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Acting to Address the Ocean-Related Impacts of Climate Change on Human and National Security, with Recommendations for Priority Actions drawn from the discussions of the Global Conference on Oceans, Climate and Security at the University of Massachusetts Boston

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A White Paper

Acting to Address the

OCEAN-RELATED IMPACTS OF CLIMATE CHANGE ON HUMAN AND NATIONAL SECURITY

– with Recommendations for Priority Actions –

drawn from the discussions of the

Global Conference on Oceans, Climate and Security

at the

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presented by the

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Contents

Introduction

In the course of the past calendar year the United States has been struck by a series of droughts, tornadoes, hurricanes, blizzards, wildfires, and floods whose size and path of resulting damage defy previously established patterns. The U.S. thus joins nations on every continent that have increasingly experienced extreme and extremely damaging weather events over the past two decades.

At the same time, the world's oceans have been exhibiting a less-visible but equally dangerous sequence of temperature rise, acidification increase, fish kills, coastal erosion, salinity shifts, algae blooms, and steady decreases in commercially available fish and shellfish species.

Those impacts are not only significant indicators of a climate change that is rapidly increasing in the natural world, they are also warning signals of the effects of that changing climate on national and human security. A new focus is emerging on how climate change impacts ocean systems, the oceans' subsequent vital role in exacerbating or mitigating those impacts, and how both climate and ocean systems substantially impact national security.

The stunning effects of Hurricane Sandy provided only an initial glimpse of the extensive primary, secondary, and tertiary impacts that will result from these system shifts domestically and internationally. Understanding the interconnectedness among oceans, climate, and security is therefore increasingly crucial to our collective future.

The first Global Conference on Oceans, Climate and Security (GC '12) was designed to raise awareness of the effects of climate change on ocean systems and the consequent impacts on national and international security. The conference attempted to identify and prioritize the knowledge gaps in science and technology that have inhibited understanding, response, and adaptation to future threats and opportunities. It then generated a series of human security policy and governance recommendations reflecting the climate, ocean, and security continuum.

Participants agreed that the required solutions were not the responsibility of either the public sector (government), the private sector (business), or the voluntary sector (NGOs) alone—but were the responsibilities of all of these working together. They also emphasized the potential in approaching the issues from the perspective of positive economic and social opportunity, rather than focusing solely on risks and threats.

This white paper presents the observations of the conference and highlights its primary conclusions. It then expands upon those to include the extraordinary impacts—both physical and political—of the recent and ongoing series of extreme-weather phenomena that peaked in 2012 with the devastation of Sandy and has continued in 2013 with a melting Arctic and floods across the U.S. Midwest.

The paper presents a series of specific recommended Priority Actions covering each of the conference's substantive areas:

- The Climate-Oceans-Security Nexus
- Coastal Impacts
- Climate, Oceans, and Human Health
- Arctic and Antarctic Implications
- Ocean Acidification Effects

It focuses responsibility for those actions on the lead organizational and stakeholder sectors active in climate, oceans, and security policy, including U.S. national and local governments, business and the private sector, the U.S. Navy and maritime forces, NOAA, the National Ocean Council, the Arctic Council, regional port agencies, and the U.N. Convention on the Law of the Sea. It also cites the responsibilities of the science, communications, and education communities, multisectoral partnerships, and economic and planning agencies.

At a moment in time that calls for a response to potentially Darwinian levels of change, we urge all to take leadership roles in creating a sustainable path for the nation's, and the world's, future security and prosperity. We hope you'll find the recommendations from the conference, and the analyses summarized in this paper, useful.

Editors

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*The views expressed are those of the author(s) and do not represent the official views or policy of the Department of Defense or the Naval Postgraduate School.

I. The Role of the Collaborative Institute for Oceans, Climate and Security

– and the Goals of the Conference

This white paper is a product of the presentations and discussions held during the Global Conference on Oceans, Climate and Security, in May 2012 at the University of Massachusetts Boston. The conference included 225 participants from 16 countries, 17 U.S. states, and many regional and local stakeholders. They included representatives of the military, private industry, academia, government officials, consulting firms, philanthropic foundations and nonprofit organizations.

The conference was organized by the Collaborative Institute for Oceans, Climate and Security (CIOCS) in order to advance understanding, develop policy options, provide information, and increase collaboration among stakeholders on three of the most critical emerging policy sectors facing national and international policy makers.

The Collaborative Institute is distinguished by its unique focus on the intersections of oceans, climate, and security, and the significant resulting policy and management challenges. Founded on the principle that collaborative partnerships have the potential to better address the human and national security threats that will continue to mount as climate and oceans drastically change, the Collaborative Institute exists to develop and communicate high-value intellectual, policy, and technical expertise to help stabilize the health of the atmosphere, marine ecosystems, and coastal communities, thereby influencing global human security, and associated national security, for all.

This paper is a product of the presentations and discussion held during those meetings and relevant developments since the conference. It does not attempt to represent the organizational or individual positions of each of the participants, but it draws heavily from their informal discussions and formal statements, and frames those in light of more recent natural and political events. The paper then attempts to integrate them into a broader narrative of the current status of the issues and the chances for political action.

An intended primary service of the paper is its proposed series of specific recommended actions that can be initiated immediately to deal with each of its five focus areas. Those actions are assigned to

the responsible societal sectors – Governments, Science, Port Authorities, U.S. Maritime Forces, Private Business, and Stakeholder Organizations – whose participation is vital in dealing with climate, ocean, and security issues.

The most critical of the recommendations are highlighted in the Executive Summary as suggested priority actions. As public officials face increased tension between newly emerging public awareness of the need for action, and pressing realities of limitations in available funds, it will be imperative that they can identify the actions which utilize those resources most effectively.

The organizers' and the authors' goal is to expand and advance the consideration of, and action on, these issues. CIOCS welcomes the reaction and comment of all members of the national and international policy communities. (Please see contact information above.)
This white paper utilizes specific language in documents provided by several of the conference speakers, and particularly from the background paper prepared by Wayne Porter. The principal authors of the paper are Robbin Peach, Felix Dodds, and Michael Strauss.

II. Executive Summary

It's true that no single event makes a trend. But the fact is, the 12 hottest years on record have all come in the last 15. Heat waves, droughts, wildfires, floods, all are now more frequent and more intense. We can choose to believe that Superstorm Sandy, and the most severe drought in decades, and the worst wildfires some states have ever seen were all just a freak coincidence. Or we can choose to believe in the overwhelming judgment of science and act before it's too late.

The good news is, we can make meaningful progress on this issue while driving strong economic growth.... I propose we use some of our oil and gas revenues to fund an Energy Security Trust that will drive new research and technology to shift our cars and trucks off oil for good.

If a nonpartisan coalition of CEOs and retired generals and admirals can get behind this idea, then so can we. Let's take their advice and free our families and businesses from the painful spikes in gas prices we've put up with for far too long.

–U.S. President Barack Obama, State of the Union Address to Congress, Feb. 12, 2013[1]

A Rising Tide of New Security Issues – *The Threats and the Opportunities*

Climate change is a threat multiplier. It can accelerate conflict as food, water and energy availability are impacted and restricted. The sooner that climate issues are addressed, the fewer and less intense those security impacts will be. As the global environment moves closer to critical tipping points, and as the global economy becomes increasingly interdependent, the entire system becomes increasingly sensitive to the actions of a relative minority of actors or events in a distant locality.

For the past 12 years in the United States policy makers have been basically immobilized, unable to set in motion the reforms needed to reduce the chances of severe climate impacts. If such paralysis continues, those impacts will become increasingly more, not less, extreme.

There has also been a significant failure in governance in many countries, and at the local, state, national and international levels, to recognize and respond to the complex interactions between climate and security systems, and to implement integrated strategies that address them.

The systems governing the world's oceans, the Earth's climate, and nations' security are fluid, complex, and fundamentally related. Environmental impacts such as extreme-weather events, melting polar ice, sea-level rise, ocean acidification, deoxygenation, and warming each pose critical threats to human populations, natural ecosystems, and to national and global political stability.

The very notion of security has evolved, and should now be viewed as referring not only to the national *military security* of the United States, but also to *human security*, which requires factoring in the agricultural, economic, social, and personal security of individuals in all nations. All these areas of security, each critically important in its own right, inevitably become integrally relevant to achieving the political security of the United States and every other nation.

In this sense, *security* and economic and social *prosperity* are also closely linked. In fact, they are interdependent. And that interdependence can be viewed not just in terms of negative threats that must be avoided, but also in terms of positive opportunities that can be gained. The more that strengthening economies and stabilizing societies can increase a sense of "freedom from vulnerability" among nations and their populations, the more likely that the motivation and capability of those nations to maintain political and military stability will also increase. Conversely, as political and military security increases, the more possible it will be that economic prosperity for all nations and people will increase as well.

It also becomes clear that effectively addressing climate change can present as much of an economic and political *opportunity* as not addressing it presents an economic and political *threat*. Failing to recognize the opportunity inherent in the development of sustainable sources of clean energy and water, for example, by overly focusing on *security* can impede the path to an enduring *prosperity* that includes economic and social growth.

A significant element of this opportunity is economic. In exploring this path, the private sector has a critical role to play and can reap great rewards. Tremendous commercial success will be gained by developing clean energy sources and production alone. Equivalent success will be achieved by developing systems that provide and conserve clean water and that sustainably produce healthy and affordable food.

The only question is which companies, and in which countries, that success will occur.

As the private sector moves to profit from such opportunity, it will also have a parallel responsibility – to develop and practice new models of globally balanced, environmentally friendly economic growth.

Another significant element of this opportunity is social – the potential for pioneering new societal models that provide inspiring education, available health care, and vital services like sustainable community planning, transportation, sanitation, and safety. Here, the active involvement of sufficiently resourced governments is essential. Their role must be to maintain a balance between growth and fairness, and to encourage the necessary cooperation and networking among large and small businesses; international, national, state, and local agencies; employees and consumers; teachers and communicators; funders and scientists; and NGOs and civic organizations of every variety.

The rewards for establishing effective models of "sustainable communities" or "sustainable social development" will be realized in both lower costs of dealing with social dysfunction and in higher benefits from the achievements of a productive population.

In all such areas of potential growth, successful strategies can be pursued consistent with the imperative of addressing climate and ocean issues. Provided that there are both actions taken to

reduce the pace of climate change and actions taken to adapt to the unavoidable impacts of that change, such strategies can catalyze a cascade of technological and social innovation that opens the way to broad, positive new models of economic and cultural cooperation, and a balance between human populations and the natural environment.

A Flood of Evidence
– *Dealing with Multiple Challenges*

Climate Change Consequences

The real-world necessity for embarking on a transition that addresses rapidly materializing climate scenarios is now unavoidably clear.

An overwhelming majority of the world's climatological, meteorological, atmospheric, and oceanographic scientists has concluded that global climate change is real, is primarily anthropogenic in origin, and is increasing rapidly in pace. The concentration of carbon dioxide (CO_2), the primary greenhouse gas, in the atmosphere has increased from its pre-industrial level of approximately 278 ppm to over 391 ppm in September 2012[2] – higher than at any time in the last 15 million years. Global mean temperature is now approximately 0.8°C above pre-industrial levels.

