Bulletin
of the
Atomic
Scientists

A moment of historic danger: It is *still* 90 seconds to midnight

2024 Doomsday Clock Statement

Science and Security Board
Bulletin of the Atomic Scientists

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IT IS 90 SECONDS
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.*

A moment of historic danger: It is *still* 90 seconds to midnight

Ominous trends continue to point the world toward global catastrophe. The war in Ukraine and the widespread and growing reliance on nuclear weapons increase the risk of nuclear escalation. China, Russia, and the United States are all spending huge sums to expand or modernize their nuclear arsenals, adding to the ever-present danger of nuclear war through mistake or miscalculation.

In 2023, Earth experienced its hottest year on record, and massive floods, wildfires, and other climate-related disasters affected millions of people around the world. Meanwhile, rapid and worrisome developments in the life sciences and other disruptive technologies accelerated, while governments made only feeble efforts to control them.

The members of the Science and Security Board have been deeply worried about the deteriorating state of the world. That is why we set the Doomsday Clock at two minutes to midnight in 2019 and at 100 seconds to midnight in 2022. Last year, we expressed our heightened concern by moving the Clock to 90 seconds to midnight—the closest to global catastrophe it has ever been—in large part because of Russian threats to use nuclear weapons in the war in Ukraine.

Today, we once again set the Doomsday Clock at 90 seconds to midnight because humanity continues to face an unprecedented level of danger. Our 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.

But the world can be made safer. The Clock can move away from midnight. As we wrote last year, "In this time of unprecedented global danger, concerted action is required, and every second counts." That is just as true today.

The many dimensions of nuclear threat

A durable end to Russia's war in Ukraine seems distant, and the use of nuclear weapons by Russia in that conflict remains a serious possibility. In February 2023, Russian President Vladimir Putin announced his decision to "suspend" the New Strategic Arms Reduction Treaty (New START). In March, he announced the deployment of tactical nuclear weapons in Belarus. In June, Sergei Karaganov, an advisor to Putin, urged Moscow to consider launching limited nuclear strikes on Western Europe as a way to bring the war in Ukraine to a favorable

conclusion. In October, Russia's Duma voted to withdraw Moscow's ratification of the Comprehensive Nuclear Test Ban Treaty, as the US Senate continued to refuse even to debate ratification.

Nuclear spending programs in the three largest nuclear powers—China, Russia, and the United States—threaten to trigger a three-way nuclear arms race as the world's arms control architecture collapses. Russia and China are expanding their nuclear capabilities, and pressure mounts in Washington for the United States to respond in kind.

Meanwhile, other potential nuclear crises fester. Iran continues to enrich uranium to close to weapons grade while stonewalling the International Atomic Energy Agency on key issues. Efforts to reinstate an Iran nuclear deal appear unlikely to succeed, and North Korea continues building nuclear weapons and long-range missiles. Nuclear expansion in Pakistan and India continues without pause or restraint.

And the war in Gaza between Israel and Hamas has the potential to escalate into a wider Middle Eastern conflict that could pose unpredictable threats, regionally and globally.

An ominous climate change outlook

The world in 2023 entered uncharted territory as it suffered its hottest year on record and global greenhouse gas emissions continued to rise. Both global and North Atlantic sea-surface temperatures broke records, and Antarctic sea ice reached its lowest daily extent since the advent of satellite data. The world already risks exceeding a goal of the Paris climate agreement—a temperature increase of no more than 1.5 degrees Celsius above pre-industrial levels—because of insufficient commitments to reduce greenhouse gas emissions and insufficient implementation of commitments already made. To halt further warming, the world must achieve net zero carbon dioxide emissions.

The world invested a record-breaking $1.7 trillion in clean energy in 2023, and countries representing half the world's gross domestic product pledged to triple their renewable energy capacity by 2030. Offsetting this, however, were fossil fuel investments of nearly $1 trillion. In short, current efforts to reduce greenhouse gas emissions are grossly insufficient to avoid dangerous human and economic impacts from climate change, which disproportionately affect the poorest people in the world. Barring a marked increase in efforts, the toll of human suffering from climate disruption will inexorably mount.

Evolving biological threats

The revolution in life sciences and associated technologies continued to expand in scope last year, including, especially, the increased sophistication and efficiency of genetic engineering technologies. We highlight one issue of special concern: The convergence of emerging artificial intelligence tools and biological technologies may radically empower individuals to misuse biology.

