

**It is
five
minutes
to
midnight**



How close are we to catastrophic destruction? The *Bulletin* monitors “minutes to midnight” on the Doomsday Clock, and publishes information and analysis about trends and technologies that threaten the survival of humanity. First and foremost, these include nuclear weapons, but they also encompass climate-changing technologies and new developments in the life sciences that could inflict irrevocable harm.

1

Nuclear Weapons

The nuclear age dawned in the 1940s when scientists learned how to release the energy stored within the atom. Immediately, they thought of two potential uses—an unparalleled weapon and a new energy source. The United States built the first atomic bombs during World War II, which they used on Hiroshima and Nagasaki, Japan in August 1945. Within two decades, Britain, the Soviet Union, China, and France had also established nuclear weapon programs. Since then, Israel, India, Pakistan, and North Korea have built nuclear weapons as well.

For most of the Cold War, overt hostility between the United States and Soviet Union, coupled with their enormous nuclear arsenals, defined the nuclear threat. The U.S. arsenal peaked at about 30,000 warheads in the mid-1960s and the Soviet arsenal at 40,000 warheads in the 1980s, dwarfing all other nuclear weapon states.

Unfortunately, however, in a globalized world with porous national borders, rapid communications, and expanded commerce in dual-use technologies, nuclear know-how and materials travel more widely and easily than before—raising the possibility that terrorists could obtain such materials and construct a nuclear device of their own. The materials necessary to construct a bomb pervade the world.

As a result, according to the International Panel on Fissile Materials, substantial quantities of highly enriched uranium, one of the materials necessary for a bomb, remain in more than 40 non-weapon states. Save for Antarctica, every continent contains at least one country with civilian highly enriched uranium. Even with the improvement of nuclear reactor design and international controls provided by the International Atomic Energy Agency (IAEA), proliferation concerns persist, as the components and infrastructure for a civilian nuclear power program can also be used to construct nuclear weapons.

2012 Updates

The Cuban Missile Crisis: A nuclear order of battle, October and November 1962

November/December 2012

Robert S. Norris and Hans M. Kristensen

At the 50th anniversary of the Cuban Missile Crisis, the authors analyzed the order of battle of nuclear forces that were available to both the US and the USSR.

No first use: The way to contain nuclear war in South Asia

March/April 2012

Lawrence J. Korb and Alexander Rothman

Relatively little attention has been paid to containment should a conflict between India and Pakistan break out. Even a limited nuclear exchange would kill millions and have far-reaching environmental effects.

The scientific jigsaw puzzle: Fitting the pieces of the low-level radiation debate

May/June 2012

Jan Beyea

Quantitative risk estimates from exposure to ionizing radiation are dominated by analysis of one-time exposures received by World War II survivors in Japan.

2

Climate & Energy

Fossil-fuel technologies such as coal-burning plants powered the industrial revolution, bringing unparalleled economic prosperity to many parts of the world. But in the 1950s, scientists began measuring year-to-year changes in the carbon-dioxide concentration in the atmosphere that they could relate to fossil-fuel combustion, and they began to see the implications for Earth's temperature and for climate change.

Today, the concentration of carbon dioxide is higher than at any time during the last 650,000 years. These gases warm Earth's continents and oceans by acting like a giant blanket that keeps the sun's heat from leaving the atmosphere, melting ice and triggering a number of ecological changes that cause an increase in global temperature. Even if carbon-dioxide emissions were to cease immediately, the extra gases already added to the atmosphere, which linger for centuries, would continue to raise sea levels and change other characteristics of the Earth for hundreds of years.

The most authoritative scientific group on the issue, the Intergovernmental Panel on Climate Change (IPCC), suggests that warming on the order of 2–10 degrees Fahrenheit over the next 100 years is a distinct possibility.

Inland, the IPCC predicts that another century of temperature increases could place severe stress on forests, alpine regions, and other ecosystems, threaten human health as mosquitoes and other disease-carrying insects and rodents spread lethal viruses and bacteria over larger geographical regions, and harm agriculture by reducing rainfall in many food-producing areas while at the same time increasing flooding in others—any of which could contribute to mass migrations and wars over arable land, water, and other natural resources.

