

**Bulletin
of the
Atomic
Scientists**

It is still 3 minutes to midnight

2016 Doomsday Clock Statement

Science and Security Board
Bulletin of the Atomic Scientists

Editor, John Mecklin

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IT IS 3 MINUTES TO MIDNIGHT

Statement from the executive director

Before I began as the *Bulletin of the Atomic Scientists'* most recent executive director and publisher in February 2015, I witnessed first-hand the power that the Doomsday Clock has in generating a global conversation about existential threats, with particular focus given to nuclear war and climate change. After last year's announcement, the *Bulletin's* offices immediately received a barrage of messages— messages of all sorts that continued throughout the year, each offering arguments for and against a variety of possible times. The time of the Clock was discussed in the most influential international media outlets as well as on local radio shows. It framed debates in committees of Parliament and shaped meetings at the United Nations. It appeared in poems and films, and on weekly talk shows. It was even the subject of a question on the NPR news quiz, *Wait Wait ... Don't Tell Me!*

Martyl Langsdorf's "Doomsday Clock," which first graced the cover of the *Bulletin's* print edition in 1947, has served for 69 years to focus the world's attention on the most pressing global threats. The time on the Clock reflects whether we are more or less safe than last year, and compares the current situation to years further in the past; the decision on where to set the Clock's hands is an attempt to reconcile the achievements and breakdowns in security efforts, broadly defined, that occur each and every year.

As in years past, this year members of the *Bulletin's* Science and Security Board set the Doomsday Clock—and this year, they had their work cut out for them. The Joint Comprehensive Plan of Action signed by Iran and six world powers has the potential to advance dramatically nuclear disarmament efforts in the Middle East and serve as a precedent for global disarmament, if all parties adhere to its terms. The 2015 Paris Climate Conference agreement brought together more than 190 countries that pledged, with a renewed sense of urgency, to make important and significant advances in the effort to limit climate change.

At the same time, North Korea's nuclear test, vastly expensive nuclear modernization programs in the United States and around the globe, the world's collective inability to effectively deal with nuclear waste, and the drumbeat of continued climate change remain very serious challenges. As the signatories to this report make clear, the Earth remains perilously and inexcusably close to metaphorical midnight.

I applaud the members of the Science and Security Board (and the fluid pen of the *Bulletin's* editor John Mecklin) for taking their role in setting the Doomsday Clock seriously and recognizing that in setting the 2016 time they are starting anew a set of important global conversations. This is one of the greatest and weightiest privileges that I have as Executive Director and Publisher of the *Bulletin*—sharing their findings with you, our longstanding and devoted followers. We invite your consideration and comments.

Rachel Bronson
21 January, 2016
Chicago, IL

It is still three minutes to midnight

Editor's note: Founded in 1945 by 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 decision to move (or to leave in place) the minute hand of the Doomsday Clock is made every year by the Bulletin's Science and Security Board in consultation with its Board of Sponsors, which includes 16 Nobel laureates. The Clock has become a universally recognized indicator of the world's vulnerability to catastrophe from nuclear weapons, climate change, and new technologies emerging in other domains.

To: Leaders and citizens of the world
Re: It is still three minutes to midnight
Date: January 26, 2016

In the past year, the international community has made some positive strides in regard to humanity's two most pressing existential threats, nuclear weapons and climate change. In July 2015, at the end of nearly two years of negotiations, six world powers and Iran reached a historic agreement that limits the Iranian nuclear program and aims to prevent Tehran from developing nuclear weaponry. And in December of last year, nearly 200 countries agreed in Paris to a process by which they will attempt to reduce their emissions of carbon dioxide, aiming to keep the increase in world temperature well below 2.0 degrees Celsius above the pre-industrial level.

The Iran nuclear agreement and the Paris climate accord are major diplomatic achievements, but they constitute only small bright spots in a darker world situation full of potential for catastrophe.

Even as the Iran agreement was hammered out, tensions between the United States and Russia rose to levels reminiscent of the worst periods of the Cold War. Conflict in Ukraine and Syria continued, accompanied by dangerous bluster and brinkmanship, with Turkey, a NATO member, shooting down a Russian warplane involved in Syria, the director of a state-run Russian news agency making statements about turning the

United States to radioactive ash, and NATO and Russia repositioning military assets and conducting significant exercises with them. Washington and Moscow continue to adhere to most existing nuclear arms control agreements, but the United States, Russia, and other nuclear weapons countries are engaged in programs to modernize their nuclear arsenals, suggesting that they plan to keep and maintain the readiness

of their nuclear weapons for decades, at least—despite their pledges, codified in the Nuclear Non-Proliferation Treaty, to pursue nuclear disarmament.

