities contain both positive and negative aspects (table 1) as well as scientific and technological challenges (table 2), and it is too early to pick winners.

Opportunity	Advantages	Disadvantages
Nuclear power	Carbon-free electricity	Large water requirement, used nuclear fuel, proliferation risk
Biofuels	Low net carbon fuels	Competes with food crops for land and water
Electric vehicles	Reduced point-of-use emissions	Requires electricity, grid, infrastructure
Net-zero-energy buildings	Reduced energy consumption	Prescriptive standards may limit innovation, cost benefit
Carbon sequestration	Reduced net emissions	Significant efficiency penalty, indemnification
Solar and wind power	Zero net carbon generation	Large footprint for generation at scale, grid integration, cost benefit

TABLE 1 Energy Opportunities: Positive and Negative Aspects

Technology	Requirements
Nuclear fission	Reduced water consumption and (maybe) economical fuel reprocessing
Nuclear fusion	Major breakthroughs in several fields
Biofuels	Efficient conversion of cellulosic materials, distribution
Electric vehicles	Improved vehicle-scale energy storage, VII
Demand-side management	“Smart grid” and smart appliances
“Clean coal”	Efficient carbon capture and sequestration
Wind/solar	Utility-scale energy storage
Utility-scale solar	New nanostructured materials

TABLE 2 Energy Opportunities: Scientific and Technological Challenges

Dr. Cantwell then proceeds to discuss her list of energy science and technology (S&T) to watch, including the potential security issues they present to security practitioners and policy-makers alike (table 3).

<ul style="list-style-type: none"> • Advanced fossil fuel options • Nuclear Power • Wind • Hydrogen • Bioenergy • Energy storage • Energy efficiency • Buildings • Distribution and Transmission • Vehicle electrification 	<p>Potential security issues?</p> <ul style="list-style-type: none"> • Nuclear materials proliferation • Development in materials science • System interconnects & issues • Resource wars – concurrent competition for water, raw materials, land use • Cybersecurity • Sensing & observing environmental & climate impacts • Global definitions of sustainability – influence on economies • Soft power options for defense engagements
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TABLE 3 Energy Science and Technology to Watch

Among her list of potential security threats, Dr. Cantwell believes that the “top four” security challenges arising from future energy S&T developments are:

- nuclear materials proliferation – advancing the use of nuclear energy will require that the back end of the fuel cycle be intelligently handled, and that both the fissile resources and waste streams be properly managed (examples of new challenges include small modular reactors that will place nuclear material in far more locations);
- development in materials science – supercomputing capabilities have been shown to greatly expand our options for “materials by design” to solve problems in nuclear, solar and energy efficiency. These computers know little to nothing about where the molecules they design can/will be sourced in real world manufacturing;
- system interconnects – as the global energy system becomes more interdependent and far more networked, how to understand (predict), manage and control – to the extent possible – the propagation of “problems” (this may be one of the best ways to mitigate resource wars); and
- cybersecurity – the future grid will be in many senses global and will be a smart grid with automated power delivery, networked to ensure a two-way flow of electricity and information between a few thousand conventional generators and hundreds of thousands of distributed and variable renewable resource generators delivering energy services to hundreds of millions of interactive and smart loads.

Dr. Cantwell concludes her presentation by proposing some options for collaboration:

- soft power options for defense engagements;
- joint scenario planning with very advanced modeling capabilities that cross all resources and are interdependent with energy/climate issues can enhance communication and collaboration on the analysis of secure, low-carbon pathways (there is no 'silver bullet' for any nation or region);
- joint efforts to analyze and examine the effects of energy S&T on newly emerging carbon markets (although this is not a subject of this presentation, it is a critical issue in promoting global transition to lower carbon economies);
- developing a structure that enhances our likelihood for ad hoc interactions around technologies and their effects; and
- joint technology investments in clean energy technologies, and more importantly, pilot studies on energy systems.

P L E N A R Y S E S S I O N 6 :

U P D A T E O N S C I E N C E
& T E C H N O L O G Y
D E V E L O P M E N T S W I T H
S I G N I F I C A N T S E C U R I T Y
I M P L I C A T I O N S

Category #4:
Environmental

*A Rational Discussion of Climate Change: The Science, the Evidence, the Response**

Benjamin D. Santer, Ph.D.

Introduction

In 1988, the Intergovernmental Panel on Climate Change (IPCC) was jointly established by the World Meteorological Organization and the United Nations Environment Programme. The goals of this panel were threefold: to assess available scientific information on climate change, to evaluate the environmental and societal impacts of climate change, and to formulate response strategies. The IPCC's first major scientific assessment, published in 1990, concluded that "unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more."¹

In 1996, the IPCC's second scientific assessment made a more definitive statement regarding human impacts on climate, and concluded that "the balance of evidence suggests a discernible human influence on global climate."² This cautious sentence marked a paradigm shift in our scientific understanding of the causes of recent climate change. The shift arose for a variety of reasons. Chief amongst these was the realization that the cooling effects of sulfate aerosol particles (which are produced by burning fossil fuels that contain sulfates) had partially masked the warming signal arising from increasing atmospheric concentrations of greenhouse gases.³

A further major area of progress was the increasing use of "fingerprint" studies.^{4,5,6} The strategy in this type of research is to search for a "fingerprint" (the climate change pattern predicted by a computer model) in observed climate records. The underlying assumption in fingerprinting is that each "forcing" of climate – such as changes in the sun's energy output, volcanic dust, sulfate aerosols, or greenhouse gas concentrations – has a unique pattern of climate response (see figure 1, pg. 130). Fingerprint studies apply signal processing techniques very similar to those used in electrical engineering.⁷ They allow researchers to make rigorous tests of competing hypotheses regarding the causes of recent climate change.

*This is the first public presentation, in abbreviated form, of the author's subsequent testimony to the U.S. Congress, prepared for the House Committee on Science and Technology, Subcommittee on Energy and Environment, at a hearing entitled "A Rational Discussion of Climate Change: The Science, the Evidence, the Response," on November 17, 2010. The testimony primarily focuses on rigorous "fingerprint" studies that compare observed spatial patterns of climate change with results from computer model simulations. For the complete report, including the "Response to Questions for the Record," see <http://www.gpo.gov/fdsys/pkg/CHRG-111hhr62618/pdf/CHRG-111hhr62618.pdf>.

*In keeping with the format followed in this publication, all the original footnotes from the GPO version were reformatted as 'endnotes'. The author also made some recent minor revisions to this paper.

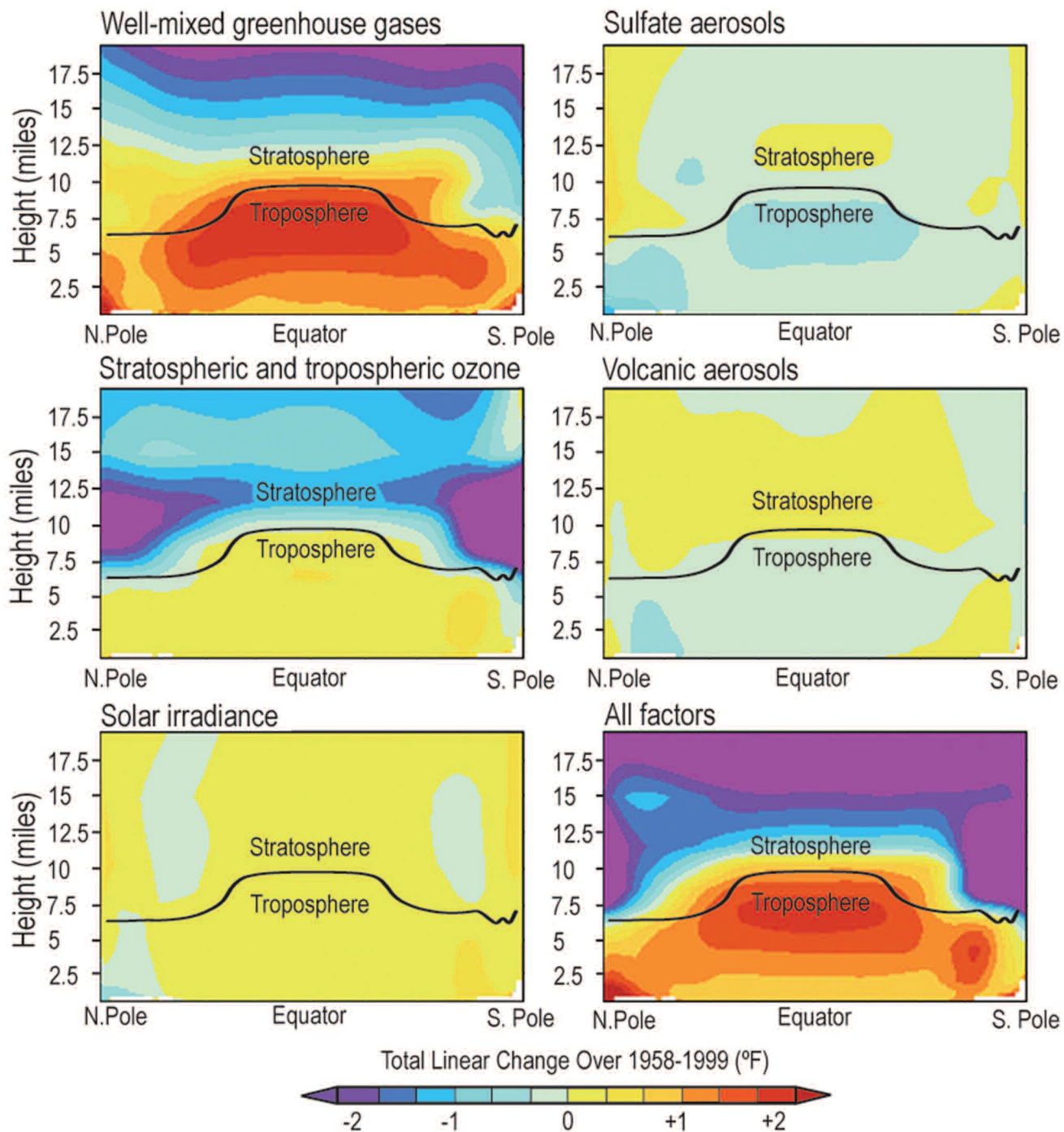


FIGURE 1 Climate simulations of the vertical profile of temperature change due to five different factors, and the effect due to all factors taken together. The panels above represent a cross-section of the atmosphere from the North Pole to the South Pole, and from the surface up into the stratosphere. The black lines show the approximate location of the tropopause, the boundary between the lower atmosphere (the troposphere) and the stratosphere.

SOURCE: T.R. Karl, J.M. Melillo, and T.C. Peterson. *Global Climate Change Impacts in the United States*. (Cambridge University Press, 2009), 21.

The third IPCC assessment was published in 2001, and went one step further than its predecessor. The third assessment reported on the magnitude of the human effect on climate. It found that “there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.”⁸ This conclusion was based on improved estimates of natural climate variability, better reconstructions of temperature fluctuations over the last millennium, continued warming of the climate system, refinements in fingerprint methods, and the use of results from more (and improved) climate models, driven by more accurate and complete estimates of the human and natural “forcings” of climate.

This gradual strengthening of scientific confidence in the reality of human influences on global climate continued in the fourth IPCC assessment report (AR4) report, which stated that “warming of the climate system is unequivocal,” and that “most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations” (where “very likely” signified >90 percent probability that the statement is correct). The AR4 report justified this increase in scientific confidence on the basis of “...longer and improved records, an expanded range of observations, and improvements in the simulation of many aspects of climate and its variability.”¹⁰ In its contribution to the AR4, IPCC Working Group II concluded that anthropogenic warming has had a discernible influence not only on the physical climate system, but also on a wide range of biological systems which respond to climate.¹¹

Extraordinary claims require extraordinary proof.¹² The IPCC’s extraordinary claim that human activities significantly altered both the chemical composition of Earth’s atmosphere and the climate system has received extraordinary scrutiny. This claim has been independently corroborated by the U.S. National Academy of Sciences,¹³ the Science Academies of 11 nations,¹⁴ and the Synthesis and Assessment Products of the U.S. Climate Change Science Plan.¹⁵ Many of our professional scientific organizations have also affirmed the reality of a human influence on global climate.¹⁶

Despite the overwhelming evidence of pronounced anthropogenic effects on climate, important uncertainties remain in our ability to quantify the human influence. The experiment that we are performing with the Earth’s atmosphere lacks a suitable control: we do not have a convenient “undisturbed Earth,” which would provide a reference against which we could measure the anthropogenic contribution to climate change. We must therefore rely on numerical models and paleoclimate evidence^{17,18,19} to estimate how the Earth’s climate might have evolved in the absence of any human intervention. Such sources of information will always have significant uncertainties.

In the following testimony, I provide a personal perspective on recent developments in the field of detection and attribution (D&A) research. Such research is directed towards detecting significant climate change, and then attributing some portion of the detected change to a specific cause or causes.^{20,21,22,23} I also make some brief remarks about openness and data sharing in the climate modeling community, and accommodation of “alternative” views in the IPCC.

Recent Progress in Detection and Attribution Research

Fingerprinting

The IPCC and National Academy findings that human activities are affecting global-scale climate are based on multiple lines of evidence:

1. Our continually improving physical understanding of the climate system and of the human and natural factors that cause climate to change;
2. Evidence from paleoclimate reconstructions, which enables us to place the warming of the 20th century in a longer-term context;^{24,25}
3. The qualitative consistency between observed changes in different aspects of the climate system and model predictions of the changes that should be occurring in response to human influences;^{26,27} and
4. Evidence from rigorous quantitative fingerprint studies, which compare observed patterns of climate change with results from computer model simulations.

Most of my testimony will focus on the fingerprint evidence, since this is within my own area of scientific expertise.

