It is two and a half minutes to midnight
The Mission

The Bulletin of the Atomic Scientists engages science leaders, policy makers, and the interested public on topics of nuclear weapons and disarmament, 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 more than 70 years, the Bulletin has bridged the technology divide between scientific research, foreign policy, and public engagement.

Letter from the Chair

Lee Francis

In 2016, NASA reported the warmest year globally since modern record-keeping began. Worldwide nuclear tensions increased as relations between the United States and Russia continued to deteriorate, and North Korea conducted two underground nuclear tests. The divisive 2016 US presidential election was marked by reckless rhetoric about nuclear weapons, climate change denials, and confusion about cyber-technology and artificial intelligence.

Through it all, we at the Bulletin of the Atomic Scientists stepped up our programming and added features to our website attracting more visitors, subscribers, and donors than ever before in more than seven decades of service. Keenly aware of growing uneasiness and concern, we maintained a sharp focus on nuclear issues, climate and energy, and threats from emerging technology, bringing together the best scientific research and public policy analysis in the hope of creating a safer and healthier planet.

The precarious nature of that hope became increasingly clear by the end of 2016. Our Science and Security Board made the decision to move the Doomsday Clock to two and a half minutes to midnight, an unprecedented step that is described in the statement beginning on page 10.

On behalf of the Governing Board, the Science and Security Board, and the Board of Sponsors, I extend our gratitude to the stakeholders who increased their own support as our small but mighty staff worked tirelessly to meet the increased expectations of an anxious world, hungry for facts and reason.
What you will see in the pages that follow is evidence of a vibrant organization that is actively rethinking its mandate in the 21st century, a time in which scientific and technological advancements are moving faster than ever.

The security landscape darkened considerably in 2016, pushing to the forefront serious questions about the future health and safety of the planet. Political leaders from across the globe including Mikhail Gorbachev, William Perry, and key NATO leaders, warned of a dangerous drift toward a new Cold War. The current US administration’s repeated assertions to augment the US nuclear arsenal, and to disregard expert advice, have only elevated concerns about our shared futures.

Citizens in large numbers are pushing back, showing a renewed interest in becoming agents of change and making their voices heard. This renewed civic engagement, around issues such as nuclear risk, climate change, and emerging technologies that have long been the focus of the Bulletin, provides enormous opportunities.

In the last few weeks alone, the Bulletin has received emails and letters from high school teachers, college students, professors, and individuals from around the world, including a 12-year-old boy, all asking how to help make the world a safer place. One writer concluded: “If you honestly think that average people like me can actually do something about the threats we face, then I have no reason not to try.”

At this pivotal moment, large numbers are turning to the Bulletin of the Atomic Scientists as a credible fact-based source of information to help underpin their local efforts. The Bulletin’s Twitter following outpaces most of its counterparts. We have seen a more than 500% increase in the number of weekly newsletter sign-ups, comparing calendar year 2015 to 2016. Traffic to the Bulletin’s website remains on a strong upward trajectory, and its demographic reach is young and international; 50% of the Bulletin’s audience is below the age of 35 with half coming from the United States, and half from abroad.

To respond to increasing demand, the Bulletin is actively developing new platforms and applications for engaging and motivating new audiences. It has radically altered its approach to the annual Doomsday Clock announcement, and is investing in new data visualizations, building new partnerships, and intentionally targeting younger audiences through a variety of activities including mounting a major new exhibit at the exalted Museum of Science and Industry. Two years in the making, the exhibit will be visited by tens if not hundreds of thousands of school children.

What you will see in the pages that follow is evidence of a vibrant organization that is actively rethinking its mandate in the 21st century, a time in which scientific and technological advancements are moving faster than ever. The risks and opportunities of such advancements are considerable, and it is up to all of us to ensure that they are channeled toward peace and security. That has always been what the Bulletin has stood for, and in today’s world I cannot think of a more important task.

We are doing our best to get out of our offices to meet those bringing new ideas and those seeking answers. Come see us in Chicago, or elsewhere around the country. Follow the Bulletin on whatever platform you get your news. Share with us your good ideas; support us at a level that is meaningful to you.

Together, we have a lot of work to do.

