S. HRG. 109–1003

THE ROLE OF SCIENCE IN ENVIRONMENTAL POLICY MAKING

HEARING

BEFORE THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS UNITED STATES SENATE

ONE HUNDRED NINTH CONGRESS

FIRST SESSION

SEPTEMBER 28, 2005

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ONE HUNDRED NINTH CONGRESS
FIRST SESSION

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THE ROLE OF SCIENCE IN ENVIRONMENTAL POLICY MAKING

WEDNESDAY, SEPTEMBER 28, 2005

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
SUBCOMMITTEE ON SUPERFUND AND WASTE MANAGEMENT,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:30 a.m. in room 406, Dirksen Senate Office Building, Hon. John Thune (chairman of the subcommittee) presiding.

Present: Senators Inhofe, Bond, Voinovich, Murkowski, Thune, DeMint, Isakson, Jeffords, Boxer, Clinton, and Lautenberg.

OPENING STATEMENT OF HON. JAMES M. INHOFE, U.S. SENATOR FROM THE STATE OF OKLAHOMA

Senator INHOFE. Our hearing will come to order. First of all, this is a real heavy group we have got here today, and I really appreciate all of your being here. You have come a long way to be here. We are so appreciative. We, I am sure, are going to have more members coming in, but the staffs are here, and we have been talking about how to handle this, because we want to make sure that everyone has ample time to make presentations.

So it is my suggestion—and if it is all right with you, Senator Jeffords—that we will go ahead and start with, say, 5-minute opening statements up here, and then as we recognize our panel, each one can have 10 minutes. You don't have to take that long, or even go a little bit over that would be fine, depending on how many people show up.

I think probably what we will do is confine our opening statement to 4 minutes, see who comes up, how many we have, then we will turn it over to the panel. Then, of course, that will give us time for several rounds of questioning. We will be stopping promptly, though, at 11:50.

I am excited about this hearing because, when I first became the chairman of this committee back in, oh, it is two and a half years ago, I guess, now, the three objectives I had was to make our decisions on sound science. Too often there is a policy that is involved in that. You see this type of research that gets funded by the discretionary grants that get awarded. It is pushing people's political agenda many times, as opposed to really concentrating on sound science.

I am particularly interested in hearing the testimony of Dr. Michael Crichton. I think I have read most of his books. In fact, I have read them all. Everyone knows Dr. Crichton as a best selling

author and an Emmy award winning producer, but what most people don't know is that Dr. Crichton's background includes degrees from Harvard College and Harvard Medical School.

He was also a visiting lecturer in physical anthropology at Cambridge University and a post-doctoral fellow at Salk Institute for biological studies, where he worked on media and science policy with Jacob Bronowski, author of Common Sense of Science, Science and Human Values, and The Identity of Man. Dr. Crichton's science background has served him well in providing material for his books.

And, of course, of all of his books that I have read, I enjoyed the most "State of Fear". I have tried to say that is required reading for this committee, but you just can't get by with that when you are dealing with Senators. While "State of Fear" is a novel, it is fiction, the footnotes are incontrovertibly scientific. So I have enjoyed that.

We will also hear from Dr. Bill Gray. Dr. Gray is known as the pioneer of hurricane prediction. In the wake of Hurricane Katrina, German Environmental Minister Juergen Trittin alleged, "the increasing frequency of these natural events can only be explained through global warming which is caused by people."

Now, this is totally absurd. If you look at the chart behind us here, you can see that the data from the National Oceanic and Atmospheric Administration demonstrates clearly that 100 years ago, even 50 years ago, we had just as many intense hurricanes as we do today. So we look forward to your thoughts on that, Dr. Gray.

We will also hear from Dr. Don Roberts, an epidemiologist in the field of science regarding DDT. The EPA banned DDT in the 1970's despite a finding by its own experts that DDT did not cause cancer in human beings, nor did it have an adverse effect on wildlife. Since then, DDT has become the most studied chemical in the world, and the only thing that has been proven is that there is no other substance, method or treatment as effective in eradicating malaria.

You know, most of the members of this committee—and I know Dr. Crichton and I have talked about this—know that I have been very active, for about 10 years, in Africa, and when you take Uganda—if you look at this up here—I would like my colleagues to see this. That is the effects of malaria. Just in Uganda alone—which I will be there in about 3 days, or at the end of this next week—it kills about 70,000 people a year. The interesting thing is we are all so concerned and the public attention is on HIV/AIDS. The same number of people who died in Uganda from AIDS are dying from malaria. So we will be looking forward to that testimony.

I would also like to welcome David Sandalow of The Brookings Institute, who is here to provide the committee with his beliefs on global warming and its perceived effects.

Finally, we have Richard Benedick, President of the National Council for Science and the Environment. He was one of the authors of the 1987 Montreal Protocol, which is a precursor for the international framework for dealing with emissions reductions.

So we look forward to meeting and hearing from all of you.

[The prepared statement of Senator Inhofe follows:]

STATEMENT OF THE HON. JAMES M. INHOFE, U.S. SENATOR FROM THE STATE OF OKLAHOMA

Today's hearing will focus on one of the three objectives I set out when I assumed the Chairmanship of the committee—to ensure that regulatory decisions are based on sound science.

Too often the environmental policy decisions made by EPA and other science-based agencies are driven by political or personal agendas. You see this in types of research that gets funded or the types of grants that get awarded. It is my hope this hearing will help shed some light on how science is used by policy-makers and that we can arrive at some concrete suggestions for making the process better.

I am particularly interested in hearing the testimony of Dr. Michael Crichton. Everyone knows that Dr. Crichton is a best-selling author and Emmy award-winning producer. But what most people do not know is that Dr. Crichton's background includes degrees from Harvard College and Harvard Medical School. He was also a visiting lecturer in Physical Anthropology at Cambridge University; and a post-doctoral fellow at the Salk Institute for Biological Studies, where he worked on media and science policy with Jacob Bronowski, the author of Common Sense of Science, Science and Human Values, and The Identity of Man. Dr. Crichton's science background has served him well in providing material for his books, many of which explore scientific issues, my favorite of which is "State of Fear". I urge you all to read this book. It's fiction, but it contains an enormous number of footnotes to real studies backing up the scientific points made in the book. Dr. Crichton, thank you for agreeing to testify today on your observations and recommendations about the use of science in public policy-making.

We also will hear today from Dr. Bill Gray, known as the pioneer of hurricane prediction. In the wake of Hurricane Katrina, German Environmental Minister Juergen Trittin (Yer-gan Trit-in) alleged, "the increasing frequency of these natural events can only be explained through global warming which is caused by people." This is absolutely absurd. This chart behind me, based on data from the National Oceanic and Atmospheric Administration, demonstrates clearly that 100 years ago, even 50 years ago, we had just as many intense hurricanes as we have today. I look forward to your thoughts on this, Dr. Gray.

We will also hear today from Dr. Don Roberts, an epidemiologist and a leader in the field of science regarding DDT. EPA banned DDT in the 1970s despite a finding by its own experts that DDT did not cause cancer in humans nor did it have an adverse effect on wildlife. Since then, DDT has become the most studied chemical in the world and the only thing that has been proven is that there is no other substance, method or treatment as effective in eradicating malaria.

As many of my colleagues are aware, I travel throughout Africa several times a year. In fact, next week, I plan to make my third visit to Uganda this year. Malaria is devastating that country and the entire continent of Africa. It kills almost the same number of people as AIDS. Yet we focus little attention on this enormous human tragedy. Malaria kills 70,000 Ugandans every year, most under the age of five. It enlarges their spleen such as in the picture behind me, causing acute suffering and eventually death. In all of Africa, a child dies from malaria every 30 seconds.

Yet, developed counties continue to stand on their environmental agenda in the face of this human rights tragedy. Earlier this year, the European Union strongly warned Uganda that its exports to Europe would be in jeopardy if it goes ahead with current plans to use DDT to fight malaria. I look forward to your thoughts on the matter, Dr. Roberts.

I would also like to welcome David Sandalow, of the Brookings Institution, who is here to provide the committee with his beliefs on global warming and its perceived effects.

Finally, we have Richard Benedick, the President of the National Council for Science and the Environment. He was one of the authors of the 1987 Montreal Protocol, which was a precursor international framework for dealing with emissions reductions.

I look forward to hearing the testimony from our witnesses today.

Senator INHOFE. With that, I will turn it over to Senator Jeffords.

OPENING STATEMENT OF HON. JAMES M. JEFFORDS, U.S. SENATOR FROM THE STATE OF VERMONT

Senator JEFFORDS. Mr. Chairman, I know that today's hearing is the one you had hoped to conduct for some time, and certainly since the "State of Fear" was published. I want to be clear that my support for you in the work we have done together should not be diminished by my concern about the timing and the content of today's hearing.

I fear I must publicly express my concern on my behalf and the minority members of the committee. Chairman, given the profound human suffering and ecological damage along the Gulf Coast, why are we having a hearing that features a fiction writer as a key witness? Some may accuse me, as a policymaker, of falling into the exact policy trap that Mr. Crichton's book critiques, being too focused on the consequences of the recent large-scale natural disasters and our Nation's policy response to them. If Mr. Crichton's book, "State of Fear", a terrorist ring is developed to cause environmental destruction and bring attention to environmental issues.

I assure you, Mr. Chairman, that unlike these characters in "State of Fear", I did not cause the two Gulf hurricanes in order to prompt this committee and this Government into action. The damage caused by the two Gulf storms is not fiction. As far as I am aware, no one on the minority side of this committee has advocated that the storms should be used as justification for the adoption of wild-eyed drastic new policy initiatives. Instead, the destruction we have witnessed in recent weeks raises serious scientific questions that need to be answered in very near term.

We should be looking into the role of the science in making critical response and recovery decisions. We need to incorporate scientific information as we develop programs to help prevent future flood damage. How will we determine the appropriate health and environmental standards for rehabilitation in inundated areas? What does science tell us about the best ways to reconstruct in the Gulf region? Should we be engaging in enhanced wetland protection and reconstruction to possibly protect against the severity of future storms?

We should be asking these questions and getting answers expeditiously, as much as we may want to be focusing our attention on the longer term interaction between science and the decision-making process. I would also say in my 30 years in the Congress, that I have been proud of some of the decisions we have made, even in the absence of perfect scientific information. We authorized a Brownfields program to help cleanup our cities and towns. We did so even though in the decade since we passed the Superfund, we have continued to learn about the nature of toxic substances and the best ways to remediate them.

As one of our witnesses will testify, the Senate ratified the Montreal Protocol to address ozone-depleting substances, even though there was some scientific uncertainty as that agreement was negotiated. Sometimes we need to act to preserve or even improve human health and the environment, even though we don't have the perfect information we wish we had.

We certainly would not want to wait until there is substantial scientific evidence of human suffering or death. In my opinion, that

is too long. We all recognize that one man's credible science is another man's baloney.

Mr. Chairman, at the same time that this hearing is being held, there is also a Finance Committee hearing on Hurricane Katrina, where the Governors of each of the affected States will be testifying. As a member of that committee, I plan to attend that hearing and will not be able to stay for all of this hearing. I ask, Mr. Chairman, that I be able to submit written questions to the witnesses and that I am able to submit additional scientific information into the record of the topics raised by the witnesses.

Senator INHOFE. Without objection, so ordered.

Senator JEFFORDS. I am anxious to hear from these Governors who may help us to better understand how the Federal Agencies we oversee in this committee may have let them down and how our committee can act to improve the crucial functioning of these agencies.

This week I will introduce legislation that the minority side of the committee believes is necessary to respond to the Gulf hurricanes. I think those affected by these disasters deserve nothing less than our full attention when they are most in need.

Thank you, Mr. Chairman.

[The prepared statement of Senator Jeffords follows:]

STATEMENT OF HON. JAMES M. JEFFORDS, U.S. SENATOR FROM THE STATE OF VERMONT

Mr. Chairman, I know that today's hearing is one you have hoped to conduct for some time, certainly since "State of Fear" was published. I want to be clear that my support for you, and the work we have done together, should not be diminished by my concern about the timing and content of today's hearing. But, I feel I must publicly express that concern on my own behalf and that of the minority members of this committee.

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I am anxious to hear from these Governors who may help us to better understand how the Federal Agencies we oversee in this committee may have let them down, and how, or if our committee can act to improve the crucial functioning of these agencies.

This week, I will introduce legislation that the minority side of this committee believes is necessary to respond to the Gulf hurricanes. I think those affected by those disasters deserve nothing less than our full attention when they are most in need.

Senator INHOFE. Thank you, Senator Jeffords. Since, in your opening statement, you ask a question of me, I will take the Chairman's prerogative and answer that question. Since Katrina we have had nearly 10 briefings for staff members, including two closed door member briefings from the Army Corps of Engineers, as well as the Environmental Protection Agency. I would say that we only had two people, you and Senator Boxer were the only two that showed up. As Chairman, I have been down there to the sites in all three States. We will be holding multiple hearings on Katrina beginning next week.

That hearing is coming at the right time. I would remind you that following the attacks on 9/11, this committee did not hold its first oversight hearing on 9/11 until over a month after the attacks. From 9/11 until that hearing, the committee did not shut down; we held hearings unrelated to 9/11 and even a 2-day conference on Senator Jeffords P4 bill. That was the Climate bill that you had.

So we have been asked by the Senators from the Gulf States, one of whom is here now, to not hold any immediate hearings that would divert recovery assets from the Gulf. Just as Chairman Jeffords waited an appropriate time following the attacks of 9/11, I have done the same thing. So I don't think this is at all inappropriate to hold this hearing at this time.

Senator Isakson.

Senator ISAKSON. Thank you, Mr. Chairman. In the interest of time and hearing from the distinguished panel, I have just two statements that I would like to make.

Senator INHOFE. I appreciate that.

OPENING STATEMENT OF HON. JOHNNY ISAKSON, U.S. SENATOR FROM THE STATE OF GEORGIA

Senator ISAKSON. My two statements are, one, I appreciate the Chair conducting this hearing and getting such a distinguished panel.+

Second, at the risk of seeming to pander, I would like to tell Dr. Crichton and thank him for the countless hours of entertainment he has given me on Delta Airlines back and forth to Washington

over many, many years. I have read "State of Fear" and I found it very educational, very knowledgeable, and very entertaining. Thank you, Dr. Crichton.

Senator INHOFE. All right. Senator Clinton.

OPENING STATEMENT OF HON. HILLARY RODHAM CLINTON, U.S. SENATOR FROM THE STATE OF NEW YORK

Senator CLINTON. Thank you very much, Mr. Chairman.

I want to certainly support Senator Jeffords' efforts to come up with legislation. I look forward to the hearings you will be holding next week.

I have to say, Mr. Chairman, I think that the topic of this hearing is a very important one. Unfortunately, I think the hearing is organized in a way that will muddy the issues around sound science, rather than helping us clarify them.

First, with all respect to the extraordinary entertainment value and success of Dr. Crichton's works, his views on climate change are at odds with the vast majority of climate scientists. More importantly, his critique of climate change science appears in a work of fiction. It is a work of fiction even if it has footnotes, Mr. Chairman. His views have not been peer reviewed; they do not appear in any scientific journal.

I won't go into an assessment of Mr. Crichton's critique point by point, because we don't have time. However, I do want to submit for the record a document prepared by the Union of Concerned Scientists that rebuts Mr. Crichton's primary arguments.

[The referenced document can be found on page 95.]

In addition, I want to submit a document prepared by James Hanson, Director of the Columbia University Earth Institute and Goddard Institute for Space Studies. In this document, Mr. Hanson details the distortions of his climate change predictions made by Mr. Crichton in his best selling novel.

[The referenced document can be found on page 83.]

Rather than focusing on Mr. Crichton's testimony, however, I would like to focus on several broader points about environmental policymaking and the record of this Administration, because I think this Administration has taken the politicization of science to new levels. That is not just my opinion; it is the opinion of hundreds of prominent scientists, 49 Nobel laureates, 63 National Medal of Science recipients, 154 members of the National Academies, and thousands of other scientists who have signed a statement criticizing the Administration's misuse and politicization of science. I want to read just a brief excerpt from that statement.

"When scientific knowledge has been found to be in conflict with its political goals, the administration has often manipulated the process through which science enters into its decisions. This has been done by placing people who are professionally unqualified or who have clear conflicts of interest in official posts and on scientific advisory committees, by disbanding existing advisory committees, by censoring and suppressing reports by the Government's own scientists, and by simply not seeking independent scientific advice. Other administrations have, on occasion, engaged in such practices, but not so systematically nor on so wide a front.

Furthermore, in advocating policies that are not scientifically sound, the administration has sometimes misrepresented scientific knowledge and misled the public about the implications of its policies. For example, in support of the President's decision to avoid regulating emissions that cause climate change, the administration has consistently misrepresented the findings of the National Academy of Sciences, government scientists, and the expert community at large.

Thus, in June 2003, the White House demanded extensive changes in the treatment of climate change in a major report by the Environmental Protection Agency. To avoid issuing a scientifically indefensible report, EPA officials eviscerated the discussion of climate change and its consequences."

Mr. Chairman, I ask that the full statement be included in the record.

Senator INHOFE. Without objection.

[The referenced report can be found on page 85.]

Senator CLINTON. Now, unfortunately, Mr. Chairman, the Administration has not only misused scientific data, they have also underfunded basic science. Funding for scientific research has flatlined over the past few years. This year the Administration's proposed budget actually calls for a decrease in real dollars for federally funded research. Most of the R&D budget increases that did occur in the President's budget were for new defense weapons systems, not for basic research in electronics, nanotechnology, computing, energy, physics, and all of the other sciences.

I believe the U.S. is in real danger of losing its lead in science and advanced technology. Federal R&D plays a critical role in the education and training of future scientists and engineers, technological innovation, advancing health, increasing economic growth and competitiveness.

Now, Mr. Chairman, I am not, unfortunately, going to be able to stay for the entire panel, but I want to just make a few additional brief comments.

Senator INHOFE. Senator Clinton, I am very, very sorry. We are all adhering to the time limit.

Senator CLINTON. Mr. Chairman, if I could just get 1-minute. I just want to make a comment about a few of the witnesses——

Senator INHOFE. Senator Boxer, would you like to yield her one of your minutes?

Senator CLINTON. I wouldn't ask that. But I think actually I may say something you agree with, Mr. Chairman.

Senator BOXER. I would ask unanimous consent that the Senator from New York have an additional 60 seconds.

Senator INHOFE. Without objection, so ordered.

Senator CLINTON. Thank you.

I want to thank the panelists. Although I think that the point of the hearing is misleading, I think that some of the testimony from the panelists is very important. I want to thank Dr. Roberts for making it clear that there are questions that need to be raised about DDT. I think that is an essential issue that we need to look at. We can't necessarily turn the clock back, but I think the threat of malaria is real.

I also want to thank Mr. Sandalow. I agree with you about the National Academy of Sciences request that you put in your testimony.

Finally, I want to thank Ambassador Benedick. Your testimony about what can happen if people act in good faith is absolutely inspiring. The Montreal Protocol did risk imposing substantial short-run economic dislocations, even though the evidence was incomplete. But as your testimony demonstrates and as you conclude in your testimony, politics is the art of taking good decisions on insufficient evidence based on the best possible science.

Thank you, Mr. Chairman.

[The prepared statement of Senator Clinton follows:]

STATEMENT OF HON. HILLARY RODHAM CLINTON U.S. SENATOR FROM THE STATE OF NEW YORK

Mr. Chairman, I want to begin by echoing the comments of our Ranking Member, Senator Jeffords, who observed that the committee's time and energy would be better spent working on Katrina response.

Having said that, I think we can all agree that science is an indispensable part of environmental policy making.

Clearly, examining the proper role of science in policy making is a worthy subject for a hearing of this committee.

Unfortunately, I think this hearing is organized in a way that will muddy this issue rather than clarifying it.

First, the views of Mr. Crichton on climate change are at odds with the vast majority of climate scientists. More importantly, Mr. Crichton's critiques of climate change science appear in a work of fiction. His views have not been peer reviewed. They do not appear in any scientific journal.

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Rather than focusing on Mr. Crichton's testimony, however, I would like to make several broader points about environmental policy making and the record of this Administration.

Because I think that this Administration has taken politicization of science to new levels.

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I want to read a brief excerpt from that statement. "When scientific knowledge has been found to be in conflict with its political goals, the administration has often manipulated the process through which science enters into its decisions. This has been done by placing people who are professionally unqualified or who have clear conflicts of interest in official posts and on scientific advisory committees; by disbanding existing advisory committees; by censoring and suppressing reports by the Government's own scientists; and by simply not seeking independent scientific advice. Other administrations have, on occasion, engaged in such practices, but not so systematically nor on so wide a front. Furthermore, in advocating policies that are not scientifically sound, the administration has sometimes misrepresented scientific knowledge and misled the public about the implications of its policies.

For example, in support of the president's decision to avoid regulating emissions that cause climate change, the administration has consistently misrepresented the findings of the National Academy of Sciences, government scientists, and the expert community at large. Thus in June 2003, the White House demanded extensive changes in the treatment of climate change in a major report by the Environmental Protection Agency (EPA). To avoid issuing a scientifically indefensible report, EPA officials eviscerated the discussion of climate change and its consequences."

Mr. Chairman, I ask that the full statement be included in the record.

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Funding for scientific research has flat-lined over the past few years. This year, the Administration's proposed budget actually called for a decrease in real dollars for federally funded research [from $55.2 billion to $54.8 billion, a 0.6 percent reduction]

Most of the R&D budget increases that did occur in the President's budget were for new defense weapons systems, not for basic research in electronics, nanotechnology computing, energy and physics

The U.S. is in real danger of losing its lead in science and advanced technology. Federal R&D plays a critical role in the education and training of future scientists and engineers, technological innovation, advancing health, increasing economic growth and competitiveness, and increasing national and homeland security. We need to do better.

I hope that at a later date, we can have a more rounded discussion of this issue that includes an opportunity to ask Administration witnesses to answer for the way that they have used science in environmental policy making.

Senator INHOFE. Thank you, Senator Clinton.

Senator BOND.

OPENING STATEMENT OF HON. CHRISTOPHER S. BOND, U.S. SENATOR FROM THE STATE OF MISSOURI

Senator BOND. Thank you very much, Mr. Chairman. Obviously, this is going to be an exciting hearing. Unfortunately, I have to go to a fiscal responsibility budget meeting on Katrina. We will let the discussion continue on what caused Katrina as we try to figure out what to pay for and how to pay for it. I do want to say that I believe it is time that we had a thorough airing of how scientific evidence either does or does not influence the policymakers and legislation and Administration.

I might just point out—and maybe Dr. Sandalow would want to expand upon it—in the previous Administration there were complaints directed against the EPA and the State Department, which apparently once urged Intergovernmental Panel on Climate Change to alter a chapter in a scientific report specifically to delete phrases that cast scientific doubts on human influences on climate. In fact, one scientist admitted doing so to satisfy the State Department, and that may be an interesting area for further discussion.

I have seen too many areas where science has been misused, causing policy decisions that are not warranted or justified, and examples over the years where there have been harsh and sweeping policy decisions, either outdated, grossly exaggerated, or highly misleading. In some decisions, existing relevant information seems to have been ignored. We see, in my State, places where faulty science has had far-reaching policy decisions affecting the livelihoods and the lives of thousands of individuals, families, and businesses.

We have heard on the DDT, where excessive concern over DDT may have been causing tremendous deaths from malaria. In my State, unsound scientific guesses have led to the possibility of flooding and risking lives, man-made flooding as a result of mandated spring rises when the rivers are already high, and potential devastation of agricultural livelihood of many areas of our State where our most bountiful crops are grown in the flood plane.

I am reading, and will continue to read, the opening statements of our distinguished panel. Dr. Gray, I was most interested to see how you have been dismayed by science and media hype over nuclear winter and human endorsed global warming hypothesis. I

think that will be an interesting subject to pursue in light of Katrina.

I too have read "State of Fear". Even though it was not assigned by our Chairman, I read it because, No. 1, it was interesting fiction. Also I found the scientific footnotes to be of great interest. We met with representatives of a leading environmental organization who had a whole list of rebuttals to this.

So I asked my staff to pursue the thesis that you put forth in your footnotes and the rebuttals, and an interesting thing came back. They said, well, the rebuttals set up straw men; they attributed to Dr. Crichton things that he did not say. He merely stated the great deal of uncertainty. I said, well, what was wrong with Dr. Crichton's thesis, his scientific footnotes? They said nothing that we can find.

The people attacking them chose to misstate his conclusions. If you set up a straw man, it is easy to knock him down.

I know all of you will have an opportunity to respond to straw men, legitimate questions and others, and I look forward to reading the record.

Senator INHOFE. Thank you, Senator Bond.

Senator LAUTENBERG.

OPENING STATEMENT OF HON. FRANK R. LAUTENBERG, U.S. SENATOR FROM THE STATE OF NEW JERSEY

Senator LAUTENBERG. Thanks very much, Mr. Chairman, and thank you for inviting the members of this distinguished panel to testify here today. We are, among the group, honored to have Dr. Crichton here, a physician by training, best known, however, as a writer of fiction and movies. The book Jurassic Park was made into a film that ranks among the 10 highest grossing movies of all times. I have 10 grandchildren; they reported back to me and they liked it, so I will use them as the yardstick and say that nobody can dispute Dr. Crichton's talent as a writer of science fiction.

But our community needs science facts. In his latest book, "State of Fear", Dr. Crichton expresses his doubt that global warming poses a real threat to our planet.

Now, Mr. Chairman, I have a full statement that I am going to ask to be included in the record.

Senator INHOFE. Without objection, that will be the case.

Senator LAUTENBERG. I will use the balance of my time to relate a personal experience. I went down to the South Pole a couple years ago because I wanted to see what was happening with the National Science Foundation. I found there alarming conclusions that the supply of fresh water that was stored in the ice was disappearing at a rapid rate, that there was a huge ice melt. We know that Ward's Island and other significant chunks of the Antarctica were afloat in the ocean, disappearing into the salt water.

You have to say, without having the scientific discussion that we would like to have here one day, Mr. Chairman, this one, but I would like to see us have another one and maybe have representation from the Union of Concerned Scientists, National Academy of Sciences, because I think that we are getting into an area of subjective thinking that represents a great danger for us currently and in the future, and you see so much evidence of it.

Now, I learned in my trip to the Antarctica and the South Pole that, if one goes to Australia, that the hole in the ozone layer and, thereby, the global warming that exists, is a threat to child health. If children go to the beaches there, they are compelled to wear full bathing suits, hats, etc. and the rate of melanoma in Australia almost exceeds that of other countries around the world by a substantial margin.

So as we look at the challenge that is raised here today, the thing that perplexes me is—and if I am able to stay, I will; otherwise, I am going to submit questions in writing, Mr. Chairman, and hope that I will be able to get an answer back—is there any agreement at all that the earth is getting warmer?

The Defense Department commissioned a report in 2003 that presented an ominous picture of what the last half of the twenty-first century might look like, with flooding in all kinds of places, including The Netherlands and Bangladesh, and suggesting that the military be prepared to fight off those seeking higher ground, those seeking survival, and attempting the worst dangers that nature can offer on oceans and mountains and you name it to get to safer ground. So we can dismiss these things by challenges that don't necessarily bear the scientific approvals that make it more valid.

I hope, Mr. Chairman, before we finish these studies of ours, that we will have gone to all sides of the issue. Thank you very much.

[The prepared statement of Senator Lautenberg follows:]

STATEMENT OF HON. FRANK R. LAUTENBERG, U.S. SENATOR FROM THE STATE OF CONNECTICUT

Mr. Chairman, thank you for convening this hearing.

We're honored to have with us today Michael Crichton, a medical doctor by training who is best known as a writer of fiction and movies.

His book "Jurassic Park" was made into a film that ranks among the 10 highest grossing movies of all time. I have 10 grandchildren so I know it well.

In "Jurassic Park", Dr. Crichton concocted a fascinating tale about scientists who clone dinosaurs using DNA from fossils.

Nobody can dispute Dr. Crichton's talent as a writer of science fiction.

But this committee needs scientific facts, not science fiction.

His latest book, "State of Fear" expresses doubt that global warming poses a real threat to our planet.

If we learned tomorrow that scientists had cloned dinosaurs from DNA in fossils, Mr. Crichton would be hailed for his astute prediction.

But most scientists who have devoted their whole lives to studying such issues do not dismiss the threat of global warming.

Everyone agrees that the Earth is getting warmer. The last 4 years have been among the five hottest years on record.

And the projections for the future are not comforting.

It's a fact that hurricanes draw their power from warm waters in the ocean. For years, climate scientists have warned that higher ocean temperatures would spawn more powerful storms.

And in fact, we do have more powerful storms today than we did just a few decades ago.

Just this month, the Journal Science reported that the proportion of storms that achieve Category four or five status has almost doubled since the 1970s.

Yet even when the warnings of climate scientists are borne out, some people cling to denial.

It might make a good story to imagine that the threat of global warming is a concoction of groups with a political agenda.

But we need scientific facts not science fiction.

Here's another fact: once greenhouse gases enter our atmosphere, they remain there for a long time. There is nothing we can do to remove them.

So every day that we fail to act, the potential consequences grow worse.

By refusing to act, we are gambling on the outside chance that most of the scientists are wrong.

Let's not take that gamble with the future of our children and grandchildren.

Let's enjoy science fiction like Jurassic Park but let's base our decisions on scientific facts.

Thank you Mr. Chairman.

Senator INHOFE. Thank you, Senator Lautenberg.

Senator Murkowski.

OPENING STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM THE STATE OF ALASKA

Senator MURKOWSKI. Thank you, Mr. Chairman. I too want to thank you for scheduling this very important hearing, and look forward to hearing from the witnesses. It is unfortunate that we have so much going on this morning and that so many of us won't be able to stay. I intend to stay for as long as I possibly can, so I will be sitting here with you to listen to the comments.

Our job in the Senate here is to understand the issues, to make the decisions based on our understanding and to form public policy based on those decisions. Very often our subjects come from areas in which we have very little personal involvement or expertise, so we have to depend on expert witnesses. They educate us on the range of viewpoints, present us with the relevant factors, and, if we are lucky, they can cut through the ticket of contradicting claims.

Unfortunately, sometimes we are not always lucky. Sometimes we see eminent scientists who provide us with only part of the story, the part of the story that might suit them. That is unfortunate, because when we only have half of the story, half of the story can result in bad decisions, and bad decisions lead to bad policy, and bad policy leads to a loss of trust. That, Mr. Chairman, is something that we simply can't afford, not as individuals, and certainly not as a Country.

Now, as an Alaskan, I have watched how several episodes of poor decisionmaking based on poor or perhaps incomplete information results in what we consider to be poor policies and negative impacts, whether they be impacts to our fishing industry or our mining industry or our forest products industry and others. Real people are affected by these decisions that are made.

Now, many of these decisions have been based on an approach often called the precautionary principle. This term is generally interpreted to mean that one should take action to prevent harm, even if the harm has not yet been determined to exist or there is still uncertainty about its cause. While the sentiment for that is laudable, it may not always be justifiable. From a scientific or science perspective, the first and most important precautionary principle may be to refrain from any action unless both the harm and the efficacy of the proposed action are both understood and understood well enough to avoid unintended adverse consequences.

Mr. Chairman, I think that this discussion is long overdue. Speculation on consequences or remedies can be a dangerous path, particularly when the proposed solutions themselves can be damaging to our interests. So I look forward to the comments this morning from this very distinguished panel, and hopefully an ongoing dialog in this vein. Thank you.

[The prepared statement of Senator Murkowski follows:]

STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM THE STATE OF ALASKA

Mr. Chairman, thank you for scheduling this important hearing. I look forward to hearing from all our distinguished witnesses.

Our job is to understand issues, to make decisions based on our understanding, and to form public policy from those decisions.

Very often our subjects come from areas in which we have little personal involvement or expertise, so we necessarily depend on expert witnesses. They educate us on the range of viewpoints, present us with relevant facts, and if we are lucky, they cut through thickets of contradicting claims.

Unfortunately, we aren't often that lucky. We've all watched eminent scientists provide only the parts of the story that suit them. We all know it's human nature for them to do so, no matter how illustrious their reputations. Most of us, I think, have learned that blowing smoke doesn't always mean there is a fire. Sometimes it's only smoke and mirrors.

The result of smoke and mirrors is bad decisions, whether they are made by Congress or by an executive branch agency. Bad decisions lead to bad policy, and bad policy leads to the loss of trust. That, Mr. Chairman, is something we simply cannot afford. Not as individuals and not as a country.

As an Alaskan I've watched several episodes of poor decision-making based on poor information and resulting in poor policies and negative impacts to our fishing industry, or mining industry, our forest products industry and others. Real people are affected by those decisions.

Many of those decisions have been based on an approach often called the "precautionary principle." This term is generally interpreted to mean one should take action to prevent harm even if "harm" has not yet been determined to exist, or there is still uncertainty about its cause.

The sentiment for that is laudable, but not always justifiable. From a science perspective, the first and most important "precautionary principle" may be to refrain from action unless both the harm and the efficacy of the proposed action are understood well enough to avoid unintended adverse consequences.

I think this discussion is long overdue. Speculation on consequences or remedies can create a dangerous path, particularly when the proposed solutions themselves can be damaging to our interests. I look forward to the witnesses' comments on the matter.

Senator INHOFE. Thank you, Senator Murkowski.

Senator Boxer.

OPENING STATEMENT OF HON. BARBARA BOXER, U.S. SENATOR FROM THE STATE OF CALIFORNIA

Senator BOXER. Thank you, Mr. Chairman, and welcome to the entire panel.

In this committee it is our job to talk about sound science. It is not in our committee rules to discuss novels or plays or TV shows or movies, although, as a Senator from California, I appreciate my chairman's focus on the arts, because it is very important to me.

I think we all agree that higher ocean temperatures result in stronger storms. I don't think that is a debate. The supposed disagreement is over the cause of the higher ocean temperatures. But, in truth, if you look at who lines up on each side of this, I don't really think there is a disagreement among the real experts that a key contributor to rising ocean temperatures is global warming. The leading scientists around the world have overwhelmingly accepted this proposition. I have a chart here I would like to show you.

You see here the organizations that support the existence of climate change: National Academy of Sciences, American Geophysical Union, American Association for the Advancement of Science,

American Meteorological Society representing 48,000 members now, National Sciences Academies of France, Germany, Italy, Canada, Japan, Russia, the United Kingdom, Brazil, India, and China.

Now, on the other side you have individuals. I won't go through their names. They are from different institutes: the George Marshall Institute, American Enterprise Institute, Competitive Enterprise, American Enterprises, again Competitive Enterprise—so these are duplicates here of some reason—Frazier Institute, Cato Institute, Center for the Study of Carbon Dioxide and Global Change, a gentleman who is here today from Colorado State University, American Council for Capital Formation, and a gentleman from the Science and Environmental Policy Project. Every one of these except two are supported by a huge oil company. So let us get it straight in terms of who fits on what side.

So, yes, there are a few dissenters on the issue, but they receive major support from the industries that would have to pay a price if in fact we move forward on global warming and doing something about it.

So given what we know about the devastating effects of hurricanes and the threats caused by global warming—which could include flooding of our coastal cities, loss of agriculture, irreparable damage to ecosystems—I think we have to focus on fact, not fiction. How do we resolve it?

So I think we must set aside all of our disagreements—and we will have disagreements, Mr. Chairman—on DDT and what alternatives there may be and our disagreements on other things. However I think we agree that—and I hope we would agree, and I know the Corps agrees—protection of wetlands would be a positive step in helping protect us against hurricanes.

So for the remainder of my time, I want to show you a chart, a picture of a situation where you see how the wetlands act as a buffer. Here you have the ocean. Here you have a very healthy wetland and here you have the land. When we were briefed—and Mr. Chairman, I do appreciate the meetings that you called—I learned so much.

When the Corps spoke to us, they basically said that the wetlands act as a cooling down element so that by the time the hurricane reaches where people are, it is not as fierce. It is also a buffer; it is also a sponge. So these wetlands are a gift from God. We are all beginning to understand better just how valuable they are.

In my home State of California, I am so sad to tell you that we have lost 91 percent of our wetlands. It is disastrous. We are suffering more flooding than ever. Now, in the lower 48, we have lost 53 percent of our wetlands. Louisiana loses the equivalent of one football field of wetlands every 38 minutes. So with our increased understanding of the importance of wetlands, I think we can work together in this committee, setting aside how we feel about why the oceans are warming up. Let us set it aside. Let us do something for our Country.

So thank you very much, Mr. Chairman.

Senator INHOFE. Thank you, Senator Boxer.

Before you speak, I want to make sure everyone here is aware that probably Senator Voinovich is the most knowledgeable person on air issues. When he was Governor of Ohio, he was chairman of

that committee of the Governors Conference, and it is always an honor to have him appear when we are talking about air issues.

Senator Voinovich.

OPENING STATEMENT OF HON. GEORGE V. VOINOVICH, U.S. SENATOR FROM THE STATE OF OHIO

Senator VOINOVICH. Thank you, Mr. Chairman, for having this hearing.

This is an area of great interest to me and of great concern. I have introduced legislation in past Congresses to improve the role of science in policy decisions at the Environmental Protection Agency. I believe that by improving science at the Agency we can improve the framework of our regulatory decisions. It is important that these regulations be effective, not onerous and inefficient. They must be based on a solid foundation of solid understanding and data.

In 2000, the National Research Council recommended changes to improve science within the EPA in their report "Strengthening Science at the U.S. Environmental Protection Agency, Research Management and Peer Review Practices." My legislation, the Environmental Research Enhancement Act, would have implemented several of the Council's recommendations.

Mr. Chairman, I understand that you are also working on legislation, and I look forward to working with you on it.

EPA was created in 1970 by President Nixon with the mission to protect human health and safeguard the environment. EPA was part of President Nixon's reorganization efforts to effectively ensure the protection, development, and enhancement of the total environment. This mission requires the EPA have a fundamental understanding of the science behind the real and potential threats to public health and the environment. Unfortunately, many institutions, citizens, and groups believe that science has not always played a significant role in EPA's decisionmaking process.

The National Research Council's 2000 report concluded: "While the use of sound science is one of EPA's goals, the Agency needs to change its current structure to allow science to play a more significant role in its decisions made by the administrator."

I want to quickly explain how my legislation was designed to improve policymaking at EPA. First, the new Deputy Administrator for Science and Technology would be established at EPA. The individual would oversee the Office of Research and Development, Environmental Information Agency, Science Advisory Board, Science Policy Council, and scientific and technical activities in the Agency's regulatory programs.

This new position would be equal in rank to the current deputy administrator and would report directly to the administrator. The new deputy would be responsible for coordinating science research and application between the scientific and regulatory arms of the Agency to ensure that sound science is the basis for decisions.

Second, EPA's current top science job, Assistant Administrator for Research and Development, would be appointed for 6 years, instead of the current 4-year political appointment. According to the Council, this position is one of EPA's weakest and most transient administrative positions, even though this position addresses some

of the Agency's more important topics. By lengthening the term of this position, I had hoped to remove it from the realm of politics, allowing the Assistant Administrator to focus on science and providing more continuity in the Agency's scientific work across administrations.

I have long believed that sound science, not politics, should drive our Nation's environmental policy. In fact, I believe that in harmonizing our Nation's economic, environmental, and energy policies, that sound science should be the uniting factor. Unfortunately, this has not been the case, and we are paying for it in thousands of lost jobs and with the highest natural gas prices in the world. And unless we start to harmonize our needs to become more energy independent, we are not going to be able to compete in the global marketplace, and our national economy and our national security will continue to be in jeopardy.

Thank you, Mr. Chairman.

[The prepared statement of Senator Voinovich follows:]

STATEMENT OF HON. GEORGE V. VOINOVICH, U.S. SENATOR FROM THE STATE OF OHIO

Mr. Chairman, thank you for holding this hearing on the important subject of the role of science in environmental policymaking. This is an area of great interest and concern for me.

I have introduced legislation in past Congresses to improve the role of science in policy decisions at the Environmental Protection Agency (EPA). I believe that by improving science at the Agency, we can improve the framework of our regulatory decisions. It is important that these regulations be effective, not onerous and inefficient. They must be based on a solid foundation of scientific understanding and data.

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This mission requires that EPA have a fundamental understanding of the science behind the real and potential threats to public health and the environment. Unfortunately, many institutions, citizens, and groups believe that science has not always played a significant role in EPA's decision-making process. The National Research Council's 2000 report concluded that, while the use of sound science is one of EPA's goals, the Agency needs to change its current structure to allow science to play a more significant role in decisions made by the Administrator.

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Unfortunately, this has not been the case, and we are paying for it in thousands of lost jobs and the highest natural gas prices in the world. Unless we start harmonizing our needs to become more energy independent, we will not be able to compete in the global marketplace and our national economy and national security will be in jeopardy.

Mr. Chairman, I again thank you for holding this hearing today.

Senator INHOFE. Thank you, Senator Voinovich.

If any other members come in, we will not recognize them for opening statements, because we are going to try to stay on our time line.

Since several statements have been made about the National Academy of Sciences, I would like to enter into the record a letter from the former president of the National Academy of Sciences to the president of the Royal Society. It refutes the charge the Bush Administration has ignored the NAS' recommendations.

The letter says: "By appending your own phrase by reducing emissions of greenhouse gases to an actual quote from our report, you have considerably changed our report's meaning and intent. As you must appreciate, having your own misinterpretation of the U.S. Academy work widely quoted in our press has caused considerable confusion both at my Academy and in our Government."

This entire letter will be entered as part of the record.

[The referenced letter can be found on page 93.]

Senator INHOFE. All right, we have already introduced our distinguished panel, and we will start with Dr. Crichton. I would like to ask the members of this panel to try to confine your comments to a maximum of 10 minutes. We will do our best to accommodate you. Don't feel like you have to take a full 10 minutes, but we will try to do that.

I would like to ask any member who has family with him to introduce that family.

Dr. Crichton, we are delighted to have you here. Thank you for your appearance.

STATEMENT OF MICHAEL CRICHTON, M.D., AUTHOR, DOCTOR

Dr. CRICHTON. Thank you, Mr. Chairman and members of the committee. I appreciate the opportunity to discuss the important subject of politicization of——

Senator INHOFE. Aren't you going to introduce Sherri?

Dr. CRICHTON. Oh, yes. I am sorry. I am going to pay for that. This is my wife, Sherri Alexander, behind me. Sorry, honey.

[Laughter.]

Dr. CRICHTON. I appreciate the opportunity to discuss the important subject of politicization of research. In that regard, what I would like to emphasize to the committee today is the importance of independent verification to science.

In essence, science is nothing more than a method of inquiry. The method says an assertion is valid and merits universal acceptance only if it can be independently verified. The impersonal rigor of the method means that it is utterly apolitical.

A truth in science is verifiable whether you are black or white, male or female, old or young. It's verifiable whether you like the results of the study or whether you don't.

Thus, when adhered to, the scientific method can transcend politics. The converse may also be true. When politics take precedent over content, it is often because the primacy of independent verification has been overwhelmed by competing interests.

Verification may take several forms. I come from medicine, where the gold standard is the randomized double-blind study, which has been the paradigm of medical research since the 1940's.

In that vein, let me tell you a story. It is 1991 and I am flying home from Germany, sitting next to a man who is almost in tears, he is so upset. He is a physician involved in an FDA study of a new drug. It is a double-blind study involving four separate teams: one plans the study, another administers the drug to patients, a third assesses the effect on patients, and a fourth analyzes the results. The teams do not know each other and are prohibited from personal contact of any sort on peril of contaminating the results.

This man has been sitting in the Frankfort Airport innocently chatting with another man when they discover to their mutual horror they are on two different teams studying the same drug. They were required to report their encounter to the FDA, and my companion was now waiting to see if the FDA would declare their multi-year, multimillion dollar study invalid because of this chance contact.

For a person with a medical background accustomed to this degree of rigor in research, the protocols of climate science appear considerably more relaxed. In climate science, it is permissible for raw data to be touched or modified by many hands. Gaps in temperature and proxy records are filled in. Suspect values are deleted because a scientist deems them erroneous. A researcher may elect to use parts of existing records, ignoring other parts. But the fact that the data has been modified in so many ways inevitably raises the question of whether the results of a given study are wholly or partially caused by the modifications themselves.

In saying this, I am not casting aspersions on the motives or fairmindedness of climate scientists. Rather, what is at issue is whether the methodology of climate science is sufficiently rigorous to yield a reliable result. At the very least, we should want the reassurance of an independent verification by another lab in which they would make their own decisions about how to handle the data and yet arrive at a similar result.

Because the fact is that any study where a single team plans the research, carries it out, supervises the analysis, and writes their own final report carries a very high risk of undetected bias. That risk, for example, would automatically preclude the validity of the results of a similarly structured study that tested the efficacy of a drug. No one would believe it.

By the same token, any verification of the study by investigators with whom the researcher had a professional relationship—people with whom, for example, he had published papers in the past—would not be accepted. That is peer review by pals and is unavoidably biased. Yet, these issues are central to the now familiar story of the "Hockey stick graph" and the debate surrounding it.

To summarize it briefly, in 1998–1999, the American climate researcher Michael Mann and his coworkers published an estimate of global temperatures from the year 1000 to 1980. Mann's results appeared to show a spike in recent temperatures that was unprecedented in the last 1,000 years. His alarming report formed the centerpiece of the U.N.'s Third Assessment Report in 2001.

Mann's work was criticized from the start, but the real fireworks began when two Canadian researchers, McIntyre and McKitrick, attempted to replicate Mann's study. They found grave errors in the work, which they detailed in 2003: calculation errors, data used twice, data filled in, and a computer program that generated a hockey stick out of any data fed to it, even random data.

Mann's work has since been dismissed by scientists around the world who subscribe to global warming. Why did the U.N. accept Mann's report so uncritically? Why didn't they catch the errors? Because the IPCC doesn't do independent verification. Perhaps also because Mann himself was in charge of that section of the report that included his own work.

The hockey stick controversy drags on. But I would direct the committee's attention to three aspects of this story. First, 6 years passed between Mann's publication and the first detailed account of errors in his work. This is simply too long for policymakers to wait for validated results.

Second, the flaws in Mann's work were not caught by climate scientists but, rather, by outsiders, in this case, an economist and a mathematician. They had to go to great lengths to obtain their data from Mann's team, which obstructed them at every turn. When the Canadians sought help from the NSA, which was the funding Agency, they were told that Mann was under no obligation to provide his data to other researchers for independent verification.

Third, this kind of stonewalling is not unique. The Canadians are now attempting to replicate other climate studies and are getting the same runaround from other researchers. One prominent scientist told them: "Why should I make the data available to you, when your aim is to try and find something wrong with it."

Even further, some scientists complain the task of archiving is so time-consuming as to prevent them from getting any work done. This is nonsense. Today we can burn data to a CD or post it at an FTP site for downloading. Archiving data is so easy it should have become standard practice a decade ago. Government grants should require a "replication package" as part of funding. Posting the package online should be a prerequisite to journal publication. There is really no reason to exclude anyone from reviewing the data.

Of course, replication takes time. Policy makers need sound answers to the questions they ask. A faster way to get them might be to give research grants for important projects to three independent teams simultaneously. A provision of the grant would be that at the end of the study period, all three papers would be published together, with each group commenting on the findings of the others. I believe this would be the fastest way to get verified answers to important questions.

But if independent verification is the heart of science, what should policymakers do with research that is unverifiable? For ex-

ample, the U.N. Third Assessment Report defines general circulation climate models as unverifiable. If that is true, are their predictions of any use to policymakers?

I would argue they are not. Senator Boxer says that we need science fact, and I completely agree. But the unavoidable truth is that a prediction is never a fact.

In any case, if policymakers decide to weight their decisions in favor of verified research, that will provoke an effort by climate scientists to demonstrate their concerns using objectively verifiable data. I think we will all be better for it.

In closing, I want to state emphatically that nothing in my remarks should be taken to imply that we can ignore our environment or that we should not take climate change seriously. On the contrary, we must dramatically improve our record on environmental management. That is why a focused effort on climate science aimed at securing a sound, independently verified answers to policy questions is so important now.

I would remind the committee that in the end it is the proper function of government to set standards for the integrity of information it uses to make policy. Those who argue that government should refrain from mandating quality standards for scientific research—and that includes some professional organizations—are merely self-serving. In an information society, public safety depends on the integrity of public information. Only Government can perform that task.

Thank you very much.

Senator INHOFE. Thank you, Dr. Crichton, for an excellent statement.

Mr. Benedick.

STATEMENT OF THE HONORABLE RICHARD E. BENEDICK, PRESIDENT, NATIONAL COUNCIL FOR SCIENCE AND THE ENVIRONMENT

Mr. BENEDICK. Thank you, Mr. Chairman. Without a reminder, I would like to introduce my fiancee, Irene Federwisch, who has come here from Berlin, and who is not a fan of Environment Minister Trittin.

This is actually the first time that I have appeared not as a government witness, so it is kind of a new feeling.

Since 1994 I have been President of the National Council for Science and the Environment, which is an organization dedicated to improving the scientific basis for environmental decisionmaking, and in this context I would like to express appreciation to Senator Voinovich for his initiatives to improve science at the Environmental Protection Agency.

During the 1980's, I served under President Reagan as Deputy Assistant Secretary of State for Environment. In 1985 I was designated by Secretary of State George Schultz and then Assistant Secretary John Negroponte to be the chief U.S. negotiator for a treaty to regulate certain chemicals suspected of depleting the stratospheric ozone layer.

I have submitted more extensive written testimony, which I will summarize today. It tells the story of a remarkable collaboration

between scientists and government in the development of public policy under conditions of risk and uncertainty.

CFCs and related halons seemed to be ideal manmade chemicals. Invented in the 1930's, they found more uses in thousands of products and processes: in pharmaceuticals, in agriculture, in electronics, in defense and agriculture and telecommunications, just to name a few. CFCs became virtually synonymous with modern standards of living.

Billions of dollars of international investment and hundreds of thousands of jobs were involved in their production and consumption. Powerful governments in Europe aligned with global economic interests in adamant opposition to controls, maintaining that alternatives were nonexistent or too costly or unfeasible.

Most other governments and peoples were unaware or indifferent to an arcane threat occurring 30 miles above earth's surface. As an Indian diplomat admonished me: "Rich man's problem—rich man's solution."

Perhaps most significant, during the negotiations the arguments for controlling CFCs rested on unproved scientific theories that these useful chemicals could damage the stratospheric ozone layer that protects life on earth from harmful solar radiation. The science was based on projections from still-evolving computer models of imperfectly understood atmospheric processes, models that yielded varying, and even sometimes contradictory predictions, each time they were refined.

Nevertheless, after contentious international negotiations, a strong control treaty was signed in Montreal in September 1987, just 18 years ago. The treaty was hailed in the U.S. Senate as "the most significant international environmental agreement in history." President Reagan became the first head of state to endorse the Montreal Protocol, pronouncing it, "a monumental achievement of science and diplomacy," and the treaty was unanimously ratified by the Senate.

The most extraordinary aspect of the Protocol was that it imposed significant short-term costs in order to protect human health and the environment against future dangers that rested on scientific theories rather than on proven facts. Unlike past environmental agreements, this was not a response to harmful events but, rather, preventive action on a global scale.

Even so, it was a near thing. For decades no one had suspected that these wonder-chemicals could cause any harm. They had been thoroughly tested by customary industrial standards and declared completely safe. Possible effects 30 miles above the earth had simply never been considered.

Unquestionably, the indispensable element in the success of the Montreal Protocol was the role of science and scientists. Without the curiosity and courage of a handful of researchers in the mid–1970's, the world might have learned too late of the hidden dangers.

Ozone's existence was unknown until 1839, and it has been characterized by NOAA scientists as "the single most important chemically active trace gas in the earth's atmosphere." The ozone layer, at its historic natural concentrations and diffusion, is simply essential for life as it currently exists on earth.

Astonishingly, the research paths leading to the suspicion that the ozone layer was in jeopardy had been serendipitous. Scientists had not set out intentionally to condemn chlorofluorocarbons. The serious theoretical dangers prompted a wave of new scientific research over the following years, led by our own NASA, NOAA, and the National Academy of Sciences.

Even as negotiators were hammering out the final compromises in Montreal, an unprecedented international scientific expedition was underway in Antarctica. Using specially designed equipment placed in balloons, satellites, a DC–8 flying laboratory, and a converted high-altitude U–2 spy aircraft, scientists were tracking stratospheric chemical reactions and measuring minute concentrations of gases.

Six months later the results came out and were stunning. No longer a theory, ozone layer depletion had at last been substantiated by hard evidence. CFCs and halons were now implicated beyond dispute, including responsibility for the "ozone hole" over Antarctica. Without modern science, the world would simply have remained unaware of an ozone problem until it was too late.

A major lesson from the ozone history is that nature does not always provide policymakers with convenient early warning signals of impending disaster. For example, chlorine concentrations in the stratosphere tripled over the decades from their natural level with no effect on the ozone layer. But when they reached two parts per billion—not a very large amount—the ozone layer over Antarctica collapsed. This nonlinear—what the scientists call a nonlinear—or threshold response has obvious implications for the potential dangers of other types of anthropogenic interference with the planet's natural cycles.

The history of the Montreal Protocol also underscored the importance of having sufficient funding for all levels of science, from curiosity-driven basic research to applied engineering solutions.

The Montreal Protocol was not, as some opponents charged, a "radical" treaty. On the contrary, it was an expression of faith in the market system. The treaty effectively signaled to the marketplace that research into solutions would now be profitable.

The protocol stimulated a virtual technological revolution in the international chemical, telecommunications, and numerous other industries. By providing producers and users of CFCs with the certainty that the CFC market was destined to decline, the Montreal Protocol unleashed the creative energies and financial resources of the private sector to find alternatives.

Another lesson from the Montreal Treaty was the importance of education. Here the role of the U.S. Congress was particularly critical in organizing many public hearings on ozone and in commissioning several important studies by the National Academy of Science.

Some European Governments allowed commercial self-interest to influence their interpretations of the science. Uncertainty was used by these governments as an excuse for delaying decisions. In contrast, the U.S. Clean Air Act opted for a low threshold to justify intervention. Our Government was not obligated to prove conclusively that a suspected substance would endanger health and envi-

ronment. All that was required was a standard of reasonable expectation.

As Governor Russell Peterson, who was a senior advisor to President Nixon, had declared in reference to other potentially harmful chemicals, CFCs, unlike U.S. citizens, would not be considered innocent until proven guilty.

By the time the evidence on such issues as ozone layer depletion and climate change is beyond dispute, the damage could be irreversible and it may be too late to avoid serious harm to human life and draconian future costs to society. Political leaders must resist the tendency to assign excessive credibility to self-serving economic interests that demand scientific certainty and who insist that simply because dangers are remote, they are therefore inconsequential.

In conclusion, there will always be resistance to change and there will always be uncertainties. But faced with plausible environmental threats, governments may need to act while some major questions remain unresolved.

As Britain's Lord Kennet stated during ozone debates in the House of Lords, "Politics is the art of taking good decisions on insufficient evidence." The ozone history demonstrates that in the real world of ambiguity and imperfect knowledge, the international community, with the assistance of science, is capable of undertaking difficult actions for the common good.