As noted above, fingerprint studies search for some pattern of climate change (the “fingerprint”) in observational data. The fingerprint can be estimated in different ways, but is typically obtained from a computer model experiment in which one or more human factors are varied according to the best-available estimates of their historical changes. Different statistical techniques are then applied to quantify the level of agreement between the fingerprint and observations and between the fingerprint and estimates of the natural internal variability of climate. This enables researchers to make rigorous tests of competing hypotheses²⁸ regarding the possible causes of recent climate change.^{29,30,31,32}

While early fingerprint work dealt almost exclusively with changes in near-surface or atmospheric temperature, more recent studies have applied fingerprint methods to a range of different variables, such as changes in ocean heat content,^{33,34} Atlantic salinity,³⁵ sea-level pressure,³⁶ tropopause height,³⁷ rainfall patterns,^{38,39} surface humidity,⁴⁰ atmospheric moisture,^{41,42} continental river runoff,⁴³ and Arctic sea ice extent.⁴⁴ The general conclusion is that for each of these variables, natural causes alone cannot explain the observed climate changes over the second half of the 20th century. The best statistical explanation of the observed climate changes invariably involves a large human contribution. These fingerprint results are robust to the processing choices made by different groups, and show a high level of physical consistency across different climate variables. For example, observed atmospheric water vapor increases⁴⁵ are physically consistent with increases in ocean heat content^{46,47} and near-surface temperature.^{48,49}

There are a number of popular misconceptions about fingerprint evidence. One misconception is that fingerprint studies consider global-mean temperatures only, and thus provide a very poor constraint on the relative contributions of human and natural factors to observed changes.⁵⁰ In fact, fingerprint studies rely on information about the detailed spatial structure (and often the combined space and time structure) of observed and simulated climate changes. Complex patterns provide much stronger constraints on the possible contributions of different factors to observed climate changes.^{51,52,53}

Another misconception is that computer model estimates of natural internal climate variability (“climate noise”) are accepted uncritically in fingerprint studies, and are never tested against observations.⁵⁴ This is demonstrably untrue. Many fingerprint studies test whether model estimates of climate noise are realistic. Such tests are routinely performed on year-to-year and decade-to-decade timescales, where observational data are of sufficient length to obtain reliable estimates of observed climate variability.^{55,56,57,58}

Because regional-scale climate changes will determine societal impacts, fingerprint studies are increasingly shifting their focus from global to regional scales.⁵⁹ Such regional studies face a number of challenges. One problem is that the noise of natural internal climate variability typically becomes larger when averaged over increasingly finer scales,⁶⁰ so that identifying regional and local climate signals becomes more difficult.

Another problem relates to the climate “forcings” used in computer model simulations of historical climate change. As scientific attention shifts to ever smaller spatial scales, it becomes more important to obtain reliable information about these forcings. Some forcings are both uncertain and highly variable in space and time.^{61,62} Examples include human-induced changes in land surface properties⁶³ or in the concentrations of carbon-containing aerosols.^{64,65} Neglect or inaccurate specification of these factors complicates D&A studies.

Despite these problems, numerous researchers have now shown that the climate signals of greenhouse gases and sulfate aerosols are identifiable at continental and sub-continental scales in many different regions around the globe.^{66,67,68,69} Related work^{70,71} suggests that a human-caused climate signal has already emerged from the background noise at spatial scales at or below 500 km,⁷² and may be contributing to regional changes in the distributions of plant and animal species.⁷³

In summarizing this section of my testimony, I note that the focus of fingerprint research has evolved over time. Its initial emphasis was on global-scale changes in Earth’s surface temperature. Subsequent research demonstrated that human fingerprints were identifiable in many different aspects of the climate system – not in surface temperature only. We are now on the verge of detecting human effects on climate at much finer regional scales of direct relevance to policymakers, and in variables tightly linked to climate change impacts.^{74,75,76,77,78}

Assessing Risks of Changes in Extreme Events

We are now capable of making informed scientific statements regarding the influence of human activities on the likelihood of extreme events.^{79,80,81} As noted previously, computer models can be used to perform the control experiment (no human effects on climate) that we cannot perform in the real world. Using the “unforced” climate variability from a multi-century control run, it is possible to determine how many times an extreme event of a given magnitude should have been observed in the absence of human interference. The probability of obtaining the same extreme event is then calculated in a perturbed climate – for example, in a model experiment with historical or future increases in greenhouse gases, or under some specified change in mean climate.⁸² Comparison of the frequencies of extremes in the control and perturbed experiments allows climate scientists to make probabilistic statements about how human-induced climate change may have altered the likelihood of the extreme event.^{83,84,85} This is sometimes referred to as an assessment of “fractional attributable risk.”⁸⁶

Recently, a “fractional attributable risk” study of the 2003 European summer heat wave concluded that “*there is a greater than 90% percent chance that over half the risk of European summer temperatures exceeding a threshold of 1.6 K is attributable to human influence on climate.*”⁸⁷ This study (and related work) illustrates that the D&A community has moved beyond analysis of changes in the mean state of the climate. We now apply rigorous statistical methods to the problem of estimating how human activities may alter the probability of occurrence of extreme events. The demonstration of human culpability in changing these risks is likely to have significant implications for the debate on policy responses to climate change.

Summary of Detection and Attribution Evidence

In evaluating how well a novel has been crafted, it is important to look at the internal consistency of the plot. Critical readers examine whether the individual storylines are neatly woven together, and whether the internal logic makes sense. We can ask similar questions about the “story” contained in observational records of climate change. The evidence from numerous sources (paleoclimate data, rigorous fingerprint studies, and qualitative comparisons of modeled and observed climate changes) shows that the climate system is telling us an internally consistent story about the causes of recent climate change.

Over the last century, we have observed large and coherent changes in many different aspects of Earth’s climate. The oceans and land surface have warmed.^{88,89,90,91,92,93,94,95} Atmospheric moisture has increased.^{96,97,98,99} Rainfall patterns have changed.^{100,101} Glaciers have retreated over most of the globe.^{102,103,104} The Greenland Ice Sheet has lost some of its mass.¹⁰⁵ Sea level has risen.¹⁰⁶ Snow and sea-ice extent have decreased in the Northern Hemisphere.^{107,108,109,110} The stratosphere has cooled,¹¹¹ and there are now reliable indications that the troposphere has warmed.^{112,113,114,115,116,117,118,119,120,121,122} The height of the tropopause has increased.¹²³ Individually, all of these changes are consistent with our scientific understanding of how the climate system

should be responding to anthropogenic forcing. Collectively, this behavior is inconsistent with the changes that we would expect to occur due to natural variability alone.

There is now compelling scientific evidence that human activity has had a discernible influence on global climate. However, there are still significant uncertainties in our estimates of the size and geographical distribution of the climate changes projected to occur over the 21st century. These uncertainties make it difficult for us to assess the magnitude of the mitigation and adaptation problem that faces us and our descendants. The dilemma that confronts us, as citizens and stewards of this planet, is how to act in the face of both hard scientific evidence that our actions are altering global climate and continuing uncertainty in the size of the planetary warming that faces us.

Openness and Data Sharing in the Climate Modeling Community

Recently, concerns have been expressed about ease of access to the information produced by computer models of the climate system. Climate modeling is sometimes portrayed as a secretive endeavor. This is not the case. In the 1970s and 1980s, the evaluation and intercomparison of climate models was largely qualitative, mostly performed by modelers themselves. It often involved purely visual examination of maps from a single model and observations (or from several different models). There were no standard benchmark experiments, and there was little or no community involvement in model diagnosis. It was difficult to track changes in model performance over time.¹²⁴

This situation changed dramatically with the start of the Atmospheric Model Intercomparison Project (AMIP) in the early 1990s. AMIP involved running different Atmospheric General Circulation Models (AGCMs) with observed sea-surface temperatures and sea-ice changes over 1979 to 1988. Approximately 30 modeling groups from 10 different countries participated in the design and diagnosis of the AGCM simulations. Subsequent “revisits” of AMIP enabled the climate community to track changes in model performance over time.¹²⁵

The next major Model Intercomparison Project (MIP) began in the mid-1990s. In phase one of the Coupled Model Intercomparison Project (CMIP-1), over a dozen fully-coupled Atmosphere/Ocean General Circulation Models (A/OGCMs) were used to study the response of the climate system to an idealized climate-change scenario – a 1 percent per year (compound interest) increase in levels of atmospheric CO₂.¹²⁶ The key aspect here was that each modeling group performed the same benchmark simulation, allowing scientists to focus their attention on the task of quantifying (and understanding) uncertainties in computer model projections of future climate change.

AMIP and CMIP have spawned literally dozens of other international Model Intercomparison Projects. MIPs are now a *de facto* standard in the climate science community. They have allowed climate scientists to:

- identify systematic errors common to many different models;
- track changes in model performance over time (in individual models and collectively);
- make informed statements about the relative quality of different models; and
- quantify uncertainties in model projections of future climate change.

Full community involvement in MIPs has led to more thorough model diagnosis, and to improved climate models. Perhaps the best-known model intercomparison is phase three of CMIP. The CMIP-3 project was a valuable resource for the Fourth Assessment Report (FAR) of the IPCC.¹²⁷ In the course of CMIP-3, simulation output was collected from 25 different A/OGCMs. The models used in these simulations were from 17 modeling centers and 13 countries. Twelve different types of simulation were performed with each model. The simulations included so-called “climate of the 20th century” experiments (with estimated historical changes in greenhouse gases, various aerosol particles, volcanic dust, solar irradiance, etc.), pre-industrial control runs (with no changes in human or natural climate forcings), and scenarios of future changes in greenhouse gases. All of the simulation output was stored at LLNL’s Program for Climate Model Diagnosis and Intercomparison (PCMDI).

At present, 35 Terabytes of CMIP-3 data are archived at PCMDI, and nearly one Petabyte of model output (1 Petabyte = 10^{15} bytes) has been distributed to over 4,300 users in several dozen countries. The CMIP-3 multi-model archive has transformed the world of climate science. As of November 2010, over 560 peer-reviewed publications used CMIP-3 data. These publications formed the scientific backbone of the IPCC FAR. The CMIP-3 archive provided the basis for roughly 75 percent of the figures in Chapters 8-11 of the Fourth Assessment Report, and for four of the seven figures in the IPCC “Summary for Policymakers.”¹²⁸

The CMIP-3 database can be used by anyone, free of charge. It is one of the most successful data-sharing models in any scientific community – not just the climate science community.

Accommodation of “alternative” views in the IPCC

Some parties critical of the IPCC have claimed that it does not accommodate the full range of scientific views on the subject of the nature and causes of climate change. In my opinion, such claims are specious. I would contend that all four previous IPCC Assessments^{129,130,131,132} have dealt with “alternative viewpoints” in a thorough and comprehensive way. The IPCC reports have devoted extraordinary scientific attention to a number of highly-publicized (and incorrect) claims.

Examples include the following claims that: 1) the tropical lower troposphere cooled over the satellite era; 2) that the water vapor feedback is zero or negative; and 3) that variations in the sun’s energy output explain all observed climate change. The climate and science community has not dismissed these claims out of hand. Scientists have done the research necessary to determine whether these “alternative viewpoints” are scientifically credible, and have shown that they are not.

Concluding Thoughts

My job is to evaluate climate models and improve our scientific understanding of the nature and causes of climate change. I chose this profession because of a deep and abiding curiosity about the world in which we live. The same intellectual curiosity motivates virtually all climate scientists I know. As my testimony indicates, the scientific evidence is compelling. We know, beyond a shadow of a doubt, that human activities have changed the composition of Earth's atmosphere. And we know that these human-caused changes in the levels of greenhouse gases make it easier for the atmosphere to trap heat. This is simple, basic physics. While there is legitimate debate in the scientific community about the size of the human effect on climate, there is really no serious scientific debate about the scientific finding that our planet warmed over the last century, and that human activities are implicated in this warming.

Notes

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7. Hasselmann, "On the signal-to-noise problem," 251-259.
8. John Theodore Houghton et al., *Climate Change 2001: The Scientific Basis* (Cambridge, U.K.: Cambridge University Press, 2001), 4.
9. IPCC, "Summary for Policymakers," in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. S. Solomon et al. (Cambridge, UK and New York, USA: Cambridge University Press, 2007).
10. Ibid.
11. IPCC, "Summary for Policymakers," in *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. M. Parry et al. (Cambridge, UK and New York, USA: Cambridge University Press, 2007).
12. This phrase is often attributed to the late sociologist Marcello Truzzi (see http://en.wikipedia.org/wiki/Marcello_Truzzi).
13. National Research Council, *Climate Change Science. An Analysis of Some Key Questions* (Washington D.C.: National Academy Press, 2001), 29.
14. Prior to the Gleneagles G8 summit in July 2005, the Science Academies of 11 nations issued a joint statement on climate

change (<http://www.nasonline.org/site>). The statement affirmed the IPCC finding that “most of the warming observed over the last 50 years is attributable to human activities” (ref. 8). The signatories were from the Academia Brasileira de Ciências, the Royal Society of Canada, the Chinese Academy of Sciences, the Académie des Sciences, France, the Deutsche Akademie der Naturforscher, the Indian National Science Academy, the Accademia dei Lincei, Italy, the Science Council of Japan, the Russian Academy of Sciences, the United Kingdom Royal Society, and the U.S. National Academy of Sciences.

15. Thomas R. Karl et al., eds. *Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences* (Asheville, NC: National Climatic Data Center, 2006), 164.

16. See, for example, the position statements on climate change issued by the American Geophysical Union (AGU), the American Meteorological Society (AMS), and the American Statistical Association (ASA). These can be found at: http://www.agu.org/sci_pol/positions/climate_change2008.shtml (AGU); <http://www.ametsoc.org/amsnews/2007/climatechangerelease.pdf> (AMS); and <http://www.amstat.org/news/climatechange.cfm> (ASA).

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23. Gabriele C. Hegerl et al., “Understanding and Attributing Climate Change,” in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. S. Solomon et al. (Cambridge, UK and New York, USA; Cambridge University Press, 2007), 663-745.

24. A recent assessment of the U.S. National Academy of Sciences concluded that “It can be said with a high level of confidence that global mean surface temperature was higher during the last few decades of the 20th century than during any comparable period during the preceding four centuries” (ref. 25, page 3). The same study also found “it plausible that the Northern Hemisphere was warmer during the last few decades of the 20th century than during any comparable period over the preceding millennium” (ref. 25, pages 3-4).

25. National Research Council, *Surface Temperature Reconstructions for the Last 2,000 Years* (Washington D.C.: National Academies Press, 2006), 196.

26. IPCC, “Summary for Policymakers,” *Climate Change 2007: The Physical Science Basis*.

27. Examples include increases in surface and tropospheric temperature, increases in atmospheric water vapor and ocean heat content, sea-level rise, widespread retreat of glaciers, etc.

28. An example includes testing the null hypothesis that there has been no external forcing of the climate system against the alternative hypothesis that there has been significant external forcing. Currently, all such hypothesis tests rely on model-based estimates of “unforced” climate variability (also known as natural internal variability). This is the variability that arises solely from processes internal to the climate system, such as interactions between the atmosphere and ocean. The El Niño phenomenon is a well-known example of internal climate noise.

