

**Closer than ever:
It is now 89 seconds to midnight**

2025 Doomsday Clock Statement

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TO MIDNIGHT**



Founded in 1945 by Albert Einstein, J. Robert Oppenheimer, and University of Chicago scientists who helped develop the first atomic weapons in the Manhattan Project, the Bulletin of the Atomic Scientists created the Doomsday Clock two years later, using the imagery of apocalypse (midnight) and the contemporary idiom of nuclear explosion (countdown to zero) to convey threats to humanity and the planet. The Doomsday Clock is set every year by the Bulletin's Science and Security Board in consultation with its Board of Sponsors, which includes nine Nobel laureates. The Clock has become a universally recognized indicator of the world's vulnerability to global catastrophe caused by man-made technologies.

Closer than ever: It is now 89 seconds to midnight

In 2024, humanity edged ever closer to catastrophe. Trends that have deeply concerned the Science and Security Board continued, and despite unmistakable signs of danger, national leaders and their societies have failed to do what is needed to change course. Consequently, we now move the Doomsday Clock from 90 seconds to 89 seconds to midnight—the closest it has ever been to catastrophe. Our fervent hope is that leaders will recognize the world's existential predicament and take bold action to reduce the threats posed by nuclear weapons, climate change, and the potential misuse of biological science and a variety of emerging technologies.

In setting the Clock one second closer to midnight, we send a stark signal: Because the world is already perilously close to the precipice, a move of even a single second should be taken as an indication of extreme danger and an unmistakable warning that every second of delay in reversing course increases the probability of global disaster.

In regard to nuclear risk, the war in Ukraine, now in its third year, looms over the world; the conflict could become nuclear at any moment because of a rash decision or through accident or miscalculation. Conflict in the

Middle East threatens to spiral out of control into a wider war without warning. The countries that possess nuclear weapons are increasing the size and role of their arsenals, investing hundreds of billions of dollars in weapons that can destroy civilization. The nuclear arms control process is collapsing, and high-level contacts among nuclear powers are totally inadequate given the danger at hand. Alarming, it is no longer unusual for countries without nuclear weapons to consider developing arsenals of their own—actions that would undermine longstanding nonproliferation efforts and increase the ways in which nuclear war could start.

The impacts of climate change increased in the last year as myriad indicators, including sea-level rise and global surface temperature, surpassed previous records. The global greenhouse gas emissions that drive climate change continued to rise. Extreme weather and other climate change-influenced events—floods, tropical cyclones, heat waves, drought, and wildfires—affected every continent. The long-term prognosis for the world's attempts to deal with climate change remains poor, as most governments fail to enact the financing and policy initiatives necessary to halt global warming. Growth in solar and wind energy has been impressive but remains insufficient

to stabilize the climate. Judging from recent electoral campaigns, climate change is viewed as a low priority in the United States and many other countries.

In the biological arena, emerging and re-emerging diseases continue to threaten the economy, society, and security of the world. The off-season appearance and in-season continuance of highly pathogenic avian influenza (HPAI), its spread to farm animals and dairy products, and the occurrence of human cases have combined to create the possibility of a devastating human pandemic. Supposedly high-containment biological laboratories continue to be built throughout the world, but oversight regimes for them are not keeping pace, increasing the possibility that pathogens with pandemic potential may escape. Rapid advances in artificial intelligence have increased the risk that terrorists or countries may attain the capability of designing biological weapons for which countermeasures do not exist.

An array of other disruptive technologies advanced last year in ways that make the world more dangerous. Systems that incorporate artificial intelligence in military targeting have been used in Ukraine and the Middle East, and several countries are moving to integrate artificial intelligence into their militaries. Such efforts raise questions about the extent to which machines will be allowed to make military decisions—even decisions that could kill on a vast scale, including those related to the use of nuclear weapons. Tensions among the major powers are increasingly reflected in competition in space, where China and Russia are actively developing anti-satellite capabilities; the United States has alleged that Russia has tested a satellite with a dummy warhead on it, suggesting plans to place nuclear weapons in orbit.

The dangers we have just listed are greatly exacerbated by a potent threat multiplier: the spread of misinformation, disinformation, and conspiracy theories that degrade the communication ecosystem and increasingly blur the line between truth and falsehood. Advances in AI are making it easier to spread false or inauthentic information across the internet—and harder to detect it. At the same time, nations are engaging in cross-border efforts to use disinformation and other forms of propaganda to subvert elections, while some technology, media, and political leaders aid the spread of lies and conspiracy theories. This corruption of the information ecosystem undermines the public discourse and honest debate upon which democracy depends. The battered information landscape is also producing leaders who discount science and endeavor to suppress free speech and human rights, compromising the fact-based public discussions that are required to combat the enormous threats facing the world.

Blindly continuing on the current path is a form of madness. The United States, China, and Russia have the collective power to destroy civilization. These three countries have the prime responsibility to pull the world back from the brink, and they can do so if their leaders seriously commence good-faith discussions about the global threats outlined here. Despite their profound disagreements, they should take that first step without delay. The world depends on immediate action.

It is 89 seconds to midnight. 🕒

Additional information on the threats posed by nuclear weapons, climate change, biological events, and the misuse of other disruptive technologies follows in the pages below.

The nuclear outlook: extremely dangerous trends continue

There were no calamitous new developments last year with respect to nuclear weapons—but this is hardly good news.

Longstanding concerns about nuclear weapons—involving the modernization and expansion of arsenals in all nuclear weapons countries, the build-up of new capabilities, the risks of inadvertent or deliberate nuclear use, the loss of arms control agreements, and the possibility of nuclear proliferation to new countries—continued or were amplified in 2024. The outgoing Biden administration showed little willingness or capacity to pursue new efforts in these areas, and it remains to be seen whether the Trump administration will seize the initiative. At this time, it is difficult to anticipate when and how these negative trends may be slowed and, ultimately, reversed.

Against the backdrop of Russia's continuing war against Ukraine, Russian President Vladimir Putin suspended compliance with the New Strategic Arms Reduction Treaty (New START), and Russia's Duma voted to withdraw Moscow's ratification of the Comprehensive Nuclear Test Ban Treaty. Western officials confirmed in March 2024 that Russian nuclear weapons have been deployed in Belarus. In August 2024, Ukrainian forces entered Russia's Kursk Oblast, and Ukraine subsequently attacked targets deeper into Russia, using US-supplied missiles with Washington's permission. Russia revised its nuclear doctrine to signal a lower threshold for the use of nuclear weapons, and it used an intermediate-

range ballistic missile against a Ukrainian target.