I thank you for the opportunity to share this experience.

Senator INHOFE. Thank you, Mr. Benedick.

Dr. GRAY.

STATEMENT OF WILLIAM GRAY, Ph.D., PROFESSOR, DEPARTMENT OF ATMOSPHERIC SCIENCE, COLORADO STATE UNIVERSITY

Dr. GRAY. Well, I appreciate very much being asked to come to this hearing. I have been simmering for 20 years at what I consider the hype on these subjects like nuclear winter and global warming.

I must say I have been a lifelong Democrat until Al Gore ran for president. I don't listen to Rush Limbaugh; I don't go to church. I come at this from having spent 52 years of my life working very hard down in the trenches looking at data, working. I have been around the world. I have done forecasting. I have done all these things. I am appalled at what has come forth.

We state that there's all these bodies. Senator Boxer showed us all the bodies that agree that human-induced global warming is such an important topic. Well, the problem is the people that sit on these boards don't know much about how the atmosphere ocean ticks. That is the problem. You know, just because two curves go up, because we have seen some modest warming in the globe the last three decades, and the human-induced greenhouse gases have gone up does not mean these are necessarily related, that one causes the other.

There is a very nice curve I could show that if you look at sunspots on a number of Republicans in the Senate, they go up on about a 10- or 12-year cycle. Now, would you accept that we could predict the number of Republicans that are going to be in the Senate 10 or 20 years down the line? I doubt it.

Now, what is wrong with the human-induced global warming scenarios? What is wrong is they have basic physics wrong in them. I don't think many people understand this. If you just take the greenhouse gases, they have gone up about a third since the industrial revolution started. They are supposed to double by the late twenty-first century. If you just take those gases and keep everything else constant, there is very little global warming. Even the scientists will tell you doing this, .2 or .3 or so degrees Centigrade, versus a 2 to 5 degrees warming that all the models show.

Now, there are basic problems in these models. One is the water vapor feedback loop. This is a technical subject. You take the greenhouse gases, by themselves they should warm the surface a little bit. You get a little more evaporation and a little more rain. Now, what the models do is take that extra rain and assume the middle and upper troposphere will slightly increase its vapor. That upper level vapor, perhaps a little cloudiness, will block additional long-wave radiation to space, and that is where most of the warming comes from. It is eight, nine times as much as the greenhouse gases themselves.

Another basic problem is the oceans are not modeled well. You have to model the ocean and the salinity variations and things, and that just is not possible.

Now, I brought a couple of graphs I would like to show. One is the complex nature of the earth atmosphere system. Here is what it is. It is impossible to write code, numerical code for all these processes and integrate this hundreds of thousands of time steps in the future.

Now, here is my last one. Let us look at how forecasting is done. I and my group make hurricane seasonal forecasts and so on. How do we do it? We admit that the atmosphere is too damn complex to understand, but there is memory signals in it. So we look at past data. We go to past years, look 3, 6, 9 months in the past and say, gee, before active hurricane seasons there seems to be a difference than before inactive ones; and we use that and make a forecast. We don't understand all the complex physics. You can use associations that work.

Now, with numerical prediction, I followed it for over 50 years. It is a great advance. The prediction out to 5 to 10 days in the future has gotten better. There is remarkable improvements here. See, as this thing goes. However, after 10 days, 15 days or so, you can't do it well. The way it can be done for 5 or 10 days in the future is the momentum fields can be extrapolated. They carry information that can be used, and this has been a great thing. When you try to go further than that, when you try to go 15, 20 days over, you bring in all these energy differences—radiation, air-sea interaction. It is a can of worms. You can't go further.

Now, what I ask, there is almost a cottage industry out there. Around the globe there are 30 numerical models that are trying to predict climate. None of them gives you a forecast. I say, look, if these climate models are OK, why don't they tell us next season, next year whether the global temperature is going to rise or not? They don't do that. The reason they don't, they know they have no damn skill in doing so. So should we believe them 50, 100 years

down the line, when they can't forecast 6 months or a year in the future? It is ridiculous.

I predict that in 15 or 20 years we are going to look back on this whole business as the Eugenics movement. You know, there used to be, 400 years ago, the majority of the scientific opinion felt the sun went around the earth. Now, damn it, don't tell me the sun rises, goes around.

Now, I think I know as much as anybody. I will take on any scientist in this field to talk about this. I predict, in the next 5 or 8 years or so, the globe is going to begin to cool as it did in the middle 1940's. You know, I was around as a little boy growing up in Washington here in the 1940's. The war was on; I was delivering newspapers. Despite the war being on, there was talk of global warming because the globe had warmed so much between 1900 and 1940. What was going to happen? Nobody knew. So about the middle 1940's the globe gradually started a cooling trend, and it went on for about 30 years and the ice age people then started coming out of the closet. Now it has changed. Now I think we are going to sort of follow that pattern the next decade or two down the line.

Now, hurricanes, my last topic. I spent my career in this. I have been all over the world. I think I know something about these storms. The globe has warmed a little bit the last two or three decades, yes, 2, 3 degrees or so Centigrade. But I have looked at intense hurricanes, and they really haven't changed. We have no basic theory, despite what others might say, as to if the globe doesn't warm much. Now, if it warmed 10, 20 degrees, yes, or cooled that amount, global tropical cyclone activity will probably change, but we don't know how, whether we would get more or less. For the small amounts of change we have seen, the statistics don't show any difference.

Now, the Atlantic is different. That is a special basin that has this thermohaleon circulation or moldy decadal cycle in it. We had a lot of storms in the 1930's through the 1950's. That is when I got started, in the 1950's. This looked like a promising field. Then in the late 1960's through the middle 1990's the number of major Atlantic basin hurricanes went down. Now it has come back the last 10 years. These are natural ocean driven features.

Senator INHOFE. Dr. Gray, your time has expired. Could you wrap up real quickly, please?

Dr. GRAY. Yes. OK.

There was a past year when a category 4 storm went just west of Houston, and 6 weeks later a category 4 storm went almost over New Orleans. That year was 1915. These things happen. Nature plays these games and these tricks. Humans are not involved, or if they are, it is so small. We just have to adapt to nature as best we can.

Thank you.

Senator INHOFE. Thank you, Dr. Gray.

Dr. ROBERTS.

STATEMENT OF DONALD R. ROBERTS, Ph.D., PROFESSOR, DIVISION OF TROPICAL PUBLIC HEALTH, DEPARTMENT OF PREVENTIVE MEDICINE AND BIOMETRICS, UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES

Dr. ROBERTS. I want to thank the members of the committee for the opportunity to present testimony this morning. I need to inform you that I am a faculty member of the Uniform Services University of the Health Sciences, and as such my comments should not be construed to represent the opinions of the University, the Department of the Defense, or U.S. Government.

As you are aware, we are making great strides against chronic diseases, and we are living longer and longer as a result. Yet, today, in much of the developing world there are greater problems of malaria and other infectious diseases than in 1960. I estimate that in just 12 countries of the Americas there were as many as 21 million more malaria cases in 1993 than in any year in the 1970's.

We should be concerned about these huge reversals in the public's health. Even if those impacted are not U.S. citizens, a failure to control diseases in other countries eventually translates into increased risk for our citizens.

These reversals in health result in part from the environmental campaign against DDT. Many charges about environmental harm of DDT are simply not true. One of the most common claims against the use of DDT is that it is a human carcinogen. Vast sums of money have been spent in attempts to prove DDT is a cause of cancer. The results argue persuasively that it is not.

In 1971, amid the growing pressure from environmentalist groups, the newly formed Environmental Protection Agency held scientific hearings into DDT. The hearings were held over 8 months, involved 125 witnesses, 365 exhibits, and produced 9,312 pages of transcript. The presiding judge, Edmund Sweeney, noted "the pros and cons of DDT have been well aired." He then ruled that DDT should not be banned, saying that "DDT is not a carcinogenic hazard to man."

In other words, it was concluded that DDT was not a cancer risk to humans, and the allegations made against the chemical did not stand up to scrutiny. Despite this evidence, then Administrator of the EPA William Ruckelshaus banned DDT.

The decision to ban DDT was essentially a political one, without any grounding in good science. This ruling was not a tragedy, because it took DDT away from agriculture. History has shown that agriculture productivity continued apace. This ruling was a tragedy for what it did to public health.

Even before the EPA hearing, the Director of Malaria Control in the Pan-American Health Organization stated that without DDT, the endemic countries would revert to conditions that existed before the advent of DDT. That is precisely what has occurred.

I hope none of you have experienced malaria. I have. I had shaking chills, a raging fever, enormous headache, and fatigue. I thought I was going to die and I only had the mild form. The dangerous form, falciparum malaria, can quickly enter a cerebral phase and kill even with good medical care.

With chronic malaria, the bodies of children become distended with enlarged livers and spleens. Malaria patients can be severely anemic. Acute cases can experience renal failure and slip into a coma and die. Latest estimates put the number of deaths over one million a year, mostly in children and pregnant women. Beyond this, there are as many as 500 million cases of malaria each year.

Malaria is a re-emerging disease, and it is a re-emerging disease because of environmental pressures against the use of insecticides. Poor countries need the freedom to use DDT for disease control if they choose to do so. Yet, they do not have that freedom. DDT continues to be portrayed negatively in the press and elsewhere. It is taken as a given that DDT is a toxic chemical with disastrous human health effects. It is not. DDT is a simple compound with unique actions to prevent transmission of malaria.

The pressure against DDT is sometimes subtle and appears in the foreign aid programs to malaria-stricken countries. Multilateral donors like The World Bank and bilateral donors like USAID pressure countries to not use DDT in malaria programs. The World Health Organization promotes use of insecticide-treated bed nets to the practical exclusion of spraying with DDT.

Bed nets are indeed a tool, but they are not nearly as effective for one simple reason: the Governments of poor African and South American Nations cannot force their citizens to sleep under bed nets every single night. On the other hand, inside walls of houses can be sprayed and DDT will be effective night after night for months on end.

Another tool for combating malaria is the use of antimalarial drugs. However, the number of malaria cases has grown to such an extent that some countries cannot even afford to treat the number of cases that they have. In 2003, Colombia had first-line treatments for only 86 percent of its cases, and Colombia is a relatively wealthy country. I have no idea how incomplete such treatments are for the poorer countries of Africa.

The only solution to this growing public health disaster is to prevent the disease. As explained in my written testimony, DDT is 90 to 95 percent effective against malaria vectors through its spatial repellant actions alone. This simply means that it stops mosquitoes from entering houses and transmitting disease. DDT exerts other protective actions as well.

In summation, the re-emergence of malaria is a colossal human health disaster. It is made more so because the decision to remove DDT was based on a political agenda and not on science. Of the three big killer diseases—malaria, TB, and AIDS—malaria should be the easiest to control. We simply need the moral clarity and political willpower to do what is necessary.

Thank you.

Senator INHOFE. Thank you, Dr. Roberts.

Mr. Sandalow.

STATEMENT OF DAVID SANDALOW, DIRECTOR, ENVIRONMENT AND ENERGY PROJECT, THE BROOKINGS INSTITUTION

Mr. SANDALOW. Thank you very much, Mr. Chairman. None of my family is here today—my three children are in school, my wife

is at work. In a very real sense they are always with me, so I appreciate the opportunity to acknowledge them, Mr. Chairman.

Hurricane Katrina has already been raised this morning, and it casts a shadow over both this hearing and over much of our national life. In fact, tomorrow it will be one month since Hurricane Katrina made landfall on the Gulf Coast. The suffering caused by this storm is well known, but no less tragic for being so. Today, countless thousands of Americans grieve relatives lost in that storm, and many more search for ways to restore shattered lives and livelihoods. As we join together as a Nation to rebuild the Gulf Coast region, our thoughts and prayers are with all of them.

Many observers have characterized Katrina as a defining moment in our Nation's history. Former Speaker Newt Gingrich said the impact of Katrina will be 30 to 100 times bigger than 9/11.

Then this past weekend our Gulf Coast was struck by another storm. Hurricane Rita was smaller and less powerful than Katrina, but only by comparison to its predecessor could Rita be considered a minor event. More than 3 million people were evacuated from their homes, causing traffic jams that lasted for more than 100 miles. The full death toll is not yet known, but exceeds several dozens. The Governor of Texas estimates the damage that occurred in his State alone exceeds $8 billion.

Mr. Chairman, the two hurricanes that struck our Nation in the past month raise important questions about science policy, environmental policy, and the intersection between the two. How can we better predict natural disasters of this kind? Will our response to Katrina be shaped by the best available science? What forces of global change shaped these two disasters and what impact will these forces have in the years to come?

Because these questions are so important, today I am recommending that the Senate ask the U.S. National Academy of Sciences to examine them. Specifically, I recommend the Senate ask the U.S. National Academy of Sciences to conduct a major new study on extreme weather events.

The report would assess the state of scientific knowledge in several areas, including: one, our ability to predict extreme weather events and how that ability might be improved; two, the causes of extreme weather events, both natural and human; three, land restoration in the Mississippi Delta both as part of the response to Katrina and to protect against future storms; and, four, human health and other risks related to the cleanup of toxic chemicals released as a result of Katrina.

This study should be done in phases, with an early product intended to help guide immediate recovery efforts in the Gulf Coast region and then an ongoing and more comprehensive program.

The first area that I believe the National Academy should look at, just to expand a bit, is improving our ability to predict extreme weather events. More than 100 years ago, on September 8, 1900, a category 4 hurricane blasted into Galveston, TX. In an era before satellites, airplanes, or modern communications, the population had scant information about the fury arriving over warm Gulf waters, and 8,000 people lost their lives.

Well, today we take for granted our ability to watch storm clouds gather from satellite photos beamed to our living rooms. We expect

government agencies, well functioning government agencies, to provide advanced warning of impending danger. We shouldn't be satisfied with our current predictive powers. Rapidly improving information and communication technologies can steadily improve these powers, preventing property damage and saving lives.

Nor, I believe, should our quest be limited to hurricanes. This summer, new heat records were set in more than 200 U.S. cities. Drought has been a chronic problem for several years in the American West, and in 2004 more than 1,700 tornadoes struck the U.S., by far the most recorded ever in a single year. I recommend the National Academy study encompass all these issues.

I also recommend the National Academy, as I said, look at land restoration and wetlands issues—critically important topics—as well as toxic cleanup issues. In the interest of time, I will not expand on those, but I would be happy to answer any questions on them.

A fourth area that I believe the National Academy should look at is responsibly addressing global warming. Today, there is ample evidence that heat-trapping gases from human activities may produce more powerful hurricanes. We should proceed responsibly with respect to this risk, steadily improving our knowledge and shaping smart policies in response. Much is already known on this topic. Heat-trapping gases from human activities, mainly the burning of fossil fuels, are warming both the atmosphere and the oceans.

Now, Dr. Gray says he disagrees with this and that he has been simmering on this topic for 20 years. I would respectfully request that Dr. Gray simmer his way right into the peer reviewed scientific literature on this topic. It is critically important that we know whether Dr. Gray's passion on this topic, which is considerable, is matched by the rigor of his analysis in the judgment of his scientific peers.

Dr. Crichton suggests that we use randomized double-blind studies. To make an obvious point, we have only one subject when it comes to planet Earth. We cannot use a randomized double-blind study with respect to our planet.

Now, that fact cannot and should not cripple either science or policymaking when it comes to atmospheric science. Mr. Benedick's testimony provides a compelling example of a way forward, one embraced by President Ronald Reagan, as Ambassador Benedick explains, on the basis of theories that were found to be the basis for policymaking.

As sea surface temperatures rise, average hurricane strength is predicted to increase as well. These predictions are consistent with observations from the historical record. During the past 30 years, as the total number of hurricanes globally has remained roughly constant, the percentage of category 4 and 5 storms has nearly doubled. In our hemisphere during this period, peak wind speeds of hurricanes have increased by roughly 50 percent.

Now, as many people have commented, there is no way to determine whether any single hurricane is or is not the result of global warming. When it comes to the strength of hurricanes, we are starting to play with loaded dice. As heat-trapping gases build in our atmosphere, the average hurricane will become more intense.

Now, these observations are especially troubling because, according to many experts, Atlantic hurricanes will likely be more frequent in the years ahead as a result of natural cycles. Thus, in the years ahead the United States faces a double threat: more frequent hurricanes due to natural cycles and more intense hurricanes due to human activities. This is a risk that we ignore at our peril.

Today there are no Federal controls on the major heat-trapping gases, although this Senate supported such controls in a bipartisan resolution passed this summer. As the Senate considers how best to translate this resolution into legislation, it should be informed by the best available scientific evidence concerning risks from extreme weather events and from global warming.

Now, in my closing minutes, Mr. Chairman, I would just like to briefly turn to some recent developments in the role of science and Federal environmental policy. You have said previously that scientific inquiry cannot be censored. Scientific debate must be open, it must be unbiased, and it must stress facts rather than political agendas.

Unfortunately, the past 2 years have not been a happy time for the role of science in Federal environmental policy. Last year, as Senator Clinton and Senator Boxer have said here, 48 Nobel laureates and 62 National Medal of Science recipients were among the more than 4,000 scientists who signed a statement expressing concern about "the manipulation of the process through which science enters into the Federal Government's decisions." Among the specific matters identified as concern were the suppression and distortion of scientific conclusions from Federal environmental agencies, specifically on the topic of climate change, and the political manipulation of expert advisory committees, specifically in some environmental areas including lead poisoning.

These are issues of great consequence. Sound policymaking cannot proceed in the face of such concerns, and I believe that they require priority attention from this committee and the Senate as a whole.

One approach as suggested by the Restore Scientific Integrity to Federal Research and Policy Making Act, introduced in the House as H.R. 839—and this may serve as a complement to your bill, Senator Voinovich, and one that might be considered together among other things. This act would help prevent the manipulation of data, strengthen the independence of Federal science advisory committees, and require an annual report to Congress by the Director of the Office of Science and Technology Policy on the state of Federal scientific integrity. This legislation would help address many of the most serious concerns that have arisen in recent years and is worthy of consideration by this body.

Thank you, Mr. Chairman, for the opportunity to address the committee.

Senator INHOFE. Thank you, Mr. Sandalow.

Let me start with just a real brief question for you. You made several references in a respectful way to Dr. Crichton and Dr. Gray. I think you know Dr. Gray's background in science, his credentials.

In a way, I kind of regret that Michael Crichton was an author. Because if he had not been an author, he would still be here today

because of his scientific credentials, having degrees from Harvard College and Harvard Medical School, visiting lecturer of Physical Anthropology at Cambridge University, post-doctoral fellow at the Salk Institute for Biological Studies. We would have him here anyway. I would ask you what your scientific background is, Mr. Sandalow, in terms of degrees and so forth.

Mr. SANDALOW. Senator, I am an attorney, although I have tried to overcome that handicap and go on to a useful and productive career. I don't claim scientific training and don't speak on the basis of any independent scientific research. I am reporting the peer reviewed results of many scientists.

Senator INHOFE. I appreciate that. Thank you very much.

Dr. Crichton, would you explain why researchers might have a vested interest in obtaining particular results? Any thoughts on that?

Dr. CRICHTON. Well, Mr. Chairman, having spent some time in the politicized environment of global warming, I am extremely reluctant to ascribe motive to people. I operate on the assumption that scientists I know are intelligent, hard working, and honest.

But what I would say is that I was a believer of the study of Michael Mann. I looked at that graph, which is very striking and extraordinary. I thought, my goodness, we have a really serious problem. So to the extent that I accepted the paper, when I began to see page after page of errors that were listed, I had disappointment to the same degree. It was very difficult for me not to believe that the people who worked on this paper never thought it would be checked. That is bad. That is bad for all of climate science.

Senator INHOFE. In your testimony, you describe the importance of being able to replicate studies. For some of us who don't have your background, can you kind of tell us why it is such a problem if studies cannot be replicated? What is the significance of replicating studies?

Dr. CRICHTON. I think we see a bit of it in the Mann study. The reason we are talking about the Mann study is that he attempted to address an extremely important question. In other words, we don't know what the future holds. There is a temperature increase, and one way to think about it is to say is this unprecedented or not. His findings indicated that it was unprecedented, and it turns out that other people who attempted to replicate this have concluded differently.

In fact, there is now some discussion about the extent to which proxy studies are even useful in this matter at all, because the proxies which have been studied from 1980—which was the end of Mann's work—to the present time don't show the kind of temperature increase that we know exists in the global record.

Senator INHOFE. I would ask this question of you or have you comment on it, as well as Dr. Gray and any of the rest who want to. When I first saw the hockey stick, with no scientific background, I looked at it and I thought, well, that seems reasonable.

But it seemed to me—and for some of us who don't have that background—they completely overlooked both the medieval warming period, the little ice age, and these things, when in fact temperatures were actually higher during the medieval warming period. Any thoughts about that for any of the experts here?

Dr. CRICHTON. That is true, sir. You know, to me, it creates the very odd thought that there may in fact be more constraints on what an American tabloid can publish than what the UNIPCC can publish.

Senator INHOFE. Well——

Mr. SANDALOW. Mr. Chairman.

Senator INHOFE. Yes.

Mr. SANDALOW. Could I comment on the Mann study, if you like?

Senator INHOFE. Well, I would rather have someone who has referred to it in their remarks. I think you did, Dr. Gray, from a scientific standpoint.

Dr. GRAY. I didn't refer to the Mann study, but I would like to comment on it. We are studying the medieval warming period. My daughter is a professor of geology, and we are working on the medieval warming period and the little ice age. She is covering more of that.

Sure there have been a lot of changes up and down. The atmosphere has always gone through these cycles. Just because the globe has warmed the last 100 years or last 30 years, we should not interpret that necessarily as human-induced, it is probably natural.

The majority of scientists, it is impossible—you see, there is grant money, there is all these things out there that compensates people that can arrange the data in such a way as to stir up interest that humans are doing these things, but there is no research money the other way.

Senator INHOFE. All right, thank you, Dr. Gray. I am going to have to cut you off here because we are going to try to stay within our time limits. It is not your fault, it is my fault.

Senator BOXER.

Senator BOXER. Thanks, Mr. Chairman.

A lot of people are being maligned here, and I take great offense at that. They are not here, but they are being maligned. One of them, Dr. Mann, who was the main subject of Dr. Crichton's testimony. I would like to place in the record a letter from Dr. Mann that was sent to a congressional committee, in which he shows how in fact his data were reproduced and used and studied. If I may place that in the record.

Senator INHOFE. Without objection.

[The referenced letter can be found on page 109.]

Senator BOXER. Thank you.

Dr. Gray, you have maligned a lot of people by a broad brush, just basically dismiss them. I want to know if your papers on global warming have been published.

Dr. GRAY. Some of them have, yes. I am working on a long paper on this now. But what——

Senator BOXER. Wait. I just want to get the answer. I don't have time to go into other subjects. So some have been published. Have they been peer reviewed?

Dr. GRAY. A couple of them have been, yes.

Senator BOXER. OK. Would you please submit those to the committee?

Dr. GRAY. I have.

Senator BOXER. Because we have tried to find peer reviewed——

Dr. GRAY. I did send a number of papers.

Senator BOXER. OK, good. Because we have tried to find some peer reviewed studies of yours—not on hurricanes, but on global warming. You say there are some peer reviewed?

Dr. GRAY. I have written some things on it, but I have been involved with——

Senator BOXER. Have they been peer reviewed?

Dr. GRAY. I am working on that now. There will be—if they will accept it. There is also——

Senator BOXER. Dr. Gray? Dr. Gray?

Dr. GRAY [continuing]. A slight bias about accepting papers that criticize peer review.

Senator BOXER. OK. I get your point. I am asking you something, I still don't have an answer. You have been peer reviewed for your articles on hurricanes. Have you been peer reviewed on your articles on global warming?

Dr. GRAY. Some have appeared. One appeared in a forum journal.

Senator BOXER. Well, Mr. Chairman, I am not getting an answer, so I am going to move on.

Now, one of the things you said at the end of your testimony is nature plays its games and tricks. You reminded me, in a very nice way, actually, about my mother, who said everything was predictable until we landed on the moon. She was convinced that changed weather patterns and everything else. So it is very easy for us all to just say that and, you know, in some ways it is comforting; say no one can really predict it. The fact is would you not agree, Dr. Gray, that there are some very talented people who believe that global warming is a phenomenon and is occurring?

Dr. GRAY. I would agree to that. The trouble with that is they don't know how the atmosphere ticks.

Senator BOXER. OK.

Dr. GRAY. They are modelers. They are people that make assumptions that are not valid and they believe them.

Senator BOXER. OK, good.

Dr. GRAY. They are probably honest people, but——

Senator BOXER. Right.

Dr. GRAY. And——

Senator BOXER. Dr. Gray, I would like to ask you this. You say people on the other side from you are wrong, and you say they don't know what they are talking about. Your attitude is not really very humble, but let me just probe you here.

Dr. James Hanson, he is one of those people. He is a chief at NASA Institute for Space Studies. He is best known for his testimony on climate control change to congressional committees in the 1980's that helped raise broad awareness of the global warming issue. He was elected to the National Academy of Sciences in 1995. He received the Hines Environment Award for his research on global warming. You think he doesn't know what he is talking about on this?

Dr. GRAY. I am glad you asked that question. James Hanson is a very bright, outstanding scientist, I have no doubt about that. He got his Ph.D., I believe, on the runaway greenhouse effect of Venus. I don't know what he knows about the atmosphere. He is not trained as a meteorologist, and I don't know why the press goes to

him so much. I don't know why he could come down here in the hot summer of 1988, before a congressional committee, and make these claims. They are ridiculous. And how——

Senator BOXER. Do you know what he was trained in?

Dr. GRAY. What?

Senator BOXER. Since you are now trying to shatter his reputation, what was he trained in? What was his area of expertise that he was trained in when he was in school?

Dr. GRAY. Who?

Senator BOXER. Dr. Hanson.

Dr. GRAY. I believe Hanson was an astronomer, a very capable, good astronomer who I have been told that his Ph.D. thesis was on a runaway greenhouse effect of Venus. He knows Venus well, just like Sagan knew Mars well.

Senator BOXER. Sir, you are making my point. He was trained in physics as well as astronomy, and he is well acclaimed. You just brush away everybody who doesn't agree with you, which I think, going in, isn't a very scientific thing to do. To prejudge——

Dr. GRAY. No. There are a lot of us out there that don't agree with——

Senator BOXER. Dr. Gray? Dr. Gray? Dr. Gray? I understand. I understand. But I am just trying to say something in a friendly way to you. It doesn't help your case to demonize everyone who doesn't agree with you, because you wind up without very much credibility.

Dr. GRAY. No, it is not everyone doesn't agree with me.

Senator BOXER. I would like to ask Dr. Crichton a question.

Dr. GRAY. I represent a lot of meteorologists who think very much like I do.

Senator BOXER. Dr. Gray, my time is running out.

Dr. Crichton, you say predictions are not science.

Dr. CRICHTON. Excuse me. I said they are not facts.

Senator BOXER. They are not facts.

Dr. CRICHTON. Right.

Senator BOXER. Predictions are not facts. Do you think that there is room for prediction in weather science, for example?

Dr. CRICHTON. Senator Boxer, yes, I think that climate modeling is excellent. I have had a lot of discussions with the climate modelers about that. I am making a single point only. It is a very interesting scientific undertaking. At the moment the models differ one from another by 400 percent, which is an enormous amount. All I am saying is you can't use them for policy.

Senator BOXER. OK. But you are saying there is room for predictions in weather science.

Dr. CRICHTON. Yes. You have heard Dr. Gray. We can make excellent predictions for 4 days.

Senator BOXER. Well, I have heard a lot of people other than Dr. Gray, but thank you very much. Also, I would like to put in the record something called "Distort Reform, A Review of the Distorted Science in Michael Crichton's State of Fear," by Gavin Schmidt. If I could put that in the record.

Senator INHOFE. Without objection, so ordered.

Senator BOXER. Thank you.

[The referenced document was not submitted at time of print.]

Senator INHOFE. Senator Thune.

Senator THUNE. Thank you, Mr. Chairman. I appreciate your holding what I believe is a crucial hearing on this subject and the importance of sound science and environmental policymaking. I am intrigued in listening to the discussion on climate change and atmospheric science, and appreciate very much this very distinguished panel being here today and sharing your thoughts and your insights and your expertise.

I want to approach it from a slightly different angle, which you could argue, I suppose, is somewhat parochial, but it comes back to the basic premise that science does inform policy. This committee will be dealing in the very near future with reforms of the Endangered Species Act, and how do we approach making that Act more workable. Frankly, if you look at since its inception in 1973, there have been very few successes in terms of recovering species, and lots of hardships imposed on landowners and State and local governments and others.

In specific I want to use one example here, and then maybe get the panel's reaction to it or comment. We had an instance here a few years ago in South Dakota where the prairie dog was listed or proposed to be listed as a threatened species under the Endangered Species Act, and at the time, of course, it was suggested that the prairie dog is the diet for the black-footed ferret, which was on the list, and that in order to provide diet for the black-footed ferret, we needed to protect the prairie dog.

Now, most of the ferrets—and I would argue a large number of the prairie dogs—are, of course, in the western part of the Country, many in South Dakota. It was feared that we didn't have enough prairie dogs for the ferrets to eat. What happened was that fear was unjustified.

In my view, and I think arguably they came to the same conclusion when they decided not to list it, but sound science was not used in that decision to list the prairie dog. In fact, if sound science had been used, it would have been proven that there are literally thousands, probably millions, I think, of prairie dogs living on South Dakota's grasslands, certainly more than there are people in South Dakota.

The Government was relying on bad science and, as a consequence, South Dakota's landowners in that area suffered. If you look at the range—and I have in that area, visited numerous times—it looks like the face of the moon. That is the impact that not managing this population has imposed on landowners out there. Anybody who has been to that area of South Dakota knows the prairie dog is not endangered.

Anyway, my question is this. I have talked to the experts about this and what is the criteria by which the standard that is used for whether or not a species goes on that list. The two questions that are asked: Is the species endangered today? Second: Will it be endangered in the foreseeable future? To answer those questions, I assume there has to be some data, some science that is used. There again, clearly in this case, that science was completely incorrect.

I guess the question I would ask—and this is with respect to the Endangered Species Act and some of the changes that we are look-

ing at making—is what should be the scientific standard that applies to such policy pronouncements? Clearly, there were some extrapolations made about the numbers out there, but I think this is another example of where we rely and decisions are sometimes made in a political environment rather than a scientific one. I frankly hope that when we make some changes in this, that we will impose some scientific standards.

I would welcome anybody's thoughts or insights about that. Mr. Benedick?

Mr. BENEDICK. Yes, thank you, Mr. Chairman. It seems to me, in listening to the conversation up until now, that we all agree that there is a need for sound science. Where the disagreement comes is: what is sound science. I think what constitutes sound science—is not as simple as some of us would like to have it. It is not black and white; there is not absolute certainty.

We have to ask the right questions and then evaluate the answers. One issue is: to whom do you address the right questions? Is it to individual scientists, some of whom have been mentioned here, or is it to bodies of scientists? That is why we have a National Academy of Sciences, for example. That is why we also have, or had, the Office of Technology Assessment within the Congress, which was designed at that time to provide scientific information.

One can't wish a problem away just because one hopes it won't happen. I honestly hope that climate change doesn't happen. But when the National Academy of Sciences, when the other institutions of real experts come out with their conclusions, I find it hard to dispute it. If it was only one or two, or only a small number of dissenters, that may not be significant. If there are real questions, I think they should be addressed to institutions like the National Academy of Sciences.

There is also some reference made about climate models varying in wide dimensions and, therefore, we can't trust them. Well, perhaps they are models at the extremes, but there is also a certain convergence. For example, if I feel ill and consult 10 doctors, and 2 of them say I am going to die right away, and 2 say no problem at all, you don't need to do anything, and the other 6 say, wait a minute, there is something that you can take for it, I will listen to that convergence. I am not going to listen to the extremes.

I would suggest that on many of the issues that we are talking about, there is a real convergence. There are going to be extremes on both sides, but we have to look for those convergences and then have the courage to act on them.

Senator INHOFE. Thank you, Mr. Benedick. In fairness to Senator Thune, who is going to have to be leaving, did anyone else want to comment on the question that he asked?

[No response.]

Senator INHOFE. All right, that is fine.

Senator THUNE. Mr. Chairman, if I might, as a matter of closing, just say this. I think that if in fact scientific truth has to be verifiable, that is a key thing. I would argue that much of the science at least that was used in predicting the number of prairie dogs on the ranges of South Dakota wasn't accurate and wasn't verified, and, as a consequence, was bad science on which to make a decision like this.

I would also argue that it ought to include, in addition to the science groups out there, the folks who do this sort of research, perhaps talking to local people. I think local input is a key. You know, you might have been able to get a lot more accurate count if you just asked a few ranchers in South Dakota about this subject.

So I know my time has expired, and I appreciate your indulgence. Again, I thank you. It has been very informative.

Senator INHOFE. Thank you, Senator Thune.

Senator Murkowski.

Senator MURKOWSKI. Thank you, Mr. Chairman. I want to follow up on this issue of verification, because I really do think that this goes to the heart of what we are talking about here today.

Mr. Sandalow, you have suggested numerous studies be conducted that would look into the aftermath of Katrina, or what happened or how we can calculate it. I am sitting up in Alaska, where I can see that we are experiencing climate change. I am not going so far as to say it is global warming, but we see climate change.

Just in this morning's press clips, I have got a clip on a major winter storm that is continuing the erosion from our coastal villages. Yesterday's account in the clips indicated that we have seen the warmest summer up north that we have seen in 400 years. The stories are out there.

So I look at not only what I am able to see and what we are able to verify as Alaskans on the ground looking at climate change, but I am also looking at the studies and at the reports. The problem is that the studies and the reports are less than conclusive. You have one that is saying one thing, another that is saying another thing.

So I don't know that I am necessarily with you in saying that the solution here is to conduct more studies. I think we need to make sure that the studies that are conducted do have some level of verification, do have some level of accountability, if you will. We are dealing in an area where the science is difficult.

I appreciate your statement, Dr. Crichton, that prediction is not fact. It is exactly that, it is prediction.

So I hear what you are saying, and you are saying let us get three independent studies going on. I don't know whether that is the answer, but I think the key here is going to be verification.

Now, Senator Boxer, in her statement, showed a list of individuals who were backed by certain institutes, and I think her suggestion was that, of all of these, only two institutes were not supported in some way by the oil industry or whatever.

To what extent does funding influence the researcher, the analysis, and the conclusions? I throw that out to any one of you if you are willing to touch it.

Dr. GRAY. I would very much like to take that. Yes, I notice myself. I have been a bit of a critic on this human-induced global warming, and I had NOAA money for 30 years to study tropical storms and stuff, and I wanted to keep on doing it. When the Clinton administration came in, I couldn't get any money out of NOAA. I was turned down by something like 13 straight proposals.

There is a lot of research support out there to find things, rearrange data, I might say, to support this human induced global warming hypothesis. I know of no way—if I go in and say I don't

believe in it, would you give me some resources so I could study and try to prove that the statements made are exaggerated. There is no funding there.

There is even a question on publication. If you submit in something that doesn't go with this general brainwashing that has occurred, I call it that, over the last 20 years in the press, the press has played a great part, government, it has been used as a political issue. The reality of it, I mean, with all the problems in the world——

Senator MURKOWSKI. Dr. Gray.

Dr. GRAY [continuing]. This is one we humans are not much involved with.

Senator MURKOWSKI. Dr. Gray, if we can, I know that Mr. Benedick and Dr. Crichton also wanted to answer the question, and we are just about out of time. Thank you.

Mr. BENEDICK. Thank you, Senator. Do I think that funding can influence scientific results? Yes, I do. Just look at the tobacco industry. On the question of funding for critics of the climate change theory, of the global warming theory, I would cite Dr. Richard Lindzen at the Massachusetts Institute of Technology, who is a very eminent critic of global warming. I don't believe he has any problem getting funding.

If we are talking about verification of data, I think that rather than cherry-picking which scientist or which particular statement or which particular footnote, that we go to the bodies that are constituted to do this: the National Center for Atmospheric Research, for example, in Boulder, CO; the National Academy of Sciences, which I mentioned earlier; the great research universities. There are plenty of resources out there if one wants to listen to them. If one doesn't want to listen to them, one can always cherry-pick and find relatively isolated people who will say whatever they want to say.

Senator MURKOWSKI. Dr. Crichton.

Mr. BENEDICK. I think that our society and our institutions are prepared, are set up to provide responsible science if we will give them a chance, if we don't try to destroy their reputations or pick out one or another thing out of context.

On the climate issue, I would like, respectfully, to suggest adding to the record the testimony of Dr. Ralph Cicerone, who is the President of the National Academy of Sciences, who testified on July 20th before the subcommittee on Global Climate Change and Impacts, of the committee on Commerce, Science and Transportation of the U.S. Senate. I would suggest this might be some part of the record. It is his statement representing the National Academy of Science.

Senator MURKOWSKI. Mr. Chairman, I know we are out of time, but if Dr. Crichton can just——

Senator INHOFE. I am going to go ahead and give you a couple of my minutes on the second round right now, because I know you directed Dr. Crichton to please respond.

Senator MURKOWSKI. Thank you, Mr. Chairman.

Dr. CRICHTON. Senator Murkowski, I think in part my comments were intended to suggest a broader issue. I think in the twenty-first century this body is going to be dealing increasingly with sci-

entific issues, and you are going to have to find some new strategies.

One of them which I think would answer Senator Thune, is if there were four studies that were let out by totally different, independent entities—not people who knew each other, not people who published together—that asked the question how are the prairie dogs doing, you are going to get a more reliable answer.

In the long run I think, yes, you are going to have to find funding. Scientists, like everyone else, know who they work for, and I think there is a perception that many government agencies now want to get back answers that confirm global warming. The notion that there are industries that don't want that, of course, I think is straightforward.

Whoever you work for, they are looking for a certain kind of answer. The solution is only to have scientists not know who they are working for in terms of where the funding is coming from.

Senator INHOFE. Senator Voinovich.

Senator VOINOVICH. I think the most alarming thing I heard today was, Dr. Roberts, your testimony. Do other people share your opinion about DDT, or are you out there in the weeds somewhere on this one?

Dr. ROBERTS. I am out there. Actually, if I could have just a couple of minutes to respond. In response, I would like to bring together a couple of things, Senator Thune's comments and Senator Boxer's list.

Senator VOINOVICH. You are on my time now, OK?

Dr. ROBERTS. OK.

Senator VOINOVICH. I would like to ask you my questions.

Dr. ROBERTS. OK.

Senator VOINOVICH. You are saying that there are lots of scientists who disagree with you on DDT? The impression that you gave me was that my good friend, Bill Ruckelshaus, when all of the testimony came in about DDT and found that it wasn't what people said it was, that he banned it anyhow and, as a result of that ban, we are seeing malaria come back all over the world, and that thousands of people are dying because of malaria; and that if we reviewed our interest in DDT, that might save thousands of lives. Is that what you are saying?

Dr. ROBERTS. That is what I am saying. The answer as to whether or not the scientific community is in support of me, we initiated an effort in the 1990's to prevent DDT from being banned through the POPs negotiations, and we circulated a letter to get scientists to sign on to that letter, and a very large number, hundreds of scientists, signed on in support of that effort. I would say that there is a very broad base of support for the continued use of DDT.

Senator VOINOVICH. Mr. Chairman, that might be something that we look at.

All of the witnesses have talked about the issue of scientists disagreeing, and the question I have to all of you is how can the Federal Government achieve good science-based decisions, making them when there are so many different opinions among the scientists with respect to a particular environmental concern? We get this all the time around here.

In my statement I mentioned the creation of a position in the EPA called the Deputy Administrator for Science and Technology, and the second thing was to take EPA's current top science job, the Assistant Administrator for Research and Development, and give them a 6-year term, which would insulate them to a certain extent from politics. Also, traditionally, it has been one of the weakest positions in the EPA.

Mr. SANDALOW. Senator, I would like to applaud what is behind your legislation. Certainly the effort to insulate environmental science from political factors is a crucially important one. So I think your bill deserves very close consideration.

I think, in answer to your question about ways to address the use of science, I would recommend a couple of things. First, it is important that we commit the most difficult questions to independent bodies, and that is one reason that I have recommended the National Academy take on various Katrina-related issues in my testimony.

Second, it is important that science be adequately funded. That has been raised a little bit today, but not much. The pressures right now on budget for scientific research are very considerable, and it is very important that we adequately fund basic science research going forward.

Third, it is critically important to have leadership from the top and from the Federal Government at all levels on this issue, and to make it clear that there will be no tolerance for political manipulation of scientific data. I think with those things we could take big steps forward.

Senator VOINOVICH. Other comments in terms of do you think we need to improve the capacity at the Environmental Protection Agency? Would you support somebody over there that would have a 6-year term that would segue into another term and possibly insulate him more from "political pressure" than someone else?

Mr. BENEDICK. Senator, I did mention at the beginning of my statement that, representing the National Council, I applaud your efforts to do this at EPA. I think that any measures that are taken to insulate scientific inquiry and the peer review process from political pressures, from wishful thinking, from "we wish it weren't there and, therefore, we are going to pick out the scientists we want," that our society will be better off if we can do this.

As I suggested earlier, there are institutions in which you can find, not the extremes on either side, but where you can find a reasonable convergence. That is what we did in the ozone history. We didn't listen to the ones who were saying the sky is falling, and we also didn't listen to the ones who said that CFCs were no problem. I think that worked out right under a conservative administration, and I believe that is the way we should go, and really keep ideology out of science as much as we can.

Senator VOINOVICH. Thank you.

Dr. GRAY. I would just like to make a statement, that in science a majority is often wrong, it is not a democracy. That is our problem. You can have these institutes and Nobel Prize people and all the credentials people you want, but that doesn't mean they are able to render a proper judgment. That is the trouble.

Senator VOINOVICH. You know, Dr. Gray, what you do is you try to get the best information that you can, and make a decision. Sometimes, I think some other witnesses mentioned, those decisions aren't black and white, sometimes they are gray. You try to do the best that you can with the information that you have, because if you take a position that they may be wrong, nothing is done.

Dr. CRICHTON. Senator, it is not exactly on the point of your question, but the confidence in the independent bodies like the NAS that some others have expressed I don't necessarily share in this particular area. I think it has become so intensely politicized that even that may not be successful.

For example, the NAS was asked at some time in the recent past to investigate the difference between satellite temperature measurements and ground temperature measurements, since those records in recent years haven't agreed, and there has been dispute about which might be incorrect or both. The NAS came back and said they are both correct, which is, in my view, simply taking a pass on the whole subject.

If in fact this is so hot among even academic communities that it can't be examined closely, I think you are going to back yourself into something like the sort of blue ribbon commission that was used to investigate the Challenger disaster, in which you bring in all kinds of outside people and ask them to assess the state of the science, because internally it is just too difficult for people to do it.

Mr. SANDALOW. Senator, in Mr. Crichton's book he writes roughly—I won't get the words exactly right—"I am the only person who doesn't have an agenda." When I read that in his book, I thought it was tongue in cheek. Hearing him sit here and question the objectivity and bona fides of the National Academy of Science, while taking it upon himself to form judgments on this question, makes me wonder whether in fact he meant to write that sentence seriously.

I think it is beyond controversy that the National Academy of Sciences of this Nation is well respected. Its product has been and is widely admired by many scientists, and I don't think this statement should go unchallenged.

Senator INHOFE. Let me make a comment about that. First of all, I hope you were listening when I entered into the record statements by the National Academy of Science. Actually, it was by the past President of the National Academy of Sciences. They have not been definite on this issue in terms of global warming, and I think we all understand that.

Let me just make a comment too, since we only have 4 minutes left, and certainly, Senator Voinovich, it is down to you and me now.

Senator VOINOVICH. I have to be excused.

Senator INHOFE. Oh, all right. Well, thank you for your contribution.

I would like to say that those of us on this side of the panel are not experts. We are not scientists, and I recognize that. But sometimes it might be healthy to sit back and kind of push back and look at it in an unscientific way, and look at it just on a logical way. You have to keep in mind that Washington, DC is the city of

hysteria; everyone has to be hysterical about everything that happens up here. When I look at this and I read some of the stuff that came out of this committee and that was on the front page of almost every magazine in America, like Time Magazine, U.S. News and World Report back in the middle 1970's, they talked about another ice age is coming.

I went back and checked, and found that the same people that now are hysterical over global warming were the ones that were talking about the ice age. I look and see what happened in the 1940's. The largest increase in the use of CO_2 increased by about 80 percent during the middle and late 1940's. Did that precipitate a warming? No, it didn't, it precipitated a cooling at times.

So I just think that we have to look at these things and try to get as much of the hysteria out of our minds. I could put it another way. I think in the case of global warming, it really has become a religion to a lot of people. A lot of people have so many years of their lives wrapped up in it that they don't want to all of a sudden realize that most of the science since 1999 has refuted it. How could I have been wrong; and did I waste 10 or 15, 20 years of my life? I kind of think this is some of the things that are going on.

We have come to the time here. We have several things that I am going to enter into the record on flawed science. Without objection, it will be a part of the record.

Let me thank all of you for your time that you have spent here. It has been a long hearing. You have come a long way. I want you to know that I personally appreciate each one of the five of you very much.

We are adjourned.

[Whereupon, at 11:45 a.m., the committee was adjourned.]

[Additional statements submitted for the record follow:]

STATEMENT OF THE HONORABLE RICHARD E. BENEDICK, PRESIDENT, NATIONAL COUNCIL FOR SCIENCE AND THE ENVIRONMENT

Since 1994, I have been President of the National Council for Science and the Environment (NCSE), an organization dedicated to improving the scientific basis for environmental decision making that is supported by over 500 universities, scientific societies, State and local Governments, corporations, chambers of commerce, foundations and civic organizations.

During the 1980s, I served under President Reagan as Deputy Assistant Secretary of State for Environment, Health and Natural Resources. In 1985, I was designated by Secretary of State George Shultz and then-Assistant Secretary John Negroponte to be chief U.S. negotiator for a treaty to regulate certain chemical substances suspected of depleting the stratospheric ozone layer. I later wrote a book on the subject, Ozone Diplomacy, which was published by Harvard University Press (1991, revised ed. 1998) and Kyogo Chosakai (Japan, 1999), and was later selected by McGraw-Hill for an anthology of environmental classics of the twentieth century.

INTRODUCTION: AN HISTORIC AGREEMENT

The ozone history illustrates the critical role that science and scientists can play in the development of public policy under conditions of risk and uncertainty. Yet, when the negotiations began on the treaty to control use of chlorofluorocarbons (CFCs), few gamblers would have wagered that they could succeed.

CFCs and their related bromine halon compounds seemed to be ideal man-made chemicals. Invented in the 1930s, they are stable, nontoxic, nonflammable, non-corrosive, and relatively inexpensive to produce—all qualities that made them uniquely suited for a myriad of consumer and industrial applications. Over the years, they found more and more uses in thousands of products and processes—in pharmaceuticals, cosmetics, spray cans, agriculture, petroleum, microchips, electronics, automotive, defense, aircraft, insulation, plastic foam, aerospace, telecommuni-

cations, refrigeration, and air conditioning, to name a few. CFCs became virtually synonymous with modern standards of living.

The scientific, economic, technological and political issues involved in the negotiations were staggeringly complex. Billions of dollars of international investment and hundreds of thousands of jobs worldwide were involved in production and consumption of CFCs and halons. Powerful governments in Europe, Japan and the Soviet Union aligned with global economic interests in adamant opposition to controlling CFCs, maintaining that technological alternatives were nonexistent or too costly or unfeasible.

The then twelve nation European Community (EC) was the primary opponent of action. Its ozone position was based largely on the self-serving data and contentions of a few major companies—including Britain's Imperial Chemical Industries (ICI), France's Atochem, and Germany's Hoechst. European industry's primary objective was to preserve their market dominance and to avoid the costs of switching to alternative products for as long as possible. Epitomizing the close EC industry-government linkages, company executives often served on official delegations. Indeed, during the protocol negotiations we actually came across an official EC instruction drafted on an Atochem corporate letterhead.

Most other governments and peoples were unaware or indifferent to an arcane threat occurring 30 miles above the earth's surface. As an Indian diplomat admonished me early in the negotiations: "Rich man's problem—rich man's solution."

Perhaps most significant of all, during the negotiations the arguments for controlling CFCs rested on unproven scientific theories. The science remained speculative, based on projections from still-evolving computer models of imperfectly understood atmospheric processes—models that yielded varying, sometimes contradictory predictions each time they were refined.

Despite the significant growth in emissions of CFCs, thirty years of recorded measurements had not demonstrated any statistically meaningful ozone depletion over mid-latitudes. The models did not even predict global depletion, with existing levels of emissions, for at least the next twenty years. Moreover, not only was there no evidence of increased levels of UV-B radiation reaching earth's surface, but such measurements as existed actually showed reduced radiation.[1] During the negotiations, the seasonal "ozone hole" over Antarctica, while alarming, was considered by most scientists to be an anomaly, since it did not conform to the theoretical ozone depletion models and could possibly have had other than anthropogenic causes.

Nevertheless, after contentious international negotiations, compounded by unexpected late controversy from within the U.S. Administration, a strong control treaty was signed in Montreal in September 1987. The treaty signing attracted worldwide media attention, and it was hailed in the United States Senate as "the most significant international environmental agreement in history."[2] President Reagan became the first head of state to endorse the Montreal Protocol, characterizing it as "a monumental achievement of science and diplomacy,"[3] and the treaty was unanimously ratified by the Senate.

Perhaps the most extraordinary aspect of the Montreal Protocol was that it imposed substantial short-term economic costs in order to protect human health and the environment against speculative future dangers—dangers that rested on scientific theories rather than on proven facts. Unlike environmental agreements of the past, this was not a response to harmful developments or events, but rather preventive action on a global scale.

Within less than six years after the negotiations began in late 1986, the Montreal Protocol had been ratified by more than 100 (later over 180) nations. Gradually unfolding scientific evidence of damage to the ozone layer led to major revisions of the protocol, expanding the list of controlled chemicals from 8 to over 90 and considerably strengthening timetables for reduction and phase out of the dangerous chemicals.[4] A veritable technological revolution was unleashed that within a few years transformed entire industries. The protocol also created the first-ever global environmental fund to assist poorer nations, and promoted an unprecedented North-

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[1]D. Albritton et al., Stratospheric Ozone: The State of the Science and NOAA's Current and Future Research (Washington, DC: National Oceanic and Atmospheric Administration, 1987), p.9; WMO, Atmospheric Ozone 1985: Assessment of Our Understanding of the Precesses Controlling Its Present Distribution and Change (Geneva, 1986), chapter 14.

[2]U.S. Senate, Committee on Foreign Relations, Ozone Protocol, Executive Report 100-14, Feb. 19, 1998, p. 61.

[3]"President Signs Protocol on Ozone-Depleting Substances," Department of State Bulletin, June 1988, p. 30.

[4]R. Benedick, Ozone Diplomacy: New Directions in the Planet (Cambridge, MA and London: Harvard University Press, rev. ed. 1998), provides a history and analysis of the ozone issue and the Montreal Protocol negotiations.

South collaboration in developing and diffusing new technologies that have now made most ozone-depleting substances obsolete.

Even so, it was a near thing. For decades after their discovery, no one had suspected that these multifaceted wonder-chemicals could cause any harm. They had been thoroughly tested by customary industrial standards and declared completely safe. Possible effects thirty miles above the earth had simply never been considered. And, because the CFCs and halons have such long atmospheric lifetimes, their deleterious impacts will still be felt for decades, even after new emissions cease.

The Montreal Protocol is generally considered to be the most successful environmental treaty in history. The heads of the World Meteorological Organization (WMO) and the United Nations Environment Programme" (UNEP) stated that "the action to defend the ozone layer will rank as one of the great international achievements of the century."[5] Given the threats to human life and the global economy that have been averted through this landmark treaty, few would challenge their statement as hyperbole.

THE ROLE OF SCIENCE AND SCIENTISTS

Unquestionably the indispensable element in the success of the Montreal Protocol was the role of science and scientists. Without the curiosity and courage of a handful of researchers in the mid-1970s, the world might have learned too late of the hidden dangers linked with rapidly expanding use of CFCs.

Ozone, whose existence was unknown until 1839, has been characterized as "the single most important chemically active trace gas in the earth's atmosphere."[6] Two singular characteristics of this remote, unstable, and toxic gas make it so critical to human society. First, certain wavelengths of ultraviolet radiation (UV-B) that can damage DNA and the immune system and can cause cancer in living cells are absorbed by the thin layer of ozone molecules scattered throughout the atmosphere; the harmful radiation is thus prevented from reaching the earth's surface. And second, differing quantities of ozone at different altitudes have major implications for global climate. In sum, human health, agriculture and livestock, fisheries, biological diversity, and many materials would be significantly impacted by damage to the ozone shield. The ozone layer, at its historic natural concentrations and diffusion, is essential to life as it currently exists on earth.

In 1973, two University of Michigan scientists, Richard Stolarski and Ralph Cicerone, in the course of examining possible effects of chemical emissions from National Aeronautics and Space Administration (NASA) rockets, theorized that chlorine in the stratosphere could unleash a complex chain reaction that would continually destroy ozone over a period of decades. Fortunately, very little "free chlorine" was thought to exist at that altitude.[7]

However, a year later, Mario Molina and Sherwood Rowland at the University of California, Irvine, became intrigued with some peculiar properties of chlorofluorocarbons. They discovered that, unlike almost all other gases, CFCs were not chemically destroyed or rained out in the lower atmosphere, but rather migrated slowly up into the stratosphere. There they remained for many decades—some variants for more than a century. The two researchers concluded that the man-made CFCs, which are not naturally present at this altitude, are eventually broken down by radiation and thereby release large quantities of free chlorine.[8]

The combined implications of these two hypotheses were nothing less than sensational: the protective ozone shield would be seriously compromised. The enhanced levels of ultraviolet radiation that would then penetrate the atmosphere and reach earth's surface could have potentially disastrous impacts. The Rowland-Molina hypotheses unleashed a firestorm of criticism and controversy in the scientific and business communities. They were later vindicated by the 1995 Nobel Prize in Chemistry (together with Paul Crutzen of the Max Planck Institute), but it is worth noting that the first popular book on this subject, published in 1978, was entitled The Ozone War.[9]

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[5]G.O.P. Obasi and Elizabeth Dowdeswell, Foreword to R. Bojkov, The Changing Ozone Layer, Geneva: WMO/UNEP, 1995.

[6]D. Albritton et al., Stratospheric Ozone: The State of the Science and NOAA's Current and Future Research (Washington, DC: National Oceanic and Atmospheric Administration, 1987), p.1.

[7]R.S. Stolarski and R.J. Cicerone, "Stratospheric Chlorine: A Possible Sink Ozone," Canadian Journal of Chemistry 52 (1974).

[8]M.J. Molina and F.S. Rowland, "Stratospheric Sink for Chloroflouromethanes: Chlorine Atomic Catalyzed Destruction of Ozone, Nature 249 (1974).