Rachel Bronson, PhD
2016: “In the pocket of Big Truth…”

1. The hit CBS television series Madam Secretary aired a special 2016 episode titled “On the Clock,” suggesting that rising tensions between India and Pakistan had prompted the Bulletin to consider moving the Doomsday Clock closer to midnight, a possibility that concerned “The President” in a tight election season. When he asked “Madam Secretary” to intervene with the Science and Security Board, an advisor counseled that the board was impervious to political pressure and “in the pocket of Big Truth.”

2. The Bulletin’s Clock Announcement on January 26, 2017 continued to generate discussion and major news coverage, including in The New York Times, which opened its lead editorial with this statement on February 6, 2017: “Scientists who study the risk of nuclear war recently moved the hands of the symbolic Doomsday Clock to 2½ minutes before midnight.”

3. London’s Bubble Theatre featured Editor-in-Chief John Mecklin as a character in “After Hiroshima” in a March production.

4. John Mecklin was a featured speaker at the Wired NextFest conference, a festival of innovation in Milan, Italy, in May.

5. From left, Natasha Egan, executive director of the Museum of Contemporary Photography at Columbia College Chicago, and Santa Fe mixed media artist Judy Tuwaletstiwa, at a workshop to discuss a new Bulletin arts initiative in which members of the creative community can present their work, interact with scientists, and help the Bulletin engage new audiences.

6. As a March dinner in Chicago featuring remarks by Bulletin columnist and nuclear strategy expert Adam Mount, Elana Bocchino, with Argonne National Laboratory, chatted with Governing Board member Mark Ramer.

7. Satirical journal The Onion reported in a spoof last May that the “Bulletin of the Atomic Scientists set the global Doomsday Clock to 11:59 p.m. following Arby’s threats to launch a 3-Cheese Jalapeño Beef ‘N Bacon Melt.”

8. Also in spring, the Bulletin announced the creation of the complete John A. Simpson Archive, a searchable collection of Bulletin articles containing every issue published since our founding in 1945. The archive is named in honor of John Alexander Simpson, a onetime chair of the Board of Sponsors.

9. At the Gene Siskel Film Center in October, Emma Belcher of the MacArthur Foundation, left, moderated a panel discussion including Rachel Bronson, right, and Eric Schlosser, author of Command and Control, which described a 1980 nuclear accident in Damascus, Arkansas. The discussion followed the Chicago premiere of the documentary based on Schlosser’s work.

10. Science and Security Board member Sivan Kartha, climate expert and senior scientist at the Stockholm Environmental Institute, delivered an address titled “Tick Tock” at the York Festival of Ideas in the United Kingdom last June.

11. After President Barack Obama visited Hiroshima in May and spoke about the grave threat that nuclear weapons still pose to the world, Executive Director and Publisher Rachel Bronson appeared on PBS’s News Hour with former Assistant Secretary of State for International Security and Nonproliferation Stephen Rademaker to discuss President Obama’s nuclear legacy.

12. Senior Editor Lucien Crowder, left, moderated a panel at the Atlantic Council in January, convened to discuss the danger that anti-satellite weapons pose to global security, the subject of a previous Bulletin roundtable.
THE BEST WRITING DOESN'T JUST CONVEY
Editor John Mecklin praised the
Bulletin Rieser Award Leonard M.
Next Generation Supporting the
Vanuatu, Perumal is conducting research
of the verifiable victories of the CDCJ
climate sit-in," a powerful examination of
campaign, but emphasizes that many
climate change.
In her essay, Perumal describes some
of the veritable victories of the CDCJ
campaign, but emphasizes that many
achievements that result from successful
activism aren't necessarily quantifiable.
It is the cause of climate justice that
keeps Perumal and her peers going: "We
keep organizing because we realize that
vulnerable communities, from the South
Bronx to rural Appalachia to the small
island nations of the Pacific, continue to
face the devastation of climate impacts
and fossil fuel extraction."

In selecting the Rieser Award winner,
Bulletin editor John Mecklin praised the
emotional impact of Perumal's work:
"The best writing doesn't just convey
information; it also provides the context
and emotional detail that are vital if
readers are to become interested—and
then be inspired to act. And if I had to use
a single word to describe Ms. Perumal's
portrayal of more than three years of
campaign, it would be 'inspirational.'"

Among the 18 Voices of Tomorrow essays
published in 2016 and therefore eligible to
receive the Leonard M. Rieser Award were
the outstanding contributions listed below
and available at thebulletin.org.

