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Can Dr. Evil Save The World?

Forget about a future filled with wind farms and hydrogen cars. The Pentagon's top weaponeer says he has a radical solution that would stop global warming now -- no matter how much oil we burn

JEFF GOODELL

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Last summer, an elite group of scientists, economists and government officials gathered at Snowmass ski resort near Aspen, Colorado, to contemplate the end of the world. The weeklong "workshop, held in the shadow of 14,000-foot-high peaks at the Top of the Village lodge, was organised by the Energy Modeling Forum, a group of academics and industry leaders affiliated with Stanford University. A few months earlier, Stanford professor John Weyant, the director of the group, had asked participants to consider a nightmare scenario: It's 2010, and global warming is not only happening, it's accelerating. The Greenland and western Antarctic ice sheets are melting at an exponential rate, leading to predictions of a twenty-foot rise in sea levels by 2070. In this scenario, southern Florida vanishes, New York City becomes an aquarium, London looks like Venice. In Bangladesh alone, 40 million people are displaced by the rising waters. Droughts cripple food production, leading to widespread famine. If you need to put a "sudden stop" on emissions of carbon dioxide, Weyant asked, how — short of shutting down the global economy — would you do it?

Spinning out blue-sky scenarios is nothing new for this crowd. But there was extra urgency in this exercise because it wasn't all blue-sky. In the Arctic, things are already getting freaky. Temperatures have warmed three times faster than the global average. Last year, scientists found that an area of polar ice twice the size of Texas had melted since NASA started compiling satellite data twenty-seven years ago. Some studies suggest that the Arctic Ocean may be ice-free by the end of the century. The giant ice sheets that cover Greenland — which were projected to grow for another century — are also behaving strangely. "It turns out we had it wrong," says Richard Alley, a noted paleoclimatologist at Penn State. "The ice sheets are shrinking, and they're doing it almost a hundred years ahead of schedule."

At the Snowmass workshop, it was clear that putting a "sudden stop" to climate-warming emissions would require something more than investing in wind turbines. In one presentation, Jae Edmonds, chief scientist at the Pacific

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Northwest National Laboratory, suggested that the only way you could radically cut emissions without shutting down the economy would be to replace coal and oil with genetically engineered biofuels, which would not only cut pollution but would suck up carbon dioxide as they grow. But making such a switch would require a massive expansion of agriculture, sweeping changes to the world's energy infrastructure, bold political leadership and trillions of dollars.

Then Lowell Wood approached the podium. At sixty-five, Wood is a big, rumped guy, tall and broad as a missile silo, with a full red beard and pale blue eyes that burn with a thermonuclear glow. In scientific circles, Wood is a dark star, the protégé of Edward Teller, the father of the hydrogen bomb and architect of the Reagan-era Star Wars missile-defense system. As a physicist at Lawrence Livermore National Lab in California for more than four decades, Wood has long been one of the Pentagon's top weaponeers, the agency's go-to guru for threat assessment and weapons development. Wood is infamous for championing fringe science, from X-ray lasers to cold-fusion nuclear reactors, as well as for his long affiliation with the Hoover Institution, a right-wing think tank on the Stanford campus. Everyone at Snowmass knew Wood's reputation. To some, he was a brilliant outside-the-box thinker; to others, he was the embodiment of Big Science gone awry.

Wood hooked up his laptop, threw his first slide onto the screen and got down to business: What if all the conventional thinking about how to deal with global warming was *wrong*? What if you could do an end run around carbon-trading schemes and international treaties and political gridlock and actually *solve the problem*? And what if the cost to get started was not trillions of dollars but \$100 million a year — less than the cost of a good-size wind farm?

Wood's proposal was not technologically complex. It's based on the idea, well-proven by atmospheric scientists, that volcano eruptions alter the climate for months by loading the skies with tiny particles that act as mini-reflectors, shading out sunlight and cooling the Earth. Why not apply the same principles to saving the Arctic? Getting the particles into the stratosphere wouldn't be a problem — you could generate them easily enough by burning sulfur, then dumping the particles out of high-flying 747s, spraying them into the sky with long hoses or even shooting them up there with naval artillery. They'd be invisible to the naked eye, Wood argued, and harmless to the environment. Depending on the number of particles you injected, you could not only stabilize Greenland's polar ice — you could actually *grow* it. Results would be quick: If you started spraying particles into the stratosphere tomorrow, you'd see changes in the ice within a few months. And if it worked over the Arctic, it would be simple enough to expand the program to encompass the rest of the planet. In effect, you could create a global thermostat, one that people could dial up or down to suit their needs (or the needs of polar bears).