Fukushima in review: A complex disaster, a disastrous response

March/April 2012

Yoichi Funabashi and Kay Kitazawa

The complex crisis at the Fukushima Daiichi Nuclear Power Station in March 2011 was exacerbated by communication gaps between the government and the nuclear industry.

Entangled histories: Climate science and nuclear weapons research

July/August 2012

Paul N. Edwards

Global networks that monitored the Fukushima radiation plume descended directly from systems and models developed to trace fallout from weapons tests.

Limits to growth: Can nuclear power supply the world's needs?

September/October 2012

Derek Abbott

Could nuclear power be rapidly expanded on a global scale? Limiting factors include site and waste disposal issues, risks of accidents and proliferation, and resource challenges.

3

Biosecurity

With greater understanding of genetic material and of how physiological systems interact, biologists can fight disease better and improve overall human health. Scientists already have begun to develop bioengineered vaccines for common diseases such as dengue fever and certain forms of hepatitis. They are using these tools to develop other innovative medical solutions, including cells that have been bioengineered to serve as physiological “pacemakers.” The mapping of the complete human genome in 2001 allows for even greater understanding of human functioning. As a consequence of the Human Genome Project, scientists have already identified more than 1,800 genes associated with particular diseases.

But along with their potential benefits, these technological advances raise the possibility that individuals or non-state actors could create dangerous known or novel pathogens. Additionally, researchers with the best intentions could inadvertently create new pathogens that could harm humans or other species. For example, in 2001, researchers in Australia reported that they had accidentally created a new, virulent strain of the mousepox virus while attempting to genetically engineer a more effective rodent control method.

Unlike the biological weapons of the last century, these new tools could create a limitless variety of threats, from new types of “nonlethal” agents, to viruses that sterilize their hosts, to others that incapacitate whole systems within an organism. The wide availability of bioengineering knowledge and tools, along with the ease with which individuals can obtain specific fragments of genetic material (some can be ordered through the mail or over the internet), could allow these capabilities to find their way into unspecified hands or even those of backyard hobbyists. Such potential dangers are forcing scientists, institutions, and industry to develop self-governing mechanisms.

Laurie Garrett: Reporting on biosecurity from America to Zaire

January/February 2012

US government officials made mistakes in response to the anthrax attacks of 2001. What are the lessons learned?

Dual-use research after the avian influenza controversy

July 11, 2012

Michael J. Imperiale

Challenges have emerged for researchers who study the H5N1 avian influenza virus, committees that review dual-use research in the life sciences, and entities that fund and publish such research.

The One Health solution

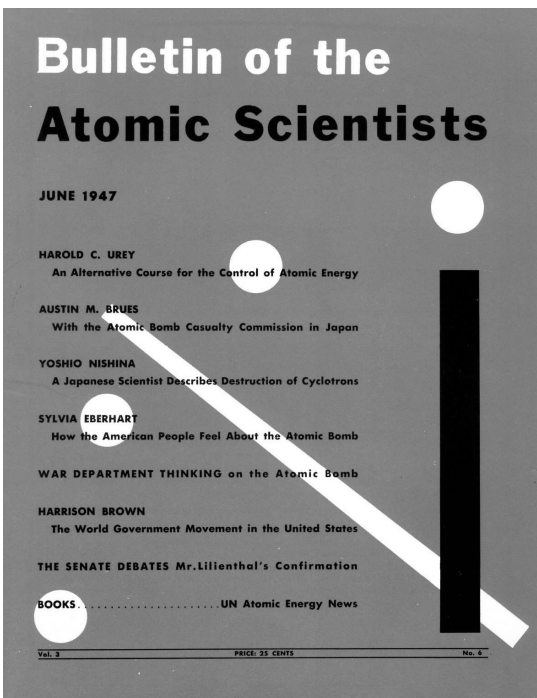
September 27, 2012

Laura H. Kahn

Environmental destruction, global trade and travel, and intensive agriculture lead to the emergence of previously unknown microbes that can infect across species.



For the lasting influence of the Clock design that she created in 1947, her drawings that still illuminate our publications, and her ebullient spirit, we honor our friend Martyl.



Cover of the *Bulletin of the Atomic Scientists* featuring the first Doomsday Clock, 1947.