China's nuclear arsenal has grown to about 600 warheads, and China may also now be deploying a small number of warheads on missiles during peacetime. In September 2024, China tested an intercontinental ballistic missile (DF-31AG) aimed at a location in the South Pacific 11,700 kilometers away; this was the first time China used the Pacific for a missile test since 1980.

At the same time, China is trying to engage other nuclear weapon states in nuclear diplomacy. In July 2024, China submitted a short working paper to the Preparatory Committee for the 2026 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). The paper "encourages the five nuclear-weapon States to negotiate and conclude a treaty on 'mutual no-first-use of nuclear weapons' or issue a political statement in this regard." In October 2024, Sun Xiaobo (director general of the Department of Arms Control of the Ministry of Foreign Affairs of China) said at the general debate of the UN General Assembly First Committee: "Nuclear-weapon States should negotiate and conclude a treaty on 'mutual no-first-use of nuclear weapons' or issue a political statement in this regard, in order to prevent nuclear arms race and reduce strategic risks." These no-first-use overtures, however, received no response from the other four permanent members of the UN Security Council.

In the Middle East, Iran continues to increase its stockpile of enriched uranium. US Secretary of State Antony Blinken said in July 2024 that Iran is one or two weeks away from producing enough highly enriched uranium for a nuclear weapon. Meanwhile, International

Atomic Energy Agency Director General Rafael Mariano Grossi has reported that the IAEA has lost continuity of knowledge with regard to important equipment and materials in Iran's nuclear program. Grossi also said that he is seeking talks with Iran's new president, Masoud Pezeshkian, who has offered to open new nuclear negotiations with the United States and its partners in return for lifting sanctions that are crippling his country's economy. Since April 2024, Israel and Iran have engaged in direct missile and drone attacks, and there are concerns that nuclear facilities could be targeted, which could quickly escalate the current crisis.

North Korea is estimated to have assembled on the order of 50 nuclear weapons, but Kim Jong Un recently declared his goal was to "exponentially expand" North Korea's nuclear arsenal in coming years. North Korea deployed troops to Russia for use in the war in Ukraine and reports of assistance for Pyongyang's nuclear and missile program emerged. In October 2023, North Korea's experimental light water reactor apparently began operations. The reactor could provide North Korea with a robust source of tritium to sustain an arsenal on the order of 100–150 thermonuclear weapons. North Korea also revealed a second uranium enrichment plant in 2024.

The United States can no longer be counted on as a voice of caution or nuclear moderation. Long a driver in the effort to prevent nuclear weapons use, reduce nuclear risks, and pursue nuclear arsenal reductions, the United States has embarked on the world's most expensive nuclear modernization, and the 2024 election results suggest the United States will pursue a faster, more expansive nuclear investment program. It is possible that the United States will expand its nuclear

efforts to include more nuclear options, rely more on nuclear brinkmanship to advance its security and deterrence goals, and shun proven efforts to reduce nuclear dangers. The United States is now a full partner in a worldwide nuclear arms race.

Climate change: devastating impacts and insufficient progress

With respect to climate change, 2024 was in many ways similar to 2023: Manifestations of a changed climate continued to be felt increasingly across the world, even as the clean-energy transition continued to gather pace against formidable headwinds.

Major climate indicators showed 2023 to be the warmest year in the 174-year observational record, with the highest measured level of ocean heat content, the highest global mean sea level on record, and the lowest measured Antarctic sea-ice extent—and 2024 is on track to be even warmer. The global average surface air temperature in the January–September period of 2024 was 1.54 degrees Celsius above the pre-industrial level, already slightly exceeding the "defense line" target of 1.5 degrees Celsius put forward in the Paris Agreement.

Similarly, extreme weather and climate events continued to negatively affect societies, rich and poor, as well as ecosystems around the world. East Asia, Southeast Europe, the Mediterranean and Middle East, the Southwestern United States, Southeast Asia, Northern India, Central America, and the Horn of Africa all suffered from heat waves. The Americas and Northwestern and Southern Africa experienced major droughts

while Europe, Brazil, the Sahel, Afghanistan, and East Africa endured devastating floods.

Attribution studies are highlighting the role of climate change in many such events. For example, a recent study has indicated that roughly half of the 68,000 deaths during the 2022 summer heat waves in Europe were attributable to warming caused by human activity.

On the economic front, a recent study suggests that climate change will result in a significant reduction in average incomes by mid-century (in comparison with a baseline with no climate change impacts). And the countries that will be hit the hardest are those in the lower latitudes that have far less wealth and whose per capita emissions are but a small fraction of those produced in the wealthy countries.

Global greenhouse gas emissions continue to increase, and it follows that globally averaged temperature will also continue to increase. The globally averaged surface concentrations for carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) reached new highs in 2023. The successors to the devastating weather events experienced in 2024 are therefore expected to be even more severe.

On the positive side, renewables continue to dominate new deployment of energy: The 473-gigawatt addition in renewable power capacity in 2023 was 86 percent of the total net capacity addition. But these additions are concentrated in only a few regions (G20 countries accounted for almost 90 percent of global renewable power capacity), and significant investment in fossil fuels continues. Global investment in the low-carbon energy transition reached almost \$1.8 trillion in 2023, an increase of 17 percent over

the previous year, and is expected to reach \$2 trillion in 2024.

The investments for adaptation to climate change impacts are, however, much lower than needed to avoid the worst climate impacts. It is estimated that climate finance (encompassing both mitigation and adaptation efforts) must increase by a factor of at least five under a 1.5C scenario.

The New Collective Quantified Goal on climate finance adopted at the COP 29 climate summit aims to increase finance allocated to developing countries from public and private sources to \$1.3 trillion per year by 2035. Grants or loans below market rates to accelerate the development of climate mitigation or adaptation actions, such as clean technologies, would also increase three-fold, from the earlier annual goal of \$100 billion to \$300 billion by 2035. While these commitments may seem impressive, given the actual magnitude of the climate challenge, many advocates for developing countries consider them grossly inadequate and even a “betrayal” of what was formerly promised.