In October, US President Joe Biden signed an executive order on "safe, secure, and trustworthy AI" that calls for protection "against the risks of using AI to engineer dangerous biological materials by developing strong new standards for biological synthesis screening." Though a useful step, the order is not legally binding. The concern is that large language models enable individuals who otherwise lack sufficient know-how to identify, acquire, and deploy biological agents that would harm large numbers of humans, animals, plants, and other elements of the environment. Reinvigorated efforts

this past year in the United States to revise and strengthen oversight of risky life science research are useful, but much more is needed.

The dangers of AI

One of the most significant technological developments in the last year involved the dramatic advance of generative artificial intelligence. The apparent sophistication of chatbots based on large language models, such as ChatGPT, led some respected experts to express concern about existential risks arising from further rapid advancements in the field. But others argue that claims about existential risk distract from the real and immediate threats that AI poses today (see, for example, "Evolving biological threats" above). Regardless, AI is a paradigmatic disruptive technology; recent efforts at global governance of AI should be expanded.

AI has great potential to magnify disinformation and corrupt the information environment on which democracy depends. AI-enabled disinformation efforts could be a factor that prevents the world from dealing effectively with nuclear risks, pandemics, and climate change.

Military uses of AI are accelerating. Extensive use of AI is already occurring in intelligence, surveillance, reconnaissance, simulation, and training. Of particular concern are lethal autonomous weapons, which identify and destroy targets without human intervention. Decisions to put AI in control of important physical systems—in particular, nuclear weapons—could indeed pose a direct existential threat to humanity.

Fortunately, many countries are recognizing the importance of regulating AI and are beginning to take steps to reduce the potential for harm. These initial steps include a proposed regulatory framework by the European Union, an executive order by President Biden, an international declaration to address AI risks, and the formation of a new UN advisory body. But these are only tiny steps; much more must be done to institute effective rules and norms, despite the daunting challenges involved in governing artificial intelligence.

How to turn back the Clock

Everyone on Earth has an interest in reducing the likelihood of global catastrophe from nuclear weapons, climate change, advances in the life sciences, disruptive technologies, and the widespread corruption of the world's information ecosystem. These threats, singularly and as they interact, are of such a character and magnitude that no one nation or leader can bring them under control. That is the task of leaders and nations working together in the shared belief that common threats demand common action. As the first step, and despite their profound disagreements, three of the world's leading powers—the United States, China, and Russia—should commence serious dialogue about each of the global threats outlined here. At the highest levels, these three countries need to take responsibility for the existential danger the world now faces. They have the capacity to pull the world back from the brink of catastrophe. They should do so, with clarity and courage, and without delay.

It's 90 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.

An undiminished nuclear threat and a new arms race

The last year was characterized by fraught relations among the world's great powers, who were engaged in vigorous nuclear modernization programs as the nuclear arms control regime continued to collapse. Within this general context, the contours of a peaceful and sustainable ending of Russia's war against Ukraine are difficult to discern, and concerns remain about Russia's possible use of nuclear weapons in this conflict.

In February 2023, Russian President Vladimir Putin announced his decision to "suspend" the New Strategic Arms Reduction Treaty (New START)—even though the treaty does not have such a suspension mechanism. While there are no indications that Russia has exceeded the treaty's central limits, the lack of data exchanges, inspections, and other verification and transparency measures will over time decrease confidence in the status of Russia's nuclear forces.

President Putin announced in March 2023 the deployment of tactical nuclear weapons in Belarus, but it remains unclear if any weapons have been moved. Russia retains some 2,000 tactical nuclear weapons for use in regional conflicts.

In October 2023, Russia's Duma voted to withdraw Moscow's ratification of the Comprehensive Nuclear Test Ban Treaty. Like the United States, Russia remains a signatory to the treaty. While Putin has said that Russia won't resume nuclear testing unless the United States does so, there have been reports about increased activity at nuclear test sites in Russia and China.

These developments are happening at a time when many nuclear weapon states are engaged in extensive modernization and expansion programs.

The United States and China are on the verge of a major nuclear arms race. One significant development in the United States is debate about whether the US nuclear arsenal may have to increase over the next decade to counter China's expansion. The argument for an expanding US nuclear arsenal was articulated recently in a consensus report by the bipartisan Congressional Commission on the Strategic Posture of the United States, which argued that the United States and its allies must be ready to "deter and defeat" both Russia and China—simultaneously. The report recommended "fully and urgently executing the US nuclear modernization." Recent history suggests that there will be tremendous pressure to further expand the US nuclear arsenal to compensate for the perceived deterrence gap with China, even if there is evidence that more nuclear weapons would actually diminish stability, and hence long-term US security.