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Reaction to Wood's proposal was fast and furious. Some scientists in the room, including Richard Tol, a climate modeler with the Economic and Social Research Institute in Dublin, Ireland, found Wood's ideas worthy of further research. Others, however, were outraged by the unscientific, speculative, downright arrogant proposal of this...this *weaponeer*. The Earth's climate, one scientist argued, is a chaotic system — shooting particles into the stratosphere could have unforeseen consequences, such as enlarging the ozone hole, that we might only discover after the damage was done. What if the particles had an effect on cloud formation, leading to unexpected droughts over northern Europe? Bill Nordhaus, a Yale economist, worried about political implications: Wasn't this simply a way of enabling more fossil-fuel use, like giving methadone to a heroin addict? If people believe there is a solution to global warming that does not require hard choices, how can we ever make the case that they need to change their lives and cut emissions?

Weyant, surprised by the "emotional and religious" debate over Wood's proposal, cut off discussion before it turned into a shouting match. But Wood was delighted by the ruckus. "Yes, there was some spirited discussion," he boasted to me a few days later. "But a surprising number of people said to me, 'Why haven't we heard about this before? Why aren't we doing this?'"

Then Wood flashed a devilish grin. "I think a few of them were ready to cross over to the dark side."

Global warming, as Al Gore put it recently, "is the only crisis we've ever faced that has the capacity to end civilization." The ultimate solution is no mystery: Among climate scientists, a consensus has developed that we must cut projected global emissions at least in half by the year 2050. But a few leading scientists have begun to suggest that reducing pollution simply can't be done fast enough to prevent a planetwide meltdown. "This is not a goal that can be achieved with current energy technology," says Marty Hoffert, a physicist at New York University. "I think we need to admit that and start thinking bigger."

According to Hoffert, the 850 coal-fired plants projected to be built worldwide in the next decade or so will emit five times more carbon dioxide than will be reduced under the Kyoto treaty on global warming. Add in 100 million newly rich Chinese road-tripping in their SUVs, and you can see why a growing number of scientists believe we are approaching a climate catastrophe faster than we think. Paul Crutzen, a respected atmospheric chemist who won a Nobel Prize for his pioneering work on ozone depletion, recently suggested that it is time to consider "last resort" options — including the idea championed by Wood and others to shoot sulfate particles into the stratosphere.

To his colleagues, Crutzen's willingness to consider deliberate intervention with the planet's climate is a sign that the debate over global warming has changed. "Here is a guy who knows more about the Earth's atmosphere than anyone else alive, and he's telling us that the situation is so dire we need to think about intervening with the atmosphere on a planetary scale," one climate scientist told me. "That's frightening, of course — but from a purely scientific point of view, it's also very interesting."

Until recently, discussion of geoengineering — intentional, large-scale manipulation of the Earth's climate — has been taboo among scientists. The pursuit is widely seen as not only a dangerous distraction from the serious business of figuring out how to cut emissions but also as borderline immoral. Lester Brown, one of the godfathers of the environmental movement and president of the Earth Policy Institute, sees geoengineering as "another step down the road of actively managing the planet — something we've already proven we're not terribly good at. The whole idea of geoengineering is based on an assumption that we know how this all works, when in truth we haven't a clue." Burton Richter, a Nobel Prize winner in physics, also dismisses the idea, arguing that "piling one un-understood problem on top of another un-understood problem is not very smart." The point was driven home a few months ago when Stewart Brand, founder of the *Whole Earth Catalog* and a supporter of geoengineering, attended a meeting with Al Gore and suggested erecting a giant sun shade in outer space to cool the planet.

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"Gore looked at me like I was crazy," Brand recalls. "He snapped, 'Right, Brand. Let's do an experiment with the entire planet.'"