Without further commitments and action to reduce greenhouse gas emissions, the world is likely to warm by more than 3°C above the pre-industrial climate. Even with the current mitigation pledges fully implemented, there is an approximately 20 percent likelihood of exceeding 4°C by 2100. If they are not met, a warming of 4°C could occur as early as the 2060s. Such a warming level would lead to a sea-level rise of 1.5 to 3 feet, or more, by 2100. [World Bank, Nov. 2012][3]

Other climate impacts will include extreme-weather events, droughts, flooding, retreating glaciers, polar ocean surface ice melts, sea-level rise, multispecies habitat shifts, and increased spread of threatening diseases. These conditions have the potential to disrupt societies around the world. Therefore, they have direct security implications for every nation.

The Impacts on Oceans

> Oceans are changing radically and rapidly. …
>
> Climate change and ocean acidification … pose serious risks to the social, economic, health and environmental benefits we derive from oceans … Compared to a century ago, oceans are now warmer, higher, stormier, saltier, lower in oxygen and more acidic. Any one of these would be cause for concern. Collectively, they cry out for action.[4]
>
> – Ray Mabus, U.S. Secretary of the Navy

The direct and secondary impacts of climate change on oceans will be varied and extensive.

Global sea-surface temperatures are projected to increase another 1.8°C to 4.0°C over this century. Warmer waters accelerate coral bleaching, range shifts, increases in diseases, altered productivity, and an increase in invasive species.

Higher sea levels, especially in combination with more frequent and more intense storms and thus storm surges, will increasingly impact on coastal communities and threaten coastal ecosystems and infrastructure, including military installations.

Extreme weather, storm surges, wind speeds, and wave heights are increasing on a global scale, with potentially significant implications for safety of populations, efficiency of shipping, consumption and generation of energy, and for security. November's Superstorm Sandy alone cost an estimated $60–$80 billion in damages.

Decreased ocean oxygen levels, due to warmer water temperatures and increased nutrient runoff results in so-called "dead zones," in which fish and shellfish cannot survive. The number of such zones around the world has approximately doubled each decade since the 1960s. A recent study5 identified more than 530 dead zones, mostly in coastal waters at the mouths of rivers.

Ocean acidification is accelerating – perhaps the least noticeable, but potentially most pervasive, of these trends. As the level of atmospheric CO_2 rises, so does that of CO_2 dissolved in the oceans. The higher levels have made oceans on average 30 percent more acidic over the past 150 years, and projected to turn far more so by 2100. Increased acidity makes waters more corrosive, affecting both man-made structures and ocean ecosystems. Those ecosystems are essential. Impacts will be particularly severe for calcifying species, including shellfish, corals, algae, and many types of plankton – species that provide critical habitat and food sources for an extensive spectrum of ocean life.

The Cascading Effects on Security

Climate change and its ocean impacts produce direct and indirect security implications. To fully understand how, it's necessary to consider the second- and third-order effects of climate and ocean changes.

As global warming is allowed to progress, erratic weather patterns and extreme-weather events will increasingly become the norm. Storm surges, repeated river basin flooding, intense precipitation deluges, and extensive droughts will lead to regional crop failures and food price spikes. As available food supplies are bought out, not just one local area but entire regions' food prices can be driven higher, affecting national and continental economies and stressing populations in neighboring countries. And when discrete weather events are particularly widespread or occur simultaneously, or coincide with critical political or economic events, global commodities markets and potentially the entire global economy can be affected.

Extreme regional weather events are already generating waves of environmental refugees fleeing famine and soaring food costs, and seeking food or housing safety in less affected rural regions, in urban areas, or across national borders. Such transient populations create their own economic and political impacts. Within primarily affected countries, impacts can result in economic chaos, public protests, the rise of populist movements, and resulting political turmoil. In refugee destination countries, impacts can include intense competition for food, jobs, and services. The results can stress local resources, instigate popular resentment, and lead to the rise of nationalist movements or political conspiracies. Eventually, it can lead to threatened or actual military actions.

Each of these environmental, economic, social, and political dynamics can have cascading effects, and can escalate as they spill over to nearby nations. A government overthrown in ethnically

conflicted North Africa, oil production shutdown in a leading producer in Latin America or the Middle East, or threats of war between nuclear-armed neighbors in South Asia all have immediate and long-range consequences. These can quickly involve nations far removed geographically.

The location and progression of specific incidents may be impossible to predict, but the seriousness of potential resulting impacts is much clearer. National and international security forces will therefore increasingly require preparation and capacity to respond to a wide range of direct and potential military situations.

Just as important – and perhaps more effective in terms of limiting economic and human costs – security forces will require preparation and capacity to help respond to preconflict situations. Such actions could include the evacuation and rapid resettlement of thousands of starving refugees, the transport and distribution of emergency food and shelter to geographically challenging locations, or the transport and installation of oil- or chemical-spill cleanup equipment in the midst of a conflict zone.

Doing so effectively can be not only a humanitarian act by wealthier nations, it can be the strategic action that preempts far more serious impacts that continue to cascade until they reach those nations' own shores. Effective preemptive humanitarian action, whether carried out by military or nonmilitary agencies, also can provide an opportunity for initiating new and more resilient economic models, and for engendering significant political goodwill.

Of course, the most effective preemptive action of all would be mitigating the activities that lead to environmental catastrophes in the first place.

Navigating the Emerging Wave
– *Key Areas for Action*

> Not only are we at an inflection point in U.S. history, in which we face a completely different strategic environment than existed through the last half of the twentieth century, we are at a Darwinian moment in time for civilization. We are testing the carrying capacity of the planet, and we need to adapt as a species if we are to evolve and survive.[6]
>
> – Capt. Wayne Porter, USN, Chair of Systemic Strategy and Complexity

In the United States for most of the past dozen years, there has been a disconnect between the approach of the nation's military, which has been acting on the assumption that climate change is in fact occurring, and the national political decision-making process, which has been unable or unwilling to address the issue.

It might be that the increased public awareness of the human and financial costs generated by recent extreme-weather events – from Hurricane Isaac and its reminder of Katrina in New Orleans, to Superstorm Sandy in New Jersey and New York, to multiple tornadoes in Missouri and Texas, to record wildfires in the mountain West, to the multiyear regional drought across the Southeast – has now created a political environment that could allow for shifting that political logjam.

Images of hundreds of miles of coastland inundated, thousands of homes destroyed or damaged, the New York subway under water, 6.2 million people without electricity, extensive gasoline shortages, the Financial Center shut and business virtually shuttered, may have convinced necessary majorities of the public, political officials, and policy makers of the reality of changing climate, and the immediacy of its threats to virtually all systems of social and economic organization.

Culminating a year in which the United States experienced 11 distinct weather-related disasters that each totaled a billion dollars or more in damages, Sandy left behind a shifted perceptual landscape upon which previously dormant public and political support is now emerging that can result in meaningful legislative and regulatory reform as well as public and private action.

Conclusions

An extensive series of steps to coordinate the roles and responsibilities of the government and stakeholder sectors, and specific actions to implement policy, will be necessary to avoid the most extreme scenarios of changing climate and oceans, and to prepare for the threats – and the opportunities – presented by the impacts that cannot be avoided.

At the local level, recent initiatives such as "NYS 2100" Report[7] in New York, and the Boston Harbor Association report "Preparing for the Rising Tide"[8] indicate that, at the initial planning level, actions are now being taken to start to identify challenges and objectives.

Achieving those objectives will require drafting and implementing initiatives and reforms in multiple policy spheres – and in significantly improving intersectoral planning and coordination. To achieve effectiveness, these policy deliberations and decisions should be taken in collaboration with a wide range of relevant stakeholders.

In such rapidly evolving arenas, decision-making structures must remain flexible and open to accepting creative strategies and new information. The need for specific programs and strategies will necessarily evolve with the emergence of feedback from the field over time.

Whether such actions are indeed taken, and how political and organizational conflicts are resolved and resources are allocated, will play a fundamental role in determining how, and whether, 7 billion humans can continue to live in a finite global ecosystem.

Participants at the conference identified the following **Priority Actions**:

A. The Climate-Oceans-Security Nexus

- **U.S. Navy and Maritime Forces**
  - Increase cooperation among U.S. maritime agencies and with other Arctic nations in order to continue strengthening partnerships that foster a secure and stable Arctic region.

- **Science**
  - Provide in-depth modeling and research into sea-level rise and its impact on coastal zones.
  - Continue to improve the reliability of storm predictability through advanced modeling of weather systems (that in recent years has taken quantum leaps, as evidenced in the eight-day accuracy of forecast for the landfall of Sandy). Maintaining and augmenting GEOS and polar satellite systems is a critical element of such coverage.

- **Governance**
  - Actively address climate change at all levels of governance, including local, state, national, and international.
  - Provide substantial new financial support to develop the adaptation plans that are vital for all countries for dealing with climate-change impacts. (The UNFCCC Green Fund should be utilized to assist developing countries.)
  - Assure sufficient funding and administrative capacity to provide oceanographic and meteorological research, monitoring, and prediction services.

- **Communications and Education**
  - Utilize national and local communications and education programs to coordinate efforts to change societal behavior and personal consumption patterns.
  - Build a broad network of trusted communicators including scientists, teachers, political and community leaders, meteorologists, and representatives of faith organizations.
  - Integrate education on 21st-century environmental issues into curricula at all levels of K–20, with as much emphasis on positive economic and social opportunities as on negative risk and threat.

- **Business and the Private Sector**
  - Intensify research, development, and implementation of low-carbon technologies and enhanced resilience strategies to help reduce the pace of climate change and adapt to the impacts that cannot be avoided.
  - Take advantage of the economic opportunities that innovation in sustainable technologies presents.
  - Explore partnerships between corporations or small businesses and local school systems and colleges – and in cooperation with NGOs – to provide funding of public education and awareness programs, thereby engendering goodwill, a more informed consumer base, and wider support for clean-energy and -water initiatives.

B. Coastal Impacts and Population Effects

- **Ports**
  - Strengthen the resilience to sea-level change of port infrastructure and intermodal transport connectors.
  - Survey the ability to expand the role of individual ports in global commerce.
  - Assess and monitor the vulnerability of ports in terms of resilience investment strategies.

- **NOAA**
  - Continue to refine, share, and fund predictive meteorological modeling programs – and the dedicated computer systems to run them – like those responsible for the extraordinarily early accuracy in tracking then-Hurricane Sandy, and which have been credited with saving hundreds of lives.
  - Review and update NOAA's "Adaptation to Climate Change: A Planning Guide for State Coastal Manager."
  - Review the implementation of the "Planning Guide" by coastal states.

- **Business and the Private Sector**
  - Governments should restructure subsidies to the insurance industry for covering coastal properties through the National Flood Insurance Policy, and require that those sited on the coast pay full insurance rates.