Martyl Langsdorf (1917–2013)

Science, art, and the legacy of Martyl

Martyl Langsdorf, the artist who created the Doomsday Clock, died on March 26th at the age of 96 in Chicago. Known to many friends and fans simply as Martyl, she was a petite and vivacious woman who had an outsize influence on public consciousness about nuclear weapons through her design of the clock that first graced the cover of the *Bulletin of the Atomic Scientists* in 1947, and continues to be used today.

Born in St. Louis, Missouri in 1917, Martyl Suzanne Schweig married Washington University physicist Alexander Langsdorf, Jr. in 1941, and came with him to the University of Chicago when he joined Enrico Fermi's group to work on nuclear fission.

Based on Fermi's research and the engineering work of the university's metallurgical laboratory, headed by John Simpson, the Manhattan Project would soon produce the first atomic bomb. Yet even as they were completing their designs for the weapon, scientists at Chicago—notably chemistry Nobel laureate James Franck, physicist Leo Szilard, and Eugene Rabinowitch, a biologist and one of the first editors of the *Bulletin of the Atomic Scientists*—had grave reservations about using the weapon on civilians. So in 1945, as they realized the terrifying significance of the United States' plan to drop these bombs on Hiroshima and Nagasaki, they began organizing meetings to debate and discuss their invention. Their arguments spilled out beyond labs and classrooms into dining rooms in private homes and onto platforms in public halls. Sometimes heatedly, and always passionately, they spoke of the role and responsibility of the scientific community in creating the most dangerous technology on Earth.

Like many others in the university community, Martyl was in the thick of these discussions. So when the founders of the *Bulletin of the Atomic Scientists* at the University of Chicago decided to make the newsletter into a magazine in 1947, co-editor Hyman Goldsmith asked Martyl if she would draw a design for the cover. He and co-editor Rabinowitch couldn't pay her much, but she thought it might be fun to help out. She also guessed that she was "the only artist they knew."

Martyl first considered using the letter U, the chemical symbol for uranium, as her design. As she listened more intently to their conversations, though, she soon realized that it was the atomic scientists' urgency about the looming dangers of this new technology that was most compelling. So she drew the hands of a clock ticking down to midnight. Like the countdown to an atomic bomb explosion, it suggested the destruction that awaited if no one took action to stop it.

Martyl created a substantial body of artwork over the years, and would sometimes chuckle about how she came to be known as the "clock lady," bemused by all the attention for a simple drawing. But I think she also came to enjoy the recognition she won for creating one of the most significant graphic designs of the 20th century.

Martyl became art editor of the *Bulletin*, illustrating issues and persuading her artist friends to contribute their drawings as well, "for pennies," as she put it. She thought the eye needed a rest from the text-heavy pages with news about atomic energy, Soviet and US nuclear bomb tests, government secrecy, and the ethics of conducting scientific research for the military.

While the drawings and designs in the *Bulletin* added humor and visual appeal, the publication also reflected a deeper connection between art and science through the quality of the writing, the expressiveness of the authors, and the continuous use of the Doomsday Clock to "exploit the wonderful capacity of the human mind to comprehend wholes without seeing the parts," as Martyl wrote on page 51 of the February 1959 issue. Her clock design conveyed the state of nuclear danger with exquisite economy; the editors appealed to both the heads and hearts of their readers.

The February 1959 issue, titled "Science and Art" and co-edited by Martyl and University of Chicago metallurgy professor Cyril Stanley Smith, drew an explicit connection. In the introductory essay, they compared the work of artists to that of scientists, suggesting that "the artist is concerned principally with complex relationships and depends on active participation of his audience in developing the pattern," while the scientist lays out results with simple precision so that the audience can understand an aspect of the world.

To this day, the *Bulletin* seeks participation by scientists, artists, writers, policy makers, and interested citizens to lead an intelligent debate about the mind-numbing, often horrifying, problems of nuclear and climate change catastrophe. To move past the numbness and provoke action, the *Bulletin* draws on art and design to create new ways of feeling, just as it taps science for new ways of knowing. In large measure, this is Martyl's legacy.

A constant presence in the *Bulletin* community, Martyl was a spirited, outspoken force among the likes of Fermi, Simpson, Szilard, Fermilab director Robert R. Wilson, and Nobel physicist Leon Lederman. She invited them and their families to her family's home for dinners and parties. She came to know their foibles and quirks in the close-knit community of Chicago scientists and intellectuals during the 1940s, 1950s, and 1960s, and she also understood that these brilliant scientists, for all their genius and wisdom, wrestled with their own demons as they sorted out their reactions to the Bomb.

