

Bulletin of the Atomic Scientists

Five minutes to midnight

Freeman Dyson

Jonathan Schell

Martin Rees

K. Eric Drexler

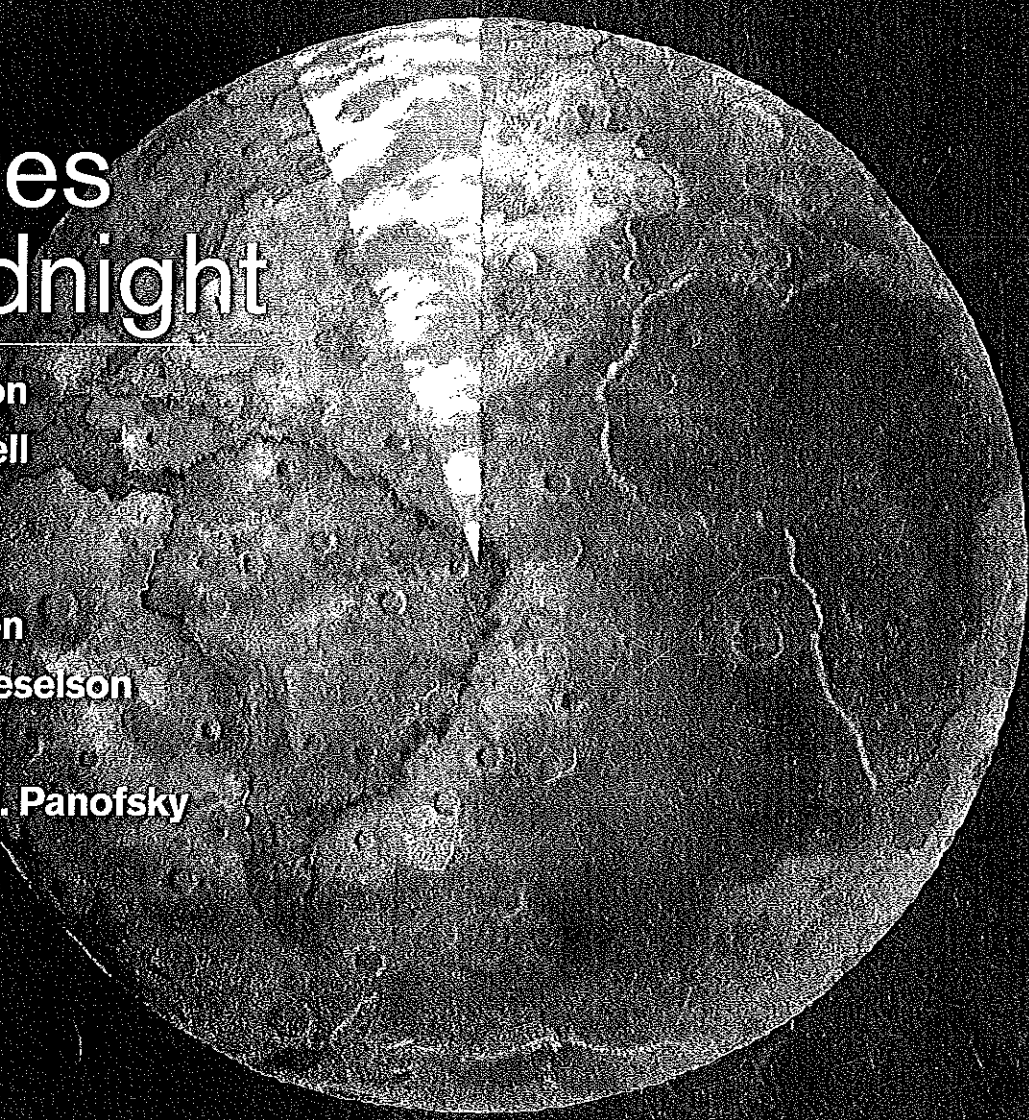
John P. Holdren

Matthew S. Meselson

Bruce G. Blair

Wolfgang K. H. Panofsky

ON DOOMSDAY



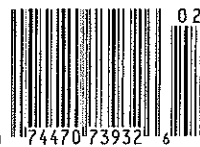
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IT IS 5 MINUTES TO MIDNIGHT



U.S. \$6 Canada \$8



02

SPECIAL REPORT: APPROACHING MIDNIGHT

Nuclear weapons still pose the most potent threat to humanity, but climate change and emerging technologies have quickened our ability to self-destruct. Experts on science and security survey this troubled terrain and chart paths to safeguard our survival.

