SUPPLEMENT TO
Testimony Before the
United States Senate
Committee on Environment and Public Works
Washington, D.C.

Submitted to the Record
October 3, 2007

A Framework to Prevent the Catastrophic Effects of Global Warming using Solar Radiation Management (Geo-Engineering)

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Purpose of Supplemental Testimony

At the September 26, 2007, hearing of the Senate Environment and Public Works Committee, Senator Mikulski (Chairman, Appropriations Subcommittee on Commerce, Justice, Science and Related Agencies) and participating in the hearing by accord of the Committee, specifically requested me to supplement my testimony for the record by providing a specific "Framework" by which to address Climate Change using geo-engineering.

The Framework below relies on the National Academy of Sciences 1992 recommendations on geo-engineering for climate change mitigation. It also reflects the extensive, recent contributions of researchers working at the U.S. Environmental Protection Agency, the Lawrence Livermore National Laboratory and the Department of Global Ecology, Carnegie Institution at Stanford University.

The 1992 NAS Recommendation

In 1992, the National Academy of Sciences, Committee on Science, Engineering, and Public Policy, released a major report entitled "Policy Implications of Greenhouse Warming." In that report, the NAS raised and evaluated three questions regarding use of geo-engineering, and specifically Solar Radiation Management (SRM) to prevent the catastrophic effects of ice sheet melting due to global warming:

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1. Does it appear feasible that engineered systems could actually mitigate the effects of greenhouse gases?

2. Does it appear that the proposed systems might be carried out by feasible technical means at reasonable costs?

3. Do the proposed systems have effects, besides the sought-after effects, that might be adverse, and can these be accepted or dealt with?

The Academy concluded the answer to the first two questions was “yes” and that it was time to more fully evaluate the third:

> An exhaustive literature search and analysis has not been completed, but it has been possible to find useful material in the literature and to make first-order estimates that suggest positive answers to these first two questions. This being the case, it seems appropriate to continue consideration of the range of geoengineering possibilities and to pursue answers to question 3 above.

The Promise and Risks of Solar Radiation Management

In the past 15 years, Solar Radiation Management (SRM) has been examined by two premier scientific groups. Lowell Wood has investigated the practicalities and risks of this approach in considerable depth. He is currently on the staff at the Lawrence Livermore National Laboratory. Ken Calderia, of the Department of Global Ecology, Carnegie Institution, has done confirmatory work at Carnegie and Livermore.

Caldeira concluded that shading the sunlight directly over the polar ice cap by less than twenty-five percent would maintain the "natural" level of ice in the Arctic, even with a doubling of atmospheric CO2 levels. By increasing the shading to fifty percent, and the ice shelves grow. Further, the restoration happens fast. Within five years, the temperature would drop by almost two degrees, stabilizing the ice, saving the polar bears and the Inuit population, and demonstrating the efficacy of planetary engineering for $1/36^{th}$ the amount appropriated to assist in recovery of the hurricane flooding disaster in New Orleans. If the aerosols are launched only over the Arctic, there is little danger of directly impacting many humans. As well, the approach is incremental and can be expanded or shut down at will so that temperature effects dissipate within months, returning the region to its "natural" state.

All researchers examining this form of geo-engineering also recognize that, at best, it is no more than a way to buy time to develop clean energy technologies. It is not a solution to the greenhouse gas problem, only a means to prevent the worst of the environmental impacts of greenhouse gases while finding ways to shift away from carbon-based fuels.

The Immediate Need for Solar Radiation Management (SRM) Research

Regarding the need for solar radiation management (using sulfate particles), Paul J. Crutzen, Nobel Laureate for his work on the ozone hole and considered one of the world's premier atmospheric physicist, stated last year:

> "the very best would be if emissions of the greenhouse gases could be reduced so much that the stratospheric sulfur release experiment would not need to take place. Currently, this looks like a pious wish."

James Hansen, recognized as this nation's leading governmental climate scientist, has predicted that massive ice sheet melting may cause damaging increases in sea levels within the next few decades, unless global temperatures can be reduced.

> "Present knowledge does not permit accurate specification of the dangerous level of human-made GHGs. However, it is much lower than has commonly been assumed. If we have not already passed the dangerous level, the energy infrastructure in place ensures that we will pass it within decades [not centuries]."

The pictures below show the effect of the predicted sea level rise on the State of Florida. We would lose three major metropolitan cities, Miami, Fort Lauderdale and Saint Petersburg, as well as the nation's trillion dollar investment at Cape Canaveral potentially by as soon as 2050.