- **Governance**
  - FEMA should expand capacity-building workshops for local and state officials on dealing with extreme-weather incidents.
  - National, state, and local government should develop climate-change mitigation and adaptation plans and promote informed decision-making.
  - State and local planning should approach "best practice" for building in coastal zones.

- **Communications and Education**
  - Cooperate among state and local government, the private/commercial sector, and other stakeholders to create communications strategies that ensure the public is aware of the risks and informed of the potential to act to mitigate the progress of global warming and thereby reduce the potential of future sea-level rise and extreme- weather events.
  - Provide ongoing training for planners, city officials, and other decision makers in use of strategies and tools to prepare for adaptation planning and extreme-weather events
  - Organize more specific public awareness campaigns to help families and individuals plan for extreme events and transition in their daily lives from present norms to more resilient approaches.

C. Climate Change, Oceans, and Human Health

- **Science**
  - Continue monitoring, research, and updating of methodologies that play a role in presentation and treatment of impacts to human health exacerbated by climate change, including the further development of an agreed set of health indicators, which can be integrated with other relevant indicators to help understand the interdependent systems that connect human society.

- **Governance at All Levels**
  - Centers for Disease Control and Prevention should increase support for surveillance of water-borne, food-borne, vector-borne, and zoonotic diseases that are amplified by climate change.

- **Communication and Education**
  - Utilize official information agencies and engage media outlets to publicize critical information on impacts to human health.

D. Arctic and Antarctic Regions

- **Ports**
  - Build any new ports to optimum standards for sustainability, adaptability, and resilience through an intergovernmental process that consults all stakeholders, including Indigenous Peoples, to ensure they benefit from the development.

- **U.S. Navy and Maritime Forces**
  - Increase cooperation among U.S. maritime agencies and with other Arctic nations in order to continue strengthening partnerships that build a secure and stable Arctic region.
    Provide timely investment in:
    - communications and operations support infrastructure needed to ensure the U.S. ability to maintain its responsibilities as an Arctic nation.
    - technologies needed to address a wide variety of adaptation capabilities, such as improving ship operational performance in cold regions and adapting coastal installations to sea-level rise.
    - the operational, communications, and support infrastructure of U.S. Maritime Forces in order to provide critical mapping, navigational, and emergency management/response capabilities.
  - Increase research-and-development investment in technology and capabilities development vis-à-vis climate studies, especially with respect to coupled models and climate forecasting on seasonal-to-decadal timescales.

- **The Arctic Council**
  - While the Arctic does not have a formal governance mechanism, the Arctic Council can be an effective forum for informal cooperation. Participating national governments should review whether the Council should be upgraded by establishing the Ottawa Declaration as a treaty with legally binding obligations,

providing it a permanent independent secretariat and giving it an active role in ecosystem-based management.
- Maximize its role as a forum to review compliance with IMO Arctic Shipping Guidelines and IACS Unified Requirements for Polar-class ships.
- Determine whether the Council should address present regulatory gaps covering marine research, archaeology, bio-prospecting, laying of cables and pipelines, artificial islands and seabed construction, and military activities.
- Decide whether the Council should address emerging and new maritime activities such as deep-sea tourism, CO_2 sequestration, and floating installations.

United Nations Convention on the Law of the Sea
- UNCLOS is the primary international regulatory mechanism for oceans. The United States should urgently ratify the Law of the Sea Treaty and its two implementation agreements – the Part XI Deep-Sea Mining Agreement and the United Nations Fish Stocks Agreement.

- **Communications and Education**
- Coordinate public information agencies and engage media outlets to publicize the fragile state and critical role that the Arctic plays in climate and ocean issues.

Multisectoral Partnerships
- Economic development activities should be subject to widely agreed environmental standards, and include costs for any restoration.

E. Securing Ocean Benefits

- **Governance**
  - Utilize all available regulatory, voluntary, and economic incentive mechanisms to protect tropical reefs – which provide shelter and food for 25 percent of known marine fish species; account for 9 to 12 percent of world fish landings; and directly and indirectly provide significant sources of nutrition and employment in developing countries through increasingly threatened local fishing and international tourism.

- **Science**
  - Assess the options for the development of environmentally sustainable aquaculture options, using species that may be more resistant to lowered pH.
  - Determine the vulnerability to ocean acidification of human communities dependent on marine resources.
  - Support a global effort to track ocean acidification through an international network of monitoring stations through the Ocean Acidification International Coordination Centre.

III. Climate Change, Ocean Impacts, and International Security

1. A Rising Tide of New Security Issues

– The Threats and the Opportunities

> In the 21st Century, the reality is that there are environmental threats which constitute threats to our national security. For example, the area of climate change has a dramatic impact on our national security: [from] rising sea levels, to severe droughts, to the melting of the polar caps, to more frequent and devastating natural disasters, all raise demand for humanitarian assistance and disaster relief.[9]
>
> – Leon Panetta, United States Secretary of Defense

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Climate Change Consequences

The real-world necessity for embarking on a transition that addresses such scenarios is now unavoidably clear.

An overwhelming majority of the world's climatologic, meteorologic, atmospheric, and oceanographic scientists has concluded that global climate change is real, is primarily anthropogenic in origin, and is increasing rapidly in pace. The concentration of carbon dioxide (CO_2), the primary greenhouse gas, in the atmosphere has increased from its pre-industrial level of approximately 278 ppm to over 391 ppm in September 2012 – higher than at any time in the last 15 million years. Global mean temperature is now approximately 0.8°C above pre-industrial levels.

Without further commitments and action to reduce greenhouse gas emissions, the world is likely to warm by more than 3°C above the pre-industrial climate. Even with the current mitigation pledges fully implemented, there is an approximately 20 percent likelihood of exceeding 4°C by 2100. If they are not met, a warming of 4°C could occur as early as the 2060s. Such a warming level would lead to a sea-level rise of 1.5 to 3 feet, or more, by 2100.[10] [World Bank, Nov. 2012]

Other climate impacts will include extreme-weather events, droughts, flooding, retreating glaciers, polar ocean surface ice melts, multi-species habitat shifts, and increased spread of threatening diseases. These conditions have the potential to disrupt societies around the world. They therefore have direct security implications for every nation.

The Impacts on Oceans

> Oceans are changing radically and rapidly. …
>
> Climate change and ocean acidification … pose serious risks to the social, economic, health and environmental benefits we derive from oceans … Compared to a century ago, oceans are now warmer, higher, stormier, saltier, lower in oxygen and more acidic. Any one of these would be cause for concern. Collectively, they cry out for action.[11]
>
> – Honorable Ray Mabus, U.S. Secretary of the Navy

The direct and secondary impacts of climate change on oceans will be varied and extensive:

Global sea-surface temperatures are projected to increase another 1.8°C to 4.0°C over this century. Warmer waters accelerate coral bleaching, range shifts, increases in diseases, altered productivity, and an increase in invasive species.

Higher sea levels, especially in combination with more frequent and more intense storms and thus storm surges, will increasingly have an impact on coastal communities and threaten coastal ecosystems and infrastructure, including military installations.

Extreme weather, storm surges, wind speeds, and wave heights are increasing on a global scale, with potentially significant implications for safety of populations, efficiency of shipping, consumption and generation of energy, and security. November's Superstorm Sandy alone cost an estimated $60–$80 billion in damages.

Decreased ocean oxygen levels due to warmer water temperatures and increased nutrient runoff results in so-called "dead zones," in which fish and shellfish cannot survive. The number of such zones around the world has approximately doubled each decade since the 1960s. A recent study identified more than 530, mostly in coastal waters at the mouths of rivers.

Ocean acidification is accelerating. As the level of atmospheric CO_2 rises, so does that of CO_2 dissolved in the oceans. The higher levels have made oceans on average 30 percent more acidic over the past 150 years, and are projected to turn far more so by 2100. Increased acidity makes waters more corrosive, affecting both man-made structures and ocean ecosystems. Those ecosystems are essential. Impacts will be particularly severe for calcifying species, including shellfish, corals, algae, and many types of plankton – species that provide critical habitat and food sources for an extensive spectrum of ocean life.

The Cascading Effects on Security

Climate change and its ocean impacts produce direct and indirect security implications. To fully understand how, it's necessary to consider the second- and third-order effects of climate and ocean changes.

As global warming is allowed to progress, erratic weather patterns and extreme-weather events will increasingly become the norm. Storm surges, repeated river basin flooding, intense precipitation deluges, and extensive droughts will lead to regional crop failures and food price spikes. As available food supplies are bought out, not just one local area but entire regions' food prices can be driven higher, affecting national and continental economies, and stressing populations in neighboring countries. And, when discrete weather events are particularly widespread or occur simultaneously, or coincide with critical political or economic events, global commodities markets and potentially the entire global economy can be affected.

Extreme regional weather events can generate waves of environmental refugees fleeing famine and soaring food costs, and seeking food or housing safety in less-affected rural regions, in urban areas, or across national borders. Such transient populations create their own economic and political impacts. Within primarily affected countries, impacts can result in economic chaos, public protests, the rise of populist movements, and resulting political turmoil. In refugee destination countries, impacts can include intense competition for food, jobs, and services. The results can stress local resources, instigate popular resentment, and lead to the rise of nationalist movements or political conspiracies. Eventually, they can lead to threatened or actual military actions.

Each of these environmental, economic, social, and political dynamics can have cascading effects, and can escalate as they spill over to nearby nations. A government overthrown in ethnically conflicted North Africa, oil production shutdown in a leading producer in Latin America or the Middle East, or threats of war between nuclear-armed neighbors in South Asia all result in immediate and long-range consequences. These can quickly involve nations far removed geographically.

The location and progression of specific incidents may be impossible to predict, but the seriousness of potential resulting impacts is much clearer. National and international security forces will therefore increasingly require preparation and capacity to respond to a wide range of direct and potential military situations.

Just as important – and perhaps more effective in terms of economic and human costs – security forces will require preparation and capacity to help respond to preconflict situations. Such actions could include the evacuation and rapid resettlement of thousands of starving refugees, the transport and distribution of emergency food and shelter to geographically challenging locations, or the transport and installation of oil- or chemical-spill cleanup equipment in the midst of a conflict zone.

Doing so effectively can be not only a humanitarian act by wealthier nations, it can be the strategic action that preempts far more serious impacts that continue to cascade until they reach those nations' own shores. Effective preemptive humanitarian action, whether carried out by military or nonmilitary agencies, also can provide an opportunity for initiating new and more resilient economic models, and for engendering significant political goodwill.

Of course, the most effective preemptive activity would be mitigating the actions that lead to environmental catastrophes in the first place.