Promising though it may be, the Paris climate agreement came toward the end of Earth's warmest year on

record, with the increase in global temperature over pre-industrial levels surpassing one degree Celsius. Voluntary pledges made in Paris to limit greenhouse gas emissions are insufficient to the task of averting drastic climate change. They are, at best, incremental moves toward the fundamental change in world energy systems that must occur, if climate change is to ultimately be arrested.

Because the diplomatic successes on Iran and in Paris have been offset, at least, by negative events in the nuclear and climate arenas, the members of the *Bulletin of the Atomic Scientists* Science and Security Board find the world situation to be highly threatening to humanity—so threatening that the hands of the Doomsday Clock must remain at three minutes to midnight, the closest

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they've been to catastrophe since the early days of above-ground hydrogen bomb testing.

Last year, we wrote that world leaders had failed to act with the speed or on the scale required to protect citizens from the danger posed by climate change and nuclear war, and that those failures endangered every person on Earth. In keeping the hands of the Doomsday Clock at three minutes to midnight, the members of the *Bulletin of the Atomic Scientists* Science and Security Board mean to make a clear statement: The world situation remains highly threatening to humanity, and decisive action to reduce the danger posed by nuclear weapons and climate change is urgently required.

A promising Iran agreement within a dangerous nuclear situation.

The year 2015 abounded in disturbing nuclear rhetoric, particularly about the usability of nuclear weapons, but contained at least one real achievement: the landmark Iran nuclear deal. The Joint Comprehensive Plan of Action (JCPOA) that the United States, China, Russia, Germany, France, and the United Kingdom reached with Iran in July 2015 ends several decades of uncertainty about Tehran's nuclear capabilities. The agreement will test the resolve of all parties to move forward and build trust, but it has the potential to transform the nuclear nonproliferation landscape in the Middle East as well as provide impetus for sorely needed innovations in the nonproliferation regime. The JCPOA covered the bases, capping the numbers and kinds of uranium-enrichment centrifuges Iran can possess, placing limits on that country's stockpile of enriched uranium, and converting the sensitive Fordow facility into a research center. The agreement also irreversibly transforms Iran's Arak research reactor so Iran cannot produce and retain plutonium. The inclusion of long-term monitoring of Iran's uranium and other nuclear supply chains will strengthen confidence that Iran has no clandestine sites. A credible effort to monitor Iran's compliance with the accord could demonstrate

The maintenance of peace requires that nuclear rhetoric and actions be tamped down.

new technologies and approaches for reducing the risks of nuclear proliferation.

The ability of key nuclear weapon states to cooperate on nuclear non-proliferation is one of the few bright spots in the world nuclear landscape; the United States and Russia continue to make reductions in deployed nuclear warheads under the new START treaty. But nuclear modernization programs—designed to maintain capabilities for the next half-century—also proceed apace. The Russians will have fewer launchers, but their future force will be more mobile and have more flexibly targeted warheads. The United States plans to spend \$350 billion in the next 10 years to maintain and modernize its nuclear forces and infrastructure, despite rhetoric about a nuclear weapons-free world. With no follow-on arms control agreement in sight and deeply disturbing nuclear rhetoric issuing from Russia, the risks of short launch times, of large warhead stockpiles, and of narrowing channels for averting crisis recall the dark days of the Cold War.

Conflict over free passage in the South China Sea is another worrisome development. China's territorial claims to islands there—some of which it has enlarged for military purposes—are contested primarily by countries in the region. But as legally justifiable as they may be, recent US efforts to assert a right of free passage in the South China Sea by sending a naval vessel and airplanes close to those islands have the potential to escalate into major conflict between nuclear powers.