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50. The argument here is that some anthropogenic “forcings” of climate (particularly the so-called indirect forcing caused by the effects of anthropogenic aerosols on cloud properties) are highly uncertain, so that many different combinations of these factors could yield the same global-mean changes. While this is a valid concern for global-mean temperature changes, it is highly unlikely that different combinations of forcing factors could produce the same complex space-time patterns of climate change (see figure 1).

51. Some researchers have argued that most of the observed near-surface warming over the 20th century is attributable to an overall increase in the Sun’s energy output. The effect of such an increase would be to warm most of the atmosphere (from the Earth’s surface through the stratosphere; see figure 1, lower left panel). Such behavior is not seen in observations. While temperature measurements from satellites and weather balloons do show warming of the troposphere, they also indicate that the stratosphere has cooled over the past 2-4 decades (ref. 15). Stratospheric cooling is fundamentally inconsistent with a ‘solar forcing only’ hypothesis of observed climate change, but is consistent with simulations of the response to anthropogenic greenhouse gas increases and ozone decreases (see figure 1, top left and middle left panels). The possibility of a large solar forcing effect has been further weakened by recent research indicating that changes in solar luminosity on multi-decadal timescales are likely to be significantly smaller than previously thought (refs. 52, 53).

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Assessing Future Security Landscapes: A View Through the Lens of Real Landscapes of Social-ecological Systems

David Brunckhorst, Ph.D.

Introduction

The focus of this paper is human-environmental, non-traditional security issues.¹ In particular contexts, emerging conditions or natural disaster situations can be of importance to more traditional security matters – for example, through the breakdown of civil norms, destruction of social cohesion and civic loyalties – which in turn influence security matters of concern to nation states.

From this perspective, bio-physical and social-ecological interactions and interdependencies in the coming decades will produce considerable landscape changes, including changes to coastal systems, inshore waters and the oceans. A summary list would include:

- landscape systems change;
- natural disasters;
- food and water security;
- bio-security (closely linked to food and water security in rural areas);
- oceans security;
- energy security; and
- synergistic combinations (e.g., coastal settlement, degradation of protective coral reefs coupled with increasing climate change perturbations and a period of increased tectonic/volcanic activity around the Pacific Rim).

Our socially and culturally influenced attitudes and behaviors produce policies and actions – particularly in the use of natural resources – that over time create a variety of contexts and conditions. These past, present and future conditions will largely dictate disruptions to both social and ecological systems from which might emerge short-term or long-term human security issues, vulnerabilities and the capacities (or not) to address such issues (figure 1, p. 146). Space is itself a critical resource, particularly areas for human settlement and resource access and as location for environmental systems to function and provide essential services.

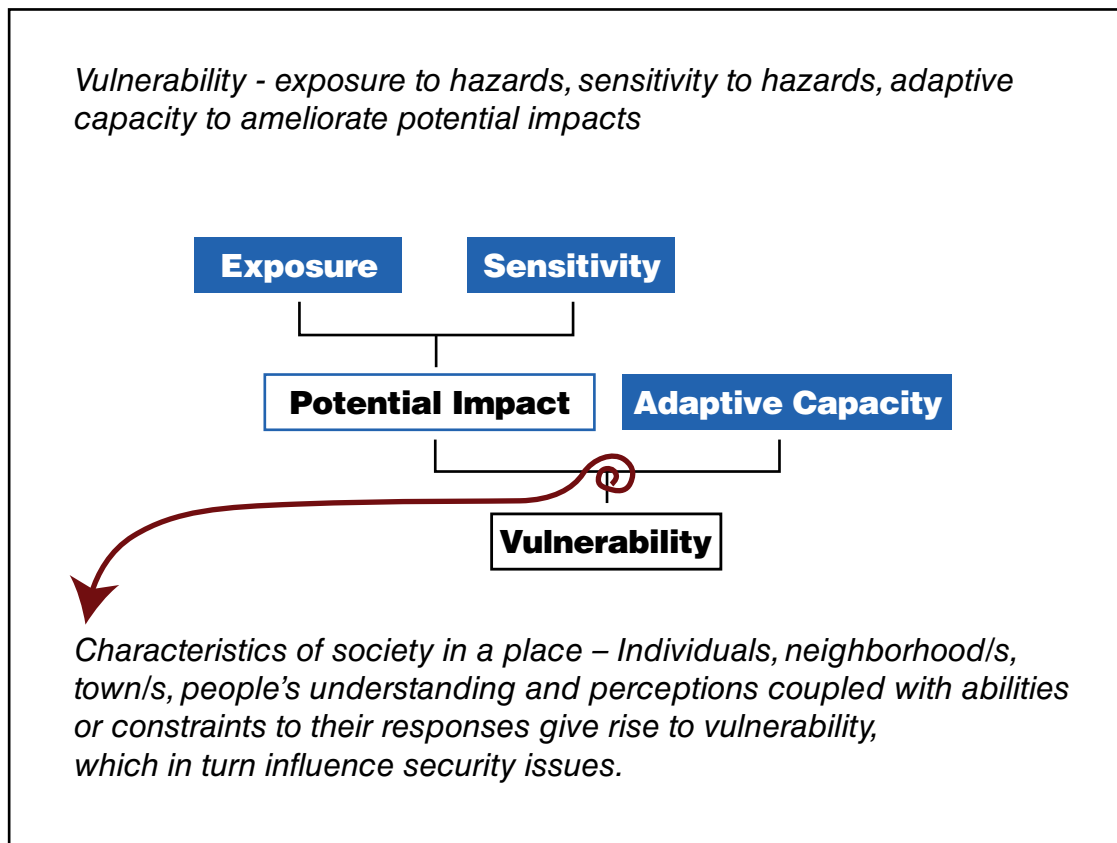


FIGURE 1 Vulnerability to human security issues: vulnerabilities are a product of exposure and sensitivity to a disturbance and its impact. Local characteristics of human settlements and communities influence their adaptive capacity and response, which in turn might ameliorate or exacerbate human security.

Landscape Systems Security – Patterns and Context

Landscapes herein are considered as areas of local geography of recognizable pattern of ecosystems and living spaces having meaning to resident communities. The spatial arrangements of human interactions with ecological systems, along with biophysical elements, clearly create observable landscape patterns that reflect the processes of decisions about settlement and resource use and ecosystem function. Over time, landscapes internalize and reflect the affects of change.

Change begets change. Mosaics of changing landscape patterns reflect responses and feedbacks of social-ecological interactions that drive change in natural resource capacity and ecosystem health. Landscape ecology provides a useful regional approach to understanding social-ecological systems interactions to assist the design of institutional arrangements towards more enduring sustainability. This structuring of landscapes and regions through social-ecological systems interactions defines operational contexts in which to integrate cross-scale interactions of resource use, property rights, agency jurisdictions and ecological patterns and processes (figure 2, p. 147).

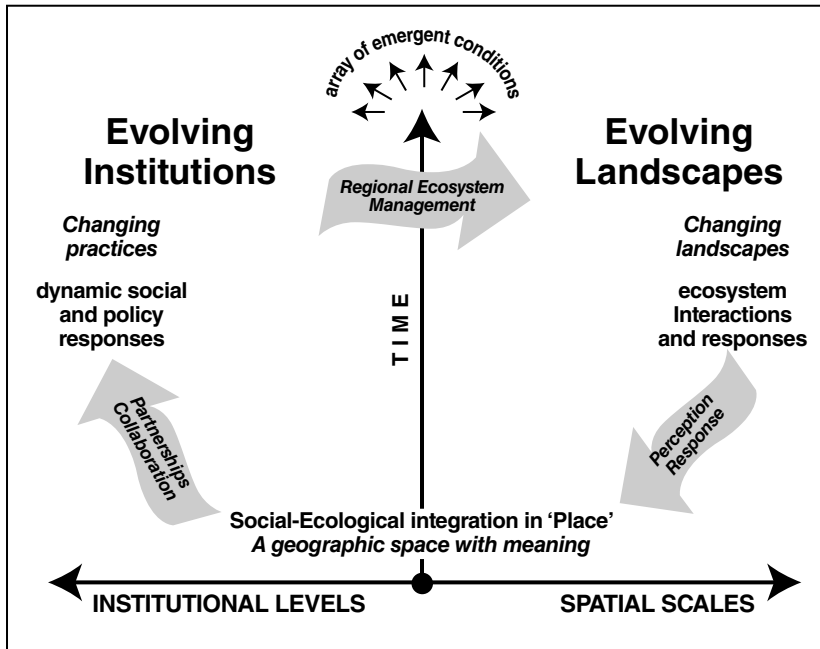


FIGURE 2 Social-ecological systems interactions and interdependencies operate as cycles of feedback and adjustment across spatial and institutional scales. Therefore, future landscapes are co-evolving and influence the emergence of stable or unstable conditions that shape human security.

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Patterns or processes that develop out of interdependent interactions occurring across landscapes are uniquely different from the individual ecosystem elements that created them. Systems scientists refer to these as emergent properties or conditions of systems interactions. Emergent conditions of social-ecological systems interactions are often at the heart of sustainability issues and may involve interactions of fast and slow moving variables, feedbacks, threshold effects, responses and re-organization (figure 2). A subtle synthesis of systems interactions might lead to a manifestation of surprises including possible systems crash, e.g., collapse of viable species populations, ecosystems or whole social-ecological systems.

These regional landscapes and context-specific conditions can give rise to significant vulnerabilities to human security in terms of safety, well-being, health, social disorder, living space and essential services. For example, the social-ecological context of the hurricane disaster in and around New Orleans emerged out of a considerable range of ecological change, human settlement conditions and social conditions. Climate change-enhanced weather events in the future are likely to have even greater impacts.

Landscapes and their human residents are inseparable in their interdependent influences on each other. Future human security issues and vulnerabilities (or resilience) are being created now and over the intermediate time period. The future conditions they will impact upon are most likely

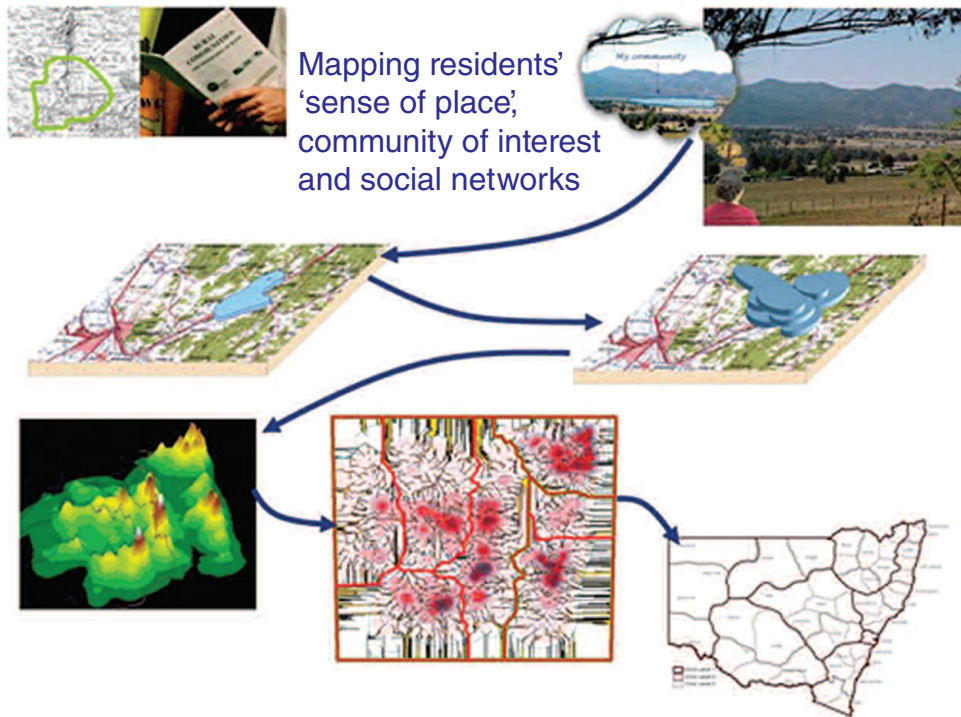
to be different from the present. There are five topics or issues of landscape systems security that I consider to be of particular importance in the future:

- water and other natural resources;
- production systems (protecting and sustaining good agricultural land, and sustained ocean fisheries);
- ecosystem services (not only for clean air and water, but also as buffers to increasing climate change perturbations);
- tenure ('living space,' amenities – urban / peri-urban / rural); and
- coastal systems (land-sea interface).

Resource security, bio-security and natural disasters are all interdependent with the above factors. Landscape change often reflects changes in all these parameters. Change is continuous, so the future will not be the same as the present. Understanding future human security issues such as those listed above requires an awareness of: first, how landscapes, human settlement patterns and resource access and use are changing; second, what future regional landscape patterns might manifest; and third the vulnerabilities that might emerge for human security in the event of natural disasters, climate change or other perturbations. Because the future will certainly be different, it is unwise, and likely to be misleading, to assess impacts on future human security based on present landscape patterns. Local circumstances and conditions provide the context within which sensitivity to impacts and adaptations occur. At various scales from the local landscape of social-ecological interactions and interdependencies, to broader regional situations (often dictated by externalities or linkages from lower levels), context is of critical importance to the emergence of circumstances around human security issues (figures 1-3, p. 146, 147 and 149). There is no panacea. As context and circumstances differ considerably from place to place and over time, policymakers and planners must be careful not to be tempted to create 'blue-print solutions.'

Science and Technology Developments Overview of Some Relevant Advances

Advances in spatially-attributed social network analysis (i.e., by Global Information Systems or GIS), community cohesion, place identity and social 'topographies' are providing valuable insights. Understanding scales of the social-ecological context is important to assessing, planning, and managing human security issues such as natural disasters. Community cohesion and human capital, important in such circumstances, are often based on contexts of community of interest, place identity and underlying natural resources. New techniques in combined social-ecological geographical analysis and spatially-attributed social survey techniques have opened the door to a better understanding of the spatial and institutional arrangements of such 'eco-civic' regions (figure 3, p. 149,). Coupled with local natural resource geographies, 'eco-civic' regionalization techniques offer particular insights to context and appropriate levels of community consultation and decision-making.



'Eco-Civic' Regionalization – A Social-ecological Synthesis (New South Wales State, Australia)

'Social Surface'

Hierarchy of community attachment and social networks.