[9]L. Dotto and H. Schiff, The Ozone War (Garden City, NY: Doubleday, 1978).

Astonishingly, the research paths leading to the suspicion that the stratospheric ozone layer was in jeopardy had been serendipitous. The scientists had not set out intentionally to condemn chlorofluorocarbons. Notwithstanding the initial controversy, the serious theoretical dangers prompted a wave of new scientific research over the following years.

It would be difficult to exaggerate the complexity of the research effort. Ozone itself amounts to considerably less than one part per million of the total atmosphere, with 90 percent of it located above six miles in altitude. The intrinsically unstable ozone molecules are continually being created and destroyed by complex natural forces involving solar radiation and interactions with even more minute quantities of other gases. Moreover, stratospheric ozone concentrations can fluctuate on a daily, seasonal, and solar-cyclical basis, and there are significant geographical as well as altitudinal variations

Amidst all these fluxes, scientists faced a formidable challenge in predicting, and then detecting, the minuscule "signal" of the beginning of a possible long-term downturn in stratospheric ozone as postulated by the theory. This necessitated the development of ever more sophisticated computer models to simulate the stratospheric interplay among radiative, chemical, and dynamic processes such as wind and temperature, for decades and centuries into the future. In addition, intricate observation and measuring devices had to be created and fitted onto aircraft, satellites, and rockets to monitor remote gases in quantities as minute as parts per trillion.

To fully understand the implications of a diminishing ozone layer, scientists had to venture far beyond atmospheric chemistry: they had to examine our planet as a system of interrelated physical, chemical and biological processes on land, in water, and in the atmosphere—processes that are themselves influenced by economic, political, and social forces. The Montreal Protocol thus became a truly multi- and interdisciplinary effort. Over the years, researching the dangers and solutions involved not only chemists and physicists, but also meteorologists, oceanographers, biologists, oncologists, economists, epidemiologists, soil chemists, toxicologists, agronomists, pharmacologists, botanists, entomologists, and electrical, chemical, automotive and materials engineers.

THE PROTOCOL IN TRANSITION

Even as the negotiators were hammering out the final compromises in Montreal in September 1987, an unprecedented international scientific expedition was under way in Antarctica. Using specially designed equipment placed in balloons, satellites, a DC-8 flying laboratory, and a converted high-altitude U-2 spy aircraft, scientists were tracking stratospheric chemical reactions and measuring minute concentrations of gases. Preliminary results, announced about two weeks after the protocol's signing, indicated high stratospheric chlorine presence and the worst-ever seasonal drop in Antarctic ozone.

Six months later, in March 1988, a joint NASA-NOAA press conference released the Ozone Trends Panel Report, a comprehensive international scientific assessment of all previous air- and ground-based stratospheric trace gas measurements, including those from the 1987 Antarctic expedition. The conclusions were stunning: no longer a theory, ozone layer depletion had at last been substantiated by hard evidence. The analysis established that between 1969 and 1986, stratospheric ozone over heavily populated regions of the northern hemisphere, including North America, Europe, and the Soviet Union, China, and Japan, had diminished by small but significant amounts. And CFCs and halons were now implicated beyond dispute—including responsibility for the ozone collapse over Antarctica.

The new scientific findings were profoundly disquieting. The most alarming implication was that the models on which the Montreal Protocol was based had proven incapable of predicting either the chlorine-induced Antarctic phenomenon or the extent of ozone depletion elsewhere. Most probably, therefore, they were underestimating future ozone losses.

Scientific studies now indicated that if existing atmospheric concentrations of chlorine and bromine were merely stabilized, the Antarctic ozone loss would be permanent. In order for ozone levels over Antarctica gradually to recover, and to avoid possibly crossing similar unforeseen thresholds in the future, it would be necessary to restore atmospheric chlorine concentrations (then at three parts per billion and rising) to levels at least as low as those prevailing in the early 1970s, namely, two parts per billion.

The original CFCs and halons would be phased out more rapidly than any of the negotiators at Montreal could have dreamed possible.

Although the work of protecting the ozone layer is still not completely finished, the major challenges have been successfully addressed. The industrialized countries have either phased out, or are in process of phasing out, all of the major ozone-depleting substances as well as the less-damaging transitional chemicals. Developing countries have also accepted phase-out schedules as a great wave of new technologies is being diffused around the world. Now, the ozone layer is slowly beginning to recover.

LESSONS FOR SCIENCE

Without modern science and technology, the world would have remained unaware of an ozone problem until it was too late. Science became the driving force behind ozone policy, but it was not sufficient for scientists merely to publish their findings. In order for the theories to be taken seriously and lead to concrete policies, scientists had to interact closely with government policy makers and diplomatic negotiators. This meant that they had to leave the familiar atmosphere of their laboratories and assume an unaccustomed shared responsibility for the policy implications of their research. The history of the Montreal Protocol is filled with instances of scientific panels being called upon to analyze and make informed judgments about the effectiveness and consequences of alternative remedial strategies and policy measures.

International scientific consensus was also essential. In effect, a community of scientists from many nations, dedicated to scientific objectivity, experienced through their research a mutual concern for protecting the planet's ozone layer that transcended divergent national allegiances. The development of an accepted common body of data and analysis was the prerequisite for a political solution among negotiating Governments whose initial positions seemed irreconcilable.

In 1984, a remarkable international collaborative research effort was launched by the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), in cooperation with the WMO, UNEP, the Federal Aviation Administration, the German Ministry for Research and Technology, and the Commission of the European Communities. Approximately 150 scientists of various nationalities worked under United States scientists' leadership for more than a year. The resulting study, Atmospheric Ozone 1985, was the most ambitious analysis of the stratosphere ever undertaken: three volumes containing nearly 1,100 pages of text and eighty-six pages of references.[10] This was followed by even more ambitions international studies.

The Montreal Protocol later institutionalized this concept by establishing independent international expert panels to periodically assess scientific, technological, economic, and environmental developments and thereby guide the negotiators in the implementation and revision of the treaty. Over the years, thousands of scientific and industry experts from dozens of countries participated in the effort to learn more about both the dangers and the possible technological solutions. This proved to be a central element in the protocol's success, facilitating agreement by negotiators on additional controls to protect the ozone layer. In effect, the protocol was deliberately designed to be a dynamic process of narrowing the ranges of uncertainties and adjusting the measures accordingly, rather than being a static one-time solution.

A major lesson from the ozone history is that Nature does not always provide policy makers with convenient early-warning signals of disaster, as exemplified in the case of the Antarctic "ozone hole." In 1985, British scientists published findings based on balloon measurements of ozone made at Halley Bay in Antarctica. It appeared that stratospheric ozone concentrations during the Antarctic early spring (September-October) were about 40 percent lower than during the 1960s. While the ozone layer recovered toward the end of each spring, the extent of the seasonal ozone collapse, or "ozone hole" (i.e., a portion of the stratosphere in which greatly diminished ozone levels were measured), had apparently accelerated beginning in 1979.

Total chlorine concentrations over Antarctica, at a natural level of 0.6 parts per billion, had been slowly increasing for decades. However, no effect on the ozone layer was evident until the concentration exceeded two parts per billion, which apparently triggered the totally unexpected collapse. In other words, chlorine concentrations had tripled with no impact whatsoever on ozone until they crossed an unanticipated threshold. This nonlinear response has obvious implications for the potential dangers of other types of anthropogenic interference with the planet's natural cycles and resources.

[10]See footnote 1.

The British group had actually initially hesitated to publish their findings because they were considered too fantastic.[11] Ironically, it was later discovered that United States and Japanese space satellites had not signaled the ozone collapse because, in order not to deluge scientists with unmanageable masses of data, satellite computers were programmed to automatically reject as anomalies any measurements so far below the "error" range of existing predictive models!

The role of scientists in the ozone history also provided some useful lessons for the climate change issue. During the 1980s, scientific assessments on climate change appeared regularly, under the aegis of WMO and UNEP, from a small group of largely self-selected scientists called the Advisory Group on Greenhouse Gases. In the summer of 1987, while preparing for the conclusive final negotiation in Montreal, I recommended that the U.S. propose establishing a formalized international assessment body on climate change, similar to what we were doing on the ozone issue. My belief was that findings would be more credible coming from a larger and more diverse group of scientists operating under intergovernmental auspices.

This idea attracted unexpected allies and opponents. Some traditionally anti-environmental officials within the Reagan administration endorsed the concept, anticipating that it would provide governments with more control over the science. In contrast, environmental groups feared that the process would become distorted by politics. My own feeling, grounded in the ozone experience, was that the great majority of scientists were unlikely to allow themselves to be influenced by political, ideological or commercial interests, and that governments for their part would have greater respect for the results of a comprehensive international process of investigation and peer review. The subsequent experience of the Intergovernmental Panel on Climate Change, founded in 1988, has largely confirmed this hope.

LESSONS FOR THE PRIVATE SECTOR

The history of the Montreal Protocol also underscored the importance of having sufficient funding for all levels of science, from curiosity-driven basic research to applied engineering solutions. Initially, most research funding came from government sources, in particular NASA and NOAA in connection with their space-related research.

But this was not always the case. In 1985, when the U.K. Government was still strongly opposed to meaningful controls over CFCs, it ceased financing, for obvious political motives, the British scientific mission in Antarctica that had uncovered the "ozone hole." Significantly, the financial gap was filled by the U.S. Chemical Manufacturers Association; the American chemical companies hoped that controls would not be necessary, but they wanted to resolve the uncertainties—one way or the other.

In general, American industry throughout the ozone negotiations was more pragmatic than ideological. Recognizing the growing scientific consensus, the Alliance for Responsible CFC Policy, a coalition of about 500 producer and user companies,

announced its acceptance of international controls in September 1986, three months before the formal negotiation process actually opened. Eight months later, American industry stayed conspicuously aloof from the campaign by anti-environmental elements within the administration to undermine a meaningful treaty, and subsequently fully endorsed President Reagan's strong position for the climactic September 1987 negotiation in Montreal.

The financial and intellectual resources of the private sector make its involvement and cooperation indispensable, since society ultimately depends primarily on industry to provide technological solutions. Technology is dynamic, and not, as often implied by those who resist change, a static element. If the market is left completely on its own, it may not necessarily bring forth the right technologies at the right time. Although the 1987 ozone protocol established targets that were initially beyond the reach of best-available technologies, the goals were in fact not unrealistic.

The Montreal Protocol was not, as some opponents charged, a "radical" treaty. On the contrary, it was an expression of faith in the market system. The treaty employed realistic market incentives to encourage technological innovation. The negotiators effectively signaled to the marketplace that research into solutions would now be profitable. Competitive—and collaborative—forces then took over, and solutions were developed much sooner, and at considerably lower cost, than had earlier been predicted.

The protocol in fact stimulated a virtual technological revolution in the international chemical, telecommunications, pharmaceutical, and numerous other indus-

[11] J. Farman, B.G. Gardiner, and J.D. Shanklin. "Large Losses of Total Ozone in Antartica Reveal Seasonal Clx/NOx Interaction," Nature, no. 315 (1985).

tries. By providing CFC producers and users with the certainty that the CFC market was destined to decline, the treaty unleashed the creative energies and financial resources of the private sector to find alternatives. Following the protocol's signing, the chemical industry began the race for substitutes. Four months after Montreal, several hundred industry representatives participated in a CFC-substitutes trade fair in Washington.

Some user industries did not wait for the chemical companies to come up with substitutes; such companies as Nortel, IBM and Motorola re-examined their manufacturing processes and found ways to eliminate CFCs. In cooperation with a small Florida company, AT&T announced a replacement for CFC 113 derived from citrus fruit, for cleaning electronic circuit boards. Japanese and American importers of electronics parts from Thailand, including AT&T, Ford, Honda, and Toshiba, teamed up with EPA and Japan's Ministry of Trade and Industry to provide non-CFC technologies to their suppliers. More than 40 multinational companies from eight countries, including Asea Brown Boveri, British Petroleum, Hitachi, and Honeywell, joined to help Viet Nam phase out CFCs.

LESSONS FOR CREDIBILITY

Another lesson from the Montreal Protocol's success was the importance of education: interpreting the continuously evolving and sometimes confusing data and communicating it intelligibly to the public, the media, and political and legislative leaders. This information flow mobilized public support for addressing the potential dangers of a diminishing ozone layer, and thereby promoted political consensus for both funding research and for policy actions. The role of the U.S. Congress was particularly critical in organizing many public hearings on the ozone issue over the years, and in commissioning several important studies by the National Academy of Sciences.

In the 1980s, environmental organizations that favored strong actions to protect the ozone layer generally avoided invoking apocalypse in order to capture media and public attention. As chief United States negotiator pressing the official American position for strong controls against the opposition of most of the other major producing and consuming countries, I insisted that our delegation in principle never exaggerate the scientific case: let the science speak for itself, even when it is not completely unambiguous. I wanted to preserve our integrity and not present the opposition with a gratuitous weapon against our position.

When some opponents of controlling CFCs within the U.S. Administration tried late in the negotiations to reverse the strong American position (and, incidentally, to dismiss me as chief negotiator), they belittled the science and the dangers, claiming inter alia that the problem could be solved by wearing cowboy hats and sunglasses. The resultant ridicule and backlash from the Congress, scientists, media, public, and the White House itself eventually led to a personal decision by President Reagan reaffirming the United States position favoring strong controls.

Unfortunately, the lesson of scientific integrity appears to have been lost in the debate over climate change that began in the late 1980s. Some environmental groups became overly alarmist in exaggerating the case for global warming following the hot summer of 1988, and, later, by crusading for the Kyoto Protocol as the only conceivable solution. This only engendered a strong counter-reaction from some affected industrial sectors. In addition, when the predicted dire consequences of climate change did not emerge soon, the American public—which in any case is accustomed to natural seasonal weather extremes—became generally apathetic toward possible long-term dangers.

For their part, skeptics of climate change were also not immune to distortion. In an effort to discredit the climate science, opponents repeatedly cite the "Heidelberg Appeal," released by a nongovernmental group at the United Nations Earth Summit in Johannesburg in 2002, as definitive evidence that most of the scientific community—more than 4000 eminent international scientist signatories, including over 70 Nobel Laureates—rejects the idea that rising anthropogenic carbon dioxide emissions could cause dangerous global climatic consequences. In actuality, the one-page document is a general treatise on the importance of science and contains not a single reference to the climate problem.[12]

LESSONS FOR GOVERNMENT

Some governments allowed commercial self-interest to influence their interpretations of the science: uncertainty was used as an excuse for delaying decisions. Some political leaders, particularly those in Europe with substantial chemical industries,

[12]See "Heidelberg Appeal" at www.sepp.org.

were initially prepared to accept speculative long-term environmental risks rather than to impose the tangible near-term costs entailed in limiting products seen as important contributors to a modern standard of living. Short-range political and economic concerns were, therefore, formidable obstacles to cooperative international action based upon the theory of ozone-depletion.

Other political leaders, however, including President Reagan and the Governments of Australia, Austria, Canada, Finland, Denmark, New Zealand, Norway, Sweden and Switzerland, decided to act even while there were still scientific ambiguities, based on a balancing of the risks and costs of delay.

As early as 1977, the U.S. Congress had authorized the Administrator of the Environmental Protection Agency (EPA) in the Clean Air Act to regulate "any substance which in his judgment may reasonably be anticipated to affect the stratosphere, especially ozone in the stratosphere, if such effect may reasonably be anticipated to endanger public health or welfare" (emphasis added). This law attempted to balance the scientific uncertainties with the risks of inaction. It opted for a low threshold to justify intervention: the Government was not obligated to prove conclusively that a suspected substance could modify the stratosphere or endanger health and environment. All that was required was a standard of reasonable expectation. As Governor Russell Peterson, a senior advisor to President Nixon, had declared in reference to other potentially harmful chemicals, CFCs would not, like United States citizens, be considered innocent until proven guilty.

Unfortunately, current tools of economic analysis are not fully adequate for evaluating the costs and risks, and can be deceptive indicators; they are in urgent need of reform. The customary methods of measuring national income do not satisfactorily reflect societal and ecological costs—especially those far in the future. Politicians should nevertheless resist the tendency to assign excessive credibility to self-serving economic interests that demand scientific certainty, and who insist that, simply because dangers are remote, they are therefore unlikely.

By the time the evidence on such issues as ozone layer depletion and climate change is beyond dispute, the damage could be irreversible and it may be too late to avoid serious harm to human life and draconian future costs to society. The signatories at Montreal risked imposing substantial short-run economic dislocations even though the evidence was incomplete. The prudence of their decision was vindicated when the scientific models turned out to have actually underestimated prospective ozone depletion. And, thanks to the ingenuity of private entrepreneurs, the costs of action turned out to be much lower than originally predicted.

CONCLUSION: ACTING UNDER UNCERTAINTY

The Montreal Protocol was by no means inevitable. Knowledgeable observers had long believed it would be impossible to achieve. The ozone negotiators confronted formidable political, economic, and psychological obstacles. The dangers of ozone depletion could touch every nation and all life on earth over periods far beyond politicians' normal time horizons. But although the potential consequences were grave, they could neither be measured nor predicted with certitude when the diplomats began their work.

In the realm of international relations there will always be resistance to change, and there will always be uncertainties—scientific, political, economic, psychological. Faced with global environmental threats, governments may need to act while some major questions remain unresolved. In achieving the Montreal accord, consensus was forged and decisions were made on a balancing of probabilities—and the risks of waiting for more complete evidence were finally deemed to be too great.

"Politics," stated Lord Kennet during early ozone debates in the House of Lords, "is the art of taking good decisions on insufficient evidence."[13] The success of the Montreal Protocol stands as a beacon of how science can help decision makers to overcome conflicting political and economic interests and reach solutions. The ozone history demonstrates that even in the real world of ambiguity and imperfect knowledge, the international community, with the assistance of science, is capable of undertaking difficult and far-reaching actions for the common good.

SUPPLEMENTARY STATEMENT OF THE HONORABLE RICHARD E. BENEDICK, PRESIDENT, NATIONAL COUNCIL FOR SCIENCE AND THE ENVIRONMENT

Like Dr. Crichton, I am not a climate scientist and also like Dr. Crichton, I have followed the controversy surrounding Dr. Michael Mann and his associates. Given

[13]U.K. House of Lords, Hansard 500 (October 20, 1988): col. 1308.

that Dr. Crichton has devoted considerable attention to this matter in his testimony, I would also like to add some observations for the record of the Hearing.

First, contrary to Dr. Crichton's assertion, it is a matter of record that the initial paper by Mann et al., which appeared in the highly respected scientific journal Nature in 1998, did undergo thorough peer review prior to its publication.

Second, it is my understanding that all of the data and methodologies used by them is publicly accessible and has been accessible since 1998. The only controversy has been about access to the specific computer program used by Dr. Mann and his co-authors. While the data and methodologies are typically the only requisites for public access, Mann and colleagues have also made their computer program available. I note that the National Science Foundation has been consulted on this matter and its legal office has stated that Dr. Mann and his colleagues have behaved in an entirely appropriate manner.

Third, Dr. Crichton is correct to assert that replication of results is a very important aspect of sound science. I understand that the work of Dr. Mann et. al has in fact been replicated by other climate scientists.

I understand that the Committee has received through other channels the letter sent by Dr. Mann to the House Committee on Energy and Science on July 15th of this year. This letter addresses in detail each of the issues raised by Dr. Crichton and others. The letter also indicates where the data, methodologies and computer programs are publicly accessible. I believe it is important that no one reading the record of this Hearing should have the impression that the statements made by Dr. Crichton have not already been addressed.

There appears, moreover, to be controversy about the type of peer review undertaken on the paper by McIntyre and McKitrick before its publication in the magazine Energy and Environment, as well as whether the alleged "errors" that they report are in fact real, and indeed whether the work of McIntyre and McKitrick is itself replicable.

In conclusion, there will always be disputes and disagreements among reputable scientists of good will. This is a normal part of the process of developing generally respected sound science. I would like to emphasize that reputable, peer-reviewed journals, and trusted, apolitical institutions like the National Academy of Sciences, have earned a deserved reputation as the best places to resolve scientific disagreements, rather than politicized innuendos, conspiracy theories, or science fiction novels. I believe that those who would make sensationalized accusations about the integrity of scientists—accusations that could destroy professional careers—have an ethical obligation to check their facts before seeking publicity. Unless they do this, their insinuations merit no credibility.

RESPONSES OF RICHARD E. BENEDICK TO ADDITIONAL QUESTIONS FROM SENATOR INHOFE

Question 1. After the Hearing, your Executive Director, Peter Saundry was quoted in the press saying:

"Outside the committee room, Peter Saundry, executive director of the National Council for Science and the Environment, said that he was bemused by Crichton's apparent position. "If you read his book, you are left with the impression that environmentalists are only one step up from the sort of people who will cross the road to murder your children, but then you get the author's note at the back and he makes this statement saying that he is not a climate change denier. It's hard to know what his position is."

Were you in fact confused by Dr. Crichton's testimony on the need for independent verification of scientific research? Does the National Council for Science and the Environment oppose independent verification of scientific research?

Response. The comments of Dr. Saundry quoted above, appear to refer to a contradiction between the murderous exploits of a fictional environmental organization and the "debunking" of the issue of climate change that is the basis of Dr. Crichton's novel, and Dr. Crichton's statement in a postscript to the novel that he does not deny the possibility of human impacts on climate. Thus, if there is some confusion on Dr. Crichton's testimony, it concerns his position on climate change rather than his position on independent verification of scientific research.

The National Council for Science and the Environment emphatically supports the independent verification of scientific research. The National Council for Science and the Environment also supports independent peer review of scientific results prior to publication, and also supports making both the data and methodology of published scientific findings sufficiently accessible for independent verification of results to be

carried out. On these principles, I believe that there is agreement between myself and Dr. Crichton.

I confess that I was also confused by the substantial part of Dr. Crichton's testimony that applied these principles to the work of Dr. Michael Mann and colleagues—especially since the initial paper by Mann et al., which appeared in the highly respected scientific journal Nature in 1998, did undergo thorough peer review prior to its publication.

It is my understanding that all of the data and methodologies used by Mann et. al. are publicly accessible and have been accessible since 1998. The only controversy appears to be about access to the specific computer program used by Dr. Mann and his co-authors. While the data and methodologies are typically the only requisites for public access, Mann and colleagues have in fact also made their computer program available. The National Science Foundation was consulted on this matter and its legal office has stated that Dr. Mann and his colleagues have behaved in an entirely appropriate manner.

I understand that the work of Dr. Mann et. al has also been replicated by other climate scientists and these independent replications have been explicitly referred to in the comprehensive letter sent by Dr. Mann to the House Committee on Energy and Science on July 15th of this year, which I understand has been submitted into the record of this hearing. The letter also indicates where the data, methodologies and computer programs are publicly accessible and addresses in detail each of the issues raised by Dr. Crichton.

In an imperfect world, there will always be disputes and disagreements among reputable scientists of good will. This is a normal part of the process of developing generally respected sound science. Peer-reviewed journals, and trusted, apolitical institutions like the National Academy of Sciences, have earned a deserved reputation as the best places to resolve scientific disagreements, rather than in works of fiction.

I believe that anyone who would make accusations about the integrity of scientists—accusations that could destroy professional careers—has an ethical obligation to independently verify facts before seeking publicity. Unless they do this, their insinuations lose credibility.

RESPONSES OF RICHARD E. BENEDICK TO ADDITIONAL QUESTIONS FROM SENATOR JEFFORDS

Question 1. In your written testimony, you write that in March 1998 a joint NASA press conference released the Ozone Trends Panel Report. Can you provide a citation for the record of the Executive Summary of that report, which you used in your remarks?

Response. R.T. Watson, F.S. Rowland, and J. Gille, "Ozone Trends Panel Executive Summary," NASA, Washington, D.C.

STATEMENT OF DR. MICHAEL CRICHTON, M.D., AUTHOR, DOCTOR

Thank you Mr. Chairman, and members of the committee. I am Michael Crichton, known to most people as the author of Jurassic Park and the creator of the television series ER. My academic background includes degrees from Harvard College and Harvard Medical School; I was a visiting lecturer in Physical Anthropology at Cambridge University; and a post-doctoral fellow at the Salk Institute, where I worked on media and science policy with Jacob Bronowski.

My recent novel "State of Fear" concerns the politicization of scientific research. I appreciate the opportunity to discuss this subject. What I would like to emphasize to the committee today is the importance of independent verification to science.

In essence, science is nothing more than a method of inquiry. The method says an assertion is valid and will be universally accepted only if it can be reproduced by others, and thereby independently verified. The impersonal rigor of the method has produced enormously powerful results for 400 years.

The scientific method is utterly apolitical. A truth in science is verifiable whether you are black or white, male or female, old or young. It's verifiable whether you know the experimenter, or whether you don't. It's verifiable whether you like the results of a study, or you don't.

Thus, when adhered to, the scientific method can transcend politics. Unfortunately, the converse may also be true: when politics takes precedent over content, it is often because the primacy of independent verification has been abandoned.

Verification may take several forms. I come from medicine, where the gold standard is the randomized double-blind study. Not every study is conducted in this way, but it is held up as the ultimate goal.

In that vein, let me tell you a story. It's 1991, I am flying home from Germany, sitting next to a man who is almost in tears, he is so upset. He's a physician involved in an FDA study of a new drug. It's a double-blind study involving four separate teams—one plans the study, another administers the drug to patients, a third assess the effect on patients, and a fourth analyzes results. The teams do not know each other, and are prohibited from personal contact of any sort, on peril of contaminating the results. This man had been sitting in the Frankfurt airport, innocently chatting with another man, when they discovered to their mutual horror they are on two different teams studying the same drug. They were required to report their encounter to the FDA. And my companion was now waiting to see if the FDA would declare their multi-year, multi-million-dollar study invalid because of this contact.

For a person with a medical background, accustomed to this degree of rigor in research, the protocols of climate science appear considerably more relaxed. A striking feature of climate science is that it's permissible for raw data to be "touched," or modified, by many hands. Gaps in temperature and proxy records are filled in. Suspect values are deleted because a scientist deems them erroneous. A researcher may elect to use parts of existing records, ignoring other parts. Sometimes these adjustments are necessary, sometimes they are questionable. Sometimes the adjustments are documented, sometimes not. But the fact that the data has been modified in so many ways inevitably raises the question of whether the results of a given study are wholly or partially caused by the modifications themselves.

In saying this, I am not casting aspersions on the motives or fair-mindedness of climate scientists. Rather, what is at issue is whether the methodology of climate science is sufficiently rigorous to yield a reliable result. At the very least, we should want the reassurance of independent verification by another lab, in which they make their own decisions about how to handle data, and yet arrive at a similar conclusion.

Because any study where a single team plans the research, carries it out, supervises the analysis, and writes their own final report, carries a very high risk of undetected bias. That risk, for example, would automatically preclude the validity of the results of a similarly structured study that tested the efficacy of a drug. Nobody would believe it.

By the same token, it would be unacceptable if the subsequent verification of such a study were conducted by investigators with whom the researcher had a professional relationship—people with whom, for example, he had published papers in the past. That's peer review by pals, and it's unavoidably biased. Yet these issues are central to the now-familiar story of the "Hockey stick graph" and the debate surrounding it.

To summarize it briefly: in 1998-99 the American climate researcher Michael Mann and his co-workers published an estimate of global temperatures from the year 1000 to 1980.[1] Mann's results appeared to show a spike in recent temperatures that was unprecedented in the last thousand years. His alarming report received widespread publicity and formed the centerpiece of the U.N.'s Third Assessment Report, in 2001. The graph appeared on the first page of the IPCC Executive Summary.

Mann's work was initially criticized because his graph didn't show the well-known Medieval Warm Period, when temperatures were warmer than they are today, or the Little Ice Age, when they were colder than today. But real fireworks began when two Canadian researchers, McIntyre and McKitrick, attempted to replicate Mann's study. They found grave errors in the work, which they detailed in 2003:[2] calculation errors, data used twice, and a computer program that generated a hockey stick out of any data fed to it even random data.

Mann's work has been dismissed as "phony" and "rubbish" by climate scientists around the world who subscribe to global warming. Some have asked why the UN accepted Mann's report so uncritically. It is unsettling to learn Mann himself was in charge of the section of the report that included his work. This episode of climate science is far from the standards of independent verification.

The hockey stick controversy drags on. But I would direct the committee's attention to three aspects of this story. First, six years passed between Mann's publication and the first detailed accounts of errors in his work. This is simply too long

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[1]Mann, M.E., R.S. Bradley and M.K. Hughes, 1998. "Global-Scale Temperature Patterns and Climate Forcing Over the Past Six Centuries," Nature, 392, 779-787.

[2]McIntyre, S. and R. McKitrick, 2003. "Corrections to the Mann et. Al. (1998) Proxy Data Base and Northern Hemisphere Average Temperature Series." Environment and Energy 14(6) 751-771. See also, McIntyre, S. and R. McKitrick, 2005. "Hockey Sticks, Principal Components and Spurious Significance", Geophysical Research Letters V 32 (3) L03710 10.1029/2004GL021750 12

for policymakers to wait for validated results. Particularly if it is going to be shown around the world in the meantime.

Second, the flaws in Mann's work were not caught by climate scientists, but rather by outsiders in this case, an economist and a mathematician. McIntyre and McKitrick had to go to great lengths to obtain the data from Mann's team, which obstructed them at every turn. When the Canadians sought help from the NSF, they were told that Mann was under no obligation to provide his data to other researchers for independent verification.

Third, this kind of stonewalling is not unique or uncommon. The Canadians are now attempting to replicate other climate studies and are getting the same runaround from other researchers. One leading light in the field told them: "Why should I make the data available to you, when your aim is to try and find something wrong with it."

Even further, some scientists complain the task of archiving is so time-consuming as to prevent them from getting any work done. But this is nonsense.

The first research paper I worked on, back in the 1960s, consisted of data on stacks of paper. When we received a request for data from another lab, I stood at a Xerox machine, copying one page a minute at 11 cents a page for several hours. Back in those days, a request for data meant a lot of work.[3]

But today we can burn data to a CD, or post it at an ftp site for downloading. Archiving data is so easy it should have become standard practice a decade ago. Government grants should require a "replication package" as part of funding. Posting the package online should be a prerequisite to journal publication. And since it's so easy, there's really no reason to exclude anyone from reviewing the data.

One problem with replication is this: while it can tell you a research result is faulty, it can't tell you what the right answer is. Policymakers need sound answers to the questions they ask. A better way to get them might be to give research grants for important projects to three independent teams simultaneously. A provision of the grant would be that at the end of the study period, all three papers would be published together, with each group commenting on the findings of the other. I believe this would be the fastest way to get verified answers to important questions.

But if independent verification is the heart of science, what should policymakers do with research that is unverifiable? For example, the UN Third Assessment Report defines general circulation climate models as unverifiable.[4] If that's true, are their predictions of any use to policymakers?

Arguably not. In 2000, Christopher Landsea and co-workers studied various computer models that had forecast the strong El Nino event of 1997-98. They concluded that the older, simpler models hardly more than simple formula had performed much better than the global circulation models when predicting the arrival and strength of the El Nino.[5]

If policymakers decide to weight their decisions in favor of verified research, that will provoke an effort by climate scientists to demonstrate their concerns using objectively verifiable research.

In closing, I want to state emphatically that nothing in my remarks should be taken to imply that we can ignore our environment, or that we should not take climate change seriously. On the contrary, we must dramatically improve our record on environmental management. That's why a focused effort on climate science, aimed at securing sound, independently verified answers to policy questions, is so important now.

I would remind the committee that in the end, it is the proper function of government to set standards for the integrity of information it uses to make policy, and to ensure that standards are maintained. Those who argue government should refrain from mandating quality standards for scientific research including some professional organizations are merely self-serving. In an information society, public

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[3]Crichton, M., N.P. Christy and A. Damon, 1981. "Host Factors in 'Chromophobe' Adenoma of the Anterior Pituitary; a Retrospective Study of 464 Patients." Metabolism, 3:248-67.

[4]"Our evaluation process is not as clear-cut as a simple search for 'falsification.' While we do not consider that the complexity of a climate model makes it impossible to ever prove such a model 'false' in any absolute sense, it does make the task of evaluation extremely difficult and leaves room for a subjective component in any assessment." IPCC TAR p 474. See also "We fully recognize the evaluation statements we make contain a degree of subjective scientific perception and may contain much 'community' or 'personal' knowledge." IPCC TAR p. 475. Evaluations that are non-falsifiable, personal, and subjective are by definition not independently verifiable.

[5]Landsea, C. et al., 2000, "How Much Skill Was There in Forecasting the Very Strong 1997-98 El Nino?" Bulletin American Meteorological Society 81: 2107-19. The authors observe: "—one could have even less confidence in anthropogenic global warming studies because of the lack of skill in predicting El Nino—the successes in ENSO forecasting have been overstated (sometimes drastically) and misapplied in other arenas."

safety depends on the integrity of public information. And only government can perform that task.

RESPONSES OF DR. MICHAEL CRICHTON TO ADDITIONAL QUESTIONS FROM SENATOR JEFFORDS

Question 1. Did your interest in climate change science stem solely from the writing of your book, or is there something else in your background that initiated your interest in this issue? Do you consider yourself to be an expert on the science of climate change?

Response. My views on global warming were entirely conventional until 2001 when I began to inspect temperature records, which are available online. I was underwhelmed by the evidence I saw and I continued my research for two years. My decision to write a book came later.

I am not a climate scientist and I consider my observations useful precisely because I am an outsider looking at this field. I do consider myself a well-educated American citizen, and I share with my countrymen a healthy skepticism toward experts of all sorts. If war is too important to be left to the generals, science is too important to be left to the scientists.

Question 2. Have you ever received funding from any person or entity for your views on climate change or any other environmental scientific issue? If so, please provide the amount received, when and for what purpose.

Response. In the 25 years of my career, I have never received funding for my views on any subject. No one has ever offered, either.

Question 3. Do you think scientific studies that have not been peer reviewed or published in a scientific peer reviewed journal should be given equal weight to studies that have has such review?

Response. In general I agree with the scientific tradition that gives greater weight to peer-reviewed articles. But I am sure you are aware that several published studies in recent years have questioned the effectiveness of peer review as a process. This has spurred a debate among scientists about the procedure. The debate has several aspects, ranging from questions of subtle censorship, to questions about whether peer-review really results in improved papers overall. One area of particular concern is whether peer-review catches statistical errors efficiently. I mention this debate to raise a questionmark behind my answer, and also to remind you that peer-review is not the same as independent replication of results (which is what I argued for in my testimony.)

Question 4. You are quite critical of Michael Mann's study on global temperature changes based on a study done by McIntyre and McKitrick. You also state that the National Science Foundation told McIntyre and McKitrick that "Mann was under no obligation to provide his data to other researchers." My understanding is that access to the data are not the issue, Mann's data are publicly available. At issue, is whether researchers need access to exactly the same computer program (or "code") as the initial researcher to get the same result.

Response. My understanding is not the same as yours on this matter. I believe McIntyre and McKitrick said they did not obtain prompt access to relevant data. The matter of computer code was only one aspect of the larger question of access.

Question 4a. Would you agree that the key to replicability is unfettered access to all of the underlying data and methodologies used by the first researcher?

Response. Yes. Such access is necessary but not sufficient. At a minimum, two other elements are required. The first is that verification be performed by a genuinely independent researcher, and the second is that the results be published, preferably by the original journal.

Question 4b. If the data and methodological information are available to anyone who wants them, are there other limitations to study replication?

Response. Replication of a study requires that the original investigator provide all the information necessary for another research laboratory to perform the replication. What constitutes "all the information necessary" will vary from instance to instance. Some back-and-forth between investigator and replicator is often required, and frequently occurs in other scientific fields.

Question 4c. Are you aware that other scientists have reproduced Mann's results based on publicly available information?

Response. It's often claimed that ten other studies have replicated the work. But four of the papers have Mann's name listed among the authors. The authors of the other six papers include scientists with whom Mann has published other papers. As I indicated in my testimony, this is not genuine independent replication. It's not a matter of honesty or good intentions. It's simply procedurally invalid.

Question 4d. As a writer, are you sympathetic to Mann's concerns regarding intellectual property protection for his climate model?

Response. I believe your question contains two erroneous assumptions. First of all, to refer to Mann's study as a "climate model" invites misunderstanding. Mann performed a meta-analysis of many studies taken together. Such meta-analyses have been carried out for decades in many fields of science; there is nothing new or unusual about such a study. There are a variety of known computer algorithms that are employed for meta-analysis. The particular computer code that Mann employed for his meta-analysis has been reported to be flawed. The determination that the code is flawed has been made by scientists around the world.

Second, you ask about intellectual property protection. As you know, ownership of intellectual work product is subject to negotiation. Scientists (and novelists) find themselves making different arrangements in different instances. Many scientists do not own the work that they do; others have a financial participation but no ownership rights regarding use or disposition of their work; others may have full control over their own work.

However, as a general principle whoever pays for the work will have much to say about how it is used. In the case of publicly-funded research, I argue that the results are owned by the American people. This is not clearly the understanding now, but it should be. And furthermore, when the public funds a study, it is because the public (or its representatives) deems that the answers provided by that study to be of public importance. In science, answers need to be verified independently. Therefore I argue that any scientist who accepts public funding also accepts the obligation to make his work available for verification by others.

Question 5. Following the publication of "State of Fear", you have spoken publicly about your concerns regarding the state of environmental science. How do you view your role in critiquing environmental science? Will it be something you will continue?

Response. I have spoken about environmental matters since the 1980s. I have always argued that our environmental knowledge is inadequate; that our efforts are insufficient; that we spend too little on the environment; and that we don't necessarily spend our money on the most important problems. These views are explicitly stated in the afterward of my book. At no time have I ever suggested that we need to do less about the environment. We need to do more. And we need to be much more effective.

Since I have been speaking on this subject for the last twenty years, I expect I will continue from time to time.

Question 6. As I think you anticipated, your book has stirred up some controversy among climate scientists, some of whom have charged that you did not accurately portray their work. Do you anticipate responding to these challenges in future editions of the book?

Response. I have included footnotes and thirty pages of annotated bibliography so that readers can go to the scientific references I used, and decide for themselves what they think. I am pleased that many readers are doing so.

Question 7. On p. 246 of "State of Fear" one of the characters talks about testimony by Dr. James Hansen, director of the Goddard Institute for Space Studies. Your character only mentions one of Hanson's three scenarios. Why? Are you aware that Dr. Hansen characterized the highest scenario that is reference in your book as not very likely? Are you aware that the middle scenario, which Dr. Hansen characterized as most likely, is consistent with the observed warming since 1988?

Response. Whenever there are multiple estimates for some future outcome, there is always an issue of which estimate to use. In keeping with the established tradition of the mainstream media, I used the highest and most dramatic estimate. The fictional character on page 246 is clearly evoking the public impact of Hansen's 1988 Senate testimony, and that impact is clear in contemporary news accounts. Nowhere did I find it reported that Dr. Hansen predicted a tenth of a degree increase in the next 10 years. On the contrary: after the Hansen testimony, the New York Times stated in several articles that increases would be on the order of 3 to 9 degrees by 2030, and might run as high as 20 degrees by 2075.

STATEMENT OF WILLIAM M. GRAY, PH.D., PROFESSOR, DEPARTMENT OF ATMOSPHERIC SCIENCE COLORADO STATE UNIVERSITY

Mr. Chairman and Members of the committee, I am William M. Gray, a Professor of Atmospheric Science at Colorado State University in Fort Collins, Colorado. I have been studying and forecasting weather and climate for over 50 years (see my

attached Vitae). My specialty has been tropical meteorology and tropical cyclones. I have made Atlantic basin seasonal hurricane forecasts for the last 22 years.

Over the last 20 years, I have been dismayed over the bogus science and media-hype associated with the nuclear winter and the human-induced global warming hypotheses. My innate sense of how the atmosphere-ocean functions does not allow me to accept either of these scenarios. Observations and theory do not support these ideas. The nuclear winter hypothesis did not recognize that the globe's hydrologic cycle operates on a time scale of 8-10 days and that nuclear- spawned dust material would be quickly rained out of the atmosphere. The human-induced global warming scenarios have a major flaw in that they accept the view that an increase in the global hydrologic cycle will cause enhanced upper-tropospheric water vapor gain and a suppression of outgoing long wave radiation (OLR) to space. The opposite is true. Global Climate Models (GCMs) are also not able to realistically predict the ocean's deep water circulation which is fundamental to any understanding of global temperature change.

As a boy, growing up here in Washington, DC, I remember the many articles on the large global warming that had occurred between 1900 and 1940. No one understood or knew if this warming would continue. Then the warming abated, and a weak global cooling trend set in from the mid-1940s to the early 1970s. The global warming talk ceased and speculation about a coming ice age came into vogue. I anticipate that the trend of the last few decades of global warming will come to an end, and in a few years we will start to see a weak cooling trend similar to that which occurred from the mid-1940s to the early 1970s.

I would like to present a different view on the likelihood of human-induced global warming and also provide evidence that global hurricane activity has not increased as the globe has warmed in recent decades. There is no significant correlation between global warming and global hurricane activity.

HUMAN-INDUCED GLOBAL WARMING

Although initially generated by honest scientific questions, this topic has long ago advanced into the political arena and taken on a life of its own. It has been extended and grossly exaggerated and misused by those wishing to make gains from the exploitation of ignorance on this subject. This includes many governments of western countries, the media, and scientists who were willing to bend their objectivity to obtain government grants for research. It is unfortunate that most of the resources for climate research come from the federal government. When a national government takes a political position on a scientific topic, the wise meteorologist or climatologist either joins the crowd or keeps his/her mouth shut. Scientists can be punished if they do not accept the current views of their funding agents. An honest and objective scientific debate cannot be held in such a political environment.

I have closely followed the greenhouse gas warming arguments. From what I have learned of how the atmosphere functions in over 50 years of study and forecasting, I have been unable to convince myself that a doubling of human-induced greenhouse gases can lead to anything but quite small and likely insignificant amounts of global warming (~ 0.2-0.3° C).

Most geophysical systems react to forced imbalances by developing responses which oppose and weaken the initial forced imbalance; hence, a negative feedback response. Recently proposed human-induced global warming scenarios go counter to the foregoing in hypothesizing a positive feedback effect. They assume that a stronger hydrologic cycle (due to increased anthropogenic greenhouse gases) will cause additional upper-level atmospheric water vapor. This increased vapor results in a reduction of OLR loss to space and causes additional warming (Fig. 1). This positive water vapor feedback assumption allows the small initial warming due to human-induced greenhouse gases to be unrealistically multiplied 8-10 times. This is where much of the global modeling is in error. As anthropogenic greenhouse gases increase it does not follow that upper-level water vapor will increase. If it does not, little global warming will result. Observation of middle tropospheric water vapor over the last few decades shows that water vapor has in fact been undergoing a small decrease. The assumed positive water vapor feedback as programmed into the GCM models is not occurring. Energy budget studies indicate that if atmospheric water vapor and the rate of condensation were held fixed, a doubling of carbon dioxide would cause only a small (~ 0.2-0.3° C) global warming. This can be contrasted to the 2-5° C warming projected in the models.

The other primary physical limitations of the GCM simulations are their inability (as yet) to properly treat the global ocean deep circulation. This requires the need to model ocean salinity variations. Climate change cannot be objectively discussed without a realistic treatment of the ocean.

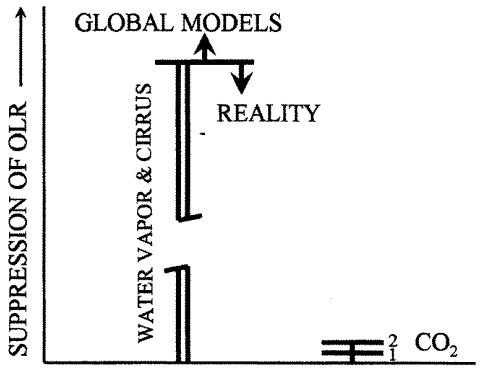

Figure 1. Illustration of the relative magnitude of the suppression of outgoing long-wave radiation (OLR) by water vapor and CO_2. The global models assume that as CO_2 doubles, water vapor increases and causes more suppression of OLR and warming. The opposite is true.

Skillful initial value GCM climate prediction is not possible and probably never will be. This is due to the complex nature of the atmosphere/ocean system and the inability of numerical models to realistically represent this physical complexity. Realistic features currently cannot be forecast more than a week or two into the future (see Figs. 2 and 3). Imperfect representations of the highly non-linear parameters of the atmosphere-ocean system tend to quickly degrade (the so-called butterfly influence) into unrealistic flow states upon long period integration. Short-range prediction is possible up to a week or 10 days into the future because there tends to be conservatism in the initial momentum fields which can be extrapolated for short periods. But beyond about 1-2 weeks, the multiple unknown and non-linear energy-moisture exchanges within the earth system become dominant. Model results soon decay in chaos. Numerical climate models cannot now and likely never will be able to be accurately forecast more than a few weeks into the future. If skillful GCM climate forecasts were possible, we would be eager to follow their predictions. Currently, GCMs do not make seasonal or yearly forecasts. How can we trust climate forecasts 50 and 100 years into the future (that can't be verified in our lifetime) when they are not able to make shorter seasonal or yearly forecasts that could be verified? They know that they dare not issue shorter forecasts because they are aware that they have little or no skill.

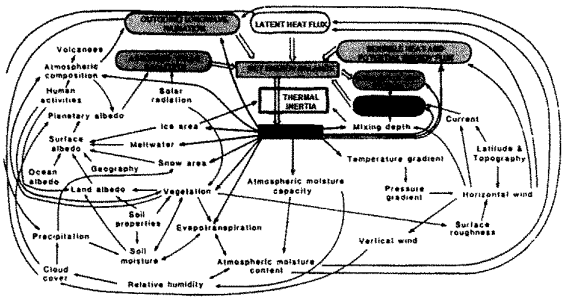

Figure 2. Illustration of atmosphere-land ocean modeling complexity. It is impossible to write computer code to represent such complexity and then realistically integrate hundreds of thousands of time steps into the future.

Besides the physical uncertainty concerning how to represent the complexity of the atmosphere-ocean system in quantitative terms, climate models have become too complex for any one person or team to understand. Due to the great complexity of the GCM system, the true reasons for success or failure often cannot be determined. These models have been developed by teams of specialists who concentrate on different parts of their model. No one person is able to understand the whole GCM simulation. Most model developers are talented and skilled technicians. However, few have ever given real-world weather briefings or made operational weather forecasts.

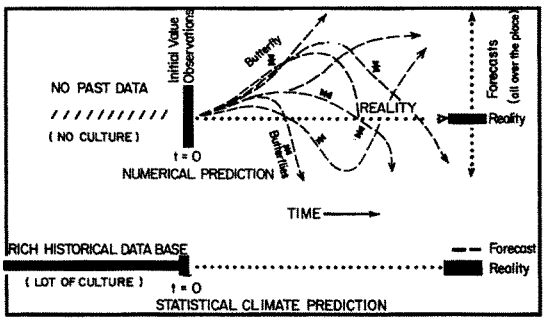

Figure 3. Illustration of the two methods of climate prediction. The top diagram shows how numerical climate prediction is made and loses skill rapidly. It does not use past data. The bottom diagram shows how statistical prediction is based on past data and can utilize associations that are not physically understood.

The potential for climate modeling mischief and false scares from incorrect climate model scenarios is enormous. Numerical modeling output gives an air of authenticity which is not warranted by the input physics and long periods of integration. How many more climate scares are we to see from climate models which are not able to realistically predict past and future climate changes let alone future decadal or century changes?

Many of my older meteorological colleagues are very skeptical of these anthropogenic global warming scenarios. But we are seldom asked for any input. Despite my 50 years of meteorology experience and my many years of involvement in seasonal

hurricane and climate prediction, I have never been asked for input on any of the International Panels on Climate Change (IPCC) reports. They know my views and do not wish to have to deal with them. Many other experienced but skeptical meteorologists and climatologists are also ignored. I find that the summary page conclusions of the IPCC reports frequently do not agree with the extensive factual material contained within them. In fact, the summary conclusions of many of the IPCC reports give the impression they were written before the research is done.

It is disappointing that more atmospheric scientists have not spoken out about the reality of human-induced global warming and the reliability of the GCM simulations. It is also mystifying to me how the global warming advocates are able to get away with the argument that extreme weather events have become more prevalent in recent years and that they likely have a human-induced component. Such assertions are factually wrong.

There is nothing we humans can do to prevent natural climate change, which I believe nearly all the recent global temperature rise is due too. We have no choice but to adapt to future climate changes. Restricting human-induced greenhouse gas emissions now, on the basis of their assumed influence on global warming, is not a viable economic option, even if it were politically possible. China and India would never restrict their growing fossil fuel usage. Restricting greenhouse gas emissions would have little or no effect on global temperature. We need to keep the western world economies vibrant if for no other reason than to be able to afford the needed large technical research funding that will be required to develop future non-fossil fuel energy sources.

I am convinced that in 15-20 years, we will look back on this period of global warming hysteria as we now look back on so many other popular, and trendy, scientific ideas—such as the generally accepted Eugenic theories of the 1920s and 1930s that have now been discredited. There are so many other more important problems in the world which need our immediate attention. We should not be distracted by a false threat that is mostly just due to natural changes in climate.

GLOBAL WARMING INFLUENCE ON HURRICANES

The Atlantic has large multi-decadal variations in major (category 3-4-5) hurricane activity. These variations are observed to result from multi-decadal variations in the North Atlantic Thermohaline Circulation (THC)-Fig. 4. When the THC is strong, it causes the North Atlantic to have warm or positive Sea Surface Temperature Anomalies (SSTA) and when the THC is weak, cold SSTAs prevail. Figure 5 shows these North Atlantic SSTAs over the last century with a projection for the next 15 years.

We observe that there are significantly more Atlantic basin major hurricanes when the THC is strong than when it is weak. Figure 6 shows the sum of tracks of Atlantic major hurricane tracks during a 20-year period when the THC was strong (left) versus an 18-year period when it was weak (right). Note the large differences. Figure 7 gives an illustration of how fortunate peninsula Florida was in terms of landfalling hurricanes during the period of 1966-2003 in comparison with the earlier period of 1932-1965. The varying strength of the Atlantic THC is partly responsible for these differences. Luck also played a role. There were many intense hurricanes just off the Florida coast during the later period that did not come ashore (i.e., Hurricane Floyd, 1999).

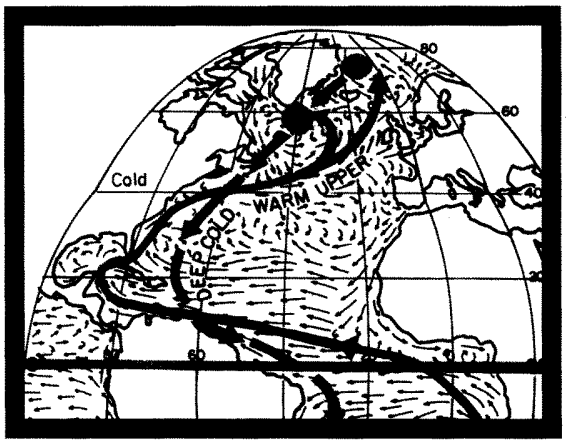

Figure 4. Idealized Atlantic Thermohaline Circulation (THC) that becomes stronger and weaker on multi-decadal time periods. More major hurricanes form in the Atlantic when it is stronger than when it is weaker.

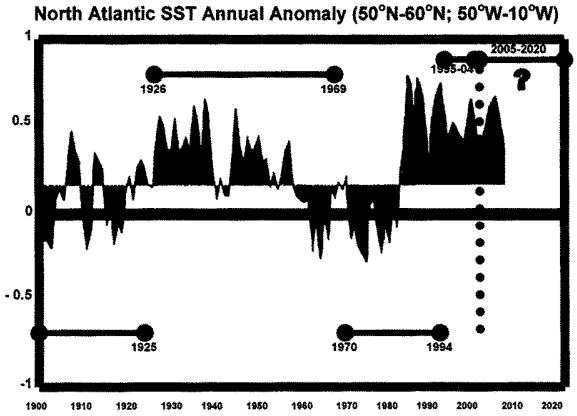

Figure 5. Last century Sea Surface Temperature Anomaly (SSTA) in the North Atlantic showing multi-decadal periods of warm and cold anomalies and a projection of these SSTAs to 2020. More major hurricanes form when SSTAs are positive and fewer when they are negative.

TRACKS OF CATEGORY 3-4-5 HURRICANES

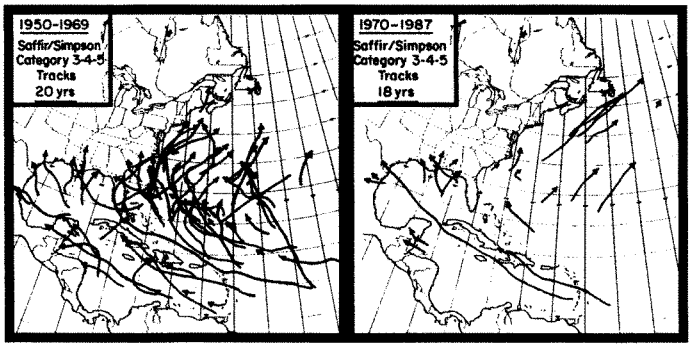

Figure 6. Tracks of major hurricanes in 20 years (1950-1969) when the thermohaline circulation was strong and the North Atlantic had positive SSTAs (left) and in 18 years (1970-1987) when the thermohaline circulation was weak and the North Atlantic had negative SSTAs (right).

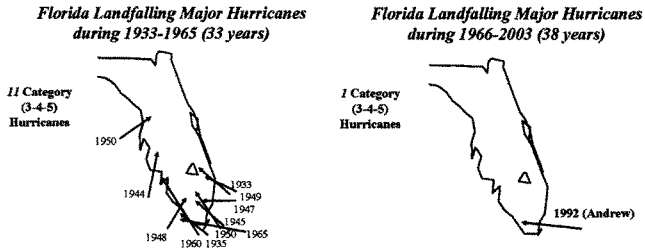

Figure 7. Comparison of Florida peninsula landfalling major hurricanes in a 33 year period (1933-1965 -- 11 landfalling major hurricanes) and in a later 38 year period (1966-2003 -- 1 landfalling major hurricane).

Recent major hurricanes Katrina and Rita and last year's four U.S. land falling major hurricanes have spawned an abundance of questions concerning the role that global warming might be playing in these events. The ideas that global warming was the cause for these last two years of greater hurricane activity has been greatly enhanced by two recent papers presenting data to show that global tropical cyclones have become more intense in recent years. They tie this increased hurricane activity to global warming. These papers are:

a) Kerry Emanuel, 4 August 2005: Increasing destructiveness of tropical cyclones over the past 30 years. Nature, 436, 686-688.

b) P.J. Webster, G.J. Holland, J. Currie and P. Chang, 16 September 2005: Changes in tropical cyclone number, duration, and intensity in a warming environment. Science, 309, 1844-1846.