The prospects for nuclear arms control beyond the United States and Russia are, in the near term, unfavorable. China, Pakistan, India, and North Korea are all increasing their nuclear arsenals, albeit at different rates. China's recent agreement to help Pakistan build nuclear missile submarine platforms is a matter of concern, but probably less so than other developments in Pakistan's arsenal, including improvements to its ballistic missiles and air-launched cruise missiles and its aggressive rhetoric regarding the use of tactical nuclear

weapons to “de-escalate” a conventional conflict (rhetoric that is unfortunately similar to Russia’s own “de-escalation” doctrine). Meanwhile, North Korean leader Kim Jong-Un announced at the end of the year that his country had developed a hydrogen bomb and followed through with a test on January 5, 2016. So far, experts assess that it likely was not a two-stage thermonuclear weapon, but there is little doubt that North Korea will continue to develop its nuclear arsenal in the absence of restraints.

The world may be used to outrageous rhetoric from North Korea, but officials in several other countries made irresponsible comments in 2015 about raising the alert status of nuclear weapon systems, acquiring nuclear capabilities, and even using nuclear weapons. We hope that, as an unintended consequence of such rhetoric, citizens will be galvanized to address risks they thought long contained. The more likely outcome is that nuclear bombast will raise the temperature in crisis situations. The maintenance of peace requires that nuclear rhetoric and actions be tamped down.

A mixed response to climate change. The year 2015 was one of mixed developments in regard to the threat of global warming. Global mean carbon dioxide concentrations passed 400 parts per million, with global mean warming since pre-industrial times exceeding 1 degree Celsius for the first time. These developments underscore the continued inadequacy of efforts to control the greenhouse gas emissions that are causing climate change.

There have been some positive developments, however, notably the agreement in Paris among 196 countries on a global climate accord. Boldly setting a goal of keeping global mean warming well below 2 degrees Celsius, the agreement recognizes the need to bring net greenhouse gas emissions to zero before the end of the century. Still, it is unclear how the world will actually meet that goal. The backbone of the accord—pledges submitted by each of the signatory countries to reduce greenhouse gas emissions—is far from sufficient. Even while acclaiming the Paris

agreement as a landmark achievement, the UN Climate Change Secretariat acknowledged that if all countries fulfill their voluntary commitments but do no more than that, then by 2025, the world will have used half of the remaining carbon dioxide budget consistent with a 2 degrees C goal. Three-quarters of that budget of carbon emissions will have been exhausted by 2030. And this assessment assumes that countries will fully comply with their pledges—even though the Paris agreement includes no effective enforcement mechanisms to assure that countries do so.

Success in limiting climate change will ultimately depend on the good faith and good will of the signatories, and their willingness to cut emissions even more than they have pledged and to make even deeper cuts over time; most of the emissions pledges now are set to end sometime between 2025 and 2030. Still, the accord represents an encouraging step forward in that it will get the world off its current path of exponentially growing emissions, which is the first step toward stabilizing the climate. Importantly, the pledges by developing countries, notably China, include serious mitigation efforts that in the aggregate exceed those of the developed countries. These pledges recognize that solving the climate problem requires the developing world to get on a low-carbon pathway compatible with its development needs, even though the climate has been brought to its present perilous state primarily through the past emissions of the developed world.

Other positive developments include the Papal encyclical *Laudato Si*, which cogently and powerfully expresses the moral imperative to restrain the human impact on climate; the growing number of corporations, educational institutions, faith-based groups, and institutional investors that have demonstrated their commitment to sustainability through disinvestment in fossil fuel companies; and the emergence of bold, on-the-ground initiatives to leapfrog to more sustainable energy systems. The elections of more climate-friendly governments in Canada and Australia are also encouraging, but must be seen against the steady backtracking of the United Kingdom’s present government on climate policies and the

continued intransigence of the Republican Party in the United States, which stands alone in the world in failing to acknowledge even that human-caused climate change is a problem.

Given the mixed nature of the year's developments regarding protection of the climate, we find no climate-related justification for a change in the setting of the Doomsday Clock.

The nuclear power leadership vacuum.

Nuclear energy provides slightly more than 10 percent of the world's electricity-generating capacity, and some countries—notably China and several countries in the Middle East—have announced ambitious programs to expand their nuclear capacity, for a host of reasons, including the need to respond to growing energy demands and to address climate change. But the international community has not developed coordinated plans to meet cost, safety, radioactive waste management, and proliferation challenges that large-scale nuclear expansion poses.

Nuclear power is growing in some regions that can afford its high construction costs, sometimes in countries that do not have adequately independent regulatory systems. Meanwhile, several countries continue to show interest in acquiring technologies for uranium enrichment and spent fuel reprocessing—technologies that can be used to create weapons-grade fissile materials for nuclear weapons. Stockpiles of highly radioactive spent nuclear fuel continue to grow (globally, about 10,000 metric tons of heavy metal are produced each year). Spent fuel requires safe geologic disposal over a time scale of hundreds of thousands of years.