As much as the *Bulletin* community loved Martyl, she loved the young journalists and art designers who worked for it. Many of us spent hours at her home and studio, where her poodles, Atom, Xander, and Piper were always ready to greet us, where the bar was always open, where the blooming of her peonies was reason enough for a party, and where the next good story usually started with, "Now, you remember..."

Yes, Martyl, we will remember.

Kennette Benedict, April 9, 2013.



A small sampling of Martyl's illustrations for the *Bulletin* over the years.

Designing the Unthinkable

In 1943, nuclear physicist Alexander Langsdorf Jr. was summoned to Chicago to work on a something secret, a nationwide effort called the Manhattan Project, becoming one of the thousands of scientists who would be consumed day and night for two years by the race to create an atomic bomb. They were a success: their scientific work made possible the bombs that were dropped on Hiroshima and Nagasaki, ending World War II. But, like many of his fellow scientists, he found that with that success came profound ambivalence. What were the social and political implications of this powerful new weapon? How would its use be controlled? And what did it mean that the human race had invented the means to render itself extinct?

To gain a wider audience for their ideas, Langsdorf joined other concerned colleagues in publishing a new magazine, *The Bulletin of the Atomic Scientists*. Langsdorf's wife Martyl was not a scientist. She was a successful landscape painter, known in the gallery world by her first name. Her fame was even greater within her husband's circle. As she once said, "I was the only artist these scientists ever knew." So it was inevitable that when the *Bulletin's* founder, Hyman Goldsmith, needed a cover design for the magazine, he turned to Martyl. It was a low budget job, two colors, a lot of type. There wasn't much extra room, but Martyl wanted to include an image that would somehow suggest the urgency of their cause. She did a number of sketches and finally hit on something she thought would work. And it did work. In fact, it might be considered the most powerful piece of information design of the 20th century. It became known as the Doomsday Clock.

For more than fifty years, arguments against nuclear proliferation have been contentious and complicated. The Doomsday Clock translates all the arguments to a simple—a brutally simple—visual analogy. The Clock suggests imminent apocalypse by marrying the looming approach of midnight and the tense countdown of a ticking time bomb. Appropriately for an organization led by scientists, the Clock sidesteps the overwrought drama of the mushroom cloud in favor of the cool mechanics of an instrument of measurement. The Clock was Martyl's idea, but she admitted she had help from a friend, Egbert Jacobson, design director of Container Corporation of America. Jacobsen suggested that the clock appear in the same design but a different color background on every issue.

There was one last crucial suggestion. Martyl had set the minute hand at seven to midnight on that first cover "simply because it looked good." Two years later, the Soviet Union tested their own nuclear device and the arms race was officially launched. "We do not advise Americans that doomsday is near and that they can expect atomic bombs to start landing on their heads a month or a year from now," wrote the *Bulletin's* editors. "But we think they have reason to be deeply alarmed and to be prepared for grave decisions." To emphasize the seriousness of the moment, the Clock was moved forward to three minutes to midnight. The static graphic emblem was thus transformed into a sort of political performance art, and the clock has been moved 18 times since, each time signifying an intensification or moderation of nuclear tensions.

With each change, Martyl's Clock became more deeply entrenched in the public imagination. The Doomsday Clock has been referenced in songs by Iron Maiden, The Who, and Bright Eyes. As a theme it dominates Alan Moore's graphic novel *Watchmen* and Senator Tom Harkin's treatise *Five Minutes to Midnight*. Over the years, the non-specific simplicity of the symbol was able to accommodate the new threats of climate change and bioterrorism. Finally, in 2007 (with—full disclosure—some advice from Armin Vit and me) the *Bulletin's* publishers adopted the clock as their organization's official identity.

The power of the Doomsday Clock was demonstrated again today. Citing "a more hopeful state of world affairs," the *Bulletin's* Science and Security Board moved the Clock's hand back by one minute as the world watched live online. "For the first time since atomic bombs were dropped in 1945, leaders of nuclear weapons states are cooperating to vastly reduce their arsenals and secure all nuclear bomb-making material," said the Board. "And for the first time ever, industrialized and developing countries alike are pledging to limit climate-changing gas emissions that could render our planet nearly uninhabitable." There is cause for cautious relief, but the threat remains, and Martyl's Doomsday Clock continues to tick. It is now six minutes to midnight.

