# Cooling the Planet

If we can't adequately reduce or sequester carbon emissions, are more-radical alternatives like orbital mirrors a solution to climate change?

By Mark Williams Pontin
February 13, 2007

**In the past two decades, various novel planet-cooling technologies have been proposed–** improbable, monumental projects such as putting into orbit giant mirrors with thousand-kilometer diameters or clouds of trillions of wafer-thin, butterfly-light lenses. Until recently, such proposals have remained on the fringes of acceptable scientific speculation. Now, with the Intergovernmental Panel on Climate Change (IPCC) claiming in its report of February 3 that there's a 90 percent probability that the last half-century of global warming has been caused by humans, a milestone moment has apparently arrived. Four hours after the IPCC report's release, even the White House (historically extremely hostile to the idea of anthropogenic climate change) had unearthed a 2001 remark by President George W. Bush acknowledging that greenhouse-gas increases were largely created by humans. Consequently, while mainstream acceptance of climate change means that the battles over what humanity should *do* about it are just beginning, radical planet-cooling technological possibilities are receiving consideration alongside the standard proposals for capping, reducing, or sequestering carbon emissions.

The notion of interposing a *really big* mirror between the Sun and Earth, which exploits the fact that our planet already reflects about 30 percent of incoming sunlight back into space by effectively increasing its reflectivity, dates back to the 1980s. Initially, such mirrors were suggested for cooling Venus as part of a theoretical future effort to terraform that planet. But in 1989, James Early of the Lawrence Livermore National Laboratory noted the harbingers of global warming and proposed deflecting a measure of sunlight with a “space shade” located at Lagrangian Point L1–an orbit 1.5 million kilometers up, where Earth’s gravity and that of the Sun are balanced so an object can remain stationary relative to both bodies.

How big a shield was Early thinking about? One 2,000 kilometers in diameter and about 10 microns thick, with a weight of about 100 megatons under Earth’s gravity. Early’s shield would have been either opaque or else transparent in the form of a Fresnel lens (the kind of lens used in lighthouses, in which the amount of material required is reduced from that needed in a conventional spherical lens because the lens is broken into concentric annular sections). Early estimated the cost at $1 to $10 trillion. As for assembling his giant mirror and placing it at L1, Early suggested using moon rock for the materials and a manufacturing plant on the lunar surface, then launching the components by a mass driver from the Moon to L1.

Given how arduous even minor assembly work on the International Space Station’s exterior has been, and given that NASA will almost certainly be unable to meet its schedule for returning to the Moon by 2020, such a megaconstruction doesn’t seem immediately feasible. Last year Roger Angel, University of Arizona Regents Professor and the Steward Observatory Mirror Laboratory’s director, offered another plan: to place in orbit at L1 a very great number of small, already assembled objects. Angel presented his concept to the National Academy of Sciences in April 2006, got a NASA grant to fund further research, and then published a detailed paper, “Feasibility of Cooling the Earth with a Cloud of Small Spacecraft near L1.”

Angel’s plan calls for small “flyers”: transparent sheets two feet in diameter and 1/5,000 of an inch thick, each weighing approximately one gram under Earth’s gravity. Trillions of these objects, according to Angel, could together form a cylindrical cloud having a diameter half that of Earth’s and a length of 60,000 miles. Interposed lengthwise between the Sun and Earth at L1, this cloud would uniformly reduce sunlight on our planet’s surface by 2 percent, which would be sufficient to offset the warming produced by even a doubling of atmospheric carbon dioxide.

Angel stresses that his plan is an emergency option, for use only if climate change so accelerates that global catastrophe looms within a decade or two. It is, he says, “no substitute for developing renewable energy, the only permanent solution.” It’s just as well that Angel makes that qualification, since he estimates that the total mass of all the flyers composing his cloud would be 20 million tons and a total of 20 electromagnetic launchers. At $10,000 a pound, conventional rockets are a prohibitively expensive way of getting that much mass into orbit. Human beings would have to launch a stack of flyers every five minutes for 10 years to put the whole structure in place.