The near universal reference to these two papers over the last two weeks by most major media outlets is helping to establish a belief among the general public and scientists not involved in tropical cyclone studies that global hurricane intensity has been rising and that global warming is primarily responsible. This conclusion is not

valid. The authors have improperly handled their data sets and their findings should not be accepted. These papers require a response from a few of us who study hurricanes. I feel I have an obligation to make formal comments on these papers (to the editors of the journals), which I will do in another week or two.

DETERMINATION OF HURRICANE INTENSITY

There always has been, and there probably always will be, problems in assigning a representative maximum surface wind to a hurricane. As technology advances and the methods of determining a hurricane's maximum winds change, different values of maximum winds will be assigned to hurricanes than would have been assigned in previous years.

With the availability of new aircraft deployed inertial dropwindsondes and the new step-frequency surface wind measurement instruments, it is being established that Atlantic hurricane surface winds are sometimes stronger than were previously determined from wind values extrapolated from aircraft altitude. Saffir/Simpson category numbers in the Atlantic due to these changes in measurement techniques have risen slightly in recent years. Although most of the comparative differences in the 38 major hurricanes of the last 10 years in the Atlantic basin (1995-2004) vs. the 14 major hurricanes of the prior 10 years (1985-1994) is thought to represent real variability, a small part of this difference may be due to the assignment of a Category 3 or Category 4 status to a hurricane which in earlier years might have received a one category lower designation.

THEORY

Despite what many in the atmospheric modeling community may believe, there is no physical basis for assuming that global tropical cyclone intensity or frequency is necessarily related to global temperature. As the ocean surface warms, so does the upper air to maintain conditionally unstable lapse-rates and global rainfall rates at their required values. Although there has been a general warming of the globe and an increase of SSTs in recent decades, observations do not show increases in tropical cyclone frequency or intensity.

VARIATION IN MAJOR HURRICANE NUMBERS DURING RECENT DECADES OF GLOBAL WARMING

The NOAA reanalysis of global mean temperature difference over the last two 10-year periods have shown that the mean annual global surface temperature has risen 0.39 degree C from the 10-year periods of 1985-1994 to 1995-2004. This is a substantial increase in global temperature (rate of 3.9 per century). Table 1 shows the number of measured major hurricanes around the globe (excluding the Atlantic). Major hurricanes have not gone up in the more recent 10-year period when SSTAs have warmed considerably.

Table 1. Comparison of observed major (Cat. 3-4-5) hurricanes-typhoons in all global basins (except the Atlantic) in the two most recent 10 year periods of 1985-94 and 1995-2004. The summertime sea surface temperature increases between these two 10-year periods are shown in the right column.

	1985-1994	**1995-2004**	**Summer Basin Δ SSTA (°C) (1995-04) *minus* (1985-94)**
North & South Indian Ocean	45	50	+0.21
South Pacific & Australia	44	41	+0.35
NW Pacific	43	53	+0.25
Northeast Pacific	65	36	+0.05
GLOBE (excluding Atlantic)	197	180	+0.22

The Atlantic has seen a very large increase in major hurricanes during the last 10-year period in comparison to the previous 10-year period (38 between 1995-2004 vs. 11 during 1985-1994). The large last decade increase is a result of multi-decadal fluctuations in the Atlantic Ocean thermohaline circulation (THC). Changes in salinity are believed to be the driving mechanism. These multi-decadal changes have also been termed the Atlantic Multi-Decadal Oscillation (AMO). Even when the large increase in Atlantic major hurricane activity is added to the non-Atlantic global total of major hurricanes, there is no significant global difference (208 vs. 218) in the numbers of major hurricanes between the two periods.

COMPARISON OF ATLANTIC HURRICANE ACTIVITY BETWEEN THE LAST 15-YEAR ACTIVE PERIOD (1990-2004) WITH THE ACTIVITY DURING THE ACTIVE 15-YEAR PERIOD OF 1950-1964.

There have been hurricane periods in the Atlantic in the past which have been just as active as the current period. A comparison of the last 15 years of hurricane activity with an earlier 15-year period from 1950-64 shows no significant difference in the more intense major hurricanes (Table 2). Note that there has actually been a slight decrease in major hurricane numbers in the most recent 15 years. The number of weak tropical Named Storms (NS) rose by over 50 percent, however. This is a reflection of the availability of the satellite in the later period. It would not have been possible that a hurricane, particularly a major hurricane, escaped detection in the earlier period. But many weaker systems far out in the Atlantic undoubtedly went undetected before satellite observations.

Table 2. Comparison of Atlantic tropical cyclones of various intensities between 1950-1964 and the recent 15 year period of 1990-2004.

	Cat. 4-5	Cat. 3	Net IH	Net H	Cat. 1-2	TS	NS	July-August SST 10-25°N; 30-70°W
1950-64 (15 yrs)	24	23	47	98	51	50	148	25.69
1990-04 (15 yrs)	25	18	43	100	57	78	178	26.11
1990-04 *minus* 1950-64	+1	-5	-4	+2	+6	+28	+30	+0.42
Percent Increase	+4%	-22%	-9%	+2%	+12%	+56%	+18%	---

CHANGE IN INTENSITY MEASUREMENT TECHNOLOGY OF THE NORTHWEST (NW) PACIFIC AND COMPARISON OF EARLIER AND LATER PERIODS

This most active of the tropical cyclone basins had aircraft reconnaissance flights during the period 1945-1986 but has not had aircraft reconnaissance since. The satellite has been the only tool to track NW Pacific typhoons since 1987.

There was an anomaly in the measurement of typhoon intensity in the 14-year period of 1973-1986 when the Atkinson-Holliday (1977) technique for typhoon maximum wind and minimum sea-level pressure (MSLP) was used. This technique is now known to have significantly underestimated the maximum winds of the typhoons in comparison with their central pressures. This has been verified by a combination of satellite-aircraft data from the Atlantic and pre-1973 NW Pacific aircraft-measured wind and MSLP. Table 3 shows the official average of the annual number of super typhoons in the West Pacific (equivalent to the number of category 3-4-5 or major hurricanes of the Atlantic). Note that between 1950-1972 and over the last 18 years, this number of super-typhoons has averaged about five per year while during the Atkinson-Holliday period of 1973-1986 it was less than half this number. Weaker storm numbers during the 1973-1986 period were the same. If we disregard this anomalous 1973-1986 period and compare annual frequency of super-typhoon activity between 1950-1972 versus 1987-2004 we see little difference despite the recent global warming trend.

Table 3. Comparison of the annual average of super- typhoon activity in three multi-decadal periods in the western North Pacific. The middle period (1973-1986) used the Atkinson-Holliday (1977) intensity scheme. This reported maximum wind values that were too low.

Years	Annual Average Number of Super-Typhoons	Basin July-Sept SST (°C) 10-25°N; 120-160°E
1950-1972	5.3	28.93
1973-1986 (AH)	2.3	28.92
1987-2004	4.9	29.22

WHAT OTHERS SAY

I fully subscribe to the view expressed by Max Mayfield, Director of the NOAA National Hurricane Center when he stated last week before the Senate Committee of Commerce, Science and Transportation Sub-Committee:

"We believe this heightened period of hurricane activity will continue due to multi-decadal variance, as tropical cyclone activity in the Atlantic is cyclical. The 1940s through the 1960s experienced an above average number of hurricanes, while the 1970s into the mid-1990s averaged fewer hurricanes. The current period of heightened activity could last another 10-20 years. The increased activity since 1995 is due to natural fluctuations/cycles of hurricane activity, driven by the Atlantic Ocean itself along with the atmosphere above it and not enhanced substantially by global warming. The natural cycles are quite large with an average 3-4 major hurricanes a year in active periods and only about 1-2 major hurricanes annually during quiet periods, with each period lasting 25-40 years".

I also subscribe to the views expressed in the new paper titled "Hurricanes and Global Warming" which will soon be published in the Bulletin of the American Meteorological Society. This paper is authored by [Roger Pielke, Jr., Director, Center for Science and Technology, University of Colorado; Christopher Landsea, Director of Research, NOAA National Hurricane Center, Miami, FL; Max Mayfield, Director, National Hurricane Center, Miami, FL; James Laver, Director, NOAA National Climate Center, Washington, DC; and Richard Pasch, Hurricane Specialist, NOAA National Hurricane Center, Miami, FL] and makes the following statements:

"Since 1995 there has been an increase in frequency and in particular the intensity of hurricanes in the Atlantic. But the changes of the past decade are not so large as to clearly indicate that anything is going on other than the multi-decadal variability that has been well documented since at least 1900 (Gray et al. 1997; Landsea et al. 1999; Goldenberg et al. 2001)" and "Globally there has been no increase in tropical cyclone frequency over at least the past several decades (Lander and Guard 1998, Elsner and Kocher 2000). In addition to a lack of theory for future changes in storm frequencies, the few global modeling results are contradictory (Henderson-Sellers et al. 1998; IPCC 2001)"

SUMMARY

Analysis of global tropical cyclone activity of all intensities does not support the hypothesis that there has been a significant increase in tropical cyclone frequency-intensity associated with global temperature rise.

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RESPONSES OF WILLIAM GRAY TO ADDTIONAL QUESTIONS FROM SENATOR INHOFE

Question 1. Is there any other information you wish to add?

Response. Yes, my below discussion and interpretation of how we should interpret the very active U.S. hurricane landfall years of 2004-2005 and their potential relationship to global warming. It is very important that we not read more into these years than is there. Although 2004 and 2005 had a rare combination of very intense hurricane activity accompanied by westward steering currents, it is not outside the realm of natural variations.

The recent U.S. landfall of major hurricanes Dennis, Katrina, Rita and Wilma and the four landfalling hurricanes of last year (Charley, Frances, Ivan and Jeanne) have raised questions about the possible role that global warming played in the last two unusually destructive seasons.

The global warming arguments have been given much attention by many media and blog citations to recent papers claiming to show such a linkage. Observations my colleagues and I have gathered do not observationally or theoretically support this contention. Despite the global warming of the sea surface of about 0.3oC that has taken place over the last 3 decades, the global number of hurricanes and major hurricanes (Category 3-4-5) have not shown increases in recent years except for the Atlantic.

The Atlantic basin has seen a very large increase in major hurricanes during the last 11-year period of 1995-2005 (average 4.0 per year) in comparison to the prior 25-year period of 1970-1994 (average 1.5 per year). This large increase in Atlantic major hurricanes is primarily a result of the strengthening of the Atlantic Ocean thermohaline circulation (THC) that is not directly related to global temperature increase. Changes in ocean salinity are believed to be the driving mechanism. These multi-decadal changes have also been termed the Atlantic Multi-Decadal Oscillation (AMO).

There have been similar past periods (the later part of the 19th century and 1940s-1960s, for example) when the Atlantic had similar activity to that observed in recent years. For instance, when we compare Atlantic basin hurricane numbers of the last 15 years with an earlier 15-year period (1950-64), we see little difference in hurricane frequency or intensity even though global surface temperatures were cooler. Also, there was a general global cooling during 1950-64 as compared with global warming during 1990-2004.

We should interpret the last two years of unusually large numbers of US landfalling hurricanes as low probability events but within the realm of natural variations. During 1966-2003, U.S. hurricane landfall numbers were substantially below the long-term average. In the last two seasons, they have been much above the long-term average. Although the 2004 and 2005 hurricane seasons have had an unusually high number of major landfall events, the overall Atlantic basin hurricane activity has not been much more active than other recent hurricane seasons such as 1995, 1996, 1998, 1999, and 2003 have been. What has made the 2004-2005 seasons so unusually destructive is the higher percentage of major hurricanes which have moved over the US coastline. These landfall events were not primarily a function of the overall Atlantic basin net major hurricane numbers, but rather of the strong westerly broad-scale Atlantic upper-air steering currents which were present the last two seasons. It was these westerly steering currents which caused so many of the major hurricanes which formed to come ashore.

It is rare to have such a strong simultaneous combination of high amounts of major hurricane activity together with especially favorable western Atlantic steering flow currents. Historical records and laws of statistics indicate that the probability of seeing another two consecutive hurricane season like 2004-2005 is very low. Even though we expect to see the current active period of Atlantic major hurricane activ-

ity to continue for another 15-20 years, it is statistically unlikely that the coming 2006 and 2007 hurricane seasons, or the seasons which follow these will have nearly the number of major hurricane U.S. landfall events that we have seen in 2004-2005.

Question 2. In your written testimony, you say it is "unfortunate that most of the resources for climate research come from the Federal Government." Is it your view that the Federal Government should not be funding climate research at all, or just that it should not be supporting certain areas of investigation?

Response. I am in favor of the Federal Government funding climate research because so many aspects of needed climate research will not be supported by the private industry of research foundations. A problem of bias occurs when top government officials desire to obtain a particular scientific outcome evidence of (human-induced global warming, for instance, by the Clinton/Gore Administration) when overall climate resources are limited. They try to concentrate funding in the areas they think will produce results verifying their views. They become reluctant to support other needed research or research which may come up with results of opposite persuasion. Those who disagree with the Government's position get typecast as anti-administration and are often cut-off from research support. I believe this has happened to me (see my answer to questions No. 3 and No. 15). The Government's funding of science should be objective and removed from a desired result.

Question 3. So the Committee has a clear understanding, what percentage of your work is federally funded versus funding by non-federal sources? Please include an estimate of your total level of research funding.

Response. Up until this fall, I have had two sources of funding for my project's research.

a. The Federal Government — NSF (~ $110k/year). This funding terminates 30 November 2005. I have a new 2-year proposal which I hope will be renewed in December 2005 at an increased funding level of $160k/year. This is the only federal funding support I receive. I have not been able to obtain NOAA, FEMA, ONR or NASA support.

b. Lexington Insurance ($50k/year). I hope to increase this to $100k/year starting this fall. This is the only private support I receive.

My total grant support, up until this fall, has thus been $160k/year. With Colorado State University overhead taken out, I barely have $100k/year to actually spend on project research. I have stopped taking a CSU salary. Two years ago I made a personal contribution of $45k in order to keep my few support staff employed, some at a reduced part-time level. See the answer to question No. 15 for more background information.

Question 4. Your written testimony states that federally funded climate research is tainted by a "political position." I think it is fair to say that this Administration has a different political view than the previous Administration with respect to the need for federal or multilateral action to address climate change. Have you noticed any change in the amount or availability of funds for those researchers that have differing viewpoints on climate change under this Administration?

Response. I applaud the new outlook on this topic by the Bush Administration. But down at my grass-roots research level, I have not observed any real changes. The federal administrators who hand out the grants are at lower administration levels and are mostly the same people who were in place during the prior Clinton/Gore Administration. They still have the same pro-human induced global warming and pro-numerical modeling biases. They are not about to discontinue federal support to those they have been supporting for years. As far as I have observed, life goes on just about the same down in the research trenches. The big government weather labs (GFDL, GISS, NACA, Livermore, etc.) seem to me to be impervious as to what the president and his higher level advisors may believe and mandate to the lower echelons.

Question 5. Have you ever received any grants from any agencies under this Committee's jurisdiction, such as the US EPA or the Fish and Wildlife Service? Or have you done any work for the Army Corps of Engineers?

Response. No — I have never had support from any of these agencies.

Question 6. Is it, in your view, only federally funded climate science that seeks to obtain results that fit with a particular policy outcome? Are you saying that, for researchers, the conduct of foundation-funded or industry-funded science is less restrictive and does not contain any presumption of outcome?

Response. I can only judge the category of federal support for human-induced global warming as being directed to obtain a desired outcome. I am sure other federally- supported research disciplines have this same problem to some extent, but I judge it to not be as blatant as with the human-induced global warming funding that VP Gore and his appointees were pushing.

I am sure foundation-funded and industry-funded research is often rendered to obtain a desired outcome. But these outcomes usually have much less impact on the global economy and the change of lifestyles of humanity as does the global warming debate. We need to have some Federal research resources specifically directed to uncovering the technical and other problems associated with the human-induced global warming hypothesis. We need to determine how much of the recent global warming trend is due to natural variability. If ever there was a topic which needed researchers to play the 'Devil's Advocate' it has to be human-induced global warming.

Question 7. You express concern in your written testimony that you have never been asked to contribute, participate or review in any report by the Intergovernmental Panel on Climate Change. Though you say you haven't ever been asked, have you ever sought a nomination by the U.S. Federal Government to serve on the IPCC? Do you work with the NOAA lab in Boulder, CO that serves as the IPCC Working group I support unit, which is the IPCC working group that is specifically tasked to assess the scientific aspects of the climate system and climate change?

Response. I am well-known in the atmospheric science field. Had they wanted my input, I am sure the organization would have solicited me as they have solicited the services of some of my former students. I did not feel that it was my responsibility to force myself on them. I know many of the NOAA Lab (Boulder) scientists and have had profitable exchanges with many of them over the years. Four years ago I gave a formal seminar on my views on global warming to a large audience at the NOAA lab. There is very little research on hurricanes conducted at the NOAA Boulder lab.

Question 8. Is it a correct assumption, in reading your testimony that though you dispute projections about the magnitude of human induced climate change, you do believe in a background or natural greenhouse effect? Do you believe there is any human contribution to climate change?

Response. There is a natural greenhouse effect. The primary driver of the natural greenhouse effect is water vapor. The globe would be much colder (about 33° C colder) than it is if it were not for water vapor acting as a greenhouse gas.

I believe that there are likely a lot of human-induced changes brought on by differing land use, industrial pollution, urban heat island effects, contrails, etc. I believe all of these human influences are present, but their influence cannot be isolated from a global temperature change perspective. None of these human influences is strong enough, in my view, to bring about anything close to the amounts of global warming of 2-5° C as projected by the GCMs for a doubling of CO_2.

Yes, I believe in human induced greenhouse gas warming but of a much smaller magnitude (~ .K 0.3° C for a doubling of CO_2). This magnitude is not sufficient to justify a forced alteration of global industry and global lifestyles as the pro-warming advocates recommend.

Question 9. In your written testimony, you say that developed country governments should not take actions to combat climate change, which you argue would possibly be very costly for governments to implement. You further say that developed country governments should take no action on climate change if only for reason that the dollars that should be spent on researching alternatives to fossil fuel. If human induced climate change is not causing climate change, what would you cite as the justification for researching fossil fuel alternatives?

Response. Fossil fuels cause local pollution which can considerably reduce air quality. Most environmental problems are local. Non-polluting energy sources are, of course, highly desirable if they are not economically prohibitive. The difference between having clean energy sources or not will make little difference in global surface temperature, however.

Question 10. Over the last few weeks it seems that the controversy over hurricanes and global warming exists because different scientists have different views as to what future research will reveal, and they have been outspoken in advancing these opinions. It seems clear that you expect future research to reveal no discernible connection between hurricanes and global warming. By contrast, others believe that a connection will be found. Future research will help to clarify this dispute. Is it the case that the two papers about which you have concerns, the Emanuel and Webster papers referred to in your testimony, are the current peer reviewed research on this topic?

Response. The Emanuel and Webster et al. papers I referred to were peer reviewed but they are just plain wrong in saying that there has been a thirty year increase in global intense hurricane activity and that this increase may be associated with global mean surface temperature rise. The peer reviewers apparently did not have the background or knowledge to properly review these papers.

Increased hurricane activity has occurred only in the Atlantic and only during the last 11 years. The Atlantic increases have resulted from the large increase in

strength of the Atlantic Ocean thermohaline circulation that has occurred since 1995. Atlantic changes are not related to overall global surface temperature change.

I have written Letters to the Editors of Nature (Emanuel paper) and Science (Webster et al. paper) showing how their interpretations of the trend in global hurricane activity is not correct. The longer versions of these reviews are available on my website (tropical.atmos.colostate.edu). I have also e-mailed copies of these reviews to John Shanahan. I recommend their reading for anyone interested in the topic of global warming's influence on global hurricane activity and why the United States hurricane seasons of 2004-2005 have been so destructive.

The authors of these two papers have little recent experience in global tropical cyclone data sets. They were naive to believe their results.

Question 11. Is it also the case that research has not been conducted that would allow for a definitive conclusion on these different opinions on hurricanes and global warming?

Response. I would recommend other research be performed on this topic but not by those with a bias toward global warming. A question exists of what magnitude of global warming will influence hurricanes. Does a warming of less than 0.5° C constitute global warming or is this just noise within the climate system? The observations of global warming and hurricanes that we have seen do not indicate a relationship.

Question 12. You suggest in your written testimony, that you may have something in the publication pipeline on the link between hurricane and warming. Will this be in the form of a new communication with the editors of Nature and Science, or are you conducting a new study?

Response. Yes, I have already sent out letters to Nature and Science discussing the many problems of accepting the research put forth in the Emanuel and Webster et al. papers. I hope to send a paper to Science in the next month or two concerning how we should interpret the very active 2004-2005 United States landfall hurricane seasons.

Question 13. Do you know if there will be any peer-reviewed scientific studies available by the end of 2005, and thus available for the next IPCC report, that clarify the issue of attribution of greenhouse gas effects on hurricanes?

Response. I do not know of any 'reliable' peer-reviewed studies that will be published by the end of 2005. I think that my answer to question No. 1 and my reviews of the Emanuel and Webster et al. papers is the best information available on this topic. I doubt that the IPCC report will take much notice of my or other views to the contrary. My extended range prediction for what the next IPCC report will say is as follows: "The weight of evidence suggests that there is a discernable association between global surface temperature increases and the increase of global tropical cyclone activity." Somehow, they will find and twist data that will lend support to this conclusion.

Question 14. In your written testimony, you review the correlations between the occurrences of hurricanes in the Atlantic during a 20-year period when THC was strong versus when the THC was weak. You state that Atlantic THC was partially responsible for the difference in the numbers of hurricanes that make landfall. You also say in your written testimony that "luck" played a role. How often, in your estimation, was hurricane landfall in the Atlantic during the 20-year period you examined associated with strong THC versus just plain luck?

Response. It is hard to make the THC versus luck distinction. This has a lot to do with the westerly Atlantic upper-air steering currents that cause hurricanes to move as they do. It is possible to have very active hurricane seasons with no landfalls if the steering currents are not favorable, and the opposite—few storms, but many come ashore if the steering currents are just right.

Luck plays a greater role on the short-time scale. On longer timescales, multidecadal periodicity is more dominant. For instance, in the 25 years between 1970-1994 when the Atlantic ocean thermohaline circulation (THC) was weak, there were 12 United States landfalling major hurricanes (~ .48/year). In the last 11 years (1995-2005) when the THC was strong, there were 10 landfalling major hurricanes (~ .96/year) — twice as many. This difference was not luck but due to natural fluctuations in Atlantic hurricane activity.

Let us now break up the last 11 years into two groups; 1) 1995-2003—9 years with only 3 of 32 (9 percent) major hurricanes making United States landfall or .33/year, and 2) 2004-2005—2 years with 7 of 13 (54 percent) major hurricanes making United States landfall or 3.5/year (10 times the number of the earlier period). This difference might be explained to a large extent as luck. With a strong THC the years of 1995-2003 should have had, by normal climate standards, eight landfalling major hurricanes but they only had three. These were lucky years. But in the last

2 years (2004-2005) we have had 7 landfalling major hurricanes. These were very unlucky years.

Question 15. You testified "scientists can be punished if they do not accept the current views of the funding agents." Have you experienced such actions? If so, please explain by whom and the circumstances.

Response. Yes, I think I was not funded by the NOAA-OGP (Office of Global Programs) in part because of my views on human-induced global warming, and also the fact that I was working on climate features (seasonal hurricane variability) that were not then of OGP interest. Also, I was not performing numerical modeling research.

I had received NOAA funding for nearly 30 years until 1990 (my last grant). I could not obtain any OGP funding after the Clinton/Gore Administration began. I submitted about 1-2 proposals per year for about 8 years (1992-2000) and was turned down on all of them (13 turn-downs in a row). Yet, my students and I were performing research on climate influences on Atlantic hurricanes and how we were likely to see large increases in United States landfalling hurricanes when the Atlantic thermohaline circulation (THC) changed to a stronger mode. This has come to pass.

I have also been issuing 2-4 seasonal forecasts per year for Atlantic hurricane activity over the last 22 years. The forecasts have received extensive media coverage and been well received by the public, emergency managers, the Red Cross, etc. I am almost a household name in some hurricane-prone areas like Florida and along the Gulf Coast. Yet none of this made a difference to NOAA-OGP. I made many protests to higher NOAA officials above OGP but to no avail.

I have given nearly 50 years of my life to studying hurricanes (and have turned out a high percentage of the best graduate students in hurricanes and tropical meteorology). Yet I was continually turned down by OGP on small $60k/year and $75k/year grants for over 9 years. What was I to think? My best estimate of what happened is as follows: VP Gore appointed the directors of NOAA-OGP and they (I believe) followed his dictates. There was little new OGP money for climate research when the Clinton/Gore administration came in. Gore wanted new money to support his global warming claims. He directed his new department heads to cut out some existing programs to free up new global warming-directed research funds. Hurricanes, at this time, were not considered important. I was consequently required to turn down a number of very promising graduate students that wanted to study hurricanes and also reduce my staff.

Question 16. You testified that there has been a substantial increase in global temperatures and sea surface temperatures. Please explain why you are convinced that this rise in temperatures will not result in a greater frequency and intensity of storms?

Response. By substantial increase, I meant that global mean surface temperatures averaged 0.4° C higher during the 10 years of 1995-2004 in comparison with the 10 years of 1985-1994. The sea surface temperature (SST) increases in the oceans where tropical cyclones formed went up only about half as much (~ 0.2° C) during these two 10-year periods.

I would say that sea surface temperature rise has not caused tropical cyclone frequency-intensity to rise because the global tropical cyclone data sets do not show a rise (except for the Atlantic) during this period. We have no theory as to why global hurricane activity should go up with a small increase in sea surface temperature.

There is no physical basis for assuming that global hurricane intensity or frequency is necessarily related to global mean surface temperature changes of less than plus or minus 0.5° C. As the ocean surface warms, so too does global upper air temperatures to maintain conditionally unstable lapse-rates and global rainfall rates at their required values. Seasonal and monthly variations of sea surface temperature (SST) within individual storm basins show only very low correlations (~ 0.30) with monthly, seasonal, and yearly variations of hurricane activity. Other factors such as tropospheric vertical wind shear, surface pressure, low level vorticity and mid-level moisture play more dominant roles in explaining hurricane variability than do surface temperatures. According to the observations, there has not been a significant increase in global major tropical cyclones except for the Atlantic which as discussed, has multi-decadal oscillations driven primarily by changes in Atlantic salinity. No credible observational evidence is available or likely will be available in the next few decades which will be able to directly associate global surface temperature change to changes in global hurricane frequency and intensity.

Question 17. Table 2 in your written testimony shows an increase in the number of Category 4-5 hurricanes, net hurricanes, thunderstorms and named storms in 1990-2004 as compared with 1950-64. You attribute the increase in hurricanes to

the availability of satellites in the later period. How do you explain the very large increase in tropical storms (56 percent increase in later years)?

Response. I do not attribute the increase of Category 1-2 or major (Category 3-4-5) hurricanes to satellites. In fact, this table shows no increase between 1950-1964 and 1990-2004. The only significant increase occurred in tropical storms (Vmax 40-75 mph). This is due to the large number of storms being named in the mid-Atlantic in recent years. During the pre-satellite era, these storms may not have been observed. The 21 named storms of 1933 would have likely been 2-5 storms higher had satellite data been available at that time.

STATEMENT OF DONALD R. ROBERTS, PH.D., PROFESSOR, DIVISION OF TROPICAL PUBLIC HEALTH, DEPARTMENT OF PREVENTIVE MEDICINE AND BIOMETRICS, UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES, BETHESDA, MD[1]

Thank you, Chairman Inhofe, and distinguished members of the committee on Environment and Public Works for the opportunity to present my views on the misuse of science in public policy. My testimony focuses on misrepresentations of science during decades of environmental campaigning against DDT

Before discussing how and why DDT science has been misrepresented, you first must understand why this misrepresentation has not helped, but rather harmed, millions of people every year all over the world. Specifically you need to understand why the misrepresentation of DDT science has been and continues to be deadly. By way of explanation, I will tell you something of my experience.

I conducted malaria research in the Amazon Basin in the 1970s. My Brazilian colleague who is now the Secretary of Health for Amazonas State and I worked out of Manaus, the capitol of Amazonas State. From Manaus we traveled two days to a study site where we had sufficient numbers of cases for epidemiological studies. There were no cases in Manaus, or anywhere near Manaus. For years before my time there and for years thereafter, there were essentially no cases of malaria in Manaus. However in the late 1980s, environmentalists and international guidelines forced Brazilians to reduce and then stop spraying small amounts of DDT inside houses for malaria control. As a result, in 2002 and 2003 there were over 100,000 malaria cases in Manaus alone.[2]

Brazil does not stand as the single example of this phenomenon. A similar pattern of declining use of DDT and reemerging malaria occurs in other countries as well, Peru[3] for example. Similar resurgences of malaria have occurred in rural communities, villages, towns, cities, and countries around the world. As illustrated by the return of malaria in Russia, South Korea, urban areas of the Amazon Basin, and increasing frequencies of outbreaks in the United States, our malaria problems are growing worse. Today there are 1 to 2 million malaria deaths each year and hundreds of millions of cases. The poorest of the world's people are at greatest risk. Of these, children and pregnant women are the ones most likely to die.

We have long known about DDT's effectiveness in curbing insect borne disease. Othmar Zeidler, a German chemistry student, first synthesized DDT in 1874. Over sixty years later in Switzerland, Paul Muller discovered the insecticidal property of DDT.[4] Allied forces used DDT during WWII, and the new insecticide gained fame in 1943 by successfully stopping an epidemic of typhus in Naples, an unprecedented achievement.[5] By the end of the war, British, Italian, and American scientists had also demonstrated the effectiveness of DDT in controlling malaria-carrying mosquitoes. DDT's proven efficacy against insect-borne diseases, diseases that had long reigned unchecked throughout the world, won Muller the Nobel Prize for Medicine in 1948.

After WWII, the United States conducted a National Malaria Eradication Program, commencing operations on July 1, 1947. The spraying of DDT on internal walls of rural homes in malaria endemic counties was a key component of the program. By the end of 1949, the program had sprayed over 4,650,000 houses. This

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[1] Observations presented here are the opinions of the author and should not be interpreted as reflecting the views or opinions of the Uniformed Services University of the Health Sciences, the Department of Defense, or the United States Government.

[2] Boletim Scientifico FMTAM-Abril/Jun-2004

[3] Guarda, Asayag, Witzig. 1999. Malaria reemergence in the Peruvian Amazon Region. Emerg Infectious Diseases. 5(2) at www://cdc.gov/ncidod/eid/vol5no2/arambG.htm#fig2

[4] http://www.cdc.gov/malaria/history/

[5] http://homepage.mac.com/msb/163x/faqs/typhus.html

spraying broke the cycle of malaria transmission, and in 1949 the United States was declared free of malaria as a significant public health problem.[6]

Other countries had already adopted DDT to eradicate or control malaria, because wherever malaria control programs sprayed DDT on house walls, the malaria rates dropped precipitously. The effectiveness of DDT stimulated some countries to create, for the first time, a national malaria control program. Countries with pre-existing programs expanded them to accommodate the spraying of houses in rural areas with DDT. Those program expansions highlight what DDT offered then, and still offers now, to the malaria endemic countries. As a 1945 U.S. Public Health Service manual explained about the control of malaria:

> "Drainage and larviciding are the methods of choice in towns of 2,500 or more people. But malaria is a rural disease. Heretofore there has been no economically feasible method of carrying malaria control to the individual tenant farmer or sharecropper. Now, for the first time, a method is available the application of DDT residual spray to walls and ceilings of homes."

Health workers in the United States were not the only ones to recognize the particular value of DDT. The head of malaria control in Brazil characterized the changes that DDT offered in the following statement:

> "Until 1945-1946, preventive methods employed against malaria in Brazil, as in the rest of the world, were generally directed against the aquatic phases of the vectors (draining, larvicides, destruction of bromeliads, etc.). These methods, however, were only applied in the principal cities of each State and the only measure available for rural populations exposed to malaria was free distribution of specific drugs."[7]

DDT was a new, effective, and exciting weapon in the battle against malaria. It was cheap, easy to apply, long-lasting once sprayed on house walls, and safe for humans. Wherever and whenever malaria control programs sprayed it on house walls, they achieved rapid and large reductions in malaria rates.

Just as there was a rush to quickly make use of DDT to control disease, there was also a rush to judge how DDT actually functioned to control malaria. That rush to judgment turned out to be a disaster. At the heart of the debate to the extent there was a debate was a broadly accepted model[8] that established a mathematical framework for using DDT to kill mosquitoes and eradicate malaria. Instead of studying real data to see how DDT actually worked in controlling malaria, some scientists settled upon what they thought was a logical conclusion: DDT worked solely by killing mosquitoes. This conclusion was based on their belief in the model. Scientists who showed that DDT did not function by killing mosquitoes were ignored. Broad acceptance of the mathematical model led to strong convictions about DDT's toxic actions.[9] Since they were convinced that DDT worked only by killing mosquitoes, malaria control specialists became very alarmed when a mosquito was reported to be resistant to DDT's toxic actions.[10] As a result of concern about DDT resistance, officials decided to make rapid use of DDT before problems of resistance could eliminate their option to use DDT to eradicate malaria. This decision led to creation of the global malaria eradication program.

The active years of the global malaria eradication program were from 1959 to 1969. Before, during, and after the many years of this program, malaria workers and researchers carried out their responsibilities to conduct studies and report their research. Through those studies, they commonly found that DDT was functioning in ways other than by killing mosquitoes. In essence, they found that DDT was functioning through mechanisms of repellency and irritancy. Eventually, as people

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[6] http://www.cdc.gov/malaria/history/

[7] U.S. Public Health Service. 1944-45. Malaria control in war areas. Federal Security Agency U.S. Public Health Service. 134pp

[8] The first direct studies on DDT as a repellent were conducted in the mid-1940s and published in 1947. However, also there were many field studies during the same timeframe that supported the idea that DDT was functioning as a spatial repellent to keep mosquitoes from entering houses and transmitting malaria. Kennedy, J., The excitant and repellent effects of mosquitoes of sub-lethal contacts with DDT. Bulletin of Entomological Research, 1947. 37: p. 593-607.

[9] Macdonald, G. and G. Davidson, Dose and cycle of insecticide application in the control of malaria. Bulleting of the World Health Organization, 1953. 9: p. 785-812

[10] "Resistance to the DDT deposits sprayed on house walls for malaria control was first discovered in 1951, in Anopheles sacharovi at Nauplion in the Peloponnese peninsula of Greece, a locality where DDT had been applied to rice fields since 1946." From Laird, M, Miles, JW. Ed. 1983. Integrated mosquito control methodologies, vol. 1. Academic Press, N.Y. page 188 of 369 pages.

forgot early observations of DDT's repellent actions, some erroneously interpreted new findings of repellent actions as the mosquitoes' adaptation to avoid DDT toxicity, even coining a term, "behavioral resistance," to explain what they saw. This new term accommodated their view that toxicity was DDT's primary mode of action and categorized behavioral responses of mosquitoes as mere adaptations to toxic affects. However this interpretation depended upon a highly selective use of scientific data.

The truth is that toxicity is not DDT's primary mode of action when sprayed on house walls. Throughout the history of DDT use in malaria control programs there has always been clear and persuasive data that DDT functioned primarily as a spatial repellent.[11] Today we know that there is no insecticide recommended for malaria control that rivals, much less equals, DDT's spatial repellent actions, or that is as long-acting, as cheap, as easy to apply, as safe for human exposure, or as efficacious in the control of malaria as DDT. Attached as Annex 1 is a more technical explanation of how DDT functions to control Malaria.

The 30 years of data from control programs of the Americas plotted in Figure 1 illustrate just how effective DDT is in malaria control. The period 1960s through 1979 displays a pattern of malaria controlled through house spraying. In 1979 the World Health Organization (WHO) changed its strategy for malaria control, switching emphasis from spraying houses to case detection and treatment. In other words, the WHO changed emphasis from malaria prevention to malaria treatment. Countries complied with WHO guidelines and started to dismantle their spray programs over the next several years. The line graph in Figure 1 illustrates the progress of the dismantling. As you can see, fewer and fewer houses were sprayed. The bar graph illustrates the cumulative increase in cases over the baseline of cases that occurred during years when adequate numbers of houses were being sprayed (1965-1979). As you can also see, as countries reduced numbers of houses sprayed, the number of malaria cases continually increased.

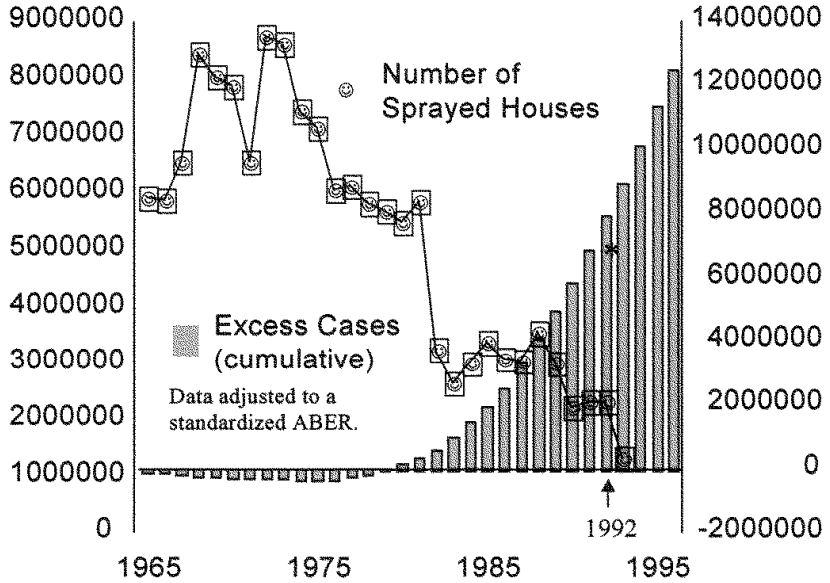

Figure 1. Impact of the World Health Organization's malaria control strategy in 1979 to de-emphasize indoor spraying of house walls and adoption of World Health Assembly resolution in 1985 to decentralize malaria control programs in the Americas. The x-axis is years and the y-axis is cumulative numbers of malaria cases above the baseline. Baseline is defined as the average number of malaria cases each year from 1965 to 1979.

[11] I am including this testimony, as Annex 2, pages from a book chapter I wrote entitled "The contextual determinants of malaria." This attachment provides a detailed explanation of the importance of spatial repellent actions of DDT in controlling malaria.

With data such as this, I find it amazing that many who oppose the use of DDT describe its earlier use as a failure. Our own citizens who suffered under the burden of malaria, especially in the rural south, would hardly describe it thus.

Malaria was a serious problem in the United States and for some localities, such as Dunklin County, Missouri, it was a very serious problem indeed. For four counties in Missouri, the average malaria mortality from 1910 to 1914 was 168.8 per 100,000 population. For Dunklin County, it was 296.7 per 100,000 a rate almost equal to malaria deaths in Venezuela and actually greater than the mortality rate for Freetown, Sierra Leone. Other localities in other states were equally as malarious.[12] Growing wealth and improved living conditions were gradually reducing malaria rates, but cases resurged during WWII. The advent of DDT, however, quickly eradicated malaria from the United States.

DDT routed malaria from many other countries as well. The Europeans who were freed of malaria would hardly describe its use as a failure. After DDT was introduced to malaria control in Sri Lanka (then Ceylon), the number of malaria cases fell from 2.8 million in 1946 to just 110 in 1961. Similar spectacular decreases in malaria cases and deaths were seen in all the regions that began to use DDT. The newly formed Republic of China (Taiwan) adopted DDT use in malaria control shortly after World War II. In 1945 there were over 1 million cases of malaria on the island. By 1969 there were only 9 cases and shortly thereafter the disease was eradicated from the island and remains so to this day.[13] Some countries were less fortunate. South Korea used DDT to eradicate malaria, but without house spray programs, malaria has returned across the demilitarized zone with North Korea. As DDT was eliminated and control programs reduced, malaria has returned to other countries such as Russia and Argentina. Small outbreaks of malaria are even beginning to appear more frequently in the United States.

These observations have been offered in testimony to document first that there were fundamental misunderstandings about how DDT functioned to exert control over malaria. Second, that regardless of systematic misunderstandings on the part of those who had influence over malaria control strategies and policies, there was an enduring understanding that DDT was the most cost-effective compound yet discovered for protecting poor rural populations from insect-borne diseases like malaria, dengue, yellow fever, and leishmaniasis. I want to emphasize that misunderstanding the mode of DDT action did not lead to the wholesale abandonment of DDT. It took an entirely new dimension in the misuse of science to bring us to the current humanitarian disaster represented by DDT elimination.

The misuse of science to which I refer has found fullest expression in the collection of movements within the environmental movement that seek to stop production and use of specific man-made chemicals.[14] Operatives within these movements employ particular strategies to achieve their objectives. By characterizing and understanding the strategies these operatives use, we can identify their impact in the scientific literature or in the popular press.

The first strategy is to develop and then distribute as widely as possible a broad list of claims of chemical harm. This is a sound strategy because individual scientists can seldom rebut the scientific foundations of multiple and diverse claims. Scientists generally develop expertise in a single, narrow field and are disinclined to engage issues beyond their area of expertise. Even if an authoritative rebuttal of one claim occurs, the other claims still progress. A broad list of claims also allows operatives to tailor platforms for constituencies, advancing one set of claims with one constituency and a different combination for another. Clever though this technique is, a list of multiple claims of harm is hardly sufficient to achieve the objective of a ban. The second strategy then is to mount an argument that the chemical is not needed and propose that alternative chemicals or methods can be used instead. The third strategy is to predict that grave harm will occur if the chemical continues to be used.

The success of Rachel Carson's Silent Spring serves as a model for this tricky triad. In Silent Spring, Rachel Carson used all three strategies on her primary target, DDT. She described a very large list of potential adverse effects of insecticides, DDT in particular. She argued that insecticides were not really needed and that the use of insecticides produces insects that are insecticide resistant, which only exacerbates the insect control problems. She predicted scary scenarios of severe harm with

[12] Hoffman, F.L. 1916. A plea and a plan for the eradication of malaria throughout the Western Hemisphere. Read in abstract before The Southern Medical Association, Tenth Annual Meeting, Atlanta, Georgia, November 14, 1916:65pp.

[13] World Health Organization, (1971) Executive Board, 42nd Session, Appendix 14 "The Place of DDT in Operations Against Malaria and Other Vector Borne Diseases" p 177. WHO, Geneva.

[14] http://www.philotast.de/ecologism.htm

continued use of DDT and other insecticides. Many have written rebuttals to Rachel Carson and others who have, without scientific justification, broadcast long lists of potential harms of insecticides. One such rebuttal (see page 143) is attached to my testimony. It is a paper by Dr. J. Gordon Edwards entitled "DDT: A case study in scientific fraud."

As shown in Annex 2, time and science have discredited most of Carson's claims.[15] Rachel Carson's descriptions of inappropriate uses of insecticides that harmed wildlife are more plausible. However harm from an inappropriate use does not meet the requirements of anti-pesticide activists. They can hardly lobby for eliminating a chemical because someone used it wrongly. No, success requires that even the proper use of an insecticide will cause a large and systematic adverse effect. However, the proper uses of DDT yield no large and systematic adverse effects. Absent such adverse actions, the activists must then rely on claims about insidious effects, particularly insidious effects that scientists will find difficult to prove one way or the other and that activists can use to predict a future catastrophe.

Rachel Carson relied heavily on possible insidious chemical actions to alarm and frighten the public. Many of those who joined her campaign to ban DDT and other insecticides made extensive use of claims of insidious effects. These claims were amplified by the popular press and became part of the public perception about modern uses of chemicals. For example, four well-publicized claims about DDT were:

1. DDT will cause the obliteration of higher tropic[16] levels. If not obliterated, populations will undergo reproductive failure. Authors of this claim speculated that, even if the use of DDT were stopped, systematic and ongoing obliterations would still occur.[17]
2. DDT causes the death of algae.[18] This report led to speculations that use of DDT could result in global depletion of oxygen.
3. DDT pushed the Bermuda Petrel to the verge of extinction and that full extinction might happen by 1978.[19]
4. DDT was a cause of premature births in California sea lions.[20]

Science magazine, the most prestigious science journal in the United States, published these and other phantasmagorical allegations and/or predictions of DDT harm. Nonetheless, history has shown that each and every one of these claims and predictions were false.

1.) The obliteration of higher tropic levels did not occur; no species became extinct; and levels of DDT in all living organisms declined precipitously after DDT was delisted for use in agriculture. How could the prediction have been so wrong? Perhaps it was so wrong because the paper touting this view used a predictive model based on an assumption of no DDT degradation. This was a startling assertion even at the time as Science and other journals had previously published papers that showed DDT was ubiquitously degraded in the environment and in living creatures. It was even more startling that Science published a paper that flew so comprehensively in the face of previous data and analysis.

2.) DDT's action against algae reportedly occurred at concentrations of 500 parts per billion. But DDT cannot reach concentrations in water higher than about 1.2 parts per billion, the saturation point of DDT in water.

3.) Data on the Bermuda petrel did not show a cause and effect relationship between low numbers of birds and DDT concentrations. DDT had no affect on population numbers, for populations increased before DDT was de-listed for use in agriculture and after DDT was delisted as well.[21]

4.) Data gathered in subsequent years showed that "despite relatively high concentrations [of DDT], no evidence that population growth or the health of individual California sea lions have been compromised. The population has increased through-

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[15] Dr. Edwards mentions some of those claims. See page 143.

[16] A tropic level can be defined by an organism's position within a food chain. The number of energy transfers to get to that level can establish the organism's position. For example, humans are at the highest atrophic level. As lions are at the top of their food chain , they are at the highest tropic level in that chain.

[17] Harrison, HL, Loucks, OL, Mitchell, JW, Parkhurst, DF, Tracy, CR, Watts, DG, Yannacone, VJ. Systems studies of DDT transport. Science 170, 30 October 1970, 503-508.

[18] Wurster, C, DDT reduces photosynthesis by marine phytoplankton. Science, 29 March 1968.

[19] Wurster, CF, Wingate, DB. DDT residues and declining reproduction in the Bermuda petrel. Science 159(818):979-81.

[20] Science 1973;181:1168-1170

[21] http://www.audubon.org/local/latin/bulletin3/featured.html

out the century, including the period when DDT was being manufactured, used, and its wastes discharged off southern California."[22]

If time and science have refuted all these catastrophic predictions, why do many scientists and the public not know these predictions were false? In part, we do not know the predictions were false because the refutations of such claims rarely appear in the literature.

When scientists hear the kinds of claims described above, they initiate research to confirm or refute the claims. After Charles Wurster published his claim that DDT kills algae and impacts photosynthesis, I initiated research on planktonic algae to quantify DDT's effects. From 1968-1969, I spent a year of honest and demanding research effort to discover that not enough DDT would even go into solution for a measurable adverse effect on planktonic algae. In essence, I conducted a confirmatory study that failed to confirm an expected result. I had negative data, and journals rarely accept negative data for publication. My year was practically wasted. Without a doubt, hundreds of other scientists around the world have conducted similar studies and obtained negative results, and they too were unable to publish their experimental findings. Much in the environmental science literature during the last 20-30 years indicates that an enormous research effort went into proving specific insidious effects of DDT and other insecticides. Sadly, the true magnitude of such efforts will never be known because while the positive results of research find their way into the scientific literature, the negative results rarely do. Research on insidious actions that produce negative results all too often ends up only in laboratory and field notebooks and is forgotten.[23] For this reason, I place considerable weight on a published confirmatory study that fails to confirm an expected result.

The use of the tricky triad continues. A copy of a recent paper (see page 150) published in The Lancet[24] illustrates the triad's modern application. Two scientists at the National Institute of Environmental Health Sciences, Walter Rogan and Aimin Chen, wrote this paper, entitled "Health risks and benefits of bis (4-chlorophenyl)-1,1,1-trichloroethane (DDT)." It is interesting to see how this single paper spins all three strategies that gained prominence in Rachel Carson's Silent Spring.

The journal Emerging Infectious Diseases had already published a slim version of this paper,[25] which international colleagues and I promptly rebutted.[26] The authors then filled in some parts, added to the claims of harm, and republished the paper in the British journal, The Lancet. To get the paper accepted by editors, the authors described studies that support (positive results) as well as studies that do not support (negative results) each claim. Complying with strategy number 1 of the triad, Rogan and Chen produce a long list of possible harms, including the charge that DDT causes cancer in nonhuman primates. The literature reference for Rogan and Chen's claim that DDT causes cancer in nonhuman primates was a paper by Takayama et al.[27] Takayama and coauthors actually concluded from their research on the carcinogenic effect of DDT in nonhuman primates that "the two cases involving malignant tumors of different types are inconclusive with respect to a carcinogenic effect of DDT in nonhuman primates." Clearly, the people who made the link of DDT with cancer were not the scientists who actually conducted the research.

The authors enacted strategy number two of the triad by conducting a superficial review of the role of DDT in malaria control with the goal of discrediting DDT's value in modern malaria control programs. The authors admitted that DDT had been very effective in the past, but then argued that malaria control programs no longer needed it and should use alternative methods of control. Their use of the second strategy reveals, in my opinion, the greatest danger of granting authority to anti-pesticide activists and their writings. As The Lancet paper reveals, the NIEHS scientists assert great authority over the topic of DDT, yet they assume no responsibility for the harm that might result from their erroneous conclusions. After many malaria control specialists have expressed the necessity for DDT in malaria control, it is possible for Rogan and Chen to conclude that DDT is not necessary in malaria

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[22] http://www.audubon.org/local/latin/bulletin3/featured.html

[23] An internationally recognized epidemiologist recently told me that three different journals had rejected his negative data on the association of DDT with human health harm.

[24] Rogan, WJ, Chen, A. Health risks and benfits of bis (4-chlorophenyl)-1,1,1-trichloroethane (DDT). The Lancet 366, August 27, 2005:763-773.

[25] Chen, A, Rogan, WJ. Nonmalarial infant deaths and DDT use for malaria control. Emerging Infectious Diseases 2003 Aug. Available from: URL: http://www.cdc.gov/ncidod/EID/vol9no8/03-0082.htm

[26] http://www.cdc.gov/ncidod/EID/vol10no6/03-0787—03-1116.htm

[27] Takayama, S, Sieber, SM, Dalgard, DW, Thorgeirsson, UP, Adamson, RH. Effects of long-term oral administration of DDT on nonhuman primates. J Cancer Res Clin Oncol (1999) 125: 219-225.

control only if they have no sense of responsibility for levels of disease and death that will occur if DDT is not used.

Rogan and Chen also employ the third strategy of environmentalism. Their list of potential harms caused by DDT includes toxic effects, neurobehavior effects, cancers, decrements in various facets of reproductive health, decrements in infant and child development, and immunology and DNA damage. After providing balanced coverage of diverse claims of harm, the authors had no option but to conclude they could not prove that DDT caused harm. However, they then promptly negated this honest conclusion by asserting that if DDT is used for malaria control then great harm might occur. So, in an amazing turn, they conclude they cannot prove DDT causes harm, but still predict severe harm if it is used.

Rogan and Chen end their paper with a call for more research. One could conclude that the intent of the whole paper is merely to lobby for research to better define DDT harm, and what's the harm in that? Surely increasing knowledge is a fine goal. However, if you look at the specific issue of the relative need for research, you will see that the harm of this technique is great. Millions of children and pregnant women die from malaria every year, and the disease sickens hundreds of millions more. This is an indisputable fact: impoverished people engage in real life and death struggles every day with malaria. This also is a fact: not one death or illness can be attributed to an environmental exposure to DDT. Yet, a National Library of Medicine literature search on DDT reveals over 1,300 published papers from the year 2000 to the present, almost all in the environmental literature and many on potential adverse effects of DDT. A search on malaria and DDT reveals only 159 papers. DDT is a spatial repellent and hardly an insecticide at all, but a search on DDT and repellents will reveal only 7 papers. Is this not an egregiously disproportionate research emphasis on non-sources of harm compared to the enormous harm of malaria? Does not this inequity contribute to the continued suffering of those who struggle with malaria? Is it possibly even more than an inequity? Is it not an active wrong?

Public health officials and scientists should not be silent about enormous investments into the research of theoretical risks while millions die of preventable diseases. We should seriously consider our motivations in apportioning research money as we do. For example consider this: the United States used DDT to eradicate malaria. After malaria disappeared as an endemic disease in the United States, we became richer. We built better and more enclosed houses. We screened our windows and doors. We air conditioned our homes. We also developed an immense arsenal of mosquito control tools and chemicals. Today, when we have a risk of mosquito borne disease, we can bring this arsenal to bear and quickly eliminate risks. And, as illustrated by aerial spray missions in the aftermath of hurricane Katrina, we can afford to do so. Yet, our modern and very expensive chemicals are not what protect us from introductions of the old diseases. Our arsenal responds to the threat; it does not prevent the appearance of old diseases in our midst. What protects us is our enclosed, screened, air-conditioned housing, the physical representation of our wealth. Our wealth is the factor that stops dengue at the border with Mexico, not our arsenal of new chemicals. Stopping mosquitoes from entering and biting us inside our homes is critical in the prevention of malaria and many other insect-borne diseases. This is what DDT does for poor people in poor countries. It stops large proportions of mosquitoes from entering houses. It is, in fact, a form of chemical screening, and until these people can afford physical screening or it is provided for them, this is the only kind of screening they have.

DDT is a protective tool that has been taken away from countries around the world, mostly due to governments acceding to the whims of the anti-pesticide wing of environmentalism, but it is not only the anti-pesticide wing that lobbies against DDT. The activists have a sympathetic lobbying ally in the pesticide industry. As evidence of insecticide industry working to stop countries from using DDT, I am attaching an e-mail message dated September 23, 2005 and authored by a Bayer official (see page 161). The Bayer official states "[I speak] Not only as the responsible manager for the vector control business in Bayer, being the market leader in vector control and pointing out by that we know what we are talking about and have decades of experiences in the evolution of this very particular market. [but] Also as one of the private sector representatives in the RBM Partnership Board and being confronted with that discussion about DDT in the various WHO, RBM et al circles. So you can take it as a view from the field, from the operational commercial level-but our companies point of view. I know that all of my colleagues from other primary manufacturers and internationally operating companies are sharing my view."

The official goes on to say that "DDT use is for us a commercial threat (which is clear, but it is not that dramatic because of limited use), it is mainly a public image threat."

However the most damming part of this message was the statement that "we fully support EU to ban imports of agricultural products coming from countries using DDT"

The e-mail (see page 161) provides clear evidence of international and developed country pressures to stop poor countries from using DDT to control malaria. This message also shows the complicity of the insecticide industry in those internationally orchestrated efforts.

Pressures to eliminate spray programs, and DDT in particular, are wrong. I say this not based on some projection of what might theoretically happen in the future according to some model, or some projection of theoretical harms, I say this based firmly on what has already occurred. The track record of the anti-pesticide lobby is well documented, the pressures on developing countries to abandon their spray programs are well documented, and the struggles of developing countries to maintain their programs or restart their uses of DDT for malaria control are well documented. The tragic results of pressures against the use of DDT, in terms of increasing disease and death, are quantified and well documented. How long will scientists, public health officials, the voting public, and the politicians who lead us continue policies, regulations and funding that have led us to the current state of a global humanitarian disaster? How long will support continue for policies and programs that favor phantoms over facts?