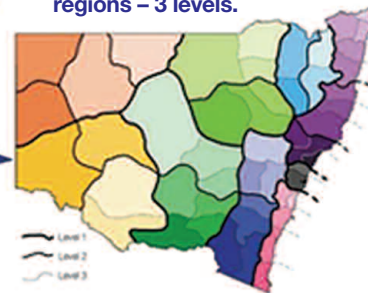
'Natural Resources'

Hierarchy of ecological regions/land use.



'Eco-Civic Regions'

Hierarchy of social-ecological regions – 3 levels.



Optimize boundary placement using 'valleys' in social-civic topography.



FIGURE 3 Mapping resident communities of interest and place attachment. Optimized with ecological regionalization, an 'eco-civic' regionalization can elucidate boundary scales for community-resource interactions, consultation and decision-making of relevance to human security issues and adaptive responses.

Identification of appropriately integrated contexts of communities and resource governance provides a much more meaningful basis for applying advanced (spatially-attributed) multi-criteria analysis techniques; for example, to concurrently assess levels of community sensitivity and adaptive capacity to a natural disaster or resource asset's security vulnerability – an example is illustrated in figure 4. Future community and socio-economic conditions are very difficult to predict. However, some advances are being made where trajectories of future settlement patterns can be modeled that will allow for more accurate predictions.

From a human security perspective, a range of social variables can provide indicators of community sensitivity to impacts and the capacity of communities to respond and/or develop adaptive resilience over time. Multi-attribute, 3-D spatially-layered maps can provide a valuable first glance to policymakers of where multiple vulnerabilities and sensitivities might 'stack up' or produce other synergistic affects (figures 5 & 6, p. 152, 153). Such analysis is useful for planning and strategic deployment of, for example, disaster relief or control centers. Spatially-explicit models

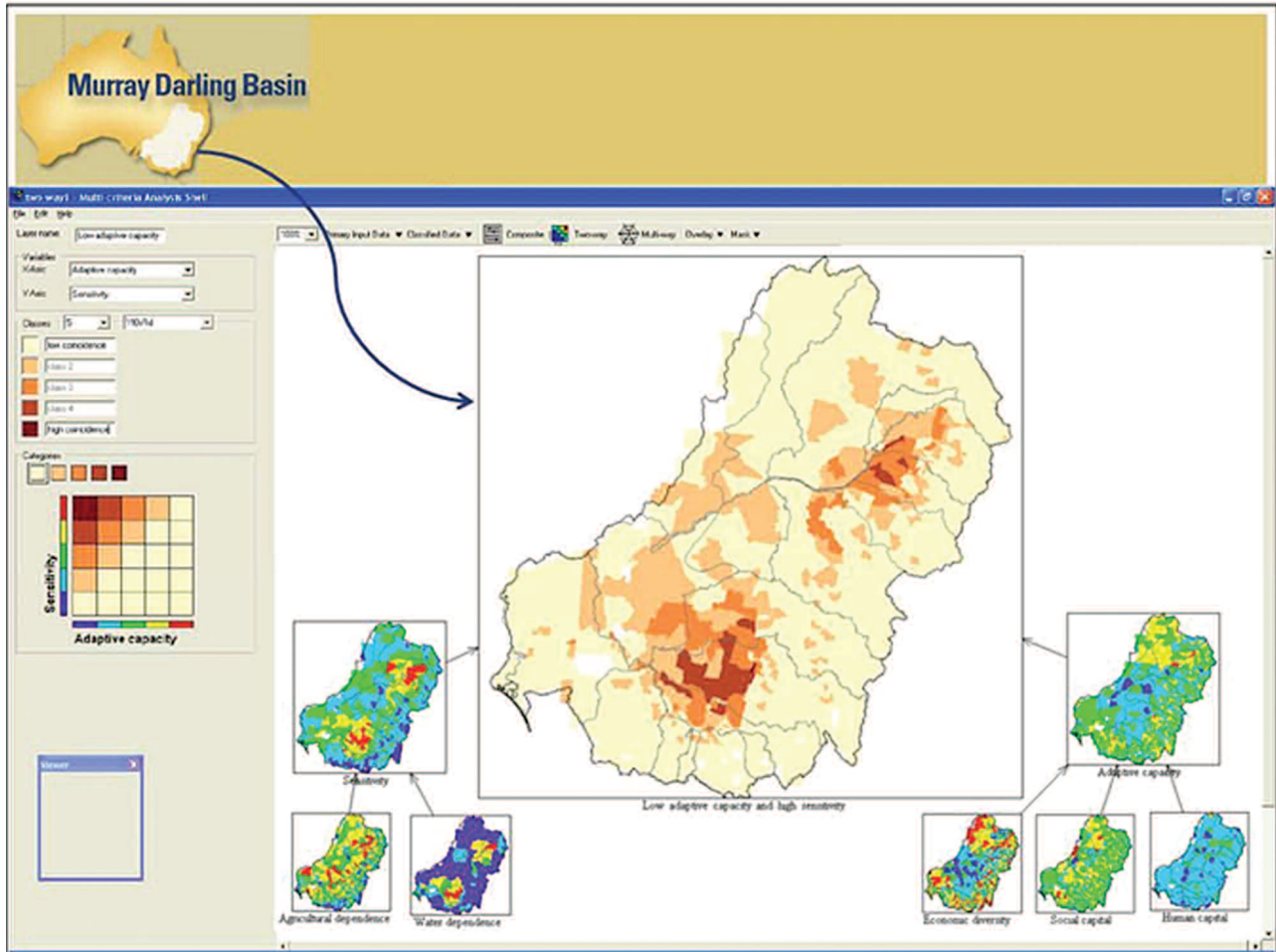


FIGURE 4 An example of spatially-attributed multi-criteria analysis of human community sensitivity vs. adaptive capacity for a particular social-ecological context (refer also to figure 1).

such as these can also be used to directly compare various current and future landscape patterns of vulnerability, landscape change and changes to vulnerabilities under a variety of scenarios.

The future will certainly be different. Constantly changing landscapes will be very different from present and past landscapes. For example, human security issues, from the impacts of climate change-enhanced storms in 2030 will be dissimilar from today because they will be impacting upon a very different landscape in 2030. Understanding patterns of the present landscape does provide a foundation to examine plausible land use and land cover (LULC) patterns of the future. Understanding past change and current pressures driving change help us to understand how and where present policies or decisions might create or ameliorate vulnerability and how various landscape elements might be vulnerable or human security issues arise. This past-present-future landscape analysis approach allows a more integrated analysis of landscape-scale social-ecological parameters that might change. This technology also allows for the examination of adaptation benefits of alternative landscape futures that need to be planned and achieved to increase resilience and reduce negative impacts. Despite the uncertainties in predicting future landscapes (patterns of land use and natural elements), a landscape futures approach provides greater insight for policymakers into the risks of not adapting to potential future exposure and vulnerability, compared to simply examining the effects of future climate change perturbations on the present landscape.

Coastal landscapes around the Asia-Pacific in particular are changing rapidly. With increasing human settlement areas, concentrating coastal-urban populations, reduction of reefs, mangroves, complex estuaries and coastal forests (all of which contribute not only food but physical and biological buffers to various perturbations), these regional landscapes are rapidly altering. Mapping and spatial analysis of the current trends creating the trajectory and pattern of these future landscapes is an important but underutilized science and technology tool. Understanding future landscapes and settlement patterns together with comparisons to designed alternative landscape futures can strategically assist planners and policymakers to chart more resilient and adaptive contexts for the future. These techniques allow for direct analysis of impact and change to better understand and predict the consequences and human security sensitivities of various likely future landscapes or planned alternative future landscapes (figures 5 & 6, p. 152, 153). In order to design adaptive policy and planning mechanisms, policymakers often require an overview of the ‘big picture’ of where potential issues might arise or where problems might ‘stack up’ creating synergistic effects. For policy purposes, the vulnerability analyses can be summarized in a map of four geographically-related surfaces as shown in figure 6. It is also useful to have the capacity to drill down into the knowledge of underlying causes.

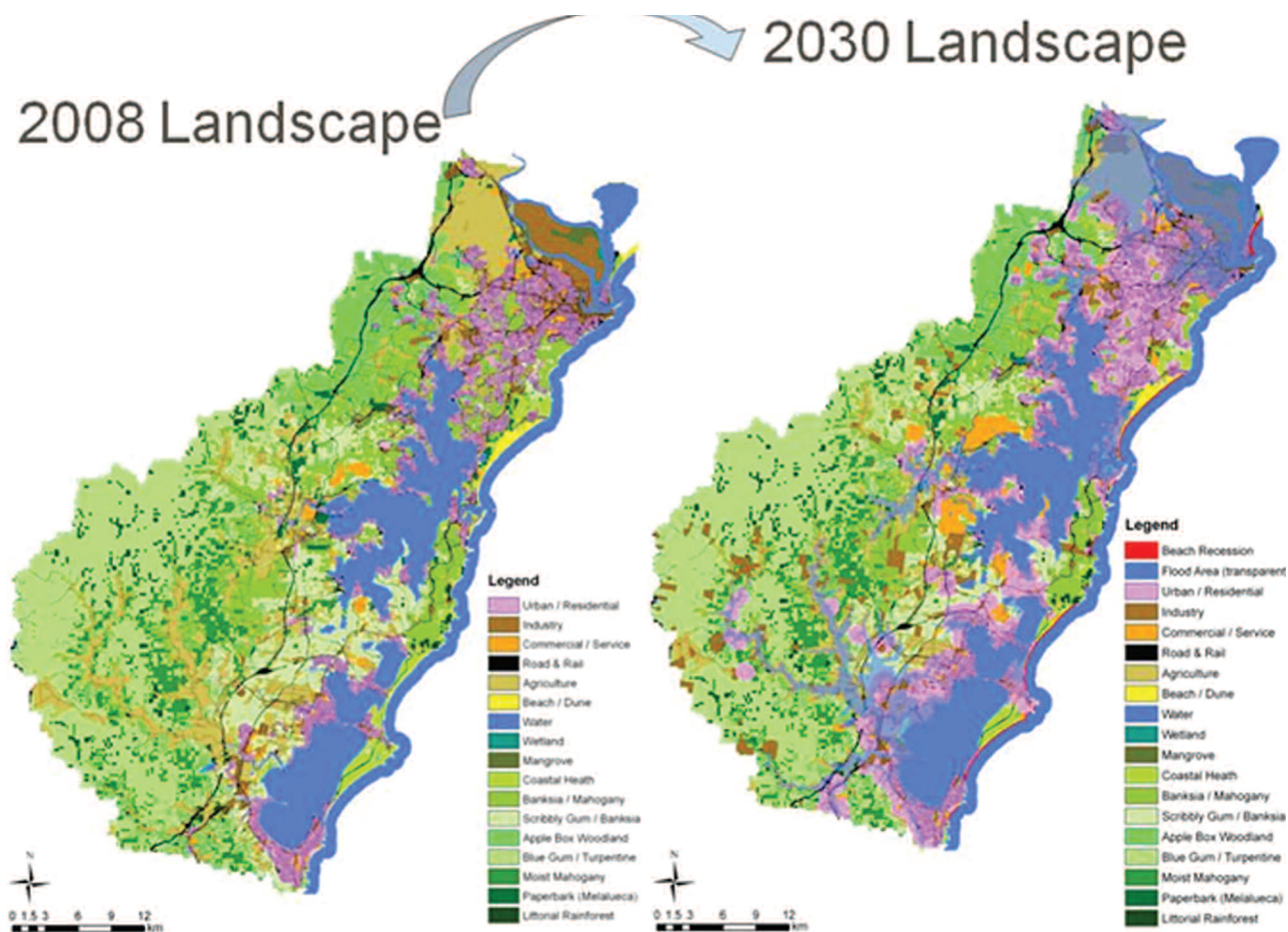


FIGURE 5 An example of a current and future landscape change analysis. In this example the past to present landscape change provides the basis for the trajectory and trends towards this (highly probable) 2030 landscape future for the Newcastle – Hunter coastal region, north of Sydney, Australia.

Summary: Strategic Planning for Human Security in Changing Landscapes

There are serious upcoming challenges to human security from the combined interactions of rapid change across social-ecological systems in a variety of contexts around the Asia-Pacific, especially on coastal plains. Access to and use of resources (especially clean fresh water), changing land uses and increasing human settlement areas are changing the nature of the future landscapes upon which challenging impacts or conflicts might impact, e.g., climate change and resource access. In increasing the community’s adaptive capacity and preparations for future changes, policymakers need to be cognizant of the importance of:

- context specificity, i.e., the local to regional landscape defined by the biophysical environment, people and their circumstances;
- change as a constant in a future that will be different in context and landscape;

Synthesis of layers of ecological, social and economic climate change vulnerabilities

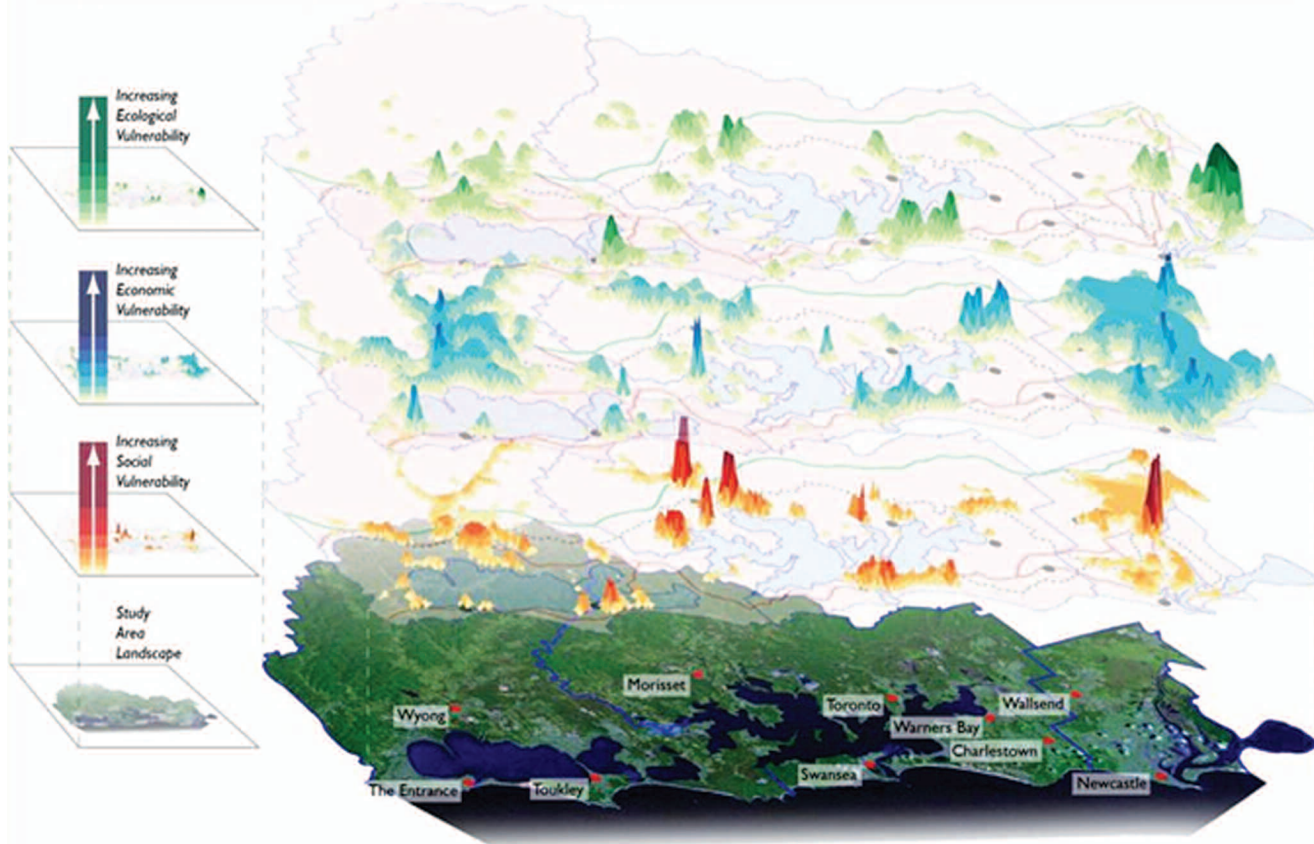


FIGURE 6 An example of spatially attributed 3-D visualization of multiple sensitivities that might influence human security issues of a likely 2030 regional landscape (current trend/trajectory) for the Newcastle – Hunter coastal region, north of Sydney, Australia (refer also to figure 5).