The US programs for handling waste from defense programs, for dismantling nuclear weapons, and for storing commercially generated spent nuclear fuel continue to flounder. Large projects—including a mixed-oxide fuel-fabrication plant at the Savannah River Site, meant to blend surplus weapons-grade plutonium with uranium so it can be used in commercial nuclear power

plants—fall ever further behind schedule, and costs continue to mount, with the US Energy Department spending some \$5.8 billion each year on environmental management of legacy nuclear waste from US weapons programs.

Because of such problems, in the United States and in other countries, nuclear power's attractiveness as an alternative to fossil fuels has decreased, despite the clear need for carbon-emissions-free energy in the age of climate change.

More attention to emerging technological threats.

The fast pace of technological change makes it incumbent on world leaders to pay attention to the control of emerging science that could become a major threat to humanity.

It is clear that advances in biotechnology; in artificial intelligence, particularly for use in robotic weapons; and in the cyber realm all have the potential to create global-scale risk. The *Bulletin* continues to be concerned about the lag between scientific advances in dual-use technologies and the ability of civil society to control them. The Science and Security Board now repeats the advice it gave last year: The international community

needs to strengthen existing institutions that regulate emergent technologies and to create new forums for exploring potential risks and proposing potential controls on those areas of scientific and technological advance that have so far been

subject to little if any societal oversight.

Three minutes is too close. Far too close. We, the members of the Science and Security Board of the *Bulletin of the Atomic Scientists*, want to be clear about our decision not to move the hands of the Doomsday Clock in 2016: That decision is not good news, but an expression of dismay that world leaders continue to fail to focus their efforts and the world's attention on reducing the extreme danger posed by nuclear weapons and climate change. When we call these dangers existential, that is exactly what we mean: They threaten the very existence of civilization and therefore should be the first order of business for leaders who care

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about their constituents and their countries.

We recognize that some progress has been made on the nuclear and climate fronts. We hail the Paris climate accord and the Iran nuclear agreement as real diplomatic achievements that required genuine political leadership. But those two accomplishments are far from sufficient to address the daunting array of major threats the world faces. A new Cold War looms, with absolutely insupportable, extraordinarily expensive, extremely shortsighted nuclear “modernization” programs continuing apace around the world. Paris notwithstanding, the fight against climate change has barely begun, and it is unclear that the nations of the world are ready to make the many hard choices that will be necessary to stabilize the climate and avert possible environmental disasters.

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Because of failures in world leadership during 2015, we see that the recommendations for action in last year’s Doomsday Clock announcement are, very unfortunately, at least as relevant today as they were a year ago, and that the North Korean situation requires renewed focus. We therefore call on the citizens of the world to demand that their leaders:

• **Dramatically reduce proposed spending on nuclear weapons modernization programs.**

The United States and Russia have hatched plans to essentially rebuild their entire nuclear triads in coming decades, and other nuclear weapons countries are following suit. The projected costs of these “improvements” to nuclear arsenals are indefensible, and they undermine the global disarmament regime.

• **Re-energize the disarmament process, with a focus on results.** The United States and Russia, in particular, need to start negotiations on shrinking their strategic *and* tactical nuclear arsenals. The world can be more secure with much, much smaller nuclear arsenals than now exist—if political leaders are truly interested in protecting their citizens from harm.

• **Engage North Korea to reduce nuclear risks.** Neighbors in Asia face the most urgent threat, but as North Korea improves its nuclear and missile arsenals, the threat will rapidly become global. Now is not the time to tighten North Korea’s isolation but to engage seriously in dialogue.

• **Follow up on the Paris accord with actions that sharply reduce greenhouse gas emissions and fulfill the Paris promise of keeping warming below 2 degrees Celsius.**

The 2-degree-above-pre-industrial-levels target is consistent with consensus views on climate science and is eminently achievable and economically viable, providing poorer countries are given the support they need to make the post-carbon transition and to weather the impacts of the warming that is now unavoidable.

• **Deal now with the commercial nuclear waste problem.** Reasonable people can disagree on whether an expansion of nuclear-powered electricity generation should be a major component of the effort to limit climate change. Regardless of the future course of the worldwide nuclear power industry, there will be a need for safe and secure interim and permanent nuclear waste storage facilities.

