

NATIONAL SECURITY AND THE THREAT OF CLIMATE CHANGE

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NATIONAL SECURITY AND THE THREAT OF CLIMATE CHANGE

To the reader,

MILITARY ADVISORY BOARD

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Chairman, Military Advisory Board

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Lieutenant General Lawrence P. Farrell Jr., USAF (Ret.)

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Vice Admiral Richard H. Truly, USN (Ret.)

General Charles F. "Chuck" Wald, USAF (Ret.)

General Anthony C. "Tony" Zinni, USMC (Ret.)

During our decades of experience in the U.S. military, we have addressed many national security challenges, from containment and deterrence of the Soviet nuclear threat during the Cold War to terrorism and extremism in recent years.

Global climate change presents a new and very different type of national security challenge.

Over many months and meetings, we met with some of the world's leading climate scientists, business leaders, and others studying climate change. We viewed their work through the lens of our military experience as warfighters, planners, and leaders. Our discussions have been lively, informative, and very sobering.

Carbon dioxide levels in the atmosphere are greater now than at any time in the past 650,000 years, and average global temperature has continued a steady rise. This rise presents the prospect of significant climate change, and while uncertainty exists and debate continues regarding the science and future extent of projected climate changes, the trends are clear.

The nature and pace of climate changes being observed today and the consequences projected by the consensus scientific opinion are grave and pose equally grave implications for our national security. Moving beyond the arguments of cause and effect, it is important that the U.S. military begin planning to address these potentially devastating effects. The consequences of climate change can affect the organization, training, equipping, and planning of the military services. The U.S. military has a clear obligation to determine the potential impacts of climate change on its ability to execute its missions in support of national security objectives.

Climate change can act as a threat multiplier for instability in some of the most volatile regions of the world, and it presents significant national security challenges for the United States. Accordingly, it is appropriate to start now to help mitigate the severity of some of these emergent challenges. The decision to act should be made soon in order to plan prudently for the nation's security. The increasing risks from climate change should be addressed now because they will almost certainly get worse if we delay.



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EXECUTIVE SUMMARY

The purpose of this study is to examine the national security consequences of climate change. A dozen of the nation's most respected retired admirals and generals have served as a Military Advisory Board to study how climate change could affect our nation's security over the next 30 to 40 years—the time frame for developing new military capabilities.

The specific questions addressed in this report are:

1. What conditions are climate changes likely to produce around the world that would represent security risks to the United States?
2. What are the ways in which these conditions may affect America's national security interests?
3. What actions should the nation take to address the national security consequences of climate change?

The Military Advisory Board hopes these findings will contribute to the call President Bush made in his 2007 State of the Union address to "...help us to confront the serious challenge of global climate change" by contributing a new voice and perspective to the issue.

FINDINGS

Projected climate change poses a serious threat to America's national security. The predicted effects of climate change over the coming decades include extreme weather events, drought, flooding, sea level rise, retreating glaciers, habitat shifts, and the increased spread of life-threatening diseases. These conditions have the potential to disrupt our way of life and to force changes in the way we keep ourselves safe and secure.

In the national and international security environment, climate change threatens to add new hostile and stressing factors. On the simplest level, it has the potential to create sustained natural and humanitarian disasters on a scale far beyond those we see today. The consequences will likely foster political instability where societal demands exceed the capacity of governments to cope.

Climate change acts as a threat multiplier for instability in some of the most volatile regions of the world. Projected climate change will seriously exacerbate already marginal living standards in many Asian, African, and Middle Eastern nations, causing widespread political instability and the likelihood of failed states.

Unlike most conventional security threats that involve a single entity acting in specific ways and points in time, climate change has the potential to result in multiple chronic conditions, occurring globally within the same time frame. Economic and environmental conditions in already fragile areas will further erode as food production declines, diseases increase, clean water becomes increasingly scarce, and large populations move in search of resources. Weakened and failing governments, with an already thin margin for survival, foster the conditions for internal conflicts, extremism, and movement toward increased authoritarianism and radical ideologies.

The U.S. may be drawn more frequently into these situations, either alone or with allies, to help provide stability before conditions worsen and are exploited by extremists. The U.S. may also be called upon to undertake stability and reconstruction efforts once a conflict has begun, to avert further disaster and reconstitute a stable environment.

Projected climate change will add to tensions even in stable regions of the world. The U.S. and Europe may experience mounting pressure to accept large numbers of immigrant and refugee populations as drought increases and food production declines in Latin America and Africa. Extreme weather events and natural disasters, as the U.S. experienced with Hurricane Katrina, may lead to increased missions for a number of U.S. agencies, including state and local governments, the Department of Homeland Security, and our already stretched military, including our Guard and Reserve forces.

Climate change, national security, and energy dependence are a related set of global challenges. As President Bush noted in his 2007 State of the Union speech, dependence on foreign oil leaves us more vulnerable to hostile regimes and terrorists, and clean domestic energy alternatives help us confront the serious challenge of global climate change. Because the issues are linked, solutions to one affect the other. Technologies that improve energy efficiency also reduce carbon intensity and carbon emissions.

RECOMMENDATIONS OF THE MILITARY ADVISORY BOARD:

1. The national security consequences of climate change should be fully integrated into national security and national defense strategies.

As military leaders, we know we cannot wait for certainty. Failing to act because a warning isn't precise enough is unacceptable. The intelligence community should incorporate climate consequences into its National Intelligence Estimate. The National Security Strategy should directly address the threat of climate change to our national security interests. The National Security Strategy and National Defense Strategy should include appropriate guidance to military planners to assess risks to current and future missions caused by projected climate change. The next Quadrennial Defense Review should examine the capabilities of the U.S. military to respond to the consequences of climate change, in particular, preparedness for natural disasters from extreme weather events, pandemic disease events, and other related missions.

2. The U.S. should commit to a stronger national and international role to help stabilize climate change at levels that will avoid significant disruption to global security and stability.

Managing the security impacts of climate change requires two approaches: mitigating the effects we can control and adapting to those we cannot. The U.S. should become a more constructive partner with the international community to help build and execute a plan to prevent destabilizing effects from climate change, including setting targets for long term reductions in greenhouse gas emissions.

3. The U.S. should commit to global partnerships that help less developed nations build the capacity and resiliency to better manage climate impacts.

As President Bush noted in his State of the Union speech, "Our work in the world is also based on a timeless truth: To whom much is given, much is required." Climate forecasts indicate countries least able to adapt to the consequences of climate change are those that will be the most affected. The U.S. government should use its many instruments of national influence, including its regional commanders, to assist nations at risk build the capacity and resiliency to better cope with the effects of climate change. Doing so now can help avert humanitarian disasters later.

4. The Department of Defense should enhance its operational capability by accelerating the adoption of improved business processes and innovative technologies that result in improved U.S. combat power through energy efficiency.

Numerous Department of Defense studies have found that combat forces would be more capable and less vulnerable by significantly reducing their fuel demand. Unfortunately, many of their recommendations have yet to be implemented. Doing so would have the added benefit of reducing greenhouse gas emissions.

5. The Department of Defense should conduct an assessment of the impact on U.S. military installations worldwide of rising sea levels, extreme weather events, and other projected climate change impacts over the next 30 to 40 years.

Many critical defense installations are located on the coast, and several strategically important ones are on low-lying Pacific islands. Sea level rise and storm surges will threaten these facilities. Planning and action can make these installations more resilient. Lack of planning can compromise them or cause them to be inundated, compromising military readiness and capability.

ABOUT THE REPORT

To better inform U.S. policymakers and the public about the threats to national security from global climate change, the CNA Corporation, a nonprofit national security analysis organization, convened a panel of retired senior military officers and national security experts and conducted an assessment of the national security implications of global climate change. In this context, we define national security to refer to the influence of climate change on geo-strategic balances and world events that could likely involve U.S. military forces or otherwise affect U.S. strategic interests anywhere in the world.

The Military Advisory Board consisted of retired flag and general officers from all four services, including service chiefs and some who served as regional combatant commanders (a regional combatant commander is a four-star officer who commands all U.S. forces in a given region of the world). The Military Advisory Board and the study team received briefings from the U.S. intelligence community, climate scientists, and business and state leaders. They also traveled to the United Kingdom to meet with high-level government and business leaders to learn what actions the United Kingdom is taking to address the threat of climate change. Members of the Military Advisory Board also presented their own views, based on experience, of the security effects of climate change on various regions of the world.

This report documents the results of that effort. We start with a discussion of the geo-strategic implications of climate change in the general sense—that is, how climate change can foster instability and affect international security. We then apply this background to address specific regional security challenges in Africa, Asia, the Middle East, Europe, and the Americas. That is followed by a discussion of the challenges from climate change that can have a direct impact on military systems and operations. We conclude with a set of findings and recommendations related to mitigation, adaptation, and preparation—specific actions the U.S. government should take in response to the challenges presented by climate change. Appendices provide background on members of the Military Advisory Board, and very briefly summarize the science of climate change and ways in which the earth's environment may potentially change.

CLIMATE CHANGE AND THE SCOPE OF THIS STUDY

Although there is a great deal of agreement among the world's climate scientists regarding the overall picture of a changing climate, there is also some disagreement about the extent of future changes.

Regardless of this continuing discussion, the board's view is quite clear: The potential consequences of climate change are so significant that the prudent course of action is to begin now to assess how these changes may potentially affect our national security, and what courses of action, if any, our nation should take.

This approach shows how a military leader's perspective often differs from the perspectives of scientists, policymakers, or the media. Military leaders see a range of estimates and tend not to see it as a stark disagreement, but as evidence of varying degrees of risk. They don't see the range of possibilities as justification for inaction. Risk is at the heart of their job: They

GENERAL GORDON R. SULLIVAN, USA (Ret.)

Chairman, Military Advisory Board | Former Chief of Staff, U.S. Army

ON RISK

Former U.S. Army Chief of Staff Gordon Sullivan enjoys a good debate. But he also knows there are times when debate must stop and action must begin. With respect to climate change, he says that time has arrived.

"We seem to be standing by and, frankly, asking for perfectness in science," Gen. Sullivan said. "People are saying they want to be convinced, perfectly. They want to know the climate science projections with 100 percent certainty. Well, we know a great deal, and even with that, there is still uncertainty. But the trend line is very clear."

"We never have 100 percent certainty," he said. "We never have it. If you wait until you have 100 percent certainty, something bad is going to happen on the battlefield. That's something we know. You have to act with incomplete information. You have to act based on the trend line. You have to act on your intuition sometimes."

"We never have 100 percent certainty. We never have it. If you wait until you have 100 percent certainty, something bad is going to happen on the battlefield."

In discussing how military leaders manage risk, Gen. Sullivan noted that significant attention is often given to the low probability/high consequence events. These events rarely occur but can have devastating consequences if they do. American families are familiar with these calculations. Serious injury in an auto accident is, for most families, a low probability/high consequence event. It may be unlikely, but we do all we can to avoid it.

During the Cold War, much of America's defense efforts focused on preventing a Soviet missile attack—the very definition of a low probability/high consequence event. Our effort to avoid such an unlikely event was a central organizing principle for our diplomatic and military strategies.

When asked to compare the risks of climate change with those of the Cold War, Gen. Sullivan said, "The Cold War was a specter, but climate change is inevitable. If we keep on with business as usual, we will reach a point where some of the worst effects are inevitable."

"If we don't act, this looks more like a high probability/high consequence scenario," he added.

Gen. Sullivan shifted from risk assessment to risk management.

"In the Cold War, there was a concerted effort by all leadership—political and military, national and international—to avoid a potential conflict," he said. "I think it was well known in military circles that we had to do everything in our power to create an environment where the national command authority—the president and his senior advisers—were not forced to make choices regarding the use of nuclear weapons.

"The situation, for much of the Cold War, was stable," Gen. Sullivan continued. "And the challenge was to keep it stable, to stop the catastrophic event from happening. We spent billions on that strategy.

"Climate change is exactly the opposite. We have a catastrophic event that appears to be inevitable. And the challenge is to stabilize things—to stabilize carbon in the atmosphere. Back then, the challenge was to stop a particular action. Now, the challenge is to inspire a particular action. We have to act if we're to avoid the worst effects."

assess and manage the many risks to America's security. Climate change, from the Military Advisory Board's perspective, presents significant risks to America's national security. Before explaining some of those risks, we touch on an important scientific point.

A global average temperature increase of 1.3°F (plus or minus 0.3°F) occurred over the twentieth century. But the temperature change on its own is not what shapes this security assessment. Rather, it is the impact that temperature increases can have on natural systems, including:

- Habitats
- Precipitation patterns
- Extreme weather events
- Ice cover
- Sea level

Throughout this report, we do not attempt to tie our findings regarding security implications to any one particular projection of future temperature changes, precipitation changes, or sea level rise whether due to ocean expansion or ice sheet breakup. Rather, our goal is to articulate the possible security implications of climate change and to consider mitigating steps the nation could take as part of an overall national security plan.

GEO-STRATEGIC IMPLICATIONS OF CLIMATE CHANGE

GEO-STRATEGIC IMPLICATIONS OF CLIMATE CHANGE

One reason human civilizations have grown and flourished over the last five millennia is that the world's climate has been relatively stable. However, when climates change significantly or environmental conditions deteriorate to the point that necessary resources are not available, societies can become stressed, sometimes to the point of collapse [1].

For those concerned about national security, stability is a primary goal. Maintaining stability within and among nations is often a means of avoiding full-scale military conflicts. Conversely, instability in key areas can threaten our security. For these reasons, a great deal of our national security efforts in the post-World War II era have been focused on protecting stability where it exists and trying to instill it where it does not.

This brings us to the connection between climate change and national security.

As noted, climate change involves much more than temperature increases. It can bring with it many of the kinds of changes in natural systems that have introduced instability among nations throughout the centuries.

In this chapter, we consider some of the ways climate change can be expected to introduce the conditions for social destabilization. The sources of tension and conflict we discuss here are certainly not solely due to climate change; they have been discussed by the national security community for many years. However, climate change can exacerbate many of them [2].
For example:

- Some nations may have impaired access to food and water.
- Violent weather, and perhaps land loss due to rising sea levels and increased storm surges, can damage infrastructure and uproot large numbers of people.
- These changes, and others, may create large number of migrants . When people cross borders in search of resources, tensions can arise.

When climates change significantly or environmental conditions deteriorate to the point that necessary resources are not available, societies can become stressed, sometimes to the point of collapse.

- Many governments, even some that look stable today, may be unable to deal with these new stresses. When governments are ineffective, extremism can gain a foothold.
- While the developed world will be far better equipped to deal with the effects of climate change, some of the poorest regions may be affected most. This gap can potentially provide an avenue for extremist ideologies and create the conditions for terrorism.

THE DESTABILIZING IMPACTS OF CLIMATE CHANGE

REDUCED ACCESS TO FRESH WATER

Adequate supplies of fresh water for drinking, irrigation, and sanitation are the most basic prerequisite for human habitation. Changes in rainfall, snowfall, snowmelt, and glacial melt have significant effects on fresh water supplies, and climate change is likely to affect all of those things. In some areas of the Middle East, tensions over water already exist.