Daunting biological threats

Emerging and reemerging infectious diseases continue to threaten the global economy, society, and security. The collective experience with COVID-19 has led to increased skepticism about the recommendations of public health officials. The off-season appearance and in-season continuance of highly pathogenic avian influenza (HPAI), the number and types of birds it has infected, the number and types of mammals to which it has spread, its appearance in dairy products, and the troubling occurrence of human cases have

combined to create an increasingly worrisome situation. The ability of all influenza viruses to mutate, break apart, and recombine to create new strains makes the emergence of a human-transmissible version of bird flu a serious possibility. Meanwhile, climate change is altering the characteristics of habitats worldwide, with more animals carrying, and more insects spreading, diseases to each other and to humans.

Concern is also growing over the continued **proliferation of high-containment biological laboratories** around the world, indicating scientific interest in high-risk biological research. Such research often underpins advances in biological science, and nations cannot afford to back away from biological research and development that will increase their competitiveness in the global bioeconomy. Yet such research also poses dangers. Continued arguments about dual-use and gain-of-function research acknowledge both the risks associated with such research efforts—including the possibility of pathogen escapes from biological labs—and the need to continue this research to find ways to treat some of humanity’s worst diseases. Proponents of synthetic biology say that it could provide much-sought-after medical breakthroughs; opponents say that the ability to engineer organisms could lead to the development of entirely new and dangerous pathogens. That we “don’t know what we don’t know” with regard to secret biological research undertaken for nefarious reasons remains an ever-present concern.

The combined threat of AI and biological research is now widely recognized.

Nonetheless, governments and the relevant scientific communities hesitate to limit or restrict AI involvement in biological research and development, fearing that doing so could

cause researchers to miss important scientific breakthroughs.

Geopolitical tensions, skirmishes, and outright war all disrupt (and in some cases, destroy) health care and public health infrastructure, increasing the risk that diseases will spread—even without the use of biological weapons. But nations known to possess active offensive **biological weapons programs** (i.e., Russia and North Korea) could deploy these weapons at any time. Russia’s recent refurbishment and expansion of one of its former biological weapons complexes increases global fears. Terrorist organizations and violent extremists continue to make known their desires to obtain and use biological agents.

Leaders around the world could reduce the biological threats facing humanity, and thereby **move the hands of the Doomsday Clock away from midnight**, by:

- Increasing surveillance of disease in humans, animals, and plants and sharing the results with all nations.
- Establishing knowledgeable authorities and experts to provide trustworthy up-to-date information about diseases of concern and their movement throughout the world.
- Increasing the reporting of changing disease patterns as the climate changes and updating preparedness, surveillance, response, recovery, and mitigation plans accordingly and immediately.
- Slowing the proliferation of high-containment laboratories and establishing norms for the use and acquisition of biological material.
- Dismantling active biological weapons programs.

Disruptive technologies to watch in 2025

As in years past, **artificial intelligence** continues to be a significant and disruptive technology. In particular, the sophistication of large language models (LLMs) such as GPT-4 has led to an intense public debate about the possible existential risks posed by such generative systems. The potential for this particular technology to constitute an existential threat on its own is highly speculative, but as succeeding generations of such models are released, the potential dangers, existential or otherwise, will increase. AI is a disruptive technology, but any physical threat to humans posed by AI must be enabled by a link to a device that can change the state of the physical world, or to decisions that humans make about that world.

Of continuing concern are applications of AI in weapons of war, and most especially in its possible future application to nuclear weapons. In the past year, there have been multiple reports of AI being incorporated in weapons targeting systems in the war in Ukraine. Israel has reportedly used an AI-based system to create target lists in Gaza. The US military is explicitly asking contractors to incorporate AI in non-nuclear command and control systems. According to public statements, Russia is planning to incorporate AI in its nuclear command and control systems. The head of the US Strategic Command recently stated that, while a human will always make the final decision on the use of nuclear weapons, it is conceivable that AI will be embedded in decision-support systems used for nuclear weapons. With respect to conventional military operations, AI is being extensively deployed in intelligence,

surveillance, reconnaissance, simulation, and training activities. Of particular concern are lethal autonomous weapons, which identify and destroy targets without human intervention. Several countries are scaling up their capacity to use AI on the battlefield, including the United States, which has plans to deploy thousands of autonomous (though non-nuclear) weapon systems in the next two years.

Fortunately, many countries are recognizing the importance of regulating AI and are beginning to take steps to minimize its potential for harm. These initial steps include the AI Act, a new regulatory framework by the European Union, and an executive order on artificial intelligence issued by US President Joe Biden that aim to seize the promise and manage the risks of AI. The first challenge in any regulation will be to agree on specific domains—for example, the military or biotechnology—in which the use of AI might be governed by widely accepted rules or norms of behavior. The second challenge will be to agree on the specific content and implementation of those rules and norms.

Increasing chaos, disorder, and **dysfunction in the world's information ecosystem** threaten society's capacity to address difficult challenges, and it is clear that AI has great potential to accelerate these processes of information corruption. AI-enabled distortion of the information environment may be an important factor in preventing the world from dealing effectively with urgent major threats like nuclear war, pandemics, and climate change. This continuing problem took on extra significance for the United States in 2024, when, according to numerous reports, Chinese and Russian disinformation campaigns attempted to subvert the 2024 US national elections. Advances in LLM technologies and

dramatic improvements in the phony video depictions known as deepfakes could have consequential future effects on the information ecosystem. Appropriate governance of AI and social media platforms is essential to an information ecosystem that supports truth and democracy.

The expansion of drone warfare, especially by Ukraine, has been dramatic. This has led many countries to begin incorporating drone warfare in their military doctrines, as well as ramping up production and trade in weaponized drones of all types. Development of new tactics and innovative uses of drones are changing military operations and will spark efforts to counter unmanned aircraft systems. As seen in the Ukraine conflict, both sides now employ drones in long-distance strikes well beyond the battlefield.

There is a growing belligerence among the United States, Russia, and China in space, and the probability of conflict in space continues

to grow. China and Russia are far more active now than in previous decades, and US activities, both governmental and private, make it difficult to avert a military space race. The use of space systems—including privately owned Starlink satellites—to support military operations continues to expand. As a result, satellites—owned both by governments and corporations—become ever more important as military targets.