Michael Bierut, designobserver.com.

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Thank you.

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(January 2012–September 2013)

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200,348 in 2012

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Recent awards

2007 National Magazine Award for General Excellence (under 100,000 circulation), from the American Society of Magazine Editors

2009 Lumity Technology Leadership Award first runner up for “innovative uses of technology in the nonprofit sector,” from Accenture

“One of Robert Lifton’s statements in his July–August 2013 column is the perfect motto for why we need the *Bulletin*: ‘We could, in a moment in time, destroy everything ourselves and all that we had every touched or loved—by means of our own technology and by our own hand.’”

Robert T. Michael, Founding Dean of the Harris School of Public Policy at the University of Chicago.

“As we look at climate change, the gap between denial and despair is very narrow. The *Bulletin* helps to extend that window by distinguishing between what is scientifically possible and what is politically realistic. The key is a well-informed public, guided by reason and facts.”

Sivan Kartha, Senior Scientist at the Stockholm Institute.

“Shahrazad Mohtadi [writing in the *Bulletin of the Atomic Scientists*] details a story that’s gotten far too little attention in the mainstream coverage of the conflict: ‘While it’s not a straight causal line, there is little question that an unrelenting drought induced by climate change combined with agricultural mismanagement and an existing refugee crisis to create a powder-keg in Syria.’”

Moyers & Company, “What We’re Reading.”

“Because the threat of nuclear proliferation is not being addressed, because missile defense technologies remain flawed and because new threats exposed by scientists have been ignored, the *Bulletin*’s annual Doomsday clock...still sits at five minutes to midnight.... Until science and data become central to informing our public policies, our civilization will be hamstrung in confronting the gravest threats to its survival.”

Lawrence M. Krauss, theoretical physicist and author, Arizona State University.

“Most of us in the community of counterterrorism experts consider the *Bulletin* as the preeminent publication on these issues. For example, law enforcement officers who work every day to counter nuclear trafficking in Eastern and Central Europe and the Black Sea need access to current, authoritative analysis of the conditions they face. Keep it up.”

Joshua Sinai, VT Research Center–Arlington, Virginia, Virginia Polytechnic Institute and State University.

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Andrea Rehmsmeier, German Radio Deutschlandfunk, www.dradio.de

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John Bynner, Emeritus Professor at the Faculty of Policy and Society Institute of Education, University of London.

“This is according to the *Bulletin of Atomic Scientists*. We estimate they [Russians] have a large inventory of operational nonstrategic warheads—5,390 is the number of tactical warheads, air defense tactical, et cetera. So they do still have more, and it still is a very legitimate concern to us.”

Senator John Kerry (D-MA) during hearings on the New START Treaty.

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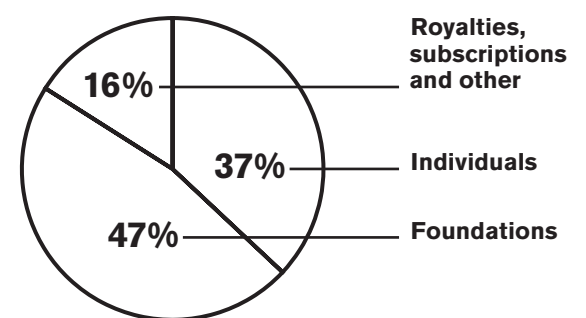
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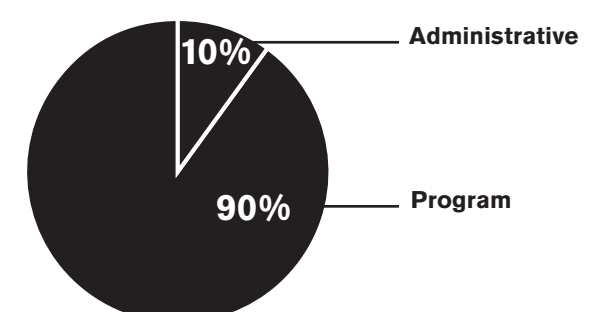
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