RESPONSES OF DONALD R. ROBERTS TO ADDITIONAL QUESTIONS FROM SENATOR JEFFORDS

Question 1. You have testified that "proper uses of DDT yield no large and systematic adverse effects." Would you clarify for us what is the "proper" use of DDT?

Response. The proper use of DDT is in public health, not agriculture.

A fundamental trait of public health programs is limited resources, to include financial, material, and human resources. Because of limited resources the public health use of DDT has always been limited, meaning that its use was highly selective in application.

There have been two very different but major public health uses of DDT. One was in malaria control, the other was to eradicate Aedes aegypti from the Americas. In each case, I consider the two different uses of DDT as "appropriate." There have been other public health uses, such as spraying DDT in clothing to effectively stop typhus epidemics, and DDT to combat plague in wild rodents. Thus, its contributions to human health have been many; but DDT was used continuously over many years for malaria and Aedes aegypti eradication. I will explain briefly how DDT was used in the two programs.

For malaria control, DDT was applied to house walls at a rate of 2 grams of active ingredient per square meter of wall surface. Each house was to be sprayed every 6 months. All houses in an endemic area were supposed to be sprayed. Theory was that at least 80 percent of houses must be sprayed (some claimed that complete coverage was necessary). The goal of such a program was disease eradication. Even today the guidelines for using DDT hark back to the goals of eradication, not malaria control. In 1969 the World Health Organization abandoned the goal of eradication. After 1969 an internationally orchestrated program of DDT elimination snuffed out the realignment of programs to use DDT for disease control, opposed to eradication.

DDT was used in programs of peri-focal spraying for eradication of Aedes aegypti from countries of the Americas. This meant that it was sprayed in and around containers of water used by the mosquito for their larvae. If the container was next to a wall, the wall closest to the container was sprayed. If the container was near a bush, the bush was sprayed. The use of peri-focal spraying of DDT for eradicating Aedes aegypti from countries of the Americas was highly successful; but environmental activist pressures in the United States ended the program in 1969.

There are important distinctions between the two uses of DDT described here; but there were also similarities. For example, in each of the two uses, if eradication was achieved for a particular area, region, or country, there was no need to continue spraying DDT. So for both malaria and Aedes aegypti eradication there was an identifiable end point beyond which routine spraying of DDT was no longer needed, or need was greatly reduced.

Unlike the goal of Aedes aegypti eradication, poverty and poor living conditions made malaria eradication a non-attainable goal in many, if not most, tropical countries. In contrast, Aedes aegyti eradication was indeed demonstrated and carried out in many tropical countries. Once the mosquito was eradicated, DDT was then needed only when a re-invasion of the mosquito was detected. Largely ignored in our his-

torical record is that the United States was the major country of the Americas that failed in its obligation to eradicate Aedes aegytpi. Not surprisingly, as environmental pressure gained strength in the United States during the late 1960s, our fledgling eradication program was stopped. Once the United States stopped, the rest of the countries of the Americas collapsed their programs and Aedes aegypti started to reinvade all of the Americas.

Basically, I have described here two uses of DDT.

The use of DDT to eradicate Aedes aegypti was realistic and largely successful. This hemisphere-wide program should have been carried to completion. The struggle against Aedes aegypti and the diseases it transmits to humans would not have ended with eradication. But the dimensions of the fight would have been greatly lessened and would have been continued through active surveillance and vigilance. As it is today, the mosquito has returned to all its old haunts and is inflicting great human health harm and suffering on counties of the Americas outside the United States.

As for the use of DDT to eradicate malaria, the goal was not realistic, but that lesson was learned slowly. In the end, use of DDT for control of malaria, opposed to eradication, was overtaken by environmental activism for DDT elimination. So today we are faced with growing problems of malaria and a growing need to make use of DDT for purposes of control, not eradication. Regrettably, environmental activism poisoned the politics of insecticide research to the point that there has been almost no research in the United States to find an acceptable alternative to DDT. For that reason, even now there is no cost-effective DDT alternative for preventing malaria transmission inside houses.

Question 2. You have done a great deal of work in mapping to predict the presence of mosquitoes and target homes for spray in developing countries. Am I correct in my understanding that the spray regime that you advocate is not spraying of every house in a developing country?

Response. You are correct in your understanding. I definitely do not advocate spraying of every house in a developing country.

In the history of house spray programs, I know of no country that sprayed even a majority of houses. Programs were highly successful by spraying only a small proportion of houses. Using advance geographic information system technology we can achieve better targeting of houses today than ever before. As houses are sprayed, the distribution of disease will change and the distribution of spraying should change as a result.

I have studied the history of spraying programs in countries of the Americas. There is almost no country where every single house was sprayed. Where this might have occurred, it was a temporary condition and spraying quickly declined to levels commensurate with greatly reduced levels of disease risk as a result of the spray program. The spraying of every house would be an abusive use of DDT—it would be costly, wasteful, and unaffordable.

Question 3. Though you have concerns about DDT bans, do you concur that restriction of the use of DDT in agriculture was an appropriate action for the U.S. to take?

Response. I concur that DDT should have been phased-out of agriculture use. I do not concur that DDT should have been de-listed for agricultural uses in such a short timeframe as occurred in 1972. I also question the validity of de-listing DDT use in agriculture when the replacement chemical (methyl parathion) was multiple times more toxic.

In essence, EPA de-listed DDT for agricultural uses even though there was no convincing proof that it caused human health harm (as revealed in the EPA hearing of 1971-72). EPA opined that DDT was not necessary and that a substitute could be used, knowing full well that the substitute would almost certainly result in human deaths (methyl parathion, the replacement chemical, is one of the most toxic insecticides in existence). Dangerous toxicity of parathion eventually resulted in it being de-listed for most agricultural uses in the United States, and even banned for all uses in many countries. In conclusion, I agree that DDT should have been phased out of agricultural use; but do not concur that the 1972 decision was appropriate. There should be no doubt that innocent Americans died as a result of that decision.

Question 4. You have looked at DDT's efficacy as a repellent. Have you examined the efficacy of the alternatives to DDT, and are they similarly effective?

Response. Yes, we have examined alternatives to DDT for efficacy as spatial repellents. In fact, we have now tested hundreds of chemicals and have yet to find another chemical equal to DDT. No other insecticide presently recommended for use in malaria control programs functions as a spatial repellent. The pyrethroid insecticides (comprising those insecticides presently used for treating bed nets) exhibit con-

tact irritant and contact toxic actions; but no spatial repellent actions. No other insecticide presently recommended for malaria control will provide protection for as many months as DDT. DDT is still the cheapest chemical to buy, offers much greater protection to sprayed households, and is the only chemical that will stop the mosquitoes from entering houses and transmitting malaria indoors. So the short answer to this question is that DDT has a unique set of actions and there is no known acceptable replacement insecticide.

Question 5. In your testimony, you state that not one death or illness can be attributed to DDT. That is in terms of human health, is that correct? Do you dispute research into the effect of DDT and its byproducts on animal health in the environment?

Response. Yes, my comment was in reference to human health.

Yes, I dispute the claims of research into the effect of DDT and its by products on animal health in the environment. I dispute those claims for the following reasons. There are criteria for evaluating a cause and effect relationship, and this relationship is really the critical issue of whether DDT has harmed animal health in the environment. I propose the following reasonable criteria: 1) consistency of results, 2) statistical coherence in the form of a proportional dose response relationship, and 3) predictive performance. Many claims of harm are just that, claims. No standards or criteria for defining cause and effect relationships are used. For these reasons, many claims of harm have been proven false. On the other hand, the cause and effect relationships between declining uses of DDT for malaria control and reemerging malaria fulfill completely the criteria listed above.

As a concluding comment, I personally do not consider the issue of DDT causing harm to animals in the environment to be truly relevant to the debate for using DDT in malaria control programs. Few would argue that spraying DDT on inside walls of houses poses a meaningful risk to animal health in the environment.

Question 6. You talk about wealth reducing the need for chemical repellents to control malaria in your written testimony. Does your work show that physical screening ultimately replaces the need for chemicals.

Response. I really cannot answer this question from standpoint of my own research. However, the research of others plus the events of countries in economic transition after controlling malaria suggest that screening, air conditioning, and other facets of a higher standard of living provide considerable protection from indoor transmission of malaria. Obviously, such protections are greater in temperate environments, less so in tropical environments. My own opinion is that you might never eliminate need for chemical control in some tropical regions; but the need would be much less if houses were well enclosed, with windows and doors screened, or houses air conditioned.

To provide a better answer to this question, consider the scenario that is played out in households across the United States. Family members are sitting on their porch on a warm summer day. As it begins to get dark the mosquitoes begin to bite. After a time, family members tire of the mosquitoes and go inside away from the mosquitoes. Inside, there are no mosquitoes. If one moves this scenario to a malaria endemic tropical country, very different conditions prevail. Family members sitting outside feel the bites and move indoors. Indoors they do not get away from mosquitoes; but the mosquitoes indoors may be very different from the ones biting outside. The mosquitoes inside are the truly dangerous ones. The mosquitoes inside the house bite as people sleep and acquire infection from sick people or transmit infection to those who are not sick. In the United States our well-enclosed houses afford protection, but the open houses of the tropics actually provide a gathering place for the most dangerous mosquitoes. Preventing those mosquitoes from being indoors is the work of DDT.

STATEMENT OF DAVID B. SANDALOW, DIRECTOR, ENVIRONMENT & ENERGY PROJECT
THE BROOKINGS INSTITUTION

Thank you Mr. Chairman. Tomorrow it will be one month since Hurricane Katrina made landfall on the Gulf Coast. The suffering caused by this storm is well known, but no less tragic for being so. Today countless thousands of Americans grieve relatives lost in the storm, and many more search for ways to restore shattered lives and livelihoods. As we join together as a nation to rebuild this region, our thoughts and prayers are with them all.

Many observers have characterized Katrina as a defining moment in our nation's history. Former Speaker Newt Gingrich said the impact of Katrina will be "30 to 100 times bigger than 9/11," arguing that the "after effects of this extreme disaster will last longer and be more complex than any domestic event since World War II."

Commentators have focused on the importance of this event to race relations, anti-poverty programs, the federal budget, homeland security and more.

Then, this past weekend our Gulf Coast was struck by another storm. Hurricane Rita was smaller and less powerful than Katrina, but only by comparison to its predecessor could Rita be considered a minor event. More than three million people were evacuated from their homes, causing traffic jams that stretched for more than one hundred miles. The full death toll is not yet known but, including fatalities that occurred during the evacuation of Houston, appears to number at least 30. The governor of Texas estimates damages exceeding $8 billion in his state alone.

Your hearing, Mr. Chairman, is timely. The two hurricanes that struck our nation in the past month raise important questions about science policy, environmental policy, and the intersection between the two. How can we better predict natural disasters of this kind? Will our response to Katrina be shaped by the best available science? What forces of global change shaped these two disasters, and what impact will these forces have in the years to come?

Because these questions are so important, today I am recommending the Senate ask the U.S. National Academy of Sciences to examine them. Specifically, I recommend the Senate ask the US National Academy of Sciences to conduct a major new study on extreme weather events, including hurricanes, droughts and floods. The report would assess the state of scientific knowledge in several areas, including (i) our ability to predict extreme weather events and how that ability might be improved, (ii) the causes of extreme weather events, both natural and anthropogenic, (iii) land restoration in the Mississippi Delta, both as part of the response to Katrina and to protect against future storms, and (iv) human health and other risks related to the clean-up of toxic chemicals released as a result of Katrina. This study should be done in phases, with an early product intended to help guide immediate recovery efforts in the Gulf Coast region, and then an ongoing and more comprehensive program.

Today I will touch briefly on several questions raised by the Katrina and Rita, and then on questions of science and environmental policy more broadly.

1. KATRINA, RITA AND SOUND SCIENCE

Sound science should guide all government policy, including in particular matters as consequential as our response to Katrina and Rita. Among the areas that require priority attention are:

A. Improving our ability to predict extreme weather events

More than 100 years ago, on September 8, 1900, a Category 4 hurricane blasted into Galveston, Texas. In an era before satellites, airplanes or modern communications, the population had scant information about the fury arriving over warm Gulf waters. Eight thousand people lost their lives.

Today we take for granted our ability to watch storm clouds gather from satellite photos beamed to our living rooms. We expect government agencies to provide advance warning of impending danger. But we should not be satisfied with our current predictive powers. Rapidly improving information and communications technologies can steadily improve these powers, preventing property damage and saving lives. New data on ocean currents, for example, may help us predict weather patterns and even project the paths of hurricanes with greater confidence than today.

Nor should our quest be limited to hurricanes. This summer, new heat records were set in more than 200 United States cities. Drought has been a chronic problem for several years in the American West. In 2004, more than 1700 tornadoes struck the United States, by far the most ever recorded in a single year.

Much more work is needed to develop the capacity to predict such events and better understand the forces causing them. Generations hence, our current abilities to predict extreme weather may seem as quaint and outmoded as those from 1900 do today.

B. Land Restoration in the Mississippi Delta

Wetlands have been called nature's "speed bumps," protecting coastal cities and from waves and storm surges. But Louisiana's wetlands have been receding for decades, largely because levees on the Mississippi River send silt-rich waters away from marshlands and directly out to sea. No restoration program can succeed without strengthening the natural buffer that protects New Orleans and other parts of Louisiana from the next hurricane.

Although a regional plan called Coastal 2050 was developed several years ago, new work is needed to understand the implications of Katrina and Rita on the strategies developed and critically—to set priorities. Furthermore, questions of first impression concerning land restoration will be raised in the process of rebuilding New

Orleans. Can enough fill be found to raise the level of whole neighborhoods? Would such fill be stable and safe? These questions require the expertise of a team of national and international experts from diverse disciplines.

C. Toxic Clean-Up

The clean-up challenge in New Orleans is unprecedented. Experts have advised residents to exercise extreme caution in returning to flooded homes, in part because of contaminants that may have settled out of still waters. E coli and fecal coliform are the best understood, but other contaminants may also threaten health and safety. At one site within New Orleans, a Superfund site was covered in several feet of water and may have leached toxic chemicals. Oil spills throughout the region rival the Exxon Valdez oil spill in total volume.

The clean-up will involve not just extraordinary resources, but difficult choices. Decisions will need to be made about steps to protect human health and safety, to restore damaged ecosystems and to re-open and rebuild parts of Louisiana's devastated sea food industry. These decisions must be informed by the best available science. Current resources within the federal and state environmental protection agencies are insufficient and should be supplemented with outside expertise.

D. Responsibly Addressing Global Warming

Today, there is ample evidence that heat-trapping gases from human activities may produce more powerful hurricanes. We should proceed responsibly with respect to this risk, steadily improving our knowledge and shaping smart policies in response.

Much is already known on this topic. Heat-trapping gases from human activities-mainly the burning of fossil fuels—are warming both the atmosphere and oceans. As sea surface temperatures rise, average hurricane strength is predicted to increase as well. These predictions are consistent with observations from the historical record. During the past 30 years, as the total number of hurricanes globally has remained roughly constant, the percentage of Category 4 and 5 storms has nearly doubled. In our hemisphere, during this period, peak wind speeds of hurricanes have increased by roughly 50 percent.

As several observers have noted, we are starting to play with loaded dice. There is no way to determine whether any single hurricane is or is not the result of global warming, but as heat-trapping gases build in our atmosphere, the average hurricane will become more intense.

These observations are especially troubling because, according to many experts, Atlantic hurricanes will likely be more frequent in the years ahead as a result of natural cycles. Hurricanes in our hemisphere appear to fluctuate on a multi-decadal basis-they were more frequent during the 1950's and 1960's, dropped from the early 1970's through mid-1990's, and have climbed in number since then.

Thus, in the years ahead the United States faces a double threat—more frequent hurricanes due to natural cycles and more intense hurricanes due to human activities. This is a risk we ignore at our peril.

Today, there are no federal controls on the major heat-trapping gases, although the Senate supported such controls in a resolution this summer. As the Senate considers how best to translate this resolution into legislation, it should be informed by the best available scientific evidence concerning risks from extreme weather events and global warming.

2. Recent Developments in the Role of Science in Federal Environmental Policy

Sound science is central to wise environmental policymaking. Our major environmental statutes all contemplate expert scientific and technical analyses as the prerequisite for federal government action. That analysis must be objective and unbiased. As the chair of this committee, Senator James Inhofe, has said: "Scientific inquiry cannot be censored-scientific debate must be open, must be unbiased and it must stress facts rather than political agendas."

Unfortunately, the past few years have not been a happy time for the role of science in federal environmental policy. Last year, 48 Nobel laureates and 62 National Medal of Science recipients were among the more than 4,000 scientists who signed a statement expressing concern about the "manipulation of the process through which science enters into [the Federal Government's] decisions." Among the specific matters noted in the scientists' statement were several relating to environmental policy.

The specific concerns expressed by these scientists and others include:

a. The suppression or distortion of scientific conclusions from federal environmental agencies. In 2003, for example, the White House insisted on changes to the climate change sections of an EPA report. Because its scientists considered the proposed changes scientifically indefensible, EPA eliminated the discussion of climate

change from its overall report. Similarly, the New York Times reported recently on extensive edits to an EPA document concerning the science of climate change by a White House political aide.

b. Political manipulation of expert advisory committees. For example, substantial concerns have been expressed about adjustments to the composition of the CDC Advisory Committee on Childhood Lead Poisoning during 2002. Experts recommended by CDC staff were rejected and replaced with individuals characterized by their opposition to tighter federal standards, some of whom may have had financial ties to the lead industry.

These are issues of great consequence. Sound policymaking cannot proceed in the face of such concerns. These issues demand priority attention from this committee and the Senate as a whole.

One approach is suggested by the Restore Scientific Integrity to Federal Research and Policy Making Act, introduced in the House as H.R. 839. Among other things, the Act would

Help prevent the manipulation of data;

Strengthen the independence of federal science advisory committees; and

Require an annual report to Congress by the Director of the Office of Science and Technology Policy on the state of Federal scientific integrity.

This legislation would help to address many of the most serious concerns that have arisen in recent years and is worthy of consideration by this body as well.

Thank you for the opportunity to address the committee. I would be pleased to answer any questions.

STATEMENT OF JAMES HANSEN, DIRECTOR, COLUMBIA UNIVERSITY EARTH INSTITUTE AND GODDARD INSTITUTE FOR SPACE STUDIES

Michael Crichton's latest fictional novel, "State of Fear", designed to discredit concerns about global warming, purports to use the scientific method. The book is sprinkled with references to scientific papers, and Crichton intones in the introduction that his "footnotes are real". But does Crichton really use the scientific method? Or is it something closer to scientific fraud?

I have not read Crichton's book, but several people have pointed out to me that Crichton takes aim at my 1988 congressional testimony and claims that I made predictions about global warming that turned out to be 300 percent too high. Is that right?

In my testimony in 1988, and in an attached scientific paper written with several colleagues at the Goddard Institute for Space Studies (GISS) and published later that year in the Journal of Geophysical Research (volume 93, pages 9341-9364), I described climate simulations made with the GISS climate model. We considered three scenarios for the future, labeled A, B and C, to bracket likely possibilities.

Scenario A was described as "on the high side of reality", because it assumed rapid exponential growth of greenhouse gases and it assumed that there would be no large volcanoes (which inject small particles into the stratosphere and cool the Earth) during the next half century. Scenario C was described as "a more drastic curtailment of emissions than has generally been imagined", specifically greenhouse gases were assumed to stop increasing after 2000. The intermediate Scenario B was described as "the most plausible". Scenario B had continued growth of greenhouse gas emissions at a moderate rate and it sprinkled three large volcanoes in the 50-year period after 1988, one of them in the 1990s.

Not surprisingly, the real world has followed a course closest to that of Scenario B. The real world even had one large volcano in the 1990s, the eruption of Mount Pinatubo, which occurred in 1991, while Scenario B placed a volcano in 1995.

In my testimony to congress I showed one line graph with scenarios A, B, C and observed global temperature, which I update below. However, all of the maps of simulated future temperature that I showed in my congressional testimony were for scenario B, which formed the basis for my testimony. No results were shown for the outlier scenarios A and C.

Back to Crichton: how did he conclude that I made an error of 300 percent? Apparently, rather than studying the scientific literature, as his footnotes would imply, his approach was to listen to "global warming skeptics". One of the skeptics, Pat Michaels, has taken the graph from our 1988 paper with simulated global temperatures for scenarios A, B and C, erased the results for scenarios B and C, and shown only the curve for scenario A in public presentations, pretending that it was my prediction for climate change. Is this treading close to scientific fraud?

Crichton's approach is worse than that of Michaels. Crichton uncritically accepts Michaels' results, and then concludes that Hansen's prediction was in error "300 percent". Where does he get this conclusion?

Let's reproduce here (Figure 1) the global temperature curves from my 1988 congressional testimony, without erasing the results for scenarios B and C. Figure 1 updates observations of global temperature using the same analysis of meteorological station data as in our 1988 paper (which removes or corrects station data from urban locations)[1]. The 2005 data point is a preliminary estimate based on the first eight months of the year.

The observations, the black curve in Figure 1, show that the Earth is indeed getting warmer, as predicted. The observed temperature fluctuates a lot, because the real world is a "noisy", chaotic system, but there is a clear warming trend. Curiously, the scenario that we described as most realistic is so far turning out to be almost dead on the money. Such close agreement is fortuitous. For example, the model used in 1988 had a sensitivity of 4.2° C for doubled CO_2, but our best estimate for true climate sensitivity[2] is closer to 3° C for doubled CO_2. There are various other uncertain factors that can make the warming larger or smaller[3]. But it is becoming clear that our prediction was in the right ballpark.

So how did Crichton conclude that our prediction was in error 300 percent? Beats me. Crichton writes fiction and seems to make up things as he goes along. He doesn't seem to have the foggiest notion about the science that he writes about. Perhaps that is o.k. for a science fiction writer[4].

However, I recently heard that, in considering the global warming issue, a United States Senator is treating words from Crichton as if they had scientific or practical validity. If so, wow—Houston, we have a problem!

Acknowledgement. I thank Makiko Sato for reproducing and updating the figure.

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[1]The warming is slightly less (change less than 0.1° C) in our analysis of observations if we combine ocean temperature measurements with the meteorological station data. However, the result is slightly more warming in the British analysis of observations by Phil Jones and associates. So the observational analysis shown in Figure 1 is representative of the various analyses of global surface temperature change.

[2]Climate sensitivity is usually expressed as the equilibrium global warming expected to result from doubling the amount of CO_2 in the air. Empirical evidence from the Earth's history indicates that climate sensitivity is about 3° C, with an uncertainty of about 1° C. A climate model yields its own sensitivity, based on the best physics that the users can incorporate at any given time. The 1988 GISS model sensitivity was 4.2° C, while it is 2.7° C for the 2005. It is suspected that the sensitivity of the 2005 model may be slightly too small because of the sea ice formulation being too stable.

[3]Our papers related to global warming can be obtained from pubs.giss.nasa.gov

[4]Discussion of Crichton's science fiction is provided on the blog

Figure & Figure Caption

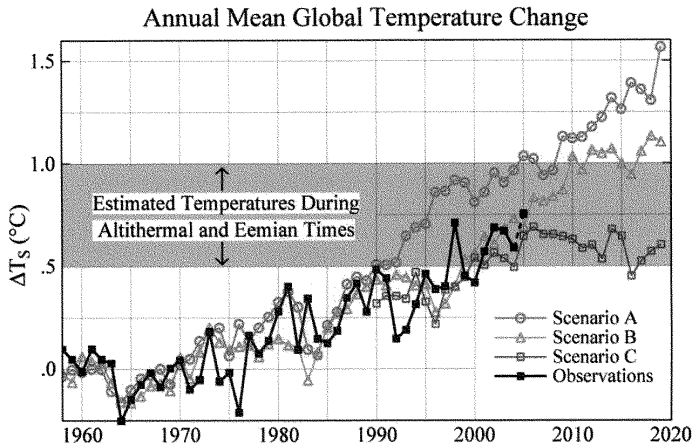

Figure 1. Annual-mean global surface air temperature computed for scenarios A, B and C. Observational data are an update of the analysis of Hansen and Lebedeff [J. Geophys. Res., 92, 13,345, 1987]. Shaded area is an estimate of the global temperature during the peak of the current interglacial period (the Altithermal, peaking about 6,000 to 10,000 years ago, when we estimate that global temperature was in the lower part of the shaded area) and the prior interglacial period (the Eemian period, about 120,000 years ago, when we estimate that global temperature probably peaked near the upper part of the shaded area). The temperature zero point is the 1951-1980 mean.

STATEMENT OF RALPH J. CICERONE, PH.D. PRESIDENT, NATIONAL ACADEMY OF SCIENCES, THE NATIONAL ACADEMIES

Good morning, Mr. Chairman and members of the Committee. My name is Ralph Cicerone, and I am President of the National Academy of Sciences. Prior to this position, I served as Chancellor of the University of California at Irvine, where I also held the Daniel G. Aldrich Chair in Earth System Science. In addition, in 2001 I chaired the National Academies Committee that wrote the report, Climate Change Science: An Analysis of Some Key Questions, at the request of the White House.

This morning I will summarize briefly the current state of scientific understanding on climate change, based largely on the findings and recommendations in recent National Academies' reports. These reports are the products of a study process that brings together leading scientists, engineers, public health officials and other experts to provide consensus advice to the nation on specific scientific and technical questions.

The Earth is warming. Weather station records and ship-based observations indicate that global mean surface air temperature increased about 0.7° F (0.4° C) since the early 1970's (See Figure). Although the magnitude of warming varies locally, the warming trend is spatially widespread and is consistent with an array of other evidence (including melting glaciers and ice caps, sea level rise, extended growing seasons, and changes in the geographical distributions of plant and animal species). The ocean, which represents the largest reservoir of heat in the climate system, has warmed by about 0.12° F (0.06° C) averaged over the layer extending from the surface down to 750 feet, since 1993. Recent studies have shown that the observed heat storage in the oceans is consistent with expected impacts of a human-enhanced greenhouse effect.

The observed warming has not proceeded at a uniform rate. Virtually all the 20th century warming in global surface air temperature occurred between the early 1900s and the 1940s and from the 1970s until today, with a slight cooling of the Northern Hemisphere during the interim decades. The causes of these irregularities and the disparities in the timing are not completely understood, but the warming trend in global-average surface temperature observations during the past 30 years

is undoubtedly real and is substantially greater than the average rate of warming during the twentieth century.

Laboratory measurements of gases trapped in dated ice cores have shown that for hundreds of thousands of years, changes in temperature have closely tracked atmospheric carbon dioxide concentrations. Burning fossil fuel for energy, industrial processes, and transportation releases carbon dioxide to the atmosphere. Carbon dioxide in the atmosphere is now at its highest level in 400,000 years and continues to rise.

Nearly all climate scientists today believe that much of Earth's current warming has been caused by increases in the amount of greenhouse gases in the atmosphere, mostly from the burning of fossil fuels. The degree of confidence in this conclusion is higher today than it was 10, or even 5 years ago, but uncertainties remain. As stated in the Academies 2001 report, "the changes observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these changes is also a reflection of natural variability."

One area of debate has been the extent to which variations in the Sun might contribute to recent observed warming trends. The Sun's total brightness has been measured by a series of satellite-based instruments for more than two complete 11-year solar cycles. Recent analyses of these measurements argue against any detectable long-term trend in the observed brightness to date. Thus, it is difficult to conclude that the Sun has been responsible for the warming observed over the past 25 years.

Carbon dioxide can remain in the atmosphere for many decades and major parts of the climate system respond slowly to changes in greenhouse gas concentrations. The slow response of the climate system to increasing greenhouse gases also means that changes and impacts will continue during the twenty-first century and beyond, even if emissions were to be stabilized or reduced in the near future.

Simulations of future climate change project that, by 2100, global surface temperatures will be from 2.5 to 10.4° F (1.4 to 15.8° C) above 1990 levels. Similar projections of temperature increases, based on rough calculations and nascent theory, were made in the Academies first report on climate change published in the late 1970s. Since then, significant advances in our knowledge of the climate system and our ability to model and observe it have yielded consistent estimates. Pinpointing the magnitude of future warming is hindered both by remaining gaps in understanding the science and by the fact that it is difficult to predict society's future actions, particularly in the areas of population growth, economic growth, and energy use practices.

Other scientific uncertainties about future climate change relate to the regional effects of climate change and how climate change will affect the frequency and severity of weather events. Although scientists are starting to forecast regional weather impacts, the level of confidence is less than it is for global climate projections. In general, temperature is easier to predict than changes such as rainfall, storm patterns, and ecosystem impacts.

It is important to recognize however, that while future climate change and its impacts are inherently uncertain, they are far from unknown. The combined effects of ice melting and sea water expansion from ocean warming will likely cause the global average sea-level to rise by between 0.1 and 0.9 meters between 1990 and 2100. In colder climates, such warming could bring longer growing seasons and less severe winters. Those in coastal communities, many in developing nations, will experience increased flooding due to sea level rise and are likely to experience more severe storms and surges. In the Arctic regions, where temperatures have risen more than the global average, the landscape and ecosystems are being altered rapidly.

The task of mitigating and preparing for the impacts of climate change will require worldwide collaborative inputs from a wide range of experts, including natural scientists, engineers, social scientists, medical scientists, those in government at all levels, business leaders and economists. Although the scientific understanding of climate change has advanced significantly in the last several decades, there are still many unanswered questions. Society faces increasing pressure to decide how best to respond to climate change and associated global changes, and applied research in direct support of decision making is needed.

My written testimony describes the current state of scientific understanding of climate change in more detail, based largely on important findings and recommendations from a number of recent National Academies' reports.

THE EARTH IS WARMING

The most striking evidence of a global warming trend are closely scrutinized data that show a relatively rapid increase in temperature, particularly over the past 30 years. Weather station records and ship-based observations indicate that global

mean surface air temperature increased about 0.7° F (0.4° C) since the early 1970's (See Figure). Although the magnitude of warming varies locally, the warming trend is spatially widespread and is consistent with an array of other evidence (e.g., melting glaciers and ice caps, sea level rise, extended growing seasons, and changes in the geographical distributions of plant and animal species).

Global annual-mean surface air temperature change derived from the meteorological station network. Data and plots available from the Goddard Institute for Space Sciences (GISS) at http://data.giss.nasa.gov/gistemp/graphs/.

The ocean, which represents the largest reservoir of heat in the climate system, has warmed by about 0.12° F (0.06° C) averaged over the layer extending from the surface down to 750 feet, since 1993. Recent studies have shown that the observed heat storage in the oceans is what would be expected by a human-enhanced greenhouse effect. Indeed, increased ocean heat content accounts for most of the planetary energy imbalance (i.e., when the Earth absorbs more energy from the Sun than it emits back to space) simulated by climate models with mid-range climate sensitivity.

The observed warming has not proceeded at a uniform rate. Virtually all the 20th century warming in global surface air temperature occurred between the early 1900s and the 1940s and since the 1970s, with a slight cooling of the Northern Hemisphere during the interim decades. The troposphere warmed much more during the 1970s than during the two subsequent decades, whereas Earth's surface warmed more during the past two decades than during the 1970s. The causes of these irregularities and the disparities in the timing are not completely understood.

A National Academies report released in 2000, Reconciling Observations of Global Temperature Change, examined different types of temperature measurements collected from 1979 to 1999 and concluded that the warming trend in global-average surface temperature observations during the previous 20 years is undoubtedly real and is substantially greater than the average rate of warming during the twentieth century. The report concludes that the lower atmosphere actually may have warmed much less rapidly than the surface from 1979 into the late 1990s, due both to natural causes (e.g., the sequence of volcanic eruptions that occurred within this particular 20-year period) and human activities (e.g., the cooling of the upper part of the troposphere resulting from ozone depletion in the stratosphere). The report spurred many research groups to do similar analyses. Satellite observations of middle troposphere temperatures, after several revisions of the data, now compare reasonably with observations from surface stations and radiosondes, although some uncertainties remain.

HUMANS HAVE HAD AN IMPACT ON CLIMATE

Laboratory measurements of gases trapped in dated ice cores have shown that for hundreds of thousands of years, changes in temperature have closely tracked with atmospheric carbon dioxide concentrations. Burning fossil fuel for energy, industrial processes, and transportation releases carbon dioxide to the atmosphere. Carbon dioxide in the atmosphere is now at its highest level in 400,000 years and continues to rise. Nearly all climate scientists today believe that much of Earth's current warming has been caused by increases in the amount of greenhouse gases in the atmosphere. The degree of confidence in this conclusion is higher today than it was 10, or even 5 years ago, but uncertainties remain. As stated in the Academies 2001 report, "the changes observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these changes is also a reflection of natural variability."

Carbon dioxide can remain in the atmosphere for many decades and major parts of the climate system respond slowly to changes in greenhouse gas concentrations. The slow response of the climate system to increasing greenhouse gases also means that changes and impacts will continue during the twenty-first century and beyond, even if emissions were to be stabilized or reduced in the near future.

In order to compare the contributions of the various agents that affect surface temperature, scientists have devised the concept of "radiative forcing." Radiative forcing is the change in the balance between radiation (i.e., heat and energy) entering the atmosphere and radiation going back out. Positive radiative forcings (e.g., due to excess greenhouse gases) tend on average to warm the Earth, and negative radiative forcings (e.g., due to volcanic eruptions and many human-produced aerosols) on average tend to cool the Earth. The Academies recent report, Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties (2005), takes a close look at how climate has been changed by a range of forcings. A key message from the report is that it is important to quantify how human and natural processes cause changes in climate variables other than temperature. For

example, climate-driven changes in precipitation in certain regions could have significant impacts on water availability for agriculture, residential and industrial use, and recreation. Such regional impacts will be much more noticeable than projected changes in global average temperature of a degree or more.

One area of debate has been the extent to which variations in the Sun might contribute to recent observed warming trends. Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties (2005) also summarizes current understanding about this issue. The Sun's brightness—its total irradiance—has been measured continuously by a series of satellite-based instruments for more than two complete 11-year solar cycles. These multiple solar irradiance datasets have been combined into a composite time series of daily total solar irradiance from 1979 to the present. Different assumptions about radiometer performance lead to different reconstructions for the past two decades. Recent analyses of these measurements, taking into account instrument calibration offsets and drifts, argue against any detectable long-term trend in the observed irradiance to date. Likewise, models of total solar irradiance variability that account for the influences of solar activity features—dark sunspots and bright faculae—do not predict a secular change in the past two decades. Thus, it is difficult to conclude from either measurements or models that the Sun has been responsible for the warming observed over the past 25 years.

Knowledge of solar irradiance variations is rudimentary prior to the commencement of continuous space-based irradiance observations in 1979. Models of sunspot and facular influences developed from the contemporary database have been used to extrapolate daily variations during the 11-year cycle back to about 1950 using contemporary sunspot and facular proxies, and with less certainty annually to 1610. Circumstantial evidence from cosmogenic isotope proxies of solar activity (14C and 10Be) and plausible variations in Sun-like stars motivated an assumption of long-term secular irradiance trends, but recent work questions the evidence from both. Very recent studies of the long term evolution and transport of activity features using solar models suggest that secular solar irradiance variations may be limited in amplitude to about half the amplitude of the 11-year cycle.

WARMING WILL CONTINUE, BUT ITS IMPACTS ARE DIFFICULT TO PROJECT

The Intergovernmental Panel on Climate Change (IPCC), which involves hundreds of scientists in assessing the state of climate change science, has estimated that, by 2100, global surface temperatures will be from 2.5 to 10.4° F (1.4 to 5.8° C) above 1990 levels. Similar projections of temperature increases, based on rough calculations and nascent theory, were made in the Academies first report on climate change published in the late 1970s. Since then, significant advances in our knowledge of the climate system and our ability to model and observe it have yielded consistent estimates. Pinpointing the magnitude of future warming is hindered both by remaining gaps in understanding the science and by the fact that it is difficult to predict society's future actions, particularly in the areas of population growth, economic growth, and energy use practices.

One of the major scientific uncertainties is how climate could be affected by what are known as "climate feedbacks." Feedbacks can either amplify or dampen the climate response to an initial radiative forcing. During a feedback process, a change in one variable, such as carbon dioxide concentration, causes a change in temperature, which then causes a change in a third variable, such as water vapor, which in turn causes a further change in temperature. Understanding Climate Change Feedbacks (2003) looks at what is known and not known about climate change feedbacks and identifies important research avenues for improving our understanding.

Other scientific uncertainties relate to the regional effects of climate change and how climate change will affect the frequency and severity of weather events. Although scientists are starting to forecast regional weather impacts, the level of confidence is less than it is for global climate projections. In general, temperature is easier to predict than changes such as rainfall, storm patterns, and ecosystem impacts. It is very likely that increasing global temperatures will lead to higher maximum temperatures and fewer cold days over most land areas. Some scientists believe that heat waves such as those experienced in Chicago and central Europe in recent years will continue and possibly worsen. The larger and faster the changes in climate, the more difficult it will be for human and natural systems to adapt without adverse effects.

There is evidence that the climate has sometimes changed abruptly in the past—within a decade—and could do so again. Abrupt changes, for example the Dust Bowl drought of the 1930's displaced hundreds of thousands of people in the American

Great Plains, take place so rapidly that humans and ecosystems have difficulty adapting to it. Abrupt Climate Change: Inevitable Surprises (2002) outlines some of the evidence for and theories of abrupt change. One theory is that melting ice caps could "freshen" the water in the North Atlantic, shutting down the natural ocean circulation that brings warmer Gulf Stream waters to the north and cooler waters south again. This shutdown could make it much cooler in Northern Europe and warmer near the equator.

It is important to recognize that while future climate change and its impacts are inherently uncertain, they are far from unknown. The combined effects of ice melting and sea water expansion from ocean warming will likely cause the global average sea-level to rise by between 0.1 and 0.9 meters between 1990 and 2100. In colder climates, such warming could bring longer growing seasons and less severe winters. Those in coastal communities, many in developing nations, will experience increased flooding due to sea level rise and are likely to experience more severe storms and surges. In the Arctic regions, where temperatures have risen almost twice as much as the global average, the landscape and ecosystems are being altered rapidly.

OBSERVATIONS AND DATA ARE THE FOUNDATION OF CLIMATE CHANGE SCIENCE

There is nothing more valuable to scientists than the measurements and observations required to confirm or contradict hypotheses. In climate sciences, there is a peculiar relation between the scientist and the data. Whereas other scientific disciplines can run multiple, controlled experiments, climate scientists must rely on the one realization that nature provides. Climate change research requires observations of numerous characteristics of the Earth system over long periods of time on a global basis. Climate scientists must rely on data collected by a whole suite of observing systems—from satellites to surface stations to ocean buoys—operated by various government agencies and countries as well as climate records from ice cores, tree rings, corals, and sediments that help reconstruct past change.

COLLECTING AND ARCHIVING DATA TO MEET THE UNIQUE NEEDS OF CLIMATE CHANGE SCIENCE

Most of the instrumentation and observing systems used to monitor climate today were established to provide data for other purposes, such as predicting daily weather; advising farmers; warning of hurricanes, tornadoes and floods; managing water resources; aiding ocean and air transportation; and understanding the ocean. However, collecting climate data is unique because higher precision is often needed in order to detect climate trends, the observing programs need to be sustained indefinitely and accommodate changes in observing technology, and observations are needed at both global scales and at local scales to serve a range of climate information users.

Every report on climate change produced by the National Academies in recent years has recommended improvements to climate observing capabilities. A central theme of the report Adequacy of Climate Observing Systems (1999) is the need to dramatically upgrade our climate observing capabilities. The report presents ten climate monitoring principles that continue to be the basis for designing climate observing systems, including management of network change, careful calibration, continuity of data collection, and documentation to ensure that meaningful trends can be derived.

Another key concept for climate change science is the ability to generate, analyze, and archive long-term climate data records (CDRs) for assessing the state of the environment in perpetuity. In Climate Data Records from Environmental Satellites (2004), a climate data record is defined as a time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change. The report identifies several elements of successful climate data record generation programs, ranging from effective, expert leadership to long-term commitment to sustaining the observations and archives.

INTEGRATING KNOWLEDGE AND DATA ON CLIMATE CHANGE THROUGH MODELS

An important concept that emerged from early climate science in the 1980s was that Earth's climate is not just a collection of long-term weather statistics, but rather the complex interactions or "couplings" of the atmosphere, the ocean, the land, and plant and animal life. Climate models are built using our best scientific knowledge, first modeling each process component separately and then linking them together to simulate these couplings.

Climate models are important tools for understanding how the climate operates today, how it may have functioned differently in the past, and how it may evolve

in the future in response to forcings from both natural processes and human activities. Climate scientists can deal with uncertainty about future climate by running models with different assumptions of future population growth, economic development, energy use, and policy choices, such as those that affect air quality or influence how nations share technology. Models then offer a range of outcomes based on these different assumptions.

MODELING CAPABILITY AND ACCURACY

Since the first climate models were pioneered in the 1970s, the accuracy of models has improved as the number and quality of observations and data have increased, as computational abilities have multiplied, and as our theoretical understanding of the climate system has improved. Whereas early attempts at modeling used relatively crude representations of the climate, today's models have very sophisticated and carefully tested treatment of hundreds of climate processes.

The National Academies' report Improving Effectiveness of U.S. Climate Modeling (2001) offers several recommendations for strengthening climate modeling capabilities, some of which have already been adopted in the United States. At the time the report was published, U.S. modeling capabilities were lagging behind some other countries. The report identified a shortfall in computing facilities and highly skilled technical workers devoted to climate modeling. Federal agencies have begun to centralize their support for climate modeling efforts at the National Center for Atmospheric Research and the Geophysical Fluid Dynamics Laboratory. However, the U.S. could still improve the amount of resources it puts toward climate modeling as recommended in Planning Climate and Global Change Research (2003).

CLIMATE CHANGE IMPACTS WILL BE UNEVEN

There will be winners and losers from the impacts of climate change, even within a single region, but globally the losses are expected to outweigh the benefits. The regions that will be most severely affected are often the regions that are the least able to adapt. For example, Bangladesh, one of the poorest nations in the world, is projected to lose 17.5% of its land if sea level rises about 40 inches (1 m), displacing tens of thousands of people. Several islands throughout the South Pacific and Indian Oceans will be at similar risk of increased flooding and vulnerability to storm surges. Coastal flooding likely will threaten animals, plants, and fresh water supplies. Tourism and local agriculture could be severely challenged.

Wetland and coastal areas of many developed nations including United States are also threatened. For example, parts of New Orleans are as much as eight feet below sea level today. However, wealthy countries are much more able to adapt to sea level rise and threats to agriculture. Solutions could include building, limiting or changing construction codes in coastal zones, and developing new agricultural technologies.

The Arctic has warmed at a faster rate than the Northern Hemisphere over the past century. A Vision for the International Polar Year 2007-2008 (2004) reports that this warming is associated with a number of impacts including: melting of sea ice, which has important impacts on biological systems such as polar bears, ice-dependent seals, and local people for whom these animals are a source of food; increased snow and rainfall, leading to changes in river discharge and tundra vegetation; and degradation of the permafrost.

PREPARING FOR CLIMATE CHANGE

One way to begin preparing for climate change is to make the wealth of climate data and information already collected more accessible to a range of users who could apply it to inform their decisions. Such efforts, often called "climate services," are analogous to the efforts of the National Weather Service to provide useful weather information. Climate is becoming increasingly important to public and private decision making in various fields such as emergency management planning, water quality, insurance premiums, irrigation and power production decisions, and construction schedules. A Climate Services Vision (2001) outlines principles for improving climate services that include making climate data as user-friendly as weather services are today, and active and well-defined connections among the Government agencies, businesses, and universities involved in climate change data collection and research.

Another avenue would be to develop practical strategies that could be used to reduce economic and ecological systems' vulnerabilities to change. Such "no-regrets" strategies, recommended in Abrupt Climate Change: Inevitable Surprises (2002), provide benefits whether a significant climate change ultimately occurs or not, potentially reducing vulnerability at little or no net cost. No-regrets measures could

include low-cost steps to: improve climate forecasting; slow biodiversity loss; improve water, land, and air quality; and make institutions—such as the health care enterprise, financial markets, and transportation systems—more resilient to major disruptions.

REDUCING THE CAUSES OF CLIMATE CHANGE

The climate change statement issued in June 2005 by 11 science academies, including the National Academy of Sciences, stated that despite remaining unanswered questions, the scientific understanding of climate change is now sufficiently clear to justify nations taking cost-effective steps that will contribute to substantial and long-term reduction in net global greenhouse gas emissions. Because carbon dioxide and some other greenhouse gases can remain in the atmosphere for many decades and major parts of the climate system respond slowly to changes in greenhouse gas concentrations, climate change impacts will likely continue throughout the 21st century and beyond. Failure to implement significant reductions in net greenhouse gas emissions now will make the job much harder in the future—both in terms of stabilizing their atmospheric abundances and in terms of experiencing more significant impacts. At the present time there is no single solution that can eliminate future warming. As early as 1992 Policy Implications of Greenhouse Warming found that there are many potentially cost-effective technological options that could contribute to stabilizing greenhouse gas concentrations.

MEETING ENERGY NEEDS IS A MAJOR CHALLENGE TO SLOWING CLIMATE CHANGE

Energy—either in the form of fuels used directly (i.e., gasoline) or as electricity produced using various fuels (fossil fuels as well as nuclear, solar, wind, and others)—is essential for all sectors of the economy, including industry, commerce, homes, and transportation. Energy use worldwide continues to grow with economic and population growth. Developing countries, China and India in particular, are rapidly increasing their use of energy, primarily from fossil fuels, and consequently their emissions of CO_2. Carbon emissions from energy can be reduced by using it more efficiently or by switching to alternative fuels. It also may be possible to capture carbon emissions from electric generating plants and then sequester them.

Energy efficiency in all sectors of the U.S. economy could be improved. The 2002 National Academies' report, Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards, evaluates car and light truck fuel use and analyzes how fuel economy could be improved. Steps range from improved engine lubrication to hybrid vehicles. The 2001 Academies report, Energy Research at DOE, Was It Worth It? addresses the benefits of increasing the energy efficiency of lighting, refrigerators and other appliances. Many of these improvements (e.g., high-efficiency refrigerators) are cost-effective means to significantly reducing energy use, but are being held back by market constraints such as consumer awareness, higher initial costs, or by the lack of effective policy.

Electricity can be produced without significant carbon emissions using nuclear power and renewable energy technologies (e.g., solar, wind, and biomass). In the United States, these technologies are too expensive or have environmental or other concerns that limit broad application, but that could change with technology development or if the costs of fossil fuels increase. Replacing coal-fired electric power plants with more efficient, modern natural-gas-fired turbines would reduce carbon emissions per unit of electricity produced.

Several technologies are being explored that would collect CO_2 that would otherwise be emitted to the atmosphere from fossil-fuel-fired power plants, and then sequester it in the ground or the ocean. Successful, cost-effective sequestration technologies would weaken the link between fossil fuels and greenhouse gas emissions. The 2003 National Academies' report, Novel Approaches to Carbon Management: Separation, Capture, Sequestration, and Conversion to Useful Products, discusses the development of this technology. Capturing CO_2 emissions from the tailpipes of vehicles is essentially impossible, which is one factor that has led to considerable interest in hydrogen as a fuel. As with electricity, hydrogen must be manufactured from primary energy sources. Significantly reducing carbon emissions when producing hydrogen from fossil fuels (currently the least expensive method) would require carbon capture and sequestration. Substantial technological and economic barriers in all phases of the hydrogen fuel cycle must first be addressed through research and development. The 2004 National Academies' report, The Hydrogen Economy: Opportunities, Costs, Barriers and R&D Needs, presents a strategy that could lead eventually to production of hydrogen from a variety of domestic sources—such as coal (with carbon sequestration), nuclear power, wind, or photo-biological processes—and efficient use in fuel cell vehicles.

CONTINUED SCIENTIFIC EFFORTS TO ADDRESS A CHANGING CLIMATE

The task of mitigating and preparing for the impacts of climate change will require worldwide collaborative inputs from a wide range of experts, including natural scientists, engineers, social scientists, medical scientists, those in government at all levels, business leaders, and economists. Although the scientific understanding of climate change has advanced significantly in the last several decades, there are still many unanswered questions. Society faces increasing pressure to decide how best to respond to climate change and associated global changes, and applied research in direct support of decision making is needed.

NATIONAL ACADEMIES' REPORTS CITED IN THE TESTIMONY

Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties (2005)
Climate Data Records from Environmental Satellites (2004)
Implementing Climate and Global Change Research (2004)
A Vision for the International Polar Year 2007-2008 (2004)
The Hydrogen Economy: Opportunities, Costs, Barriers and R&D Needs (2004)
Understanding Climate Change Feedbacks (2003) Planning Climate and Global Change Research (2003)
Novel Approaches to Carbon Management: Separation, Capture, Sequestration, and Conversion to Useful Products (2003)
Abrupt Climate Change: Inevitable Surprises (2002)
Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards (2002)
Climate Change Science: An Analysis of Some Key Questions (2001)
Improving the Effectiveness of U.S. Climate Modeling (2001)
A Climate Services Vision: First Steps Towards the Future (2001)
Energy Research at DOE, Was It Worth It? (2001)
Reconciling Observations of Global Temperature Change (2000)
Adequacy of Climate Observing Systems (1999)
Policy Implications of Greenhouse Warming (1992)

NATIONAL ACADEMY OF SCIENCES
THE NATIONAL ACADEMIES

Office of the President

June 9, 2005

The Honorable Larry E. Craig
United States Senator
Hart Senate Office Building
Washington, DC 20510-1203

Dear Senator Craig:

Thank you for your letter of June 8 concerning the statement by eleven science academies on Global Response to Climate Change. I was very dismayed when I read the press release issued by the Royal Society, especially the quote by Dr. Robert May contained in your letter. Their press release does not represent the views of the U.S. National Academy of Sciences, and it was not seen by us in advance of public release. The press release is not an accurate characterization of the eleven academies statement, and it is not an accurate characterization of our 1992 report. I have enclosed a copy of the letter that I sent yesterday to Dr. May, President of the Royal Society, expressing my displeasure with their press release.

The eleven academies statement was carefully prepared, and in our view it is consistent with the findings and recommendations of previous reports issued by our academy that underwent rigorous review. These reports include the Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base (1992) and Climate Change Science: An Analysis of Some Key Questions (2001).

Our hope was that eleven academies statement would be useful to policy makers as they deal with this important issue. Regarding the timing of the statement, the goal of the academies was to have the statement released prior to the G8 summit in July. The participating academies planned for a release in May, but preparation of the statement and securing its approval took longer than anticipated. As soon as the statement was approved by all of the academies, it was released a few days later.

I would be glad to provide any additional information or to answer any remaining questions you may have.

Sincerely,

Bruce Alberts

Bruce Alberts
President

THE NATIONAL ACADEMIES
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June 8, 2005

Bruce Alberts, Ph.D.
President
National Academies of Sciences
2101 Constitution Avenue, N.W.
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Dear Dr. Alberts:

I received a copy of the "Joint Science Academies' Statement: Global Response to Climate Change" yesterday and read it with great interest. I was pleased that the recommendations contained in that Statement mirror actions that our government has taken during the last five years to address the potential threat of climate change and reduce greenhouse gases.

As you know, the United States has committed billions of dollars to mobilize the science and technology community to enhance research and development efforts which will better inform climate change decisions. Indeed, the Administration has initiated a Climate Change Science Program Strategic Plan that the Academy reviewed and endorsed. Moreover, the United States is engaged in extensive international efforts on climate change, both through multilateral and bilateral activities. The United States is by far the largest funder of activities under the United Nations Framework Convention on Climate Change and the Intergovernmental Panel on Climate Change.

So, it was with dismay that I read the attached press release from the Royal Society, attempting to characterize the Joint Statement as a rebuke of U.S. policies on climate change. Statements such as:

> "The current US policy on climate change is misguided. The Bush Administration has consistently refused to accept the advise of the US National Academy of Sciences (NAS).

contained in the press release are offensive and inconsistent with my understanding of the facts. Moreover, the interpretation of the NAS 1992 report on climate change is also contrary to my understanding of that document. Indeed, it appears to me that the Joint Statement is being hijacked by the Royal Society for reasons that have nothing to do with the advancement of scientific understanding of this most complex and controversial subject.

I would appreciate a clarification of the meaning of the Joint Science Academies Statement. I am also interested in the origins of this Statement and am very curious about the timing of the release of this Statement.

Thank you for your prompt attention to this request

Sincerely,

Larry E. Craig
United States Senator

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Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions | fact sheet

Separating Fact from Fiction: Crichton's Thriller *State of Fear*

In 2004, the fiction author Michael Crichton released his latest novel, *State of Fear*. This book depicts characters debating data and concepts that cast doubt on the validity of global warming evidence. Below are some examples where Crichton's fiction does not reflect scientific fact. These examples by no means represent a comprehensive list of the scientific errors in Crichton's novel.

1. How was Crichton able to take the same data that climate scientists use and come to the conclusion that global warming isn't a real threat?

The climate studies Crichton uses, and the way they are presented, seem to make a case against global warming. Scientists with climate expertise, however, have considered not just the narrow sampling of the scientific literature that Crichton cites but many hundreds of additional papers in order to understand the full complexity of the climate system.

The National Academy of Sciences, The American Geophysical Union, The American Meteorological Society, and the Intergovernmental Panel on Climate Change (IPCC) have all issued statements affirming that climate change is underway, the impacts are significant, and humans have influenced recent climate changes. Climate scientists agree on the most basic key points while they continue to refine such questions as the magnitude and rate of climate change.

2. *State of Fear* uses many graphs that don't show a warming trend. How can specific locations show cooling if global warming is happening?

Increases in carbon dioxide (CO2) create an overall warming tendency in the atmosphere. Shifts in clouds, water vapor, and the great currents in the ocean and air, however, cause complex responses in which some regions warm more than the average while others warm less than average – or even cool. Finding a cooling trend in some regions (including the Antarctic interior, which Crichton highlights) is therefore fully compatible with the physics on which climate models are based.

In general, climate trends are often difficult to detect in data from individual stations because each station is subject to local effects. These variations can be reduced by averaging together the data from many stations, which is why climate scientists rely on such averages in detecting the first signs of the effect of CO2 increases on temperature.

3. What is the "urban heat island effect," and is it contributing to warming?

State of Fear characters suggest that the "urban heat island effect" may be responsible not only for heating in cities but also for global warming. They note that many long-term temperature stations are now surrounded by larger cities and could contribute to the warming seen in urban stations. While amplified warming does occur in cities and is an important local phenomenon, cities occupy only a small fraction of the planet compared to the vast area of oceans, ice caps, uninhabited mountains, and rural landscapes. Scientists take measures to adjust for this effect so that the overall temperature trend is not biased.