Mountain glaciers are an especially threatened source of fresh water [3]. A modest rise in temperature of about 2° to 4°F in mountainous

VICE ADMIRAL RICHARD H. TRULY, USN (Ret.)

Former NASA Administrator, Shuttle Astronaut and the first Commander of the Naval Space Command

ON DRAWING HIS OWN CONCLUSIONS

Retired Vice Adm. Richard H. Truly was a space shuttle commander and NASA administrator and is a member of the National Academy of Engineering. When he began service as director of the Department of Energy's National Renewable Energy Laboratory in 1997, he reminded his staff that he would be confronted with a new set of issues.

"I told them that I was unencumbered with experience or knowledge of the energy business, and that I would need their help," Adm. Truly said. "I had a pretty steep learning curve."

One of the first issues he was asked to consider was the extent to which fossil fuel emissions were affecting the climate.

"I wasn't convinced by a person or any interest group—it was the data that got me."

"I was a total agnostic," Truly said. "I had spent most of my life in the space and aeronautics world, and hadn't really wrestled with this. I was open-minded."

"Over the course of the next few years, I started really paying attention to the data. When I looked at what energy we had used over the past couple of centuries and what was in the atmosphere today, I knew there had to be a connection. I wasn't convinced by a person or any interest group—it was the data that got me. As I looked at it on my own, I couldn't come to any other conclusion. Once I got past that point, I was utterly convinced of this connection between the burning of fossil fuels and climate change. And I was convinced that if we didn't do something about this, we would be in deep trouble."

Adm. Truly noted an ironic twist about his path to this conclusion. "I was NASA administrator when Jim Hansen was first talking about these issues," he said, referring to NASA's top climate scientist. "But I was focused elsewhere then, and I should have listened more closely. I didn't become a convert until I saw the data on my own."

"The stresses that climate change will put on our national security will be different than any we've dealt with in the past. For one thing, unlike the challenges that we are used to dealing with, these will come upon us extremely slowly, but come they will, and they will be grinding and inexorable. But maybe more challenging is that they will affect every nation, and all simultaneously. This is why we need to study this issue now, so that we'll be prepared and not overwhelmed by the required scope of our response when the time comes."

When asked about his experience twenty-five years ago in space, and how it affects him today, Adm. Truly said, "It does change you, there's no doubt about it. I have images burned in my mind that will never go away—images of the earth and its fragility. I was a test pilot. I was an aviator. I was not an environmentalist. But I do love the natural environment, and seeing the earth from space was the experience that I return to when I think about what we know now about the climate."

"One of the things that struck me on my first day in space is that there is no blue sky. It's something that every human lives with on Earth, but when you're in space, you don't see it. It looks like there's nothing between you and the surface of the earth. And out beyond that, it looks like midnight, with only deep black and stars."

"But when you look at the earth's horizon, you see an incredibly beautiful, but very, very thin line. You can see a tiny rainbow of color. That thin line is our atmosphere. And the real fragility of our atmosphere is that there's so little of it."

regions can dramatically alter the precipitation mix by increasing the share falling as rain while decreasing the share falling as snow. The result is more flooding during the rainy season, a shrinking snow/ice mass, and less snowmelt to feed rivers during the dry season [4]. Forty percent of the world's population derives at least half of its drinking water from the summer melt of mountain glaciers, but these glaciers are shrinking and some could disappear within decades. Several of Asia's major rivers—the Indus, Ganges, Mekong, Yangtze, and Yellow—originate in the Himalayas [4]. If the massive snow/ice sheet in the Himalayas—the third-largest ice sheet in the world, after those in Antarctic and Greenland—continues to melt, it will dramatically reduce the water supply of much of Asia.

Most countries in the Middle East and northern Africa are already considered water scarce, and the International Water Resource Management Institute projects that by 2025, Pakistan, South Africa, and large parts of India and China will also be water scarce [5]. To put this in perspective: the U.S. would have to suffer a decrease in water supply that produces an 80 percent decrease in per capita water consumption to reach the United Nations definition of "water scarce." These projections do not factor in climate change, which is expected to exacerbate water problems in many areas.

IMPAIRED FOOD PRODUCTION

Access to vital resources, primarily food and water, can be an additional causative factor of conflicts, a number of which are playing out today in Africa. Probably the best known is the conflict in Darfur between herders and farmers. Long periods of drought resulted in the loss of both farmland and grazing land to the desert. The failure of their grazing lands compelled the nomads to migrate southward in search of water and herding ground, and that in turn led to conflict with the farming tribes occupying those lands. Coupled with population growth, tribal, ethnic, and religious differences, the competition for land turned violent. Probably more than any other recent conflict, Darfur provides

In some areas of the Middle East, tensions over water already exist.

a case study of how existing marginal situations can be exacerbated beyond the tipping point by climate-related factors. It also shows how lack of essential resources threatens not only individuals and their communities but also the region and the international community at large.

Worldwide food production will be affected by climate change in a variety of ways. Crop ecologists estimate that for every 1.8°F rise in temperature above historical norms, grain production will drop 10 percent [6].

Most of the world's growth in food demand is occurring on the Indian subcontinent and in sub-Saharan Africa, areas already facing food shortages [6]. Over the coming decades, these areas are expected to become hotter and drier [7].

HEALTH CATASTROPHES

Climate change is likely to have major implications for human health. While some impacts, such as reduced deaths from cold temperatures in some areas, will be positive, the World Health Organization estimates that the overall impact will be negative [8].

The major concern is significant spreading of the conditions for vector-borne diseases, such as dengue fever and malaria, and food-borne diseases, such as salmonellosis [8]. The decline in available fresh water in some regions will also have an impact, as good health and adequate supplies of clean water are inextricably linked.

A health emergency involving large numbers of casualties and deaths from disease can quickly expand into a major regional or global security

challenge that may require military support, ranging from distribution of vaccines to full-scale stability operations [9].

LAND LOSS AND FLOODING: DISPLACEMENT OF MAJOR POPULATIONS

About two-thirds of the world's population lives near coastlines [10], where critically important facilities and infrastructure, such as transportation routes, industrial facilities, port facilities, and energy production and distribution facilities are located. A rise in sea level means potential loss of land and displacement of large numbers of people. Even in our own nation, Hurricane Katrina showed the social upheaval and tensions that can result from land loss and displaced populations. But while the impact of inundation from one-time occurrences such as Hurricane Katrina is temporary, even as it is devastating, inundation from climate change is likely to be permanent on the scale of human lifetimes. Rising sea levels will also make coastal areas more vulnerable to flooding and land loss through erosion.

Storm surges will also take a greater toll on coastal communities and infrastructure as sea levels rise. According to a Pacific Institute study, a six-inch rise in the water level of San Francisco Bay would mean a fairly routine one-in-ten-year storm would wreak as much damage as a far more serious "hundred-year storm" would have caused before the sea level rise [11]. In the U.S., we may be able to cope with such a change, but poorer nations would be greatly challenged.

Most of the economically important major rivers and river deltas in the world—the Niger, the Mekong, the Yangtze, the Ganges, the Nile, the Rhine, and the Mississippi—are densely populated along their banks. As sea levels rise and storm surges increase, saline water can contaminate groundwater, inundate river deltas and valleys, and destroy croplands.

SECURITY CONSEQUENCES OF THESE DESTABILIZING EFFECTS

GREATER POTENTIAL FOR FAILED STATES AND THE GROWTH OF TERRORISM

Many developing countries do not have the government and social infrastructures in place to cope with the types of stressors that could be brought on by global climate change.

When a government can no longer deliver services to its people, ensure domestic order, and protect the nation's borders from invasion, conditions are ripe for turmoil, extremism and terrorism to fill the vacuum. Lebanon's experience with the terrorist group Hezbollah and the Brazilian government's attempts to reign in the slum gang First Capital Command [12] are both examples of how the central governments' inability to provide basic services has led to strengthening of these extra-governmental entities.

MASS MIGRATIONS ADD TO GLOBAL TENSIONS

The reasons for mass migrations are very complex. However, when water or food supplies shift or when conditions otherwise deteriorate (as from sea level rise, for example), people will likely move to find more favorable conditions [13]. Although climate change may force migrations of workers due to economic conditions, the greatest concern will be movement of asylum seekers and refugees who due to ecological devastation become settlers:

- By 2025, 40 percent of the world's population will be living in countries experiencing significant water shortages [14].
- Over the course of this century, sea level rise could potentially cause the displacement of tens of millions of people from low-lying areas such as Bangladesh [15].

Migrations in themselves do not necessarily have negative effects, although taken in the context of global climate change a net benefit is highly unlikely. Three types of migration patterns occur.

ADMIRAL T. JOSEPH LOPEZ, USN (Ret.)

Former Commander-in-Chief, U.S. Naval Forces Europe and of Allied Forces, Southern Europe

ON CLIMATE CHANGE AND THE CONDITIONS FOR TERRORISM

Some Americans believe we don't need to worry about climate change for decades. They say the issue isn't as urgent as the war on terror. Adm. Lopez, the retired top NATO commander in Bosnia, has a different take. He sees a strong connection between the two.

"Climate change will provide the conditions that will extend the war on terror," Adm. Lopez said.

"You have very real changes in natural systems that are most likely to happen in regions of the world that are already fertile ground for extremism," Adm. Lopez said. "Droughts, violent weather, ruined agricultural lands—those are the kinds of stresses we'll see more of under climate change."

Those changes in nature will lead to changes in society. "More poverty, more forced migrations, higher unemployment. Those conditions are ripe for extremists and terrorists."

In the controversial war on terrorism, Adm. Lopez noted, there is general agreement on at least one thing: It's best to stop terrorism before it develops. "In the long term, we want to address the underlying conditions that terrorists seek to exploit. That's what we'd like to do, and it's a consensus issue—we all want to do that. But climate change prolongs those conditions. It makes them worse."

"Dealing with instability and how you mitigate that leads to questions about the role U.S. security forces can play," Adm. Lopez added. "What can we do to alleviate the problems of instability in advance? And keep in mind this will all be under a challenged resource situation. This is very complicated. Of course, the military can be a catalyst for making this happen, but it can't do it all. This is also about economics, politics, and diplomacy.

"In the military, we've often run into problems associated with what we call 'stovepipes,' where each branch of the service has its own way of doing things. And we've learned that stovepipes don't work well. We have to take the same approach with our government, to ensure that the many agencies are working together. In those cases where we do get involved, the task should not automatically be the responsibility of the U.S. military."

He also described other layers of complexity. Even in those cases where the U.S. may choose to embrace such a role, the best solutions may require a nongovernmental component. "If you don't include economists or far-thinking, out-of-the-box business people in this, you'll get shortchanged." He also said the U.S. "can't imply that we'll do this all alone. We need to make sure we don't give that impression. The same forces of economics, business, politics, diplomacy, and military and security interests can function to build coalitions in order to maintain stability when challenged by dramatic climate change."

> "Climate change will provide the conditions that will extend the war on terror."

The greatest concern will be movement of asylum seekers and refugees who due to ecological devastation become settlers...

Some migrations take place within countries, adding to a nation's political stress, causing economic upheaval—positive and negative—and distracting from other issues. As a developed nation, the U.S. was able to absorb the displacement of people from the Gulf Coast in the wake of Hurricane Katrina without suffering economic or political collapse, but not without considerable turmoil.

Some migrations cross international borders. Environmental degradation can fuel migrations in less developed countries, and these migrations can lead to international political conflict. For example, the large migration from Bangladesh to India in the second half of the last century was due largely to loss of arable land, among other environmental factors. This affected the economy and political situation in the regions of India that absorbed most of this population shift and resulted in violence between natives and migrants [16].

A third form of migration involves not only crossing international borders but moving across vast regions while doing so. Since the 1960s, Europe has experienced this kind of "south to north" migration, with an influx of immigrants from Africa and Asia. The shift in demographics has created racial and religious tensions in many European countries, as evidenced in the 2005 civil unrest in France.

POTENTIAL ESCALATION OF CONFLICTS OVER RESOURCES

To live in stability, human societies need access to certain fundamental resources, the most important of which are water and food. The lack, or mismanagement, of these resources can undercut the stability of local populations; it can affect regions on a national or international scale.

Disputes over key resources such as water do not automatically trigger violent outcomes, and no recent wars have been waged solely over water resources. In areas with a strong government and societal cohesiveness, even tense disputes and resource crises can be peacefully overcome. In fact, in recent years, arguments have been made that multinational cooperation over precious water resources has been more an instrument of regional peace than of war [17].

Nevertheless, resource scarcity always has the potential to be a contributing factor to conflict and instability in areas with weak and weakly supported governments [19]. In addition, there is always the potential for regional fighting to spread to a national or international scale. Some recent examples include: the 1994 genocide in Rwanda that was furthered by violence over agricultural resources; the situation in Darfur, Sudan, which had land resources at its root and which is increasingly spilling over into neighboring Chad; the 1970s downfall of Ethiopian Emperor Haile Selassie through his government's inability to respond to food shortages; and the 1974 Nigerian coup that resulted largely from an insufficient response to famine [19].

Whether resource scarcity proves to be the impetus for peaceful cooperation or an instigator of conflict in the future remains to be seen. Regions that are already water scarce (such as Kuwait, Jordan, Israel, Rwanda, Somalia, Algeria, and Kenya) may be forced to confront this choice as climate change exacerbates their water scarcity.

REGIONAL IMPACTS OF CLIMATE CHANGE

AFRICA

VULNERABLE TO CLIMATE CHANGE IMPACTS

Africa's importance to U.S. national security can no longer be ignored. Indeed, with the recent establishment of a U.S. African Command, the U.S. has underscored Africa's strategic importance. Its weak governments and the rising presence of terrorist groups make Africa important to the fight against terrorism. Moreover, Africa is also of strategic value to the U.S. as a supplier of energy; by 2015, it will supply 25 to 40 percent of our oil, and it will also be a supplier of strategic minerals such as chrome, platinum, and manganese.

Such changes will add significantly to existing tensions and can facilitate weakened governance, economic collapses, massive human migrations, and potential conflicts.

Reductions in soil moisture and further loss of arable land may be the most significant of the projected impacts of climate change in Africa. At the same time, extreme weather events are likely to increase. These expected changes portend reduced supplies of potable water and food production in key areas. Such changes will add significantly to existing tensions and can facilitate weakened governance, economic collapses, massive human migrations, and potential conflicts. In Somalia, for example, alternating droughts and floods led to migrations of varying size and speed and prolonged the instability on which warlords capitalized.

Increased political instability in Africa potentially adds additional security requirements for the U.S. in a number of ways. Stability operations, ranging from humanitarian direct delivery of goods and the protection of relief workers, to the establishment of a stable and reconstructed state, can place heavy demands on the U.S. military. While the nature of future stability operations is a matter of speculation, historically some stability operations have involved significant military operations and casualties. Political instability also makes access to African trade and resources, on which the U.S. is reliant for both military and civilian uses, a riskier proposition.

UNSTABLE GOVERNMENTS AND TERRORIST HAVENS

Africa is increasingly crucial in the ongoing battle against civil strife, genocide, and terrorism. Numerous African countries and regions already suffer from varying degrees of famine and civil strife. Darfur, Ethiopia, Eritrea, Somalia, Angola, Nigeria, Cameroon, Western Sahara—all have been hit hard by tensions that can be traced in part to environmental causes. Struggles that appear to be tribal, sectarian, or nationalist in nature are often triggered by reduced water supplies or reductions in agricultural productivity.