Gregory Benford, a professor of plasma physics and astrophysics at the University of California, comments, “This whole L1 idea is neat, but it’s going to cost trillions of dollars, we can’t do it right away, and it gets used to label the entire field of geoengineering as smoke and mirrors.” Benford, besides having been an advisor for NASA, the Department of Energy, and the White House Council on Space Policy, has been a science-fiction writer, and he distinguishes carefully between currently feasible technological solutions and the kinds of advanced possibilities that he writes about in his fiction. “These are fun ideas for the year 2,100. But we don’t live there. People don’t quite understand that we will never again in our lifetime see the level of $CO_2$ in the atmosphere that we enjoyed just yesterday. Our grandchildren likely won’t, either.”

What's to be done? Other scientists have proposed Earth-based environmental megamodifications, such as reflective films laid over the planet's deserts or fertilizing the seas with iron to create vast blooms of plants that would then consume tons of carbon dioxideand, as the plants died, drag the carbon into the sea. But even these measures are problematical and grandiose when most European and North American environmentalists remain committed to an international regime of carbon emissions caps and reject the idea of radical new technologies to mitigate the climate change that technological society has already created.

On the one hand, such folks do have a point inasmuch as any global modification to the environment that went wrong would be a cure worse than the disease. On the other hand, it seems increasingly unlikely that a global agreement on emissions caps will be enacted anytime soon. The IPCC report claims there is a high likelihood that Earth's climate has already moved past the point of no return and that sea levels will continue rising for millennia. Simultaneously, billions of people in China and India are arriving at the First World banquet table: according to the International Energy Agency, in two years China will pass the United States as the largest source of carbon emissions. "The political impossibility of what I call the prohibitionist agenda–that is, carbon prohibitionism–brings a kind of hallucinogenic quality to the global-warming discussion," says Benford. "No economist I know believes that global carbon emissions can be restrained within a century to even the level we have now. Every economist knows that the timescale for changing energy infrastructure is at least half a century to a century, just because of replacement costs. Economists are scientists too, and ignoring them isn't just blind: it's perverse."

Benford has a proposal that possesses the advantages of being both one of the simplest planet-cooling technologies so far suggested and being initially testable in a local context. He suggests suspension of tiny, harmless particles (sized at one-third of a micron) at about 80,000 feet up in the stratosphere. These particles could be composed of diatomaceous earth. "That's silicon dioxide, which is chemically inert, cheap as earth, and readily crushable to the size we want," Benford says. This could initially be tested, he says, over the Arctic, where warming is already considerable and where few human beings live. Arctic atmospheric circulation patterns would mostly confine the deployed particles around the North Pole. An initial experiment could occur north of 70 degrees latitude, over the Arctic Sea and outside national boundaries. "The fact that such an experiment is reversible is just as important as the fact that it's regional," says Benford.

Is Benford's proposal realistic? According to Ken Caldeira, a leading climate scientist at Stanford University and the Carnegie Institution's Department of Global Ecology, "It appears as if any small particle would do the trick in the necessary quantities. I've done a number of computer simulations of what the climate response would be of reflecting sunlight, and all of them indicate that it would work quite well." He adds, "I wouldn't look to these geoengineering schemes as part of normal policy response, but if bad things start to happen quickly, then people will demand something be done quickly."

Given that our social systems would crash without the economic growth that depends on the existing energy infrastructure that we have, Benford personally believes that governments can't be counted on to develop and deploy alternatives: "Anybody who thinks governments are suddenly going to leap into action is dreaming." Benford says that one of the advantages of his scheme is that it could be implemented unilaterally by private parties. "Applying these technologies in the Arctic zone or even over the whole planet would be so cheap that many private parties could do it on their own. That's really a dangerous idea because it suggests the primary actor in this drama will not be the nation-state anymore. You could do this for a hundred million bucks a year. You could do the whole planet for a couple of billion. That’s amazingly cheap.”

*Mark Williams is a contributing editor to* ***Technology Review****.*