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66 IT IS FIVE MINUTES TO MIDNIGHT

We stand at the brink of a second nuclear age. The deteriorating state of global affairs has prompted the *Bulletin's* Board of Directors to move the minute hand of the "Doomsday Clock" from seven to five minutes to midnight.

BAS: *Where is the Kyoto Protocol in all of this?*

HOLDREN: Kyoto is rapidly becoming irrelevant. The United States has refused to ratify it, and most of the countries that did aren't going to meet their targets. Plus, there has never been any agreement on what the penalty is for not meeting those targets. The key questions now are what the world collectively is going to do for an "encore" at the end of the Kyoto commitment period in 2012, and what the major emitting countries—including especially the United States and China—are going to do individually in the meantime.

Some years ago, by the way, I suggested that the penalty for a country missing its Kyoto target should be a commitment to increase the amount of money to be invested in carbon-free energy technologies in proportion to the amount by which the target is missed. In other words, make the punishment fit the crime and make it palatable, because it's what the countries should want to do anyway if they're figuring out that climate change is threatening them. I still think this feature would be a useful element of the approach that needs to be devised to follow Kyoto.

One of the most interesting recent developments in the global arena is that the Chinese are figuring out that climate change is directly threatening *them*. They have estimated that the glaciers on the Tibetan Plateau that feed the great Chinese rivers are disappearing at a rate of 50 percent per decade. This means that the cycle of flood and drought that's always plagued China is going to get worse. Chinese scientists also believe that the monsoon disruptions that have been plaguing them for the last decade or so are being driven by global climate change. And these insights are changing the position of the Chinese leadership on climate policy. The old position was, "This might be an interesting problem, but our willingness to participate is going to depend on how much you pay us." The new position is, "Climate change is harming China now, and we're going to have to participate in the solution, no matter what."

BAS: *What advice would you give to the policy community?*

HOLDREN: Scientists and politicians have to get better at understanding that, while the scientific facts are never everything, they're always something. In other words, on the one hand, scientists should not expect that the science will always govern outcomes, because there are other considerations that are important and legitimate. The science has to be weighed along with political, social, and economic factors. On the other hand, the politicians have to realize that making decisions based on ideology alone is a mistake. Ignoring what the best science has to say about an issue can be dangerous.

The scientific, technological, and economics communities need to continue to strive for more comprehensive, more interdisciplinary, more accessible analyses of these matters, making clear what the economics, technology, and environmental science add up to when taken together. Of course, the world will continue to need lots

of specialists in all the relevant disciplines, but it's increasingly important that a share of our brightest people become specialists in putting the pieces together and in communicating the big picture to policy makers.

There also needs to be a much larger effort in science education. In the end, what the public knows and can absorb is of real consequence for getting the policies right. It's interesting that in this country something like 90 percent of the public believes that climate change is happening and that humans have something to do with it. That doesn't mean that the whole 90 percent wants to do something about it. Still, 90 percent understanding that there is an issue here is a far higher number than the roughly 50 percent who believe evolution is a fact, so maybe there's hope. *

Facing new unknowns

BY ROBERT H. SOCOLOW

As with nuclear weapons, we need new science, new resolve, and new ethics to deal with climate change.

THE BULLETIN'S ICONIC CLOCK CAPTURES more than the imminence of catastrophe. It signifies the transformative power of science, a planetary consciousness, and the ironies of moral behavior. All of these messages are of first-order importance in grappling with climate change.

The transformative power of science was demonstrated to the world at Hiroshima and Nagasaki. A small part of the energy released in nearby supernovae before our Earth was formed—but a colossal amount in human terms—had been stored close to Earth's surface in heavy nuclei, hidden from all life-forms for more than 3 billion years, until scientists less than a century ago learned how to see these nuclei.