Other nuclear crises continue to fester.

US government officials have acknowledged that the United States does not currently prioritize talks on a return to some form of the Iran nuclear deal (or Joint Comprehensive Plan of Action) "given all the other domestic strife inside Iran and the support that Iran has given to Russia in Ukraine." Because the nuclear agreement remains in limbo, international monitors are increasingly unable to capture data on Iran's nuclear efforts. This is a particularly worrisome development, given the escalating war in Israel/Gaza, which raises the possibility of a wider conflict in the Middle East. Iran now has the means to rapidly

produce the fissile material for a small number of weapons within weeks of a decision to do so.

North Korea's nuclear weapons program continues to advance steadily. In March 2023, North Korea released a number of photographs showing a row of warheads ("Hwasan-31") of a new and smaller type, which could be deployable on shorter-range missiles. In April 2023, North Korea claimed it had successfully tested a solid-fuel intercontinental ballistic missile for the first time ("Hwasong-8"). These missiles can be moved and launched more rapidly, increasing the survivability of these forces. In response, South Korea has asked for a greater role in America's nuclear commitments to defend the south, something that may ultimately fail to dull South Korea's appetite for a deterrent of its own.

While May 2023 marked the 25th anniversary of India's and Pakistan's series of nuclear tests, both countries continue to accumulate weapons and delivery systems. There have been no constructive developments with regard to the nuclear forces, postures, and fissile material production of these two countries. Prospects for cooperation and threat reduction in the region remain bleak.

This will be the last Doomsday Clock statement before the 2024 US presidential election. All US presidential elections raise the issue of the immense and almost completely unfettered nuclear power vested in US presidents, each of whom has the sole authority to order the use of nuclear weapons. In the closing days of the previous administration, Chairman of the Joint Chiefs of Staff Gen. Mark A. Milley was sufficiently concerned with the then-president's temperament and comportment that he took steps to ensure that he would be consulted in the event that the president sought to launch nuclear weapons. The candidates' suitability to shoulder the immense presidential authority to launch nuclear weapons has serious implications for international stability and should be a central concern in the 2024 presidential campaign.

The mixed outlook for climate action

The myriad climate impacts seen around the world in 2023—including massive wildfires, large-scale flooding, and prolonged heat waves—and the continued rise of greenhouse gas emissions are cause for much concern. But the clean-energy transition has also gathered momentum in terms of deployment, investment, and policies related to lowering carbon dioxide emissions.

The world entered "uncharted territory" for climate impacts last year, with conditions exceeding past extremes by enormous margins. The past year was the hottest on record, including extreme summer conditions. Both global and North Atlantic sea-surface temperatures broke records, and Antarctic sea ice reached its lowest daily relative extent since the advent of satellite data, some 2.67 million square kilometers (an area about the size of Kazakhstan) below the 1991–2023 average. Looking ahead, by some estimates, the global surface temperature has a high probability (66 percent) of exceeding 1.5 degrees Celsius above pre-industrial levels—an aspirational goal adopted in the 2015 Paris Agreement—for at least one year between 2023 and 2027. Furthermore, most of the loss of human life (over 90 percent) and a majority of the economic losses (an estimated 60 percent) worldwide from weather-related disasters has occurred

in developing countries, highlighting the unequal distribution of climate impacts.

Global greenhouse gas emissions continue to increase. Carbon dioxide equivalent emissions in 2022 were 1.5 percent higher than in 2021, reaching a record high of 57.5 gigatons. The unconditional nationally determined contributions pledged by countries as part of the Paris Agreement process, even if fully implemented, would lead to a temperature rise far above the aspirational goal of 1.5 degrees mentioned in the agreement. The window for raising future commitments and implementing existing commitments to limit warming to the 1.5-degree goal is rapidly narrowing.

Alongside these concerning factors, it is encouraging that the world is seeing record and surging investments in renewables. The latest estimates from the International Energy Agency suggest that of the $2.8 trillion that will be invested in energy in 2023, $1.7 trillion will go to clean energy. But there still are significant investments—more than an estimated $1 trillion in 2023—being made in fossil fuel supply. Solar and wind energy continued to dominate renewable capacity expansion, jointly accounting for 90 percent of all net renewable additions in 2022. This growth in wind and solar led to the highest annual increase in renewable generating capacity and the second highest growth on record in percentage terms. Notably, emerging economies occupy two of the top five spots in total installed solar and wind capacity. Wind and solar energy represented a record 12 percent of global electricity generation in 2022, up from 10 percent in 2021. A recent analysis by the International Energy Agency suggests that with the progress in renewables, the world is on track to see demand for all fossil fuels peak by 2030.