The challenges Africa will face as a result of climate change may be massive, and could present serious threats to even the most stable of governments. Many African nations can

GENERAL CHARLES F. "CHUCK" WALD, USAF (Ret.)

Former Deputy Commander, Headquarters U.S. European Command (USEUCOM)

ON CLIMATE CHANGE IN AFRICA

When asked why Americans should be interested in African security issues, retired Air Force Gen. Chuck Wald gave a number of reasons.

"We ought to care about Africa because we're a good country," Gen. Wald said. "We have a humanitarian character; it's one of our great strengths, and we shouldn't deny it. Some may be tempted to avert their eyes, but I would hope we instead see the very real human suffering taking place there. We should be moved by it, challenged by it. Even in the context of security discussions, I think these reasons matter, because part of our security depends on remaining true to our values.

"There are exotic minerals found only in Africa that have essential military and civilian uses," Gen. Wald continued. "We import more oil from Africa than the Middle East—probably a shock to a lot of people—and that share will grow. Africa could become a major exporter of food.

"My view is that we'll be drawn into the politics of Africa, to a much greater extent than in the past. A lot of Americans today would say Africa is an optional engagement. I don't think that's the case, even today, but it certainly won't be in the future."

To show how climate change can worsen conditions that are already quite desperate, Gen. Wald described a trip to Nigeria.

"We landed in Lagos late in the afternoon," Gen. Wald said. "This is a city, now, with roughly 17 million people. The best way to describe our drive from the airport to the hotel is that it reminded me of a 'Mad Max' movie. There were massive numbers of people on the roads, just milling around. There were huge piles of trash. There were fires along the roadside and in the distance—huge fires. It was just short of anarchy.

"That's the situation today. Even in a time of relative stability, there is very little civil governance, and very little ability to serve huge numbers of people with basics like electricity, clean water, health care, or education.

"If you add rising coastal waters and more extreme weather events, you then have millions of people who could be displaced. There really is no controlled place for them to go, no capacity for an organized departure, and no capacity to make new living situations. When you add in the effects of climate change, it adds to the existing confusion and desperation, and puts more pressure on the Nigerian government. It makes the possibility of conflict very real. If the delta is flooded, or if major storms damage their drilling capacity, you lose the primary source of income.

"My view is that we'll be drawn into the politics of Africa, to a much greater extent than we have in the past."

"Culturally, you have a country that is split geographically between Muslims and Christians. If migrations occur, you put real pressure on that country. It's already tense and fragile. When you exacerbate that situation with climate change effects, it's not hard to postulate on the dangers."

best be described as failed states, and many African regions are largely ungoverned by civil institutions. When the conditions for failed states increase—as they most likely will over the coming decades—the chaos that results can be an incubator of civil strife, genocide, and the growth of terrorism.

LESS EFFECTIVE GOVERNANCE AND POTENTIAL MIGRATIONS

More than 30 percent of the world's refugees and displaced persons are African. Within the last decade, severe food shortages affected twenty-five African countries and placed as many as 200 million people "on the verge of calamity" [20].

Expected future climate change will exacerbate this problem. The Sahara desert is spreading [21], and the sub-Saharan region is expected to suffer reduced precipitation [22]. As climate changes and agricultural patterns are disrupted, the geopolitics of the future will increasingly be the politics of scarcity. Potential rainfall decreases in North Africa would likely exacerbate the problem of migration to Europe. Reduced rainfall and increasing desertification of the sub-Saharan region will likely also result in migrations to Europe, as well as migrations within the African continent.

> ...the chaos that results can be an incubator of civil strife, genocide, and the growth of terrorism.

LAND LOSS AND WEATHER DISASTERS

Sea level rise could also result in the displacement of large numbers of people on the African continent, as more than 25 percent of the African population lives within 100 kilometers (sixty-two miles) of the coast, and six of Africa's ten largest cities are on the coast. Nigeria and Mozambique are particularly vulnerable to the effects of sea level rise and storm surges. Two cyclones in 2000 displaced 500,000 people in Mozambique and caused 950,000 people to require some form of humanitarian assistance [23]. The Niger Delta accounts for about 7.5 percent of Nigeria's land area and a population of 20 million people.

In light of the potential magnitude of the human crisis that could result from major weather-related natural disasters and the magnitude of the response and recovery efforts that would be required, stability operations carried out by international militaries will likely occur more frequently.

HEALTH CHALLENGES WILL CONTINUE TO ESCALATE

Severe and widespread continental health issues complicate an already extremely volatile environment. Climate change will have both direct and indirect impacts on many diseases endemic to Africa such as malaria and dengue fever [24]. Increases in temperature can expand the latitude and altitude ranges for malaria, and flooding from sea level rise or severe weather events can increase the population of malaria vectors. For example, a temperature rise of 2°F can bring a malaria epidemic to Kenya. Excessive flooding is also conducive to the spread of cholera.

VICE ADMIRAL PAUL G. GAFFNEY II, USN (Ret.)

Former President, National Defense University; Former Chief of Naval Research and Commander, Navy Meteorology and Oceanography Command

ON MILITARY RESEARCH AND CLIMATE SCIENCE

The Department of Defense and the intelligence community have in the past used their immense capability for data collection and analysis to address national and international environmental questions. Retired Vice Adm. Paul G. Gaffney II says we have the capacity to do this again, this time for better understanding and monitoring of climate change.

The DoD offers equipment, talent and, as Adm. Gaffney put it, "Data, data, data."

"You will find the defense and intelligence communities have extraordinary amounts of data, and, if done in a careful and deliberate manner, data collected in the past and into the future can be made available to climate scientists," Adm. Gaffney said. "Be it imagery, other satellite records, data from Navy oceanographic ships and vehicles, surface warships and submarines, or observations collected by aircraft—you can find ways to smooth it to protect what must be protected if the raw data cannot be released. If climate change is, in fact, a critical issue for security, then the military and intelligence communities should be specifically tasked to aggressively find ways to make their data, talent, and systems capabilities available to American efforts in understanding climate change signals.

"Most of our ships are already outfitted to collect basic atmospheric and oceanic information. U.S. military platforms are all over the world, all of the time; they become platforms of opportunity to collect data for this global issue."

Adm. Gaffney also cited staff capabilities.

"The quality of personnel from the defense and intelligence organizations is exceptional," he said. "Within the DoD, we have labs that are as good as any that exist anywhere in the world, using whatever metrics you want—papers published, patents, Nobel laureates.

"Look at the Navy ocean modelers and remote sensing experts. They worked with scientists at NASA's Jet Propulsion Lab to unlock the secrets of El Niño, using space-borne altimetry data and new numerical ocean circulation models. The mission was a military one, but it ultimately played a role in helping us understand more about the climate."

Throughout the Cold War, the U.S. and the Soviet Union each collected data in the Arctic. Ice thickness and sub-ice ocean conditions affecting acoustics were critical security issues.

"The mission was a military one, but it ultimately played a role in helping us understand more about the climate."

After the breakup of the Soviet Union, many saw that that data could be used to determine temperature and ice condition changes over time. The two sides collaborated on ways to share and reconcile the data, and in 1996 released the Arctic Ocean Atlas to the world's scientific community. The data have advanced understanding of climate change in significant ways.

"I think there's another component to this," said Adm. Gaffney. "Defense employees [military and civilian] actually have a responsibility to the nation when they have a certain skill. They have a responsibility to share that with the public and the nation, as long as security is not compromised. They've done this in the past. And I'd love to see them able to do this more often in the future."

ASIA

CLIMATE CHANGE CAN AFFECT IMPORTANT U.S. STRATEGIC INTERESTS

Most climate projections indicate increasing monsoon variability, resulting in increases in both flood and drought intensity in temperate and tropical Asia [24]. Almost 40 percent of Asia's population of nearly 4 billion lives within forty-five miles of its nearly 130,000-mile-long coastline. Sea level rise, water availability affecting agricultural productivity, and increased effects of infectious disease are the primary climate effects expected to cause problems in Asia.

SEA LEVEL RISE MAY THREATEN MILLIONS

Some of the most vulnerable regions in the world to sea level rise are in southern Asia, along the coasts of Pakistan, India, Sri Lanka, Bangladesh, and Burma; and Southeast Asia, along the coasts between Thailand and Vietnam, including Indonesia and the Philippines.

Asia, where hundreds of millions of people rely on waters from vanishing glaciers on the Tibetan plateau, could be among the hardest hit regions.

Sandy coastlines backed by densely populated, low-lying plains make the Southeast Asian region particularly vulnerable to inundation. Coastal Malaysia, Thailand, and Indonesia could all be threatened with flooding and the loss of important coastal farmlands.

The location and topography of Bangladesh make it one of the most vulnerable countries in the world to a rise in sea level. Situated at the northeastern region of South Asia on the Bay of Bengal, it is about the size of Iowa with a population of almost 150 million. It is very flat and low lying, except in the northeast and southeast regions, and has a coastline exceeding 300 miles. About 10 percent of Bangladesh is within three feet of mean sea level. Over the next century, population rise, land scarcity and frequent flooding coupled with increased storm surge and sea level rise could cause millions of people to cross the border into India. Migration across the border with India is already such a concern that India is building a fence to keep Bangladeshis out.

India and Pakistan have long, densely populated and low-lying coastlines that are very vulnerable to sea level rise and storm surge. Coastal agriculture, infrastructure, and onshore oil exploration are at risk. Possible increases in the frequency and intensity of storm surges could be disproportionately large in heavily developed coastal areas and also in low-income rural areas, particularly such low-lying cities such as Mumbai, Dhaka and Karachi.

WATER STRESS AFFECTS ASIA'S ABILITY TO FEED ITS PEOPLE

By 2050, regions dependent on glacial melting for water may face serious consequences. Asia, where hundreds of millions of people rely on waters from vanishing glaciers on the Tibetan plateau, could be among the hardest hit regions.

Climate change has the potential to exacerbate water resource stresses in most regions of Asia [7]. Most countries in Asia will experience

ADMIRAL JOSEPH W. PRUEHER, USN (Ret.)

Former Commander-in-Chief of the U.S. Pacific Command (PACOM) and Former U.S. Ambassador to China

ON CLIMATE CHANGE IN THE PACIFIC

In a discussion of climate change issues in the Pacific region, retired Adm. Joseph Prueher first considered the issue from a singular perspective: the impact climate change may have on the region's governments and their relative stability.

Using Singapore as an example, he said, "It's a democracy, but with a very strong leadership. They've prospered, but owing to lack of space they have many restrictions we do not have. If one looks ahead to the effects of climate change, you start with the understanding that Singapore, low lying and very hot, will face more storms and more moisture. It will face coastal impacts. Those kinds of changes, in a crowded nation, create a whole set of issues that affect not just the economy and culture, but the security dynamic as well."

Adm. Prueher then shifted the conversation to the region's governments in general.

"It may well be that in very crowded nations, a stronger government is necessary in order to avoid instability," he said. "In Asia, one sees a whole line of countries with governments exercising very firm control. But when you look to the future to consider the kinds of impacts we may see—flooding, extreme weather events, real disruptions—you also have to consider some steps that we in the U.S. would think offensive. Those are steps these governments may feel they need to take in order to avoid chaos."

Referencing low-lying regions where arable land will be lost, he said, "You see mass destruction in countries where the government is not robust. When people can't cope, governing structures break down."

Adm. Prueher noted that how a government responds presents a new set of issues for American political and military leaders.

"Most of our security forces are for protecting our nation from outside, but that's not necessarily the case in the rest of the world," Adm. Prueher said. "Military personnel elsewhere are often directed internally. They focus on keeping internal order. There might be cases where the U.S. military might be in a position to help deal with the effects of climate change—with floods or the migrations that might result from them. The immediate goal would be to relieve suffering, not to preserve governments. But if you're partnering with a nation's army keeping domestic order, that can be a real challenge."

When asked about China, Adm. Prueher noted that the European Union is working to identify ways of cooperating with the Chinese on the development of clean coal technologies. And he cautioned against those in the U.S. who oppose any kind of technology exchange with China.

"Yes, China is focused heavily on growth. Yes, there is what I think is a quite remote possibility of future military conflict. And, yes, it is a real challenge to negotiate with them; one can count on them to negotiate toward what they perceive to be their own national interest," he said. "Reasonable enough. But on the issue of carbon emissions, it doesn't help us to solve our problem if China doesn't solve theirs. And that means we need to engage them on many fronts. Issues of great importance to our world will not get solved without U.S.-Chinese cooperation. I happen to like dealing with the Chinese. You may not, or you may be suspicious of them, but we need to cooperate.

"They have 1.3 billion people, 200 million of whom are under-employed or unemployed," Adm. Prueher said. "They have a great deal of pride and see themselves as a great nation. Most of what we say to enhance environmental progress in China is seen by them as a way to stop them from continuing economic growth.

"Not talking to the Chinese is not an option."

LIEUTENANT GENERAL LAWRENCE P. FARRELL JR., USAF (Ret.)

Former Deputy Chief of Staff for Plans and Programs, Headquarters U.S. Air Force

ON CLIMATE, ENERGY AND BATTLEFIELD READINESS

Retired Air Force Lt. Gen. Larry Farrell sees a great deal of uncertainty about climate change and appears willing to engage any credible scientist in discussions of discrepancies among climate models.

"You might say I'm from Missouri on this issue—you have to show me," he said. "And there is still much uncertainty and debate on this issue." Despite this, Gen. Farrell sees indications that some change is occurring.

"Clearly, there has been some warming over the past 100 years and some climate change. These changes have been accompanied by fairly significant increases in the greenhouse gases carbon dioxide and methane. If there is a connection between warming trends and greenhouse gases, our use of energy may be playing a part in this. If these trends continue into the future, the changes could well exacerbate existing social and political instabilities and create new ones. The military has the obligation to assess the potential military implications of these trends." Gen. Farrell's preference is to focus on solutions.

"If you advocate intelligent energy solutions, you'll solve this problem," Gen. Farrell said, before walking through a long list of reasons for a focus on energy.

A key concern for Gen. Farrell: battlefield readiness.

"Seventy percent of the tonnage on the battlefield is fuel," he said. "That's an amazing number. Between fuel and water, it's almost everything we take to the battlefield. Food and ammo are really quite small in comparison.

"Delivering that fuel requires secure lines of communication," Gen. Farrell said. "If you have bases nearby, you may be able to deliver it with much less risk, but that's a supply line issue. And we see in Iraq how dangerous it can be to transport fuel.

"The military should be interested in fuel economy on the battlefield," he said. "It's a readiness issue. If you can move your men and materiel more quickly, if you have less tonnage but the same level of protection and firepower, you're more efficient on the battlefield. That's a life and death issue."

Gen. Farrell talked about the challenge of focusing on long-term issues.

"Climate change is not something people can recognize," he said. "In geologic times, it's quick. But in human terms, it's still very slow. It's hard to get all of us to do something about it. And that leads me to believe we should deal with other things that are a problem today but that also get us to the heart of climate change. That's where I get to the issue of smart energy choices.