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Temperature monitoring stations exist around the globe, on both land and sea, and we see a clear warming trend from many locations. The IPCC (2001) stated that urban heat island effects could contribute no more than six percent of the rising average temperature trends in 1990, and a National Academy study of the surface temperature record concluded that the global surface temperature trend accurately reflects warming.

4. Crichton argues that C02 in the atmosphere is not closely correlated with warming trends. So why is C02 blamed as a greenhouse gas?

Over a century ago, scientists researching CO2 discovered that the earth's temperature is very sensitive to small changes in atmospheric CO2. Crichton's novel includes a graph showing the relationship between global average temperatures and atmospheric CO2 levels between 1880 and 2003. This graph shows a broad correlation between temperature and CO2, although some time periods do not match up. A character in the novel asks, "So, if rising carbon dioxide is the cause of rising temperatures, why didn't it cause temperatures to rise from 1940 to 1970?"

The answer is that CO2 is only one of several factors that influence temperature, such as volcanic eruptions, solar variability, sulfur dioxide emissions, and small changes in the earth's orbit. The combined impact of all effects was cooling for those middle decades of the 20th century. When climate scientists look at the entire last century, however, they are unable to explain the significant temperature increases solely from natural causes. Only when the trends for human-induced heat-trapping gases, sulfur dioxide emissions, soot, ozone, and land use changes are also included do the model results and the recorded reality match up. This is particularly true of the pronounced warming that has occurred since 1970.

5. Michael Crichton says we can't predict the future. Does this preclude our taking steps to reduce heat trapping gas emissions?

By way of analogy, the occurrence of large earthquakes is also very difficult to predict. Just because we can't predict when the next big earthquake in California will occur, should we stop building earthquake-resistant buildings? The IPCC projects that global temperatures will increase anywhere from +2.5°F to +10.4°F (+1.4°C to +5.8°C) by century's end. Scientists show a range of temperature changes, rather than a single number, for a couple of different reasons: (i) imperfect knowledge about certain climate processes, such as cloud feedbacks and (ii) different assumptions about how much CO2 and other pollutants people will put into the atmosphere. The results provide a range of possible outcomes for policy makers to evaluate.

Since a large portion of the projected range in temperature increases are based on human actions, the good news is that the future is in our hands. We have the opportunity right now to make choices for the future that will avoid the worst climate change impacts from occurring.

Fully referenced version available at:
www.ucsusa.org/global_warming/science/crichton-thriller-state-of-fear.html

Union of Concerned Scientists Statement on Scientific Integrity

Successful application of science has played a large part in the policies that have made the United States of America the world's most powerful nation and its citizens increasingly prosperous and healthy. Although scientific input to the government is rarely the only factor in public policy decisions, this input should always be weighed from an objective and impartial perspective to avoid perilous consequences. Indeed, this principle has long been adhered to by presidents and administrations of both parties in forming and implementing policies. The administration of George W. Bush has, however, disregarded this principle.

When scientific knowledge has been found to be in conflict with its political goals, the administration has often manipulated the process through which science enters into its decisions. This has been done by placing people who are professionally unqualified or who have clear conflicts of interest in official posts and on scientific advisory committees; by disbanding existing advisory committees; by censoring and suppressing reports by the government's own scientists; and by simply not seeking independent scientific advice. Other administrations have, on occasion, engaged in such practices, but not so systematically nor on so wide a front. Furthermore, in advocating policies that are not scientifically sound, the administration has sometimes misrepresented scientific knowledge and misled the public about the implications of its policies.

For example, in support of the president's decision to avoid regulating emissions that cause climate change, the administration has consistently misrepresented the findings of the National Academy of Sciences, government scientists, and the expert community at large. Thus in June 2003, the White House demanded extensive changes in the treatment of climate change in a major report by the Environmental Protection Agency (EPA). To avoid issuing a scientifically indefensible report, EPA officials eviscerated the discussion of climate change and its consequences.

The administration also suppressed a study by the EPA that found that a bipartisan Senate clean air proposal would yield greater health benefits than the administration's proposed Clear Skies Act, which the administration is portraying as an improvement of the existing Clean Air Act. "Clear Skies" would, however, be less effective in cleaning up the nation's air and reducing mercury contamination of fish than proper enforcement of the existing Clean Air Act.

Misrepresenting and suppressing scientific knowledge for political purposes can have serious consequences. Had Richard Nixon also based his decisions on such calculations he would not have supported the Clean Air Act of 1970, which in the following 20 years prevented more than 200,000 premature deaths and millions of cases of respiratory and cardiovascular disease. Similarly, George H.W. Bush would not have supported the Clean Air Act Amendments of 1990 and additional benefits of comparable proportions would have been lost.

The behavior of the White House on these issues is part of a pattern that has led Russell Train, the EPA administrator under Presidents Nixon and Ford, to observe, "How radically we have moved away from regulation based on independent findings and professional analysis of scientific, health and economic data by the responsible agency to regulation controlled by the White House and driven primarily by political considerations."

Across a broad range of policy areas, the administration has undermined the quality and independence of the scientific advisory system and the morale of the government's outstanding scientific personnel:

- Highly qualified scientists have been dropped from advisory committees dealing with childhood lead poisoning, environmental and reproductive health, and drug abuse, while individuals associated with or working for industries subject to regulation have been appointed to these bodies.
- Censorship and political oversight of government scientists is not restricted to the EPA, but has also occurred at the Departments of Health and Human Services, Agriculture, and Interior, when scientific findings are in conflict with the administration's policies or with the views of its political supporters.
- The administration is supporting revisions to the Endangered Species Act that would greatly constrain scientific input into the process of identifying endangered species and critical habitats for their protection.
- Existing scientific advisory committees to the Department of Energy on nuclear weapons, and to the State Department on arms control, have been disbanded.
- In making the invalid claim that Iraq had sought to acquire aluminum tubes for uranium enrichment centrifuges, the administration disregarded the contrary assessment by experts at Livermore, Los Alamos and Oak Ridge National Laboratories.

The distortion of scientific knowledge for partisan political ends must cease if the public is to be properly informed about issues central to its well being, and the nation is to benefit fully from its heavy investment in scientific research and education. To elevate the ethic that governs the relationship between science and government, Congress and the Executive should establish legislation and regulations that would:

- Forbid censorship of scientific studies unless there is a reasonable national security concern;
- Require all scientists on scientific advisory panels to meet high professional standards; and
- Ensure public access to government studies and the findings of scientific advisory panels.

To maintain public trust in the credibility of the scientific, engineering and medical professions, and to restore scientific integrity in the formation and implementation of public policy, we call on our colleagues to:

- Bring the current situation to public attention;
- Request that the government return to the ethic and code of conduct which once fostered independent and objective scientific input into policy formation; and
- Advocate legislative, regulatory and administrative reforms that would ensure the acquisition and dissemination of independent and objective scientific analysis and advice.

Signers of the scientists' statement on scientific integrity include 49 Nobel laureates, 63 National Medal of Science recipients, and 154 members of the National Academies. A partial list of signers occurs below.

Note: Italicized names are those of the original signers of the statement

National Medal of Science *
Nobel Laureate †
Crafoord Prize #
National Academies of Science ^

Andreas Acrivos * ^
City College of the City University of New York

Edward Adelberg ^
Yale University

Eric Adelberger ^
University of Washington

Peter Agre † ^
Johns Hopkins University School of Medicine

Don L. Anderson * # ^
California Institute of Technology

Philip W. Anderson * † ^
Princeton University

Nancy C. Andreasen * ^
University of Iowa College of Medicine

Francisco J. Ayala * ^
University of California, Irvine

David Baltimore * † ^
California Institute of Technology

Guy Octo Barnett ^
Harvard University

Dr. Michael VL Bennett ^
Albert Einstein College of Medicine

Paul Berg * † ^
Stanford University School of Medicine

R. Stephen Berry ^
University of Chicago

Rosina Bierbaum
University of Michigan

Nicolaas Bloembergen * † ^
University of Arizona

Felix Boehm ^
California Institute of Technology

Paul D. Boyer † ^
University of California, Los Angeles

Lewis M. Branscomb ^
Harvard University

Ronald Breslow * ^
Columbia University

Robert H. Burris * ^
University of Wisconsin, Madison

Joost A. Businger ^

Dr. John Cairns, Jr. ^
Virginia Polytechnic Institute and State University

Eric Chivian †
Harvard Medical School

Joel E. Cohen ^
The Rockefeller University

Hael D. Collins ^
Carnegie Mellon University

Eric Conn ^
University of California, Davis

Robert W. Corell
American Meteorological Society

F. Albert Cotton * ^
Texas A&M University

James Cronin * † ^
University of Chicago

James Crow ^
University of Wisconsin

James E. Darnell, Jr. * ^
The Rockefeller University

Margaret Davis ^
University of Minnesota

Mark Davis ^
University of California, Berkeley

Johann Deisenhofer † ^
University of Texas Southwestern Medical Center

Robert C. DeVries ^
General Electric (Retired)

Theodor O. Diener * ^
University of Maryland

Carl Djerassi * ^
Stanford University

Paul M. Doty ^
Harvard University

Renato Dulbecco † ^
Salk Institute

Paul Ehrlich # ^
Stanford University

Herman Eisen ^
Massachusetts Institute of Technology

Thomas Eisner * ^
Cornell University

S. Walter Englander ^
University of Pennsylvania School of Medicine

William K. Estes * ^
Indiana University

John B. Fenn †
Virginia Commonwealth University

Christopher Field ^
Carnegie Institution of Washington

Gerald D. Fischbach ^
Columbia University Medical School

Edmond Fischer † ^
University of Washington

Val L. Fitch * † ^
Princeton University

Jerry Franklin
University of Washington

Gerhart Friedlander ^
Brookhaven National Laboratory

Jerome Friedman † ^
Massachusetts Institute of Technology

Mary Gaillard ^
University of California, Berkeley

Richard L. Garwin * ^
International Business Machines Corporation

Murray Gell-Mann † ^
Santa Fe Institute

John H. Gibbons ^
Former Science Advisor to the President

Walter Gilbert † ^
Harvard University

Donald A. Glaser † ^
University of California, Berkeley

Sheldon L. Glashow † ^
Boston University

Marvin L. Goldberger ^
California Institute of Technology

Lynn R. Goldman
John Hopkins School of Public Health

Peter Goldreich * ^
Institute for Advanced Study

Kurt Gottfried
Cornell University

David Grimes
University of North Carolina School of Medicine

Roger Guillemin * †
Salk Institute

Henry C. Harpending ^
University of Utah

Richard Havel ^
University of California, San Francisco

Dudley Herschbach * † ^
Harvard University

Roald Hoffmann * † ^
Cornell University

John P. Holdren ^
Harvard University

Norman Horowitz ^
California Institute of Technology

H. Robert Horvitz † ^
Massachusetts Institute of Technology

David H. Hubel † ^
Harvard University

John Huchra ^
Harvard-Smithsonian Center for Astrophysics

J. David Jackson ^
University of California, Berkeley

Daniel H. Janzen # ^
University of Pennsylvania

Leo P. Kadanoff * ^
University of Chicago

Eric R. Kandel * † ^
Columbia University

Anne Kapuscinski
University of Minnesota

Jack Keller ^
Keller Bliesner Eng. LLC and Utah State Univ.

Kenneth H. Keller ^
University of Minnesota

Gerald T. Keusch ^
Boston University

Daniel Kleppner ^
Massachusetts Institute of Technology

Walter Kohn * † ^
University of California, Santa Barbara

Arthur Kornberg * † ^
Stanford University School of Medicine

Lawrence Krauss
Case Western Reserve University

Herbert Kroemer † ^
University of California, Santa Barbara

Neal F. Lane
Former Science Advisor to the President

Robert B. Laughlin † ^
Stanford University

Alexander Leaf ^
Harvard Medical School

Leon M. Lederman * † ^
Fermi National Accelerator Laboratory

David M. Lee † ^
Cornell University

Anthony Leggett † ^
University of Illinois, Urbana-Champaign

Sidney Leibovich ^
Cornell University

Simon Levin ^
Princeton University

Gene Likens * ^
Institute of Ecosystem Studies

William Lipscomb † ^
Harvard University

Jane Lubchenco ^
Oregon State University

Michael C. MacCracken
International Association of Meteorology and Atmospheric Sciences

Lynn Margulis * ^
University of Massachusetts

Paul A. Marks * ^
Memorial Sloan-Kettering Cancer Center

Douglas S. Massey ^
Princeton University

James J. McCarthy
Harvard University

Harden M. McConnell * ^
Stanford University

Jerry M. Melillo
Woods Hole Research Center

N. David Mermin ^
Cornell University

Matthew S. Meselson ^
Harvard University

David Michaels
George Washington University

Charles D. Michener ^
University of Kansas

Mario Molina † ^
Massachusetts Institute of Technology

Walter H. Munk * ^
University of California, San Diego

Joseph E. Murray † ^
Harvard Medical School

Herbert L. Needleman ^
University of Pittsburgh School of Medicine

Louis Nirenberg * # ^
New York University

Marshall Nirenberg * † ^
National Heart, Lung, and Blood Institute

Michael Oppenheimer
Princeton University

Gordon Orians ^
University of Washington

Douglas D. Osheroff † ^
Stanford University

Jeremiah P. Ostriker * ^
Princeton University

George E. Palade * † ^
University of California, San Diego

W.K.H. Panofsky * ^
Stanford University

Eugene N. Parker * ^
University of Chicago

Martin L. Perl † ^
Stanford University

David Perkins ^
Stanford University

Thomas D. Petes
University of North Carolina

Gregory Petsko ^
Brandeis University

Norman Phillips ^
National Weather Service

Stuart Pimm
Duke University

Robert V. Pound * ^
Harvard University

Ron Pulliam
University of Georgia

Norman F. Ramsey * † ^
Harvard University

Stuart A. Rice * ^
University of Chicago

Anthony Robbins
Tufts University School of Medicine

John D. Roberts * ^
California Institute of Technology

Wendell L. Roelofs * ^
Cornell University

Allan Rosenfield
Columbia University School of Public Health

John Ross * ^
Stanford University

F. Sherwood Rowland † ^
University of California, Irvine

Janet D. Rowley * ^
University of Chicago Medical Center

Vera Rubin * ^
Carnegie Institution of Washington

Eli Ruckenstein * ^
State University of New York at Buffalo

Liane Russell ^
Oak Ridge National Laboratory

Edwin E. Salpeter # ^
Cornell University

Allan Sandage * #
The Observatories of the Carnegie Institution of Washington

William Schlesinger ^
Duke University

William F. Schreiber ^
Massachusetts Institute of Technology

J. Robert Schrieffer * † ^
National High Magnetic Field Laboratory

Seymour I. Schwartz ^
University of California

Dana S. Scott ^
Carnegie Mellon University

Andrew Sessler ^
Lawrence Berkeley National Laboratory

Roger N. Shepard * ^
Stanford University

Robert Silbey ^
Massachusetts Institute of Technology

Richard Smalley † ^
Rice University

Franklin Stahl ^
University of Oregon

Jack Steinberger * † ^
European Organization for Nuclear Research (CERN)

Joan A. Steitz * ^
Yale University School of Medicine

Felicia Stewart
University of California, San Francisco

Albert James Stunkard ^
University of Pennlsylvania

Henry Taube * † ^
Stanford University

Saul Teukolsky ^
Cornell University

E. Donnall Thomas * † ^
Fred Hutchinson Cancer Research Center

George Tilton ^
University of California, Santa Barbara

Kevin Trenberth
National Center for Atmospheric Research

Myron Tribus ^
Massachusetts Institute of Technology

Daniel Tsui † ^
Princeton University

Harold E. Varmus * † ^
Memorial Sloan-Kettering Cancer Center

Gerald J. Wasserburg # ^
California Institute of Technology

Robert A. Weinberg * ^
Massachusetts Institute of Technology

Steven Weinberg * † ^
University of Texas, Austin

Zena Werb ^
University of California

Frank H. Westheimer * ^
Harvard University

Gilbert F. White * ^
University of Colorado

Eric Wieschaus † ^
Princeton University

E.O. Wilson * # ^
Harvard University

Edward Witten * ^
Institute for Advanced Study

Lincoln Wolfenstein ^
Carnegie Mellon University

George M. Woodwell ^
Woods Hole Research Center

Donald Wuebbles
University of Illinois

Charles Yanofsky ^*
Stanford University

Herbert F. York
University of California, San Diego

Bruno Zumino ^
University of California, Berkeley

July 15, 2005

Via Federal Express

Joe Barton, Chairman
House Committee on Energy and Commerce
Ed Whitfield, Chairman
Subcommittee on Oversight and Investigations
2125 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Barton and Chairman Whitfield:

This letter responds to your letter of June 23, 2005, which seeks information on issues relating to my research on the historical record of temperatures and climate change.[1] Your letter lays out a number of "concerns" about the research my colleagues and I have conducted about global warming. Your letter also inquires about the role I played in the preparation of the United Nation's Intergovernmental Panel on Climate Change Third Assessment Report (the so-called "TAR").

I will address each of your questions in turn. Before doing so, however, let me state that my research findings, which support the conclusion that the earth's surface is warming, and that recent warming is due in large part to human influences, are consistent with the overwhelming scientific consensus on climate change. My research has been subject to intensive peer-review. Other scientists have replicated all facets of my research and have found it accurate and reliable. The specific conclusion published by my colleagues and me that late 20th century Northern Hemisphere warmth is anomalous in the context of at least the past millennium is common to many studies. Based on multiple supporting studies, the TAR came to a similar conclusion. The TAR did not rely solely on the work of my colleagues and me in reaching this conclusion. Recent work since the TAR has provided further support for this conclusion, which is now common to more than a dozen independent studies published in the peer-reviewed scientific literature. (I have provided for reference a comprehensive review by Jones and Mann in the journal "Reviews of Geophysics" of the American Geophysical Union (AGU).) The criticisms your letter cites have been soundly rejected by the scientific community.

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1 This response is submitted without waiving any objection I might have to the Committee's jurisdiction over the subject matter of this inquiry.

The most serious contention in your letter — namely, that my work has not been subject to replication because I have failed to make available the underlying research data — is incorrect. Your letter notes that the National Research Council's "gold standard" for scientific research is the ability of other scientists to replicate first-generation research, and I fully agree. My colleagues and I follow the National Research Council's guidance with regards to the disclosure of research data, and all of our data and methodologies have been fully disclosed and are available to anyone with a computer and an internet connection. As a result of our willingness to share our research with others, an independent team of scientists has used the research data my colleagues and I have made public to replicate our research and confirm the reliability of our findings. *See* Wahl, E.R., Ammann, C.M., *Robustness of the Mann, Bradley, Hughes Reconstruction of Surface Temperatures: Examination of Criticisms Based on the Nature and Processing of Proxy Climate Evidence,* Climate Change (2005) (forthcoming) and associated website: http://www.cgd.edu/ccr/ammann/millennium/MBH_reevaluation.html.

Let me now turn to your specific questions, which ask that I provide the following information:

Q1: Your letter first asks that I furnish the Committee my *curriculum vitae,* along with a "list of all studies relating to climate change research for which you were an author or co-author and the source of funding for those studies."

A: This material is attached.

Q2: Your letter next asks that I "[l]ist all financial support" I have received to support my research.

A: See attachment.

Q3: Your letter requests that I provide, for all "work involving federal grants or funding support under which you were a recipient of funding or a principal investigator," "all agreements relating to those underlying grants or funding, including, but not limited to, any provisions, adjustments, or exceptions made in the agreement relating to the sharing of research results."

A: These requests are not directed to the appropriate person. The committee should contact the University of Massachusetts and University of Virginia offices of grant administration for these materials. With respect to the UMass NSF research funds (which supported the 1998 *Nature* article), it should furthermore be noted that I was *not* the Principal Investigator for this NSF project, and I am not, nor have I ever, been in possession of any official paperwork related to this grant.

Q4: Your next question asks for "the location of all data archives relating to each published study for which" I was "an author or co-author" and whether such data would be sufficient to permit other researchers to replicate the work.

A: The data, descriptions of methods, and results related to my research — more than sufficient to permit other researchers to replicate the research — have been extensively archived (in many cases, in several archives) on public websites, and data links within the websites. The website addresses appear in the margin.[2]

Q5: This question begins by stating that, "[a]ccording to *The Wall Street Journal*, you have declined to release the exact computer code you used to generate your results." The question then poses a series of questions: "(a) Is that correct? (b) What policy on

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2 http://fox.rwu.edu/~rutherfo/supplements/jclim2003a/
http://www.ngdc.noaa.gov/paleo/pubs/jones2004/jones2004.html
http://www.ngdc.noaa.gov/paleo/pubs/mann2003b/mann2003b.html
http://www.ngdc.noaa.gov/paleo/pubs/mann2003/mann2003.html
http://www.ngdc.noaa.gov/paleo/ei/ei_cover.html
http://www.ncdc.noaa.gov/paleo/ei/ei_datarev.html
http://www.ncdc.noaa.gov/paleo/ei/ei_reconsa.html
http://www.ncdc.noaa.gov/paleo/ei/ei_reconsb.html
http://www.ncdc.noaa.gov/paleo/ei/ei_reconsc.html
http://www.ncdc.noaa.gov/cgi-bin/paleo/mannplot2.pl
http://www.ncdc.noaa.gov/paleo/ei/data_supp.html
http://www.ncdc.noaa.gov/paleo/ei/stats-supp-annual.html
http://www.ncdc.noaa.gov/paleo/ei/stats-supp-cold.html
http://www.ncdc.noaa.gov/paleo/ei/stats-supp-warm.html
http://www.ncdc.noaa.gov/paleo/ei/ei_nodendro.html
ftp://ftp.ngdc.noaa.gov/paleo/paleolimnology/newengland/glacial_lake_hitchcoc
k/
ftp://eclogite.geo.umass.edu/pub/mann/MANNETAL98/nino3.dat
ftp://eclogite.geo.umass.edu/pub/mann/ONLINE-
PREPRINTS/Millennium/DATA/RECONS/
ftp://holocene.evsc.virginia.edu/pub/sdr/temp/nature/MANNETAL98/
http://www.ngdc.noaa.gov/paleo/pubs/mann1998/frames.htm
ftp://eclogite.geo.umass.edu/pub/mann/MANNETAL98/
ftp://holocene.evsc.virginia.edu/pub/MBH98/
ftp://holocene.evsc.virginia.edu/pub/MANNETAL98/
ftp://holocene.evsc.virginia.edu/pub/MANNETAL98/FIGUREDATA/
ftp://holocene.evsc.virginia.edu/pub/MANNETAL98/INSTRUMENTAL/
ftp://holocene.evsc.virginia.edu/pub/MANNETAL98/METHODS/
ftp://holocene.evsc.virginia.edu/pub/MANNETAL98/PROXY/
ftp://holocene.evsc.virginia.edu/pub/mann/Filter/lowpass.m
ftp://holocene.evsc.virginia.edu/pub/mann/Filter/lowpassmin.m
http://www.atmos.ucla.edu/tcd/ssa/
http://holocene.evsc.virginia.edu/Mann/tools/MTM-RED
http://holocene.evsc.virginia.edu/Mann/tools/MTM-COHERE
http://holocene.evsc.virginia.edu/Mann/tools/CMPLXDEMOD
http://holocene.evsc.virginia.edu/Mann/tools/MTM-SVD

sharing research and methods do you follow? (c) What is the source of that policy? (d) Provide this exact computer code used to generate your results."

The question presumes that in order to replicate scientific research, a second researcher has to have access to exactly the same computer program (or "code") as the initial researcher. This premise is false. The key to replicability is unfettered access to all of the underlying data and methodologies used by the first researcher. My data and methodological information, and that of my colleagues, are available to anyone who wants them.[3] As noted above, other scientists have reproduced our results based on publicly available information.

It also bears emphasis that my computer program is a private piece of intellectual property, as the National Science Foundation and its lawyers recognized. The National Science Foundation — the government agency that establishes policy in this area — has confirmed that my colleagues and I have met every requirement of transparency and openness in our research. My research is all based on data sets regarding the Earth's

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3 All of the proxy data (tree-rings, coral, ice cores, and historical documents) used in Mann *et al.* (1998) has been available since May 2000 on this public website: ftp://holocene.evsc.virginia.edu/pub/MBH98. The methodology used by my colleagues and me is described in detail in the initial publication, and further expanded upon in July 2004 on *Nature*'s supplementary website (http://www.nature.com/nature/journal/v430/n6995/suppinfo/nature02478.html) and on our own website, ftp://holocene.evsc.virginia.edu/pub/MANNETAL98. Moreover, independently-derived source codes for implementing our algorithm, and all required input data, have been posted on the website of the National Center for Atmospheric Research. *See* http://www.ucar.edu/ccr/ammann/millennium/CODES_MBH.html. For these reasons, charges that our work is not subject to replication are unfounded. The initial description of the work was sufficient to permit researchers to independently produce the key algorithms. *See, e.g.*, Zorita, E., F. Gonzalez-Rouco, and S. Legutke, *Testing the Mann et al.(1998) approach to paleoclimate reconstructions in the context of a 1000-yr control simulation with the ECHO-G Coupled Climate Model*, J. Climate, 16, 1378-1390 (2003); Von Storch, H., E. Zorita, J.M. Jones, Y. Dimitriev, F. Gonzalez-Rouco, F., and S.F.B. Tett, *Reconstructing Past Climate from Noisy Data*, Science, 306, 679-682 (2004). Not only have we replicated our results with a different methodology (Rutherford, S., Mann, M.E., Osborn, T.J., Bradley, R.S., Briffa, K.R., Hughes, M.K., Jones, P.D., *Proxy-based Northern Hemisphere Surface Temperature Reconstructions: Sensitivity to Methodology, Predictor Network, Target Season and Target Domain*, Journal of Climate (2005) (to appear in July issue), but an independent group has replicated our original methods and results (*See* Wahl, E.R. and Ammann, C.M., *Robustness of the Mann, Bradley, Hughes Reconstruction of Surface Temperatures: Examination of Criticisms Based on the Nature and Processing of Proxy Climate Evidence*, Climatic Change (2005) (forthcoming)).

climate that are freely and widely available to *all* researchers. Whether I make available my computer programs is irrelevant to whether our results can be reproduced. And whether I make my computer programs publicly available or not is a decision that is mine alone to make. Since other scientists have used the methods we described and the data we archived to replicate our results, the issue of whether my computer program is available has no bearing whatsoever on the veracity of our results. The question you posed — whether I have fully satisfied established scientific standards for data-sharing — has been fully considered by the National Science Foundation. As your letter notes, two Canadian researchers, Steve McIntyre and Ross McKitrick, contacted NSF to inquire whether I had complied with National Science Foundation requirements. The National Science Foundation twice informed them that I have, in fact, complied with all applicable transparency and openness standards and that, under long-standing Foundation policy, the computer codes referred to by *The Wall Street Journal* are considered the intellectual property of researchers and are not subject to disclosure.[4]

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4 For the sake of completeness, let me quote in its entirety the email message sent by Dr. David J. Verardo, Director, Paleoclimate Program, Division of Atmospheric Sciences, National Science Foundation to Mr. Steve McIntyre (copied to me), on December 17, 2003, in response to a previous email that McIntyre had sent to Dr. Verardo (copied to me):

Dear Mr. McIntyre,

I apologize if my last electronic message was not clear but let me clarify the US NSF's view in this current message. Dr. Mann and his other US colleagues are under no obligation to provide you with any additional data beyond the extensive data sets they have already made available. He is not required to provide you with computer programs, codes, etc. His research is published in the peer-reviewed literature which has passed muster with the editors of those journals and other scientists who have reviewed his manuscripts. You are free to your analysis of climate data and he is free to his. The passing of time and evolving new knowledge about Earth's climate will eventually tell the full story of changing climate. I would expect that you would respect the views of the US NSF on the issue of data access and intellectual property for US investigators as articulated by me to you in my last message under the advisement of the US NSF's Office of General Counsel.

Respectfully,
David J. Verardo
Director, Paleoclimate Program
Division of Atmospheric Sciences
National Science Foundation
4201 Wilson Blvd.
Arlington, VA 22203

Even more recently, the National Science Foundation confirmed its view that my computer codes are my intellectual property. A recent issue of the *Chronicle of Higher Education* states: "According to David Stonner, of the Congressional-

With this background in mind, let me now respond to your specific inquiries:

A (Q5A): I have made available all of the research data that I am required to under United States policy as set by the National Science Foundation. In accordance with the rules promulgated by the Foundation and supported by the Foundation's General Counsel, I maintain the right to decline to release any computer codes, which are my intellectual property.

A (Q5B): The policy regarding sharing research and methods I and my colleagues follow is to disclose any information that might be useful to other researchers, including the data, description of methodology, and so forth, that would enable a competent scientist to replicate our work. The proof here, of course, is that other scientists have in fact succeeded in replicating our work. And, as noted above, our policies are fully in keeping with those established by the National Science Foundation.

A(Q5C): The source of these policies is the National Science Foundation.

A(Q5D): My computer program is a piece of private, intellectual property, as the National Science Foundation and its lawyers recognize. It is a bedrock principle of American law that the government may not take private property "without [a] public use," and "without just compensation."

That notwithstanding, the program used to generate the original Mann *et al.* 1998 temperature reconstructions is posted at this website:
ftp://holocene.evsc.virginia.edu/pub/MANNETAL98/
(see "METHODS" subdirectory)

Q6: The Committee next asks that, "[r]egarding study data and related information that is not publicly archived, what requests have you and your co-authors received for data relating to climate change studies, what was your response, and why?"

A: I can of course only speak for myself, but I do not believe that there is any "study data" used in my published work that is not publicly archived. Having said that, I do respond diligently to any requests from scientific colleagues for data or methodological details relating to our research.

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affairs office at the National Science Foundation, Mr. McIntyre contacted the foundation last year to ask for Mr. Mann's computer code. Mr. Stonner said the agency had told Mr. McIntyre that the code was the intellectual property of Mr. Mann . . .." Richard Monastersky, *Congressman Demands Complete Records on Climate Research by 3 Scientists Who Support of Global Warming,* Chronicle of Higher Education (July 1, 2005), available at:
http://chronicle.com/temp/email.php?id=dopjw74bwvqzvd3k9tekp5avlofvb2yu.

Q7: This question poses a number of questions based on an article published by McIntyre and McKitrick in *Energy & Environment.* The question states that these authors "report a number of errors and omissions in Mann *et al.* 1998 and how these may affect the underlying conclusions of the work." The question goes on to list a number of topics that I should address in a "narrative explanation."

A: I want to begin by emphasizing that nothing in McIntyre and McKitrick's article undermines the conclusion of my research. My colleagues and I stand foursquare behind our work. So does the scientific community.

The various claims of McIntyre and McKitrick — including the ones repeated in your question — have been exhaustively examined by two different groups of climate researchers who have found their objections to be unfounded.[5] *See also* National Center for Atmospheric Research, *Media Advisory: The Hockey Stick Controversy New Analysis Reproduces Graph of Late 20th Century Temperature Rise* (May 11, 2005) (available at: http://www.ucar.edu/news/releases/2005/ammann.shtml). Moreover, it is my understanding that several other groups of climate researchers have examined McIntyre and McKitrick's criticisms and also have found their criticisms lacking in merit. On the other hand, I know of no independent scientific group that has found any of McIntyre and McKitrick's claims to be valid.

Nor is that surprising. *Energy & Environment* is *not* a peer reviewed scientific journal; it is a journal primarily devoted to *policy* rather than science that appears to engage in, at most, haphazard review of its articles. And neither McIntyre nor McKitrick is a trained climate scientist. According to the biographical data on their websites, Mr. McIntyre is a mining industry executive with no formal training in any discipline related to climate research and Mr. McKitrick is an economist with no scientific training, hardly credentials that lend force to their academic arguments. *See* http://www.uoguelph.ca/~rmckitri/cv.html and http://www.uoguelph.ca/~rmckitri/research/stevebio.doc.

Adding to the problem, the editor of *Energy & Environment,* Ms. Sonja Boehmer-Christiansen, has candidly acknowledged that the publication has a clear editorial bias. In the September 5, 2003 issue of the *Chronicle of Higher Education,* Ms. Boehmer-Christiansen is quoted as describing the editorial policy of *Energy & Environment* in this way: "I'm following my political agenda – a bit, anyway. *** But isn't that the right of

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5 *See, e.g.*, Rutherford, S., Mann, M.E., Osborn, T.J., Bradley, R.S., Briffa, K.R., Hughes, M.K., Jones, P.D., *Proxy-based Northern Hemisphere Surface Temperature Reconstructions: Sensitivity to Methodology, Predictor Network, Target Season and Target Domain*, Journal of Climate (2005) (in press, to appear in July issue); Wahl, E.R. and Ammann, C.M., *Robustness of the Mann, Bradley, Hughes Reconstruction of Surface Temperatures: Examination of Criticisms Based on the Nature and Processing of Proxy Climate Evidence*, Climatic Change (2005) (forthcoming).

an editor?" As to "peer review," Ms. Boehmer-Christiansen has acknowledged in an email to Dr. Tim Osborn of the Climatic Research Unit at the University of East Anglia (U.K.), that in her rush to get the McIntyre and McKitrick piece into print for political reasons *Energy & Environment* dispensed with what scientists consider peer review ("I was rushing you to get this paper out for policy impact reasons, e.g. publication well before COP9"). As Ms. Boehmer-Christiansen added, the "paper was amended until the very last moment. There was a trade off in favour of policy." McIntyre and McKitrick's work has been discredited by ample peer-reviewed, scientific work.

Nonetheless, let me try to respond to the Committee's specific questions.

A(7A,7B): The Committee inquires about the sensitivity of the results of the Mann *et al.* 1998 study to the inclusion or omission of certain North American tree-ring data ("the bristlecone pine series" and "archived Gaspe tree ring data" referred to in the Committee's letter). For a complete scientific response, you should consult the article my co-authors and I published back in 1999 addressing precisely these issues: Mann, M.E., Bradley, R.S., and Hughes, M.K., *Northern Hemisphere Temperatures During the Past Millennium: Inferences, Uncertainties, and Limitations*, Geophysical Research Letters, 26, 759-62 (1999).

The issues raised by the Committee involve a 100 year sub-interval of our reconstruction from AD 1400-1500. As my co-authors and I explained in our 1999 article cited above, given the proxy data available at that time, certain key tree-ring data (including the series mentioned above) were essential, if the reconstructed temperature record during early centuries were to have any climatologic "skill" (that is, any validity or meaningfulness). These conclusions were of course reached through analyses in which these key datasets were excluded, and the results tested for statistical validity. Our conclusions have been confirmed by Wahl and Ammann (see above). These researchers have demonstrated that the reconstructions produced by McIntyre and McKitrick result from ignoring these key data, and fail the accepted, basic tests for statistical validity. Moreover, Wahl and Ammann demonstrate that the climatologically improbable results obtained by McIntyre and McKitrick, which would suggest that the Northern Hemisphere was unusually warm during the 15th century (the middle of the so-called "Little Ice Age"), are statistically meaningless, and an artifact of both their exclusion of key proxy data (as discussed above) and the use of a flawed implementation of the Mann *et al.* 1998 method. *See* http://www.cgd.ucar.edu/ccr/ammann/millennium/CODES_MBH.html) (chart at the bottom of the page).

Since 1999 new proxy data have become available and new methodologies developed for using them. Studies using these data and methodologies have confirmed the primary conclusion of our work (e.g. Mann *et al.* 1998 and Mann *et al.* 1999) that the most recent decades were likely the warmest of the past 1,000 years for the Northern Hemisphere on the average. The most recent such study (published in *Nature*) in fact extends this conclusion to at least the past 2,000 years. Moberg, A., D.M. Sonechkin, K. Holmgren, N.M. Datsenko, and W. Karlen, *Highly Variable Northern Hemisphere*

Temperatures Reconstructed from Low- and High-resolution Proxy Data, Nature, 433, 613-617 (2005).

A(7C): The Committee inquires about the calculation of the R2 statistic for temperature reconstruction, especially for the 15th Century proxy calculations. In order to answer this question it is important to clarify that I assume that what is meant by the "R2" statistic is the squared Pearson dot-moment correlation, or r^2 (i.e., the square of the simple linear correlation coefficient between two time series) over the 1856-1901 "verification" interval for our reconstruction. My colleagues and I did not rely on this statistic in our assessments of "skill" (i.e., the reliability of a statistical model, based on the ability of a statistical model to match data not used in constructing the model) because, in our view, and in the view of other reputable scientists in the field, it is not an adequate measure of "skill." The statistic used by Mann *et al.* 1998, the reduction of error, or "*RE*" statistic, is generally favored by scientists in the field. *See, e.g.*, Luterbacher, J.D., *et al.*, *European Seasonal and Annual Temperature Variability, Trends and Extremes Since 1500*, Science 303, 1499-1503 (2004).

RE is the preferred measure of statistical skill because it takes into account not only whether a reconstruction is "correlated" with the actual test data, but also whether it can closely reproduce the mean and standard deviation of the test data. If a reconstruction cannot do that, it cannot be considered statistically valid (i.e., useful or meaningful). The linear correlation coefficient (r) is not a sufficient diagnostic of skill, precisely because it cannot measure the ability of a reconstruction to capture changes that occur in either the standard deviation or mean of the series outside the calibration interval. This is well known. *See* Wilks, D.S., STATISTICAL METHODS IN ATMOSPHERIC SCIENCE, chap. 7 (Academic Press 1995); Cook, *et al.*, *Spatial Regression Methods in Dendroclimatology: A Review and Comparison of Two Techniques,* International Journal of Climatology, 14, 379-402 (1994). The highest possible attainable value of r^2 (i.e., $r^2 = 1$) may result even from a reconstruction that has no statistical skill at all. *See, e.g.*, Rutherford, *et al.*, *Proxy-based Northern Hemisphere Surface Temperature Reconstructions: Sensitivity to Methodology, Predictor Network, Target Season and Target Domain*, Journal of Climate (2005) (in press, to appear in July issue)(available at: ftp://holocene.evsc.virginia.edu/pub/mann/RuthetalJClimate-inpress05.pdf). For all of these reasons, we, and other researchers in our field, employ *RE* and not r^2 as the primary measure of reconstructive skill.

As noted above, in contrast to the work of Mann *et al.* 1998, the results of the McIntyre and McKitrick analyses fail verification tests using the accepted metric *RE*. This is a key finding of the Wahl and Ammann study cited above. This means that the reconstructions McIntyre and McKitrick produced are statistically inferior to the simplest possible statistical reconstruction: one that simply assigns the mean over the calibration period to all previous reconstructed values. It is for these reasons that Wahl and Ammann have concluded that McIntyre and McKitrick's results are "without statistical and climatological merit."

A(7D): The Committee asks "[w]hat validation statistics did you calculate for the reconstruction prior to 1820, and what were the results?" Our validation statistics were described in detail in a table provided in the supplementary information on *Nature*'s website accompanying our original nature article, Mann, M.E., Bradley, R.S., Hughes, M.K., *Global-Scale Temperature Patterns and Climate Forcing Over the Past Six Centuries*, Nature, 392, 779-787 (1998). These statistics remain on *Nature*'s website (*see* http://www.nature.com/nature/journal/v392/n6678/suppinfo/392779a0.html) and on our own website. *See* ftp:holocene.evsc.virginia.edu/pub/Mannetal98.

A(7E): The Committee asks how I "choose particular proxies and proxy series." Again, this information is furnished in detail in both our original 1998 article in *Nature*, and expanded upon in a follow-up article published in 2000. *See* Mann *et al.*, *Global Temperature Patterns in Past Centuries: An Interactive Presentation,* Earth Interactions 4-4, 1-29 (2000), specifically this link therein: http://www.ncdc.noaa.gov/paleo/ei/ei_nodendro.htlm.

As our 1998 study and the additional information mentioned above make clear, we made use of all long-term, annually-resolved proxy indicators available to us in the public domain or through colleagues at the time the research was initiated (1996-1997) that met requirements for suitable length, age model reliability, and in the case of tree ring series, replication, inter-correlation and metadata as described above.

Q8: This question asks me to "[e]xplain in detail" my work "for and on behalf of the Intergovernmental Panel on Climate Change," including my "role in the Third Assessment Report" (referred to as "TAR"), and a host of information as to how TAR was prepared and how the authors of TAR verified the soundness of the data that formed the basis for the conclusions set forth in TAR.

A: As is set forth on my *curriculum vitae*, I was one of ten lead authors of chapter 2 of TAR, and I served as a contributing author for chapters 7, 8, and 12 of the report. Given the breadth of the project, there were two layers of editorial review that oversaw the work of the lead authors for each chapter, so the chapter reflected a consensus scientific view, not merely the views of any single author. The TAR had 672 scientist reviewers. In the United States, anyone who wanted to review the drafts was allowed access to them to provide a review. I am not myself familiar with any scientific document that has been more comprehensively reviewed than the TAR.

Information concerning the "dates of key meetings," the steps taken by "reviewers, and lead authors to ensure the data . . . were sound and accurate," and the "identity of people who wrote and reviewed" portions of TAR should be obtained directly from the Intergovernmental Panel on Climate Change ("IPCC"). As I am sure you can appreciate, I am not an agent of the IPCC and I am not empowered to speak on IPCC's behalf on these matters. Nor have I been authorized by the IPCC to make public information that the IPCC itself has not chosen to make publicly available. If the Committee is interested in pursuing these matters, I would urge that the Committee

contact Sir John Houghton, the head of the Working Group, at the Hadley Centre in England.

For the Committee's convenience, I have sent along with this letter copies of key scientific articles referred to in this letter. Please let me know if you have questions.

Respectfully submitted,

Michael E. Mann, Ph.D.
Associate Professor and
Director of Earth System Science Center
Department of Meteorology
The Pennsylvania State University[6]

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6 I do not formally assume this position until August 22, 2005. I currently serve as Assistant Professor, Department of Environmental Sciences, University of Virginia, Charlottesville.

Written Testimony of Roger Bate[1] and Richard Tren[2] to the Senate Environment and Public Works Committee hearing on the role of science in environmental policy making, Wednesday 28th September, 2005, Room 406 of the Dirksen Senate Office Building.

Dear Mr. Chairman,

Thank you for inviting Africa Fighting Malaria to submit written testimony to this most valuable hearing. Africa Fighting Malaria is a health advocacy group based in South Africa and the US. We monitor the activities of aid agencies and health groups in Africa, and in other parts of the world, and advise those interested in policies to combat malaria and other diseases.

Executive Summary

This committee seeks to understand the influence of science in public policy and consequences of the misuse of that science in such policy. There can be few more compelling and tragic examples of the abuse of science and misuse in ongoing public policy than that of DDT and public health.

DDT helped eradicate malaria from Europe and the United States in the 1950s, and was used to eradicate malaria in many other countries in the following two decades. It is still used widely in at least a dozen countries (perhaps as many as two dozen), but these countries have been discouraged by virtually all United Nations organizations, donor agencies and commercial interests.

DDT is safe for human use and there has never been a peer-reviewed replicated study showing any human harm from the chemical, even though billions have been exposed to it (hundreds of millions in moderate to high doses). Its bioaccumulation and persistence in the environment have caused far less harm than is commonly believed. But small problems did occur when massive amounts were used in farming, and today, quite correctly, it is used solely in disease control where tiny amounts are used. But some environmental groups continue to conflate tiny vital use in disease control with massive and potentially dangerous use in agriculture. These groups have sustained pressure against its use for over three decades with disastrous results. Today, their mistaken rhetoric is repeated by aid agencies around the world.

The UN's World Health Organization has dithered and although not rhetorically opposed to DDT has purchased none in recent years. The malaria program of the United States Agency for International Development has been the subject of other Senate hearings for failure to use DDT, or even to make significant purchases of any useful commodities. Very recently a senior manager within the German corporation, Bayer Crop Sciences, has gone on record supporting EU threats of trade sanctions against those countries that seek to use DDT solely for malaria control.

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[1] US Director Africa Fighting Malaria, Resident Fellow American Enterprise Institute.
[2] South African Director, Africa Fighting Malaria.

Ultimately it is poor children in Africa that pay for these policy failures, based on abused science. As President Bush has announced a massive increase in federal funds for malaria control, we urge the US Government to insist that years of scaremongering and bad science be reversed and to take a strong stance against the EU and Bayer Crop Sciences.

Introduction

Africa Fighting Malaria is a health advocacy group based in Johannesburg, South Africa and Washington DC. For the past five years, we have researched the political economy of malaria control and advocated improved malaria control policies from the various UN organizations and donor agencies. Much of our efforts have been directed towards improving the public and donor community's understanding of dichlorodiphenyltrichloroethane (DDT) and its place in malaria control.

Broadly we believe that scientific and public health officers in malarial countries generally know better than donors what their countries require, and should have far greater powers in determining the best public health interventions. Unfortunately, far too often, that power is taken away from them and malaria control policies are influenced by donor agency contractors with vested interests that use unsound science to support their case. The net result is that effective malaria control is undermined and many young children in malarial countries die before they reach their fifth birthday.

We greatly appreciate the opportunity to submit this testimony and warmly welcome the objectives of this hearing. The abuse of science and its effect on public policy has far reaching effects around the globe. The case study of DDT and its place in malaria control is a perfect example of how bad science and scaremongering allows government officials, UN agencies and private companies to put their own interests, commercial or otherwise, ahead of those that they are supposed to be assisting.

Our submission gives an overview of the malaria situation in Africa and the importance of DDT to malaria control. We will address the reasons given for banning DDT for agricultural use in the United States in 1972 and how this banning influenced the use of DDT in malaria control around the world. We will address the precautionary principle, which has increasing traction among policy makers, and will apply this principle to DDT in malaria control.

We will then summarize the way in which unsound science and scaremongering has influenced public policy with regard to malaria control and how lives have been lost as a direct result of such actions.

Malaria in Africa

The most recent and credible studies estimate that there are approximately 515 million episodes of malaria every year and that more than two thirds of those cases occur in Africa[34]. Overall 2.2 billion people are at risk from malaria and even though these

[3] Robert Snow et al. "The Global distribution of clinical episodes of *Plasmodium falciparum* malaria" *Nature 434*, 214-217. 10 March 2005

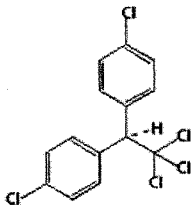
figures are conservative, the scale of the malaria problem is larger than previously thought. Of the four types of malaria that can infect man, the deadliest is *Plasmodium falciparum* and the vast majority of cases in Africa are of this lethal strain[5].

The World Health Organization estimates that over 1 million people die from malaria every year, most of these deaths occur in Africa among children under the age of 5[6]. Some estimates put the economic cost of malaria to Africa at over $12 billion per year and could reduce economic growth in Africa by 1.3% per year[7]. In spite of the enormous human and economic burden imposed by malaria, effective tools to halt the spread of the disease exist and several countries are using such tools and reducing cases and deaths accordingly. One such intervention is the careful spraying of small amounts of DDT on the inside walls of houses. As we explain below however, many countries are unable to use DDT because of a combination of donor country pressure, the threat of trade sanctions and misinformation and misunderstandings about the way in which DDT is used.

We give a brief history of the use of DDT and its role in malaria control. We then discuss the banning of DDT for agriculture and the pressure to reduce the use of DDT in malaria control. Last we address the stance that the donor community has taken to the use of DDT and their support of malaria control in Africa.

DDT in Malaria Control

DDT was first synthesized by Othmar Zeidler in 1874 when, as a German graduate student he was experimenting with different chemicals. Zeidler reacted chloral hydrate with chlorobenzene in the presence of sulphuric acid and found that it produced dichlorodiphenyltrichloroethane – DDT. Zeidler didn't actually do anything with the DDT that he produced and for almost sixty years the compound was unused.



Graphical depiction of DDT

During the 1930s a scientist working for the Swiss chemical company JR Geigy, Dr. Paul Mueller was looking for an insecticide to control clothes moths and happened upon DDT.

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[4] Snow et al. expose the fact that previous studies underestimated the scale of falciparum malaria in South East Asia.
[5] The other forms of malaria are *P. malariae*, *P. vivax* and *P. ovale*.
[6] WHO "World Malaria Report 2005" WHO, Geneva, www.rbm.who.int/wmr2005/html/exsummary_en.htm
[7] Jeffrey Sachs "Economic analyses indicate that the burden of malaria is great" Roll Back Malaria Partnership, WHO, Geneva, http://rbm.who.int/docs/abuja_sachs2.htm

Thus Mueller discovered one of mankind's most useful chemicals. There were numerous toxic substances available to control insecticides at the time, and although not realized at first, DDT's most revolutionary aspect was its ability to repel insects and not its toxicity.

The Allied forces first used DDT during the Second World War to control typhus, dusting civilians, concentration camp survivors, and their troops with DDT powder, which was highly effective at killing the body lice that transmitted the disease. Scientists soon noted that because of its ease of application and long lasting residual action, DDT would be useful in controlling another vector borne disease, malaria.

When it is used in malaria control, sprayers apply small amounts of DDT, usually 2g of active ingredient per square meter, on the inside walls of houses and under the eaves outside where mosquitoes rest between blood meals (this is known as IRS – indoor residual spraying). Because of its long lasting action – up to 1 year – DDT vastly improved malaria control as previously, shorter acting insecticides had to be applied to dwellings every 1 to 2 weeks. DDT works in three ways: it is a spatial repellent and as such repels mosquitoes so that they do not enter areas that have been sprayed; it acts as an irritant, so that those mosquitoes that were not repelled, are irritated and exit structures, often before they have fed; finally DDT is acutely toxic to the *Anopheles* mosquitoes and therefore very effective at killing them. With DDT, malaria control officers had within their grasp a tool that could potentially eradicate malaria.

After the Second World War, Southern European countries were the first to attempt IRS programs using DDT. Within a few short years DDT spraying had eradicated malaria from Europe. The United States Government adopted DDT spraying soon after the war, and its use successfully eradicated malaria by 1952. In 1945 the government of Bolivia started using DDT against *Aedes aegypti*, the mosquito vector of the dengue and yellow fever viruses.[8] By 1947 Bolivia had eradicated the mosquito. Bolivia's quick success encouraged the Pan American Health Organization to begin a hemisphere-wide program to eradicate *Aedes aegypti*. By the early 1950s many countries had eradicated or greatly reduced the distribution of this dangerous mosquito. Through their successes, the risks of dengue and yellow fever epidemics largely disappeared from Central and South America.

Table 1 below details DDT's dramatic impact on malaria cases in selected countries in the Americas.

Table 1 Changes in Malaria Morbidity in Countries Before and After Malaria Was Controlled or Eradicated by DDT [9]

Country	Years	Cases	% Change
Cuba	1962 1969	3,519 3	99.9

[8] Severo, O., *Eradication of the Aedes aegypti mosquito from the Americas*, in *Yellow fever: A symposium in commemoration of Carlos Juan Finlay*. 1955, The Jefferson Medical College of Philadelphia: Philadelphia, PA, USA. p. 39-58.

[9] World Health Organization, (1971) Executive Board, 42nd Session, Appendix 14 "The Place of DDT in Operations Against Malaria and Other Vector Borne Diseases" p 177. WHO, Geneva.

Dominica	1950 1969	1,825 Nil	100
Dominican Republic	1950 1968	17,310 21	99.8
Grenada and Curacao	1951 1969	3,233 Nil	100
Jamaica	1954 1969	4,417 Nil	100
Trinidad and Tobago	1950 1969	5,098 5	99.9
Venezuela	1943 1958	817,115 800	99.9

At the same time, many African and Asian countries started using DDT. The vector control programs in South Africa quickly adopted DDT in 1946 and before long the total malarial area was reduced by 80% to low lying border areas with Mozambique and Zimbabwe (then known as Portuguese East Africa and Southern Rhodesia). In the Transvaal Province[10], the number of malaria cases fell to about one tenth of the number of cases reported in 1942/43.

The number of malaria cases on the Indian sub continent was far higher than in South Africa, and the scale of success in malaria control was far more dramatic. In 1951, India's malaria control program began to use DDT and soon after saw some spectacular health benefits. Between 1953 and 1957, morbidity was more than halved from 10.8% to 5.3% of the total population and malaria deaths were reduced almost to zero (the use of new drugs was another key factor in mortality reductions).

After DDT was introduced to malaria control in Sri Lanka (then Ceylon), the number of malaria cases fell from 2.8 million in 1946 to just 110 in 1961. Similar spectacular decreases in malaria cases and deaths were seen in all the regions that began to use DDT. The newly formed Republic of China (Taiwan) adopted DDT use in malaria control shortly after the Second World War. In 1945 there were over 1 million cases of malaria on the island, however by 1969 there were only 9 cases and shortly thereafter the disease was eradicated from the island (and remains eradicated)[11].

In 1955, emboldened by the successes achieved with DDT against malaria, the WHO launched its malaria eradication program, based on the extraordinary successes that had been seen with DDT. The plan was funded mostly by the US Government and was based on four stages:

- preparation,
- attack,
- consolidation and

[10] After South Africa's political transformation to democracy, provincial borders were redrawn and the Transvaal province was turned into 4 new provinces – Gauteng, Mpumalanga, Limpopo Province and North West Province.
[11] World Health Organization, (1971) p 177

- maintenance

In the early 1950s cases of DDT resistance among various Anopheles species was detected by public health experts. In order to preempt the development of insecticide resistance, the WHO proposed that the attack phase would overwhelm the mosquito population with spraying and reduce the population dramatically before any insecticide resistance could develop. The attack phase was only supposed to last 5 years, after which it was anticipated that the transmission of malaria would have been interrupted for a sufficient period that the disease would be eradicated.

The WHO malaria eradication program has been characterized as a failure, and in as far it did not ultimately achieve eradication, that is true. However, the eradication program did dramatically reduce malaria cases and deaths around the world and save millions of live. The WHO no longer plans to eradicate the malaria, but seeks to control it, primarily by promoting its multi-partner Roll Back Malaria (RBM) campaign[12].

While the WHO's malaria eradication plan failed to eradicate malaria, it was extraordinarily successful at reducing malaria cases and deaths. RBM has failed to achieve anything like the kind of successes achieved in the 1950s and 60s by WHO.

In recent years several respected scientific and medical journals have criticized RBM and the agencies behind it. A recent article in the leading medical journal The Lancet, concluded that RBM had not only "failed in its aims, but it may also have caused harm."[13] In 2004, a commentary in the British Medical Journal called RBM "a failing global health campaign."[14] Again in 2004, the leading science journal Nature, published a special report on malaria which recommended, among other things, that legislators hold hearings into the agencies behind RBM to understand why the program is a failure and to take the necessary action to remedy the situation.

We believe that a major reason for the failure of RBM is that it has shunned the use of indoor residual spraying with insecticides, in particular DDT. As we explain below, there is little scientific basis for not supporting DDT in malaria control given the historic and contemporary success of the chemical in controlling malaria and the paucity of data relating to negative environmental or human health effects.

The public policy decisions relating to malaria control has relied on unsound science, and companies seeking to sell alternatives to DDT have used this corrupt process to their own advantage and are going even further in encouraging trade sanctions against countries that seek to use DDT in malaria control.