But of course, we're already running an experiment with the entire planet — it's called civilization. To keep this civilization going, we dump billions of tons of CO₂ into the atmosphere each year, the impact of which we're just beginning to understand. "In effect, we're already engineering the climate," says Ken Caldeira, a senior scientist at the Carnegie Institution's Department of Global Ecology at Stanford who collaborated with Wood on the "Save the Arctic" proposal. "We just don't want to admit it. You can argue that the only real difference between what we're doing today and what geoengineering advocates are proposing is a matter of intention. And frankly, the atmosphere doesn't care about what's going on in our heads."

Many scientists who support the idea of actively managing the Earth's climate believe that it's simply too late to rely on a more gradual approach to global warming. James Lovelock, who coined the Gaia hypothesis of the planet as a single living organism in the 1960s, compares geoengineering to chemotherapy. "There is only a small chance to save the patient, but we have to try it," Lovelock says. "It is a survival strategy, a leaky lifeboat."

Wood, whom Lovelock praises as a "man of great invention," understands how ethically fraught his idea is, and how it raises anew a fundamental question about our relationship with the world we live in — are we the caretakers of the Earth, or the masters of it? Indeed, the very subversiveness of geoengineering may be one reason why Wood

champions it. "Lowell enjoys playing the role of Dr. Evil," says Caldeira, whose own politics are solidly enviro-lefty. "But he also happens to be brilliant. And he's one of the few people I know who is thinking about the nuts and bolts of how to actually manage the Earth's climate. I don't really think of him as a scientist — he's a planetary engineer."

Lowell Wood was a rocket boy, a child of the American West's postwar optimism. The son of a real estate investor, he grew up in the suburb of Simi Valley, north of Los Angeles, just as the old walnut ranches were being bulldozed to make way for tract homes and the air was filled with sonic booms from military jets. He devoured books about rocketry and space exploration, such as Willy Ley's classic *Conquest of the Moon*. For Wood, it was not a distant dream. Nearby was the Santa Susana Field Laboratory, a government facility where the engines that powered the Apollo rockets were tested and the famous German rocketeer Werner von Braun sometimes worked. "Boys are seemingly 'doomed' by their Y chromosomes to be hikers and climbers and explorers," Wood says, "so I not infrequently hiked a few miles to watch the big rocket engines test-fired." After high school, he majored in math and chemistry at UCLA, where he met the man who would change his life: Edward Teller.

Teller, who fled his native Hungary as a young man to escape the Nazis, helped build the first hydrogen bomb and co-founded the Lawrence Livermore lab. With enormous dark eyebrows, a prosthetic foot and an unshakable belief in the Soviet Union as an Evil Empire, Teller was one of the most influential scientists of the nuclear age — and an inspiration for the character of Dr. Strangelove in Stanley Kubrick's 1964 film. Teller was impressed enough by Wood to invite him to join the Livermore lab. At first, Wood explored nuclear fission and supernova astrophysics; by the early 1970s, he was hard at work designing nuclear weaponry.

In their partnership, Teller was the big-picture guy, Wood the detail man. "Lowell is a much better engineer than Teller was," says Freeman Dyson, a physicist who knew both men well. "Teller loved big ideas but was not so interested in how to actually implement them." But as the Cold War cranked up and fear of mushroom clouds shadowed the world, both men became symbols of the unholy marriage of science and war. In 1971, torch-carrying antiwar protesters in Berkeley marched on Teller's home and threatened to burn him alive. Wood found death threats pinned to the gate of his home.

To Teller, nuclear bombs were not just instruments of war but tools of progress. He embarked on "Project Plowshare," a perverse scheme to promote the use of nukes to excavate harbors, canals and mines. ("We will change the Earth's surface to suit us," Teller proclaimed.) Despite the idea's insanity, he nearly gained approval to use five nuclear bombs to dig a harbor at Cape Thompson, Alaska, until the plans were halted by an international outcry. Teller even proposed setting off a nuclear blast several hundred feet beneath the surface of the moon, predicting that it would unleash a great fountain of water and enable humanity to colonize the lunar surface.

But the fullest expression of Teller's apocalyptic vision came in the 1980s, when he and Wood developed the idea of nuke-powered X-ray lasers in space that could vaporize Soviet missiles before they reached the U.S. It was a fantastically costly and complex scheme, but Teller managed to sell it to President Reagan, who was eager to fund anything that might rattle the Soviets. Officially dubbed the Strategic Defense Initiative but known to everyone as Star Wars, the project became the centerpiece of Reagan's defense policy. Billions of dollars in research money flowed to Livermore — much of it to support the "O Group," a ragtag bunch of Berkeley and Stanford grads assembled by Wood to build the X-ray laser.