2. A Flood of Evidence

– Dealing with Multiple Challenges

> On a range of crosscutting issues from global hunger to global health, changing global temperatures and weather patterns will inject a new element of chaos into the already-fragile existences of the world's poorest people. Among the predictions are more famine and drought, expanding epidemics, more natural disasters, more resource scarcity and significant human displacement. Ominously, the poorest and least equipped to respond are likely to be among the hardest hit. …
>
> The impacts of climate change threaten the stability of our development strategies. It's time we craft a path forward where our development and climate goals are mutually reinforcing.[12]
>
> – John Kerry, U.S. Secretary of State, Sept. 21, 2010

An overwhelming majority of the world's climatological, meteorological, atmospheric, and oceanographic scientists have concluded that global climate change is real, is primarily anthropogenic in origin, and is increasing rapidly in pace. Climate impacts over the coming decades will include extreme-weather events, droughts, flooding, sea-level rise, retreating glaciers, polar surface ice melts, multispecies habitat shifts, and increased spread of threatening diseases. These conditions have the potential to disrupt societies around the world and force nations to change the way they handle the safety and security of their populations.

The UN IPCC's Fourth Assessment Report (AR4) in 2007 concludes:

- The concentration of the main greenhouse gas, carbon dioxide (CO_2), in the atmosphere has continued to increase from its pre-industrial concentration of approximately 278 parts per million (ppm) to over 391 ppm in September 2012, with the rate of increase now at 1.8 ppm per year.
- The present CO_2 concentration is higher than paleoclimatic and geologic evidence indicates has occurred at any time in the last 15 million years.
- Emissions of CO_2 are, at present, about 35,000 million metric tons per year (including land-use change) and, absent further policies, are projected to rise to 41,000 million metric tons of CO_2 per year in 2020.
- Global mean temperature has continued to increase and is now approximately 0.8°C above pre-industrial levels.

> 97 percent of scientists agree on the reality of climate change.[13]
>
> – Dr. Jim Yong Kim, President, World Bank Group

The most recent report by the World Bank, titled "Turn Down the Heat" (November 2012),[14] expressed the urgency of the problem:

> Without further commitments and action to reduce greenhouse gas emissions, the world is likely to warm by more than 3°C above the pre-industrial climate. Even with the current mitigation commitments and pledges fully implemented, there is roughly a 20 percent likelihood of exceeding 4°C by 2100. If they are not met, a warming of 4°C could occur as early as the 2060s. Such a warming level and associated sea-level rise of 0.5 to 1 meter, or more, by 2100 would not be the end point:

Over the last 10,000 years, the Earth has seen a fluctuation in its surface-temperature range of only ±1°C. To observe a 4°C rise, one would need to go back 30 million years.

The direct and secondary results that this expected human climate impact will have on oceans will be extensive:

- ***Temperatures*** – Global sea surface temperatures have warmed appropriately 0.4°C since the 1950s, due primarily to the burning of fossil fuels. Sea surface temperatures are projected to increase another 1.8°C to 4.0°C over the 21st Ccntury. Warmer waters accelerate coral bleaching, range shifts, increases in diseases, altered productivity, and an increase in invasive species.

- ***Sea-Level Rise*** – By the end of this century, the mean global sea level is expected to rise by more than 2 feet, under a low emissions scenario, or nearly 3.5 feet under a higher emissions scenario. Higher sea levels, especially in combination with more frequent and more intense storms and storm surges, will increasingly impact on coastal communities and threaten coastal ecosystems and infrastructure, including military installations.

- ***Storms and Waves*** – Extremes in wind speed and wave height are increasing on a global scale. This pattern – documented in a 2012 *Science* paper review of a 23-year database of calibrated and validated satellite altimeter measurements – holds potentially significant implications for safety and efficiency of shipping, for consumption and generation of energy, and for security. The recent Superstorm Sandy showed vividly the impacts of storm surges to the United States, with an estimated $60-$80 billion needed to address the damage caused.

- ***Low Oxygen*** – Monitoring has observed decreased ocean oxygen levels, or eutrophication, due to both warmer water temperatures and increased runoff of nutrients from the land. Warmer waters are significantly a result of warmer atmospheric conditions, each significantly driven by climate change. Increased nutrient runoff results from enhanced land-based activities: increased use of fertilizers, loss of native vegetation along streams and rivers, and more concentrated livestock operations, which collectively have led to increased runoff of nitrogen and phosphorus compounds. This nutrient pollution encourages algae growth that results in areas of low to no oxygen (so-called “dead zones”) in which fish and shellfish cannot survive. The number of dead zones around the world has approximately doubled each decade since the 1960s. A recent study identified more than 530 of such zones around the world, most in coastal waters at the mouths of rivers draining agricultural areas.

- ***Ocean Acidification*** – Ocean waters absorb carbon dioxide. While this makes them a valuable carbon “sink” and thereby an active component in limiting the pace of global warming, it also directly affects the ability of the waters to support life. As the level of CO_2 in the atmosphere rises, so does the CO_2 dissolved in the oceans. The higher levels of carbon dioxide make the ocean water more acidic. Oceans have, on average, become approximately 30 percent more acidic over the past 150 years and are expected to become far more so by the end of this century. The increased acidity makes waters more corrosive, with effects on both man-made structures and on ocean ecosystems. Impacts of ocean acidification will be particularly severe for calcifying species, including shellfish, corals, and many types of plankton – species that provide critical habitat and food sources for an extensive spectrum of ocean life.

3. Navigating the Emerging Wave

– Key Areas for Action

> One of the most serious mistakes we can make is analyzing the systemic and ecological changes we are experiencing on too short a time line, and with too linear a mind-set. It isn't the linear derivative of change we should be focused on, but the many-ordered integral function that represents a cumulative effect over a longer period of time. In today's terms, that means our horizon must extend beyond myopic media and political cycles to the lifetimes of our children, our grandchildren, and beyond. The model of economic growth pioneered in America in the middle of the last century was developed at a time when there was an abundance of fossil fuels and most Americans were blissfully unconcerned with the finite nature of resources. What has become clear, however, is that this model is unsustainable.[15]
>
> – Capt. Wayne Porter, USN, Chair of Systemic Strategy and Complexity

A. The Climate-Oceans-Security Nexus

– Effects on Resources and Populations

The multilayered systems of climate, oceans, and security involve an exceptionally broad range of geophysical, economic, social, and political issues. The following areas represent some of the most critical intersections of those issues.

1. Critical Issues

In the United States for most of the past dozen years, there has been a disconnect between the approach of the nation's military, which is acting on the assumption that climate change is in fact occurring, and of the national political decision-making process, which has been unable or unwilling to address the issue. Significant, if uneven, efforts have taken place locally and globally. But the stalemate that has persisted at the national level has limited the federal government's ability to anticipate and respond to either systemic patterns of a changing climate or to discrete catastrophic weather events.

It could be that the degree of public awareness of the human and financial costs generated by specific recent extreme-weather events – such as Hurricane Katrina and Superstorm Sandy – might now have created a political environment that could allow for shifting that political logjam. The reality of seeing 132 Americans dead, tens of thousands of homes and businesses destroyed or damaged, the New York subway under water, hundreds of miles of coastland inundated, 6.2 million people without electricity, extensive gasoline shortages, the Financial Center shut, and business and tourism virtually frozen, may have convinced previously uncertain majorities of the reality of climate change and the immediacy of its threats to virtually all systems of social and economic organization.

Culminating a year in which the United States experienced 11 distinct weather-related disasters – ranging from storm-surge flooding, to outbreaks of multiple tornadoes, to catastrophic wildfires, to a previously unexperienced derecho, to a massive regional drought – that each totaled one billion dollars or more in

damages (NOAA Report, Dec. 22, 2012)[16] – Sandy may have led American public opinion to an emotional tipping point that could allow a mobilization of the level of political support necessary to allow meaningful legislative and regulatory action.

At the least, it should encourage a more rational approach to building resilience into coastal zones.

> The devastation that Hurricane Sandy brought to New York City and much of the Northeast – in lost lives, lost homes, and lost business – brought the stakes … into sharp relief. The floods and fires that swept through our city left a path of destruction that will require years of recovery and rebuilding work. In just 14 months, two hurricanes have forced us to evacuate neighborhoods – something our city government had never done before. If this is a trend, it is simply not sustainable.
>
> Our climate is changing. And while the increase in extreme weather we have experienced in New York City and around the world may or may not be the result of it, the risk that it may be – given the devastation it is wreaking – should be enough to compel all elected leaders to take immediate action.
>
> – Mayor Michael R. Bloomberg, New York City, Nov 1, 2012 [17]

The established model of economic growth and consumption was developed when the world's population was approximately 1 billion. It is now over 7 billion. That model of growth was adopted when societies were not aware of the finite quantity of natural resources or of the impact their consumption would have on planetary systems.

Annual global growth is already consuming the equivalent of about 1.5 times the actual amount of new natural resources (or "ecosystem services," such as food, textile crops, forests, freshwater, and breathable air) generated each year by the entire planet.[18] That ratio will increase substantially as populations in countries with emerging economies continue to afford higher levels of consumer products. Needless to say, the annual consumption of far more than the planet can naturally annually replenish is unsustainable.

> 200 years ago, at the beginning of the industrial revolution, we could not imagine that we were able, by our activities, to change the great balance of our planet. We can see today the difficulties in the negotiations about climate change. This means that what we have to do is to think out of the box. We are in a very exciting moment of the story of humankind: we need to reinvent a world, taking into account the fact that our planet is a limited world, with limited resources. And we, the ocean community, are convinced that an important part of the solution will come from the sea.[19]
>
> – Philippe Vallette, Co-President, World Oceans Network

The world's oceans are vital for human life. Oceans provide vast amounts of food, jobs, and significant economic benefits. The livelihoods of 12 percent of the world's population depend directly or indirectly on fisheries and aquaculture. The oceans are the primary source of protein for 17 percent of the world's population.[20]

The ocean also acts as a primary component in multiple geological processes. It serves as a global geological "sink," collecting and storing heat and carbon dioxide, and thereby slowing down the pace of climate change. Oceans absorb approximately 25 percent of all CO_2 emitted by humans from fossil fuels and deforestation, and 93.4 percent of the heat trapped by greenhouse gases.

Given the intensity, complexity, and extensiveness of the systems involved, it is possible that over the coming decades the Earth's oceans may reach catastrophic tipping points before there is sufficient warning to avoid them. These might involve major shifts in the direction and speed of ocean circulation due to increases in temperature or shifts in salinity governed by the halide cycle, or the collapse of undersea ice shelves caused by freshwater runoff from melting glaciers. Potentially affected currents include the North Atlantic Gulf Stream, which regulates weather patterns along the U.S. East Coast and over much of Western Europe. A shift in large-scale ocean circulation could produce dramatic weather impacts.

Another large-scale risk is the potential escape of massive quantities of undersea methane, a potent greenhouse gas stored in deep ocean layers and on the seabed, which would contribute to global temperature rise, and is a scenario not included in any present IPCC estimates. It could also cause widespread fish-kills and intense local toxicity incidents affecting human populations.

The impacts of climate change have already driven 24 million people from their homes, a number that could rise to 1 billion by 2050 (IOM).[21]

> Continued investments in science are needed to understand the ocean, particularly to monitor possible causes of rapid and severe changes.[22]
>
> – Steve Fetter, PhD

2. Suggested Objectives

Following are a series of primary objectives for addressing the challenges of climate change, its ocean impacts, and their international security implications.