The European Union's 2023 Green Deal Industrial Plan—in some ways a counterpart to the US Inflation Reduction Act—intends to support the green energy transition in the EU through investments as well as other policies and programs. Such major policy efforts should greatly help industry contribute to climate action.

The world is increasingly aware that achieving the goals of the Paris Agreement requires greatly expanded clean energy deployment not just in developed but also in developing countries—and the world is poorly positioned to accomplish this shift. But efforts to strengthen the approach toward climate finance, catalyzed by the Bridgetown Initiative, are continuing to gain ground. At the same time, there are concerns that many developing countries may miss out on the benefits of the "green tech" revolution without appropriate action from governments and the international community. While developing countries' exports of green tech rose from $57 billion to $75 billion between 2018 and 2021, their share of the global green tech market fell to 33 percent from 48 percent during this period.

Despite some hopeful signs in the growth of renewables, to halt further warming the world economy must achieve net zero carbon dioxide emissions, and the sooner this is done, the less human suffering from climate disruption there will be. Set against this necessity, the continued rise in carbon dioxide emissions highlights a disturbing fact: The world has not yet entered a trajectory that will lead to net zero.

The expanding scope of biological threats

The revolution in the life sciences and associated technologies continues to accelerate and expand in scope, enabling an increasing number of individuals, in groups and alone, to pose threats arising from both accidental and deliberate misuse. During the past six months, the potential for artificial intelligence tools to empower individuals to misuse biology has become far more apparent.

As noted in our disruptive technology sidebar, generative AI capabilities are expanding exponentially. Concern and controversy continue to swirl around the possibility that generative AI could provide information that would allow states, subnational groups, and non-state actors to create more harmful and transmissible biological agents. Current evidence suggests that, with generative AI, the acquisition of known harmful agents is more likely at present than the creation of entirely new ones. But it is clearly also possible to use generative AI as a tool to enhance existing pathogens. It would be foolish to bet against AI-assisted design of novel biological agents and weapons happening in the future.

In October 2023, President Biden signed an executive order about "safe, secure, and trustworthy AI." It calls for protection "against the risks of using AI to engineer dangerous biological materials by developing strong new standards for biological synthesis screening." While a useful step in managing the use of AI in biotechnology, these standards are not legally binding and are at best only a small deterrent to malefactors. The executive order calls for "extensive red-team testing" of AI systems and their ability to enable the acquisition of biological agents. There are also concurrent calls for transparency in the design and development of AI algorithms.

Transparency, however, may not be a good idea with respect to risks of misuse of AI in the life sciences. For example, recent work suggests that the public release of detailed information on large language models enabled hackers to easily evade safeguards and obtain "nearly all key information needed" to produce the 1918 pandemic influenza virus. High-level state-sponsored convenings to discuss management of AI risks, including the AI Safety Summit at Bletchley Park in the United Kingdom, offer hope for the development of guardrails and top-down risk oversight of AI development and use in the life sciences. But so far these efforts have resulted in largely aspirational and voluntary measures.

During this past year, the evolution of the war in Ukraine may have lessened the perception of existential risk to the leadership or viability of Russia. In turn, these developments may have diminished the likelihood of use of biological agents. At the same time, Russian policy on the use of biological weapons is opaque, the Russia-Ukraine conflict remains fluid, and the possibility of escalation persists.

Terrorist organizations continue to pursue biological agents and weapons, and events around the world heighten concern about the possible use of biological agents by terrorist groups in the Middle East and elsewhere. The use of a biological agent would lead to strong international intervention and (if accurately attributed) widespread condemnation of and action against the country or group that initiated the attack.

Two other types of biological risks remain causes for concern: accidental release of organisms from laboratories and naturally occurring infectious diseases, especially

those with pandemic potential. Deforestation, urbanization, and climate change continue to destabilize microbe-host relationships and facilitate the emergence of infectious diseases. Meanwhile, high-biosafety-level laboratories have proliferated around the world, as has risky research motivated by interests in controlling these diseases. Despite the importance of understanding and countering naturally occurring biological threats, it isn't clear that all of these high-biosafety-level laboratories or high-risk experiments are needed for achieving these goals. As the number of laboratories and amount of risky research increases, and the failure to standardize safe laboratory practices and to institute adequate research oversight persists, the risk of accidental release of dangerous pathogens worsens.