Members of the O Group worked insane hours, fueled mostly by soft drinks and ice cream, driven by a sense of mission and pride in the fact that they were the smartest weapons builders on the planet. Richard Gabriel, a software-industry pioneer who worked at the lab in the early 1980s, recalls that one team member kept two maps above his desk — one of the Soviet Union and one of the moon — labeled "before" and "after." Some of the scientists carried weapons in their cars to protect them from the KGB. In their rare moments of free time, the group would hang out at the enormous log home that Wood had built by hand in the hills above the lab, where they'd goof off by cranking open a gas line that ran through the property and lighting it, creating a thirty-foot-high tower of fire.

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Plenty, of course. When Wood presented the idea to a room full of climate scientists at a 1998 conference at the Aspen Global Change Institute in Colorado, he hardly received a rousing welcome. "I was stunned to see Lowell Wood — the grandest of Cold Warriors — talking about global warming," says David Keith, a physicist at the University of Calgary in Alberta with a long-standing interest in the moral and

technical complexities of geoengineering. Like other scientists in the room, Keith was well aware of Teller's past scheme to blast canals and harbors with nuclear bombs. Now the old man's protege was proposing to save the planet with a giant dust cloud?

In Wood's presentation, there was precious little talk of potential side effects of this new scheme, such as how it might affect the oceans or the notoriously complex chemistry of the upper atmosphere. At one point, recalls Ken Caldeira, Wood even joked that the best way to stop global warming was to start a nuclear war. "It was pretty outrageous," Caldeira admits. "But now I realize it was just Lowell playing provocateur."

After Wood's presentation, Caldeira was dubious. As a climate modeler, he knew that heat from sunlight was different than heat trapped in the atmosphere by a thicker blanket of CO₂, and he believed that Wood's scheme might inadvertently blur the temperature differences between night and day, reduce seasonal changes and disrupt the spread of heat between the equator and the poles. Determined to prove his point, Caldeira checked it on a highly sophisticated computer model of the Earth's climate. After running the simulation for several months, he was startled by the results: Injecting particles into the stratosphere would have little effect on local climates. Wood's calculations, it turned out, were correct.

Despite its near-mythological status as the dark heart of weapons research, the Livermore nuclear lab looks like any other big industrial facility — a collection of low, brown buildings about a half-hour east of Berkeley, surrounded by strip malls and rolling hills. Inside, the grounds feel like a community-college campus — albeit one with brightly marked radiation shelters every few hundred feet. On the day I arrived at the lab, the conference room where I was to meet Wood for the first time was empty. A few minutes later, I noticed what looked like a janitor struggling with a lock on the side door. His blue shirt was untucked, and sweat beaded on his forehead. I thought he had come to clean the room. Only when I looked at his badge did I realize it was Wood, the great weaponeer.

At times, Wood seems like a caricature of an absent-minded professor: disheveled, distracted, his pockets stuffed with odd bits of paper. In the 1960s, colleagues hid a lead brick in his briefcase; Wood toted it around for days without noticing it. They tell stories about him picking locks on jetways when he missed his flight, or chartering private planes to rush him to nuclear test sites. Although he has a reputation as a bad-boy physicist, his e-mails are punctuated with emoticons and smiley faces.

When Star Wars tanked, Wood became, as one Livermore alumnus puts it, "a pariah." With the Soviet Union gone, he needed a new enemy to fight, one that came with federal funding attached. Lately, terrorism has fit the bill. "Threats are my business," he says. "I help the government figure out who can kill us, and how, and when." Although officially retired, Wood still has an office at Livermore; his top concern at the moment is the outbreak of an engineered pandemic, such as anthrax or smallpox. He also chaired a congressional commission that investigated the risk of attack from an electromagnetic pulse bomb — basically, a nuke that explodes at high altitude, leaving people unharmed but disabling every power line and computer and electrical device in the country.

For a guy who spends many of his waking hours dreaming up ways to fight terrorists, Wood seems remarkably cheerful. One day in September, when we meet for lunch in Silicon Valley, the arrest of twenty-four suspected bombers in England has grid-locked airports worldwide. But Wood, who has spent the morning on the phone with government officials assessing the threat, only marvels at the unoriginality of the plot. "It's an oldie but goodie," he says, pointing out that Al Qaeda bomber Ramzi Yousef tried to bring down a Philippine airliner in 1994 using a similar device assembled from liquid explosives. "If this is the best they can come up with..."