Achieving these objectives in an enduring way will require effective communications to build public constituencies that can provide the necessary political will for implementing policy change. It will require significant planning and coordination, and investment of public and private financial resources, to strengthen organizational capacities and physical infrastructure to help avoid the impacts of changing natural systems, and to mitigate the damage of those impacts when they do occur.

Success in the long-term objective of reducing ocean impacts and maintaining national and international security can only be achieved in concert with a reduction in the pace of climate change itself. This entails, at minimum, taking actions that will keep development activity within the goals of the Copenhagen Accord, agreed in 2009 by 114 nations (including the United States), who recognized that "the scientific view that the increase in global temperature should be below 2°C."[23]

- ✓ Increasing cooperation to refine models and expand monitoring of atmospheric and ocean systems and the interactions between them.
- ✓ Building coalitions among scientists, public officials, military representatives, businesses, and advocacy organizations to communicate broadly and effectively to political leaders, policy makers, and the public about the realities of climate change and ocean impacts.
- ✓ Developing high-complexity modeling of the interconnectedness between climate and ocean impacts, and human and national security systems.
- ✓ Communicating clear explanations of those connections to achieve deeper policy-level and public understanding.

- ✓ Strengthening national and local governance mechanisms that act to reduce human activities that exacerbate climate and ocean impacts, and participating in international governance mechanisms that have already agreed to do so.

3. Recommended Actions

Suggested actions require specific roles by key sectors.

- **The U.S. Navy and Maritime Forces**

  The Navy views energy security as critical to the success of any of its missions. Energy security safeguards the Navy's energy infrastructure and shields the Navy from a volatile energy supply. The Navy has consequently taken a leading role in demonstrating energy innovation throughout its history. By 2015, the DoN will reduce petroleum use in the fleet by 50 percent, and by 2020 will produce at least 50 percent of shore-based energy requirements from alternative sources. This past year it has launched the "Great Green Fleet," which represents its first use of biofuels. Continued actions the Navy can take include:
  - Increase cooperation among U.S. maritime agencies and with other Arctic nations in order to continue strengthening partnerships that build a secure and stable Arctic region.
  - Expand efforts to adapt fleet and facilities to sustainable energy sources in order to increase flexibility, and help mitigate the pace of global warming and the rise in sea level that threatens ports and coastal installations.
  - Liaise with DoD, DoE, and other relevant government departments to assess readiness for impacts from severe-weather incidents.
    Make the U.S. Navy Energy Road Map available to all levels of government, the media, and all relevant stakeholders.
  - Review the potential impacts of a 4–6°C rise in temperature for military installations.
  - Plan to approach possible scenarios involving environmental refugees.

- **Science**

  Scientific, academic, and research organizations should be enabled to fully participate in decision making on climate, oceans, and security issues. They can be of critical help to
  - Provide in-depth modeling and research into sea-level rise and its impact on coastal zones.
  - Maintain and augment GEOS and polar satellite systems as a critical element of such coverage. While in recent years modeling of weather systems has taken quantum leaps (as evidenced in the eight-day accuracy of forecast for the landfall of Sandy), continued improvement and reliability in storm predictability is essential.
  - Provide further required research on the direction and pace of rapid and extreme ocean impacts.
  - Increased research to better understand potential thresholds and tipping points in oceans systems. These include critical issues such as the dynamics of ocean circulation.

- An MS-level study might calculate the potential costs of the next ten environmental disasters, to help express the value of investment now to avoid such damages.

- **Governance**
  - Actively address climate change **at all levels of governance**, including local, state, national, and international.
  - Provide substantial new financial support to developing countries, through the UNFCCC Green Fund, to develop the adaptation plans that are vital for all countries for dealing with climate-change impacts.
  - Assure sufficient funding and administrative capacity to provide oceanographic and meteorological research, monitoring, and prediction services.
  - At the international level, the ratification of the UN Convention on the Law of the Sea (UNCLOS) by all nations is vital.
  - The United States should continue to play a vital role through USAID, supporting bilateral aid to enable countries at greatest risk to be able to address climate-change adaptation.
  - At the state level, government working with the Network for Regional Government for Sustainable Development (NRG4SD) to share experiences on climate-change adaptation policies from around the world. In the United States, working with the National Governors Association.
  - At the local level, working with ICLEI (the global network for local government and sustainable development) to learn how other cities and towns are addressing climate change in different parts of the world. In the United States, working with the National League of Cities.
  - Urban areas are particularly vulnerable to climate impacts, with 8 of the world's 10 largest cities located on coasts. Retrofitting older cities will require significant investment.

- **Communications and Education**

  Communications and education programs must underpin any effort to change societal behavior and consumption patterns.
  - Build a broad network of trusted communicators, including scientists, teachers, political and community leaders, meteorologists, and representatives of faith organizations.
  - Integrate education on 21st-century environmental issues into curricula at all levels of K-20, with as much emphasis on positive economic and social opportunities as on negative risk and threat.
  - Encourage the education community at the university level to help develop an interdisciplinary approach to oceans, and to help prepare revised school curricula for primary and secondary schools.

- **Business and the Private Sector**
  - Intensify research, development, and implementation of low-carbon technologies and enhanced resilience strategies to help reduce the pace of climate change and adapt to the impacts that cannot be avoided.

- Take advantage of the economic opportunities that innovation in sustainable technologies presents.
- Explore partnerships between corporations or small businesses and local school systems and colleges – and in cooperation with NGOs – to provide funding of public education and awareness programs, thereby engendering goodwill, a more informed consumer base, and wider support for clean-energy and -water initiatives.

- **Multisectoral Partnerships**
  - The challenges that the world faces will require a new cooperative approach. The capacities of all stakeholders, including local communities, should be built to anticipate and respond to environmental changes and their implications for human mobility.
  - The international financial community should be encouraged to build on its creative early initiatives to structure public and private investment plans for financing the adaptation of not only island nations and developing countries, but also of major developed countries' cities.
  - The private and commercial sector must play a leading role in developing technologies and products to sustain a growing global consumer base without surpassing the carrying capacity of the planet. The incentives for doing so go beyond altruism to recognizing the repercussions of potentially massive decreases in a post–global warming world's supply of critical resources, and increases in its crisis-fueled demand.

B. Coastal Impacts and Population Effects

– Building Resilience and Sustainability

The 95,331 miles of ocean and Great Lakes coastlines are home to almost 153 million people, about 53 percent of the total U.S. population. Our nation's coasts host a variety of industrial and business activities – fisheries, energy facilities, marine transportation, and recreation – that contribute tens of billions of dollars to the economy per year. Our ports handle about $700 billion in merchandise, the cruise industry generates $12 billion annually, and retail expenditure on recreational boating accounts for over $30 billion nationwide. Tourism and recreation continue to add value to the nation's fastest growing business sectors, with some 180 million people visiting the coasts each year.

But there's more! Over 37 million people and 19 million homes were added to coastal areas over the last three decades. On average, about 3,600 people relocate to coastal areas each day, and by 2015 the coastal population is estimated to reach 165 million.[24]

– National Oceanic and Atmospheric Administration

1. Critical Issues

Coastal communities are vital to economic development of many countries. Much of the global GDP is concentrated in coastal zones, which are particularly vulnerable to climate impacts. In the United States, coastal watershed counties contribute 57 percent of GDP. Worldwide, more than three billion people depend on marine and coastal biodiversity for their livelihoods. Marine fisheries alone, directly or indirectly, employ more than 200 million people. Ocean- and coastal-related ports, transportation, recreation, and tourism employ hundreds of millions more.

The rise in sea level will vary in different global regions. The IPCC estimates that the increase will be 20 percent greater in tropical regions. More than 200 million people presently live in coastal zones, a number that will increase to 400–500 million by the end of the 21st century. They all will be affected directly.

Coastal zones are the region's most at risk from extreme-weather events and particularly from the obvious and devastating impacts of rising sea levels and storm surges. Such extreme impacts are already being experienced. According to the OECD [2007], about 40 million people were "exposed to a '1 in 100 year' coastal flood event" as of 2005. But by 2070, this risk will increase to 150 million people "due to the combined effects of climate change (sea-level rise and increased chance of severe storms), land subsidence, population growth and urbanization."[25]

By 2070, the directly exposed population in the New York–Newark region will be nearly 3 million, and exposed assets will be $2.147 trillion. In 2011, there were 78 disaster-related events, which cost approximately $600 billion. While totals for 2012 are not yet available, the impact of Superstorm Sandy alone will be $70–100 billion. That a single weather event could all but immobilize New York, a city that accounts for 10 percent of U.S. GDP, is indicative of how vulnerable to the impacts of climate change are even the most developed economies.

At the opposite extreme of economic development, the vulnerability is even more pronounced, with stark economic and human implications. At almost precisely the same time that Superstorm Sandy was swamping the United States, Typhoon Bopha was inundating the Philippines, with a loss of over a

thousand lives from landslides, capsizing, and floods. It was only one of *five* major typhoons to hit that Pacific nation in the year. An increasing stream of environmental refugees from Bangladesh – where 90 percent of land is less than 10 meters above sea level – has been physically blocked from seeking safe ground in India, which fears political destabilization. In the Indian Ocean archipelago of the Maldives, according to projected scenarios, none of the nearly 200 currently habitable islands will be above water by 2100.

It has been estimated that up to 24 Caribbean airports could be under water within the next 30 years. In the Pacific, estimates for the number of people predicted to be displaced in and from island nations as a result of environmental impacts by 2050 range in one study from 665,000 to 1,725,000.[26] And in Australia, the parliament has authorized legislation that has purchased land designated for use by those recognized as environmental refugees.

> So when we report amount of disaster losses, we are probably only capturing about 40 percent of actual losses.
>
> – Margaret Davidson, Director of the NOAA Coastal Services Center[27]

While some of the economic costs of these impacts can be quantified, it is usually only the measurable impacts to the "official" economy, and insured damages to physical infrastructure that are totaled. And that does even begin to address the unquantifiable value of the loss of individuals' personal history, shared community, and collective culture.

> I know that the Sandy reconstruction is going to be hard. I know that families are continuing to pay a dear, dear price. But I also know we have an extraordinary opportunity to not just rebuild but to build back better. We can rebuild a better society than we had. We can rebuild thousands of miles of roads. We can improve homes. We can get control of utility companies that have been out of control for too long. We can rise back from the ashes, and we can be smarter and stronger than ever.[28]
>
> – Governor Andrew M. Cuomo, New York "State of the State" Address, Jan. 9, 2013

The opportunity presented in proactively dealing with coastal impacts is represented by the local and regional agencies that have begun to mobilize to address immediate impacts and intermediate threats. In Massachusetts, the Boston Harbor Association provided policy makers, planners, and commercial property owners with site-specific examples of how to assess vulnerability and increase resilience to coastal flooding.[29] In New York State, the NYS 2100 Commission released initial recommendations and surveyed options, including the construction of a movable $40 billion tidal surge barrier to protect parts of Manhattan and the Brooklyn shore.[30]

Such projects would pump tens of billions of dollars into local and national economies.