- human security vulnerabilities (sensitivity & adaptive capacity) that stem from the context of the social-ecological landscape and pressures of change;
- the uncertainties of “future landscape influences” on community and regional security;
- the development of multiple planned options including those for adaptable futures, and designs and assessments of various alternative landscape futures.

There are a range of very useful, strategic and policy-relevant, science and technology (S&T) tools that have recently been developed and are undergoing further development through case study applications and modelling. Some of these include: combined social-civic, resource and ecological regionalization techniques for planning, community engagement and multi-level policy and decision making; spatially-attributed, contextual, social sensitivity and adaptive capacity analysis; comparative analysis and modelling of current and future landscape change; and “Landscape Futures” scenario, design, modelling and analysis. Such context-relevant, multi-criteria, “alternative

landscape futures” range of S&T tools will be valuable in understanding future human security issues as well as provide policy options towards planning for both future resilience and adaptive responses.

Notes

1. A large volume of relevant research, science and technology, and case studies are cited and referenced in the following:

D.J. Brunckhorst, “Using Context in Novel Community Based Natural Resource Management: Landscapes of Property, Policy and Place,” *Journal of Environmental Conservation* 37, no.1 (2010): 1-7.

D.J. Brunckhorst et al., “Strategic spatial governance: Deriving social-ecological frameworks for managing landscapes and regions,” in *Landscape Analysis and Visualisation: Spatial Models for Natural Resource Management and Planning*, C. Pettit et al., eds. (Berlin: Springer, 2008): 253-276.

J. Graham, I. Reeve, and D.J. Brunckhorst, eds. *Landscape Futures: Social and Institutional Dimensions*. Refereed proceedings of the Second International Symposium on Landscape Futures, December 2001. (Armidale. NSW, Australia: Institute for Rural Futures, University of New England, 2002).

P. Morley and D.J. Brunckhorst, *Sea-Change and Landscape Change* (Saarbrucken, Germany: Lambert Academic Publishing, 2010).

Environmental Risk Transitions in Southeast Asia and the Role of Peri-urbanization

Sumeet Saksena, Ph.D.

Introduction

This paper describes the environmental risk transition framework that is currently used to study the link between development and health. The paper highlights the risks that societies in transition face as they move from a situation where only traditional risks exist to a situation where only modern risks exist. It is argued that within developing countries, peri-urban areas are places where traditional and modern risks overlap in complex ways. As an example, the regional problem of avian influenza in Southeast Asia is discussed as it is most likely to occur in peri-urban areas.

Environmental Risk Transition

There are many conceptual frameworks that systematically organize information to study the links between health and economic development. The most influential of these has been the Demographic and Epidemiologic Transitions framework that focuses on changes in fertility, mortality and morbidity. These variables are key components in the overall Health Transition approach.¹ Modifying these frameworks to include environmental determinants of health (such as waterborne biological and chemical pollutants) is a more recent development.² For instance, the 'Risk Transition' conceptual framework merges the concepts of health transition and environmental health risk assessment.³ The Demographic Transition involves a shift from Stage 1 (traditional equilibrium) where population sizes are stable due to high death rates and high birth rates; to Stage 2 (population explosion), when death rates decline more rapidly than birth rates; and eventually to Stage 3 (modern equilibrium), when birth rates decline and catch up with death rates.⁴ The Demographic Transition is linked to the Epidemiologic Transition, a concept that first emerged in the late 1960s.⁵ It describes the phenomenon where the majority of developing countries simultaneously experience great reductions in certain kinds of diseases and illnesses along with increases in others. The historically high 'traditional' diseases associated with rural poverty trend downward during economic development, although at different rates in different places and periods. As the traditional diseases decline, there tends to be an increasing fraction of deaths due to modern diseases, number of disease types and morbidity. Modern diseases include degenerative diseases, such as cancer, heart disease and stroke, along with certain new types of accidents and occupational hazards. Industrialization, urbanization and agricultural modernization bring attendant environmental pollution hazards that primarily cause 'modern' diseases.

The shift of disease patterns from traditional to modern is due to changes in the underlying risk factors for the various forms of ill-health. It might be argued that there is no particular advantage

in differentiating between ill-health and risk. This might be true for certain classes of diseases, particularly those where there is a fairly short delay between changes in the risk factors and changes in ill-health. For these, monitoring disease rates are expected to be a fair indicator of what is happening and thus be a reasonably good guide for decision making. For other classes of disease however, present patterns of ill-health are quite poor indicators of actual risk, e.g. tobacco smoking. The distinction between risk and ill-health is also important for another category of hazards – pollutants that make their way slowly through the environment and reaching humans through water, air or food. The release of pollutants into the environment is a risk even though it may be many years before the disease manifests itself due to environmental and physiological latencies. Most importantly, modern risks differ from traditional risks in that many important outcomes do not have a unique cause. Traditional diseases like cholera are caused by a limited number of specific identifiable agents. Modern diseases like cancer cannot easily be linked to one specific cause. The impacts of ‘modern’ risks are less ‘visible’ than the impacts of ‘traditional’ risks.

Risk Overlap

The swiftness of the risk transition creates a situation where traditional risks persist while modern risks start earlier in the development process (figure 1). This results in a larger degree of ‘risk overlap,’ where some populations are exposed to a significant amount of both types but in a rapidly changing pattern. In the overlap phase, modern risks are beginning to rise while traditional risks are still significant although dropping rapidly. An example is when pesticide runoff starts to add to water pollution due to poor sanitation. Another example is offered by those places where urban air pollution from fossil fuel combustion is rising while large village and urban air pollution exposures from household combustion of traditional biofuels still exist.

Another way to view the transition is shown in figure 2 (p. 157). It highlights phenomenon where certain environmental risks first increase with development, and then begin to decrease once a certain level of affluence is reached. Examples are urban air pollution and deforestation that operate mainly at the community level. Traditional risks, e.g. sanitation, operate essentially at the household level. The modern risks generally have a regional or global spatial character (such as Chloro Fluro Carbons or greenhouse gases).

The risk overlap can lead to interactions with important

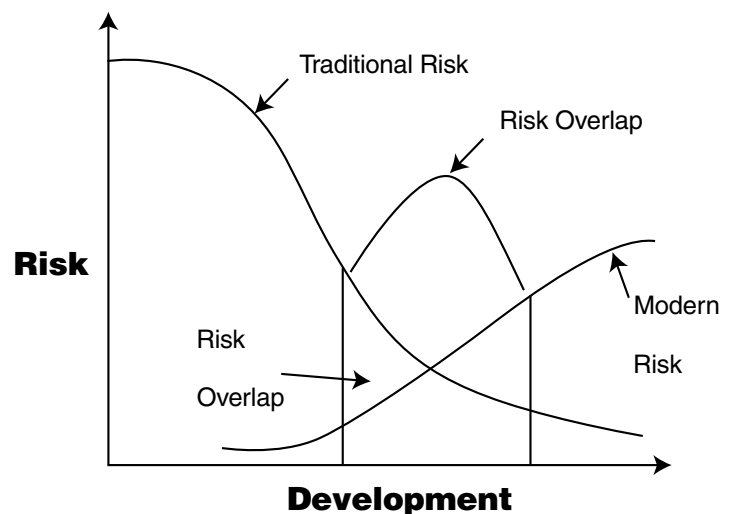


FIGURE 1 Development and Risk Overlap
SOURCE: Adapted from Kirk R. Smith, “The Risk Transition,” *International Environmental Affairs* 2 (1990): 230.

implications for risk assessment by magnifying or masking the separate impacts of modern and traditional risks. Six kinds of interactions are identified:⁶

- *Risk genesis* – where risk overlap may lead to the creation of an entirely different sort of risk, e.g., mixing of modern (motorized) and traditional (muscle-powered) vehicles leads to new kinds of accident risks and risk management needs;
- *Risk synergism* – where exposure to one agent causes immunity or sensitivity to other agents, e.g., where traditional intestinal diseases due to poor water quality increase sensitivity to waterborne and airborne modern pollutants;
- *Risk mimicry* – where morbidity and mortality may be attributed to traditional sources of risk but may be actually due to modern or synergistic risks, e.g., lung cancer being attributed to acute or chronic lung diseases;
- *Risk competition* – where abnormally high or low risks of one disease may actually be an indication of the increase or decrease in the risks of an entirely different disease, e.g., where low lung-cancer rates may not necessarily mean that the risk of lung cancer is low but just that people are dying of other diseases first and not living long enough to develop cancer;
- *Risk layering* – where the movement of people or their activities concentrates risk in one region and dilutes risk on another, e.g., where rural-urban migrants are healthier than the average person left back in the villages; and
- *Risk transfer* – where efforts to control risk from traditional hazards may enhance modern risks (or vice-versa), as when pesticides are used to control malaria.

Global Risk Overlaps

Most of the examples discussed above are cases of *local* risk overlap involving the interaction of traditional and modern risks on a local scale. These can be serious but are amenable to various local solutions. *Global* risk overlaps, in contrast, will continue as long as there are great disparities anywhere in the world between risk patterns of different groups. The most important examples are ozone- and climate- threatening chemical

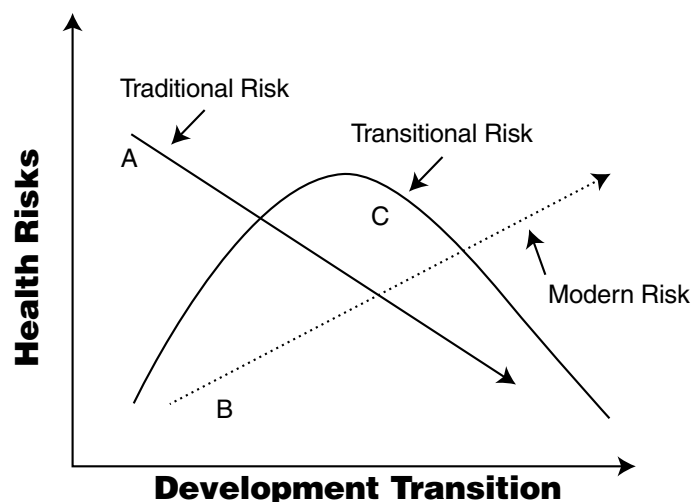


FIGURE 2 Transitional risks
 SOURCE: Adapted from Kirk R. Smith, "The Risk Transition,"
International Environmental Affairs 2 (1990): 230.

releases. Although mostly created by modern activities in countries well along the health transition, these pollutants affect the whole world. They will probably have their biggest impacts among communities still burdened by traditional risks. Unlike local risks, the global overlaps cannot be eliminated by releasing pollutants elsewhere.

Implications for Risk Assessment and Monitoring

Understanding the overall or net risk from any particular technology, project, policy, regulation or activity requires evaluation of both classes of risk. Developing countries will find that to adopt risk assessment methods from developed countries – which focus on modern risks – will be misleading. Indeed, focusing only on the modern risk curve for each new project as part of what might be called micro-risk analysis could lead to skewed macro-risk results. There are numerous studies on the overall relationship of economic development with health status, but few have conducted project-level analysis. It is at the project level, however, where individual decisions are made and policies are implemented. To do such an analysis would necessitate understanding the changes created by a project on income, employment, training, education, housing and other relevant factors, and analysis of the impact of each of these factors on risk is also imperative. The evaluation of net risks is complex, considering the trend of some modern risks to become significant at earlier stages of the development process than in the past because of the impact of international and internal trade, information technology and foreign aid. As the period of risk overlap increase, so will the need for net risk assessment.

The rationale for focusing on risk rather than ill-health is its suitability for management, especially for modern risks. For these hazards, we need to monitor further back along the causal chain, which runs from pollutant emissions to environmental concentration, exposures, doses, pre-clinical changes and ill-health.

Peri-urbanization and Risk Overlaps

Urbanization is one of the most important determinants in the transition from traditional to modern risks. In many developing countries, economic growth results in places that simultaneously have rural and urban characteristics. These peri-urban areas are linked to an urban center but are themselves not urban in the usual sense. They are characterized by rapid increases in the variety and intensity of workplaces and land uses intermixed with traditional farming areas. This overlap causes the release of toxic materials from small-scale industrial activities like electro-plating directly into wet rice paddies, creating a particularly acute form of water pollution. Peri-urban areas at the same time also become the hotspots for emerging infectious diseases such as avian influenza.