"Focus on conservation and on energy sources that aren't based in carbon. Move toward a hydrogen economy, in part because you know it will ultimately give you efficiency and, yes, profit. When you pursue these things, you build alliances along the way. That's safety. It's a benefit we see right now."

He suggested another reason as well: There are military impacts that come from our energy use.

"We're forced to be interested in parts of the world because of our energy consumption," he said. "Solving the energy problem solves a real security problem. You get to choose your points of engagement. It's like one of the things your grandmother told you. 'Don't go looking for trouble. If you find trouble, you have to deal with it—but don't go looking for it!' Well, when we go looking for oil, we're really looking for trouble."

substantial declines in agricultural productivity because of higher temperatures and more variable rainfall patterns [25]. Net cereal production in South Asia, for example, is projected to decline by 4 to 10 percent by the end of this century under the most conservative climate change projections.

But the problem isn't just water scarcity—too much water can also be a problem. By 2050, snow melting in the high Himalayas and increased precipitation across northern India are likely to produce flooding, especially in catchments on the western side of the Himalayas, in northern India, Nepal, Bangladesh, and Pakistan.

RISING SPREAD OF INFECTIOUS DISEASE

Climate change is expected to increase the geographic range of infectious diseases such as malaria, dengue fever, and schistosomiasis and increase the risk of water-borne disease. Climate projections indicate the Asia/Pacific region as a whole is likely to become warmer and wetter in the coming decades, creating conditions more conducive to disease vectors such as mosquitoes. With the exception of east central China and the highlands of west China, much of the Asia/Pacific region is exposed to malaria and dengue or has conditions suitable for their spread. This region will continue to be a hot spot for these diseases in the decades ahead, with certain regions becoming more prone to epidemics.

EUROPE

THREATENED BY CLIMATE PROBLEMS FROM OTHER PARTS OF THE WORLD

Europe is getting warmer overall, northern Europe is getting wetter, and southern Europe is getting drier. (For the purposes of this report, Europe includes the western part of the former Soviet Union.)

The developed nations of Europe will likely be able to deal with the direct climate changes expected for that region, but some of the less developed nations (the Balkans, for instance) might be stressed. Europe has already experienced extreme weather events that herald potential climate change effects: the more than 35,000 deaths associated with the heat wave of 2003 are a reminder of the vulnerability of all nations to climate extremes [26]. However, the major impact on Europe from global climate change is likely to be migrations, now from the Maghreb (Northern Africa) and Turkey, and increasingly, as climate conditions worsen, from Africa.

With its shortages of water, the Mediterranean area could experience considerable strain.

DIRECT IMPACTS: HOTTER TEMPERATURES AND RISING SEAS

Most of Europe has experienced surface air temperature increases during the twentieth century (1.44°F on average), with the largest increases over northwest Russia and the Iberian Peninsula. Temperatures in Europe since 1990 have been the warmest since records have been kept. More heat waves across all of Europe are likely to increase stress on human health and could produce an increased risk of malaria and dengue fever in southern Europe. Agricultural zones would move north, and the Mediterranean regions, especially in Spain, would suffer a greater loss of productivity.

Precipitation is expected to increase in the north but decrease in the central and eastern Mediterranean zones and south Russia, with acute water shortages projected in the Mediterranean area, especially in the summer.

MITIGATION AND ADAPTATION TO CLIMATE CHANGE IN EUROPE

The capacity for adaptation to these changes is very high in most of prosperous, industrial Europe, but less so in lesser-developed places like the Balkans, Moldova, and the Caucasus. With its shortages of water, the Mediterranean area could experience considerable strain. In northern Europe, countries may build higher dikes, as they have done in the past, but at a certain point that may not be sufficient, and much port and other coastal infrastructure would have to be moved further inland, at great expense. Some northern migration within Europe might be expected—the Italians already face a large Albanian immigration, and others may press north from the Balkans.

THE PRIMARY STRATEGIC CONCERN OF EUROPEANS: MASSIVE MIGRATIONS TO EUROPE

The greater threat to Europe lies in migration of people from across the Mediterranean, from the Maghreb, the Middle East, and sub-Saharan Africa. Environmental stresses and climate change are certainly not the only factors driving migrations to Europe. However, as more people migrate from the Middle East because of water shortages and loss of their already marginal agricultural lands (as, for instance, if the Nile Delta disappears under the rising sea level), the social and economic stress on European nations will rise.

It is possible that Europeans, given their long and proximate association with the sub-Saharan African countries, may undertake more stability operations, as they have in Sierra Leone and Côte d'Ivoire. Their militaries, and in particular their navies and coast guards, would also have to increase their activities in securing their borders and in intercepting migrants moving by sea, as is now going on through the Canary Islands.

MIDDLE EAST

ABUNDANT OIL, SCARCE WATER AND INTERNATIONAL CONFLICT

The Middle East has always been associated with two natural resources, oil (because of its abundance) and water (because of its scarcity). The Persian Gulf contains more than half (57 percent) of the world's oil reserves, and about 45 percent of the world's natural gas reserves. And because its production costs are among the world's lowest, the Persian Gulf region is likely to remain the world's largest oil exporter for the foreseeable future. At the end of 2003, Persian Gulf countries produced about 32 percent of the world's oil. Because of its enormous oil endowment, the Middle East is one of the most strategically significant regions of the world. The security impacts of climate change on the Middle East are greatly magnified by its historical and current levels of international conflict, and competition for increasingly scarce resources may exacerbate the level of conflict. This is the region of the world in which the U.S. is most engaged militarily.

WATER: INCREASING STRESS ON AN EXISTING SHORTAGE

In this region, water resources are a critical issue; throughout history, cultures here have flourished around particular water sources. With the population explosion underway, water will become even more critical. Of the countries in the Middle East, only Egypt, Iran, and Turkey have abundant fresh water resources. Roughly two-thirds of the Arab world depends on sources outside their borders for water. The most direct effect of climate change to be felt in the Middle East will be a reduction in precipitation. But the change will not be uniform across the region.

The flows of the Jordan and Yarmuk rivers are likely to be reduced, leading to significant water stress in Israel and Jordan, where water demand already exceeds supply. Exacerbation of water shortages in those two countries and in Oman, Egypt, Iran, and Iraq are likely to threaten conventional crop production, and salinization of coastal aquifers could further threaten agriculture in those regions.

SEA LEVEL RISE

Sea level rise combined with increased water demand from growing populations are likely to exacerbate saltwater intrusion into coastal fresh water aquifers, already a considerable problem for the Gaza Strip. Salinization of coastal aquifers could further threaten agriculture in these regions. Additional loss of arable land and decreases in food security could encourage migration within the Middle East and Africa, and from the Middle East to Europe and elsewhere.

INFLAMING A REGION OF POLITICAL INSTABILITY

Climate change has the potential to exacerbate tensions over water as precipitation patterns change, declining by as much as 60 percent in some areas. In addition, the region already suffers from fragile governments and infrastructures, and as a result is susceptible to natural disasters. Overlaying this is a long history of animosity among countries and religious groups. With most of the world's oil being in the Middle East and the industrialized and industrializing nations competing for this resource, the potential for escalating tensions, economic disruption, and armed conflict is great.

GENERAL ANTHONY C. "TONY" ZINNI, USMC (Ret.)

Former Commander-in-Chief of U.S. Central Command (CENTCOM)

ON CLIMATE CHANGE, INSTABILITY AND TERRORISM

A starting point in understanding this connection might be to "look at how climate change effects could drive populations to migrate," Gen. Zinni said. "Where do these people move? And what kinds of conflicts might result from their migration? You see this in Africa today with the flow of migrations. It becomes difficult for the neighboring countries. It can be a huge burden for the host country, and that burden becomes greater if the international community is overwhelmed by these occurrences.

"You may also have a population that is traumatized by an event or a change in conditions triggered by climate change," Gen. Zinni said. "If the government there is not able to cope with the effects, and if other institutions are unable to cope, then you can be faced with a collapsing state. And these end up as breeding grounds for instability, for insurgencies, for warlords. You start to see real extremism. These places act like Petri dishes for extremism and for terrorist networks."

In describing the Middle East, the former CENTCOM commander said, "The existing situation makes this place more susceptible to problems. Even small changes may have a greater impact here than they may have elsewhere. You already have great tension over water. These are cultures often built around a single source of water. So any stresses on the rivers and aquifers can be a source of conflict. If you consider land loss, the Nile Delta region is the most fertile ground in Egypt. Any losses there could cause a real problem, again because the region is already so fragile. You have mass migrations within the region, going on for many decades now, and they have been very destabilizing politically."

Gen. Zinni referenced the inevitability of climate change, with global temperatures sure to increase. But he also stressed that the intensity of those changes could be reduced if the U.S. helps lead the way to a global reduction in carbon emissions. He urged action now, even if the costs of action seem high.

> "It's not hard to make the connection between climate change and instability, or climate change and terrorism."

"We will pay for this one way or another," he said. "We will pay to reduce greenhouse gas emissions today, and we'll have to take an economic hit of some kind. Or we will pay the price later in military terms. And that will involve human lives. There will be a human toll.

"There is no way out of this that does not have real costs attached to it. That has to hit home."

THE WESTERN HEMISPHERE

RISKS FOR THE UNITED STATES AND OUR NEIGHBORS

Latin America includes some very poor nations in Central America and in the Caribbean, and their ability to cope with a changing climate will present challenges for them and thus for the U.S. Global climate change can lead to greater intensity of hurricanes as sea surface temperatures rise, with enormous implications for the southeastern U.S., Central America, and Caribbean nations. Loss of glaciers will strain water supply in several areas, particularly Peru and Venezuela. Rising sea levels will threaten all coastal nations. Caribbean nations are especially vulnerable in this regard, with the combination of rising sea levels and increased hurricane activity potentially devastating to some island nations.

The primary security threats to the U.S. arise from the potential demand for humanitarian aid and a likely increase in immigration from neighbor states. It is important to remember that the U.S. will be dealing with its own climate change issues at the same time.

INCREASING WATER SCARCITY AND GLACIAL MELT

The melting of glaciers at an accelerated rate in Venezuela and the Peruvian Andes is a particular concern because of the direct reliance on these glaciers for water supplies and hydroelectric power. The Peruvian plains, northeast Brazil, and Mexico, already subject to drought, will find that droughts in the future will last longer. That would lead to further land degradation and loss of food production—a blow to Latin America, which is particularly dependent on food production for subsistence, and to Brazil, whose economy is fueled by food exports.

Drought and decreased rainfall is projected to also affect the central southern U.S. That could have significant impact on food production and sources of water for millions. The High Plains (or "Ogallala") aquifer underlies much of the semi-arid west-central U.S. The aquifer provides water for 27 percent of the irrigated land in the country and supplies about 30 percent of the groundwater used for irrigation. In fact, three of the top grain-producing states—Texas, Kansas, and Nebraska—each get 70 to 90 percent of their irrigation water from the Ogallala aquifer [27]. Human-induced stresses on this groundwater have resulted in water-table declines greater than 100 feet in some areas [28]. This already difficult situation could be greatly exacerbated by a decrease in rainfall predicted for the region. Similarly, a recent study by the National Research Council on the Colorado River basin (the river is the main water source for tens of millions of people in the Southwest) predicted substantial decreases in river flow, based on higher population coupled with the climate change affects [29].

STORMS AND SEA LEVEL RISE

In looking at the relationship between warmer temperatures and storm intensity, a panel convened by the World Meteorological Organization concluded: "It is likely that some increase in tropical cyclone peak wind-speed and rainfall

ADMIRAL DONALD L. "DON" PILLING, USN (Ret.)

Former Vice Chief of Naval Operations

ON OPERATIONAL CHALLENGES OF CLIMATE CHANGE

Retired Adm. Donald L. Pilling, former vice chief of naval operations, highlighted one of the reasons government agencies have been slow to respond to the issue of climate change.

"One of the problems in talking about this issue is that no one can give you a date by which many of the worst effects will be occurring," Adm. Pilling said. "If it's 2050, there isn't a guy in uniform today who will be wearing a uniform then. The Pentagon talks about future year plans that are six years down the road."

Still, Adm. Pilling was able to talk about the issue and the planning challenges it might offer. He enumerated a list of operational impacts, starting with the assumption that there would be increased instances of large migrations—people fleeing homelands that have felt the impacts of climate changes.

"This is key because it's easy to see how our allies can be consumed by this," Adm. Pilling said. "They won't have time to participate in exercises at sea because all of their assets will be focused on protecting the border and beaches. Europe will be focused on its own borders. There is potential for fracturing some very strong alliances based on migrations and the lack of control over borders.

"Open seas at the Arctic means you have another side of this continent exposed," he said. "Between the Canadians and us, there are a handful of ships oriented for the northernmost latitudes. But there is not much flexibility or depth there."

He said that an increase in the frequency or intensity of hurricanes could have a destabilizing effect on maintenance and the stability of ships and fleets. "It may cause you to move ships north to avoid hurricanes. If a ship's captain thinks he's in the middle of hurricane season, he's going to go out—get away from port. It impacts maintenance schedules and impacts operational structures. And that doesn't factor in the damage that hurricanes can do to our ports and maintenance facilities. We spent a few billion to restore Pascagoula after Hurricane Katrina—and we're not done yet. But at least that's an impact you can see. People can get their hands around that."

"There is potential for fracturing some very strong alliances based on migrations and the lack of control over borders."

Over time, some of the operational issues related to climate change would be increasingly difficult to resolve.

"At headquarters, they would need to be much more thoughtful about investment decisions," he said. "Why invest significant resources in bases that are in low-lying regions? Why invest in bases that may continue to be flooded? Those are tough questions to ask, but I'd ask them."

will occur if the climate continues to warm. Model studies and theory project a 3-5% increase in wind-speed per degree Celsius increase of tropical sea surface temperatures" [30]. Warming seas and their link to storm energy are especially worrisome for Central American and small Caribbean island nations that do not have the social infrastructure to deal with natural disasters.

Flooding could increase with sea level rises, especially in the low-lying areas of North America—inundation models from the University of Arizona project that a sea level rise of three feet would cause much of Miami, Fort Myers, a large portion of the Everglades, and all of the Florida Keys to disappear [31].

In the past, U.S. military forces have responded to natural disasters, and are likely to continue doing so in the foreseeable future [32]. The military was deployed to Central America after Hurricane Mitch in 1998 and to Haiti following the rains and mudslides of 2004. The U.S. military was also heavily involved in the response to Hurricane Katrina. Climate change will likely increase calls for this type of mission in the Americas in the future.

INCREASED MIGRATION/REFUGEE FLOWS INTO THE U.S.

The greater problem for the U.S. may be an increased flow of migrants northward into the U.S. Already, a large volume of south to north migration in the Americas is straining some states and is the subject of national debate. The migration is now largely driven by economics and political instability. The rate of immigration from Mexico to the U.S. is likely to rise because the water situation in Mexico is already marginal and could worsen with less rainfall and more droughts. Increases in weather disasters, such as hurricanes elsewhere, will also stimulate migrations to the U.S. [32].

GENERAL PAUL J. KERN, USN (Ret.)