Voices of Tomorrow

Who killed the US-Russia plutonium
agreement, and does it really matter?
Darya Dolzikova

The Kremlin's decision to suspend
implementation of the Plutonium
Management and Disposition Agreement
is symptomatic of much deeper issues
between Russia and the United States.

Climate science, nuclear strategy,
and the humanitarian impacts debate
William Ossoff

New collaboration is needed between
climate scientists and military strategists
to assess the long-term effects of the most
plausible scenarios of nuclear weapons
use.

A brighter future for Iranian
nonproliferation? Farnaz Alinezhad
Iran's cooperation with the Czech
Republic on civilian nuclear energy is
a good sign for the rest of the world.

The flawed analogy between nuclear
and cyber deterrence
Patrick Cirenza

High-ranking officials draw dangerous
parallels between nuclear and
cyber warfare at a time when cyber
weapons don't meet the criteria for
a credible deterrent.

Anti-ship missiles: a dangerous
gateway
Nolan Fahrenkopf

Sales of anti-ship missiles level the playing
field for weaker countries, making it easier
for them to develop advanced missiles.

Communications Workshops

In our ongoing series of workshops
connecting experienced public
communicators with emerging science
and security experts, the Bulletin
conducted a daylong session in May 2016
in Palo Alto with the Nuclear Science
and Security Consortium at UC Berkeley and
the Center for International Security and
Cooperation at Stanford.

In July, David Sanger of The New York
Times, below, delivered the keynote
address titled “Communicating National
Security” at the James Timbie Forum for
Awards Control and Nonproliferation.

The Bulletin welcomed Hayeong Rho as a full-time extern serving
as our Program Manager for Special Initiatives, supported by the
government of the Province of Alberta, Canada.

Eight highly motivated university students were accepted for
part-time internships to assist in communications, data collection,
editorial research, and fundraising and development. The 2016
summer interns were supported by fellowships from the Metcalf
Internship Program and the Institute of Politics, both at the
University of Chicago.

Debate about the future of nuclear power has evolved rapidly over the last 10 years, gathering momentum in the early 2000s when there was widespread belief in a “nuclear renaissance” and slowing considerably after the frightening events at Japan’s Fukushima Daiichi nuclear power plant five years ago and the collapse of the price of natural gas. With this important policy discussion in mind, the Bulletin of the Atomic Scientists prepared to add several new and important contributions to the debate.

The 2016 Clock Symposium: The Bulletin devoted its annual half-day gathering to the question of whether nuclear power should be a major part of the world’s response to climate change. Members of our board—respected leaders—and select guests were invited to explore whether and how technological innovations could affect the debate, new and abandoned constructions, and reactor startups and shutdowns on a global scale through more than 60 years of crisis reporting.

Special issue: Bulletin editors also prepared the January/February issue of the subscription journal to focus upon the question of whether nuclear power should be a major part of the world’s response to global warming. This special issue was also produced in partnership with the Pulitzer Center on Crisis Reporting.

Interactive website feature: The Bulletin also launched a brand-new interactive on the website: World Nuclear Power Reactor Construction 1991–2017. Built in partnership with the Pulitzer Center on Crisis Reporting, Visionscarto, and the World Nuclear Industry Status Report, this interactive enables users to find out about status and developments in nuclear power plant building, new and abandoned constructions, and reactor startups and shutdowns on a global scale through more than 60 years of nuclear industry history.

The Bulletin continued to expand its readership and influence significantly over the past year, in ways that were powered by many factors, including authoritative special journal issues, additions to an extensive stable of expert columnists and authors, new multimedia offerings, and inventive coverage related to Donald Trump’s election as US president. As we grew our audience, the Bulletin also continued to garner attention from thought-leading publications and top-tier think tanks like The New York Times, The Atlantic, the Los Angeles Times, the Council on Foreign Relations, and Harvard’s Belfer Center for Science and International Affairs.

On the quantitative front, readership of our open website grew by about 20 percent over the previous year. The site drew 312,000 more pageviews than in 2015, and many of our new readers continued to come from the Web-native social media and news aggregation sites that tend to attract younger audiences. And as analysis of our website traffic in 2016 showed, the Bulletin’s audience is young, indeed, with more than half of our readers below age 35, and nearly two thirds under 45.

These increases in readership and impact came as we continued to emphasize top experts and quality writing about the most pressing issue of our time—the preservation of humanity in the face of potentially catastrophic technological threats.