At the other end of the technology and investment spectrum, in the cleanup after Sandy it was discovered that building and maintaining a series of simple grass-covered sand dunes had been able to almost completely protect certain seaside communities, while neighboring communities that had left themselves open to the ocean experienced hundreds of millions in losses.[31]

In the Pacific, the Caribbean, and the Indian Oceans, various small island nations are implementing climate-adaptation projects such as building seawalls, strengthening coastal roads, and in one case literally raising the elevation of entire islands. While some of these actions represent a tragic acceptance of the loss of natural beaches and coral reefs, the most creative may pioneer ways to utilize public-private partnerships to protect environmental resources and invest in successful survivability strategies.

The potential benefits from addressing climate issues go beyond investment in construction. Coastal zones are also optimal sites for installation of offshore wind-, wave-, and tidal-energy generating plants. Such plants could provide thousands of gigawatts of sustainable power for local and inland use by residents and industry.

2. Suggested Objectives

- ✓ Expansion of modeling and monitoring systems to predict weather and ocean events, and to understand the real-time dynamics of their impacts.
- ✓ Establishing orderly processes for siting civilian and defense facilities.
- ✓ Implementing integrated strategies to build resilience in housing, energy systems, fisheries, port facilities, transportation, emergency services, and national defense installations.
- ✓ Establishing effective governance mechanisms to build coordination to anticipate extreme-weather impacts.
- ✓ Providing the facilities and resources to deal with such events as they occur.

3. Recommended Actions

- **Ports**
  U.S. and international ports will be impacted by more frequent and more severe flooding and extreme-weather patterns. Over 80 percent of products that are consumed internationally travel through ports. Port authorities will need to:
  - Strengthen the resilience to sea-level change of port infrastructure and intermodal transport connectors.
  - Survey the ability to expand the role of individual ports in global commerce.
  - Assess and monitor the vulnerability of ports in terms of resilience investment strategies.
    - The resilience to sea-level rise of port infrastructure and the intermodal connectors.
    - The vulnerability of ports in terms of resilience investment strategies as climate change impacts on coasts.
    - The ability to expand a port's role in global commerce in light of climate change.

- **National Ocean Council** should move to
  - Review its approach to coastal and Marine Spatial Planning in light of recent events.

- Revise its handbook and distribute to all relevant authorities.

- **NOAA**
  NOAA plays a significant role in coastal zone management, giving advice through the authority in the Coastal Zone Management Act. In light of recent events such as Sandy, it should:
  - Continue to refine, fund, and share its predictive meteorological modeling programs that were responsible for the extraordinarily early accuracy in tracking then–Hurricane Sandy, and which has been credited with saving hundreds of lives.
  - Review and update NOAA's "Adaptation to Climate Change: A Planning Guide for State Coastal Manager."
  - Review the implementation of the "Planning Guide" by coastal states.

- **U.S. Navy and Maritime Forces**
  U.S. military forces in general could take a more active role in publically endorsing new energy technology and addressing climate change. This might include:
- Communicate the consequences to security of not taking mitigating steps.
- Review the placement and vulnerability of military installations, and pursue leading-edge alternative energy technologies to more efficiently power them.
- Prepare comprehensively for environmental refugees from the Caribbean.
- Assess the impacts of sea-level rise and associated coastal impacts, such as storm surges on its coastal installations, and prioritize adaptation measures for the most vulnerable sites.

- **Business and the Private Sector**
  Reimbursements by insurance companies to owners of coastal properties have soared over recent decades, and premiums charged to customers have therefore done so, as well. Companies and government should:
  - End subsidies of coastal properties through the National Flood Insurance Policy, and charge full insurance rates to those on the coast.
  - Inform prospective property buyers of the insurance costs before agreeing to a sale.

- **Science**
  - Climate-modeling capacity must be supported and strengthened, particularly regarding impacts on coastal areas. Agencies such as NOAA, NASA, and the Oceans Council should coordinate with other research agencies and cooperate with the efforts of the International Panel on Climate Change.
  - Supporting the development of an effective coordinated network of sentinel sites to track changes in the ocean, coastal, and Great Lakes environments and communities, and to strengthen that monitoring and information provision.
  - Building the interlinkages between science disciplines to ensure better prediction in the future.

- Increasing research into coastal zone erosion and its timelines to advise local and state-level planners.

- **Governance at All Levels**
  - FEMA should expand capacity-building workshops for local and state officials on dealing with extreme-weather incidents.
  - National, state, and local governments should develop climate-change mitigation and adaptation plans and promote informed decision-making.
  - State and local planning should approach "best practice" for building in coastal zones.
  - The UN Refuge Council (UNHCR), with other relevant UN agencies, needs to play a proactive role in preparation for environmental refugees fleeing for disasters and climate-change impacts, in particular on coastal zones.
  - National governments take responsibility for development of an up-to-date Integrated Coastal Zone Management (ICZM) Plan in all countries. The state and local government's approach should be based on the international legal principles of Coastal Zone Management.[32]
  - In the United States, FEMA should be enabled to update and publish its floodplain maps without congressional oversight.
  - FEMA, state, and local governments to review, in light of Sandy, how they can plan effectively together for the most appropriate responses at the most appropriate level.
  - Federal, state, and local government should not subsidize property development in coastal zones.
  - State and local government should publish information to all properties on the coast on what to do if an incident happens annually.
  - State and local government should better control land-based freshwater runoff that contains fertilizers and other pollutants.
  - State, local, and community-level resilience should be based on anticipation, responding, recovering, and reducing future risk.

- **Communications and Education**
  - Cooperate among state and local government, the private/commercial sector, and other stakeholders to create communications strategies that ensure the public is aware of the risks and informed of the potential to act to mitigate the progress of global warming and thereby reduce the potential of future sea-level rise and extreme-weather events.
  - Provide ongoing training for planners, city officials, and other decision makers in strategies and tools for preparation for extreme-weather events.
  - Organize more specific public awareness campaigns to help families and individuals plan for extreme events and transition in their daily lives from present norms to more resilient approaches.
  - More specific communication campaigns and education to explain how to militate against such events and limit their impacts.

- **Multisectoral Partnerships**
  - Organizing forums sponsored by state and local government forums to bring together industry and other relevant stakeholders so that they can help in the development and implementation of adaptation and resilience strategies.
  - Effectively communicating across sectors will be critical to encourage adaptation or resilience strategies [e.g., academic, military, policy, health, economics, industry, insurance, fishing, education, media, and agriculture].

- **Economic and Planning Strategies**
  - There should be greater engagement with the banking and insurance companies in helping to quantity financial risk.
  - The banking and investment industry can be motivated to produce financial instruments that help raise funding for climate projects.
  - All planning should review water and sanitation impacts of severe-weather incidents on coastal zones, as well as have plans for potential population relocation.

C. Climate Change, Oceans, and Human Health

– Identifying the Dangers

> The climate challenge before us is real. The nation needs targeted climate services at scales from local to global to help people understand, adapt to, and mitigate climate change.[33]
> – Jane Lubchenco, Ph.D., Under Secretary of Commerce for Oceans and Atmosphere Administrator, National Oceanic and Atmospheric Administration (NOAA)

1. Critical Issues

The coastal environment in all global regions has been under intense pressure for decades. Higher densities of urban settlements, intensified utilization of natural resources, increased shipping, growing aquaculture production, expanding tourism activities, and marine resource exploitation all contribute both individually and collectively to higher risks to public health and the spread of diseases.

The World Health Organization (WHO) estimated that 166,000 deaths and about 5.5 million disability-adjusted life years (DALYs, a measure of overall disease burden) were attributable to climate change in 2000.[34]

As climate change impacts intensify, they can impact human health through a variety of mechanisms:

- Asthma, respiratory allergies and food-borne diseases are among the results of longer-lasting, harmful algal blooms. Such algal blooms can deplete oxygen and block sunlight that other organisms need to live. Some produce toxins that are harmful to the health of plants, animals, humans, and entire ecosystems.
- Food- and water-borne illness can be transmitted through the rise in seafood-related infections.
- Disease-carrying vectors – whether birds, mammals, shellfish, or insects – can adapt to temperature changes by migrating to newly habitable geographic locations. In doing so, they bring contact to previously unexposed populations.
- Annually, malaria strikes 300–500 million people, of whom 1 million die.[35] While until now such cases have been overwhelmingly clustered in economically poor, high-rainfall, tropical nations, a shift of those weather characteristics to previously temperate, developed nations could lead to vulnerability to the same disease patterns.
- Another mosquito-carried disease that historically has already hit a developed nation was yellow fever. The United States experienced its most severe episode in 1878, when an outbreak killed an estimated 20,000 individuals. Significantly, a recent study found that of the nine largest such yellow fever epidemics in the United States [1793–1905], seven coincided with years of intense El Niño events, bringing increased temperatures and heavy rainfall across the southern and central United States, where most of the incidents were centered – an indication of clear meteorological correlation.

- Potential disease can directly transfer from marine animals to humans. An example is domoic acid toxicity, first discovered in the late 1980s. Since then, domoic acid poisoning has been responsible for several unusual mortality events involving seabirds and marine mammals, and also has caused detrimental effects to humans who consume the toxin through shellfish consumption. Impacts range from nausea and headaches to more severe symptoms, including neurological damage, seizures, and potentially death.
- Extreme-weather events result in extreme public health issues, impacting hospitals, involving evacuations, and stranding individuals. Water-borne disease can quickly spread following extreme-weather events when standing groundwater from excess precipitation is contaminated.
- Previously unseen diseases can be transported great distances and transferred to humans by birds. West Nile virus, carried by migratory birds that have been bitten by infected mosquitoes, was limited to a range in tropical latitudes, primarily in northern Africa. Unknown in the Western Hemisphere prior to 1999, it appeared in the New York metropolitan region, causing severe and at times fatal fever. Currently active in Texas, its program costs include preventative insecticide spraying – from the air and by street vehicles – which carries its own toxic and respiratory risks to vulnerable human populations.

2. Suggested Objectives

- Establishing cooperation between members of the ocean sciences and the biomedical communities to support interdisciplinary research into areas where marine processes and public health risks intersect.
- Increasing international cooperation to monitor movements of disease-carrying vectors within and between all global regions.
- Expanding research into treatment and eradication of potentially migrating diseases.
- Providing full access to resulting information and treatment methods to populations in all countries, without economic barriers.

3. Recommended Actions

- **Science**
  - Continue monitoring, research, and updating of methodologies that play a role in presentation and treatment of impacts to human health exacerbated by climate change, including the further development of an agreed set of health indicators, which can be integrated with other relevant indicators to help understand the interdependent systems that connect human society.
  - Develop an agreed set of health indicators, which can be integrated with other relevant indicators to help understand the interdependent systems that connect human society.
  - Share data in a national and global data network.