Former Commanding General, U.S. Army Materiel Command

ON WEATHER, LOGISTICS, AND THE CAUSES OF WAR

In 1989, Gen. Kern commanded a brigade based at Fort Stewart, Georgia, and was preparing to send men and materiel to Turkey in advance of NATO training exercises. Those plans were interrupted by Hurricane Hugo, which appeared headed to Savannah, the port of departure for the mission.

"We were all ready to go, but the ships involved in transport had to be sent to Norfolk," Gen. Kern said. "So we broke down the shipments that had already been assembled for delivery. We then moved our aviation assets out, and moved base families into shelters. Ultimately, the hurricane hit Charleston, and did major damage to the airbase there. That meant one of my military battalions was deployed to Charleston to help with the recovery there."

"These weren't immense challenges for us—they were things we could handle," Gen. Kern said. "But the planned training exercises—preparing us for our core military mission—were not as good as they could have been. It's a very subtle thing, but there you have it in a nutshell: Extreme weather can affect your readiness."

Looking ahead, Gen. Kern, now retired from active duty, discussed wider global trends that the military must address to achieve an optimal state of readiness. He believes "the critical factors for economic and security stability in the twenty-first century are energy, water, and the environment. These three factors need to be balanced for people to achieve a reasonable quality of life. When they are not in balance, people live in poverty, suffer high death rates, or move toward armed conflict."

The need for water illustrates the consequences of imbalance. "When water is scarce, people move until they can find adequate supply," he said. "As climate change causes shifts in accessibility to water, we observe large movements of refugees and emigration."

He said Africa offers prime examples of this, and referenced a passage from the book Transboundary Rivers, Sovereignty and Development (Anthony Turton, Peter Ashton, and Eugene Cloete, eds.), which states that "there is a vast and growing literature that cites water as a likely cause of wars in the twenty-first century, and the 15 international basins in the Southern African Development Community (SADC) are regularly named as points of tension, second only to the arid and hostile Middle East."

He quoted from a letter written to him by Anthony Turton, a soldier in the war over the Okavong River basin, who wrote that "to serve one's country on the field of battle is truly noble, but to serve as a peace-builder is truly great." Turton also wrote that in his new role of restoring river basins, he has "found personal peace."

Gen. Kern also cited the late Nobel Laureate, Dr. Rick Smalley, of Rice University, who often lectured on the world's top 10 problems. Smalley listed energy, water, food, and the environment at the top of his list.

"While the military community has not focused on these issues, we often find ourselves responding to a crisis created by the loss of these staples, or by a conflict over claims to one or more of them," Gen. Kern said. "In my view, therefore, military planning should view climate change as a threat to the balance of energy access, water supplies, and a healthy environment, and it should require a response. Responding after the fact with troops—after a crisis occurs—is one kind of response. Working to delay these changes—to accommodate a balance among these staples—is, of course, another way."

"Military planning should view climate change as a threat to the balance of energy access, water supplies, and a healthy environment, and it should require a response."

DIRECT IMPACTS ON MILITARY SYSTEMS, INFRASTRUCTURE, AND OPERATIONS

DIRECT IMPACTS ON MILITARY SYSTEMS, INFRASTRUCTURE, AND OPERATIONS

Climate change will stress the U.S. military by affecting weapons systems and platforms, bases, and military operations. It also presents opportunities for constructive engagement.

WEAPONS SYSTEMS AND PLATFORMS

Operating equipment in extreme environmental conditions increases maintenance requirements—at considerable cost—and dramatically reduces the service life of the equipment. In Iraq, for instance, sandstorms have delayed or stopped operations and inflicted tremendous damage to equipment. In the future, climate change—whether hotter, drier, or wetter—will add stress to our weapons systems.

A stormier northern Atlantic would have implications for U.S. naval forces [34]. More storms and rougher seas increase transit times, contribute to equipment fatigue and hamper flight operations. Each time a hurricane approaches the U.S. East Coast, military aircraft move inland and Navy ships leave port. Warmer temperatures in the Middle East could make operations there even more difficult than they are today. A Center for Naval Analyses study showed that the rate at which U.S. carriers could launch aircraft was limited by the endurance of the flight deck crew during extremely hot weather [34].

BASES THREATENED BY RISING SEA LEVELS

During the Cold War, the U.S. established and maintained a large number of bases throughout the world. U.S. bases abroad are situated to provide a worldwide presence and maximize our ability to move aircraft and personnel. Climate change could compromise some of those bases. For example, the highest point of Diego Garcia, an atoll in the southern Indian Ocean that serves as a major logistics hub for U.S. and British forces in the Middle East, is only a few feet above sea level. As sea level rises, facilities there will be lost or will have to relocated. Although the consequences to military readiness are not insurmountable, the loss of some forward bases would require longer range lift and strike capabilities and would increase the military's energy needs.

Closer to home, military bases on the eastern coast of the United States are vulnerable to hurricanes and other extreme weather events. In 1992, Hurricane Andrew ravaged Homestead Air Force Base in Florida so much that it never reopened; in 2004 Hurricane Ivan knocked out Naval Air Station Pensacola for almost a year. Increased storm activity or sea level rise caused by future climate change could threaten or destroy essential base infrastructure. If key military bases are degraded, so, too, may be the readiness of our forces.

Climate change—whether hotter, drier, or wetter—will add stress to our weapons systems.

MILITARY OPERATIONS

Severe weather has a direct effect on military readiness. Ships and aircraft operations are made more difficult; military personnel themselves must evacuate or seek shelter. As retired

Army Gen. Paul Kern explained of his time dealing with hurricanes in the U.S. Southern Command: "A major weather event becomes a distraction from your ability to focus on and execute your military mission."

In addition, U.S. forces may be required to be more engaged in stability operations in the future as climate change causes more frequent weather disasters such as hurricanes, flash floods, and extended droughts.

THE ARCTIC: A REGION OF PARTICULAR CONCERN

A warming Arctic holds great implications for military operations. The highest levels of planetary warming observed to date have occurred in the Arctic, and projections show the high northern latitudes warming more than any other part of the earth over the coming century. The Arctic, often considered to be the proverbial "canary" in the earth climate system, is showing clear signs of stress [33].

The U.S. Navy is concerned about the retreat and thinning of the ice canopy and its implications for naval operations. A 2001 Navy study concluded that an ice-free Arctic will require an "increased scope of naval operations" [35]. That increased scope of operations will require the Navy to consider weapon system effectiveness and various other factors associated with operating in this environment. Additionally, an Arctic with less sea ice could bring more competition for resources, as well as more commercial and military activity that could further threaten an already fragile ecosystem.

As extreme weather events becomes more common, so do the threats to our national electricity supply.

DEPARTMENT OF DEFENSE ENERGY SUPPLIES ARE VULNERABLE TO EXTREME WEATHER

The DoD is almost completely dependent on electricity from the national grid to power critical missions at fixed installations and on petroleum to sustain combat training and operations. Both sources of energy and their distribution systems are susceptible to damage from extreme weather.

The national electric grid is fragile and can be easily disrupted. Witness the Northeast Blackout of 2003, which was caused by trees falling onto power lines in Ohio. It affected 50 million people in eight states and Canada, took days to restore, and caused a financial loss in the United States estimated to be between $4 billion and $10 billion [36]. People lost water supplies, transportation systems, and communications systems (including Internet and cell phones). Factories shut down, and looting occurred.

As extreme weather events becomes more common, so do the threats to our national electricity supply.

One approach to securing power to DoD installations for critical missions involves a combination of aggressively applying energy efficiency technologies to reduce the critical load (more mission, less energy); deploying renewable energy sources; and "islanding" the installation from the national grid. Islanding allows power generated on the installations to flow two ways—onto the grid when there is excess production and from the grid when the load exceeds local generation. By pursuing these actions to improve resiliency of mission, DoD would become an early adopter of technologies that would help transform the grid, reduce our load, and expand the use of renewable energy.

For deployed systems, the DoD pays a high price for high fuel demand. In Iraq, significant combat forces are dedicated to moving fuel and protecting fuel supply lines. The fuel delivery situation on the ground in Iraq is so limited

that that the Army has established a "Power Surety Task Force" to help commanders of forward operating bases cut the number of fuel convoys by using energy more efficiently. Maj. Gen. Richard Zilmer, USMC, commander of the multinational force in the Anbar province of Iraq, asked for help in August 2006. His request was for renewable energy systems. According to Gen. Zilmer, "reducing the military's dependence on fuel for power generation could reduce the number of road-bound convoys … 'Without this solution [renewable energy systems], personnel loss rates are likely to continue at their current rate. Continued casualty accumulation exhibits potential to jeopardize mission success….'" Along a similar vein, Lt. Gen. James Mattis, while commanding general of the First Marine Division during Operation Iraqi Freedom, urged: "Unleash us from the tether of fuel."

Energy-efficiency technologies, energy conservation practices and renewable energy sources are the tools forward bases are using to stem their fuel demand and reduce the "target signature" of their fuel convoys.

Numerous DoD studies dating from the 2001 Defense Science Board report "More Capable Warfighting Through Reduced Fuel Burden" have concluded that high fuel demand by combat forces detracts from our combat capability, makes our forces more vulnerable, diverts combat assets from offense to supply line protection, and increases operating costs. Nowhere are these problems more evident than in Iraq, where every day 2.4 million gallons of fuel is moved through dangerous territory, requiring protection by armored combat vehicles and attack helicopters [37].

DoD planners estimate that it costs $15 to deliver one gallon of fuel from its commercial supplier to the forward edge of the battlefield and about $26 to deliver a gallon of fuel from an airborne tanker, not counting the tanker aircraft cost. Furthermore, DoD's procedures for determining the types of systems it needs do not take these fuel burden considerations into account. DoD should require more efficient combat systems and should include the actual cost of delivering fuel when evaluating the advantages of investments in efficiency [38, 39].

… reducing the military's dependence on fuel for power generation could reduce the number of road-bound convoys …

DoD should have an incentive to accurately account for the cost of moving and protecting fuel and to invest in technologies that will provide combat power more efficiently. Deploying technologies that make our forces more efficient also reduces greenhouse gas emissions. The resulting technologies would make a significant contribution to the vision President Bush expressed in his State of the Union speech when he said, "America is on the verge of technological breakthroughs that will … help us to confront the serious challenge of global climate change."

Given the human and economic cost of delivering fuel to combat forces and the almost total dependence on the electric grid for critical missions, DoD has strong operational economic incentives to aggressively pursue energy efficiency in its combat systems and its installations. By investing at levels commensurate with its interests, DoD would become an early adopter of innovative technologies and could stimulate others to follow.

ENGAGEMENT OPPORTUNITIES

Climate change threats also create opportunities for constructive engagement such as stability operations and capacity building. The U.S. military helped deliver relief to the victims of

the 2005 Indian Ocean tsunami because it is the only institution capable of rapidly delivering personnel and materiel anywhere in the world on relatively short notice. DoD Directive 3000.05, issued in 2006, provides the mandate to conduct military and civilian stability operations in peacetime as well as conflict to maintain order in states and regions. The Combatant Command's Theater Security Cooperation Program, which seeks to engage regional states, could be easily focused on climate change mitigation and executed in concert with other U.S. agencies through U.S. embassy country teams. The objective would be to build the host nation military's capabilities and capacity to support civilian government agencies. It also enhances good governance and promotes stability, making failed states and terrorist incursion less likely. Because many climate change problems cross borders, it could also promote regional communication and cooperation.

If the frequency of natural disasters increases with climate change, future military and political leaders may face hard choices about where and when to engage. Deploying troops affects readiness elsewhere; choosing not to may affect alliances. And providing aid in the aftermath of a catastrophic event or natural disaster can help retain stability in a nation or region, which in turn could head off U.S. military engagement in that region at a later date.

ADMIRAL FRANK "SKIP" BOWMAN, USN (Ret.)

Former Director, Naval Nuclear Propulsion Program; Former Deputy Administrator-Naval Reactors, National Nuclear Security Administration

ON CLIMATE CHANGE, ENERGY, AND NATIONAL SECURITY

Adm. Bowman's more than thirty-eight years of naval service in the nuclear submarine community lead him to these thoughts: "Our nuclear submarines operate in an unforgiving environment. Our Navy has recognized this environment and has mitigated the risk of reactor and undersea operations through a combination of: a) careful selection of motivated, intelligent people whom we train and qualify to the highest standards; b) rigorous quality assurance of component design and manufacturing; c) verbatim compliance with strict rules of operation; d) routine examination of all aspects of reactor and submarine operations; and, e) a constant sharing of the lessons we learn through these processes. These components lead to a defense in depth against a very low probability, but high consequence event. We should begin planning for a similar approach in dealing with potential climate change effects on our national security."

Adm. Bowman notes that today, a raging debate is underway over a potential set of climate-induced global changes that could have a profound impact on America's national security interests. Our Military Advisory Board has heard the arguments, some depicting near-doomsday scenarios of severe weather and oceanic changes exacerbated by man-made emissions of greenhouse gases to our environment, others depicting a much less severe outcome as merely one in many observed cyclic weather patterns over time, with virtually no man-made component.

Adm. Bowman concludes that regardless of the probability of the occurrence, the projected weather-driven global events could be dire and could adversely affect our national security and military options significantly. He therefore argues that the prudent course is to begin planning, as we have in submarine operations, to develop a similar defense in depth that would reduce national security risks even if this is a low probability event, given the potential magnitude of the consequences. He feels that as the debate over cause, effect, and magnitude continues, we in the military should begin now to take action to provide a resilient defense against the effects of severe climate change, not only within our own borders, but also to provide resiliency to those regions of unrest and stress that already are threatening our national security today.

> "Our nuclear submarines operate in an unforgiving environment. Our Navy has recognized this environment and has mitigated the risk. … We should begin planning for a similar approach in dealing with potential climate change effects on our national security."

The admiral further believes that "our national security is inextricably linked to our country's energy security." Thoughtful national policy is required as we debate a correct course of future energy policy. International participation is necessary for this global issue. Adm. Bowman firmly believes that "energy and economic security—key components of our national security—must be undergirded by alternative forms of energy available indigenously and from countries whose values are not at odds with our own. As our economy and GDP have grown, so have our energy needs. This demand for energy strains available supplies: energy sources used for one purpose, such as electricity generation, are not available for other needs. Natural gas used for electricity is not available as feedstock for many industries that depend on it, like the chemical industry, the fertilizer industry, and the plastics industry. Short-term decisions made over the past decade to build cheap gas generation placed an unsustainable demand on natural gas and has resulted in hundreds of thousands of U.S. jobs moving offshore."

Adm. Bowman warns that this interdependence between energy policy and national security must be viewed over the long haul as the country addresses global climate change. "Coal and nuclear electricity generation remain the obvious choices for new U.S. generation. However, to meet the concerns over measured and measurable increases in CO_2 concentrations in our atmosphere and their potential effect on climate, the country, as a matter of national urgency, must develop the technologies to capture and sequester CO_2 from coal generation. This technology is not available today on a commercial scale, and the lead time for its development is measured in tens of years, not months.

Therefore, Adm. Bowman argues, we should begin developing plans to shore up our own defenses against the potentially serious effects of climate, regardless of the probability of that occurrence, while making more resilient those countries ill-prepared today to deal with that potential due to disease, poor sanitation, lack of clean water, insufficient electricity, and large coastal populations. In doing so, these plans must recognize the interdependency of energy and security.