Similarly, for the first time during that same 3-billion-plus years, one species is unlocking the history of Earth and revealing that a randomness at every timescale has modified its own habitats and the habitats of its fellow creatures. The ensuing knowledge contains the message that we human beings could plausibly be presenting a huge headache to those who follow us. Quite possibly, our own actions (especially, the extraction and burning of fossil fuel) are significantly altering our planet's habitability. As a result, our descendants could find themselves spending much of their time and treasure moving cities inland,

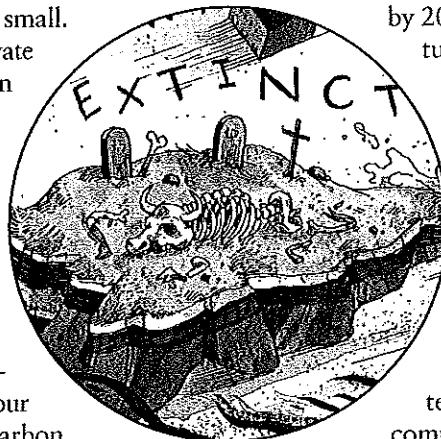
Climate change

managing refugee populations, relocating agriculture, and keeping other creatures from going extinct.

Right now, we know mostly that the critical gaps in our understanding cannot be read as reassurance that the damage from our current actions will be small.

The scientific community simply must elevate the study of Earth's natural science within the family of sciences. There is an urgent need for more intense and creative measurement and modeling, so that a larger fraction of what we learn about Earth in the next half century comes from our cleverness, and a smaller fraction comes from watching what the passage of time reveals. More quickly than is now expected, we must master the feedback loops that determine how sensitive our climate is to the atmosphere's elevated carbon dioxide levels.

A planetary consciousness has been at the heart of the struggle to create a framework of sense and sensibility for nuclear weapons. The assumption has been that each nation's leaders will act rationally on behalf of their citizenry's survival. Until very recently, no political leader in a country already possessing nuclear weapons thought it wise to make nuclear weapons attractive to the leaders of countries without them. All assumed a commonality of interest in avoiding nuclear war. Nonetheless, crucial international agreements such as the Nuclear Non-Proliferation Treaty



of technology transfer are based on avoiding domestic action in industrialized countries and imposing neocolonial relationships on developing countries. The leading emitter of carbon dioxide, the United States, is walking away from responsibilities it helped frame, arguing that the two-tier structure is misguided.

With a new set of policy instruments required by 2012, there is an opportunity for a restructuring of assignments, moving toward a single world system with more dispersed initiative and greatly accelerated investment in carbon-responsive technology. The world's nations, all of them currently investing recklessly in inefficient infrastructure, may be able to coordinate and integrate the learning-by-doing that accompanies experimenting with new solutions. Much faster penetration of the new technology should result. The scientific community's deep tradition of conducting its business oblivious to nationality may serve to facilitate this transition from a two-tier to a one-tier world.

The ironies of moral behavior are becoming clear in the domain of weaponry as the world confronts the limitations of nuclear deterrence. Deterrence is robust only if those with the power to destroy are rational and are believed to be rational. Irrationality trumps deterrence. So does martyrdom. Where will we find guidance in the face of these novel threats?

Here the similarity with climate change is more in the novelty of the problems ahead than in the problems themselves. With deeper knowledge of Earth and of our impacts on it, we gain the ability to geoengineer the planet to make it more comfortable for ourselves, and we develop an interest in doing so. Scientists are thrusting options forward that promise to counter global warming with reflecting particles in the stratosphere and mirrors in space. The allure of these solutions is great, to the extent that they truly present alternatives to belt-tightening and to large changes in the relative prices of what we buy.

Where will we find guidance regarding geoengineering? How will such systems be governed? What weight must we give to the preservation of other species?

Looking ahead, we need new science, new politics, and new ethics, and we need them urgently. *

Robert H. Socolow is a professor of mechanical and aerospace engineering at Princeton University and the coprincipal investigator of Princeton University's Carbon Mitigation Initiative. He was awarded the 2003 Leo Szilard Lectureship Award by the American Physical Society.

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presumed a two-tier world, with haves and have-nots. Many perverse incentives for the have-nots resulted, exacerbated by the haves showing only occasional interest in their treaty obligation of moving toward disarmament.

The crucial 1992 U.N. Framework Convention on Climate Change also institutionalizes a two-tier world with "common but differentiated responsibilities." Here, too, many consequences have been perverse. The enormous investments in infrastructure (buildings, roads, power plants, etc.) currently under way in the developing world are exempted from scrutiny. The mechanisms