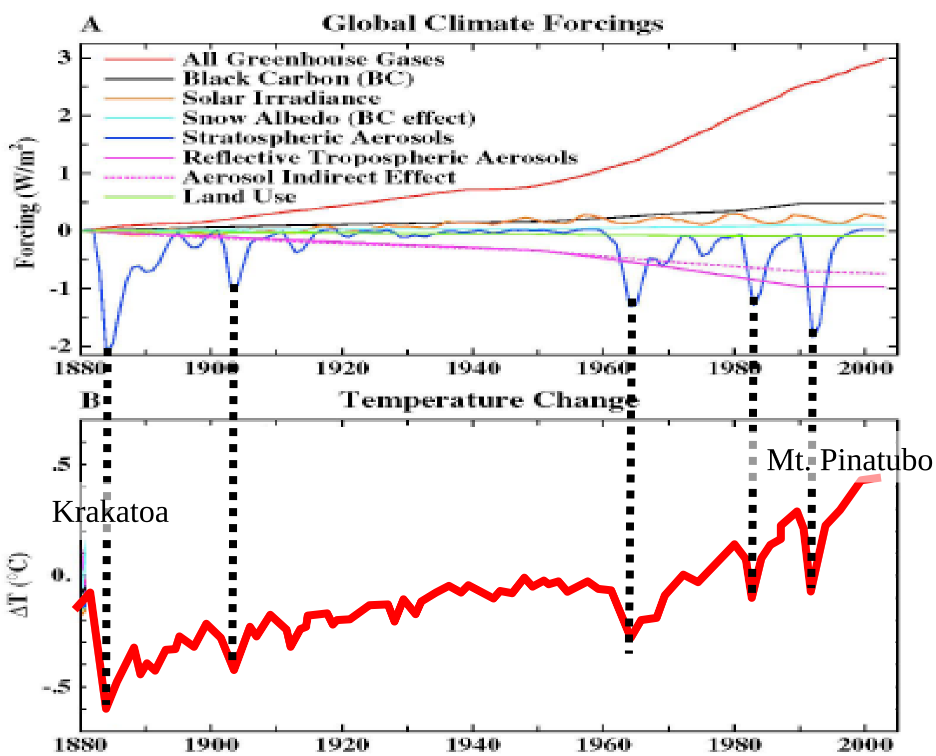
Figure 1

How Solar Radiation Management Works

It has long been recognized that particles in the atmosphere reflect incoming sunlight and thereby decrease the amount of heat retained by the Earth. In essence, they lower the global temperature. Although quickly removed by rain in the troposphere, they have a much longer life in the upper atmospheric levels, the stratosphere. In the language of physics, these particles "force" temperatures to go down. Greenhouse gases, in contrast, force temperatures to go up.

Volcanic eruptions show the effect of stratospheric particles on temperature. The figures below show the size of various "forcings," including stratospheric particles, over the last 125 years. Note the exact correlation between the volcanic eruptions (upper blue line) and reduced global temperatures. Note the size and speed of temperature reductions from these stratospheric aerosols. They are sufficient to counter-balance the effects of greenhouse gases.

Figure 2



For this reason both the National Academy of Sciences (1992) and Nobel Prize winner Paul Crutzen (2006) have recognized the usefulness of this effect to prevent/control climate change.

The purpose of the Framework below is to outline how solar radiation management, using stratospheric particles, can be evaluated and employed with complete certainty and within the time needed to prevent the most catastrophic effects of global warming.

The Framework below is based on solar radiation management (SRM) as detailed by Alan Carlin (2007a and 2007c), and as conceived by Wood, Caldeira and others.

<u>Relationship of Geo-Engineering to Greenhouse Gas Reduction</u>

It is important to note that the use of solar radiation management does not conflict in any way with proposals to reduce GHG emissions to control global warming. When and if these proposals should bring about actual reductions in GHG emissions, the scope of SRM efforts could simply be scaled back so as to continue to achieve the objectives defined in the Framework offered below. That is, the two approaches are complimentary and not "either-or." If successfully implemented, both approaches can theoretically control climate change. As explained above, however, it is very doubtful that GHG emissions control could prevent dangerous climate changes. (Carlin, 2007c).

A Framework for Implementing Solar Radiation Management
<u>to Prevent the Catastrophic Consequences of Global Warming</u>

The Framework would consist of five core elements, each of which is essential to application of the proposed geo-engineering. These five elements reflect the concerns of the National Academy of Sciences and the consensus of climate scientists and economists conducting both science and policy research on geo-engineering.

1. **Precisely Define Solar Radiation Management Objectives:**

In light of the potential to apply SRM incrementally, much like adjustment of a global thermostat, and in light of the potential for any nation or consortium to use SRM without "permission," the first element of the Framework is specification of the objective being sought so that any nation or international body would have a basis for responsible action. Objective (3), below, discusses the need for an international body to address actual implementation of SRM.

Proposed Objective:

> **Maintain the global energy balance at a level that will preserve the historic mass of all three major ice sheets (Greenland, West Antarctic, and East Antarctic)**.