We now turn to the evidence, or lack thereof, against the use of DDT and discuss the process by which DDT was banned for agricultural use in the US.

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[12] Roll Back Malaria was formed in 1998 as a partnership between among others, WHO, UNICEF, the World Bank, US Agency for International Development (USAID). See www.rbm.who.int

[13] Lancet Editorial comment, "Reversing the failures of Roll Back Malaria" April 23 2005. The Lancet

[14] Gavin Yamey, "Roll Back Malaria – a failing public health campaign" *British Medical Journal*, 328, 1086-1087 (2004) http://bmj.bmjjournals.com/cgi/content/full/328/7448/1086

The campaigns against DDT

Rachel Carson's famous 1962 book *Silent Spring* questioned the impact that synthetic chemicals were having on the environment. Carson's argument was that DDT and its metabolites, DDE and DDD, thin bird eggshells, which leads to egg breakage and embryo death. Carson postulated that DDT would therefore severely harm bird reproduction and led to her theorised silent spring.

There is some evidence that DDT – actually one of DDT's metabolites, DDE – is linked to thinner eggshells for raptors. In particular, a 1975 study by Jeffrey Lincer found an inverse correlation between DDE in North American raptor eggs and eggshell thickness in the American Kestrel[15]. However despite numerous studies on DDT and eggshells, scientists still do not understand how the mechanism by which DDT is supposed to thin eggshells. DDT and its metabolites do not seem to have any effect on poultry, fowl, herring birds and most passerine birds[16].

Despite the evidence concerning the effect of DDE on kestrel eggs, there is a great deal of evidence to suggest that egg shell thinning was occurring long before DDT was ever used. A 1998 study for the Royal Society for the Protection of Birds in the UK found that eggshell thinning had actually begun 50 years before the introduction of DDT. It is likely that changes in habitat, all sorts of other pollutants (oil, lead, and mercury to name but a few), increased noise and other environmental factors could have had an impact on the eggshells.

Without any good evidence, Rachel Carson suggested that insecticides were responsible for the decline in numbers of eagles in America[17]. What Carson didn't point out was that the Bald Eagle had been placed on the endangered species list in 1921, 25 years before DDT was ever produced. In 1937, the bald eagle had disappeared from New England and had declined dramatically in Alaska – one reason was that $100,000 was paid in bounties for over 115,000 bald eagles between 1917 and 1942. The population of bald eagles actually started increasing quite dramatically in the 1960s and early 70s, while DDT was still being used.

Overall the number of birds in the US increased while DDT was being used. The Audubon Society reported in 1960 that 26 bird species had become more numerous since 1941 – interestingly some of those species included raptors[18]. It is likely that the bird

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[15] Lincer, J.L. (1975) DDE-induced eggshell-thinning in the American kestrel: a comparison of the field situation and laboratory results. *Journal of Applied Ecology*, **12:** 781-793.

[16] Passerine birds are perching birds that have feet with four toes so that they can grip onto branches. With around 5,400 species, more than half of all bird species are passerines.

[17] Like the robin, another American bird seems to be on the verge of extinction. This is the national symbol, the eagle. Its populations have dwindles alarmingly within the past decade. The facts suggest that something is at work in the eagle's environment which has virtually destroyed its ability to reproduce. What this may be is not yet definitely known, but there is some evidence that insecticides are responsible. Carson (1972) Silent Spring, Penguin, London, p 113.

[18] See Anon. 1942. The 42nd annual Christmas bird census." Audubon Magazine 44;1-75 (Jan/Feb 1942), and Cruicjshank, AD (editor) 1961. The 61st annual Christmas bird census. Audubon Field Notes 15(2); 84-300

numbers increased because DDT actually killed off many of the parasites that transmitted avian diseases.

Rachel Carson was not the only writer attacking DDT, among others, the biologist Paul Ehrlich wrote:

> The Department of Health Education and Welfare announced studies which showed unequivocally that increasing death rates from hypertension, cirrhosis of the liver, liver cancer, and a series of other diseases has resulted from the chlorinated hydrocarbon load. They estimated that Americans born since 1946 (when DDT usage began) now had a life expectancy of only 49 years, and predicted that if current patterns continued, this expectancy would reach 42 years by 1980, when it might level out[19].

The Department of Health Education and Welfare and Ehrlich were wrong. In 1980, life expectancy at birth for both males and females in the United States was 73.7 years, 31.7 years longer than Erhlich predicted in his alarmist and misleading publication.

Amid the growing pressure from environmentalist groups, in 1971 the newly formed Environmental Protection Agency (EPA) held scientific hearings into DDT. The hearings were held over 8 months, involved 125 witnesses, with 365 exhibits and produced a 9,312 page manuscript. The presiding judge, Edmund Sweeny noted that:

> ...no Hearing Examiner will ever enjoy the privilege that I had in listening to so many leaders in the field of scientific and medical achievement...No restrictions were placed on the number of witnesses they could present, other than the necessary exhortations concerning relevance and materiality. The pros and cons of DDT have been well aired. I think the right of cross-examination spurred a genuinely sober assessment of the facts available, particularly on the question of the benefits and risks of DDT. [20]

Sweeny ruled that DDT should not be banned and with reference to the supposed environmental harms associated with DDT noted that:

> The uses of DDT under the registration involved here do not have a deleterious effect on freshwater fish, estuarine organisms, wild birds or other wildlife[21].

In his ruling Sweeny also noted that:

> "DDT is not a carcinogenic hazard to man... DDT is not a mutagenic or teratogenic hazard to man..."[22]

In other words, Sweeney concluded that DDT did not pose a cancer risk to humans, did not cause mutations in humans and did not pose a threat to developing foetuses. Overall,

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[19] Paul Erhlich, "Eco-Catastrophe" *Ramparts,* September 1969, p. 24-28 reprinted in *Ecocide and Population,* Michel Adelstein and Jean G. Pival, eds. New York: St. Martin's Press (1971).
[20] Edmund Sweeny, Introduction to the Examiner's Report (1972).
[21] Sweeney EM. EPA Hearing Examiner's recommendations and findings concerning DDT hearings., 40 CFR 164.32, 25 April 1972.
[22] Ibid

the conclusion of the hearings was that DDT was relatively benign and the allegations made against it did not stand up to scrutiny. There was no case for banning DDT, and yet Sweeney was overruled by the then administrator of the EPA, William Ruckelshaus who didn't even attend one hour of the hearings. The decision to ban DDT was essentially a political one without any grounding in good science[23].

The reality is that many of the catastrophic predictions made by Carson simply never materialized. Currently DDT is only approved for use in public health programs, which involve spraying tiny amounts of the insecticide on the inside walls of houses. The environmental contamination from this usage is negligible and so criticisms of DDT use on environmental grounds lack scientific validity and are largely irrelevant.

Since the discovery of DDT countless millions of people have been exposed to DDT in one way or another. In this respect AG Smith, of the Medical Research Council's Toxicology Unit at the UK's University of Leicester, writes in the respected peer-reviewed British medical journal, *The Lancet,* that "in the 1940s many people were deliberately exposed to high concentrations of DDT through dusting programmes or impregnation of clothes, without any apparent ill effect" Furthermore, since the 1940s, thousands of tonnes have been produced and distributed throughout the world and millions of people have come into direct contact with DDT. Initially, the distribution was restricted to soldiers in WWII and then to the general public in the aftermath of WWII. When demand for DDT escalated in the post WWII period, a plethora of studies were conducted with regards to DDT's safety for humans. Indeed, Smith notes, "If the huge amounts of DDT used are taken into account, the safety record for human beings is extremely good."

The political nature of the banning of DDT is exemplified by William Ruckelshaus's change in opinion about DDT. Before his position as the head of the EPA, Ruckelshaus was assistant attorney general, where he stated in a US Court of Appeals Report on August 31, 1970 that "DDT has an amazing and exemplary record of safe use, does not cause a toxic response in man or other animals, and is not harmful. Carcinogenic claims regarding DDT are unproven speculation."

However less than a year later when he was with the EPA, he addressed the US Audubon Society, of which he was a member, and noted that "As a member of the Society, myself, I was highly suspicious of this compound, to put it mildly. But I was compelled by the facts to temper my emotions ... because the best scientific evidence available did not warrant such a precipitate action. However, we in the EPA have streamlined our administrative procedures so we can now suspend registration of DDT and the other persistent pesticides at any time during the period of review."[24] Ruckelshaus later explained his ambivalence by stating that as assistant attorney general he was an advocate for the government, but as head of the EPA he was "a maker of policy."

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[23] DDT was the first project that the EPA undertook and Ruckelshaus was probably keen to demonstrate the power of the newly formed authority.. On February 10th 1970, President Nixon announced, "we have taken action to phase out the use of DDT and other hard pesticides." This was before the EPA had even been established.

[24] Address to the Audubon Society, May 2, 1971. Source: Barrons, November 10, 1975.

DDT and Human Health

DDT is probably the most studied synthetic chemical in history and has been used around the world in various different forms and for different reasons for around 60 years. Often DDT was sprayed widely in the environment in enormous quantities and as DDT is persistent in some environments (such as soil), it is likely that most humans have some level of DDT or its metabolites DDE and DDT in their systems. Yet despite its widespread use and thousands of scientific studies, there is little or no compelling evidence to suggest that DDT causes any actual human health harm.

Annex 1 of this report contains a more detailed discussion of the evidence that DDT causes harm to human health. DDT is classified as a possible human carcinogen by the International Agency for Research on Cancer (IARC) which is the same classification given to coffee and numerous other every day foodstuffs. DDT is non-toxic to humans; even people who have attempted suicide by ingesting large amounts of DDT have failed in their endeavor. Although DDT is found in breast milk and is known to act as an endocrine disrupter (much like many natural substances), there are no data to suggest that it causes any actual human harm.

The absence of any credible, scientific evidence against DDT on environmental and/or human health grounds has not stopped individuals, organizations and agencies for calling DDT use to be scaled back. In 2001, the World Health Organization developed an "Action Plan for the Reduction of Reliance on DDT in Disease Vector Control" on the basis of an earlier World Health Assembly resolution (WHA resolution 50.13) that called for the reduction in the use of insecticides in the control of vector-borne diseases[25]. In 2001, the UN Environment Program's Stockholm Convention on Persistent Organic Pollutants granted an exemption for DDT to be used in vector-borne disease control. However, according to the WHO, the Convention also recognized "the need to work towards a longer-term goal of reducing reliance on vector control programmes on pesticides in general and DDT in particular to safeguard ecosystem (sic) and human health alike from the insidious effects of POPs pesticides."[26]

The above statement exposes an inherent bias against insecticides and against DDT in particular. Even though there is little or no evidence of environmental or human health harm from DDT and there is overwhelmingly strong evidence in favor of DDT as a public health tool, pressure against its use continues.

One way of evaluating the need for DDT is to apply the precautionary principle (its possible that the EPA DDT ban was based on an ultra-precautionary concern about DDT's effects). There are various interpretations of the precautionary principle, but a popular definition is known as the Wingspread Definition and states:

> "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect

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[25] World Health Organization "Action Plan for the Reduction of Reliance on DDT in Disease Vector Control" WHO/SDE/WSH/01.5 *WHO*, Geneva, 2001

[26] Ibid. Forward by Dr Richard Helmer, Director, Protection of the Human Environment.

> relationships are not established scientifically. In this context the proponent of the activity, rather than the public, should bear the burden of proof."

US Government policy analyst Indur Goklany suggests that when evaluating a chemical such as DDT, one should apply the precautionary principle with regard to four criteria[27]. First, one should evaluate the impact on human mortality and morbidity where human lives must be considered to be more important than bird or animal life. Second, one must evaluate the immediacy of the threat, where immediate threats should be considered more important than potential threats in the future. One reason for this is that in the future we may have some method of mitigating the potential negatives consequences of the chemical. Third, one must consider the uncertainty surrounding the use of DDT, where any outcomes that we know of with certainty must be given more weight than any outcomes that we are uncertain about. Lastly, one has to consider the irreversibility criterion; whereby potentially negative outcomes that are irreversible must be treated more seriously than those that are reversible.

When evaluating the use of DDT, applying every one of these criteria would rule in favor of DDT use in malaria control. Due to DDT's remarkable effectiveness in averting human illness and death from vector borne diseases and the negligible impact on the environment when used in public health, the first criterion must rule in favor of DDT.

Second, the immediacy criterion must rule in favor of DDT. Every thirty seconds a child dies from malaria and yet in the 60 years that DDT has been used, no scientific replicated study has been able to point to actual human harm from the insecticide. Even in the unlikely event that some negative human health effect was scientifically proven in the future, the fact that lives can be saved by using DDT right now, one must reject calls for DDT not to be used.

Third, given the certainty of illness and potential death that arises from malaria and the ongoing uncertainty surrounding the impact of DDT on human health and the environment, again, one must rule in favor of DDT when evaluating the uncertainty criterion.

Lastly, we know that when DDT was banned for agricultural use, levels of DDT and its metabolites DDE and DDD in the environment fell. The potential environmental harm that could arise from DDT is therefore reversible, however it is impossible to reverse the deaths that arise from malaria. Once again, on this criterion, one can only favor DDT.

In summary, when malarial countries evaluate the risks that their citizens face from disease and apply the precautionary principle to DDT, they can only favor its use in malaria control. It is perhaps for this reason that countries in Africa are returning to the use of DDT in malaria control, however not without opposition from donor

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[27] Indur Goklany (2001) "The Precautionary Principle" Cato Institute, Washington DC

agencies, private enterprise with vested interests in the use of other insecticides and the European Union.

DDT in malaria control today

South Africa maintained its IRS program using DDT from 1946 to 1996. In 1996 the Department of Health replaced DDT with synthetic pyrethroid insecticides. As DDT is best sprayed on traditional mud structures, and an increasing number of houses in rural malarial areas are made in the western style with plastered and painted walls, the government was correct to attempt to introduce alternative insecticides. However, largely because agriculture uses synthetic pyrethroid insecticides, insecticide resistance soon became a problem. A highly efficient malaria vector, *Anopheles funestus*, believed to have been eradicated in the 1970s, soon reappeared in South Africa.[28] What followed was one of the worst malaria epidemics in the country's history. Malaria cases rose from around 6000 in 1995 to over 60 000 in 2000.[29]

In early 2000, South Africa reintroduced DDT to malaria control in KwaZulu Natal Province, the province worst hit by the epidemic. In 2001, South Africa further introduced new artemesinin-based combination therapies to treat malaria patients. The combination of effective insecticides and drugs ensured that malaria cases fell by almost 80% by the end of 2001.

In 2000 a privately funded IRS program in the Zambian Copperbelt Province began using DDT in its IRS program. The DDT spraying was solely responsible for 50% decline in malaria cases after just one spraying season.[30] The success of this program continues and has influenced national malaria control policy such that other parts of Zambia have implemented DDT IRS programs. Other southern African countries that have successfully used DDT to control malaria include Swaziland, Namibia, Zimbabwe and Madagascar.

All of these countries ensure that well structured, vertical malaria control programs use DDT, programs that have good scientific oversight and control and monitor the use of the chemical (Zimbabwe's economy has collapsed and its program is far less effective than before, but nevertheless it was previously successful). For instance, when Zambia returned to using DDT, it did so with the full cooperation and involvement of the Environmental Council of Zambia (ECZ), Zambia's equivalent of the Environmental Protection Agency (EPA). It is directly in the interests of malaria control program managers to ensure that no DDT is diverted to agriculture or some other use – should that happen it may jeopardize their control programs by causing insecticide resistance.

Despite the clear and unequivocal success of DDT in malaria control in several southern African countries, there is still a great reluctance, or outright refusal, among the various

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[28] K Hargreaves et al. (2002) "Anopheles funestus resistance to synthetic pyrethroid insecticides in South Africa." Medical and Veterinary Entomology, 14, no.2: 181-89

[29] South African Department of Health, *National Malaria Update* (SA Dept of Health, 2003, Pretoria)

[30] B Sharp et al. (2002) "Malaria control by residual insecticide spraying in Chingola and Chililabombwe, Copperbelt Province, Zambia" *Tropical Medicine and International Health*, 7, no 9: 732-36

UN agencies involved in malaria control to support indoor residual spraying (IRS) and/or DDT.

For instance, WHO's Geneva office, which is far removed from those offices in malarial countries, has either ignored DDT or actively discouraged its use. An example of this anti-DDT and anti-insecticides bias is found in the 2003 Africa Malaria Report which is a fine example of WHO Geneva's stonewalling of DDT and more generally of IRS[31]. Although this report advertises itself as a comprehensive study on the malaria situation, it barely mentions IRS, even though this is the main method of malaria control for much of southern Africa.

The United States Agency for International Development (USAID), like most other donors, has followed WHO and other UN agency lead and has not supported IRS for many years. USAID's official position is that it will only promote DDT as a "measure of last resort". This gives the agency carte blanche never to support DDT as they can always claim that other tools of malaria control have not been tried.

> "in those (relatively rare) cases where DDT is truly needed for malaria control, the benefits of its use as a vector control tool are considered to outweigh the risks the chemical presents to human health and the environment.[32]"

While some misplaced concern for the environment and human health may be part of USAID's reasons for refusal to fund IRS, the more significant reason is likely to be the vested interests that influence its spending plans. In 2004, USAID's budget for malaria control stood at around US$80 million. However, the agency provides no documentation that it spends a single cent buying either insecticides or effective artemsinin drugs for malaria control[33]. The vast majority of the agency's budget is directed towards US-based consultants who 'advise' malaria control programs and conduct nebulous projects that have no clear deliverables. USAID, like most other donor agencies, is far more comfortable directing its funding to its own consultants, rather than the departments of health in the countries they are supposed to be assisting.

Should an aid agency wish to support IRS, either with or without the use of DDT, it would have to direct funds specifically into a Department of Health or some other agency that would then procure insecticides, spray pumps and hire and train the required personnel. However for this to happen, the aid agency and its preferred contractors would lose control of the funds and the power that those funds give them; something they appear loath to do.

Several congressional hearings have been held in order to understand better USAID's malaria control program, to increase its transparency and accountability and to improve

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[31] World Health Organization (2003) Africa Malaria Report, WHO, Geneva. http://www.rbm.who.int/amd2003/amr2003/amr_toc.htm

[32] Pers Comm. Brian Hirsch, USAID, 20 June 2001

[33] Roger Bate & Benjamin Schwab (2005) The Blind Hydra, USAID Fails to Control Malaria. American Enterprise Institute, Washington DC, April 22 2005

its overall performance[34]. Indeed, in April 2005 Senators Brownback (R, KS), Landrieu (D, LA) and Coburn (R, OK) as well as yourself, Mr. Chairman, introduced the End Neglected Diseases Bill (S.950) which is designed to set earmarks for commodity procurement made by USAID and to increase the transparency with which USAID spends taxpayers money. (See Annex 2)

We appreciate the fact that Senate appropriators have included language in the Foreign Operations and Related Program Appropriations Act that requires the purchase of commodities and we hope that this Senate language is retained in Conference. (See box below) Given USAID's poor track record on malaria control in the past, we would have preferred to see specific earmarks for USAID malaria spending in the appropriations language. We are however reassured in the knowledge that the US Senate will exercise sufficient oversight over USAID to ensure that it does indeed purchase sufficient commodities for malaria control.

HR 3507 – Department of State, Foreign Operations and Related Program Appropriations Act, 2006 (Engrossed Amendment as Agreed to by Senate)

Malaria

SEC. 6125. Of the funds appropriated under the heading `Child Survival and Health Programs Fund', not less than $105,000,000 should be made available for programs and activities to combat malaria: Provided, That such funds should be made available in accordance with best public health practices, and considerable support should be provided for the purchase of commodities and equipment including: (1) insecticides for indoor residual spraying that are proven to reduce the transmission of malaria; (2) pharmaceuticals that are proven effective treatments to combat malaria; (3) long-lasting insecticide-treated nets used to combat malaria; and (4) other activities to strengthen the public health capacity of malaria-affected countries: Provided further, That no later than 90 days after the date of enactment of this Act, and every 90 days thereafter until September 30, 2006, the Administrator of the United States Agency for International Development shall submit to the Committees on Appropriations a report describing in detail expenditures to combat malaria during fiscal year 2006.

In July 2005, President Bush announced a significant increase in funding for malaria control of $1.2 billion over five years. It is now clear that these funds will be utilized by USAID, yet without specific legislation that would compel the agency to purchase commodities that save lives and to support activities that are proven to work, the funds will probably be wasted.

In addition to the way in which USAID favors its own contractors over the needs of malarial countries when funding malaria control, it now appears that private companies have been taking advantage of the bad science and misinformation around the use of DDT in order to advance their own commercial interests.

[34] On 12 May 2005, the US Senate Subcommittee on Federal Financial Management, Government Information and International Security (FFM) held a hearing into the practices of USAID on malaria control..

For several years, the Government of Uganda has been attempting to reintroduce the use of DDT to its malaria control program. The WHO reports that in 2003 there were over 12 million cases of malaria and around 93% of the 27 million strong population live at risk from the disease. The decision to use DDT is a wise one, based on the successful use of DDT in the past in Uganda and the contemporary success of DDT in malaria control in other African countries. In a pilot project between 1959 and 1960 in the Kigezi district of Uganda, DDT spraying ensured that malaria parasite prevalence for all ages fell from 22.4% to just 0.5% when DDT was sprayed three times a year and from 12.5% to 0% where it was sprayed twice a year[35].

Yet opposition to DDT is considerable and on February 2 2005, the UN news agency IRIN reported that the European Union had cautioned Uganda against using DDT. Specifically the agency reported:

"If Uganda is to use DDT for malaria control, it is advisable to do so under strictly controlled circumstance and in consultation with other countries in the region that may be affected." In addition the EU has called for a parallel system to monitor foodstuffs and to take corrective measures "to address DDT-related health concerns of consumers in Uganda and in export destinations."[36]

On 26 April 2005, the EU made further statements in order to discourage Uganda from using DDT. The UN Newswire reported that chief of the EU mission in Uganda, Sigurd Illing, said "there could be dire consequences for the country's exports to Europe - which account for more than 30 percent of Uganda's total exports - if DDT was detected in export commodities such as horticultural produce. The EU has strict maximum limits of pesticide levels in products meant for animal or human consume, especially on prohibited chemicals such as DDT."

Africa Fighting Malaria recently obtained evidence that the EU is being supported by among others, Bayer Crop Science, a division of the giant multi-national chemical and pharmaceutical company that produces alternatives to DDT[37]. In an email dated September 23 2005, Dr. Gerhard Hesse of Bayer Crop Sciences first admits that his company has a direct commercial interest in DDT not being used and then states that on the basis that some DDT might be diverted from public health programs to agriculture, he and his company therefore:

" fully support EU to ban imports of agricultural products coming from countries using DDT."[38]

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[35] World Health Organization, (1971) Executive Board, 42nd Session, Appendix 14 "The Place of DDT in Operations Against Malaria and Other Vector Borne Diseases" p 179. WHO, Geneva.

[36] UN Newswire "EU cautions over plans to use DDT to fight malaria" February 2 2005. http://www.reliefweb.int/rw/RWB.NSF/db900SID/DDAD-699MXX?OpenDocument

[37] Bayer Crop Sciences recorded annual sales in 2004 of over US$ 7bn. For more information on Bayer Crop Sciences see. http://www.bayer.com/subgroups/bayer-cropscience/page1311.htm

[38] Pers comm. Dr Gerhard Hesse September 23 2005

Without providing any actual evidence that DDT was indeed being diverted out of public health programs and into agriculture, Bayer Crop Sciences is ignoring decades of evidence of safe and effective use of DDT and is playing on the misguided fears about the insecticide.

We fear that commercial entities such as Bayer and intransigent and ineffective agencies such as USAID are using bad science and fear about DDT in order to advance their own particular interests. The outrageous tragedy is that children in Uganda and elsewhere are paying with their lives and facing a blighted future so that this coalition of industrial concerns and public agencies can maintain their power base and profits.

Standing in stark contrast to the behavior of aid agencies such as USAID is the Global Fund for AIDS, TB and Malaria (GFATM). This organization acts purely as a funding agency, providing funds for projects that an expert panel considers feasible and valuable. The GFATM does not seek to advise a country on how to conduct its public health programs; it simply provides funds for projects that an expert panel has vetted. Perhaps it is precisely because of this difference in structure that the Global Fund is currently funding some of the most successful malaria control interventions, which include IRS and DDT, while the bilateral donor agencies are funding ITNs, which have failed to reduce the incidence of malaria in any significant way.

Summary and Conclusion

We hope that this testimony has shed some light on the importance of DDT as a public health insecticide and has explained how bad science and the vested interests of commercial organizations, various UN bodies and career bureaucrats has restricted its use in malaria control. We now have evidence that the private sector is complicit in using the threat of trade sanctions to stop Uganda and possibly other countries from using DDT. The role that Bayer Crop Science and the European Union has played in undermining malaria control in Uganda deserves further investigation and we feel that legal action through the World Trade Organization should not be discounted.

Mr. Chairman, we thank you for the opportunity to make this submission and sincerely hope that this hearing will advance the use of good science and expose the disastrous and long term consequences that arise when good science is ignored.

Annex 1

DDT and Human Health.

Is DDT toxic to humans?

DDT's detractors claim that DDT is toxic to humans and when ingested leads to tremors, liver damage, neurological disorders, to name a few. Scientists have studied very few chemicals as extensively as DDT, either experimentally or in human beings. Before DDT was ever used, extensive tests were conducted to establish the safety and efficacy of the chemical. According to West and Campbell,

> "..literally hundreds of animals were experimented upon before DDT was used in the Services. It was administered by mouth, cutaneously and sub-cutaneously; it was rubbed on the skin, with and without the presence of fatty oils...and then a complete history of any pathological symptoms recorded. Post-mortem examination was carried out on all the important organs and tissues, and microscopic slides made of the examination of the degree of affection. The decision was finally made in favor of the use of DDT...."[39]

Even prior to the ban, one of the leading scientific journals, Science, ran a large number of papers on DDT. The majority of these papers were antagonistic, despite the editor of Science, Phil Abelson's own conclusion that:

> "...DDT and its relatives are not truly persistent but are slowly destroyed in soil. DDT is slowly degraded in man, and it is also excreted, so that concentrations do not build up indefinitely."

Malaria specialists refuted the numerous claims against DDT, however the assault on the chemical persisted despite the lack of evidence.

Professor Chris Curtis of the London School of Hygiene and Tropical Medicine has studied the health of 'spraymen', insecticide public health sprayers, from Brazil and India who had been exposed to DDT "was similar to other men of their age."[40] Furthermore, a controlled study conducted on the long term effects of DDT exposure in the early 1950s, which was funded by the United States Public Health Service, found that despite the volunteers in the sample consuming as much as 35 milligrams of DDT every day for 18 months, no adverse effects were found, either at the time of the study or during the follow up investigation ten years later. Indeed, AG Smith notes, "Ingestion of DDT, even when repeated, by volunteers or people attempting suicide has indicated low lethality, and large acute exposures can lead to vomiting, with ejection of the chemical".

Smith summed up the prevailing evidence on DDT human toxicity as follows:

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[39] -West. T.F. and G.A. Campbell, *DDT and Newer Persistent Insecticides*, New York: Chemical Publishing Co., Inc. (1952).

[40] Curtis CF and Lines JD "Should DDT be banned by international treaty" Parasitology Today vol. 16, no. 3, 2000 pp 119-121

> In the 1940s many people were deliberately exposed to high concentrations of DDT thorough dusting programs or impregnation of clothes, without any apparent ill effect. There are probably few other chemicals that have been studied in as much depth as has DDT, experimentally or in human beings.[41]

An agency that has conducted considerable research into DDT is the Agency for Toxic Substances and Disease Registry (ATSDR). This agency forms part of the US Department of Health and Human Sciences and is charged with assessing the health hazards and health effects arising from exposure to hazardous substances. The ATSDR works with its sister organization, the Centers for Disease Control (CDC) and has a joint office of the Director of the National Centre for Environmental Health.

The ATSDR contains the following conclusions for non-occupational inhalation exposure: "No studies were located regarding death in humans or animals after inhalation exposure to DDT *or any of its derivatives* DDE, and DDD". Furthermore, they note that "No studies were located regarding cardiovascular, gastrointestinal, haematological, musculoskeletal, hepatic, renal or dermal effects in humans or animals after inhalation exposure to DDT, *or its derivatives* DDE and DDD" (ATSDR 2002). More broadly the ASTDR states that "studies have monitored human tissue and blood for DDT and its metabolites, but no correlation has been made between the levels found in these tissues and specific disease states."[42]

Thus in terms of the toxicity of DDT and its derivatives on both an acute and chronic basis, the results tend to suggest that DDT is relatively harmless to humans and animals.

Does DDT cause cancer in humans?

The International Agency for Research on Cancer (IARC) categorizes DDT as a possible human carcinogen. The IARC is part of the World Health Organization and its mission is:

> " to coordinate and conduct research on the causes of human cancer, the mechanisms of carcinogenesis, and to develop scientific strategies for cancer control. The Agency is involved in both epidemiological and laboratory research and disseminates scientific information through publications, meetings, courses, and fellowships."[43]

The IARC has five categorizations of carcinogenicity:

Group 1: The agent (mixture) is carcinogenic to humans. The exposure circumstance entails exposures that are carcinogenic to humans.
Group 2 (two classifications):
Group 2A: The agent (mixture) is probably carcinogenic to humans. The exposure circumstance entails exposures that are probably carcinogenic to humans.

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[41] A.G. Smith, "How Toxic is DDT?" *Lancet*, Vol. 36, No.9226, July 22, 2000.) http://www.malaria.org/smithddt.html.
[42] ATSDR Toxicological Profile of DDT, 2002, p. 206, http://www.atsdr.cdc.gov/toxprofiles/tp35.html
[43] http://www.iarc.fr/

Group 2B: The agent (mixture) is possibly carcinogenic to humans. The exposure circumstance entails exposures that are possibly carcinogenic to humans.
Group 3: The agent (mixture, or exposure circumstance) is not classifiable as to carcinogenicity in humans.
Group 4: The agent (mixture, exposure circumstance) is probably not carcinogenic to humans.[44]

The IARC classifications list the agents or groups of agents according to their carcinogenic risk. The classifications also list mixtures of products as well as the likely circumstances in which humans may be exposed to cancer risk. Some of the agents that make up Group 1 include asbestos, mustard gas, plutonium 239, radium 224,226,228 and their decay products and X and gamma radiation. The mixtures that make up group 1 include tobacco, wood dust and Chinese-style salted fish and the circumstances that would put one at risk to Group 1 agents include tobacco smoking, furniture and cabinet making, boot and shoe manufacture and repair and aluminum production.

Group 2A agents include androgenic (anabolic) steroids, Benzedrine-based dyes and ultraviolet radiation A,B and C. The mixtures of agents are made up of, among others, creosotes and diesel engine exhaust and the circumstances under which humans may be exposed to Group 2A products include hair dressing, petroleum refining and using sun beds and sun lamps.

Group 2B agents include aflatoxin, insecticides such as DDT and chlordane, lead and zidovudine which forms part of the HIV/AIDS treatment AZT. The mixtures contained in Group 2B include coffee, carageenan, which is used as a thickener in many dairy products and east Asian-style pickled vegetables. The likely activities that would expose humans to these agents and mixtures are dry cleaning, carpentry and joinery and textile manufacturing.

The agents that are non-classifiable according to their carcinogenicity, Group 3 agents, include fluorescent lighting, fluorides, dieldrin, sulphur dioxide and surgical implants including dental implants and silicone. The mixtures of products include tea, fuel oil, diesel fuels and printing inks and the circumstances of exposure to the various products include the use of personal hair dying products, the manufacture of leather goods and paint manufacture.

The only substance that IARC has officially declared to probably not be a carcinogen, the sole member of Group 4, is caprolactam, which is used in the manufacture of synthetic fibers. All other tested substances fall into Groups 1 to 3.

Although the World Health Organization's cancer agency ranks DDT in the same category as coffee, the US Environmental Protection Agency (EPA) classifies DDT as a probable human carcinogen, giving it a higher carcinogen weighting.

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[44] http://monographs.iarc.fr/monoeval/grlist.html

Based upon these classifications it would appear that the EPA possesses additional information about DDT's potential carcinogenicity that IARC does not have, but that is not the case. Both agencies appear to have considered exactly the same data.

Likewise EPA appears to have used similar data, but it appears to assign more weight to animal studies than does IARC. To be classified as a probable carcinogen (Class B2), as DDT is, there needs to be ""sufficient" evidence from animal studies" and ""inadequate evidence" or "no data" from epidemiologic studies."

One of the most common allegations against DDT is that it is carcinogenic, yet neither EPA nor IARC have reached this conclusion. Although this allegation has been publicized widely by various organizations and commentators, there is little substance to the claim.

Furthermore, the Agency for Toxic Substances and Disease Registry notes reviewed studies testing the hypothesis that DDT and its metabolites could cause cancer in humans. The ATSDR, which is an agency of the US Department of Health and Human Services, reviewed breast cancer, pancreatic cancer, Hodgkin's disease and Non-Hodgkin's Lymphoma, multiple myeloma, prostate and testicular cancer, endometrial cancer and the occurrence of any other cancer. Their conclusion was that:

> "The possible association between exposure to DDT and various types of cancers has been studied extensively, particularly breast cancer. Thus far, there is no conclusive evidence linking DDT and related compounds to cancer in humans"[45] (ASTDR 2000).

The Health and Human Services report makes it clear that HHS has arrived at similar conclusions to IARC as to carcinogenicity for the report states. "Overall, in spite of some positive associations for some cancers within certain subgroups of people, there is no clear evidence that exposure to DDT/DDE causes cancer in humans."

Leading US toxicologists, Bruce Ames, who was awarded the top scientific honor, the National Medal of Science by President Clinton in 1999, and Lois Gold of University of California at Berkeley, put the cancer risk associated with DDT into a wider perspective. Their research shows that even at the height of DDT's usage in agriculture, the cancer risk associated with DDT was far lower than that of the cancer risk associated in everyday foodstuffs.

For instance, our intake of coffee is about 50 times more carcinogenic than our intake of DDT before it was banned. Figure 1 below shows clearly the risk – represented by the Human Exposure Dose/Rodent Potency dose – the relative cancer risk of DDT compared with chemicals that we consume in everyday food products.

Figure 1 Human Exposure Dose/Rodent Potency of possible human carcinogens. (Ames and Gold 1999)

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[45] ATSDR, (2002) p 124

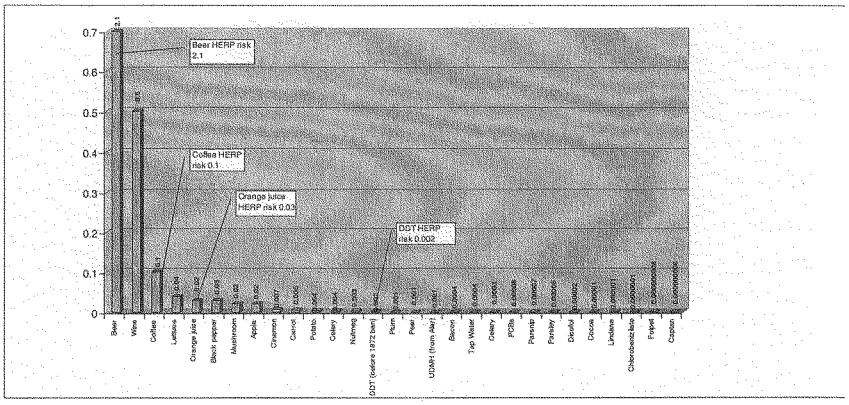

Table 2 below gives more detailed data for some of the possible carcinogenic hazards features in figure 1 above. Some of these carcinogenic substances that many of us ingest as part of a normal, balanced diet, are classified in groups 1, 2A and 2B of the IARC rating system. For instance, 8-Methoxypsoralen which is found in celery, parsnip and fresh parsley is classified in Group 1 and as a carcinogenic to humans. Of course the exposure at which humans encounter this substance means that the Human Exposure Rodent Potential hazard is only 0.0002% for celery, 0.00007% for parsnip and 0.0005% for fresh parsley.

Coffee contains several possible carcinogens, such as caffeic acid and catechol, both of which are classified as Group 2B, possible human carcinogens. Indeed caffeic acid is found in several foodstuffs, such as apples, plums, pears, lettuce and carrots.

Table 2 Selected ranking of possible carcinogenic hazards from average US exposures

Possible hazard HERP (%)	Average daily US exposure	Human dose of rodent carcinogen	Potency TD_{50} (mg/kg/da	
			Rats	Mice
2.1	Beer, 257g	Ethyl alcohol 13.1ml	9110	(-)
0.5	Wine, 28.0g	Ethyl alcohol 3.36ml	9110	(-)
0.1	Coffee, 13.3g	Caffeic acid 23.9mg	297	(4900)
0.04	Lettuce, 14.9g	Caffeic acid, 7.90mg	297	(4900)
0.03	Orange Juice 138g	d-Limonene 4.28mg	204	(-)
0.03	Pepper, black 446g	d-Limonene, 3.57mg	204	(-)
0.02	Mushroom (*Agaricus bisporus* 2.55g)	Mixture of hudrazines, etc. (whole mushroom)	-	20,300

0.02	Apple, 32.0g	Caffeic acid, 3.40mg	297	(4900)
0.007	Cinnamon, 21.9mg	Coumarin, 65.0mg	13.9	(103)
0.002	Carrot, 12.1g	Caffeic acid, 374g	297	(4900)
0.002	DDT: daily US avg before 1972 ban	DDT, 13.8g	(84.7)	12.3
0.001	Pear, 2.00g	Caffeic acid, 240mg	297	(4900)
0.0008	DDE, daily US avg before 1972 ban	DDE 6.91 mg	(-)	12.5
0.0002	Celery, 7.95g	8-Methoxypsoralen, 4.86mg	32.4	(-)
0.00001	Cocoa, 3.34g	a-Methylbenzyl alcohol 4.3mg	458	(-)

a = no data in CPDB; (-) = negative in cancer test; (+) = positive cancer test(s) not suitable for testing TD_{50}

In summary, agency opinion and the written literature finds no good evidence linking DDT or its metabolites with human cancer. Given the fact that DDT has been used in enormous quantities for over six decades and that many studies into its potential carcinogenicity have been conducted, without drawing any evidence thereof, we can be relatively secure in asserting that DDT is not responsible for cancer in humans.

DDT and Endocrine Disruption

The possibility that man-made chemicals, such as DDT, could disrupt the functioning and development of an organism came about during the 1990s. Scientists from a range of disciplines have proposed that synthetic chemicals can interfere with glands and hormones in humans and animals. This is not something that can easily be dismissed – the ATSDR confirms that DDT given during pregnancy can slow the growth of a foetus and it may change the way the reproductive and nervous systems work. Some studies have showed that DDT or its metabolites can mimic the properties and actions of natural hormones. Tests on rats have shown that DDT can delay puberty and tests on mice showed that DDT could cause neurobehavioural problems when they grow up.

This may sound very worrying, but it is likely that even if DDT acts in this way, it is likely to be biologically insignificant. While the studies into endocrine disruption are of course important, they should be weighed against many studies conducted over many years that can find no harm to the reproductive capability or general health of monkeys, dogs, rats and so on.

One study conducted in 2001 by Mathew Longnecker observed that as maternal serum DDT levels increase, so do the odds of small-for-gestational-age and preterm infants[46]. Yet there were many flaws with Longnecker's study. For instance over half of the children selected for the study were expressly chosen because something was wrong with them. Boys were specifically included because they had deformations of the penis, testicles or nipples and both boys and girls that deviated from normal cognitive and neurological tests were selected. In essence, Longnecker 'cherry picked' his data. Furthermore the study does not explain if DDT-related effects were found in the children

[46] Longnecker MP, Klebanoff MA, Zhou H, Brock JW. "Association between maternal serum concentration of the DDT metabolite DDE and preterm and small-for-gestational-age babies at birth" *Lancet* 358:110–4 (2001).

that were randomly chosen. The study is also flawed because the researchers fail to disclose what objective standard they used to judge smallness-for-gestational age. Most worryingly, the researchers did not control for the presence of other organochlorines. Given that at least one other organochlorine – PCBs – was found in the same pregnant women, it would seem to be highly relevant and important to control for this factor.

Longnecker's study and others fail to demonstrate that DDT is associated with endocrine disruption, small-for-gestation age and reduced lactation.

It is important of course, as with the claims about DDT and cancer, to put the endocrine disruption allegations into some sort of context. It is crucial to link endocrine disrupting compounds with adverse human health effects because the human diet contains naturally occurring endocrine disruptors in fruits and vegetables. Indeed the effect of naturally occurring endocrine disruptors in foodstuffs such as potatoes, carrots, peas, beans, apples, garlic and coffee is far stronger than the hormonal effects of synthetic chemicals. As Stephen Safe, Professor of Toxicology at Texas A&M University explains, "the amount of estrogenic compounds found in a single glass of cabernet wine is 1000 times greater than the estimated daily intake of estrogenic organochlorine pesticide residues."[47]

Not only have the potential endocrine disrupting action of organochlorines not been put in perspective, but claims persist that chemicals such as DDT are linked to declining male reproductive capacity and to breast cancer[48] [49]. Pressure against the use of organochlorines (among them DDT) persist because of the claim that they are linked to a fall in sperm quality. In 1992 Danish scientists of the Copenhagen University Hospital[50] published a paper showing that the number of sperm cells in men's semen had fallen over the past 50 years.

The study was widely reported by the media and used very effectively by environmentalist groups such as Greenpeace in their campaign against synthetic chemicals. The study has however been widely criticized and subsequent studies have found stable sperm counts. Part of the problem with these studies is that we do not have reliable pre-1970 data and so time series comparisons of sperm quality are inherently unreliable. According to Stephen Safe, "researchers have found no correlation between chemical exposures and measures of decreased male reproductive capacity. Demographic differences are more likely to account for the differences seen in the initial studies.[51]"

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[47] ibid, p. 190

[48] Liroff, R "Reduction and elimination of DDT should proceed slowly" *British Medical Journal*, **Vol 321**. 2 December 2000, pp 1404-1405

[49] World Wildlife Fund *Resolving the DDT Dilemma*, World Wildife Fund (1998)

[50] Carlsen, E, Giwercman A, Keiding, N, Skakkebæk, N "Evidence for decreasing quality of semen during the past 50 years" *British Medical Journal* **Vol. 305**, pp 09-13

[51] Safe (2000) p 190. For instance, we know that the shorter the time since an ejaculation, the lower a man's sperm count is. During the time period chosen 1992 Danish study, statistics have shown that the frequency of masturbation has doubled for unmarried men (from 30 times a year to 60) and it also rose for married men (from 6 times a year to 24). At the same time the frequency of marital coitus also increased from around 1.9 times a week to 3 times a week (for married 30-year olds). So the sexual revolution of the 1960s could contribute greatly to the any observed decrease in sperm quality. Lomborg, B The *Skeptical Enironmentalist*, Cambridge, 2001. p 240

More recently a study conducted in the Limpopo Province of South Africa failed to find any strong evidence for a link between DDT and low semen quality among DDT spraymen[52].

The theory of endocrine disruption does not fix on a precise role that DDT is supposed to play. Because of this, the theory of endocrine disruption is hard to prove or disprove. However, given the paucity of data supporting any harm from DDT and the decades of actual data supporting the fact that wherever DDT has been used, both mortality and morbidity have fallen and populations have risen, one can safely conclude that the evidence in favor of DDT disrupting the endocrine system is weak or non-existent.

DDT and Non-Hodgkin's Lymphoma

As with breast cancer, attempts have been made to associated DDT and its metabolites with non-Hodgkin's lymphoma; and as with breast cancer, the conclusion of the scientific community simply does not support the association.

A 1998 study found that "no strong consistent evidence was found for an association between exposure to DDT and the risk of non-Hodgkin's lymphoma."[53] A study of nonfarmers and farmers in four Midwestern states also failed to find an association between DDT exposure and NHL. The ATSDR notes that the odds ratio for the occurrence of NHL "were lower and not statistically significantly elevated above unity for using or handling DDT applied to animals or applied to animals and crops combined. When adjusted for use of other individual pesticides or pesticide groups, when evaluated by type of non-Hodgkin's lymphoma disease, or when stratified by co-exposure to 2,4-D and organophosphate pesticides, no significant odds ratios were observed. No association was observed between estimated duration of DDT use and occurrence of non-Hodgkin's lymphoma, adjusted for use of other pesticides."[54]

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[52] Dalvie MA, Myers JE, Thompson ML, Robins TG, Dyer S, Riebow J, Molekwa J, Jeebhay M, Millar R, Kruger P. "The long-term effects of DDT exposure on semen, fertility, and sexual function of malaria vector-control workers in Limpopo Province, South Africa." Envrion Res 2004 Sep;96(1):1-8

[53] Barris D, Zahm SH, Cantor KP, Blair A "Agricultural use of DDT and risk of non-Hodgkin's lymphoma" pooled analysis of three case-control studies in the United States." Occup Environ Med 55:522-7 (1998)

[54] ATSDR, Toxicological profile, DDT, p 119.

DDT: A Case Study in Scientific Fraud

J. Gordon Edwards, Ph.D.

ABSTRACT

The chemical compound that has saved more human lives than any other in history, DDT, was banned by order of one man, the head of the U.S. Environmental Protection Agency (EPA). Public pressure was generated by one popular book and sustained by faulty or fraudulent research. Widely believed claims of carcinogenicity, toxicity to birds, anti-androgenic properties, and prolonged environmental persistence are false or grossly exaggerated. The worldwide effect of the U.S. ban has been millions of preventable deaths.

Fraud in science is a major problem. A 2002 report published by the American Association for the Advancement of Science (AAAS) on "fraud in science in Germany" stated that International Scientific Misconduct Rules should "punish deliberate or grossly negligent falsification or fabrication of data," and that "failure to cooperate with investigations will be considered an admission of guilt." Ombudsmen will be appointed "to probe for examples of misconduct, including falsification, fabrications, selective use of data, and manipulation of graphs and figures."[1] Upon reading this article, I prepared a 34-page list of frauds published in U.S. scientific journals and sent it to the editor of *Science*. Although he responded courteously, he evidently did not wish to publicize this.

The most common examples of fraud in the United States appear to be environmental, including acid rain, ozone holes, carbon dioxide, ultraviolet radiation, global cooling, global warming, endangered species, and pesticides. This article will primarily concern the last, especially DDT.

Value of Pesticides to Humanity

DDT (dichlorodiphenyltrichloroethane) was first produced in 1874 by German chemist Othmar Zeidler, but he did not suggest any actual use for it. Sixty years later, Paul Müller duplicated the procedure and discovered the chemical's insecticidal potential. For this, he received the Nobel Prize in 1948.

DDT has been effective in controlling mankind's worst insect pests, including lice, fleas, and mosquitoes. This was of enormous importance for human health because at least 80 percent of human infectious disease worldwide is arthropod borne.[2] Hundreds of millions have died from malaria, yellow fever, typhus, dengue, plague, encephalitis, leishmaniasis, filariasis, and many other diseases. In the 14th century bubonic plague (transmitted by fleas) killed a fourth of the people in Europe and two-thirds of those in the British Isles. Yellow fever killed millions before it was found to be transmitted by *Aedes* mosquitoes. It infected British troops in the Louisiana Territory in 1741, killing 20,000 of the 27,000 soldiers. In 1802, French troops arrived there but departed after 29,000 of the 33,000 soldiers died of yellow fever. More than 100 epidemics of typhus ravaged civilizations in Europe and Asia, with mortality rates as high as 70 percent. But by far the greatest killer has been malaria, transmitted by *Anopheles* mosquitoes.

In 1945 the goal of eradicating this scourge appeared to be achievable, thanks to DDT. By 1959, the U.S., Europe, portions of the Soviet Union, Chile, and several Caribbean islands were nearly malaria free.[3] In 1970 the National Academy of Sciences stated: "To only a few chemicals does man owe as great a debt as to DDT. In little more than two decades DDT has prevented 500 million human deaths due to malaria that would have otherwise have been inevitable."[4]

Today, however, after the U.S. ban on DDT, there is a global malaria burden of 300 to 500 million cases and 1 to 2.5 million deaths annually,[5,6] mostly among young children. Malaria kills an African child every 30 seconds.[7]

Many South American countries suffered more than 90 percent increases in malaria rates after halting DDT use, but Ecuador used DDT again and enjoyed a 61 percent *reduction* in malaria.[8]

Rachel Carson's *Silent Spring*

On the first page of the book widely credited with launching the environmental movement as well as bringing about the ban on DDT, Rachel Carson wrote: "Dedicated to Dr. Albert Schweitzer, who said 'Man has lost the capacity to foresee and forestall. He will end by destroying the earth'."[9] She surely knew that he was referring to atomic warfare, but she implied that he meant there were deadly hazards from chemicals such as DDT. Because I had already found a great many untruths in her book, I obtained a copy of Dr. Schweitzer's autobiography, to see whether he even mentioned DDT. He wrote: "How much labor and waste of time these wicked insects do cause, but a ray of hope, in the use of DDT, is now held out to us."[10]

Effects of Pesticides on Human Beings

Many allegations have been made about the harmful effects of pesticides in general, and DDT in particular, on human health. Even statements about the amount actually ingested by human beings have been dramatically false.

On May 15, 1975, the U.S. Environmental Protection Agency (EPA) released a report claiming that people in the United States were ingesting 15 milligrams of DDT every day. In response to a letter stating that this was obviously untrue, an EPA official responded: "You are correct in stating that EPA's DDT report erred on human dietary uptake. The correct figure should have been 15 *micrograms* per day, instead of 15 *milligrams* per day" (Laurence O'Neall, personal communication, Sept. 11, 1975). He stated that "We will make every effort to rectify the erroneous figures with the news media." Indeed, the EPA did issue a correction stating that the actual number was a thousand times less than that given in their report.[11]

Human volunteers in Georgia ingested up to 35 milligrams daily, for nearly two years, and did not experience any difficulties then or later.[12] Workers in the Montrose Chemical Company had 1,300 man-years of exposure, and there was never any case of cancer during 19 years of continuous exposure to about 17 mg/man/day.[13,14] Concerns were sometimes raised about possible carcinogenic effects of DDT, but instead its metabolites were often found to be *anti*-carcinogenic, significantly reducing tumors in rats. DDT ingestion induces hepatic microsomal enzymes, which destroy carcinogenic aflatoxins and thereby inhibit tumors.[15,16]

After an 80-day hearing in 1972 on the potential for carcinogenicity, the EPA concluded that "DDT is not a carcinogenic hazard for man."[17] Nevertheless, EPA Administrator William Ruckelshaus banned DDT two months later, stating that "DDT poses a carcinogenic risk" to humans.[5] The primary evidence used to support his assertion was two animal studies. The first was challenged because it was not replicated by other workers using similar dosages and because the findings might have resulted from food contaminated with aflatoxin. The second study, which used a nearly lethal dose, reported hepatomas in 32 percent of the experimental group compared to 4 percent of the control group. However, the tumors were not shown to be malignant, and the litters were not distributed randomly.[5]

The Effect of DDT on Birds

Many anti-DDT activists alleged that DDT was killing birds or causing them to produce thin-shelled eggs. Some extremists even wrote that because of DDT "birds dropped from the sky, dead."[18] Others said that "birds were falling out of trees by the thousands."[19] No such tragedies actually occurred, not even to a few birds. It was easy to test such claims of toxicity by simply feeding known quantities of DDT to caged birds. Even extreme amounts of DDT in the food did not seriously poison birds.

Rachel Carson declared that "like the robin, another American bird, [the Bald Eagle] seems to be on the verge of extinction."[9] That same year Roger Tory Peterson, America's greatest ornithologist, wrote that the robin was "the most abundant bird in North America." There is no doubt as to which writer was correct![20]

During the "DDT Years," the Audubon Christmas Bird Counts published the numbers seen per observer in 1941 (pre-DDT)[21] and 1960 (after peak use of DDT).[22] The actual numbers seen increased from 90 birds seen per observer in 1941 to 971 birds seen per observer in 1960.[23]

Similarly, the counts of raptorial birds migrating over Hawk Mountain, Pennsylvania, indicated that there were many more hawks there during the "DDT years" than previously. The numbers counted there increased from 9,291 in 1946 (before much DDT was used) to 13,616 in 1963 and 29,765 in 1968, after 15 years of heavy DDT use.[24]

In Massachusetts, herring gulls on Tern Island increased from 2,000 pairs in 1940 (before DDT) to 35,000 pairs by 1970, before DDT was banned. Gulls were on the state's list of "protected sea birds," but the Audubon Society was permitted to poison 30,000 of them there. William Drury of the Society said that killing those 30,000 gulls was "kind of like weeding a garden."[25]

On Funk Island, in the north Atlantic, the gannets increased from 200 pairs in 1945 (when DDT use began) to 2,000 pairs in 1958, and 3,000 pairs by 1971 (before DDT was banned). Murres there increased from 15,000 pairs in 1945 to 150,000 pairs in 1958 to 1.5 million by 1971.[26]

Effects of DDT on Eggshells

The alleged thinning of eggshells by DDT in the diet was effective propaganda; however, actual feeding experiments proved that there was very little, if any, correlation between DDT levels and shell thickness. Thin shells may result when birds are exposed to fear, restraint, mercury, lead, parathion, or other agents, or when deprived of adequate calcium, phosphorus, Vitamin D, light, calories, or water.[27-29] While quail fed a diet containing 2 percent calcium produced thick shells, a calcium content of only 1 percent resulted in shells 9 percent thinner than normal.[30] In the presence of lead, shells were 14 percent thinner, and with mercury, 8 percent thinner.[31]

Bitman and coworkers demonstrated eggshell thinning with DDT by reducing calcium levels to 0.56 percent from the normal 2.5 percent.[32] After this work was exposed as anti-DDT propaganda, Bitman continued his work for another year. Instead of the calcium-deficient diets, however, he fed the quail 2.7 percent calcium in their food. The shells they produced were not thinned at all by the DDT. Unfortunately, the editor of *Science* refused to publish the results of that later research. Editor Philip Abelson had already told Dr. Thomas Jukes of the University of California in Berkeley that *Science* would never publish anything that was not antagonistic toward DDT (T. Jukes, personal communication). Bitman therefore had to publish the results of his legitimate feeding experiments in an obscure specialty journal,[33] and many readers of *Science* continued to believe that DDT could cause birds to lay thin-shelled eggs.

Did DDT Endanger Brown Pelicans?