- Recognize that nontraditional data sourcing needs to be examined as a source to assess emerging complex and integrated questions evolving from changing environmental conditions. Resulting from this will be a need to develop new assessment/modeling tools that integrate both social and environmental data.
- Develop climate and ocean research, scenarios, services, and forecasting across timescales.
- Coordinate programs on oceans and human health, marine animal health programs, and climate and health development products and services that need to be developed in conjunction with CDC, state, local, and international public health agencies (e.g., heat wave prediction, malaria and cholera early warning, shellfish and beach management tools, air-quality forecasts, harmful algal bloom forecasts).
- Refine early-warning HABs, vibrios, marine mammals, and integrated surveillance.

- **Governance**
  - *National, state and local agencies* – Not only expand lateral cooperation, but also continue to develop a high degree of coordination with other governance levels, including the U.S. Department of Health and Human Service to review its policies to provide climate-resilient health services.
  - *HHS* – Work with other federal agencies, and state and local government, to build effective climate preparation programs.
  - *Centers for Disease Control and Prevention* – Increase support for surveillance of water-borne, food-borne, vector-borne, and zoonotic diseases that are amplified by climate change.
  - *CDC* – Build effective use of GIS technology as a tool for helping develop a public health response to climate change.

- **Communication and Education**
  - Utilize official information agencies and engage media outlets to publicize critical information on impacts to human health.

D. Arctic and Antarctic Regions

– Impacts to Fragile Ecosystems

1. Critical Issues

The extraordinarily rapid impact of global warming on the northern polar region has led the Arctic to suddenly emerge as a new area of commercial and security attention. In September 2012, the Arctic ice cover shrank to its lowest total area in recorded history, approximately 1.5 million sq km below the previous all-time low, reported in the summer of 2007.

The Arctic does not have an effective governance mechanism. While there are three international environmental and political conventions that protect the land, ecosystems, and seas surrounding the Antarctic region, there is none that covers the Arctic polar region. This lack of effective regional or global agreements can increase security problems and the possibility of conflict.

The United Nations Convention on the Law of the Sea could play a critical role. Its mandates cover issues such as exclusive economic zones, which assign nations unilateral rights over exploration and use of marine resources in territorial waters, including producing energy from water and wind. EEZs cover 200 nautical miles from countries' coastlines. UNCLOS could be strengthened or used as a legal instrument to develop additional requirements that could apply to the Arctic Ocean.

The Arctic Council (composed of the United States, Canada, Denmark, Norway, Russia, Sweden, Finland, and Iceland) is an informal body with no regulatory mechanism. It supports cooperation and dialogue on all issues that are of relevance to the Arctic and the people who live there, but has no standing to adjudicate or decide on environmental matters, economic issues, or military conflict.

The five so-called "polar nations" that surround the Arctic Ocean (the United States, Canada, Denmark, Norway, and Russia) all have stable governments that effectively cooperate in multiple fora. The chance of armed conflict is therefore presently considered low. However, maritime traffic in the Arctic has increased more than 60 percent since 2008, and the opening of new sea-lanes and seasonal areas that are clear of ice raises the potential for future political and economic conflict.

> Canada and the United States, and Canada and Denmark have unresolved territorial sea and exclusive economic zone disputes in the Arctic. Norway and Russia disagree over offshore areas around Svalbard. The status of the Northwest Passage through the Canadian archipelago internal Canadian waters or an international strait – has been a Canadian concern since at least 1985. The issue is not resolved, and current transits are allowed through nation-to-nation bilateral agreement for icebreaker transits.[36]
>
> – National Security Implications of Climate Change for U.S. Naval Forces

After its Fleet Arctic Operations War Game in 2011, the U.S. Navy concluded that it was not able to adequately perform long-term Arctic operations (it presently can deploy no icebreakers, while Russia has 25) and would have to rely on support from the Coast Guard, among others, to bolster its capacity.[37] The Canadian Defense Department has also produced a set of scenarios in 2011 for possible increased tensions between Canada and Russia over Arctic sovereignty.[38]

If current trends continue, the Arctic will be largely ice free in summer months within 30 years [U.S. National Snow and Ice data Centre [39]]. That is 40 years earlier than suggested by the most recent IPCC report (2007). The melting of the Arctic ice will itself accelerate warming through a decrease in the ice-covered area that reflects solar radiation and an increase in the darker-colored, and more absorptive, surface area of the sea (the ice-albedo feedback loop). Thus, as the Arctic gets warmer, it will make itself and the rest of the Earth's land, atmosphere, and oceans warmer still.

As the ice decreases and the Arctic region opens up, there will be a significant increase in fishing and oil and gas exploration. More ports will be built, tanker terminals will be constructed, and pipelines will be planned. Each of these activities will generate extensive environmental, economic, and security implications. Negotiating and implementing governance structures and jurisdictional boundaries will be necessary. Setting up port security will be critical. Establishing environmental standards and controls will be vital.

2. Suggested Objectives

Ensuring stability in the Arctic will require that effective governance processes are in place to address the challenges posed by the changing nature of the region. These will require:

- ✓ Negotiating boundaries of national political and economic jurisdictions in intergovernmental fora.
- ✓ Establishing effective national and international governance mechanisms, and coordination and implementation of their agreements.
- ✓ Agreeing on environmental standards, oversight, and enforcement.
- ✓ Application of marine spatial planning principles that balance competing uses, including those of ecosystem services. Increased levels of research, data collection and monitoring, and cooperation in their collection and application.
- ✓ Designing resilient port security.

3. Recommended Actions

Effective strategies will require expanded articulation of the roles already assumed by key governmental and nongovernmental sectors, and active coordination among them. Following are priority sectoral responsibilities:

- **Ports**
  - Build any new ports to optimum standards for adaptability and resilience through an intergovernmental process that consults all stakeholders, including Indigenous Peoples, to ensure they benefit from the development.

- **U.S. Navy and Maritime Forces**
  - Increase cooperation among U.S. maritime agencies and with other arctic nations in order to continue building partnerships that foster a secure and stable Arctic region.
  - Provide timely investment in:
    - communications and operations support infrastructure needed to ensure the U.S. the ability to maintain its responsibilities as an Arctic nation.

        - technologies needed to address a wide variety of adaptation capabilities, such as improving ship operational performance in cold regions and adapting coastal installations to sea-level rise.
        - the operational, communications, and support infrastructure of U.S. Maritime Forces in order to provide critical mapping, navigational, and emergency management/response capabilities.
    - Increase cooperation among U.S. maritime agencies and with other Arctic nations in order to continue building partnerships that foster a secure and stable Arctic region.
    - *Increase research-and-development investment in technology and capabilities development vis-à-vis climate studies, especially with respect to coupled models and climate forecasting on seasonal-to-decadal timescales.*

- **The Arctic Council**

  While the Arctic does not have a formal governance mechanism, the Arctic Council can be an effective forum for informal cooperation. Participating national governments should
    - Review whether the Council should be upgraded by:
        - Establishing the Ottawa Declaration as a treaty with legally binding obligations.
        - Providing the Council with a permanent independent secretariat.
        - Giving the Council an operational role.
        - Deciding if it should play a role in ecosystem-based management.
        - Maximizing its role as a discussion forum and reviewing whether states, ship-owners and operators, crew, and International Association of Classification Societies members comply with the IMO Arctic Shipping Guidelines and with the IACS Unified Requirements concerning Polar-class ships.
    - Determine whether the Council should address present regulatory gaps covering marine scientific research and archaeology; bio-prospecting; laying of cables and pipelines; artificial islands and seabed construction; military activities.
    - Decide whether the Council should address emerging and new maritime activities, such as deep-sea tourism; activities relating to CO_2 sequestration; floating installations.

- **UNCLOS and Intergovernmental Agencies**
    - UNCLOS is the primary international regulatory mechanism for oceans. The Unied States should urgently ratify the Law of the Sea Treaty and its two implementation agreements – the Part XI Deep-Sea Mining Agreement and the United Nations Fish Stocks Agreement.
    - The United States should actively support the proposal of the UN Conference on Sustainable Development ("Rio+20"), that governments should negotiate and ratify an agreement to address the issue of marine biodiversity in areas beyond national jurisdiction by 2014.

- The International Maritime Organization plays a leadership role in environmental governance and enforcement of the discharge of waste to the ocean. The IMO should develop standards for discharge, emission, or ballast water exchange for the Arctic region.
- Regulation of oil and gas exploration and production in the Arctic will be critical. The United States should encourage the Russian Federation to become a party to the International Convention on Oil Pollution Preparation and

- **Communicatin and Education**
  - Cooperation.Coordinate public information agencies and engage media outlets to publicize the fragile state and critical role that the Arctic plays in climate and oceans issues.

- **Science**
  - Improve scenarios of the potentialities and impacts of abrupt climate change.
  - Improve modeling of the physics of sea ice formation, ice sheets and permafrost, and their interaction with atmosphere, oceans, and coastal zones.
  - Conduct basic fisheries research, utilizing the Arctic Council (through its Conservation of Arctic Flora and Fauna working group) to develop models of future scenarios covering geographic areas, seasonal dates, species, fishing techniques, and potential impacts on nontarget species.
  - Urgently invest in an improved system of positioning and navigation coordinated by international agencies or national governments to address the lack of coverage of the Arctic by the Global Navigational Satellite System (GNSS).[40]

- **Multisectoral Partnerships**
  - Economic development activities should be subject to widely agreed environmental standards and include costs for any restoration.
  - Economic and Planning needs to ensure that economic benefits – including jobs – also accrue to local communities, particularly those including Indigenous Peoples.
  - Planning and monitoring of all activities should include competent participation by impacted stakeholders.

E. Securing Ocean Benefits

in the Face of Acidification and Climate Change

> All bivalves since the Cambrian have faced the challenge of oceans shifting from aragonite stability towards calcite stability. But the challenge has never met them with such ferocity of speed and ill consequences.[41]
> – Dr. Robyn Hannigan, School for the Environment, University of Massachusetts Boston

1. Critical Issues

Oceans feed the world, the United Nations Food and Agriculture Organization (FAO) estimates that 2.6 billion people depend on the oceans for their primary source of protein. Many small island nations' populations obtain over 20 percent of their protein from mollusks – one of the marine species that will be severely affected by ocean acidification. The loss of oceans-derived nutrition would contribute to a significant increase in economic and political insecurity in many of the countries impacted most.

There has been a substantial increase in ocean acidity since pre-industrialized times. Scenarios now being contemplated involving global warming of 4°C would result in CO_2 concentration above 800pp and a further decrease of pH by another 0.3, a result that would be equivalent to a 150 percent acidity increase since pre-industrial levels.

Ocean acidification has been associated with previous mass extinctions.[42] The rate of changes in overall ocean biogeochemistry currently observed and projected appears to be unparalleled in the Earth's history.[43] The chemistry of the oceans is being altered at a rate not recorded since the extinction of the dinosaurs, 65 million years ago.[44] Some predictions indicate that 20 to 30 percent of species may be at risk of extinction due to effects of current climate change trends. That could lead to immediate security implications, as the loss of productive ecosystems and fisheries could be likely to cause conflicts between nations.