AI and other disruptive technologies to watch

The most significant development in the disruptive technology space last year was the dramatic advance in generative artificial intelligence. The sophistication of text generators based on large language models, such as GPT-4, led some respected experts to express concern about possible existential risks arising from further rapid advancements in the field. This point is highly contested, with other experts arguing that the potential for AI-related existential risk is highly speculative and distracts from real and immediate non-existential risks that AI poses today.

It is clear that AI is a paradigmatic disruptive technology. Any physical threat posed by AI must be enabled by a link to devices that can change the state of the physical world. For example, connecting the metaphorical nuclear launch button to ChatGPT would certainly pose an existential threat to humanity—but the existential threat would be from nuclear weapons, not AI. In work published in December 2023, an autonomous laboratory run by robots was coupled to the output from natural language models to create novel materials. Bad human decisions to put AI in control of important physical systems could indeed pose existential threats to humanity.

Increasing chaos, disorder, and dysfunction in our information ecosystem threaten democracy and our capacity to address difficult challenges, and it is abundantly clear that AI has great potential to vastly accelerate these processes of information corruption and deformation. AI-enabled corruption of the information environment may be an important factor in preventing the world from dealing effectively with other urgent threats, such as nuclear war, pandemics, and climate change.

Military uses of AI are accelerating, with extensive use already occurring in intelligence, surveillance, reconnaissance, simulation, and training. Generative AI is likely to be included in information operations. Of particular concern are lethal autonomous weapons, which identify and destroy targets without human intervention. The United States is dramatically scaling up its use of AI on the battlefield, including plans to deploy thousands of autonomous (though nonnuclear) 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 a proposed regulatory framework by the European Union, an executive order by President Biden, the Bletchley Declaration endorsed by 28 countries, and the Political

Declaration on Responsible Military Use of Artificial Intelligence and Autonomy endorsed by 51 states. The first challenge will be to agree on specific domains, such as military and biotechnology applications, in which the use of AI is 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.

The use of AI and other information technologies, combined with various sensors for real-time analysis, has accelerated the ability of authoritarian regimes to monitor the activities of citizens, repress and persecute dissenters, censor what citizens are able to see and hear, and manipulate public opinion. China is a leader in digital authoritarianism; in April 2023 the US Justice Department charged 34 People's Republic of China police officers with using thousands of fake social media accounts to harass dissidents living in the United States. Russia also is an active purveyor of disinformation, spreading false and misleading narratives on its war in Ukraine in a variety of ways, including through websites that impersonate international news organizations.

While the rapid proliferation of small satellites promises greater access to an uncensored internet and increased resilience to attack, there is a growing belligerence among the United States, Russia, and China in space. Russia in particular continues to demonstrate aggressive behavior toward US systems, and China's growing development of threatening space systems is worrying.

Some private-sector actors wield power and influence through their control of disruptive technology such as social media, artificial intelligence, and access to space-based internet service providers. One of the most significant recent events in the domain of cyber-enabled disinformation was the acquisition of Twitter by Elon Musk. Renamed "X," the platform has all but abandoned previous measures to reduce online impersonation and sharply curtailed its efforts to reduce or identify conspiracy theories and malicious misinformation. Appropriate governance of such technologies is an essential aspect of managing their emergence.

Finally, the increasing presence of hypersonic weapons in regional theaters raises the escalatory stakes of a conflict. In particular, the mere presence of Chinese hypersonic weapons could force US aircraft carriers to assume stations farther from areas of potential conflict, such as the South China Sea.

Science and Security Board Biographies

Rachel Bronson (Ex Officio) is the president and CEO of the *Bulletin of the Atomic Scientists*, where she oversees the publishing programs, management of the Doomsday Clock, and a growing set of activities around nuclear weapons, nuclear energy, climate change, and disruptive technologies. Before joining the *Bulletin*, she served for eight years at the Chicago Council on Global Affairs in a number of capacities including: vice president of studies, vice president of programs and studies, and senior fellow, global energy. She also taught "Global Energy" as an adjunct professor at the Kellogg School of Management.

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.

Steve Fetter is associate provost, dean of the graduate school, and 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 and Leo Szilard Lectureship awards, the Federation of American Scientists' Hans Bethe Science in the Public Service award, and the Secretary of Defense Medal for Outstanding Public Service.