Finally, the growing presence of **hypersonic weapons** in contested regional theaters substantially increases the risk of escalation. Russia's recent use of an advanced, experimental medium-range ballistic missile, presumably in response to Ukraine's use of a US-supplied Army Tactical Missile System (ATACMS missile), is an example of this dangerous technology trend. The presence of Chinese hypersonic weapons also could worsen security dynamics in contested areas like the South China Sea. 📡

Science and Security Board Biographies

Edmund G Brown Jr. (Executive Chair) completed his fourth term as Governor of the State of California in 2019. He began his career in public service in 1969 as a trustee for the LA Community College District and became California Secretary of State in 1970 and Governor of California in 1974 and 1978. After his governorship, Brown lectured and traveled widely, practiced law, served as chairman of the state Democratic Party, and ran for president. Brown was elected Mayor of Oakland in 1998 and California Attorney General in 2006; he was elected to a third gubernatorial term in 2010 and a fourth term in 2014. During this time, Brown helped eliminate the state's multi-billion budget deficit, spearheaded successful campaigns to provide new funding for California's schools, and established a robust Rainy Day Fund to prepare for the next economic downturn. His administration established nation-leading targets to protect the environment and fight climate change. Brown attended the University of California, Berkeley, and earned a JD at Yale Law School.

Siegfried Hecker (Ex Officio) is director emeritus at the Los Alamos National Laboratory where he spent 34 years in positions ranging from a summer graduate student to a postdoctoral fellow, director of the Center of Materials Science, director of the laboratory, and senior fellow. In 2005 he joined Stanford University, where he was a senior fellow at the Center of International Security and Cooperation, including serving as co-director for six years, and professor (research) in the Department of Management Science and Engineering. After retiring from Stanford University in August 2022, he joined the Department of Nuclear Engineering at Texas A&M University as professor of practice and the Middlebury Institute of International Studies at Monterey as distinguished professor of practice. Hecker received B.S., M.S., and PhD degrees in metallurgy and materials science from Case Western Reserve University and its predecessor, Case Institute of Technology. Among other awards, Hecker received the Presidential Enrico

Fermi Award (2009), the Department of Energy's E. O. Lawrence Award (1984), and the 2018 American Association of Engineering Societies National Engineering Award. He also received the American Nuclear Society Dwight D. Eisenhower Medal in 2017 (with Sam Nunn and Richard Lugar). His book *Hinge Points: An Inside Look at North Korea's Nuclear Program*, written with Elliot Serbin, was published by Stanford University Press in 2023.

Steve Fetter is a professor of public policy at the University of Maryland. He served for five years in the White House Office of Science and Technology Policy during the Obama administration, where he led the environment and energy and the national security and international affairs divisions. He is a fellow of the American Physical Society and a member of the Union of Concerned Scientists board of directors and the National Academy of Sciences Committee on International Security and Arms Control. He has worked on nuclear policy issues in the Pentagon and the State Department and has been a visiting fellow at Stanford, Harvard, MIT, and Lawrence Livermore National Laboratory. He also served as associate director of the Joint Global Change Research Institute and vice chairman of the Federation of American Scientists. He is a recipient of the American Physical Society's Joseph A. Burton Forum Award, the Federation of American Scientists' Hans Bethe Science in the Public Service award, and the Secretary of Defense Medal for Outstanding Public Service.

Inez Fung is a Professor Emerita of Atmospheric Science in the Department of Earth and Planetary Science and the Department of Environmental Science, Policy and Management at the University of California, Berkeley. She pioneered the use of global three-dimensional models of atmospheric circulation to infer carbon sources and sinks at the surface. She was the US lead for the 2014 joint NAS-Royal Society study "Climate Change: Evidence and Causes" and its 2020 update. Fung is a member of the US National Academy of Sciences; a foreign member of the Royal Society,

Biographies (cont.)

London; and a member of Academia Sinica (Taiwan). Among her other honors are the Roger Revelle Medal from the American Geophysical Union and the C.G. Rossby Research Medal from the American Meteorological Society.

Asha M. George is the executive director of the Bipartisan Commission on Biodefense. She is a public health security professional whose research and programmatic emphasis has been practical, academic, and political. George served in the US House of Representatives as a senior professional staffer and subcommittee staff director at the House Committee on Homeland Security in the 110th and 111th Congress. She has worked for a variety of organizations, including government contractors, foundations, and nonprofits. As a contractor, she supported and worked with all federal departments, especially the Department of Homeland Security and the Department of Health and Human Services. George also served on active duty in the US Army as a military intelligence officer and as a paratrooper. She is a decorated Desert Storm veteran. She holds a Bachelor of Arts in Natural Sciences from Johns Hopkins University, a Master of Science in Public Health from the University of North Carolina at Chapel Hill, and a Doctorate in Public Health from the University of Hawaii at Manoa. She is also a graduate of the Harvard University National Preparedness Leadership Initiative.

Alexander Glaser is an associate professor in the School of Public and International Affairs and in the Department of Mechanical and Aerospace Engineering at Princeton University. Glaser has co-directed Princeton's Program on Science and Global Security since 2016. Along with Harold Feiveson, Zia Mian, and Frank von Hippel, he is co-author of *Unmaking the Bomb* (MIT Press, 2014). For Princeton's work on nuclear warhead verification, *Foreign Policy* magazine selected him as one of the 100 Leading Global Thinkers of 2014. In September 2020, Glaser was elected a Fellow of the American Physical Society for "advancing the scientific and technical basis for nuclear arms control, nonproliferation, and disarmament verification."

Along with Tamara Patton and Susanna Pollack, he is one of the executive producers of the VR documentary *On the Morning You Wake*. Glaser holds a PhD in Physics from Darmstadt University, Germany.

Daniel Holz (Chair) is a professor at the University of Chicago in the Departments of Physics, Astronomy & Astrophysics, the Enrico Fermi Institute, and the Kavli Institute for Cosmological Physics. His research focuses on general relativity in the context of astrophysics and cosmology. He is a member of the Laser Interferometer Gravitational-Wave Observatory (LIGO) collaboration and was part of the team that announced the first detection of gravitational waves in early 2016 and the first multi-messenger detection of a binary neutron star in 2017. Holz is also founding director of the University of Chicago Existential Risk Laboratory (XLab). He received a 2012 National Science Foundation CAREER Award, the 2015 Quantrell Award for Excellence in Undergraduate Teaching, and the Breakthrough Prize in Fundamental Physics in 2016. Holz was selected as a Kavli Fellow of the National Academy of Sciences and is a Fellow of the American Physical Society. He received his PhD in physics from the University of Chicago and his AB in physics from Princeton University. As chair of the Science and Security Board, Holz is a member of the Governing Board, *ex officio*.