While atmospheric CO_2 levels have been higher in Earth's prehistoric past than they are now, it is the rate of increase that is of greatest relevance, not the absolute concentrations. Organisms require long periods of time to adapt to such environmental changes, and the current extraordinarily rapid rate of CO_2 increase may make acclimation untenable over biologically, and indeed humanly, relevant timescales.

As important as the issue of CO_2 equilibrium in ocean waters is the concentration of carbonate ions, which primarily appear today in the form of calcium carbonate ($CaCO_3$). The CO_2 equilibrium in oceans directly impacts the concentration of CO_3. As levels of carbonate in ocean waters decrease, it is not only more difficult for organisms to produce new calcium carbonate to build their shell, it is also more difficult to maintain what they do produce. $CaCO_3$ dissolution is the gravest issue facing the marine lives that utilize it. In bivalves, pteropods, and others that do not undergo seasonal molting, shells cannot maintain integrity with the increasingly acidic condition of the oceans.

Ocean acidification also will have economic consequences, with the collapse of coral reef ecosystems leading to adverse implications for marine species and entire ecosystems and the loss of marine production. Coral reefs provide food and livelihood security for 500 million people worldwide.[45]

2. Suggested Objectives

- Developing robust scientific model–based knowledge detailing the magnitude and timescale of risks of both ocean acidification and climate change.
- Monitoring the degree and rate at which acidification is taking place.
- Determining technologies that strengthen resilience against acidification in maritime facilities and infrastructure.
- Exploring systems that might protect ocean ecosystems and allow continued sustainable access to ocean benefits.
- Encouraging all actions that might reduce the pace at which acidification is occurring.

3. Recommended Actions

- **Governance**
  - Utilize all available regulatory, voluntary, and economic incentive mechanisms to protect tropical reefs – which provide shelter and food for 25 percent of known marine fish species; account for 9 to 12 percent of world fish landings; and directly and indirectly provide significant sources of nutrition and employment in developing countries through increasingly threatened local fishing and international tourism.

- **Science**
  - Assess the options for the development of environmentally sustainable aquaculture options, using species that may be more resistant to lowered pH.
  - Determine the vulnerability to ocean acidification of human communities dependent on marine resources.
  - Support a global effort to track ocean acidification through an international network of monitoring stations through the Ocean Acidification International Coordination Centre.
  - Integrate the science of ocean acidification into fisheries management tools.
  - Collect baseline data on methane release from beneath the Arctic Ocean.
  - Increased research and monitoring of pH and ecosystem and biological impacts.
  - Identify species that are more flexible to change and assess how these may affect ecosystems and food security.
  - Develop more effective methods of forecasting corrosive conditions and improved monitoring to better understand acidification trends and impacts.

- **Communications and Education**
  - Build a greater public awareness, media, and policy makers understanding of acidification impacts and what can be done to reduce impacts in their communities.

- **Economic and Planning Strategies**
  - The aquaculture industry is one of the fastest-growing food producers in the world, with income increasing 7 percent per annum, and the proportion of fish

produced worldwide rising to 50 percent of total production. The industry is therefore an increasingly important job provider. However, siting and management issues must be anticipated to avoid serious potential environmental, waste, and health issues for adjacent coastal communities, wetlands and ocean areas, and wild fish and shellfish populations.

- Utilize all available regulatory, voluntary, and economic incentive mechanisms to protect tropical reefs – which provide shelter and food for 25 percent of known marine fish species and account for 9 to 12 percent of world fish landings. They also directly and indirectly provide significant sources of nutrition and employment in developing countries through local fishing and international tourism activities, which are both under threat.
- Build in increased resilience in offshore wind energy, wave energy, and tidal energy systems, which constitute a massive potential source of non-carbon-emitting power generation. The considerable environmental and economic advantages of these could be significantly impacted by extreme-weather events and more rapid corrosion in increasingly acidified ocean waters.

4. Conclusions

Politics is much harder than physics.[46]
– Albert Einstein

The Issues

This paper highlights the increasingly critical nexus among the issues of climate change, its ocean impacts, and their resulting effects on international security, the current state of each of the three areas, and the dynamic tensions to which each is subject.

If all are left to continue along existing paths, the implications for the future are not positive.

A wide range of policy reforms, organizational restructuring, and actions to influence the behavior of individuals and economies are achievable within existing resources and with present technological capabilities. The primary missing elements inhibiting these so far have been a profound lack of awareness, a persistent failure to coordinate, and a pervasive absence of political will. All are within the ability of our populations, our policy makers, and our leaders to overcome.

In all areas, higher-profile presentation at all levels of K-20 education curricula is essential to increasing public understanding of the environment in the 21st century, with as much emphasis on positive opportunities as on negative risk and threat.

Meanwhile, private-sector research, development and implementation of low-carbon technologies and resilience-enhancing strategies is required to help reduce the pace of climate change and to take advantage of the economic opportunities that innovation in such technologies presents. One model for reinforcing both goals would be for corporations and small businesses to support funding of public education and awareness programs – perhaps in partnership with NGOs – thereby engendering public goodwill, a more informed consumer base, and wider support for clean-energy and -water initiatives.

Throughout this paper are suggested priority actions that could be taken to obviate those negative impacts that can still be avoided and to mitigate those that cannot. In dealing with a series of highly complex and interdependent systems there will always be multiple and ultimately incalculable potential trajectories and outcomes. Our collective goal must be to optimally increase the probability of achieving the best possible outcomes.

Necessary Objectives

All these complex systems – each exceptionally resilient and exquisitely sensitive – are now under increased threat due to the rapidly advancing impacts of unchecked CO_2 emissions and consequent warming of the atmosphere.

The near-range objective of mobilizing public- and private-sector *attention* to the challenges of ocean impacts and climate change will require communicating clear, compelling messages to the public and decision makers. Creating ongoing cooperation among public officials, business leaders, scientists, military representatives, employees' organizations, advocacy groups, and potential funders will be a useful mechanism for building public constituencies – and the necessary political will – for mobilizing resources and implementing effective policy change.

The mid-range objective of mobilizing *action* will require significant planning and coordination, and investment of public and private financial resources, to strengthen organizational capacities and physical infrastructure. The continuing objective must be to help minimize the extent of change in the earth's natural systems, and to mitigate the damage of its impacts when they do occur. Such planning, coordination, and investment will itself demand a high level of cooperation among policy communities, public constituencies, and political decision makers.

The long-term objective of obtaining *results* that avoid worst-case scenarios of climate chaos and ocean ecosystem collapse, and that achieve stable national and international security patterns, can only be achieved through the reduction of the pace of global warming. This entails, at minimum, taking actions that will keep development activity within the goals of the Copenhagen Accord, agreed in 2009 by 114 nations (including the United States), which commits to preventing dangerous anthropogenic interference with the climate system and recognizes "the scientific view that the increase in global temperature should be below 2°C."

Achieving those objectives will require drafting and implementing initiatives and reforms in multiple policy spheres – and in significantly improving intersectoral planning and coordination. To achieve effectiveness, these policy deliberations and decisions should be taken in collaboration with a wide range of relevant stakeholders.

In such rapidly evolving arenas, decision-making structures must remain flexible and open to accepting creative strategies and new information. The need for specific programs and strategies will necessarily evolve with the emergence of feedback from the field over time. Participants at the conference identified the following priority actions that should initially be taken.

Whether such actions are taken, and how political and organizational conflicts are resolved and resources are allocated, will play a fundamental role in determining how, and whether, 7 billion humans can continue to live on one small planet.

Guiding Principles

The following series of general principles could serve as a guide to actions by and cooperation among the public and private sectors dealing with ocean, climate, and security issues. A series of more specific **Recommended Actions** are presented in the Executive Summary and throughout the paper.

Science

- Secure, use, and share the optimal science and data.
- Improve understanding of potential tipping points and thresholds.

- Connect the systems of the earth sciences and the processes, interactions, and exchanges.
- Make all information easily available, sharing nationally and globally.
- Integrate social and natural scientific information into decision making.

Governance

- Locate, control, and where possible eradicate invasive species.
- Improve unmanned and satellite remote-sensing systems.
- Build effective governance to address the challenges at all levels vertically and horizontally.
- Build capacity and training and decision-supporting tools.
- Work with all relevant stakeholders.

U.S. Military

- Ensure that the U.S. Oceanographic Fleet is at effective and seaworthy levels.
- Continue playing a communications and leadership role in addressing climate mitigation and adaptation issues.

Communications and Education

- Assemble networks of effective communicators – including scientists, teachers, community leaders, meteorologists, NGOs, and representatives of faith organizations – to convey accurate information that helps build public support for action on environmental causes and impacts.
- Build coalitions among all stakeholders to build public constituencies and the necessary political will for implementing policy change.

Economic and Planning Strategies

- Assess the vulnerability of coastal and ocean environments and communities to climate change at decision-relevant scales.
- Improve resilience assessment and the adaptation/sustainability planning process regarding the coasts, involving all relevant stakeholders.
- Strengthen the interagency coordination and development of adaptation guidance, information, training, and tools.
- Reduce the rural and urban runoff of nutrients and toxins into the sea.
- Advance the governance, information systems, and data for the Arctic.
- Prioritize securing the necessary resources to pursue the full spectrum of actions mentioned above.

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We have interjected … the imperative to get military capabilities aligned [for] when the effects of climate change start to impact these massive populations. If it goes bad, you could

have hundreds of thousands or millions of people displaced and then security will start to crumble pretty quickly.

– Admiral Samuel J. Locklear III, Chief of U.S. Pacific Forces. Cited in "Chief of US Pacific Forces Calls Climate Biggest Worry," *Boston Globe,* March 9, 2013

Threats are more diverse, interconnected, and viral than at any time in history … We now monitor shifts in human geography, climate, disease, and competition for natural resources because they fuel tensions and conflicts. Local events that might seem irrelevant are more likely to affect U.S. national security in accelerated time frames.

– James R. Clapper, Director of National Intelligence. Statement to Senate Select Committee on release of "Worldwide Threat Assessment of the U.S. Intelligence Community," March 12, 2013

We are supporting the passing of [the UN Convention on] the Law of Sea – 161 countries have passed it. It hurts us militarily and economically [not to]. Twelve chiefs of naval operations, five Secretaries of the Navy and the last five Presidents of the United States have endorsed the passing of the Law of the Sea Treaty. It is time to pass it.

– Ray Mabus, U.S. Secretary of the Navy—speech at the conference dinner

Education of the population needs to be front and center of what we do … We can't have the conversation without an educated populace that understands the science behind the changes and the risks behind them.

– Rear Admiral Fred Byus (ret.), VP, Navy and Special Operations Market Sector, Battelle Memorial Institute

Energy and environmental security are vital to our country's success… Massachusetts ranks number one in America on energy efficiency. We are on course to reach the most ambitious target in the country, to reach a greenhouse gas emissions reduction of 25 percent of 1990 levels by 2020. … We have seen our clean-energy jobs grow by 6.7 percent last year, and they are expected to double by the end of 2012.

– Massachusetts Governor Deval Patrick

I think the environment should be put in the category of our national security. Defense of our resources is just as important as defense abroad. Otherwise, what is there to defend?

– Robert Redford