For a moment, he seems to regret the glory days of the Soviet empire, when he at least had an adversary worthy of engagement. He laughs off the notion that either North Korea or Iran is capable of lobbing a missile at us. "Give me a break," he says. "These aren't threats. These are annoyances."

Wood is equally unimpressed by President Bush. "He's no Ronald Reagan, that's for sure," he says. In 2004, during testimony before the House Committee on Armed Services, Wood did not mince words about the administration's failure to muster a timely response to 9/11. "More time has lapsed since the 9/11 attack and the present day than elapsed between Leslie Groves taking over the brand-new Manhattan Project and the nuclear raids on the Japanese that ended World War II," Wood noted. "Yet we Americans are still cowering under vague but stern threats from our

imperfectly informed national leadership in the war against global terror."

Because of the classified nature of his work, Wood is reluctant to talk about his personal life beyond the fact that he's married and has a teenage daughter (who, not surprisingly, is a math prodigy). He discusses his government research only in person or on secure phones or faxes, never via e-mail. Although he sometimes works as a corporate consultant, money clearly isn't of much interest to him (he drives a dusty, sagging Toyota 4Runner). He goes out of his way to make the point that all the work he has done on geoengineering has been on his own time, not at taxpayer expense.

That may be true, but as Wood knows, climate engineering has often been little more than an extension of weapons re-search. In the 1940s, the discovery that "seeding" clouds with silver iodide crystals would create rain led American military strategists to dream of someday fighting wars with hurricanes and thunderstorms. During the Vietnam War, the U.S. military used cloud seeding in an attempt to increase rainfall over the Ho Chi Minh Trail — a secret program that prompted the United Nations to ban "environmental modification techniques" as weapons. Wood considers the issue moot. "As a tool of warfare," he says, "weather modification has been a complete failure."

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But that hasn't stopped conspiracy theorists from believing that the government is secretly tinkering with the weather. Type the word "chemtrails" into Google and you'll get about 814,000 hits, most of them linked to the Web sites of people who insist that the New World Order began spraying the atmosphere with particles years ago in a massive campaign to mask the devastating effects of global warming. Evidence of this stealth campaign, they say, can be seen in the contrails of jets — which are actually "chemtrails" dumping polymer aerosols into the sky to reflect sunlight and cool the planet. According to chemmie conspiracists, millions of people are being poisoned from the barium and aluminum in these aerosols as they invisibly rain down on our heads.

When I ask Wood about this, he looks deeply amused. "A secret government conspiracy? One of the remarkable things I've learned about working with the government is that there are no secrets. It's all out there. You just have to know where to look."

"No secrets?" I ask.

"Well," he admits, "maybe five or six."

You might think the Bush administration would love the kind of geoengineering advocated by Wood, if for no other reason than it might enable the world to keep guzzling fossil fuels for another generation. But in fact, geoengineering has received little support from the Bushies. The administration first explored the idea in September 2001 during a high-level meeting of a dozen scientists, with Wood participating by speak-erphone. "It was a frank discussion of geoengineering options and the need for research funding," recalls physicist David Keith. A draft paper was written up, but it went nowhere. Then, in 2003, several high-level administration officials attended a conference at the Aspen Global Change Institute, where Wood gave a presentation about the practicality of geoengineering. Again, nothing happened. Nor has Wood received much back-channel support from the administration. "To talk openly about geoengineering, you would first have to admit there is a problem," Wood says. "And right now, no one is willing to do that in Washington. The issue is completely polarized."

Without official support, geoengineers have been forced to pursue their theories with all the zeal of a dad fixing up an old car on the weekend. Some dream of launching a flotilla of cloudmaking machines in the ocean; others want to build machines that will turn carbon dioxide into rocks — in effect speeding the natural process by which CO₂ is turned into limestone. In comparison to such wild-eyed schemes, the notion of spraying aerosols into the stratosphere seems downright pedestrian. "The technological complexity of this is near zero," Wood says. In addition to cooling the planet, he argues, injecting particles into the stratosphere would also boost crop yields, reduce harmful UV radiation that causes 60,000 deaths each year from skin cancer and even generate more colorful sunsets. "Who doesn't like pretty

sunsets?" Wood quips.