The 2016 presidential campaign was the backdrop for renewed public interest in two issues that we cover most heavily—nuclear weapons and climate change—bringing a surge in attention to the Bulletin itself. On both our open website and in our subscription journal, we offered readers a wide variety of expert policy commentary and analysis as the campaign unfolded, including questions for both presidential candidates from Princeton’s Frank von Hippel and Zia Mian, Stanford’s Sig Hecker, Center for Strategic and International Studies nuclear expert Sharon Squassoni, and many other Bulletin experts.

Almost from the minute Donald Trump’s surprising election was confirmed, the Bulletin’s connection with the public has expanded and strengthened. From November 9, 2016 through February 2017, traffic to our website surged almost 40 percent above the preceding year—in no small part because of extraordinary worldwide interest in the Science and Security Board’s decision to move the Doomsday Clock 30 seconds closer to midnight, a move related in significant ways to Trump’s statements and actions during and after the presidential campaign. And since the election, articles on the Bulletin site with the word “Trump” in the headline have been viewed some 33,000 times.

Just the same, the Bulletin’s strong showing in 2016 was multidimensional, with most of our content having no direct connection to Trump.

In the nuclear realm, the Bulletin published a special issue on US-Russia relations that included “Putin: The one-man show and the West doesn’t understand,” an authoritative profile of the Russian president by noted Brookings Institution senior fellow Fiona Hill. Since our last annual report, we have also produced a wide swatch of distinguished climate change coverage, including a comprehensive special issue focused on whether nuclear power should be a major part of the world’s response to climate change.

And early in 2017, we published “Coming to grips with emerging technological threats,” an expert survey of technologies—from artificial intelligence to swarming drones—that could endanger humanity’s future, if not properly governed.

Through the last half of 2016, the Bulletin marshaled the resources to create its newest interactive multimedia offering, the Global Nuclear Power Database, which provides an extraordinary wealth of information on all commercial nuclear power reactors begun since the dawn of the Atomic Age—at the click of a computer mouse. This interactive was built via a partnership among: the Bulletin, the Pulitzer Center on Crisis Reporting, Visionscarto data design firm, and the Paris-based World Nuclear Industry Status Report. The database was launched, the Bulletin’s major interactives—including the Doomsday Dashboard, the Nuclear Notebook, and the Nuclear Fuel Cycle Cost Calculator—exhibited remarkable growth, garnering some 233,000 pageviews in 2016, up about 80 percent over the preceding year.

Looking to the future, we will add a pair of columnists this year to cover events as diplomats from around the world descend on UN headquarters in New York to negotiate what would be a true (and truly controversial) landmark of the Atomic Age—a treaty to ban nuclear weapons. We are working on a special issue on the US nuclear modernization program and continuing our coverage of the world’s efforts to turn the climate change promises of the Paris Agreement into reality.

And although it is hardly the only subject we will cover, thanks to your continued support—for which the entire staff thanks you—the Bulletin is well positioned to continue to give the international security implications of Trump administration nuclear and climate policies the nonpartisan and rigorously expert attention they deserve.

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It is two and a half minutes to midnight.

From: The Bulletin of the Atomic Scientists Science and Security Board
To: Leaders and citizens of the world
Date: January 26, 2017
Re: Annual Clock Statement

The Bulletin of the Atomic Scientists Science and Security Board takes a broad and international view of existential threats to humanity, focusing on long-term trends. Because of that perspective, the statements of a single person—particularly one not yet in office—have not historically influenced the board’s decision on the setting of the Doomsday Clock.

But waning public confidence in the democratic institutions required to deal with major world threats do affect the board’s decisions. And this year, events surrounding the US presidential campaign—including cyber offensives and deception campaigns apparently directed by the Russian government and aimed at disrupting the US election—have brought American democracy and Russian intentions into question and thereby made the world more dangerous than was the case a year ago.

For these reasons, the Science and Security Board of the Bulletin of the Atomic Scientists has decided to move the minute hand of the Doomsday Clock 30 seconds closer to catastrophe. It is now two minutes and 30 seconds to midnight.

The board’s decision to move the clock less than a full minute—something it has never before done—reflects a simple reality: The world is in the grips of humanity’s most pressing existential threats, nuclear weapons and climate change.