This objective might be modified to require additional cooling in the short term to offset the heating now underway and causing accelerated melting of the Arctic ice, should it be decided that the world does not wish to have a North-West Passage available for shipping and other purposes. Presumably the cooling offered by SRM would be roughly equivalent to that created by the Mount Pinatubo eruption in 1992 (the last blue blip down in stratospheric aerosol forcing shown in Figure 2, above). The proposed objective reflects prevention of the primary catastrophic effect of global warming, sea level rise, an event that would displace more than a quarter of the population of the world and, as former Vice-President Gore suggests, would end civilization as we know it.

2. **SRM Research:**

Although there is no question that a nation could successfully implement SRM by doing no more than replicating the major volcanic eruptions, Dr. Wood recommends more optimum types of particles and more targeted placement of them into the stratosphere. We need research on each of the following:

a. The optimal size, composition, and placement of particles (elevation and geographic coverage) and determination of the optimum radiation wavelengths to be reduced, in order to achieve the Framework Objective;

b. The particle quantities required as a function of temperature reduction (energy balancing) as needed to meet the Framework Objective, *i.e.*, in order to preserve the historic mass of all three major ice sheets;

c. Evaluation of the optimal transport mechanism to carry particles into stratosphere;

d. Identification of, and evaluation of means to eliminate or reduce, potential adverse non-temperature environmental effects of particles;

For further discussion, see, references listed in footnote 119 of Carlin, 2007a.

3. Design and implement an institutional setting for use of SRM

Professor Barrett, Director of Johns Hopkins University's School of Advanced International Studies, argues there is an immediate need to examine how to manage SRM use through an international body, a policy recommendation also made by Alan Carlin of the U.S. Environmental Protection Agency (Barrett 2007, Carlin 2007). To prevent the political pathologies observed in the operations of the IPCC and the UN Environmental Program, an international institution patterned after the Federal Reserve Board or the International Monetary Fund might be expected to provide neutral leadership. Such an apolitical body would likely operate in small incremental steps, much as the Federal Reserve and the IMF do with monetary policy. Recalling that SRM could be implemented by a single country with the needed financial and technological resources, this element of the Framework would serve to ensure international consensus on this global activity.

4. **Legislative Leadership to Limit SRM Legal Liability**

Adjusting climates will create global winners but always has the potential to create some local losers. For example, a decision to cool the Arctic in order to prevent melting of the Greenland Ice Sheet would also likely close the North-West Passage and may limit rainfall above the Arctic Circle. Those relying on use of that passage or the rainfall would be losers. Although SRM is now expected to have few unintended consequences, risk of legal liability could prevent use of this geo-engineering. Congress will need to address this issue in order to ensure sensible and timely use of SRM. For a more extensive discussion of this issue, see Carlin, 2007a, p. 181.

5. Proposed Timeline

This Framework contemplates a five phase approach that would likely achieve its objective of guaranteeing prevention of catastrophic sea level rise within five years.

Phase I – Laboratory Research and Institutional Development: A consortium to include the national leaders in SRM, would conduct preliminary research and technical development work and draft a detailed plan to accomplish the necessary pilot scale testing of SRM, to include funding requirements. The ideal leader of this consortium would be Professor Wood (with significant assistance by Professor Caldeira and his colleagues), and would include institutional experts such as Professor Barrett at Johns Hopkins. Most physical research would involve laboratory scale physics and chemistry, as well as computer simulations, modeling, and analyses of the kind routinely conducted by climate scientists today. Simultaneously, the institutional research branch would identify alternative means to regulate and manage SRM use, to include formation of a specific objective such as presented in the first Element above. The plan would include a detailed proposal for formation of a control institution to test and regulate the use of SRM. The plan would ideally be reviewed and accepted by experts from a very wide spectrum of relevant disciplines (18 months, $3.5 million estimated).

Phase II: Careful real world testing of subscale versions of SRM at gradually increasing scales to verify any remaining questions and development of revised implementation plan; appointment and organization of the SRM control organization (18 months).

Phase III: Review research results and propose and take comment on an SRM schedule of events. This would be the first major action of the international SRM control body. It would include a reexamination of the objective to ensure adequate global support (18 months).

Phase IV: Solar Radiation Management (SRM) begins under international control through the SRM control body. Implementation would be transparent and would include continuing monitoring and reporting of physical effects as well as and semi-annual plan revisions based on new information gained. Full SRM for the geographic area selected/world would be realized within weeks of full implementation. Note that if the quantities are correctly selected, it would be possible to design SRM so that no further warming of the area selected/world would occur after that time regardless of other climatic events as long as an appropriate level of particles is maintained.

Phase V: Maintenance of SRM system based on continued comparisons between objectives (element 1 above) and actual achievements. The SRM program, if effective, would be expected to continue until no longer needed (when greenhouse gases are adequately controlled), and could be expected to remain in place for a century.

For a more lengthy discussion on some of the concepts underlying this Framework, see Carlin, 2007.

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