But most important, according to Wood, is the price. He calculates that the cost of a global aerosol program — about \$1 billion a year — works out to the equivalent of about a penny per ton of carbon reduced. In contrast, the cost of reducing a ton of carbon under the Kyoto treaty, which is set to begin in 2008, is expected to be at least fifteen dollars. And as Wood points out, the United Nations Framework Convention on Climate Change, the 1992 agreement on which Kyoto is based, mandates that countries choose the *least expensive way* to avoid dangerous climate change.

But many leading scientists note that such cost estimates don't take into account the possible side effects of geoengineering. Michael Oppenheimer, a geosciences professor at Princeton University, says that Wood's particles could boost stratospheric levels of chlorine, the chemical most damaging to the ozone layer. "The chemistry of the Earth's atmosphere is exceedingly complex," Oppenheimer says. "You're trading one destructive environmental problem for another — not a good idea, either in the short run or the long run."

Even worse, scientists say, injecting particles into the atmosphere could destroy the world's oceans by allowing carbon dioxide to continue to rise. When that additional CO₂ dissolves in water, it forms carbonic acid—which, in turn, is absorbed by the oceans. For years, climate scientists assumed that the Earth's natural buffering capacity would prevent the seas from growing too acidic. But in 2003, Caldeira and a colleague, Michael Wickett, calculated that higher CO₂ levels could make the oceans more acidic than they have been for 50 million years — dissolving coral reefs and threatening plankton that form the foundation of the oceanic food chain.

That, of course, is the fundamental problem with geoengineering — it doesn't even attempt to address the root source of global warming. Gavin Schmidt, a climate modeler at the NASA Goddard Institute for Space Studies, offers a simple analogy to illustrate the point. "Think of the climate as a small boat on a rather choppy ocean," Schmidt wrote recently. "Under normal circumstances the boat will rock to and fro, and there is a finite risk that the boat could be overturned by a rogue wave. But now one of the passengers has decided to stand up and is deliberately rocking the boat ever more violently. Someone suggests that this is likely to increase the chances of the boat capsizing. Another passenger then proposes that with his knowledge of chaotic dynamics he can counterbalance the first passenger and, indeed, counter the natural rocking caused by the waves. But to do so he needs a huge array of sensors and enormous computational resources to be ready to react efficiently but still wouldn't be able to guarantee absolute stability, and indeed, since the system is untested, it might make things worse.

"So," Schmidt concluded, "is the answer to a known and increasing human influence on climate an ever more elaborate system to control the climate? Or should the person rocking the boat just sit down?"

Last June, Wood and Caldeira were discussing the problem of melting polar ice with their friend Gregory Benford, a noted science-fiction writer and physics professor at the University of California at Irvine. Benford, himself an outspoken advocate of geoengineering, had an idea. "Why don't you do an experiment?" he suggested.

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A real-life experiment in the Arctic was, of course, out of the question. But after some discussion, Caldeira and Wood decided to run some computer modeling to see if shooting particles into the stratosphere over the North Pole could help stabilize the region. How much sunlight, they wondered, would you have to reflect to stop the ice from melting? What effect would it have on the rest of the Earth's climate?

Scientists routinely use such computer models to test the effects of various climate-related scenarios, from rising CO₂ levels to the impact of deforestation on global warming. After several weeks of running a climate simulation on Stanford's superfast computer network, 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. Push the shading up to fifty percent, and the ice grows. Even better, the restoration happens fast: Within five years, the temperature would drop

by almost two degrees.

The modeling results interested Wood. He calculated that it would take roughly 300,000 metric tons of particles each year to shade the sunlight in the Arctic by twenty-five percent — a tiny amount, on a planetary scale. As for how to get those particles up there, Wood thinks that a half-dozen 747s could do the job. Even better, you could build a Kevlar tube fifteen miles long, with a diameter slightly larger than a garden hose. The bottom of the hose would be connected to a combustor that created the aerosols, while the top would be held in place by high-tech kites or a high-altitude airship that the Defense Department is developing. "It's nothing more than a fancy blimp," Wood says.