Highly Pathogenic Avian Influenza: A Regional Transitional Risk and its Links with Peri-urbanization

Since late 2003, avian influenza (often referred to in the media as ‘bird flu’) has become one of the most publicized emerging infectious diseases. This followed the detection of highly pathogenic avian influenza (HPAI) caused by viruses of the H5N1 subtype in many countries in Asia. These Asian-lineage HPAI viruses produced a fatal disease in poultry, wild birds, humans and other mammals, with subsequent spread of disease to some 60 countries across three continents. Affected countries and the international donor community mobilized hundreds of millions of dollars to assist in controlling this disease, mainly because of concerns about the potential of these viruses to unleash a global pandemic of human influenza.

Over the last 10 years, more than 200 million domestic birds died or were culled. Tens of thousands of wild birds have died. Since 2003, there have been more than 240 human cases and 141 deaths, most of these in Southeast Asia. Migratory water fowl – most notably wild ducks – constitute the natural reservoir of the virus. Though wild bird migration is a major risk factor, the critical role of other variables such as agriculture production systems and poultry trade largely remain unexamined and have not been well-studied.

Kaplan et al.⁷ maintain that the ongoing process in Southeast Asia of replacing traditional farming methods such as multi-species livestock husbandry with industrial, mass-production-oriented operations, pose significant environmental health risks⁸ due to increases in livestock pools, thus creating opportunities for disease transmission. Simultaneously, rapid urban and peri-urban development in these countries is often accompanied by more refuse, standing water and animals in and around homes, all of which are correlated with environmental health risks.⁹ With respect to HPAI, expansion of the urban fringe has placed a larger proportion of the human population in contact with formerly dispersed farm environments that include potentially infected poultry and swine populations. Such urban–rural interfaces become hotspots of other infectious diseases such as leishmaniasis.¹⁰

An array of anthropogenic and ecological studies of the determinants of HPAI in Southeast Asia support these hypotheses. Gilbert et al.¹¹ show that the interaction of poultry and particularly domestic duck populations within the rice paddy production system is an important factor for the maintenance and spread of HPAI virus in Thailand. Pfeiffer et al. demonstrate that rice paddy production intensity and density of domestic chickens and water birds are also associated with a higher risk of HPAI outbreaks in Vietnam,¹² lending support to the rice-duck-chicken hypothesis. The same study shows that increased distance from high density human population areas consistently decrease HPAI risk.¹³ The study finds support for the hypothesis of “the presence of a fairly widespread infection reservoir in Vietnam . . . , possibly in domestic and wild water birds.”¹⁴ Gilbert et al. find that a few key factors such as human population density, rice cropping intensity, and to some extent poultry density, manage to explain a large proportion of the spatial variation in HPAI disease risk.¹⁵ The same study also notes that considerable variations remain unexplained, and suggests a consideration of other factors such as poultry production and marketing systems,

agricultural seasonality, the potential for contacts between domestic and wild birds, and climatic and other conditions affecting the persistence of the virus in the environment. Another study finds the minimal distance to the nearest national highway, annual precipitation and the interaction between the nearest lake and wetland were important predictive environmental variables for the risk of HPAI in China.¹⁶

Finally, of particular interest is the claim by Gilbert, Xiao, Wint and Slingenbergh (in press) that the highest risks of HPAI impact in Southeast Asia are to be expected where extensive and intensive systems of poultry production co-exist.¹⁷ This is usually observed in the peri-urban areas: while the extensive systems allow virus circulation and persistence, the intensive systems promote disease evolution. Factors that explain this phenomenon include the global and regional risk overlap aspect of avian influenza, the dramatic globalization of poultry trade involving large multi-national companies, as well as the illegal cross boundary trade by individuals and small operators.

Developing policy options for peri-urban area development requires explicit attention in improving transportation and connectivity in order to strengthen rural–urban linkages. Peri-urban livelihoods are constructed across both urban and rural spaces, and transportation has a role in bridging the rural–urban divide. This translates into an increased emphasis on intermediary transport between the villages and the towns. For peri-urban areas located along highways, this requires the creation of platforms for dialogue and coordination across the village, province and national levels of government.¹⁸ However, the increasing movement of humans and animals that modernized transportation systems enable both locally as well as internationally has further increased the spatial and temporal scope of human exposure to people and livestock infected with HPAI and other infectious diseases and could well increase the subsequent spread of H5N1 to novel hosts as it did in the SARS epidemic.¹⁹ Thus, policy development should entail a fine balancing act between the needs of peri-urban areas and disease prevention.

At the same time, there is a need to protect common property institutions upon which the livelihoods of the poor and landless depend – and to which they lose access as they are converted to other uses. The acquisition of common property resources – either through their takeover by the village authorities or by means of their conversion into urban uses and purposes – makes the landless more vulnerable and dependent upon those who have land for their supplies of subsistence items. Thus, the peri-urban interface creates clear implications for social and power relationships among peri-urban dwellers.

Finally, siting and location norms can have an important role in improving the quality of life of people residing in peri-urban settlements. These areas often serve as dumping grounds for industries that are relocating from bigger cities and towns because the urban periphery is less subject to stringent controls and regulations. This situation has adverse impacts on the health and quality of life of peri-urban settlement inhabitants. Concerted action such as strong social mobilization or political will are required to prevent the relocation of factories to the boundaries of peri-urban settlements.

Utilization of the Risk Transition Framework

Policymakers rarely apply the risk transition framework described above to real life problems involving emerging infectious diseases such as avian influenza. To counter threats of avian influenza pandemics, bodies such as the United Nations, World Health Organization (WHO) and the Food and Agricultural Organization (FAO) prefer what is referred to as ‘evidence-based’ or ‘science-based’ approaches to risk management.²⁰ These techniques reduce the multiple, complex and indeterminate dimensions of knowledge to just two readily quantified kinds of parameters: outcomes and probabilities. The resulting numbers are used objectively to justify certain particular interventions over others. Unfortunately, in the case of avian influenza, the so-called ‘evidence-based’ and ‘science-based’ approaches ignore the complex, open-ended, nonlinear interactions between the tightly coupled ecological, agronomic and institutional systems.

Early risk models for avian influenza imply that the global problem could easily be mitigated by focusing on containment at the source of the outbreak.²¹ Yet competing but equally scientific analyses that are based on an appreciation of complex dynamics suggest alternative policy framings. These complex dynamics include the interplay between viral ecology and genetics (such as patterns of antigenic shift and drift), transmission mechanisms (e.g., the role of wild birds or poultry, backyard chickens or large factory units) and impacts including the consequences of immunocompromised individuals and populations. The risk transition framework helps introduce complex dynamics in traditional risk assessments, especially at the meso- and macro-scales while examining links to economic growth.

Conclusion

The occurrence of infectious disease in poor countries is attributable to household environmental risks such as poor sanitation, water and hygiene. Household environmental risks, however, decline markedly and nearly uniformly with development. Although in a global context community risks are about half those from household risks, they are spread differently across the development spectrum, with the highest rates in middle-income regions. Thus, developing countries face a major and unique challenge in smoothly managing the risk transition such that traditional risks continue to fall *and* modern risks are minimized. This is especially true in peri-urban areas where agriculture interfaces with industrialization.

In the case of emerging regional risks such as avian influenza in Southeast Asia, policymakers need to focus beyond surveillance and outbreak control at source. Using the risk transition framework would imply greater multi-sectoral risk assessments and policy formulation, with a focus on poverty reduction, social justice and development.

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Closing Keynote Address

Global Nuclear Risk Reduction by Science Diplomacy

Siegfried S. Hecker, Ph.D.

When I gave this presentation in October 2010, the world faced a troubling reality for advocates of nuclear nonproliferation. The 20 months between then and now have seen the situation deteriorate significantly. North Korea is likely supplementing its small nuclear arsenal by developing a second path to the bomb through uranium enrichment, and Kim Jong-il's death may make substantive negotiations more difficult, at least in the short term. An increasingly isolated and aggressive Iran has moved steadily toward the nuclear weapon option, having made significant advances in its uranium enrichment program during this time. I, along with former Secretary of Defense William J. Perry, continue to work to mitigate global nuclear threats through the Nuclear Risk Reduction Project. The goals of this project are simple: to reduce the threats of nuclear weapons by working towards: a) fewer nuclear weapons in the world; b) fewer fingers on the nuclear trigger; and c) keeping nuclear weapons and material out of terrorists' hands. While the goals are simple, achieving these goals is the challenge not only for our lifetimes, but also that of the next generation. I have devoted much of my career and the last two decades to decreasing nuclear risks through scientific diplomacy in places like North Korea, Russia and China. In this presentation, I review my efforts to reduce nuclear risks and emphasize the essential role that scientists must play in working to mitigate the risks of nuclear weapons and the spread of weapon-usable nuclear material.

Fewer Nuclear Weapons

Dr. Perry, along with former Secretaries of State George Schultz and Henry Kissinger and former Senator Sam Nunn, has dedicated much of the past five years toward a world free of nuclear weapons. The four horsemen, as they have been affectionately called, advocate a set of steps that reduce the number of nuclear weapons that include ratification and entry into force of the Comprehensive Nuclear Test Ban Treaty (CTBT), negotiation and ratification of a Fissile Material Cut-Off Treaty (FMCT), further disarmament negotiations, and reductions in tensions surrounding ballistic missile defense. These steps constitute an important part of a broader nonproliferation agenda that should be adopted worldwide to reduce nuclear risks. I am currently engaged with my Stanford and Los Alamos National Laboratory colleagues in a study analyzing the benefits and costs of ratifying the CTBT and expect to hold a workshop presenting the findings in Washington D.C. in the spring of 2012. Entry into force of the CTBT could play a vital role in limiting the ability of states that possess nuclear weapons from increasing the sophistication of their nuclear forces and may help erect additional barriers for aspiring nuclear states to test weapons and declare themselves as nuclear weapons states.

Fewer Fingers on the Nuclear Trigger

In the last ten years, North Korea built and tested nuclear devices and declared itself to be a nuclear power. Iran has inched closer to a nuclear weapon capability, but apparently has not yet decided to proceed with building nuclear weapons. Decreasing the number of countries that possess nuclear weapons is essential to any effort to increase peace and stability around the world. I have visited North Korea seven times,¹ six with my Stanford colleague John Lewis, with the goal of making an assessment of North Korea's nuclear capabilities. Such assessments improve our understanding of the risks of their program and assist policy makers in laying the way for formal, productive negotiations. In my first visit in 2004, I held in my hands a sealed glass jar containing what North Korean scientists told me was 200 grams of plutonium metal, the essential ingredient for a bomb. After asking a number of basic questions of North Korea's scientists and conducting some experiments once back at Los Alamos to simulate some of the situations experienced in the Yongbyon nuclear complex, I concluded with high confidence that North Korea had mastered what we did in the Manhattan Project and that it could make a rudimentary plutonium bomb – which it confirmed in October 2006 when it detonated its first nuclear device. Although that test was only partially successful, it confirmed its ability to build a working plutonium bomb with a second, successful test in May 2009. The extraordinary access the North Koreans gave me to their nuclear facilities allowed me to conclude that today, North Korea likely has 24-42 kg of plutonium, sufficient for 4 to 8 bombs. Based on their test history, I believe these are likely primitive plutonium bombs on the order of the Nagasaki plutonium bomb. I do not believe that they have been able to miniaturize their nuclear devices to mount on ballistic missiles.

In each of my visits since, North Korea has had a specific message for me and my American colleagues. In 2004, for example, they allowed me to hold the plutonium in order for me to carry the message back to Washington that Pyongyang now has the bomb. In 2010 (only one month after I gave this presentation), they showed me and my Stanford colleagues an impressive uranium enrichment facility and demonstrated their determination to build an indigenous light water reactor – and, to the consternation of the rest of the world, provide Pyongyang with an alternative route to the bomb. These visits were interspersed between formal and informal negotiations by the U.S. government. Upon my return from each visit, I briefed U.S. government officials on what I saw and what the North Koreans told me. I believe that our visits have helped provide important information, both technical and diplomatic, for official negotiations to be successful. From these visits, we know that at present, North Korea likely possesses 4 to 8 primitive plutonium bombs, is constructing a 25 megawatt-electric Light Water Reactor (LWR) and is pursuing a robust uranium centrifuge enrichment program. I believe it is unlikely that the North will give up its nuclear weapons anytime soon, especially after the death of Kim Jong-il and the transfer of power to his young son. Nevertheless, I strongly believe that negotiations should restart to limit further escalation of their nuclear program and prevent future nuclear tests. I advocate a strategy of three no's in exchange for one yes: no more bombs, no better bombs and no nuclear exports, in exchange for addressing Pyongyang's security concerns that lie at the heart of this dispute.

North Korea is not the only international nonproliferation concern. Iran is putting in place all the capabilities necessary so that it can flip a switch if it chooses and develop nuclear weapons in less than a year. It is increasing capacity to enrich uranium in its facilities in Natanz and Qom. Tehran claims that these facilities are being operated to supply low-enriched uranium for its commercial and research reactors. However, Tehran has not provided sufficient transparency in its nuclear program to assure the rest of the world that it will not use these or other covert facilities to produce highly-enriched uranium bomb fuel. Iran is also constructing a heavy-water reactor in Arak that it claims to use for medical isotope production, but it will produce plutonium suitable for weapons as a side product. It has also engaged in experiments relating to weaponization and nuclear triggers. These developments indicate Iran's desire to possess a nuclear option, even if it has not yet made the decision to build the bomb. Pakistan is further developing its nuclear arsenal and employing troubling nuclear strategies as far as deployment and targeting. These developments increase the risk of a nuclear exchange with India over disputes along the Kashmir border, or over attacks by proxy terrorist groups supported or at least tolerated by elements of Pakistani government. Solving these problems is far from simple or easy. As is the case for North Korea, our project works alongside governmental efforts to catalyze a path for official negotiations or collaborations to reduce these nuclear risks.

Keeping Nuclear Bombs and Material Out of Terrorists' Hands

One of my greatest concerns is that a terrorist organization might gain access to a nuclear weapon or nuclear material and explode it somewhere in the world. The risks of nuclear terrorism present very different challenges from the state-centric risks described previously, given the difficulties in deterring or denying terrorists. I see three main risks associated with terrorists and nuclear technology. First, a terrorist group could detonate a nuclear device, resulting in a massive and devastating loss of life and property. Second, a terrorist group could get its hands on radioactive materials and detonate a radiological dispersal device (RDD), otherwise known as a "dirty bomb." Third, a terrorist group could sabotage a nuclear facility or power plant with the goal of releasing radiation into a populated area. Of these three risks, that of a "dirty bomb" is the most likely given that radiation sources are everywhere – as key ingredients of medicine, commerce and agriculture.