WEATHER AND WARFARE

An increase in extreme weather can make the most demanding of tasks even more challenging.

Increases in global temperatures will increase the likelihood of extreme weather events, including temperature extremes, precipitation events, and intense tropical cyclone activity [7].

With this in mind, we ask the obvious: How does extreme weather affect warfare?

The impacts are significant. There are countless historical examples of how weather events have affected the outcome of a conflict.

- Typhoons (Divine Wind) twice saved Japan from invasion by Kublai Khan and his Mongol horde.
- North Sea gales badly battered the Spanish Armada in 1588 when Sir Francis Drake defeated it, saving England from invasion.

An increase in extreme weather can make the most demanding of tasks even more challenging.

- The severe and unpredictable Russian winter has defeated three invading armies: Charles XII of Sweden in 1708, Napoleon in 1812 and Hitler in 1941.
- During the American Revolution, George Washington would have been surrounded at the Battle of Long Island had adverse winds not prevented the British from landing and cutting him off.
- Hardships from a severe drought in 1788 are thought to be the spark that caused the French Revolution.
- Napoleon was defeated at the Battle of Waterloo in large part because a torrential downpour obscured visibility and delayed the French attack.

Though technology allows us to overcome many obstacles, weather still poses great threats to successful military operations on the land, sea, or in the air.

- During World War II, Typhoon Cobra capsized three destroyers, a dozen more ships were seriously damaged and 793 men died. This natural disaster, called the Navy's worst defeat in open seas in World War II, killed nearly a third as many as in the attack on Pearl Harbor.
- Many know that D-Day awaited the right weather before it began. Many don't know that a freak storm destroyed floating docks shortly beforehand, almost canceling the invasion.
- During the 1991 Persian Gulf War, heavy winds prevented Saddam Hussein from launching Scud missiles at Israel and coalition forces.
- During the Persian Gulf War and the Iraq war, sandstorms delayed or stopped operations and did tremendous damage to equipment. In March 2003, the entire invasion of Iraq was stalled for three days because of a massive sandstorm.

These examples are not meant to suggest that weather changes will put the American military at a disadvantage. They do, however, help illustrate ways in which climate change can add new layers of complexity to military operations. An increase in extreme weather can make the most demanding of tasks even more challenging.

FINDINGS AND RECOMMENDATIONS

FINDINGS AND RECOMMENDATIONS

This report is intended to advance a more rigorous national and international dialogue on the impacts of climate change on national security. We undertook this analysis for the primary purpose of presenting the problem and identifying first-order solutions. We therefore keep this list of findings and recommendations intentionally brief. We hope it will stimulate further discussion by the public and a more in-depth analysis by those whose job it is to plan for our national security.

FINDINGS

Finding 1:
Projected climate change poses a serious threat to America's national security.

Potential threats to the nation's security require careful study and prudent planning—to counter and mitigate potential detrimental outcomes. Based on the evidence presented, the Military Advisory Board concluded that it is appropriate to focus on the serious consequences to our national security that are likely from unmitigated climate change. In already-weakened states, extreme weather events, drought, flooding, sea level rise, retreating glaciers, and the rapid spread of life-threatening diseases will themselves have likely effects: increased migrations, further weakened and failed states, expanded ungoverned spaces, exacerbated underlying conditions that terrorist groups seek to exploit, and increased internal conflicts. In developed countries, these conditions threaten to disrupt economic trade and introduce new security challenges, such as increased spread of infectious disease and increased immigration.

Overall, climate change has the potential to disrupt our way of life and force changes in how we keep ourselves safe and secure by adding a new hostile and stressing factor into the national and international security environment.

Finding 2:
Climate change acts as a threat multiplier for instability in some of the most volatile regions of the world.

Many governments in Asia, Africa, and the Middle East are already on edge in terms of their ability to provide basic needs: food, water, shelter and stability. Projected climate change will exacerbate the problems in these regions and add to the problems of effective governance. Unlike most conventional security threats that involve a single entity acting in specific ways at different points in time, climate change has the potential to result in multiple chronic conditions, occurring globally within the same time frame. Economic and environmental conditions in these already fragile areas will further erode as food production declines, diseases increase, clean water becomes increasingly scarce, and populations migrate in search of resources. Weakened and failing governments, with an already thin margin for survival, foster the conditions for internal conflict, extremism, and movement toward increased authoritarianism and radical ideologies. The U.S. may be drawn more frequently into these situations to help to provide relief, rescue, and logistics, or to stabilize conditions before conflicts arise.

Because climate change also has the potential to create natural and humanitarian disasters on a scale far beyond those we see today, its consequences will likely foster political instability

where societal demands exceed the capacity of governments to cope. As a result, the U.S. may also be called upon to undertake stability and reconstruction efforts once a conflict has begun.

Finding 3:
Projected climate change will add to tensions even in stable regions of the world.

Developed nations, including the U.S. and Europe, may experience increases in immigrants and refugees as drought increases and food production declines in Africa and Latin America. Pandemic disease caused by the spread of infectious diseases and extreme weather events and natural disasters, as the U.S. experienced with Hurricane Katrina, may lead to increased domestic missions for U.S. military personnel—lowering troop availability for other missions and putting further stress on our already stretched military, including our Guard and Reserve forces.

Our current National Security Strategy, released in 2002 and updated in 2006, refers to globalization and other factors that have changed the security landscape. It cites, among other factors, "environmental destruction, whether caused by human behavior or cataclysmic mega-disasters such as floods, hurricanes, earthquakes or tsunamis. Problems of this scope may overwhelm the capacity of local authorities to respond, and may even overtax national militaries, requiring a larger international response. These challenges are not traditional national security concerns, such as the conflict of arms or ideologies. But if left unaddressed they can threaten national security."

In addition to acknowledging the national security implications of extreme weather and other environmental factors, the National Security Strategy indicates that the U.S. may have to intervene militarily, though it clearly states that dealing with the effects of these events should not be the role of the U.S. military alone.

Despite the language in our current National Security Strategy, there is insufficient planning and preparation on the operational level for future environmental impacts. However, such planning can readily be undertaken by the U.S. military in cooperation with the appropriate civilian agencies, including the State Department, the United States Agency for International Development, and the intelligence community.

Finding 4:
Climate change, national security, and energy dependence are a related set of global challenges.

As President Bush noted in his 2007 State of the Union speech, dependence on foreign oil leaves us more vulnerable to hostile regimes and terrorists, and clean domestic energy alternatives help us confront the serious challenge of global climate change. Because the issues are linked, solutions to one affect the others. Technologies that improve energy efficiency also reduce carbon intensity and carbon emissions.

RECOMMENDATIONS

Recommendation 1:

The national security consequences of climate change should be fully integrated into national security and national defense strategies.

As military leaders, we know we cannot wait for certainty. Failing to act because a warning isn't precise is unacceptable. Numerous parts of the U.S. government conduct analyses of various aspects of our national security situation covering different time frames and at varying levels of detail. These analyses should consider the consequences of climate change.

The intelligence community should incorporate climate consequences into its National Intelligence Estimate. The National Security Strategy should directly address the threat of climate change to our national security interests. It also should include an assessment of the national security risks of climate change and direct the U.S. government to take appropriate preventive efforts now.

The National Security Strategy and the National Defense Strategy should include appropriate guidance to military planners to assess risks to current and future missions of projected climate change, guidance for updating defense plans based on these assessments, and the capabilities needed to reduce future impacts. This guidance should include appropriate revisions to defense plans, including working with allies and partners, to incorporate climate mitigation strategies, capacity building, and relevant research and development.

The next Quadrennial Defense Review should examine the capabilities of the U.S. military to respond to the consequences of climate change, in particular, preparedness for natural disasters from extreme weather events, pandemic disease events, and other missions the U.S. military may be asked to support both at home and abroad. The capability of the National Guard and Reserve to support these missions in the U.S. deserve special attention, as they are already stretched by current military operations.

The U.S. should evaluate the capacity of the military and other institutions to respond to the consequences of climate change. All levels of government—federal, state, and local—will need to be involved in these efforts to provide capacity and resiliency to respond and adapt.

Scientific agencies such as the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA) and the United States Geologic Survey (USGS) should also be brought into the planning processes. The defense and intelligence communities should conduct research on global climate and monitor global climate signals to understand their national security implications. Critical security-relevant knowledge about climate change has come from the partnership between environmental scientists and the defense and intelligence communities. That partnership, vibrant in the 1990s, should be revived.

Recommendation 2:

The U.S. should commit to a stronger national and international role to help stabilize climate changes at levels that will avoid significant disruption to global security and stability.

All agencies involved with climate science, treaty negotiations, energy research, economic policy, and national security should participate in an interagency process to develop a deliberate policy to reduce future risk to national security

from climate change. Actions fall into two main categories: mitigating climate change to the extent possible by setting targets for long-term reductions in greenhouse gas emissions and adapting to those effects that cannot be mitigated. Since this is a global problem, it requires a global solution with multiple relevant instruments of government contributing.

While it is beyond the scope of this study to recommend specific solutions, the path to mitigating the worst security consequences of climate change involves reducing global greenhouse gas emissions. Achieving this outcome will also require cooperation and action by many agencies of government.

Recommendation 3:

The U.S. should commit to global partnerships that help less developed nations build the capacity and resiliency to better manage climate impacts.

Some of the nations predicted to be most affected by climate change are those with the least capacity to adapt or cope. This is especially true in Africa, which is becoming an increasingly important source of U.S. oil and gas imports. Already suffering tension and stress resulting from weak governance and thin margins of survival due to food and water shortages, Africa would be yet further challenged by climate change. The proposal by DoD to establish a new Africa Command reflects Africa's emerging strategic importance to the U.S., and with humanitarian catastrophes already occurring, a worsening of conditions could prompt further U.S. military engagement. As a result, the U.S. should focus on enhancing the capacity of weak African governments to better cope with societal needs and to resist the overtures of well-funded extremists to provide schools, hospitals, health care, and food.

The U.S. should target its engagement efforts, through regional military commanders and other U.S. officials, toward building capacity to mitigate destabilizing climate impacts. For example, regional commanders have routinely used such engagement tools as cooperation on disaster preparedness to help other nations develop their own ability to conduct these efforts.

Cooperative engagement has the potential to reduce the likelihood of war fighting. As Gen. Anthony C. (Tony) Zinni (Ret.) has said: "When I was commander of CENTCOM, I had two missions: engagement and war fighting: If I do engagement well, I won't have to do war fighting." The U.S. cannot do this alone; nor should the military be the sole provider of such cooperative efforts. But the U.S. can lead by working in cooperation with other nations. Such efforts promote greater regional cooperation, confidence building and the capacity of all elements of national influence to contribute to making nations resilient to the impacts of climate change.

Recommendation 4:

The Department of Defense should enhance its operational capability by accelerating the adoption of improved business processes and innovative technologies that result in improved U.S. combat power through energy efficiency.

DoD should require more efficient combat systems and should include the actual cost of delivering fuel when evaluating the advantages of investments in efficiency. Numerous DoD studies dating from the 2001 Defense Science Board report "More Capable Warfighting Through Reduced Fuel Burden" have concluded that high fuel demand by combat forces detracts from our combat capability, makes our forces more vulnerable, diverts combat assets from offense to supply line protection, and increases operating costs. Nowhere are these problems more evident than

in Iraq, where every day 2.4 million gallons of fuel is moved through dangerous territory, requiring protection by armored combat vehicles and attack helicopters.

Deploying technologies that make our forces more efficient also reduces greenhouse gas emissions. DoD should invest in technologies that will provide combat power more efficiently. The resulting technologies would make a significant contribution to the vision President Bush expressed in his State of the Union when he said, "America is on the verge of technological breakthroughs that … will help us to confront the serious challenge of global climate change."

Recommendation 5:

DoD should conduct an assessment of the impact on U.S. military installations worldwide of rising sea levels, extreme weather events, and other possible climate change impacts over the next 30 to 40 years.

As part of prudent planning, DoD should assess the impact of rising sea levels, extreme weather events, drought, and other climate impacts on its infrastructure so its installations and facilities can be made more resilient.

Numerous military bases, both in the U.S. and overseas, will be affected by rising sea levels and increased storm intensity. Since World War II, the number of overseas bases has diminished, and since the Base Realignment and Closure process began the number of stateside bases has also declined. This makes those that remain more critical for training and readiness, and many of them are susceptible to the effects of climate change. For example, the British Indian Ocean Territory island of Diego Garcia, an atoll in the southern Indian Ocean, is a major logistics hub for U.S. and British forces in the Middle East. It is also only a few feet above sea level at its highest point. The consequences of the losing places like Diego Garcia are not insurmountable, but are significant and would require advance military planning. The Kwajalein is a low-lying atoll, critical for space operations and missile tests. Guam is the U.S. gateway to Asia and could be moderately or severely affected by rising sea levels. Loss of some forward bases would require us to have longer range lift and strike capabilities and possibly increase our military's energy needs.

Military bases on the eastern coast of the U.S. are vulnerable to hurricanes and other extreme weather events. In 1992, Hurricane Andrew virtually destroyed Homestead Air Force Base in Florida. In 2004 Hurricane Ivan knocked out Naval Air Station Pensacola for almost a year. Most U.S. Navy and Coast Guard bases are located on the coast, as are most U.S. Marine Corps locations. The Army and Air Force also operate bases in low-lying or coastal areas. One meter of sea level rise would inundate much of Norfolk, Virginia, the major East Coast hub for the U.S. Navy. As key installations are degraded, so is the readiness of our forces.

APPENDICES

APPENDIX 1:
BIOGRAPHIES, MILITARY ADVISORY BOARD MEMBERS

ADMIRAL FRANK "SKIP" BOWMAN, USN (Ret.)

Former Director, Naval Nuclear Propulsion Program;
Former Deputy Administrator-Naval Reactors, National Nuclear Security Administration

Admiral Skip Bowman was director, Naval Nuclear Propulsion, Naval Sea Systems Command. Prior assignments include deputy administrator for naval reactors in the Naval Nuclear Security Administration, Department of Energy; chief of naval personnel; and director for Political-Military Affairs and deputy director of naval operations on the Joint Staff.

He was commissioned following graduation in 1966 from Duke University. In 1973, he completed a dual master's program in nuclear engineering and naval architecture/marine engineering at the Massachusetts Institute of Technology and was elected to the Society of Sigma Xi. Admiral Bowman has been awarded the honorary degree of Doctor of Humane Letters from Duke University.

In 2005, Admiral Bowman was named president and CEO of the Nuclear Energy Institute. NEI is the policy organization for the commercial nuclear power industry. In 2006, Admiral Bowman was made an Honorary Knight Commander of the Most Excellent Order of the British Empire in recognition of his commitment in support of the Royal Navy submarines program.

LIEUTENANT GENERAL LAWRENCE P. FARRELL JR., USAF (Ret.)

Former Deputy Chief of Staff for Plans and Programs, Headquarters U.S. Air Force

Prior to his retirement from the Air Force in 1998, General Farrell served as the deputy chief of staff for plans and programs, Headquarters U.S. Air Force, Washington, D.C. He was responsible for planning, programming and manpower activities within the corporate Air Force and for integrating the Air Force's future plans and requirements to support national security objectives and military strategy.