In Wood's view, this was a no-brainer. You could stabilize the ice, save the polar bears and demonstrate the virtues of planetary engineering for less money than it takes to feed and clothe the soldiers in Iraq for a year. Because the aerosols are launched only over the Arctic, there is little danger of directly impacting humans. And best of all, you can try it for a few years and see if it works. If something goes wrong, you can quit, and within a year or so, all the particles will have dissipated, returning the region to its "natural" state.

But getting the science right may be the least of it. As Benford, the sci-fi writer, told me, "All the real complexity is in the politics." It would take years to reach international consensus for an actual experiment, much less to secure funding. A serious discussion of geoengineering would likely spark worldwide protests: Americans would be seen as toying with the integrity of the Earth's climate just so we don't have to give up our SUVs. To expedite things, Wood speculates about getting private funding for a small-scale experiment from someone like Paul Allen, the Microsoft billionaire, whom he knows slightly because of Allen's interest in space travel. "As far as I can determine," Wood says, "there is no law that prohibits doing something like this." But he also knows that the last thing someone like Allen wants is to mess with the Earth's climate. Billionaire kills millions when global engineering scheme goes awry. It's safer to stick with building football stadiums and rock & roll museums.

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To his credit, Wood believes the decision to move beyond research and actually implement a large-scale geoengineering project must not be made by scientific elites. "Let's debate fully," he says. "Then let's all vote." But even if funding is somehow obtained and experiments are successful, it would only open the door to an even more complex question: Whose hand will be on the global thermostat? The Inuits won't like the idea of a warming Arctic, but the Russians might not mind — it could open shipping lanes, make oil and gas exploration easier and boost agricultural productivity in places like Siberia. "Will we have Greenland and Bangladesh arguing over the 'right' temperature?" says Richard Alley, the Penn State paleoclimatologist. "Will your neighbor try to sue somebody if the tomatoes freeze?" And once you commit to countering the rise of CO₂ emissions with a geoengineering scheme, Alley adds, you're hooked. "This is not something you can do for twenty or thirty years, then quit," he says. "It's a techno fix we'd become dependent on." Even Caldeira views geoengineering as, at best, a way to buy time to develop clean energy technologies. "As a long-term strategy," Caldeira says, "it's nuts."

Despite such obstacles, Wood believes that geoengineering the climate is inevitable, if only because politics and economics will demand it. Geoengineers, he says in a recent e-mail, will just have to wait patiently until the "political elites" decide that it is in their best interest to act. Once they realize that geoengineering is the cheapest solution, he predicts, "they'll swiftly-&-reliably beat a path to the Geoengineering Door. :-) The future is ours, Comrades — history (well, geophysics-&-economics) is on Our Side! :-)"

Perhaps. Or perhaps Wood is still entranced by the sound of rockets he heard in the California hills when he was a kid. Unlike many of his peers, Wood retains an unshakable faith in technology as a tool to reshape the world to our liking. "Isn't agriculture a form of geoengineering?" he says. "How about building houses, installing air conditioning, building roads? Where do you draw the line between what is acceptable and what isn't? We've engineered every other environment we live in — why not the planet?"

Hell, as long as we're at it, why not engineer other planets? For Wood, the promise of geoengineering extends all the way to Mars, where he hopes to see human settlement one day. Indeed, according to physicist Marty Hoffert, who has known Wood for decades, restoring the Earth's climate is just "the first stop" in Wood's grander ambition to terraform the Red Planet. "It is the manifest destiny of the human race!" Wood declared at a space convention once. "In this country we are the builders of new worlds. . . . We took a raw wilderness and turned it into the shining city on the hill of our world." Of course, we also raped and pillaged that raw wilderness along the way, heating up the planet to a point where vast sections of it could become uninhabitable. But in Wood's view, that may be the price of progress. Like his mentor Edward Teller before him, Wood is the embodiment of a certain kind of hubris, a Promethean figure whose relentless pursuit of Big Science helped bring us a thumb-twitch away from Armageddon. But in his oddly sunny view, no global destruction wreaked by global warming — or, for that matter, by his own brazen ideas to counteract it — could ever be so great that we, in all our ingenuity, will not find a way to fix it.

"Human beings are like cockroaches," Wood says with typical black humor. "It's fairly easy to kill the first ten percent of the population. And if you try really hard, you might even get the next ten percent. But no matter what you do, you'll never get that last ten percent. We will find a way to survive."

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