The United States and Russia—which together possess more than 90 percent of the world’s nuclear weapons—remained at odds in a variety of theaters, from Syria to Ukraine to the borders of NATO, both countries continued wide ranging modernizations of their nuclear forces, and serious arms control negotiations were nowhere to be seen. North Korea conducted its fourth and fifth underground nuclear tests and gave every indication it would continue to develop nuclear weapons delivery capabilities. Threats of nuclear warfare hung in the background as Pakistan and India faced each other warily across the Line of Control in Kashmir after militants attacked two Indian army bases.

The climate change outlook was somewhat less dismal—but only somewhat. In the wake of the landmark Paris climate accord, the nations of the world have taken some actions to combat climate change, and global carbon dioxide emissions were essentially flat in 2016, compared to the previous year. Still, they have not yet started to decrease; the world continues to warm. Keeping future temperatures at less-than-catastrophic levels requires reductions in greenhouse gas emissions far beyond those agreed to in Paris—yet little appetite for additional cuts was in evidence at the November climate conference in Marrakech.

This already-threatening world situation was the backdrop for a rise in strident nationalism worldwide in 2016, including in a US presidential campaign during which the eventual victor, Donald Trump, made disturbing comments about the use and proliferation of nuclear weapons and expressed disbelief in the overwhelming scientific consensus on climate change.

The Bulletin of the Atomic Scientists Science and Security Board

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.

Over the course of 2016, the global security landscape darkened as the international community failed to come effectively to grips with humanity’s most pressing existential threats, nuclear weapons and climate change.

The United States and Russia—which together possess more than 90 percent of the world’s nuclear weapons—remained at odds in a variety of theaters, from Syria to Ukraine to the borders of NATO, both countries continued wide ranging modernizations of their nuclear forces, and serious arms control negotiations were nowhere to be seen. North Korea conducted its fourth and fifth underground nuclear tests and gave every indication it would continue to develop nuclear weapons delivery capabilities. Threats of nuclear warfare hung in the background as Pakistan and India faced each other warily across the Line of Control in Kashmir after militants attacked two Indian army bases.

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Last year, and the year before, we warned that world leaders were failing to act with the speed and on the scale required to protect citizens from the extreme danger posed by climate change and nuclear war. During the past year, the need for leadership only intensified—yet inaction and brinkmanship have continued, endangering every person, everywhere on Earth.

Who will lead humanity away from global disaster?
Nuclear Weapons

A dangerous situation on multiple fronts

Predictability and continuity are often prized when it comes to nuclear weapons policy, because the results of misinformation or miscalculation could be so catastrophic. Last year, however, the nuclear weapons superpowers—North Korea and the United States—continued to engage in a dangerous situation on multiple fronts.

North Korea conducted two more nuclear weapons tests, the second, in September, yielding about twice the explosive power of the first. In January, Pyongyang also test-launched ballistic missiles, achieving a rate of about two launches per month in 2016. In his 2017 New Year’s statement, Kim Jong-un declared he would soon achieve a state of nuclear deterrence, with the capability to be self-sufficient in the production of nuclear weapons, and that his country would soon test a missile with an intercontinental range.

Elsewhere, nuclear volatility has been (and remains) the order of the day. While the US president-elect engaged in casual talk about nuclear weapons, suggesting South Korea and Japan acquire their own nuclear arsenals, North Korea, other countries vied in the UN to move forward toward a treaty to ban nuclear weapons, passing Resolution L41. In 2017, those states will continue to hold meetings in New York, with the participation of about 38 countries—including the US and a number of its allies—that voted against the ban. A ban would be merely symbolic without the participation or input of countries that have nuclear weapons. But this approach—which circumvents traditional, often glacial efforts like the Conference on Disarmament—reflects long-held frustration with the slow pace of progress toward nuclear disarmament.

The world saw the 20th anniversary of the first signature on the Comprehensive Nuclear Test Ban Treaty pass in 2016; the treaty still awaits its entry into force.

The Iran nuclear deal has been successful in accomplishing its goals during its first year, but its future is in doubt under the Trump administration. No firm plans have been made to extend the nuclear security summit process. Discussions over Ukraine, Syria, ballistic missile defenses in Europe, and election interference have the United States and Russia talking with little if any prospect that nuclear arms reduction negotiations will resume.

Progress in reducing the overall threat of nuclear war has stalled—and in many ways, gone into reverse. This state of affairs poses a clear and urgent threat to civilization, and citizens around the world should demand that their leaders quickly address and lessen the danger.