Previous positions include vice commander, Air Force Materiel Command, Wright-Patterson Air Force Base, Ohio, and deputy director, Defense Logistics Agency, Arlington, Virginia. He also served as deputy chief of staff for plans and programs at Headquarters U.S. Air Force in Europe. A command pilot with more than 3,000 flying hours, he flew 196 missions in Southeast Asia and commanded the 401st Tactical Fighter Wing, Torrejon Air Base, Spain. He was also the system program manager for the F-4 and F-16 weapons systems with the Air Force Logistics Command, Hill Air Force Base, Utah.

General Farrell is a graduate of the Air Force Academy with a bachelor's degree in engineering and an MBA from Auburn University. Other education includes the National War College and the Harvard Program for Executives in National Security.

General Farrell became the president and CEO of the National Defense Industrial Association in September 2001.

VICE ADMIRAL PAUL G. GAFFNEY II, USN (Ret.)

Former President, National Defense University; Former Chief of Naval Research and Commander, Navy Meteorology and Oceanography Command

Admiral Gaffney has been the Naval Research Laboratory commander and worked in a number of other science and oceanography administration assignments. He served as the 10th president of the National Defense University, and before that as chief of naval research. He also was the senior uniformed oceanography specialist in the Navy, having served as commander of the Navy Meteorology and Oceanography Command from 1994 to 1997. He was appointed by President George W. Bush to the Ocean Policy Commission and served during its full tenure from 2001 to 2004. He served in Japan, Vietnam, Spain, and Indonesia, and traveled extensively in official capacities.

He has been recognized with a number of military decorations; the Naval War College's J. William Middendorf Prize for Strategic Research, the Outstanding Public Service Award from the Virginia Research and Technology Consortium, and the Potomac Institute's Navigator Award. He has served on several boards of higher education and was a member of the Ocean Studies Board of the National Re-search Council from 2003 to 2005. He has been selected to be a public trustee for the New Jersey Consortium and chaired the Governor's Commission to Protect and Enhance New Jersey's Military Bases.

He graduated from the U.S. Naval Academy in 1968 and has a master's degree in mechanical engineering (ocean) from Catholic University and a master's of business administration from Jacksonville University.

Admiral Gaffney is currently the president of Monmouth University in West Long Branch, New Jersey.

GENERAL PAUL J. KERN, USA (Ret.)

Former Commanding General, U.S. Army Materiel Command

General Kern was commanding general, Army Materiel Command from 2001 to 2004, and senior adviser for Army Research, Development, and Acquisition from 1997 to 2001.

General Kern had three combat tours. Two were in Vietnam as a platoon leader and troop commander. His third was as commander of the Second Brigade of the 24th Infantry in Desert Shield/Desert Storm. The Second Brigade played a pivotal role in the historic attack on the Jalibah Airfield, which allowed the Twenty-Fourth Infantry Division to secure key objectives deep inside of Iraq. He also served as the assistant division commander of the division after its redeployment to Fort Stewart, Georgia.

General Kern's assignments included senior military assistant to Secretary of Defense William Perry. During that period, he accompanied Secretary Perry to more than 70 countries, meeting numerous heads of state, foreign ministers, and international defense leaders. He participated in U.S. operations in Haiti, Rwanda, Zaire, and the Balkans, and helped promote military relations in Central and Eastern Europe, South America, China, and the Middle East.

General Kern received the Defense and Army Distinguished Service Medals, Silver Star, Defense Superior Service Medal, Legion of Merit, two Bronze Star Medals for valor, three Bronze Star Medals for service in combat, and three Purple Hearts. He has been awarded the Society of Automotive Engineers Teeter Award, the Alumni Society Medal from the University of Michigan, and the German Cross of Honor of the Federal Armed Forces (Gold).

A native of West Orange, New Jersey, General Kern was commissioned as an armor lieutenant following graduation from West Point in 1967. He holds master's degrees in both civil and mechanical engineering from the University of Michigan, and he was a Senior Security Fellow at the John F. Kennedy School of Government at Harvard University.

He is an adviser to Battelle Memorial Institute and holds the Chair of the Class of 1950 for Advanced Technology at the United States Military Academy.

General Kern is a member of the Cohen Group, which provides strategic advice and guidance to corporate clients.

ADMIRAL T. JOSEPH LOPEZ, USN (Ret.)

Former Commander-in-Chief, U.S. Naval Forces Europe and of Allied Forces, Southern Europe

Admiral Lopez's naval career included tours as commander-in-chief of U.S. Naval Forces Europe and commander-in-chief, Allied Forces, Southern Europe from 1996 to 1998. He commanded all U.S. and Allied Bosnia Peace Keeping Forces in 1996; he served as deputy chief of naval operations for resources, warfare requirements and assessments in 1994 to 1996,; commander of the U.S. Sixth Fleet in 1992 to 1993; and senior military assistant to the secretary of defense in 1990 to 1992.

Admiral Lopez was awarded numerous medals and honors, including two Defense Distinguished Service Medals, two Navy Distinguished Service Medals, three Legion of Merits, the Bronze Star (Combat V), three Navy Commendation Medals (Combat V) and the Combat Action Ribbon. He is one of just two flag officers in the history of the U.S. Navy to achieve four-star rank after direct commission from enlisted service.

He holds a bachelor's degree (cum laude) in international relations and a master's degree in management. He has been awarded an honorary doctorate degree in humanities from West Virginia Institute of Technology and an honorary degree in information technology from Potomac State College of West Virginia University.

Admiral Lopez is president of Information Manufacturing Corporation (IMC), an information technology service integrator with major offices in Manassas, Virginia, and Rocket Center, West Virginia.

ADMIRAL DONALD L. "DON" PILLING, USN (Ret.)

Former Vice Chief of Naval Operations

Admiral Pilling assumed duties as the 30th vice chief of naval operations, the Navy's chief operating officer and second-ranking officer, from November 1997 until his retirement from active service in October 2000.

Ashore, he was assigned to a variety of defense resources and planning billets. In his earlier career, he served four years in program analysis and evaluation in the Office of the Secretary of Defense. As a more senior officer, he served as a Federal Executive Fellow at the Brookings Institution in 1985-86. A member of the National Security Council staff from 1989 until 1992, Admiral Pilling was selected to flag rank in 1989 while serving there. From 1993 to 1995, he was the director for programming on the staff of the Chief of Naval Operations, and later served as the Navy's chief financial officer from 1996 to 1997.

Admiral Pilling also commanded a warship; a destroyer squadron; a cruiser destroyer group; a carrier battle group; the U.S. Sixth Fleet; and NATO's Naval Striking and Support Forces Southern Europe.

Admiral Pilling has a bachelor's degree in engineering from the U.S. Naval Academy and a doctorate in mathematics from the University of Cambridge.

He served as vice president for strategic planning at Battelle Memorial Institute and became president and CEO of LMI, a nonprofit research organization, in 2002.

ADMIRAL JOSEPH W. PRUEHER, USN (Ret.)

Former Commander-in-Chief of the U.S. Pacific Command (PACOM) and Former U.S. Ambassador to China

Admiral Prueher completed thirty-five years in the United States Navy in 1999. His last command was commander-in-chief of the U.S. Pacific Command (CINCPAC); the largest military command in the world, spanning over half the earth's surface and including more than 300,000 people. Admiral Prueher also served as ambassador to China from 1999 to 2001. He served two presidents and was responsible for directing, coordinating, and managing the activities of all United States executive branch activities in China.

From 1989 through 1995, Admiral Prueher served as commandant at the U.S. Naval Academy at Annapolis; commander of Carrier Battle Group ONE based in San Diego; commander of the U.S. Mediterranean Sixth Fleet and of NATO Striking Forces based in Italy; and as vice chief of naval operations in the Pentagon.

Admiral Prueher graduated from Montgomery Bell Academy in Nashville, Tennessee, and then graduated with distinction in 1964 from the U.S. Naval Academy, later receiving a master's degree in international relations from George Washington University. He is also a graduate of the Naval War College in Newport, Rhode Island. In addition to co-authoring the Performance Testing manual used by naval test pilots for many years, he has published numerous articles on leadership, military readiness, and Pacific region security issues. Admiral Prueher has received multiple military awards for combat flying as well as naval and Joint Service. The governments of Singapore, Thailand, Japan, Korea, the Philippines, Indonesia, and Australia have decorated him.

Admiral Prueher is a consulting professor at Stanford University's Institute of International Studies and senior adviser on the Preventive Defense Project. He is on the board of trustees of the Nature Conservancy of Virginia.

GENERAL GORDON R. SULLIVAN, USA (Ret.)

Chairman, Military Advisory Board
Former Chief of Staff, U.S. Army

General Sullivan was the 32nd chief of staff—the senior general officer in the Army and a member of the Joint Chiefs of Staff. As the chief of staff of the Army, he created the vision and led the team that helped transition the Army from its Cold War posture.

His professional military education includes the U.S. Army Armor School Basic and Advanced Courses, the Command and General Staff College, and the Army War College. During his Army career, General Sullivan also served as vice chief of staff in 1990 to 1991; deputy chief of staff for operations and plans in 1989 to 1990; commanding general, First Infantry Division (Mechanized), Fort Riley, Kansas, in 1988 to 1989; deputy commandant, U.S. Army Command and General Staff College, Fort Leavenworth, Kansas, in 1987 to 1988; and assistant commandant, U.S. Army Armor School, Fort Knox, Kentucky, from 1983 to 1985. His overseas assignments included four tours in Europe, two in Vietnam and one in Korea. He served as chief of staff to Secretary of Defense Dick Cheney in the administration of President George H.W. Bush.

General Sullivan was commissioned a second lieutenant of armor and awarded a bachelor of arts degree in history from Norwich University in 1959. He holds a master's degree in political science from the University of New Hampshire.

General Sullivan is the president and chief operating officer of the Association of the United States Army, headquartered in Arlington, Virginia. He assumed his current position in 1998 after serving as president of Coleman Federal in Washington, D.C.

VICE ADMIRAL RICHARD H. TRULY, USN (Ret.)

Former NASA Administrator, Shuttle Astronaut and the first Commander of the Naval Space Command

Admiral Truly served as NASA's eighth administrator from 1989 to 1992, and his career in aviation and space programs of the U.S. Navy and NASA spanned 35 years. He retired as a vice admiral after a Navy career of more than thirty years. As a naval aviator, test pilot and astronaut, he logged over 7,500 hours and made over 300 carrier-arrested landings, day and night.

Admiral Truly was the first commander of Naval Space Command from 1983 to 1986 and became the first naval component commander of U.S. Space Command upon its formation in 1984. While still on active duty following the *Challenger* accident, he was called back to NASA as associate administrator for space flight in 1986 and led the accident investigation. He spearheaded the painstaking rebuilding of the space shuttle, including winning approval of President Reagan and the Congress for building of *Endeavor* to replace the lost *Challenger*. In 1989, President Reagan awarded him the Presidential Citizen's Medal.

Truly's astronaut career included work in the Air Force's Manned Orbiting Laboratory program, and NASA's Apollo, Skylab, Apollo-Soyuz and space shuttle programs. He piloted the *747/Enterprise* approach and landing tests in 1977, and lifted off in November 1981 as pilot aboard *Columbia*, the first shuttle to be reflown into space, establishing a world circular orbit altitude record. He commanded *Challenger* in August-September 1983, the first night launch/landing mission of the space shuttle program.

He served as vice president of the Georgia Institute of Technology and director of the Georgia Tech Research Institute (GTRI) from 1992 to 1997. Admiral Truly retired in January 2005 as director of the Department of Energy's National Renewable Energy Laboratory (NREL).

Truly is a member of the National Academy of Engineering. He has previously served on the board of visitors to the U.S. Naval Academy, the Defense Policy Board, the Army Science Board, and the Naval Studies Board. He is a member of the National Research Council Space Studies Board, a trustee of Regis University and the University Corporation for Atmospheric Research, and a member of the advisory committee to the Colorado School of Mines Board of Trustees.

GENERAL CHARLES F. "CHUCK" WALD, USAF (Ret.)

Former Deputy Commander, Headquarters U.S. European Command (USEUCOM)

From 2001 to 2002 General Wald was deputy chief of staff for air and space operations at the Pentagon, and from December 2002 until his retirement in 2006 General Wald was deputy commander, Headquarters U.S. European Command, Stuttgart, Germany. USEUCOM is responsible for all U.S. forces operating across 91 countries in Europe, Africa, Russia, parts of Asia and the Middle East, and most of the Atlantic Ocean.

General Wald commanded the 31st Fighter Wing at Aviano Air Base, Italy, where on Aug. 30, 1995, he led one of the wing's initial strike packages against the ammunition depot at Pale, Bosnia-Herzegovina, in one of the first NATO combat operations. General Wald commanded the Ninth Air Force and U.S. Central Command Air Forces, Shaw Air Force Base, South Carolina, where he led the development of the Afghanistan air campaign for Operation Enduring Freedom, including the idea of embedding tactical air control parties in ground special operations forces. He has combat time as an O-2A forward air controller in Vietnam and as an F-16 pilot flying over Bosnia. The general has served as a T-37 instructor pilot and F-15 flight commander. Other duties include chief of the U.S. Air Force Combat Terrorism Center, support group commander, operations group commander, and special assistant to the chief of staff for National Defense Review. He was also the director of strategic planning and policy at Headquarters U.S. Air Force, and served on the Joint Staff as the vice director for strategic plans and policy.

General Wald is a command pilot with more than 3,600 flying hours, including more than 430 combat hours over Vietnam, Cambodia, Laos, Iraq, and Bosnia. The general earned his commission through the Air Force ROTC program in 1971.

Currently, General Wald serves as president of Wald and Associates, an international management consulting and strategic planning firm, and is an adjunct lecturer at the Atlantic Council. He is also a member of the Bipartisan Policy Center, National Commission on Energy Policy, and the Securing America's Future Energy Commission.

GENERAL ANTHONY C. "TONY" ZINNI, USMC (Ret.)

Former Commander-in-Chief of U.S. Central Command (CENTCOM)

General Zinni's joint assignments included command of U.S. Central Command (CENTCOM), which is responsible for U.S. military assets and operations in the Middle East, Central Asia and East Africa.

General Zinni's joint assignments also include command of a joint task force and he has also had several joint and combined staff billets at task force and unified command levels. He has made deployments to the Mediterranean, the Caribbean, the Western Pacific, Northern Europe, and Korea. He has held numerous command and staff assignments that include platoon, company, battalion, regimental, Marine Expeditionary Unit, and Marine expeditionary force command. His staff assignments included service in operations, training, special operations, counter-terrorism and manpower billets. He has also been a tactics and operations instructor at several Marine Corps schools and was selected as a fellow on the Chief of Naval Operations Strategic Studies Group.

General Zinni joined the Marine Corps in 1961 and was commissioned an infantry second lieutenant in 1965. General Zinni holds a bachelor's degree in economics from Villanova University, a master's in international relations from Salvae Regina College, a master's in management and supervision from Central Michigan University, and honorary doctorates from William and Mary College and the Maine Maritime Academy.