Robert Latiff retired from the US Air Force as a major general in 2006. He is an adjunct professor at the University of Notre Dame and at George Mason University's School of Engineering. He is a member of the National Academy of Sciences, Committee on Transformative Science and Technology for the Department of Defense. Latiff is the author of *Future Peace: Technology, Aggression, and the Rush to War*, which looks at the role technology plays in leading us into conflict. He is also the author of *Future War: Preparing for the New Global Battlefield*.

Biographies (cont.)

Herb Lin is a senior research scholar for cyber policy and security at the Center for International Security and Cooperation and Hank J. Holland Fellow in Cyber Policy and Security at the Hoover Institution, both at Stanford University. His research interests relate broadly to policy-related dimensions of cybersecurity and cyberspace, and he is particularly knowledgeable about the use of offensive operations in cyberspace as instruments of national policy and the security dimensions of information warfare and influence operations on national security. In 2016, he served on President Obama's Commission on Enhancing National Cybersecurity. He has also served as professional staff member and staff scientist for the House Armed Services Committee (1986-1990), where his portfolio included defense policy and arms control issues.

Suzet McKinney is the principal and director of Life Sciences for Sterling Bay where she oversees relationships with the scientific, academic, corporate, tech, and governmental sectors involved in the life sciences ecosystem. She also leads the strategy to expand Sterling Bay's footprint in life sciences nationwide. She previously served as CEO and executive director of the Illinois Medical District, where she managed a 24/7/365 environment that included 560 acres of medical research facilities, labs, a biotech business incubator, universities, raw land development areas, four hospitals, and more than 40 health-care-related facilities. In 2020 McKinney was appointed by Illinois Governor JB Pritzker as operations lead for the State of Illinois' Alternate Care Facilities, a network of alternate medical locations designed to decompress the hospital system during the COVID-19 pandemic. McKinney holds her Doctorate degree from the University of Illinois at Chicago School of Public Health and received her Bachelor of Arts in Biology from Brandeis University. She received her Master of Public Health degree and certificates in Managed Care and Health Care Administration from Benedictine University in Lisle, IL.

Steve Miller is director of the International Security Program, editor-in-chief of the quarterly journal *International Security*, and co-editor of the International Security Program's book series, Belfer Center Studies in International Security (published by the MIT Press). Previously, he was senior research fellow at the Stockholm International Peace Research Institute and taught defense and arms control studies in the department of political science at the Massachusetts Institute of Technology. He is co-author of the monograph *War with Iraq: Costs, Consequences, and Alternatives* (American Academy of Arts & Sciences, 2002). Miller is editor or co-editor of more than two dozen books including, most recently, *Going Nuclear* (MIT Press, 2010) and *Contending with Terrorism* (MIT Press, 2010).

Scott Sagan is the Caroline S.G. Munro Professor of Political Science, the Mimi and Peter Haas University Fellow in Undergraduate Education, Co-Director and Senior Fellow at the Center for International Security and Cooperation, and Senior Fellow at the Freeman Spogli Institute at Stanford University. He also serves as Chairman of the American Academy of Arts and Sciences' Committee on International Security Studies. Before joining the Stanford faculty, Sagan was a lecturer in the Department of Government at Harvard University and served as special assistant to the director of the Organization of the Joint Chiefs of Staff in the Pentagon. Sagan has also served as a consultant to the office of the Secretary of Defense and at the Sandia National Laboratory and the Los Alamos National Laboratory.

Ambuj Sagar is the deputy director (strategy & planning) and the Vipula and Mahesh Chaturvedi Professor of Policy Studies at the Indian Institute of Technology (IIT) Delhi. He previously served as the founding head of the School of Public Policy at IIT Delhi. Sagar's research interests broadly lie at the intersection of science, technology, and sustainable development. Sagar was a lead author in Working Group III of the IPCC's Sixth Assessment Report, a member of the Independent Group of Scientists appointed by the UN Secretary-General

Biographies (cont.)

to prepare the Global Sustainable Development Report 2023, and a member of the NAS panel that authored the 2021 report on geoengineering research and governance. He has served as a respected advisor to various Indian government agencies as well as many multilateral and bilateral agencies.

Manpreet Sethi is a distinguished fellow at the Centre for Air Power Studies in New Delhi, where she heads its program on nuclear issues. She is also a Senior Research Advisor at the Asia Pacific Leadership Network. Since receiving her doctorate in 1997, she has worked on nuclear energy, strategy, missile defense, arms control, nuclear risk reduction, and disarmament. Over 130 papers have been written, and nine books authored, co-authored, or edited by Sethi. She lectures at the National Defence College and other establishments of the Indian Armed Forces, Police, Foreign Services, and Universities. She is co-chair of the Working Group on Reducing Pathways to Nuclear Use at Harvard University's Belfer Center and co-chair of Women in Nuclear-India. She is a Board Member of the Missile Dialogue Initiative, IISS. She is the recipient of the K. Subrahmanyam Award (2014), Commendation by Chief of Air Staff (2020), and Commendation by Commander-in-Chief, Strategic Forces Command (2022). She is a member of the International Group of Eminent Persons selected by Japan's Prime Minister to explore possibilities of nuclear elimination.

Robert Socolow is professor emeritus in the Department of Mechanical and Aerospace Engineering at Princeton University. He currently serves on the National Academy of Sciences Advisory Committee to the US Global Change Research Program. From 2000 to 2019, he and Steve Pacala were the co-principal investigators of Princeton's Carbon Mitigation Initiative, a 25-five-year (2001-2025) project supported by BP. His best-known paper, with Pacala, was in *Science* (2004): "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies." Socolow is a member of the American Academy of Arts and Sciences, an associate of the National Research Council of the National Academies,

a fellow of the American Physical Society, and a fellow of the American Association for the Advancement of Science. His awards include the 2009 Frank Kreith Energy Award from the American Society of Mechanical Engineers and the 2005 Axelson Johnson Commemorative Lecture award from the Royal Academy of Engineering Sciences of Sweden (IVA). In 2003 he received the Leo Szilard Lectureship Award from the American Physical Society.