Dirty bombs are weapons of mass *disruption* rather than weapons of mass destruction, likely causing more psychological damage and economic damage than a massive loss of life. The most important measure to deal with a dirty bomb is be prepared to respond since prevention is very difficult given the ubiquitous nature of the radiation sources that can be used to make a radiation dispersal device and the simplicity of constructing it. It is critical, therefore, to work with first responders, the media and the public to respond effectively in the event of a terrorist attack.

Although nuclear weapons are much less likely to be used by terrorists, the effects would be devastating. The most likely route for a nuclear weapon to get into the hands of terrorists is that they may gain access to fissile materials, plutonium or highly-enriched uranium, by theft or diversion from a state's nuclear facilities (fortunately, the production of fissile materials is beyond

the means of all terrorist organizations today). With the bomb fuel in hand, terrorists may then build a simple, improvised nuclear device and find a way to detonate it in a metropolitan area somewhere in the world. The most important measure to prevent this type of nuclear terrorism is to secure the fissile materials at their source – that is, to make certain they do not get out of control of the governments that possess them. This effort has consumed much of my nuclear scientific cooperative activities around the world during the past two decades.

I have visited Russia 43 times since 1992 both while I was at the Los Alamos National Laboratory and as an academic with the goal of helping the Russian nuclear and security specialists to secure their enormous stock of fissile materials – a legacy of the huge Soviet nuclear programs. The Soviet-style security through guns and guards no longer sufficed after the dissolution of the Soviet Union at the end of 1991. We have worked closely with the Russians to help them develop a comprehensive system of nuclear safeguards that we call materials protection, control and accounting (MPC&A). President Obama focused the world's attention on the risks of nuclear security and terrorism in his April 2010 Nuclear Security Summit. The summit's goal of locking down the world's nuclear materials in four years, while admirable and important, is insufficient in dealing with the risks of the spread of nuclear materials. Nuclear materials are constantly moving between nuclear plants and facilities and military installations – it is not possible to simply lock them down in a vault and declare the job completed. More important is the adoption of a system of MPC&A for comprehensive safeguards.

A Role for Scientific Diplomacy

Although the end of the Cold War has greatly reduced the likelihood of a massive nuclear war, the likelihood of a nuclear explosion somewhere in the world has actually increased. Of greatest concern are a potential nuclear exchange between Pakistan and India, the nuclear ambitions of North Korea and Iran, and the threat of nuclear terrorism. Twenty years after I first started lab-to-lab contacts, I believe more firmly than ever that scientists can play an important role in international security diplomacy. They look through different lenses than politicians and build different relationships. They typically develop deep personal friendships. They speak a common language and usually respect each other, making it easier to build trust. Communications are much less formal, with e-mail instead of diplomatic cables, and scientists can explore a broader spectrum of potential solutions than government officials. To conduct science diplomacy effectively, I found it was crucial to work constructively with the government. But it is also important to share our findings with the public at large. Building personal friendships and sharing with the public are critical components of science diplomacy.

Notes

1. This author visited North Korea in November of 2010 following this presentation, making the total number of visits to seven.

FINAL BRIEFBACK and DISCUSSION SUMMARY

The participants' discussion sessions were divided into three parts. The first focused on an examination of the current state of the S&T-security nexus, in particular, the institutional relationship of the S&T and security communities. The outcome of these discussions identified prerequisite conditions necessary towards developing effective responses to S&T phenomena that have serious security implications. The discussions then flowed to the second part where the participants identified the top three S&T areas of concern derived from the SME presentations on information technology, biotechnology, energy and environment. The third part concluded the discussions: Dr. William Perry and Dr. Siegfried Hecker, co-directors of Stanford University's Center for International Security and Cooperation (CISCA), received the briefs culled from all the previous sessions. They also proposed an outline of ideas that can be used as points of departure for follow-up dialogues between the S&T and security communities.

Understanding the S&T and Security Relationship

There was general agreement among the participants that the international security and S&T environments are very dynamic, interfacing with ever-increasing complexity and urgency. However, a significant gap – a “*valley of disconnection*” (figure 1, p. 170) – exists between the S&T and security policy communities within, and across, countries in the region. The disconnection stems from institutional and policy stovepiping where the “problem/solution set” of the S&T community and the “problem/policy set” of the security community are not coordinated or integrated. Bridging this divide is an integral element of an “interdisciplinary framework” response to S&T developments that have serious security implications.

The group's central discussion focused on identifying the specific variables that articulate this “valley of disconnection” and finding solutions to these challenges. The first concern is the lack of a robust and sustained dialogue between the communities. The group recommended the creation of a “*policy and political space*” where members of the two groups can *dialogue* in an institutional context while also providing the opportunity for both sides to educate each other on their respective areas of expertise and concerns. More importantly, this arrangement provides the opportunity to develop consensus on the understanding of “security,” the nature of the threats and challenges, possible responses, and the allocation of resources. The ideal outcome is the formulation of a coordinated set of policy responses.

Closing the gap between the S&T and security communities also require “*translators.*” The group pointed out that there is a dearth of expertise – organizations and individuals - that are able to effectively translate knowledge between the S&T and security worlds. Policy dialogue between S&T professionals and security practitioners will vastly improve with the presence of these translators or “interface institutions,” and the group stressed the need to develop and institutionalize these capabilities as soon as possible.

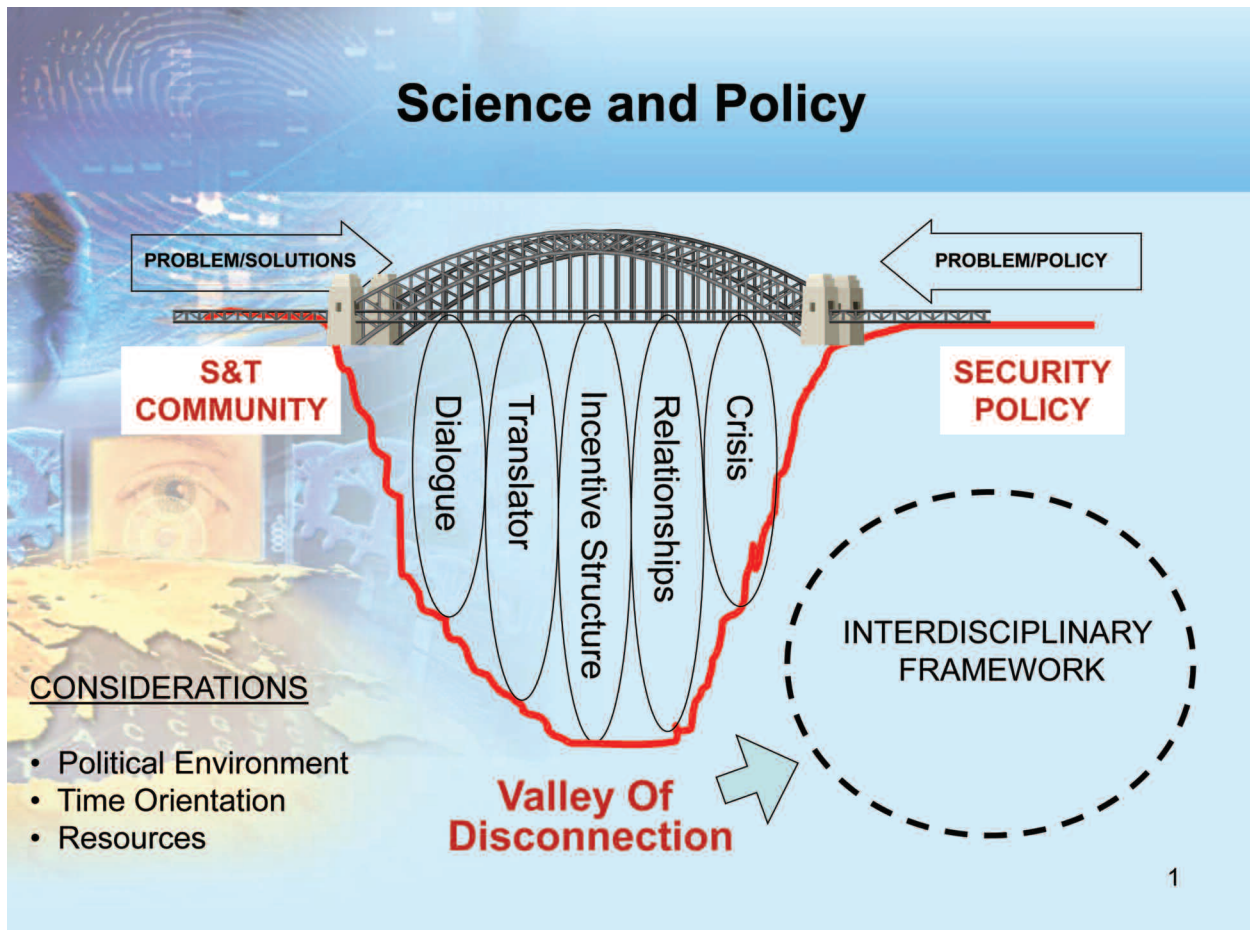


FIGURE 1 Bridging the Divide

The discussions also raised the issue of the differences in the “*incentive structures*” between the two communities: while scientists and engineers try to “find the truth,” the broad mandate of security policy makers and practitioners is to ensure the safety and security of their communities. Provision of “mutual incentive structures” for members of the two communities should consider the appropriate scales, levels and contexts for dialogue as well as establishing key connections between different levels of hierarchies. Ultimately, the development of a “culture of shared incentives” reduces misunderstanding, manages expectations and allows for the creation of a common framework for action.

Another way of bridging the divide between the two communities is to develop and nurture *relationships* and to “customize” the dialogues when translators have access to the appropriate organizations and people called upon to address particular policy issues and challenges.

Finally, the group also discussed the emergence or occurrence of a *crisis* situation as an opportunity to bridge the divide between the S&T and security communities. The group conceptualized crisis as a phenomenon generating a plan of action that necessitates dynamic cooperation between the two groups. Some participants observed that the severe conditions of a

crisis also call for “extreme” measures of cooperation, and this may be very useful for bridging the divide.

The group also included a list of considerations crucial to the S&T-security community interface. Insofar as the *political environment* is concerned, strengthening the dialogue between the two groups requires a strong political will, and there was general agreement among the group that the role of having a powerful political backer or “champion” who can “influence the influencers” is a vital one. The group also noted that policy makers will need to consider and reconcile the “*time orientation*” of the S&T community (long) and the security policy makers (short) when formulating responses to threats or challenges. Finally both communities depend on the availability of significant *resources* from the “start-up” period to the “sustain” phase of cross-community cooperation.

The critical value of bridging the S&T-security community divide emphasizes the importance of adopting an “*interdisciplinary framework*” in developing policy responses to the challenges rooted in the interface of S&T and security. Participants pointed out the increasing interrelatedness of various S&T disciplines as well as the growing linkages between various comprehensive security issues that were discussed in the panel presentations: there are technoscientific developments as well as security challenges that link information technology, energy, environment and biotechnology in multiple ways. This growing trend requires a commensurate institutional response to broaden and expand the policy space to recognize and include critical stakeholders.

Identifying the top three S&T areas of concern now and ahead

Informed by the formal presentations and discussions on the four S&T areas (information technology, environment, energy and biotechnology), the participants identified the top three phenomena from these four areas that are likely to have the most significant global impact in the next 20 years and provide focus to future interagency, regional and global interface collaborative efforts.

Initial group deliberations focused on developing the criteria that informed the group’s final top three choices. The consensus criteria the group selected were *impact*, *technology*, *institutions* and *infrastructure*. Based on these four variables, the participants identified information technology, energy and water as the S&T areas of most concern in the next 20 years. The group clarified the four criteria as summarized below:

Impact of the S&T phenomena

- scale of impact
 - felt on all levels of human organization (global, regional, national, local, individual)
 - includes the rate and scale of impact on the economic, social and cultural dimensions of human society (high likelihood of a crisis situation)

- extent to which the phenomena allows for the highest possible confluence between national priorities and national needs
- very high applicability of ‘the law of unintended consequences’

Technologies relevant to the S&T phenomena

- their increasing rate of diffusion and speed of adoption or evolution
- greatly influence trajectories of other technologies and technological systems
- generate widespread and rapid innovations in dual-use applications, further blurring the lines between civilian and military S&T
- possessing high capability to create ‘surprises’ and ‘revolutions’

Institutional issues

- S&T phenomena require dramatic change(s) in national and international frameworks for governance
- S&T phenomena increase the rate of gap between institutional change capacity and S&T phenomena change(s)
- S&T phenomena generate tensions in the areas of intellectual property rights

Infrastructure implications

- S&T phenomena demand increasing/new capabilities and resource requirements, including human capacity
- S&T phenomena raise significant demand for resilience and adaptability due to the emergence of new risks
- S&T phenomena exacerbate tension between embedded infrastructure and new design requirements generated by S&T phenomena

The participants then proceeded to examine each of the top three areas of concern and organized the discussions around the following categories: impact, challenges, opportunities for collaboration and policy implications.

The top three S&T areas of concern now and ahead

Information Technology

Impact

- Security threats
- Malicious attacks
- Cybertheft
- Cyberspying

All these are now occurring now and their impacts are on a global scale. These security breaches can paralyze commerce, be used to ‘weaponize’ infrastructure (e.g., detonate power plants, crash planes) and create panic, distrust and exploitable instability.

Challenges

- These are technically sophisticated, global problems
- Must develop secure software to reduce vulnerabilities
- Must develop network architectures and components that are intelligent and regenerative (self-aware, self-detecting, self-healing)

Opportunities

- Applicable technologies are emerging from government-funded institutions AND in commercial settings
- IT paired with open source data have profound global power implications

Policy Implications

- Need to establish international forums to coordinate countermeasures
- Need to exploit public-private cooperation to effectively respond

Energy

Impact

- Population growth and industrialization mean global energy needs will increasingly outpace supply
- Dependence on fossil fuels potentially empowers hostile nations
- Security threats

Challenges

- Must develop improved generation, storage and distribution technologies
- Need modeling capabilities that enable optimal matching of national needs and resources with technologies that would streamline implementation
- Compared with other emerging modalities, nuclear energy specifically is at once “ready for prime time,” clean and scalable. However, it has a higher potential for accidents and weaponization AND has material disposal challenges.