• **Create institutions specifically assigned to explore and address potentially catastrophic misuses of new technologies.** Scientific advance can provide society with great benefits, but the potential for misuse of potent new technologies is real, and government, scientific, and business leaders need to take appropriate steps to address possible devastating consequences of these technologies.

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.

Science and security board biographies

Lynn Eden (Co-Chair Science and Security Board) is a member of the International Pugwash Council and co-chair of U.S. Pugwash. Her current scholarly work focuses on U.S. nuclear war planning in historical and organizational perspective—and, more broadly, how organizations enable those within to develop plans, which, if executed, would be utterly catastrophic. She was formerly a senior research scholar and associate director for research at Stanford University's Center for International Security and Cooperation. Eden's *Whole World on Fire: Organizations, Knowledge, and Nuclear Weapons Devastation* won the American Sociological Association's 2004 Robert K. Merton award for best book in science and technology studies.

Rod Ewing is the Frank Stanton Professor in Nuclear Security in the Center for International Security and Cooperation in the Freeman Spogli Institute for International Studies and a Professor in the Department of Geological Sciences in the School of Earth, Energy and Environmental Sciences at Stanford University. Ewing's research focuses on the back end of the nuclear fuel cycle, mainly nuclear materials and the geochemistry of radionuclides. He is the past president of the International Union of Materials Research Societies. Ewing has written extensively on issues related to nuclear waste management and is co-editor of *Radioactive Waste Forms for the Future and Uncertainty Underground: Yucca Mountain and the Nation's High-Level Nuclear Waste*. He received the Lomonosov Medal of the Russian Academy of Sciences in 2006. He was appointed by President Barack Obama to chair the Nuclear Waste Technical Review Board.

Sivan Kartha is a Senior Scientist at SEI whose research and publications for the past twenty years have focused on technological options and policy strategies for addressing climate change, concentrating most recently on equity and efficiency in the design of an international climate regime. His current work deals primarily with

the economic, political, and ethical dimensions of equitably sharing the effort of an ambitious global response to climate change. This work examines the climate crisis in the context of the equally urgent development crisis confronting the world's poor majority.

Kartha has also worked on mitigation scenarios, market mechanisms for climate actions, and the environmental and socioeconomic impacts of biomass energy. His work has enabled him to advise and collaborate with diverse organizations, including the UNFCCC Secretariat, various United Nations and World Bank programs, numerous government policy-making bodies and agencies, foundations, and civil society organizations throughout the developing and industrialized world. He served as a Coordinating Lead Author in the preparation of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change released in 2014, co-leading the chapter on Equity and Sustainable Development.

Lawrence Krauss (Chair-Board of Sponsors, ex officio SASB) is the inaugural director of the Origins Initiative at Arizona State University and foundation professor at ASU's School of Earth and Space Exploration and Physics Department. In addition to writing the best-seller, *The Physics of Star Trek*, Krauss has written six other books, including *Fear of Physics* and the science epic *Atom: An Odyssey from the Big Bang to Life on Earth...and Beyond*. He also frequently writes commentary for *New Scientist* magazine.

Thomas Pickering served as Under Secretary of State for Political Affairs (1997-2000) and as U.S. Ambassador to the Russian Federation, India, Israel, El Salvador, Nigeria, and Jordan. He also was the U.S. Ambassador and Representative to the United Nations in New York, where he led the U.S. effort to build a coalition in the UN Security Council during and after the first Gulf War. He has held additional positions in Tanzania, Geneva, and Washington, including as Assistant Secretary

Biographies (cont.)

of State for the Bureau of Oceans, Environmental and Scientific Affairs and as Special Assistant to Secretaries of State William P. Rogers and Henry A. Kissinger. In 2012, he chaired the State Department's Benghazi Accountability Review Board.

Raymond Pierrehumbert is the 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) and the American Academy of Arts and Sciences, and has been named Chevalier de l'Ordre des Palmes Académiques by the Republic of France. He was awarded the Kung Carl XVI Gustaf visiting chair in environmental sciences for the academic year 2014/2015, and received an honorary doctorate from Stockholms Universitet in that year. Pierrehumbert's central research interest is how climate works as a system and developing idealized mathematical models to be used to address questions of climate science such as how the earth kept from freezing over: the faint young sun paradox. Current interests include climate of extrasolar planets.