Jon Wolfsthal is the director of global risk at the Federation of American Scientists and a senior adjunct fellow at the Center for a New American Security. He was appointed to the US Department of State's International Security Advisory Board in 2022. He served previously as senior advisor to Global Zero in Washington, DC. Before 2017, Wolfsthal served as Special Assistant to President of the United States Barack Obama for National Security Affairs and is a former senior director at the National Security Council for arms control and nonproliferation. He also served from 2009-2012 as Special Advisor to Vice President Joseph R. Biden for nuclear security and nonproliferation and as a director for nonproliferation on the National Security Council. During his government service, Wolfsthal has been involved in almost every aspect of US nuclear weapons, deterrence, arms control, and nonproliferation policy.

Editor

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About the *Bulletin of the Atomic Scientists*

At our core, the *Bulletin of the Atomic Scientists* is a media organization, publishing a free-access website and a bimonthly magazine. But we are much more. The *Bulletin's* website, iconic Doomsday Clock, and regular events equip the public, policy makers, and scientists with the information needed to reduce man-made threats to our existence. The *Bulletin* focuses on three main areas: nuclear risk, climate change, and disruptive technologies, including developments in biotechnology. What connects these topics is a driving belief that because humans created them, we can control them.

The *Bulletin* is an independent, nonprofit 501(c)(3) organization. We gather the most informed and influential voices tracking man-made threats and bring their innovative thinking to a global audience. We apply intellectual rigor to the conversation and do not shrink from alarming truths.

The *Bulletin* has many audiences: the general public, which will ultimately benefit or suffer from scientific breakthroughs; policy makers, whose duty is to harness those breakthroughs for good; and the scientists themselves, who produce those technological advances and thus bear a special responsibility. Our community is international, with more than half of our website visitors coming from outside the United States. It is also young. Half are under the age of 35.

To learn more, visit our website:

<https://thebulletin.org>

Timeline of the Doomsday Clock



IT IS 89 SECONDS TO MIDNIGHT

In setting the Clock one second closer to midnight, the Science and Security Board sends a stark signal: Because the world is already perilously close to the precipice, a move of even a single second should be taken as an indication of extreme danger and an unmistakable warning that every second of delay in reversing course increases the probability of global disaster.



IT IS STILL 90 SECONDS TO MIDNIGHT

The Doomsday Clock remains at 90 seconds to midnight because humanity continues to face an unprecedented level of danger. The decision should not be taken as a sign that the international security situation has eased. Instead, leaders and citizens around the world should take this statement as a stark warning and respond urgently, as if today were the most dangerous moment in modern history. Because it may well be.



IT IS 90 SECONDS TO MIDNIGHT

The Science and Security Board moves the hands of the Doomsday Clock forward, largely (though not exclusively) because of the mounting dangers of the war in Ukraine. The war has raised profound questions about how states interact, eroding norms of international conduct that underpin successful responses to a variety of global risks. The Clock now stands at 90 seconds to midnight—the closest to global catastrophe it has ever been.



IT IS STILL 100 SECONDS TO MIDNIGHT

Leaders around the world must immediately commit themselves to renewed cooperation in the many ways and venues available for reducing existential risk. Citizens of the world can and should organize to demand that their leaders do so—and quickly. The doorstep of doom is no place to loiter.



IT IS STILL 100 SECONDS TO MIDNIGHT

If humanity is to avoid an existential catastrophe—one that would dwarf anything it has yet seen—national leaders must do a far better job of countering disinformation, heeding science, and cooperating to diminish global risks. Citizens around the world can and should organize and demand—through public protests, at ballot boxes, and in other creative ways—that their governments reorder their priorities and cooperate domestically and internationally to reduce the risk of nuclear war, climate change, and other global disasters, including pandemic disease.



IT IS 100 SECONDS TO MIDNIGHT

Humanity continues to face two simultaneous existential dangers—nuclear war and climate change—that are compounded by a threat multiplier, cyber-enabled information warfare, that undercuts society's ability to respond. Faced with this daunting threat landscape and a new willingness of political leaders to reject the negotiations and institutions that can protect civilization over the long term, the Science and Security Board moved the Doomsday Clock 20 seconds closer to midnight—a warning to leaders and citizens around the world that the international security situation is now more dangerous than it has ever been, even at the height of the Cold War.



IT IS STILL 2 MINUTES TO MIDNIGHT

The “new abnormal” that the world now inhabits is unsustainable and extremely dangerous. It is two minutes to midnight, but there is no reason the Doomsday Clock cannot move away from catastrophe. It has done so in the past, because wise leaders acted—under pressure from informed and engaged citizens around the world. Today, citizens in every country can insist on facts, and discount nonsense. They can demand action to reduce the existential threat of nuclear war and unchecked climate change. Given the inaction of their leaders to date, citizens of the world should make a loud and clear demand: #RewindTheDoomsdayClock.



IT IS 2 MINUTES TO MIDNIGHT

The failure of world leaders to address the largest threats to humanity's future is lamentable—but that failure can be reversed. The world has seen the threat posed by the misuse of information technology and witnessed the vulnerability of democracies to disinformation. But there is a flip side to the abuse of social media. Leaders react when citizens insist they do so, and citizens around the world can use the power of the internet to improve the long-term prospects of their children and grandchildren. They can seize the opportunity to make a safer and saner world.



IT IS TWO AND A HALF MINUTES TO MIDNIGHT

In its two most recent annual announcements on the Clock, the Science and Security Board warned: “The probability of global catastrophe is very high, and the actions needed to reduce the risks of disaster must be taken very soon.” In 2017, we find the danger to be even greater, the need for action more urgent. Wise public officials should act immediately, guiding humanity away from the brink. If they do not, wise citizens must step forward and lead the way.

Timeline (cont.)



IT IS STILL 3 MINUTES TO MIDNIGHT

"Last year, the Science and Security Board moved the Doomsday Clock forward to three minutes to midnight, noting: 'The probability of global catastrophe is very high, and the actions needed to reduce the risks of disaster must be taken very soon.' That probability has not been reduced. The Clock ticks. Global danger looms. Wise leaders should act—immediately."