Opportunities

- Improved materials for storage and diverse new energy generation modalities (solar, biofuel, wind, fusion, nano-scale fuels, etc.) are already being developed in academic and industrial settings. These can be prioritized and exploited depending on national regional needs.
- Leaders can exploit “low-hanging fruits” by encouraging conservation
- Energy independence reduces conflict

Policy Implications

- Need to develop a region-specific plan for prioritizing the development and implementation of generation, storage, and distribution technologies that addresses the natural resources, growth trajectory, etc. of the countries in the region

Water

Impact

- Security threat: Access to clean water is critical to directly sustain human life, to support agriculture and to prevent the spread of disease
- The need for clean water is growing due to population expansion and industrialization
- Unpredictable shocks to water supply may occur due to climate change
- Conflicts over control of clean water may be increasingly likely and could provoke social unrest

Challenges

- Technologies to definitively stop global warming and comprehensively address the unpredictability of water supply do not exist
- Global modeling technologies to predict climate change lack components relevant to understanding future changes in water
- Nations most directly impacted by this threat tend to be less industrialized – so although they are most likely to be hurt, they are “less responsible” for the problem and “less responsible” for paying for the solution.
- Many scientists blame industrialized nations for causing the problem – but most industrialized nations are minimally impacted on a day-to-day basis by the issue and often defensive to the accusations. This can impair the participation of such nations in solution-finding.

Opportunities

- Continue to harness desalination technologies
- Technologies that improve modeling may be increasingly available

Collaborative Proposals

- Establish collaboration and actions at appropriate levels of decision-making
- Improve international laws, treaties and technical collaboration
- Identify success in collaboration efforts in other areas for lessons learned that are applicable to creating opportunities
- Align multinational incentives to promote global cooperation
- Design global integrated assessment models that address interconnectedness of energy, water, economies, agriculture, climate and global health
- Develop down-scaled models to address regional and local impacts (context)
- Actively leverage innovations from multinational public and private institutions
- Harness S&T diplomacy as a proactive way to address near-term threats and reduce long-term conflict potential

Final Comments

Dr. Perry and Dr. Hecker put forth an outline of ideas for the group's consideration as possible points of departure for future follow-up dialogues between the S&T and security communities.

First, there is a need to revisit the existing baseline understanding and formulations of “big” concepts such as risk, vulnerability, adaptability, resilience and disruptive innovation. On risk, the question is whether there is a way to develop regional and global initiatives to manage the “spectrum of risks” borne out of the S&T-security interface. Moreover, Drs. Perry and Hecker also raised the notion of “transitional risks” defined as a “special” set of risks of developing nations as they transition from managing “traditional” to “modern” risks. With the increasing linkage between S&T developments and comprehensive security issues growing rapidly, the concept of vulnerability is also undergoing transformation. The question is how to live with it and define it in this fast-changing world. On the issue of adaptability and resilience, Dr. Perry suggests that there is a need to re-examine national and international institutions, i.e., if these are setting realistic goals and trade-offs in light of the rapidly evolving S&T and security environments. And finally, the increasing occurrence of disruptive innovations bring to the fore the question of whether ad hoc responses are sufficient for ad hoc developments.

The second consideration pertains to the deepening global and regional spill-over effects of S&T developments on the security environment and conversely, the impact of changes in the security arena on S&T trajectories. This highly dynamic situation provides an opportunity to re-think the prevailing world order. Is it time to develop alternative ways of viewing and arranging the international system? Should India and China be categorized differently?

Dr. Perry also stressed the importance of sustaining, if not increasing, the capacity to develop advanced integrated assessment tools to capture the intersection of S&T and security developments.

These are transformational tools that are particularly crucial now and into the future because certain security issues such as climate change are comprehensive and long-term in its impact.

Finally, Dr. Hecker highlighted the need to enhance and sustain international modes of cooperation and collaboration: to leverage international S&T diplomacy, to develop more robust and sustainable private public partnerships, and to capture, institutionalize and share successful collaboration efforts. Dr. Perry added that there is a need for us to shift our mindset from “independence” to “interdependence” in managing complex and interrelated S&T and security challenges. An example would be adopting a policy of “assurance through diversity” where all countries develop a multi-sourced energy portfolio to stabilize and secure energy resource supplies, consequently creating a thick web of regional and global interdependent networks that favor and affirm collaborative and cooperative behavior. In the same vein, he also noted that S&T priorities will depend on the politics, capacity, legal frameworks, location and resources of the local communities.

The top three S&T phenomena that the participants selected as areas generating the most concern in the next 20 years cannot be resolved by technoscientific solutions alone: Dr. Perry agreed with the findings of the group that the political, socio-cultural and regulatory “sensitivities” are considerations that critically inform national and international responses. Furthermore, the ethical, legal, societal implications (ELSI) of S&T developments must also inform policy responses – scientific and technological developments are necessary, but not sufficient, conditions to solve security concerns and issues. While the S&T phenomena are global in scope, the operationalization of the challenges, opportunities and security implications are local. In broad terms, the deepening interface of S&T and comprehensive security developments in a globalized context calls for a reexamination of established approaches to both S&T and security management.

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***The Interface of Science, Technology & Security:
Areas of Most Concern, Now and Ahead
APCSS Seminar
Honolulu, Hawaii
4 - 8 October 2010***

Monday 4 Oct 2010

Arrivals and hotel check-in

- 1645-1700 **Registration** Lanai
- 1700-1800 **Keynote Address (followed by Q & A and brief self-introductions)** Auditorium
- Introduction: Lieutenant General (Ret) Ed Smith, APCSS
 - Speaker: Dr. Arun Majumdar, Director, Advanced Research Projects Agency-Energy (ARPA-E)
- 1800-1930 **Welcome Reception** Lanai
(Hosted by The APCSS Foundation)

Tuesday 5 Oct 2010

- 0730-0800 **Registration and Morning Coffee** Lanai
- 0800-0925 **Opening Remarks, Overview of Workshop Flow, Initial Theme Canvassing** CCR
- Lieutenant General (Ret) Ed Smith, Director, Asia-Pacific Center for Security Studies (APCSS)
- 0925-0930 **Administrative Announcements** CCR
- Dr. Virginia Watson, APCSS
- 0930-1000 **Group Photo and Break** Front Lawn & Lanai
- 1000-1145 **Plenary Session 1: Thoughts on Current Security Landscape** CCR
- Moderator: Lieutenant General (Ret) Ed Smith, APCSS
 - Mr. Ralph Cossa, Pacific CSIS
 - Dr. Mohan Malik, APCSS
 - Prof. Kerry Nankivell, APCSS
- Question and Answer Session to follow*

DAY ONE (Afternoon): Tuesday 5 Oct 2010

- 1145-1230 **Working Lunch:** Open Discussions Lanai
- 1230-1345 **Plenary Session 2: Thoughts on Current Science & Technology (S&T) Landscape** CCR
- Moderator: Lieutenant General (Ret) Ed Smith, APCSS
 - Dr. Virginia Watson, APCSS
 - Dr. J. Scott Hauger, APCSS
 - Dr. William Wieninger, APCSS
- Question and Answer Session to follow*
- 1345-1400 **Break** Lanai
- 1400-1405 **Break-out Group Discussion Focus** CCR
- 1405-1600 **Facilitated Break-out Group Discussions:** B118 & B119
- “Defining the Framework” Discussion Focus:**
- Group 1: Identify how security officials capture and use the new knowledge that the scientific and engineering community creates for the common good.
- Facilitator: Prof. Shyam Tekwani, APCSS
 - Recorder: LTC David Longbine, APCSS
- Group 2: Identify how officials from the scientific and engineering community better inform security officials about emerging and potential security impacts/implications related to new S&T knowledge being created.
- Facilitator: Dr. Virginia Watson, APCSS
 - Recorder: COL Stephen Myers, APCSS
- ▶ For this discussion period only, Group 1 consists of Security Practitioners and Group 2 consists of Scientists and Technologists.
 - ▶ For all following discussion periods, Group 1 and 2 will consist of a mix of Security Practitioners, Scientists and Technologists
- 1600- **Evening at Leisure**

DAY TWO: Wednesday 6 Oct 2010

0700-0800	Morning Coffee	Lanai
0800-0805	Review Plan of the Day Lieutenant General (Ret) Ed Smith, Director, Asia-Pacific Center for Security Studies (APCSS)	CCR
0805-0915	Group Brief-backs on Day 1 Findings & Open Discussion • Moderator: Lieutenant General (Ret) Ed Smith, APCSS (each group brief-back <u>allotted 15 minutes</u>)	CCR
0915-0930	Break	Lanai
0930-1100	Plenary Session 3: Update on Science & Technology Developments with Significant Security Implications Category #1: Information Technology • Moderator: Mr. Shyam Tekwani, APCSS • Mr. Richard Schaeffer, Riverbank Associates, (US) • Dr. Robert Childs, National Defense University (US) • Dr. Igor V. Kotenko, Russian Academy of Sciences (Russia) <i>Questions and Answer Session to follow</i>	CCR
1100-1115	Break	Lanai
1115-1245	Plenary Session 4: Update on Science & Technology Developments with Significant Security Implications Category #2: Biotechnology • Moderator: Dr. Virginia Watson, APCSS • Dr. Lynn Jelinski, President, Sunshine Consultants (US) • Dr. Ashley Dombkowski, MPM Capital (US) • Dr. Cong Cao, Levin Institute Center for STI in China (US) <i>Questions and Answer Session to follow</i>	CCR
1245-1330	Working Lunch: Open Discussion	Lanai
1330-1335	Break-out Group Discussion Focus	CCR
1335-1530	Facilitated Break-out Group Discussions: “Identifying & Prioritizing” Discussion Focus: Group 1 and Group 2: Identification, prioritization, and rationale for Top 4 S&T initiatives/phenomena from <u>combined</u> morning session Categories #1 & #2 in terms of security-related impacts, challenges & opportunities, and policy implications.	B118 & B119
1530-1545	Break	Lanai
1545-1700	Group Brief-backs on Day 2 Findings & Open Discussion • Moderator: Lieutenant General (Ret) Ed Smith, APCSS (each group brief-back <u>allotted 15 minutes</u>)	CCR
1700-1705	Plan for the Next Day • Lieutenant General (Ret) Ed Smith, APCSS	
1800-	Optional Shopping Trip to Ala Moana Center (van transport)	Hale Koa Lobby

DAY THREE: Thursday 7 Oct 2010

0730-0800	Morning Coffee	Lanai
0800-0805	Review Plan of the Day Lieutenant General (Ret) Ed Smith, Director, Asia-Pacific Center for Security Studies (APCSS)	CCR
0805-0930	Plenary Session 5: Update on Science & Technology Developments with Significant Security Implications	CCR
	Category #3: Energy <ul style="list-style-type: none">• Moderator: Mr. Dave Shanahan, Deputy Dean, APCSS• Ms. Lydia Powell, Observer Research Foundation (India)• Dr. In-ho Kim, Agency for Defense Development (Republic of Korea)• Dr. Elizabeth Cantwell, Lawrence Livermore National Laboratory (US) <i>Questions and Answer Session to follow</i>	
0900-0945	Break	Lanai
0945-1115	Plenary Session 6: Update on Science & Technology Developments with Significant Security Implications	CCR
	Category #4: Environment <ul style="list-style-type: none">• Moderator: Dr. J. Scott Hauger, APCSS• Dr. Benjamin Santer, Lawrence Livermore National Laboratory (US)• Dr. David Brunckhorst, University of New England (Australia)• Dr. Sumeet Saksena, East-West Center (India) <i>Questions and Answer Session to follow</i>	
1115-1200	Working Lunch: Open Discussion	Lanai
1200-1205	Break-out Group Discussion Focus	CCR
1205-1400	Facilitated Break-out Group Discussions: “Identifying & Prioritizing” Discussion Focus: Group 1 and Group 2: Identification, prioritization, and rationale for Top 4 S&T initiatives/phenomena from <u>combined</u> morning session Categories #3 & #4 in terms of security-related impacts, challenges & opportunities, and policy implications.	B118 & B119
1400-1415	Break	Lanai
1415-1515	Group Brief-backs on Day 3 Findings & Open Discussion <ul style="list-style-type: none">• Moderator: Lieutenant General (Ret) Ed Smith, APCSS (each group brief-back <u>allotted 15 minutes</u>)	CCR
1515-1530	Break	Lanai
1530-1630	Keynote #2: Global Nuclear Risk Reduction by Science Diplomacy <ul style="list-style-type: none">• Introduction: Dr. Virginia Watson, APCSS• Speaker: Dr. Siegfried Hecker, Co-director, Center for International Security and Cooperation (CISCA), Stanford University Director Emeritus, Los Alamos National Laboratory <i>Questions and Answer Session to follow</i>	CCR

- 1630-1640 **Plan for the Next Day** CCR
 • Lieutenant General (ret) Ed Smith, APCSS
- 1640-1700 **Enduring Links to APCSS: Staying Connected** CCR
 • Ms. Mary Markovinovic, APCSS
 • Mr. John Gasner, APCSS
- 1800- **Optional No-host Hawaiian Dinner and Show (“Luau”)** Hale Koa Hotel

DAY FOUR: Friday 8 Oct 2010

- 0800-0830 **Morning Coffee** Lanai
- 0830-1015 **Facilitated Break-Out Group Preparations of Final Briefings: “Identifying Collaborative Opportunities”** B118 & B119
Discussion Focus:
 Group 1 and Group 2: Identify, From All S&T Categories, The **Top 3** S&T Initiatives/Phenomena Likely To Have The Most Significant Global Impacts During The Next 20 Years...And Focus Interagency, Regional And Global Interface Opportunities To Prepare Collaboratively
- 1015-1045 **Break** Lanai
- 1045-1215 **Break-out Groups’ Final Briefings to Dr. William Perry, former U.S. Secretary of Defense and Dr. Siegfried Hecker, Co-Director - CISCA (Stanford University)** CCR
 • Moderator: Lieutenant General (Ret) Ed Smith, APCSS
 (Each group brief-back allotted 25 minutes)
Question and Answer Session to follow each presentation
- 1215-1330 **Working Lunch: Open Discussion** Lanai
Participants Complete On-line Workshop Evaluation
- 1330-1445 **Response to Final Briefings by Dr. William Perry and Dr. Siegfried Hecker (Followed by Open Discussion)** CCR
 • Moderator: LTG (Ret) Ed Smith, APCSS
- 1445-1515 **Final Thoughts/Closing Remarks** CCR
 • LTG (Ret) Ed Smith, APCSS
 • Dr. William Perry

Saturday 9 Oct 2010 - Departures