He has worked with the University of California's Institute on Global Conflict and Cooperation, the U.S. Institute of Peace, and the Henry Dunant Centre for Humanitarian Dialogue in Geneva. He is on the International Council at the Joan B. Kroc Institute for Peace and Justice. He is also a Distinguished Advisor at the Center for Strategic and International Studies, a member of the Council on Foreign Relations. He has also been appointed as a member of the Virginia Commission on Military Bases.

General Zinni has co-authored, with Tom Clancy, a New York Times bestseller on his career entitled *Battle Ready*. His book, *The Battle For Peace: A Frontline Vision Of America's Power And Purpose*, was published in 2006.

APPENDIX 2:
CLIMATE CHANGE SCIENCE—A BRIEF OVERVIEW

There is a vast amount of scientific literature on the subject of climate change, and a complete discussion on the current state of the world climate and its deviation from climatological norms could fill volumes. In this appendix we discuss the consensus of the science community on climate change, effects observed thus far, and projections about what may happen in the future.

We have drawn information from the Intergovernmental Panel on Climate Change (IPCC), peer-reviewed scientific literature, and data, reports, and briefings from various respected sources, including the National Academy of Sciences, National Oceanic and Atmospheric Administration, National Air and Space Administration, and the United Kingdom's Hadley Centre for Climate Change

CURRENT CONSENSUS

The IPCC's latest assessment report affirmed the following:

- While natural forces have influenced the earth's climate (and always will), human-induced changes in levels of atmospheric greenhouse gases are playing an increasingly dominant role.
- After considering the influences of the known causes of climate change—natural- and human-induced—the significant increase in the average global temperatures over the last half century can be attributed to human activities with a certainty of more than 90 percent [7].
- Those temperature increases have already affected various natural systems in many global regions.
- Future changes to the climate are inevitable.

CHANGING GLOBAL TEMPERATURES

INCREASED CARBON MEANS INCREASED TEMPERATURES

Throughout its history, the earth has experienced oscillations between warm and cool periods. These shifts in climate have been attributed to a variety of factors, known as "climate forcings," that include orbital variations, solar fluctuations, landmass distribution, volcanic activity, and the atmosphere's concentration of greenhouse gases, such as carbon dioxide, methane, and water vapor. The changes we see today are occurring at a more rapid rate than is explainable by known natural cycles [15].

Throughout the earth's past, temperature and greenhouse gas concentration have been closely linked through the planet's natural greenhouse effect; i.e. greenhouse gases trap heat in the atmosphere and thereby warm the earth. Throughout Earth's previous four glacial and warming cycles, atmospheric CO_2 concentration, and temperature show a high degree of correlation. Other greenhouse gases, such as methane, also show a similar relationship with temperature.

The recent and rapid rise in atmospheric CO_2 levels is of concern to climate scientists and policymakers. CO_2 concentrations never exceeded 300 parts per million by volume (ppmv) during previous large swings in climate conditions, but the CO_2 concentration now is about 380 ppmv [41], representing a 35 percent increase since the onset of the industrial revolution in the mid-eighteenth century. CO_2 levels are likely at their highest levels in the last 20 million years, and "the current rate of increase is unprecedented during at least the last 20,000 years" [41].

Thus, the current atmosphere is significantly different from its preindustrial state in a way that is compatible with increased heating.

AVERAGE GLOBAL TEMPERATURES HAVE ALREADY BEGUN TO RISE

Average global surface temperature is the most fundamental measure of climate change, and there is no dispute that the earth's average temperature has been increasing over the last century (albeit not uniformly), with an acceleration in warming over the last 50 years. Over the last century, the average surface temperature around the world has increased by 1.3°F ± 0.3°F [7]. Temperatures since the 1950s were "likely the highest [of any 50-year period] in at least the past 1,300 years" [7]. Of the hottest twelve years on record since temperatures began to be measured in the 1850s, eleven have occurred in the last twelve years [7].

The burning of fossil fuels (such as oil, natural gas, and coal) is the main source of the rise in atmospheric CO_2 over the last two and a half centuries; deforestation and other changes in land use are responsible for a portion of the increase as well.

Human activities have also been responsible for a portion of the rise in other heat-trapping greenhouse gases, such as methane, which has risen 148 percent since preindustrial times, and nitrous oxide, which has risen 18 percent during the same period. Currently, half of the annual methane emitted is from activities such as burning fossil fuel and agricultural processes; [41] humans are responsible for about a third of nitrous oxide emissions, mainly from agriculture.

There is no known natural forcing that can account for the severity of the recent warming. For example, while claims are made that variation in the intensity of the sun is responsible, the variation in solar radiation's effect on the climate is estimated to be less than 5 percent as strong as that of human-induced greenhouse gases [7].

MORE THAN TEMPERATURE RISE: OBSERVED IMPACTS ON EARTH'S NATURAL SYSTEMS

A 1.3°F increase in average global surface temperature over the last century may seem like an insignificant change, but in fact it has had a marked impact on many of the earth's natural systems.

PRECIPITATION PATTERNS HAVE CHANGED

A change in the temperature of the atmosphere has a great impact on pre-cipitation patterns. As an air mass warms, it is able to hold more water vapor, so a warmer atmosphere can absorb more surface moisture and produce drier ground conditions. However, this increase in atmospheric content will also lead to more severe heavy rain events, when this higher water-content atmosphere drops its moisture.

Changes in precipitation amounts have been detected over large portions of the world. Annual precipitation has increased 5 to 10 percent over the past century across eastern North America, northern Europe, and northern and central Asia [7, 41]. The Mediterranean region experienced drying [7]. The tropics have witnessed a slightly lower increase, of 2 to 3 percent, and most of sub-Saharan Africa has shown a decrease in precipitation of 30 to 50 percent [42].

The Northern Hemisphere subtropics experienced a decrease in precipitation of approximately 2 percent [41]. Some of the most noticeable drying occurred in the Sahel and portions of southern Asia [7]. No significant change was detected in rainfall patterns across wide areas in the Southern Hemisphere; however, precipitation was noticeably decreased in southern Africa [41].

EXTREME WEATHER EVENTS ARE MORE FREQUENT

Since 1950, cold days and nights and frost days have become less frequent, while hot days and nights and heat waves have become more frequent [7].

Global patterns of both heavy precipitation events and intense droughts have changed over recent decades. The increase in heavy precipitation events is consistent with the general increase in temperatures and the commensurate increase in atmospheric water vapor content. Droughts have become more intense, particularly in the tropics and subtropics, because of higher temperatures, more frequent heat waves, and changes in precipitation patterns [7].

The combination of increasing atmospheric temperatures and increased sea surface temperatures can increase the energy of tropical storms [43]. Preliminary observations since 1970 suggest that this effect has been observed in the North Atlantic and perhaps other regions as well [7].

ICE AND SNOW COVER IS DISAPPEARING

Glacial ice and snow cover are disappearing in many regions around the world. The Arctic region, in particular, is one of the areas being affected most by rising temperatures. As a result of temperatures that have increased at nearly twice the global average rate, Arctic sea ice is thinning and shrinking in extent, glaciers are melting throughout the region, and the snow season has shortened. Alaskan glaciers have retreated at a rapid pace; in fact, the amount of glacial mass lost in Alaska alone represents half of the estimated worldwide total [44]. There will be little to no sea ice in the Arctic's summers toward the end of this century [7]. Glaciers in other regions, such as high-altitude glaciers in tropical areas, are also melting at an increasing rate [7].

Increased melting of the Greenland ice sheet is one of the most worrisome Earth responses observed thus far. Data from NASA's Goddard Space Flight Center show that the seasonal melt area over Greenland has trended upward at 7 percent per year over the last twenty-five years, and the ice shelf surrounding Greenland has thinned by 230 feet over the last five years [15]. Recent satellite data analyzed by NASA have shown that from 2003 through 2005, Greenland annually lost three times more ice through melting than it gained through snowfall [45].

Antarctica's ice cover has also responded to the increasing temperature, but in different ways. West Antarctica has lost ice mass, while the ice sheet in East Antarctica has thickened. The thickening has been explained as being due to increased snow fall (as a result of warming temperatures that lead to more water vapor in the atmosphere) [46] as well as a slowing of glaciers for reasons unrelated to climate [45].

The melting of ice cover is an important positive feedback that reinforces heating, because of ice's contribution to the reflectivity of the earth. As ice melts, it exposes either land or water, depending on its location. Because land and water both reflect less solar radiation than ice, they reinforce rising temperatures, which in turn melts more ice. Once such loops begin, predicting their stopping point is difficult.

OCEANS ARE WARMING

The oceans have an enormous capacity to hold heat; because of their volume and heat capacity they require extremely large inputs of heat to change their temperatures. Nevertheless, the global mean sea surface temperature increased 0.9°F globally in the twentieth century [47], and the IPCC stated that "global ocean heat content has increased significantly since the late 1950s" [41].

SEA LEVELS ARE RISING

Ocean temperature is important to sea level rise because as temperatures increase, water expands, causing sea levels to rise. Because of the thermal inertia of the oceans, once sea level begins to rise because of thermal ex-pansion, it will continue to do so for centuries regardless of any mitigative actions.

Sea levels are also raised by the melting of land-based ice and snow because of the direct transfer of water into the sea. Sea-based ice, however, does not raise sea levels as it melts.

From 1961 through 2003, global mean sea level has risen about three inches, with nearly half of that increase occurring between 1993 and 2003 [7]. Over the entirety of the twentieth century, sea levels have risen nearly seven inches. The IPCC concluded that this rise was caused by thermal expansion of the ocean as well as melting of mountain glaciers and snow cover [7].

OCEAN SALINITY HAS CHANGED

Oceanographers have observed dramatic changes in salinity levels in the oceans. Oceans in the mid- and high latitudes have shown evidence of freshening, while those in tropical regions have increased in salinity [7].

Increases in ocean acidity have also been observed since preindustrial times. Increased atmospheric CO_2 is absorbed in the ocean where it combines with water to form carbonic acid, a mild acid. Most people are familiar with acid rain; this is its ocean equivalent. Forecasts project the increase in acidity over the coming century to be three times as great as the increase over the last 250 years [7]. Higher acidity could have a major impact on ocean life by preventing the formation of shells and skeletons of some very numerous and important zooplankton [48]. Coral reefs are particularly vulnerable.

FUTURE SCENARIOS: A CHOICE FOR HUMANS

To help illustrate the changes in climate that may occur, the IPCC developed a set of more than three dozen scenarios that describe different paths along which the world may evolve over the next century [49]. These paths are divided into six overarching categories distinguished by the assumptions made for factors such as economic growth, interactions among nations, population growth, and technological advances.

The scenarios were used as inputs to drive various climate models. The IPCC's 2007 report documents a range of climate change outcomes for the next century for each of the six categories used. According to the IPCC report, when considering the climate model results for each scenario, the average temperature projected in years 2090 to 2099 is expected to exceed the average temperature observed from 1980 to 1999 by 2.0° to 11.5°F. Sea levels are projected to rise between seven and twenty-three inches. This projection does not include the effect of potential changes in ice flow dynamics of large, land-based glaciers that may further contribute to the rise in sea level. To put this in perspective, recall that over the last century, the temperature increased about 1.3°F, and the sea level increased seven inches.

Because most of the inter-model studies assessed by the IPCC focus on three specific scenario categories, the IPCC's 2007 report necessarily focuses mostly on the same three. The "low" scenario (i.e., the one that results in the lowest temperature increase) describes a future in which population levels come under control, the global economy moves away from a manufacturing focus, and nations work together on improvements in environmental sustainability and developing clean technologies. The "medium" scenario describes a future where the assumptions regarding population and economic growth are similar to those made in the low scenario. Moreover, in the "medium" scenario the IPCC assumes the development of efficient technologies, and the production of energy from a variety of sources other than fossil fuels. The "high" scenario is the same as the "middle" scenario except energy production remains heavily focused on fossil fuel sources.

Each of the IPCC scenarios lead to different projections for temperature change; however, they all project significant global warming, with the most intense warming occurring in the Arctic and the high northern latitudes.

Some of the areas hardest hit by temperature increases will also very likely experience significantly less rainfall by the end of the century. Domestically, the southwestern portion of the United States will very likely experience the worst combination of these factors. Decreasing precipitation and markedly increasing temperatures will also stress northern and southern Africa and the Middle East.

While the earth's natural systems will continue to experience greater stress due to future climate changes, so will some key human systems [24]:

- **Coastal populations:** Increases in flooding and inundation from rising seas and more intense storms will affect coastal populations across the world, particularly those in Bangladesh and low-lying island nations.
- **Agriculture:** Temperature increases of a few degrees and increases in atmospheric CO_2 levels

may help agricultural productivity in mid- and high latitudes but will surely hurt agriculture in the tropics and subtropics, where crops already exist at the top of their temperature range; higher increases in temperature, as well as heat waves, changes in precipitation, and increased pests, will hurt agricultural productivity across much of the globe.

• **Water resources:** Five billion people are expected to live in water-stressed countries by 2025 even without factoring in climate change. Expected changes in climate will exacerbate water-stress in some areas (including most of Asia, southern Africa, and the Mediterranean), while alleviating it in others (such as the United Kingdom). Areas that depend on tropical mountain glaciers for water (such as Lima, Peru), will face a precarious situation as the glaciers continue to melt and eventually disappear. Developing nations with little capacity to manage water will be among the hardest hit.

• **Health:** Rising temperatures and heat waves will increase the number of heat-related deaths in summer months. This increase will be partially offset by decreases in cold-related winter deaths. The reach of vector-borne diseases, such as malaria and dengue fever, is expected to spread. Increasing frequency of floods will harm human health by its direct impact on populations as well as by facilitating the spread of disease to affected areas. Vital health infrastructure can be damaged, making minor and treatable injuries become life-threatening.

A WILD CARD: ABRUPT CLIMATE CHANGE

For many years it was believed that climate changes have been gradual—that the earth gradually cycles between glacial periods and warm interglacial periods. We now know this is not always the case [50].

Abrupt climate changes present the most worrisome scenario for human societies because of the inherent difficulties in adapting to sudden changes. Abrupt sea level rise is particularly worrisome. The great ice sheets along the edges of Greenland and the West Antarctic are vulnerable to sudden breakup: as the edges of the sheet thaw and meltwater seeps to the ice-ground boundary, the meltwater will act as a lubricant and facilitate a slippage into the sea. This physical phenomenon is an example of a positive feedback mechanism that, once started, is difficult to reverse [15]. Melting of these ice sheets would be catastrophic. The Greenland Ice Sheet could raise sea levels by twenty-three feet over a millennium [7]; the West Antarctic Ice Sheet would have a more immediate impact, raising sea levels more than three feet per century for five centuries [41]. The probability of a collapse of the West Antarctic Ice Sheet before 2100 is estimated to be between 5 and 10 percent [7].

None of these abrupt climate changes are projected by the climate models driven by the IPCC's 2007 future scenarios. However, if temperature increases were at the high end of the ranges projected by the models, abrupt climate changes such as those discussed above are more likely to occur. Such abrupt climate changes could make future adaptation extremely difficult, even for the most developed countries.

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