IT IS 3 MINUTES TO MIDNIGHT

"Unchecked climate change, global nuclear weapons modernizations, and outsized nuclear weapons arsenals pose extraordinary and undeniable threats to the continued existence of humanity." Despite some modestly positive developments in the climate change arena, current efforts are entirely insufficient to prevent a catastrophic warming of Earth. Meanwhile, the United States and Russia have embarked on massive programs to modernize their nuclear triads—thereby undermining existing nuclear weapons treaties. "The clock ticks now at just three minutes to midnight because international leaders are failing to perform their most important duty—ensuring and preserving the health and vitality of human civilization."



IT IS 5 MINUTES TO MIDNIGHT

"The challenges to rid the world of nuclear weapons, harness nuclear power, and meet the nearly inexorable climate disruptions from global warming are complex and interconnected. In the face of such complex problems, it is difficult to see where the capacity lies to address these challenges." Political processes seem wholly inadequate; the potential for nuclear weapons use in regional conflicts in the Middle East, Northeast Asia, and South Asia are alarming; safer nuclear reactor designs need to be developed and built, and more stringent oversight, training, and attention are needed to prevent future disasters; the pace of technological solutions to address climate change may not be adequate to meet the hardships that large-scale disruption of the climate portends.



IT IS 6 MINUTES TO MIDNIGHT

International cooperation rules the day. Talks for a follow-on to the Strategic Arms Reduction Treaty are nearly complete, and negotiations for further reductions in the US and Russian nuclear arsenals are planned. Barack Obama becomes the first US president to publicly call for a nuclear-weapon-free world. Dangers posed by climate change are still great, but there are pockets of progress. At Copenhagen, the developing and industrialized countries agree to take responsibility for carbon emissions and to limit global temperature rise to 2 degrees Celsius.



IT IS 5 MINUTES TO MIDNIGHT

The world stands at the brink of a second nuclear age. The United States and Russia remain ready to stage a nuclear attack within minutes, North Korea conducts a nuclear test, and many in the international community worry that Iran plans to acquire the Bomb. Climate change also presents a dire challenge to humanity. Damage to ecosystems is already taking place; flooding, destructive storms, increased drought, and polar ice melt are causing loss of life and property.



IT IS 7 MINUTES TO MIDNIGHT

Concerns regarding a nuclear terrorist attack underscore the enormous amount of unsecured—and sometimes unaccounted for—weapon-grade nuclear materials located throughout the world. Meanwhile, the United States expresses a desire to design new nuclear weapons, with an emphasis on those able to destroy hardened and deeply buried targets. It also rejects a series of arms control treaties and announces it will withdraw from the Anti-Ballistic Missile Treaty.



IT IS 9 MINUTES TO MIDNIGHT

India and Pakistan stage nuclear weapons tests only three weeks apart. "The tests are a symptom of the failure of the international community to fully commit itself to control the spread of nuclear weapons—and to work toward substantial reductions in the numbers of these weapons," a dismayed *Bulletin* reports. Russia and the United States continue to serve as poor examples to the rest of the world. Together, they still maintain 7,000 warheads ready to fire at each other within 15 minutes.



IT IS 14 MINUTES TO MIDNIGHT

Hopes for a large post-Cold War peace dividend and a renouncing of nuclear weapons fade. Particularly in the United States, hard-liners seem reluctant to soften their rhetoric or actions, as they claim that a resurgent Russia could provide as much of a threat as the Soviet Union. Such talk slows the rollback in global nuclear forces; more than 40,000 nuclear weapons remain worldwide. There is also concern that terrorists could exploit poorly secured nuclear facilities in the former Soviet Union.



IT IS 17 MINUTES TO MIDNIGHT

With the Cold War officially over, the United States and Russia begin making deep cuts to their nuclear arsenals. The Strategic Arms Reduction Treaty greatly reduces the number of strategic nuclear weapons deployed by the two former adversaries. Better still, a series of unilateral initiatives remove most of the

Timeline (cont.)

intercontinental ballistic missiles and bombers in both countries from hair-trigger alert. “The illusion that tens of thousands of nuclear weapons are a guarantor of national security has been stripped away,” the *Bulletin* declares.



1990

IT IS 10 MINUTES TO MIDNIGHT

As one Eastern European country after another (Poland, Czechoslovakia, Hungary, Romania) frees itself from Soviet control, Soviet General Secretary Mikhail Gorbachev refuses to intervene, halting the ideological battle for Europe and significantly diminishing the risk of all-out nuclear war. In late 1989, the Berlin Wall falls, symbolically ending the Cold War. “Forty-four years after Winston Churchill’s ‘Iron Curtain’ speech, the myth of monolithic communism has been shattered for all to see,” the *Bulletin* proclaims.



1988

IT IS 6 MINUTES TO MIDNIGHT

The United States and Soviet Union sign the historic Intermediate-Range Nuclear Forces Treaty, the first agreement to actually ban a whole category of nuclear weapons. The leadership shown by President Ronald Reagan and Soviet Premier Mikhail Gorbachev makes the treaty a reality, but public opposition to US nuclear weapons in Western Europe inspires it. For years, such intermediate-range missiles had kept Western Europe in the crosshairs of the two superpowers.



1984

IT IS 3 MINUTES TO MIDNIGHT

US-Soviet relations reach their iciest point in decades. Dialogue between the two superpowers virtually stops. “Every channel of communications has been constricted or shut down; every form of contact has been attenuated or cut off. And arms control negotiations have been reduced to a species of propaganda,” a concerned *Bulletin* informs readers. The United States seems to flout the few arms control agreements in place by seeking an expansive, space-based anti-ballistic missile capability, raising worries that a new arms race will begin.



1981

IT IS 4 MINUTES TO MIDNIGHT

The Soviet invasion of Afghanistan hardens the US nuclear posture. Before he leaves office, President Jimmy Carter pulls the United States from the Olympic Games in Moscow and considers ways in which the United States could win a nuclear war. The rhetoric only intensifies with the election of Ronald Reagan as president. Reagan scraps any talk of arms control and proposes that the best way to end the Cold War is for the United States to win it.