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 non-profits. 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

been co-directing 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 and 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. 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 a research professor at George Mason University's School of Engineering. He is also a member of the Intelligence Community Studies Board and the Committee on International Security and Arms Control of the National Academies of Sciences, Engineering, and Medicine. Latiff's new book, *Future Peace: Technology, Aggression, and the Rush to War*, 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*.

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 the policy and national security dimensions of cybersecurity and cyberspace, with focus on offensive operations in cyberspace and information warfare and influence operations. Lin holds additional affiliations with the National Academies, Columbia's Saltzman Institute, and the Aspen Cybersecurity Group. In 2019, he was elected a fellow of the American Association for the Advancement of Science. In 2016, he served on President Obama's Commission on Enhancing National Cybersecurity. He has previously served as a 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 healthcare 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.

Biographies (cont.)

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 at the Belfer Center for Science and International Affairs in Harvard University's Kennedy School of Government. He is a fellow of the American Academy of Arts and Sciences, where he is a member of the Committee on International Security Studies (CISS). Miller is also co-chair of the US Pugwash Committee, and is a member of the Council of International Pugwash. Miller co-directed the Academy's project on the Global Nuclear Future Initiative with the *Bulletin*'s former Science and Security Board chair, Robert Rosner.

Raymond Pierrehumbert is Halley Professor of Physics at the University of Oxford. He was a lead author on the IPCC Third Assessment Report, and a co-author of the National Research Council report on abrupt climate change. He was awarded a John Simon Guggenheim Fellowship in 1996, which was used to launch collaborative work on the climate of Early Mars with collaborators in Paris. He is a Fellow of the American Geophysical Union (AGU), a Fellow of the American Academy of Arts and Sciences, and has been named Chevalier de l'Ordre des Palmes Académiques by the Republic of France. Pierrehumbert's central research interest is the use of fundamental physical principles to elucidate the behavior of the present and past climates of Earth and other planets, including the growing catalog of exoplanets. He leads the European Research Council Advance Grant project EXOCONDENSE.

David A. Relman is the Thomas C. and Joan M. Merigan Professor in Medicine, and a professor of Microbiology & Immunology at Stanford University, and chief of infectious diseases at the Veterans Affairs Palo Alto Health Care System. He is also senior fellow at the Center for International Security and Cooperation at Stanford and served as the Center's science co-director from 2013-2017. Relman was an early pioneer in the identification of previously unrecognized microbial pathogens and in the modern study of the human microbiome (the microbial communities that inhabit the human body). He served as president of the Infectious Diseases Society of America, and as chair of the Forum on Microbial Threats at the US National Academies of Science, and is currently a member of the Defense Science Board for the US Department of Defense and the Science and Technology Advisory Committee for the US Department of Homeland Security's National Biodefense Analysis and Countermeasures Center. He was elected to the National Academy of Medicine in 2011 and the American Academy of Arts & Sciences in 2022.

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 was a lead author in Working Group III of the IPCC's Sixth Assessment Report and currently is a member of the Independent Group of Scientists appointed by the UN

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

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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 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 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

For the last two years, the minute hand of the Doomsday Clock stayed set at three minutes before the hour, the closest it had been to midnight since the early 1980s. 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.

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

Timeline (cont.)

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 between Washington and Moscow for a follow-on agreement to the Strategic Arms Reduction Treaty are nearly complete, and more negotiations for further reductions in the U.S. and Russian nuclear arsenal are already planned. Additionally, Barack Obama becomes the first U.S. president to publicly call for a nuclear-weapon- free world. The dangers posed by climate change are still great, but there are pockets of progress. Most notably: 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 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.

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,

Timeline (cont.)

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.

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 U.S. nuclear weapons in Western Europe inspires it. For years, such intermediate-range missiles had kept Western Europe in the crosshairs of the two superpowers.

IT IS 3 MINUTES TO MIDNIGHT

U.S.-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.

IT IS 4 MINUTES TO MIDNIGHT

The Soviet invasion of Afghanistan hardens the U.S. 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.

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.'"

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 (MIRV), both countries can now load their intercontinental ballistic missiles with more nuclear warheads than before.

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.

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."

IT IS 7 MINUTES TO MIDNIGHT

Regional wars rage. U.S. 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 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."

Timeline (cont.)

IT IS 12 MINUTES TO MIDNIGHT

After a decade of almost non-stop 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."

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.