Ramamurti Rajaraman is an emeritus professor of physics at Jawaharlal Nehru University and a co-chair of the International Panel on Fissile Materials. His research areas include particle physics, quantum field theory, and solitons. He has written about fissile material production in India and Pakistan and the radiological effects of nuclear weapon accidents.

Robert Rosner (Co-Chair Science and Security Board) is a theoretical physicist, on the faculty of the University of Chicago since 1987, where he is the William E. Wrather Distinguished Service Professor in the departments of Astronomy &

Astrophysics and Physics, as well as in the Enrico Fermi Institute and the Harris School of Public Policy Studies. He served as Argonne National Laboratory's Chief Scientist and Associate Laboratory Director for Physical, Biological and Computational Sciences (2002-05), and was Argonne's Laboratory Director from 2005-09; he was the founding chair of the U.S. Department of Energy's National Laboratory Directors' Council (2007-09). His degrees are all in physics (BA, Brandeis University; PhD, Harvard University). He was elected to the American Academy of Arts and Sciences in 2001, and to the Norwegian Academy of Science and Letters (as a Foreign Member) in 2004; he is also a Fellow of the American Physical Society. Within the past few years, he has been increasingly involved in energy technologies, and in the public policy issues that relate to the development and deployment of various energy production and consumption technologies, including especially nuclear energy, the electrification of transport, and energy use in urban environments. He was the founding director of the Energy Policy Institute at Chicago (EPIC), a joint program of the Harris School of Public Policy Studies, the Dept. of Economics, and the Booth School of Business of the University of Chicago.

Jennifer Sims is currently a senior fellow at the Chicago Council on Global Affairs and is writing a book on intelligence in international politics. She is also a consultant on intelligence and homeland security for private corporations and the US government. Sims was previously deputy assistant secretary of state for intelligence coordination and later served as an intelligence advisor to the under secretary for management and coordinator for intelligence resources and planning at the US Department of State. She received her MA and her PhD from Johns Hopkins University's School of Advanced International Studies. In 1998, Sims received the intelligence community's highest civilian award, the National Distinguished Service Medal.

Biographies (cont.)

Richard Somerville is Distinguished Professor Emeritus and Research Professor at Scripps Institution of Oceanography at the University of California, San Diego. He formally retired in 2007 but remains active in research, education and outreach. He is an expert on climate change who has received awards from the American Meteorological Society for both his research and his popular writing.

Richard Somerville is the 2015 recipient of the American Geophysical Union's Climate Communication Prize. His work embodies what the Prize was created to highlight: "promoting scientific literacy, clarity of message, and efforts to foster respect and understanding of science-based values as they relate to the implications of climate change."

Sharon Squassoni is a senior fellow and director of the Proliferation Prevention Program at the Center for Strategic and International Studies (CSIS). She joined CSIS from the Carnegie Endowment for International Peace, where she authored *Nuclear Energy: Rebirth or Resuscitation?* (2009). Her work focuses on reducing nuclear risks, whether in nuclear security, nuclear energy or nuclear weapons. Ms. Squassoni spent fourteen years in the U.S. government, including as a senior specialist in weapons of mass destruction at the Congressional Research Service and in safeguards and policy planning positions in the State Department and the Arms Control and Disarmament Agency.

David Titley is a nationally known expert in the field of climate, the Arctic, and National Security. He served as a naval officer for 32 years and rose to the rank of Rear Admiral. Titley's career included duties as Commander, Naval Meteorology and Oceanography Command, Oceanographer and Navigator of the Navy, and Deputy Assistant Chief of Naval Operations for Information Dominance. While serving in the Pentagon, Titley initiated and led the US Navy's Task Force on Climate Change. After retiring

from the Navy, Titley served as the Deputy Undersecretary of Commerce for Operations, the Chief Operating Officer position at the National Oceanic and Atmospheric Administration. Titley has spoken across the country and throughout the world on the importance of climate change as it relates to National Security. Titley has testified on climate and national security issues numerous times before the U.S. Congress. Titley is a member of the Hoover Institution's Arctic Security Initiative and serves on numerous Advisory Boards. He has served on several National Academies of Science (NAS) committees and currently chairs the NAS committee on 'Extreme Weather Events and Climate Change Attribution'.