In 1918 T. G. Pearson and Robert Allen estimated that there were 65,000 brown pelicans along the 1,500-mile Gulf of Mexico coastline.[34] In 1934, after he became president of the National

Audubon Society but many years before DDT was used, Allen repeated that Gulf survey and found an 82 percent decrease in pelicans. He saw only 200 pelicans in Texas, and practically none in Louisiana.[35]

In 1971, Robert Finley of the U.S. Fish and Wildlife Service presented testimony to the California Water Quality Control Board in Los Angeles, asserting that "a population of over 50,000 brown pelicans has all but disappeared from the Gulf Coast of Texas and Louisiana since 1961."[36] This figure had been published elsewhere;[37] however, since the pelicans were known to have been very scarce there in 1959, an increase to 50,000 by 1961 would have been impossible![38] I called Finley and questioned his figures. He responded by letter on Mar. 29, 1971, stating: "Although the reports are sketchy, Jim Keith and I both feel that the estimate of 50,000 is not unreasonably high." On August 2, 1971, Finley wrote to Congressman W. R. Poage (before whom I had testified earlier about Finley's erroneous figures), admitting that "the year 1961 was merely a hasty approximation of an unknown time. After reviewing the evidence, I think now that I should have said that 50,000 pelicans disappeared *by* 1961" [instead of his previous claim that they had disappeared *since* 1961]. Both of those statements were incorrect, but the anti-DDT environmental propagandists never corrected them!

In California, brown pelicans had experienced no difficulties during 20 years of heavy use of DDT, but suddenly suffered nesting failures just two months after the great Santa Barbara oil spill surrounded their nesting island (Anacapa) about Jan. 28, 1969.[39] Environmentalists, however, blamed only DDT for the nesting failure, and never mentioned that great oil spill! They also concealed the fact that California Fish and Game found that anchovies there contained 17 ppm of lead, which is known to cause severe shell thinning. They collected hundreds of pelican eggs from that colony during the next two summers, and the shells were measured with screw micrometers. (Collecting 74 percent of all the pelican's eggs for analysis, of course, was obviously harmful to the success of the colony.[40]) After April 2, 1972, I obtained all of those measurements, and found that they clearly revealed *inverse* correlations between DDT residues and shell thicknesses. Some of the thinnest shells were those of eggs with low DDT, and the higher DDT concentrations were often in the thicker-shelled eggs. This was presented to the EPA and to Congress.[41,42]

Robert Finley, however, wrote to Poage on August 2, 1971, to criticize my testimony. He told the Congressmen that "there is not a shred of evidence that spilled oil is capable of causing thin-shelled eggs or otherwise affecting bird reproduction." In response, I cited many references to the contrary.[43-47] Nothing further was heard from Robert Finley.

Purported Anti-Androgenic Effects of DDT

Florida's Lake Apopka became famous when anti-pesticide propagandists stated that DDT killed fish and caused shortened alligator penises. It was stated that a mere 0.1 nanogram (1 nanogram = 10^{-9} g) of ethinyl estradiol (EE) per liter of water is a potent estrogen.[48] W. R. Kelce claimed that DDT was anti-androgenic, based on an experiment in which he gavaged DDT metabolite DDE directly into pregnant female rat stomachs for five days, at a level 200,000 times the average human dietary intake. "The resulting male pups retained their nipples for 13 days," indicating, Kelce said, "prenatal anti-androgen activity of DDT."[49]

However, it was reported that "Lake Apopka is a fetid shallow body of water, the state's most embarrassing pollution problem. Human waste is dumped into the lake from the Winter Garden's sewage treatment plant," as well as citrus-processing wastes, agricultural chemicals, and fertilizers. Also, the alligators had been exposed to the birth control chemical EE that was in the sewage water with the urine of women in Winter Garden.[50] Moreover, it was reported that alligators there were also being killed by a bacterium, *Aeromonas liquifasciens*, which dissolves internal organs of marine animals.[51]

It is also worthy of note that the estrogenic potency of naturally occurring plant bioflavonoids relative to 17β-estradiol is 0.001 to 0.0001, whereas for estrogenic pesticides it is about 0.000001. The estrogen equivalent intake of plant bioflavonoids is about 102μ/day, compared to 2.5×10^{-6} μ/day from estrogenic pesticide residues. Therefore, the estrogen equivalent ingested in natural substances is estimated to be about 40 million times that from estrogenic pesticides.[52]

DDT in the Environment

DDT was claimed to have dire effects on marine life. Charles Wurster claimed that marine algae died in his tank of seawater because it contained 500 ppb DDT.[53] Paul Ehrlich seemed to approve of Wurster's hoax, for he wrote an article based on it, which many schoolchildren were required to read.[54] The following year Ehrlich published that same article in England, in a Sphere Book titled *The Year's Best Science Fiction*–a more appropriate outlet.

Because DDT is only soluble in water at 1.2 ppb, Ehrlich was asked how he could have such high concentrations of DDT in his seawater. He explained that he had added enough *alcohol* to the tanks to obtain the desired concentrations of DDT in the water. Of course, the seas do not contain much alcohol, so what happened in his tanks bore no resemblance to what would happen in unaltered seawater. Not surprisingly, two other scientists had earlier reported that DDT in their tanks of seawater caused no harm to the same species of algae that Wurster used.

It has often been said that DDT persists for decades in the ocean. Researchers at EPA's Gulf Breeze Laboratory in Louisiana added DDT to seawater in huge submerged containers. They reported that 92 percent of the DDT *and* its metabolites, DDD and DDE, disappeared from the seawater in just 38 days.[55]

At the EPA consolidated hearings on DDT, George Woodwell, testifying under oath, attempted to convince the court that DDT was building up to high levels in the environment. Incredibly, he had had an article published in *Science* a month earlier, in which he and his coauthors found that only 11 million pounds of the 6 billion pounds of DDT that had been produced–less than one-thirtieth of a

year's production in the 1960s–could be accounted for in the world's biota. Indeed, they concluded that "most of the DDT produced has either been degraded to innocuousness or sequestered in places where it is not freely available to the biota."[56]

How the EPA Came to Ban DDT

The printed testimony from seven months of hearings on DDT filled 9,300 pages. My impression was that persons chosen to testify often presented very biased reports that were not truthful.

In an interview with reporters for *Business Week*, published on July 8, 1972, George Woodwell said that he was told by EPA lawyers not to mention his article in *Science*, lest his testimony be disallowed. I specifically discussed Woodwell's testimony in a letter to William Ruckelshaus concerning the frequent absence of truthfulness in testimony. Ruckelshaus responded: "Not only did we not tell Dr. Woodwell to avoid making those statements, but he was not our witness and our lawyers did not talk to him at all" (W. Ruckelshaus, personal communication, 1972). I again read Woodwell's testimony to determine whether that was true. The EPA lawyer (Mr. Butler) had stated: "I'd like to call our next witness, Dr. George M. Woodwell." Notice that Butler said "*our* next witness."

In his final 113-page decision[57] issued on April 25, 1972, Hearing Examiner Edmund Sweeney wrote: "DDT is not a carcinogenic, mutagenic, or teratogenic hazard to man. The uses under regulations involved here do not have a deleterious effect on fresh water fish, estuarine organisms, wild birds, or other wildlife...and...there is a present need for essential uses of DDT."

This decision, however, was overruled by EPA Administrator William Ruckelshaus, who never attended a single day of the seven months of DDT hearings. In his 40-page Final Opinion, handed down on June 2, 1972, he omitted most scientific data, misnamed the major chemicals involved, and proposed that farmers "should use organophosphates, like carbaryl, instead." (Carbaryl is *not* an organophosphate). He also recommended substituting parathion, a very deadly chemical, for DDT.[58] He later wrote that "in such decisions the ultimate judgement remains political" (W. Ruckelshaus, letter to American Farm Bureau President Allan Grant, April 26, 1979).

The Effect on Science

The procedure for banning DDT reflected the method described by Stanford biology professor Stephen Schneider, who appeared on the scene during fraudulent anti-pesticide debates, predicting grave environmental harm. In a widely quoted statement[59] to Jonathan Schell in a 1989 article in *Discover*, he explained: "We need to get loads of media coverage, so we have to offer up scary scenarios and make dramatic statements. Each of us has to decide what the right balance is between being effective and being honest." Schneider has objected to the omission of the last line, "I hope that means being both."[60]

Schneider's "double ethical bind" is the dilemma of scientists involved in advocacy of public policy, particularly that based on the "precautionary principle." The remote prospect of an infinite hypothetical harm justifies drastic, urgent intervention, in this view. As Jonathan Schell wrote: "Scientists should disavow the certainty and precision that they normally insist on. There are perils that we can be certain of avoiding only at the cost of never knowing with certainty that they were real."[61]

"Forecasting environmental disasters often requires taking a value-laden leap of faith beyond the present state of knowledge," writes Jocelyn Kaiser.[62] Thus, scientist activists lead a "double life," imperiling the credibility of science.

Balancing the Good of Humanity

The balance sought by environmental activists is not one of costs and benefits to humanity. Rather, they balance the needs of humanity against the needs of the Planet and the Biosphere in general, as they perceive them. One measure of planetary health is the viability of species. The extinction of any species is a cosmic tragedy, and huge numbers of species are allegedly threatened.

Paul Ehrlich and E.O. Wilson wrote that there is "a massive extinction rate caused by human activity, which threatens the aesthetic quality of the world." They predicted that "thousands of species will become extinct each year, before they have even been discovered"[63]–in spite of the fact that Ehrlich himself said that only three species of forest birds became extinct during all of the "destruction" (his word) of eastern North America.[64]

Other assertions about massive species extinctions include these: Norman Myers estimated that we lose "one species a day" and "most haven't even been identified." He added: that "The extinction rate will accelerate to one species every hour, by the late 1980s."[65] Thomas Lovejoy, formerly of the Smithsonian Institution predicted that "15 to 20% of all species, [or] as many as 1,875,000 species, would become extinct" and "at least ten million species, would be extinct by 2000."[66] In the Global Report 2000 commissioned by President Jimmy Carter, the range of extinctions was stated as 3 to 10 million species.[67] Former Vice President Al Gore stated that "species of animals and plants are now vanishing *one thousand times faster* than at any time in the past 65 million years"[68] [emphasis in original].

Obviously there can never be any factual basis for such hypothetical suggestions, and no credence can be accorded to predictions which have already been proven to be false. Between 1600 and 1900, the estimated extinction rate of known species was about one every 4 years.[69] Since the endangered species list was established, precisely seven species have been declared extinct in the U.S.[70]

In attempting to reach the stated if mostly hypothetical objective of preventing a decrease in nonhuman inhabitants of Earth, environmental activist policies have demonstrably increased the human death rate, primarily by thwarting efforts to control malaria. Could this be the true objective of many activists? Jacques Cousteau stated, "World population must be stabilized and to do that we must eliminate 350,000 people per day."[71] This is nearly 128 million people per year, or 1.27 billion people over 10 years. Edwin

J. Cohn of the U.S. Agency for International Development (AID) Office of Policy Development was quoted as saying, with reference to the fecundity of many women in poor tropical countries, "Rather dead than alive and riotously reproducing."[71,72]

Malaria Control?

Environmentalist Gro Brundtland, Director of the World Health Organization, stated in 2001 that her goal was "to halt half of the malarial mortality by 2010 and half again by 2015."[73] Apparently, Brundtland will be content if by 2010 only one child dies of malaria every minute, instead of two children dying every minute as at present.

Currently, no obvious efforts are being made to reduce the numbers of infective mosquito adults or larvae, and neither Brundtland nor any of the dozens of recent malaria researchers have proposed plans to help save human lives by killing mosquitoes or their larvae. Such humane preventive endeavors have not even been mentioned in *Science* in recent years! Instead, hundreds of millions of dollars are devoted to the search for vaccines, which might or might not be effective.

At least two malaria vaccine researchers have been indicted. Dr. Miodrag Ristic received $3.28 million in grants, but developed nothing. In 1990 he was indicted on four counts and heavily fined, but not imprisoned. Dr. Wasim Siddiqui of the University of Hawaii, who had claimed that his vaccine was almost ready for clinical trials, was accused by the U.S. Inspector General of "an apparent diversion and theft of funds, submission of false claims, and criminal conspiracy." Siddiqui was arrested by Honolulu police, but that very day the Vaccine Research Office of AID awarded him another $1.65 million "to continue his research." Hawaiian Senator Inouye then announced on live television that if Siddiqui was handed any more federal funds he personally would see to it that the University of Hawaii would never get another grant of federal research money.[72] Siddiqui served six months of house detention, but the local newspapers reported that he was still receiving his salary of $92,340 a year, even though not teaching classes.[74]

The malaria protections that were hoped to replace mosquito controls have simply been expensive fantasies. After 25 years, AID's malaria vaccine research project is still proving to be a disaster. In a 6-year effort, during which perhaps 18 million human beings died of malaria, U.S. Navy researchers sequenced the genome of the parasite causing falciparum malaria, which has about 6,000 genes, compared to fewer than 30 in a typical virus. The "breakthrough" was announced at a joint press conference in Washington, D.C., called by *Science* and *Nature*.[75] The genome of the *Anopheles gambiae* vector, which contains nearly 300-million DNA base pairs, has also been sequenced.[76] To date, there is no evidence that knowing the sequences will lead to any methods of controlling malaria transmission.

With no better methods available, past mosquito control programs were terminated. From 1974 to 1977, the U.S. Export-Import Bank financed more than $3 billion of pesticides, saving millions of human lives. In 1977 environmental groups sued to force AID to ban exports of DDT, after which many countries could no longer obtain any. The World Bank extended $165 million dollars to India's malaria sufferers, but specified that no DDT could be used. Madagascar suffered from a similar forced lack of mosquito control. Dozens of other countries, where massive numbers of malaria deaths continue to occur, also cannot receive financial aid unless they agree *not* to control mosquitoes by using DDT. In 1986, the AID issued Regulation 16 Guidelines. Secretary of State George Schultz, relying on that as his authority, telegraphed orders to all embassies, stating: "The U. S. cannot, repeat cannot, participate in programs using any of the following: (1) lindane, (2) BHC, (3) DDT, or (4) dieldrin." Millions of poor natives in tropical countries died as a result, from starvation or from malaria and other insect-transmitted diseases.[73] The term "genocide" is used in other contexts to describe such numbers of casualties.

Conclusions

The ban on DDT, founded on erroneous or fraudulent reports and imposed by one powerful bureaucrat, has caused millions of deaths, while sapping the strength and productivity of countless human beings in underdeveloped countries. It is time for an honest appraisal and for immediate deployment of the best currently available means to control insect-borne diseases. This means DDT.

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Review

Health risks and benefits of bis(4-chlorophenyl)-1,1,1-trichloroethane (DDT)

Walter J Rogan, Aimin Chen

DDT (bis[4-chlorophenyl]-1,1,1-trichloroethane) is a persistent insecticide that was used worldwide from the mid-1940s until its ban in the USA and other countries in the 1970s. When a global ban on DDT was proposed in 2001, several countries in sub-Saharan Africa claimed that DDT was still needed as a cheap and effective means for vector control. Although DDT is generally not toxic to human beings and was banned mainly for ecological reasons, subsequent research has shown that exposure to DDT at amounts that would be needed in malaria control might cause preterm birth and early weaning, abrogating the benefit of reducing infant mortality from malaria. Historically, DDT has had mixed success in Africa; only the countries that are able to find and devote substantial resources towards malaria control have made major advances. DDT might be useful in controlling malaria, but the evidence of its adverse effects on human health needs appropriate research on whether it achieves a favourable balance of risk versus benefit.

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DDT (bis[4-chlorophenyl]-1,1,1-trichloroethane, also called dichlorodiphenyl trichloroethane) was first synthesised in 1874, and its insecticidal properties were described by Paul Müller in the late 1930s.[1] It was first used to protect military areas and personnel against malaria, typhus, and other vector-borne diseases. Commercial sales began in 1945, and DDT became widely used in agriculture to control insects, such as the pink boll worm on cotton, codling moth on deciduous fruit, Colorado potato beetle, and European corn borer. The compound was also used in sylvaculture and, in a powder form, as a directly applied louse-control substance in people. In the USA, use of DDT rose until 1959 (35 771 tonnes), after which it declined gradually (11 316 tonnes in 1970).[1-3] The eighth World Health Assembly in 1955 adopted a Global Malaria Eradication Campaign based on widespread use of DDT indoor and outdoor spraying against adult mosquitoes, and by 1967 endemic malaria was eradicated in developed countries and many subtropical Asian and Latin American countries. However, few African countries participated in the campaign. The 22nd World Health Assembly in 1969 ended the campaign after authorities realised that the infrastructure necessary to support global eradication did not exist. Additionally, mosquitoes were becoming resistant to DDT.[4]

Sweden banned DDT in 1970, the USA in 1972, and the UK in 1986, largely on the basis of ecological considerations, including persistence in the environment and sufficient bioaccumulation and toxic effects to interfere with reproduction in pelagic birds (ie, eggshell thinning).[1,3,5,6] Toxic effects in human beings did not have a role in bans enacted during the 1970s. During the next 30 years, a combination of research findings and public concern led to bans of many other persistent chlorinated compounds, such as the cyclodiene pesticides (ie, dieldrin and mirex) and polychlorinated biphenyls. Before the Stockholm Convention on Persistent Organic Pollutants proposed a global ban of DDT and 11 other persistent organic pollutants in 2001, some senior malaria experts objected, citing the rising burden of malaria in sub-Saharan Africa, the historical effectiveness of DDT against malaria vectors, and the absence of obvious toxic effects caused by DDT in human beings.[7-9] More than two dozen countries, mostly in sub-Saharan Africa, requested exemption from the ban for DDT use in malaria vector control.[10] However, adverse effects of DDT on human health have been reported, and these will probably affect the decision. Since the Stockholm Convention was to be effective from May, 2004,[11] a review of the currently available evidence was appropriate. We discuss some of the advances in knowledge about the toxic effects of DDT, especially chronic or delayed toxic effects occurring at low doses, including neurological, carcinogenic, reproductive, and developmental effects. Where possible, we review the potential for such toxic effects to take place at exposures expected to result from modern insect-control practices. We also consider the problem of the measurement and comparison of possible benefits of DDT in the reduction of malarial mortality, and the possible harm from an increase in non-malarial infant deaths.

DDT exposure and concentration in human tissues

Technical-grade DDT contains 65–80% p,p′-DDT, 15–21% o,p′-DDT, and up to 4% p,p′-DDD (bis[4-chlorophenyl]-1,1,-dichloroethane).[2] When sprayed, DDT

Search strategy and selection criteria

We did a search of PubMed from the mid-1960s to February, 2005, for the use, body burden, and toxic and health effects of DDT. We used the keywords "DDT" and "DDE" and any of "malaria", "mosquito", "drug resistance", "toxicity", "health", "cancer", "reproduction", "oestrogen", "neurological", and "development". Of 3650 reports published on DDT, we gave preference to studies in the past 5 years on human health effects of DDT.

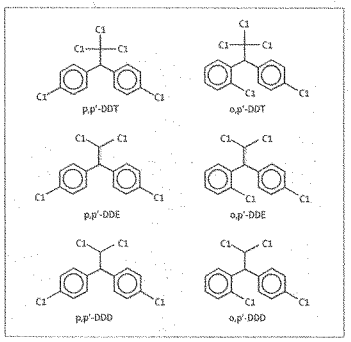

Figure 1: Chemical structures of isomers of DDT, DDE, and DDD

can drift, sometimes for long distances. In the soil, the compound can evaporate or attach to wind-blown dust. In the environment, DDT breaks down to p,p'-DDE (bis(4-chlorophenyl)-1,1-dichloroethene),[1] an extremely stable compound that resists further environmental breakdown or metabolism by organisms. DDE is the form usually found in human tissue in the highest concentration, especially in areas where there has been no recent use of the parent compound. Figure 1 shows the chemical structures of these DDT isomers. The general population is exposed to DDT mainly through food, whereas occupational exposures are mainly through inhalation and dermal contact. DDT and DDE can also be transferred from the placenta and breastmilk to fetuses and infants. Although some ingested DDT is converted to DDA (bis(4-chlorophenyl)-acetic acid) and excreted, any non-metabolised DDT and any DDE produced is stored in fat, as is all absorbed DDE, which cannot be metabolised. DDT and DDE are highly soluble in lipid; their concentrations are much higher in human adipose tissues (about 65% fat) than in breastmilk (2·5–4% fat), and higher in breastmilk than in blood or serum (1% fat).[12] The half-life of DDE is about 7–11 years.[13] DDT and DDE concentrations increase with age.[12]

With the use of DDT declining since the 1970s, concentrations of DDT and its metabolites in human tissue have fallen greatly worldwide.[14,15] Currently, people in Europe, the USA, Canada, Australia, New Zealand, and Japan have lower concentrations of DDT compounds in their tissues than previously. For example, in Sweden, the total DDT concentration in breastmilk fat was 2·9 μg/g in 1972 and 0·3 μg/g in 1992. However, in Central and South America, Mexico, Africa, and some Asian countries, where DDT has been used for vector control in the past 5–10 years, DDT concentrations in human tissues remain high. For example, in Mexico, the total DDT concentration in breastmilk fat was 5·7 μg/g in 1994–95 and 4·7 μg/g in 1997–98.[16] In South Africa, continuous DDT spraying has resulted in a median DDE concentration range of 5·2–7·7 μg/g in breastmilk fat in the treated area, compared with a much lower 0·4–0·6 μg/g in the untreated area.[17] In South Africa, the mean concentration of serum DDE in a DDT-treated area was 103 (SD 85) μg/L whereas in an untreated area the value was 6 (7) μg/L.[18] In countries with DDT use in the past 5–10 years, the DDT-to-DDE concentration ratio, which can approach 100% in these areas, is much higher than that in Europe or the USA (2–20%).[14]

Workers using DDT to control mosquitoes have very high DDT concentrations. Mexican data revealed that the geometric mean of total DDT was 104·48 μg/g in adipose tissue of 40 DDT sprayers in 1996;[19] whereas in Finland, the USA, and Canada, the value was less than 1 μg/g in adipose tissue in the general population.[14] In another Mexican study, the serum concentration of p,p'-DDE was much higher in DDT sprayers (188 μg/L) than in children (87 μg/L) and in adults (61 μg/L) who lived in sprayed houses but were not otherwise exposed to DDT.[20]

Toxic effects of DDT

Toxic effects of DDT and its analogues have been extensively studied in laboratory animals. Acute exposure to a high dose of DDT can cause death.[12] Exposure to DDT or DDE increases liver weight, induces liver cytochrome P450 (CYP) 2B and 3A and aromatase,[21–23] and causes hepatic-cell hypertrophy and necrosis.[12] DDT is insecticidal because of its neurological toxic effects. In laboratory animals, DDT causes hyperactivity, tremor, and seizures. DDT is carcinogenic in mice and rats, mainly causing liver tumours,[12] although negative results are also seen,[24] and the compound is carcinogenic in non-human primates.[25] The o,p'-DDT isomer is the most oestrogenic component of the DDT complex (having a relative binding affinity to oestrogen receptors of $2·9\times10^{-3}$ relative to 17-β oestradiol),[26] with p,p'-DDT being much less oestrogenic than its o,p' isomer. The p,p'-DDE isomer is anti-androgenic by inhibitive binding to androgen receptors (with a relative binding affinity to androgen receptors of $3·1\times10^{-3}$ relative to dihydrotestosterone).[27,28] Prenatal exposure to DDT in early pregnancy in rabbits can reduce overall fetal bodyweight and brain and kidney weight in offspring.[29] Immunosuppressive effects of DDT have been shown in rats and mice.[30,31]

In people, DDT use is generally safe; large populations have been exposed to the compound for 60 years with little acute toxicity apart from a few reports of poisoning.[12] Doses as high as 285 mg/kg taken accidentally did not cause death, but such large doses did lead to prompt vomiting. One dose of 10 mg/kg can result in illness in some people.[12] Subclinical and subtle

functional changes have not been meticulously sought until the past few decades.

Neurobehaviour

DDT poisoning usually results in paresthesia, dizziness, headache, tremor, confusion, and fatigue.[12] Occupational exposure to DDT was associated with reduced verbal attention, visuomotor speed, sequencing, and with increased neuropsychological and psychiatric symptoms in a dose-response pattern (ie, per year of DDT application) in retired workers aged 55–70 years in Costa Rica.[31] Although DDT or DDE concentrations were not determined in this study, they probably were very high. People who regularly consumed fish from the American Great Lakes were reported to have higher serum DDE concentrations (median 10 μg/L) than those who did not eat fish (5 μg/L), but they did not show impaired motor function,[33] impaired executive and visuospatial function, or reduced memory and learning.[34]

Cancer

Although extensively studied, there is no convincing evidence that DDT or its metabolite DDE increase human cancer risk. Mainly on the basis of animal data, DDT is classified as a possible carcinogen (class 2B) by the International Agency for Research on Cancer (IARC)[35] and as a reasonably anticipated human carcinogen by the US National Toxicology Program.[36]

Breast cancer has been examined most closely for an association with p,p′-DDE. In a study in 1993,[37] breast cancer patients had higher serum DDE concentrations (11·8 μg/L) than controls (7·7 μg/L), and results from several subsequent studies supported such an association.[38–41] However, large epidemiological studies[13,42–49] and subsequent pooled and meta-analyses[50–52] failed to confirm the association. Most of these studies have been analysed, accounting for several factors including sample size, exposure, and odds ratios. Good evidence now indicates that, in white women in North America or Europe, DDE does not raise breast cancer risk, irrespective of oestrogen receptor status in the tumour or polymorphisms in host metabolic enzymes (glutathione-S-transferase, CYP).[53] The role of o,p′-DDT—the most oestrogenic isomer—in areas of recent DDT use still needs further investigation.[51,53]

With detailed work history of chemical manufacturing workers to estimate DDT exposure, a nested case-control study[54] reported occupational DDT exposure associated with increased pancreatic cancer risk. A weak association of self-reported DDT use with pancreatic cancer was reported in another case-control study.[55] A report indicated a higher standardised mortality ratio for pancreatic cancer in outdoor workers with a history of DDT exposure of less than 3 years, but the standardised mortality ratio of DDT workers with exposure of 3 years or more was not significantly raised.[56] The association of serum DDE concentrations (median 1·3 μg/g and 1·0 μg/g lipid in cases and controls, respectively) with pancreatic cancer was not clearly shown in another study when co-exposure to polychlorinated biphenyls was taken into account.[57] Although one study reported higher DDT and DDE concentrations in *K-ras*-mutated pancreatic cancer patients than in controls,[58] this finding was not reported from another study.[59]

Previous case-control studies have suggested that a history of DDT use was associated with a raised risk of non-Hodgkin's lymphoma,[60,61] but subsequent studies[62] using measurements of total DDT concentrations in serum did not find such increased risk. Two other studies[63,64] using the history of DDT application as the exposure measure and one[65] using adipose DDE concentration reported a slightly raised risk associated with DDT or DDE, but the effect disappeared if data were adjusted for history of use or concentration of other pesticides.

Data from an Italian study[66] of malaria workers showed that, although those directly exposed to DDT had raised risk of liver and biliary tract cancers, workers who did not have direct occupational contact with DDT also showed increased risk.[66] Another ecological study in 22 US states indicated a correlation between adipose DDE amounts and age-adjusted liver-cancer mortality rates in white men in a multivariate analysis, but not in white women or black men.[67] In both studies no individual measure of DDT exposure was available, thus making interpretation difficult.

Association of DDT with multiple myeloma,[66–68] prostate and testicular cancer,[69,70] endometrial cancer,[71–73] and colorectal cancer[74] was sought but results have been inconclusive or generally do not support an association.

Reproductive health

Various reproductive and hormonal endpoints have been examined in both men and women, and although associations have been recorded, causal links have not been confirmed. In Chiapas, Mexico, where DDT was sprayed for malaria control, serum p,p′-DDE concentrations were inversely correlated with semen volume, sperm count, and bioavailable-to-total testosterone ratios in 24 young men not occupationally exposed to DDT.[75] However, results from another study of South African malaria workers did not confirm these findings although their exposure was nearly as high as that previously reported.[76,77] Studies of populations with a much lower exposure than that seen in current malaria-endemic areas have shown only weak, inconsistent associations between DDE and testosterone amounts, semen quality, and sperm DNA damage.[78–84]

An increase of 15 μg/L of DDE in maternal serum was associated with a 1-year advance of the age at menarche in daughters.[85] One cross-sectional study in Laotian immigrants to the USA with high DDT (mean 2 μg/L) and DDE (21 μg/L) concentrations indicated that the highest quartiles of concentration were associated with a

reduction of 1·5 days in the mean luteal-phase length of menstrual cycles.[86] Data from the large US Collaborative Perinatal Project undertaken in 1959–66 did not show any association between DDE concentration and menstrual-cycle length.[87] Raised DDE concentration was associated with earlier natural menopause in two studies.[88,89]

With respect to time to pregnancy, an increase of 10 μg/L of p,p′-DDT in maternal serum was reported to reduce daughters' probabilities of pregnancy by 32%, whereas the same increase in p,p′-DDE concentrations raised the probability by 16%.[90] The discrepancy of DDT and DDE effect cannot be easily explained by any known mechanism, and these results need confirmation. Spouses of DDT users were shown to have a non-significantly lower probability of pregnancy than those unexposed.[91]

Data from the US Collaborative Perinatal Project indicated that DDE correlated with the risk of spontaneous abortion,[92] which were consistent with findings from four small studies.[93–96] However, two other studies[97,98] did not show these results. A study[99] of 45 recurrent miscarriage cases and 30 controls showed no increased risk associated with DDE, but the DDE concentrations were much lower than those in previous studies.

Raised serum concentration of DDE correlated with risk of preterm delivery in the US Collaborative Perinatal Project data, with odds ratios of 1·5–3·1 for DDE amounts of 15 μg/L or more compared with those less than 15 μg/L,[100] in accordance with several small studies.[94,97,101,102] Another US study did not show the same results,[103] although the median DDE concentration was only 1·4 μg/L in that study (much lower than the concentration in the Collaborative Perinatal Project[100]). DDE has also shown an association with small-for-gestational-age in data from the US Collaborative Perinatal Project,[100] low birthweight in a study of fish eaters in the Great Lakes,[104] and intrauterine growth restriction in a small Indian study.[105] However, other studies in North Carolina, USA,[106] Greenland,[107] Ukraine,[108] and Michigan, USA,[109] with various DDE or DDT concentrations, failed to find this association.

Low incidence of birth defects reduces the power of studies examining the causal effect of DDT. The US Collaborative Perinatal Project data have been consistent with a small increase in risk for cryptorchidism, hypospadias, and polythelia with very high concentrations of DDE in maternal serum DDE (>60 μg/L), but the results are inconclusive,[110] similar to another study.[111] Two other studies found no association between concentrations of DDT and DDE and hypospadias[112] or cryptorchidism.[113] In a study of Mexican anti-malaria workers, high paternal DDE concentration (>61 μg/g lipid) was associated with a raised risk of birth defects, but these birth defects were few and mostly arose in the nervous system.[114]

High DDE concentration in breastmilk has shown an association with a shortened duration of lactation.[115,116] In 858 women, those with the highest concentration of DDE in milk (>6 μg/g lipid) weaned at an average of 2·5 months, whereas those with the lowest concentration (<1 μg/g lipid) weaned at 6·5 months.[115] In 229 Mexican women, rising DDE amounts in breastmilk (from <2·5 μg/g to >12·5 μg/g lipid) were associated with a reduction in the mean duration of lactation (from 7·5 months to 3 months).[116] The table summarises the overall findings of reproductive outcomes and DDT exposure amounts in different populations.

Infant and child development

Although infant and child growth and neurodevelopment have been studied, no study has been large enough to show an effect on infant and child survival. In a German study,[117] girls with the highest quartile of DDE concentration (>0·44 μg/L whole blood) were an average of 1·8 cm shorter at age 8 years than girls with the lowest quartile of DDE; the difference narrowed at age 9 years and disappeared at age 10 years. However, no such effect was seen in boys. Another study did not show any association between maternal serum DDE and anthropometric and pubertal measures in boys.[118] However, follow-up of children in North Carolina showed that at age 12–14 years, the height of boys (but not girls) at puberty rose with transplacental exposure to DDE. Age at pubertal stages, which was mostly assessed prospectively, was unaffected by any measure of DDE exposure.[119] Serum concentration of p,p′-DDE (>1 μg/L) was associated with precocious puberty in one unconfirmed study.[120]

DDE concentration in the blood serum of the umbilical cord was negatively associated with mental and psychomotor development of children assessed at 13 months of age.[121] A longitudinal study[122–124] showed no association between transplacental or lactational DDE exposure and children's cognitive or motor development at age 12–60 months or school reports at age 10 years. The Program for International Student Assessment study[125] showed that high DDT concentration in human milk could be inversely associated with mental capacities at age 15 years.

Immunology and DNA damage

Increased plasma concentrations of DDE were associated with raised IgA in one study[126] and with reduced IgG in another.[127] Plasma p,p′-DDE was inversely associated with in-vitro secretion of tumour necrosis factor (TNF) α by umbilical cord-blood mononuclear cells.[128] Do these effects translate into immunological disorders with clinical consequences? One study suggested that raised prenatal exposure of p,p′-DDE increased the risk of otitis media in Inuit infants,[129] but this association was not seen in another study.[115] In Mexican women, blood concentrations of DDT, DDE, and DDD were associated with DNA damage in blood cells measured by comet assays,[130] but data from US residents living near a

pesticide dump site did not indicate any such relation between plasma DDE and lymphocyte micronuclei, although DDE was associated with reduced mitogen-induced lymphoproliferative activity.[126]

Efficacy and effectiveness of DDT for malaria control

Convincing historical evidence has shown that indoor residual house-spraying with DDT was the main method by which malaria was eradicated or greatly reduced in many countries worldwide in the 1940s to 1960s. However, these programmes had not been aimed to rigorously investigate the efficacy of individual components nor of local factors that might modify their effects. In sub-Saharan Africa, early pilot projects of malaria eradication also showed that the disease is highly responsive to vector control by DDT and to aggressive treatment campaigns to eliminate residual foci of transmission. Despite reductions in anopheline vectors and malaria cases, transmission could not be interrupted in the endemic tropical and lowland areas of sub-Saharan Africa.[131] Subsequently, international interest in malaria and funding for malaria research and control waned in most countries on the continent. As a result, residual spraying was not used in sub-Saharan Africa, apart from southern Africa and some islands such as the Reunion, Mayotte, Zanzibar, Cape Verde, and São Tome. In southern Africa, the countries that have developed national malaria control programmes have built up human, financial, and organisational resources for great advances in malaria control.[132]

However, the effectiveness of DDT can be compromised by insecticide resistance and social resistance to DDT indoor spray. Because of the irritating, excito-repellent nature of the DDT residue, some mosquitoes tend to leave before they have absorbed a lethal dose, or tend to avoid entering the house or resting on the wall at all.[131] By the end of Global Malaria Eradication Campaign, some mosquito species had developed resistance to DDT, especially in India and Sri Lanka.[3] In 1968, high amounts of resistance to DDT in *Anopheles gambiae* was reported in Upper Volta (now Burkina Faso); shortly thereafter, DDT had no effect on mosquito mortality, biting frequency, or resting in houses in trials undertaken in Togo and Senegal.[131] In the 1980s when DDT was judged to control the resurgence of malaria in Zanzibar after the DDT spraying programme finished in 1968, resistance was found in *A gambiae* ss and *A arabiensis*.[133] In 2002, 2 years after DDT residual spraying was reintroduced in KwaZulu-Natal to control the increase of malaria cases, resistance was recorded in *A arabiensis*, although *A funestus* was still susceptible to DDT.[134] Social resistance to DDT indoor sprays occurs because bedbugs are resistant to DDT, and DDT leaves stains on walls, which residents then replaster.[132] In practice, the efficacy of DDT spraying for vector control depends on the coverage of spraying, mosquito species, and resistance to DDT. Climate—especially rainfall, temperature, and latitude—could affect the stability of transmission, and thus also affect DDT efficacy. WHO points out that DDT spraying is "most effective in reducing the overall malaria burden in unstable transmission areas, areas with marked seasonal transmission peaks and disease outbreaks, and highland areas".[135]

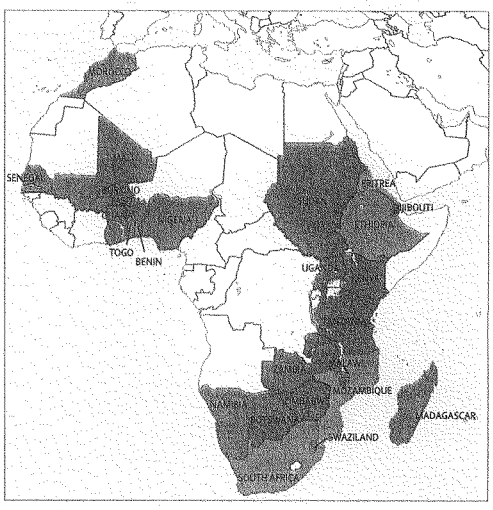

Figure 2: Roll Back Malaria strategic plans in African countries
Countries are coloured if their national strategic plan is to use insecticide residual spraying (blue), insecticide-treated bed nets (red), or both (green). Countries with undetermined plans are not coloured. Adapted from reference 137, with permission from Elsevier.

A report from Chingola and Chiliabombwe, Zambia, showed that spray coverage of all houses with DDT (80%) or pyrethroid (20%) between peak transmission in 2000 resulted in a 35% fall in malaria incidence in the subsequent 6 months compared with 2 years before spraying.[136] Currently in Africa, indoor residual spraying (mainly with DDT) has become part of the national Roll Back Malaria strategic plan in several countries (figure 2).[137] Data for the efficacy of DDT are increasing and will be used to assess the efficacy of DDT spraying.

Debate and decision-making

Since evidence now indicates that DDT might have adverse effects on human health, it is prudent to consider currently available evidence of benefits and possible risks of DDT use in the context of modern malaria control.

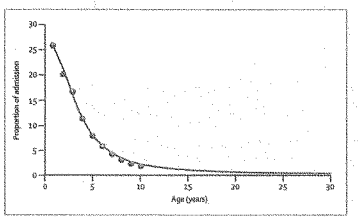

Figure 3: Predicted proportional age-specific malaria mortality in Africa, by admission
Adapted from reference 138, with permission.

Infants are generally known to bear the burden of mortality from malaria worldwide (figure 3);[138] most such mortality occurs in the first 5 years of life and in areas south of the Sahara (figure 4).[139] The decision to use DDT would be straightforward if we had data from trials in sub-Saharan Africa showing larger reductions in infant mortality in houses treated with DDT than reductions in houses treated with a different insecticide or where bed nets are used. However, such data are unavailable, and thus any such decision will need several assumptions.

Benefits of DDT spraying in sub-Saharan Africa

The success of the Malaria Eradication Campaign in 1955–69 was attributed to DDT.[1] However, these programmes often included other components, such as provision of basic medical care, and were not designed to allow investigation of their individual parts. Thus, Giglioli[140] showed large improvements in infant and all-cause mortality during three decades for employees of the sugar plantations in South America, but the quantitative role of DDT is impossible to specify. Without the appropriate controls, the effects of secular trends also cannot be disentangled.[141] Moreover, effective malaria prevention programmes can be associated with a fall in infant mortality that is larger than can be accounted for if malaria is eliminated entirely as a cause of death. This problem could be due to malaria's ability to produce anaemia and immunodeficiency in both mother and child (rendering them susceptible to death from other causes) or due to other interventions.[142] Because poverty, malnutrition, diarrhoea, and respiratory diseases account for most infant mortality in sub-Saharan Africa, the benefits of DDT use could be dwarfed by interventions to improve nutrition, vaccination, sanitation, personal hygiene, and medication accessibility.

Snow and colleagues[143] attempted to estimate malaria mortality for African children in the subcontinent. They reported that the median number of deaths from malaria in children aged 0–4 years in population-based studies was nine in 1000 per year; on the basis of deaths occurring in hospital, four in 1000; and in children aged up to 59 months attributable to malaria from intervention studies, seven in 1000. These numbers might not have included all infant deaths that could be avoided by malaria prevention, such as those from preterm delivery and with low birthweight caused by maternal malaria during pregnancy. Maternal malaria was estimated to have caused 3–8% of all infant deaths in areas of Africa with stable malaria transmission.[144] Thus, residual spraying with DDT might end mortality from malaria and reduce overall infant mortality if most or all dwellings are sprayed at least twice a year, if malaria-transmitting mosquitoes do not become resistant, if few people clean or replaster the sprayed wall, and if funding and personnel are always available for residual spraying, among other actions. However, under the actual conditions in sub-Saharan Africa, various technical and logistical barriers hamper the achievement of this goal.

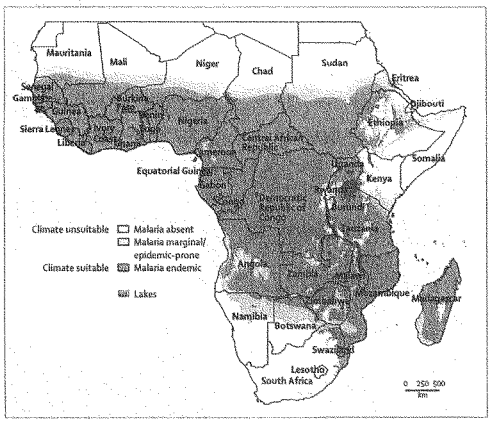

Figure 4: **Distribution of endemic malaria in Africa**
Adapted from reference 139, with permission.

Risks of DDT spraying in sub-Saharan Africa

For indoor residual spraying to effectively prevent infant mortality from malaria, women of child-bearing age, pregnant women, and breastfeeding women will need to be exposed to DDT. Such spraying might be without the ecological effects that caused the ban (although more data are needed), but will unavoidably expose women to amounts of DDT that are associated with forms of toxic effects that might increase infant mortality. Of adverse effects to human health, reproductive outcomes are the major concern (table). Of these, the association of DDE with increased risk of preterm birth and earlier weaning are most relevant to sub-Saharan Africa.[100,115,116] Although

Ref	Design and population	DDT or DDE concentrations	Effects
Semen quality			
75	24 men from DDT-sprayed area in Mexico (mean age 21 years)	Mean p,p'-DDE 78 µg/g serum lipid	DDE amounts inversely associated with semen volume, sperm count, and testosterone concentration
76,77	47 malaria workers in South Africa (mean age 45 years)	Mean p,p'-DDE 52 µg/g serum lipid	No consistent association with oestradiol, testosterone, or semen quality
78	137 black farmers in the USA (mean age 62 years)	Median p,p'-DDE 1·2 µg/g serum lipid or 7·7 µg/L serum	Only top tenth percentile of DDE associated with reduced testosterone
79	110 Baltic seafish eaters (age range 23–79 years)	Median p,p'-DDE 0·8 µg/g serum lipid	Weak, negative (but non-significant) association with testosterone
80	107 previous malaria workers in Italy (mean age 78 years)	Median p,p'-DDE 0·4 µg/g serum lipid	No association with oestradiol, testosterone, luteinising hormone, follicle-stimulating hormone, and sex-hormone-binding globulin
81,82	212 male partners of subfertile couples in the USA (mean age 37 years)	Median p,p'-DDE 0·2 µg/g serum lipid	Weak association with sperm motility but not with sperm concentration, morphology, and DNA damage
83,84	195 Swedish fishermen (median age 51 years)	Median p,p'-DDE 0·2 µg/g serum lipid	Percentage of sperm DNA fragmentation index rose non-significantly with DDE dose; no association with other semen indices
Menstrual cycle			
89	219 Hispanic women in the USA	Mean p,p'-DDE 36 µg/L serum	High DDE concentration associated with early age at menopause
87	2314 pregnant women in the USA	Mean DDE 30 µg/L	Menstrual cycle irregularity slightly increased, no association with cycle length and bleeding duration
86	50 Laotian immigrants coming to the USA	Mean DDE 21 µg/L serum	Highest quartile of DDE associated with reduced mean luteal-phase length (by 1·5 days) and decreased progesterone during luteal phase
85	151 offspring of anglers in the USA	Maternal DDE range 0–17 µg/L serum	High maternal DDE associated with decreased age at menarche
88	1407 women in a breast cancer case-control study in the USA	Median DDE 3 µg/L plasma	High DDE associated with early age at menopause
Time to pregnancy			
90	289 women born in the early 1960s in the USA	Maternal postpartum median p,p'-DDE 48 µg/L serum, p,p'-DDT 13 µg/L serum	DDE associated with raised probability of pregnancy, and DDT associated with reduced probability of pregnancy
91	Spouses of 105 malaria workers in Italy	Work history	Slightly increased stillbirth rate; reduced male-to-female ratio among offspring and probability of pregnancy in DDT users
Spontaneous abortion			
94	10 cases and 25 controls in India	Mean DDE 164 µg/L (cases) and 13 µg/L serum (controls)	Raised DDE associated with increased risk of spontaneous abortion
92	1717 pregnancy women in the USA	Median DDE 25 µg/L serum	Raised DDE associated with increased fetal loss in previous pregnancies
93	15 cases and 15 controls in China	Mean DDE 22 µg/L (cases) and 12 µg/L serum (controls)	Raised DDE associated with increased risk of spontaneous abortion
98	120 cases and 120 controls in Italy	Mean DDE 5·2 µg/L (cases) and 4·6 µg/L serum (controls)	No associations recorded
96	89 women with repeated miscarriages in Germany	Mean DDE 1·2 µg/L serum	14% of cases with DDE higher than range of previously investigated reference population
99	45 cases and 30 controls in Japan	Mean DDE 0·7 µg/L (cases) and 0·9 µg/L serum (controls)	No associations recorded
Preterm delivery			
94	15 preterm cases and 25 full-term controls in India	Mean DDE 58 µg/L (cases) and 13 µg/L serum (controls)	Cases had higher maternal DDE concentrations than did controls
100	2613 pregnant women in the USA	Median DDE 25 µg/L serum	Raised maternal DDE associated with increased risk of preterm delivery
103	20 preterm cases and 20 full-term controls in the USA	Median DDE 1·3 µg/L (cases) and 1·4 µg/L serum (controls)	No association recorded
102	100 preterm cases and 133 full-term controls in Mexico	Median DDE 0·19 µg/g (cases) and 0·15 µg/g serum lipid (controls)	Suggestive positive relationship between DDE and preterm delivery
Birthweight			
100	2613 pregnant women in the USA	Median DDE 25 µg/L serum	Raised maternal DDE associated with increased risk of small-for-gestational-age
106	912 infants in the USA	Maternal median DDE at birth 13 µg/L serum	Maternal DDE burden not associated with birthweight
105	30 intrauterine growth restriction cases and 24 controls in India	Mean DDE 9 µg/L (cases) and 6 µg/L serum (controls)	Raised maternal DDE associated with increased risk of intrauterine growth restriction
107	178 newborn babies in Greenland	Maternal mean DDE 5 µg/L plasma	No association with birthweight
104	119 frequent fish eaters and 24 infrequent fish eaters in the USA	Median DDE 2 µg/L (frequent eaters) and 1 µg/L serum (infrequent eaters)	Natural log of maternal serum DDE inversely associated with birthweight
108	197 singleton infants in Ukraine	Median DDE 2·5 µg/g breastmilk fat	No association between DDE and birthweight after adjustment for potential confounders
Birth defects			
111	75 cryptorchidism, 66 hypospadias and 283 control babies in the USA	Median DDE 43 µg/L (cryptorchidism and controls) and 41 µg/L (hypospadias)	DDE ≥61 µg/L resulted in slightly raised but non-significant risk for both defects
110	219 cryptorchidism, 199 hypospadias, 167 polythelia, and 552 control babies in the USA	Median DDE 24 µg/L (cryptorchidism, hypospadias, and controls) and 32 µg/L (polythelia)	DDE ≥60 µg/L resulted in slightly raised risk for investigated birth defects, but results were inconclusive
Duration of lactation			
116	229 postpartum women in Mexico	Median DDE 6 µg/g breastmilk fat	Raised DDE associated with reduced duration of lactation
115	858 postpartum women in the USA	Median DDE 2 µg/g breastmilk fat	Raised DDE associated with reduced duration of lactation

Rows are in order of decreasing serum DDE dose.

Table: Summarised DDT and DDE effects on reproductive outcomes

causality has not been established and the studies were done in North America, the methods are not so flawed that the findings can be dismissed by argument.

If we assume that preterm births and early weaning are caused by DDT exposure, that the strength of the association is similar to that observed in North American studies, and that previous weaning or early birth carries a risk of mortality in Africa similar to the risk elsewhere, we would estimate that about 20 excess deaths per 1000 livebirths will result from continuous DDT indoor residual spraying (ie, serum DDE >60 μg/L or breastmilk DDE >5 μg/g lipid).[145] The risk estimate provides a general framework of risk assessment in sub-Saharan Africa, although applicability to a specific country or area depends on the variation in malaria transmission, total infant mortality, DDT spraying strategy, incidence of preterm birth, and duration of lactation.

Balance of benefits and risks from DDT use in malaria control

Malaria remains a difficult problem in Africa. Indoor residual spraying of DDT could be effective in some settings; the procedure is unlikely to lift the entire malaria mortality burden in infants and children. Additionally, if continuous DDT spraying does cause increased preterm births and shortened breastfeeding duration, infant deaths will occur, perhaps to the same extent as the deaths spraying would potentially prevent. Mothers would also carry a body burden of DDT, and even if they were to leave the malaria-protected house, they would still have raised risk of preterm birth and early weaning. Other risks, such as neurological and reproductive effects in spraying staff, might also apply.

Whether such problems do or do not occur is still uncertain, since they cannot be dismissed on grounds of low doses or flawed studies nor can they be reasonably assumed to happen. In areas where DDT is to be introduced, reintroduced, or continuously used for malaria control, caution based on the accumulation of evidence of adverse DDT effects in people is appropriate. Whenever possible, proper controls in the assessment of DDT efficacy and continued parallel research on its effect in human beings should be undertaken. Alternative antimalarial approaches such as use of insecticide-treated bed nets, intermittent presumptive treatment during pregnancy, early diagnosis, artemisinin-based treatment, combination regimen treatment, and health education are all effective.[146–148] Well-coordinated anti-malarial efforts in combination with efficient health infrastructure should have improved success in malaria control than the sole reliance of disease control on indoor residual spraying of DDT.

Future perspectives

DDT was originally banned because of ecological effects, such as eggshell thinning, and accumulation in the environment and organisms, including human beings. Although acute toxic effects are scarce, toxicological evidence shows endocrine-disrupting properties; human data also indicate possible disruption in semen quality, menstruation, gestational length, and duration of lactation. The research focus on human reproduction and development seems to be appropriate. DDT could be an effective public-health intervention that is cheap, longlasting, and effective. However, various toxic-effects that would be difficult to detect without specific study might exist and could result in substantial morbidity or mortality. Responsible use of DDT should include research programmes that would detect the most plausible forms of toxic effects as well as the documentation of benefits attributable specifically to DDT. Although this viewpoint amounts to a platitude if applied to malaria research in Africa, the research question here could be sufficiently focused and compelling, so that governments and funding agencies recognise the need to include research on all infant mortality when DDT is to be used.

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E-MAIL MESSAGE DISTRIBUTED ON SEPTEMBER 23, 2005 BY DR. GERHARD HESS OF BAYER ENVIRONMENTAL SCIENCES S.A.S.

Dear Robert,

Sorry for joining the ongoing discussion rather late, You can be assured that I followed the discussion very closely, travelling now through Asia and having met my Indian and African colleagues here in Bangkok for a meeting, during which we discussed intensively the DDT issue. I can give you the following additions to the discussion. Not only as the responsible manager for the vector control business in Bayer, being the market leader in vector control and pointing out by that we know what we are talking about and have decades of experiences in the evolution of this very particular market. Also as one of the private sector representatives in the RBM Partnership Board and being confronted with that discussion about DDT in the various WHO, RBM et al circles. So you can take it as a view from the field, from the operational commercial level but our companies point of view. I know that all of my colleagues from other primary manufacturers and internationally operating companies are sharing my view. Even the international pesticide manufacturers association Crop life International has standpoint on that (I can make contacts if you wish).

DDT use is for us a commercial threat (which is clear, but it is not that dramatic because of limited use), it is mainly a public image threat

We agree with WHO that DDT should be used as an exception, when there is no alternative efficacy and economically wise, we can proof from the field that there are alternatives in nearly all cases where DDT is re-introduced (but these alternatives are not considered as it should be, reasoning to be speculated!

We agree with WHO that DDT should be used for indoor residual spraying for malaria mosquito control only. It is an open secret in the market that considerable quantities of the DDT ends up in agriculture, worst case from one country program showed a "loss" of 40 percent of the allocated DDT volume during the spraying operation. Checking agricultural products from "DDT countries" show increasing residues.

Therefore we fully support EU to ban imports of agricultural products coming from countries using DDT.

We are in discussion with WHO's Pesticide Evaluation Scheme (WHOPES) on manufacturers association level (here Public Health Project Team from CropLife International) about the significance of the DDT specification available. The value of that specification is more than questionable, it is very old, non updated since than, and done only according to the old specification procedure. This is due to the reason that there is not a single DDT manufacturer in the world but a group of producers, which are not always (to be polite) producing WHO standard quality material. So WHO has to admit that it is very difficult to guarantee to the country programs, seeking advice from WHO, a WHO confirmed quality of the product "recommended".

This brings us into the situation that WHOPES evaluated and recommended products are split into a two class society: the DDT class with basically no guarantee possible for quality and conformity to the specs, and the other pesticides which have to run through the WHOPES system with a necessary dossier about tox, efficacy, chem/phys data etc. etc., and which are encouraged to update their specification according to the new system to stay in "business". WHOPES is a perfect and marvelous system from WHO to guarantee the highest efficacy and quality for products used in public health in general and in vector control in special.

Needless to say that if one DDT supplier (or a consortium) will go nowadays through the expensive and time consuming WHOPES, he will fail already in Phase I when it comes to the supply of the tox data and the risk and safety assessment. Every new compound which is evaluated in WHOPES and the data fill proves that it accumulates in the food chain, and that there are doubts about the long term tox impacts will be rejected. But there is no supplier of DDT doing that, so there is no change in listing of DDT as recommended product for indoor residual spraying against mosquitoes by WHO. This seems to be the weakness of the system.

Difficult and sensitive area: country cases and how the use of DDT sometimes evolves (not a general statement but some anecdotal data). India has widespread DDT (and Pyrethroid and OP) resistance in malaria vectors, still DDT (and pyrethroids) are used accepting control levels below 40 percent.

Resistance management programs are hardly accepted by the central authorities despite pressure from WHO, the State authorities and the academical side, because resistance is denied. Here international donors (like World Bank for India), Global Fund etc. giving funds to those countries are asked to take necessary restrictive ac-

tions when it comes to product choice and strategies selected, here WHO can play the referee role.

Southern Africa: political pressure is made on neighboring countries from the Republic of South Africa to use DDT (reasons can only be speculated). Surprisingly at the end let me define a role for DDT: if there is widespread resistance to pyrethroids e.g. being the major class of insecticides for indoor residual spraying nowadays and there is no confirmed cross-resistance to DDT-than DDT might play a role for a short term rotational partner in a resistance management scheme. Short term in the sense unless the level of resistance for the other insecticides in use reaches a level which allows re-introduction of these. Of course close monitoring and evaluation of the resistance has to be included in the scheme. Needless to say that there are other alternatives like carbonates which can be used in rotational programs.

It would be interesting to get the findings of the various resistance networks, e.g. the African network, discussed in this forum, especially what is the level of resistance for DDT.

Thanks for having the chance to share these thoughts with you, looking forward to feedback.

Best regards
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