1980

IT IS 7 MINUTES TO MIDNIGHT

Thirty-five years after the start of the nuclear age and after some promising disarmament gains, the United States and the Soviet Union still view nuclear weapons as an integral component of their national security. This stalled progress discourages the *Bulletin*: “[The Soviet Union and United States have] been behaving like what may best be described as ‘nucleoholics’—drunks who continue to insist that the drink being consumed is positively ‘the last one,’ but who can always find a good excuse for ‘just one more round.’”



1974

IT IS 9 MINUTES TO MIDNIGHT

South Asia gets the Bomb, as India tests its first nuclear device. And any gains in previous arms control agreements seem like a mirage. The United States and Soviet Union appear to be modernizing their nuclear forces, not reducing them. Thanks to the deployment of multiple independently targetable reentry vehicles (MIRVs), both countries can now load their intercontinental ballistic missiles with more nuclear warheads than before.



1972

IT IS 12 MINUTES TO MIDNIGHT

The United States and Soviet Union attempt to curb the race for nuclear superiority by signing the Strategic Arms Limitation Treaty (SALT) and the Anti-Ballistic Missile (ABM) Treaty. The two treaties force a nuclear parity of sorts. SALT limits the number of ballistic missile launchers either country can possess, and the ABM Treaty stops an arms race in defensive weaponry from developing.



1969

IT IS 10 MINUTES TO MIDNIGHT

Nearly all of the world’s nations come together to sign the Nuclear Non-Proliferation Treaty. The deal is simple—the nuclear weapon states vow to help the treaty’s non-nuclear weapon signatories develop nuclear power if they promise to forego producing nuclear weapons. The nuclear weapon states also pledge to abolish their own arsenals when political conditions allow for it. Although Israel, India, and Pakistan refuse to sign the treaty, the *Bulletin* is cautiously optimistic: “The great powers have made the first step. They must proceed without delay to the next one—the dismantling, gradually, of their own oversized military establishments.”



1968

IT IS 7 MINUTES TO MIDNIGHT

Regional wars rage. US involvement in Vietnam intensifies, India and Pakistan battle in 1965, and Israel and its Arab neighbors renew hostilities in 1967. Worse yet, France and China develop nuclear weapons to

Timeline (cont.)

assert themselves as global players. “There is little reason to feel sanguine about the future of our society on the world scale,” the *Bulletin* laments. “There is a mass revulsion against war, yes; but no sign of conscious intellectual leadership in a rebellion against the deadly heritage of international anarchy.”



IT IS 7 MINUTES TO MIDNIGHT

As the *Bulletin* evolves from a newsletter into a magazine, the Clock appears on the cover for the first time. It symbolizes the urgency of the nuclear dangers that the magazine’s founders—and the broader scientific community—are trying to convey to the public and political leaders around the world.



IT IS 12 MINUTES TO MIDNIGHT

After a decade of almost nonstop nuclear tests, the United States and Soviet Union sign the Partial Test Ban Treaty, which ends all atmospheric nuclear testing. While it does not outlaw underground testing, the treaty represents progress in at least slowing the arms race. It also signals awareness among the Soviets and United States that they need to work together to prevent nuclear annihilation.



IT IS 7 MINUTES TO MIDNIGHT

Political actions belie the tough talk of “massive retaliation.” For the first time, the United States and Soviet Union appear eager to avoid direct confrontation in regional conflicts such as the 1956 Egyptian-Israeli dispute. Joint projects that build trust and constructive dialogue between third parties also quell diplomatic hostilities. Scientists initiate many of these measures, helping establish the International Geophysical Year, a series of coordinated, worldwide scientific observations, and the Pugwash Conferences, which allow Soviet and American scientists to interact.



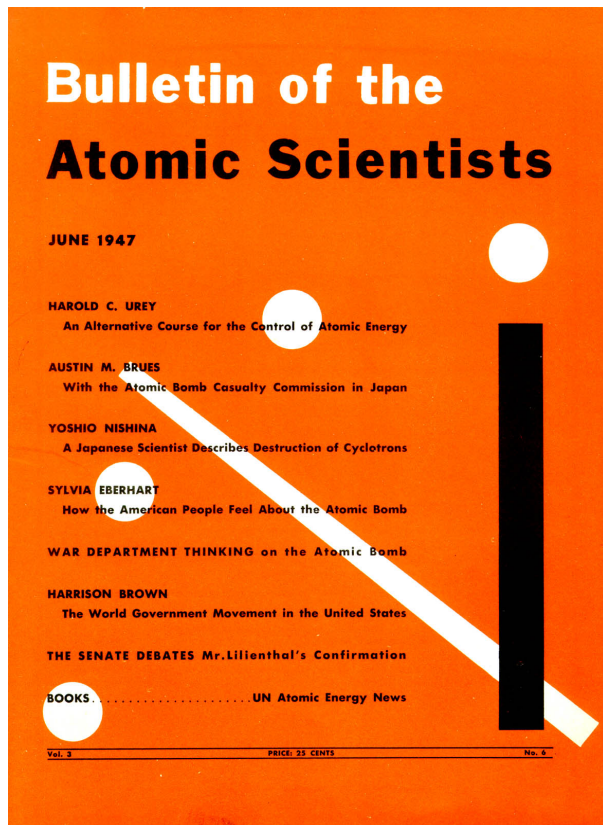
IT IS 2 MINUTES TO MIDNIGHT

After much debate, the United States decides to pursue the hydrogen bomb, a weapon far more powerful than any atomic bomb. In October 1952, the United States tests its first thermonuclear device, obliterating a Pacific Ocean islet in the process; nine months later, the Soviets test an H-bomb of their own. “The hands of the Clock of Doom have moved again,” the *Bulletin* announces. “Only a few more swings of the pendulum, and, from Moscow to Chicago, atomic explosions will strike midnight for Western civilization.”



IT IS 3 MINUTES TO MIDNIGHT

The Soviet Union denies it, but in the fall, President Harry Truman tells the American public that the Soviets tested their first nuclear device, officially starting the arms race. “We do not advise Americans that doomsday is near and that they can expect atomic bombs to start falling on their heads a month or year from now,” the *Bulletin* explains. “But we think they have reason to be deeply alarmed and to be prepared for grave decisions.”



The Doomsday Clock appeared for the first time on the cover of the Bulletin’s June 1947 issue, set at 7 minutes to midnight.