Editor

John Mecklin is the editor-in-chief of the *Bulletin of the Atomic Scientists*. Previously, Mecklin was editor-in-chief of *Miller-McCune* (since renamed *Pacific Standard*), an award-winning national magazine that focused on research-based solutions to major policy problems. Over the preceding 15 years, he was also: the editor of *High Country News*, a nationally acclaimed magazine that reports on the American West; the consulting executive editor for the launch of *Key West*, a regional magazine start-up directed by renowned magazine guru Roger Black; and the top editor for award-winning newsweeklies in San Francisco and Phoenix. In an earlier incarnation, he was an investigative reporter at the *Houston Post* and covered the Persian Gulf War from Saudi Arabia and Iraq. Writers working at his direction have won many major journalism contests, including the George Polk Award, the Investigative Reporters and Editors certificate, and the Sidney Hillman Award for reporting on social justice issues. Mecklin holds a master in public administration degree from Harvard's Kennedy School of Government.

About the *Bulletin of the Atomic Scientists*

The *Bulletin of the Atomic Scientists* engages science leaders, policy makers, and the interested public on topics of nuclear weapons and disarmament, the changing energy landscape, climate change, and emerging technologies. We do this through our award winning journal, iconic Doomsday Clock, public access website and regular set of convenings. With smart, vigorous prose, multimedia presentations, and information graphics, the *Bulletin* puts issues and events into context and provides fact-based debates and assessments. For 70 years, the *Bulletin* has bridged the technology divide between scientific research, foreign policy and public engagement.

The *Bulletin* was founded in 1945 by Manhattan Project scientists who “could not remain aloof to the consequences of their work.” The organization’s early years chronicled the dawn of the nuclear age and the birth of the scientists’ movement, as told by the men and women who built the atomic bomb and then lobbied with both technical and humanist arguments for its abolition.

Today, the *Bulletin* is an independent nonprofit 501(c)(3) organization. With our international network of board members and experts, we assess scientific advancements that involve both benefits and risks to humanity, with the goal of influencing public policy to protect our planet and all its inhabitants.

The *Bulletin*’s website is a robust public and research-oriented source of detailed reports and cogent analysis from the scientists and experts who are directly involved. It receives an average of over 140,000 visits per month. The bimonthly magazine, which can be found in over 15,000 leading universities and institutions worldwide, attracts a large number of influential readers. According to the Journal Citations Report, an industry standard that assesses the impact of academic journals, the *Bulletin* ranks in the top 1/3 of all international relations

journals. About half of the *Bulletin*’s website and journal readers reside outside the United States.

The *Bulletin*’s signature strength is its capacity to synthesize and inform by linking critical issues, treaty negotiations, and scientific assessments to threats represented by the iconic Doomsday Clock. The Clock attracts more daily visitors to our site than any other feature, and commands worldwide attention when the *Bulletin* issues periodic assessments of global threats and solutions.

In 2007 the *Bulletin* won the National Magazine Award for General Excellence, the magazine industry equivalent of an Oscar for Best Picture. The *Bulletin* also was named one of four 2009 finalists for the Lumity Technology Leadership Award, presented by Accenture to a nonprofit organization that is effectively applying innovative technologies. Today, the *Bulletin* supplements its cutting-edge journalism with interactive infographics and videos, and amplifies its messages through social media platforms.

To advance the *Bulletin* as a thriving public forum over the next 70 years, we are opening more channels between scientific and policy leaders as we increase our outreach to supporters all over the world. Two partnerships are key to these efforts—one with the University of Chicago’s Harris School of Public Policy and the other with Routledge, a new publishing relationship that began in January 2016.

See more at: <http://thebulletin.org>

Timeline of doomsday clock changes

 2015 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, and world leaders have failed to act with the speed or on the scale required to protect citizens from potential catastrophe. These failures of political leadership endanger every person on Earth.”
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.”

 2012 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.

 2010 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.

 2007 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.

 2002 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.

Timeline of doomsday clock changes (cont.)

 1998 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.

 1995 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.

 1991 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.

 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 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.

 1984 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.

Timeline of doomsday clock changes (cont.)

 1981 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 Olympics 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 (MIRV), 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. 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.”

 1963 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.

Timeline of doomsday clock changes (cont.)



1960 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.

magazine’s founders--and the broader scientific community--are trying to convey to the public and political leaders around the world.



1953 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.”



1949 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.”



1947 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