Climate Change

The clear need for climate action

Global efforts to limit climate change have produced mixed results over the last year. The Paris Agreement went into effect in 2016, and countries are taking some actions to bring down emissions of greenhouse gases, although many are not on track to meet their goals. The past year, though, there is no assurance this heralds a break point. If the global economy has weakened itself from exponentially growing emissions and growing inequality, it will need to transition to a far more sustainable financial model. But because carbon dioxide persists in the atmosphere for centuries, net emissions must eventually be put on a trajectory to reach zero if global warming is to be stemmed. The longer it takes to shift toward that trajectory, the greater the warming—and the consequences—that current and future generations will face. The true success of the Paris Agreement should be measured against a strict criterion: Do the next two or three decades bring about a real break in the growth rate of carbon dioxide emissions necessary to keep world temperatures from reaching levels that: threaten catastrophic sea level rise; change rainfall patterns and therefore threaten agriculture; increase storm severity; reduce biodiversity; and alter ocean chemistry (among the many negative impacts that unchecked global warming will cause)?

The continued warming of the world measured in 2016 underscores one clear fact: Nothing is fundamentally amiss with the scientific understanding of climate physics. The burning of fossil fuels adds carbon dioxide to the atmosphere; carbon dioxide is a greenhouse gas, inhibiting the radiation of heat into space. The relationship between increased atmospheric carbon dioxide levels and increased terrestrial temperature has been researched for decades, and the scientific agreement is strong across the world. Human activity is the primary cause of climate change, and unless we take down emissions are dramatically reduced, global warming will threaten the future of humanity.

In 2016, however, the international community did not take the steps needed to begin the path toward a net zero-carbon-emissions world. The Marrakech Climate Change Conference, for instance, produced little progress beyond the emissions goals pledged under the Paris Accord.

The political situation in the United States is of particular concern. The Trump transition team has put forward candidates for cabinet-level positions (especially the Environmental Protection Agency and Energy Department) with little or no experience. It is possible that the new administration will be openly hostile to progress toward even the modest efforts to avert catastrophic climate disruption.

Climate change should not be a partisan political issue. The well-established, overwhelming scientific consensus is neither liberal nor conservative in character. The planet will continue to warm to dangerous levels so long as carbon dioxide continues to be pumped into the atmosphere—regardless of who is chosen to lead the United States or any other country.

International leaders need to refocus their attention on achieving the additional carbon emission reductions that are needed to meet the promises of the Paris Agreement. As a very first step, the Trump administration needs to make a clear, unequivocal statement that it accepts climate change, caused by human activity, as a scientific reality. No problem can be solved, unless its existence is recognized.

Nuclear Power

An option worth careful consideration

During the last half of the 20th century, the most profound existential threat facing the world was the prospect of global nuclear holocaust, sparked by decisions made under the pressure of preposterous weapons proliferations. In the post-Cold War era, the threat of nuclear winter has receded, but so has the will to reach their targets. In the 21st century, another existential threat looms: global warming caused by greenhouse gas emissions from fossil fuels. In 2017, the United States and Russia are the top carriers of global warming—make nuclear power a tempting part of the solution to the climate change problem. Some 440 nuclear power plants already generate 11 percent of the world’s electricity.

In addition to its promise, however, nuclear power has safety, cost, waste, and proliferation challenges. One can argue that the number of deaths and adverse health effects caused by nuclear power has been minimal, even when major accidents have occurred. But a single accident can change governmental policy and public attitudes toward nuclear power. That single accident can also affect multiple countries and produce effects that stretch over decades—such as the Chernobyl and Fukushima disasters have shown.

Although new nuclear power plants are being built, mainly in Asia, it is not enough: the world will need to achieve a 50 percent reduction in carbon dioxide emissions by 2050 to keep temperatures below 2 degrees Celsius of pre-industrial levels. To achieve just 6 percent of needed reductions in greenhouse gas emissions, nuclear power would have to increase in capacity at least 16-fold. The world currently generates about 300 gigawatts of power, but in 2050 the world will need to reach 2,000 megawatts of capacity per month, the equivalent of a new large power plant every 2 weeks. Such growth in new nuclear capacity would also require significant commitments to nuclear safety, security, and waste management that are politically, technically, and intergenerationally responsible.

In the short and medium terms, governments will need to discourage the premature closure of existing reactors that are—as determined on a case-by-case basis—safe and economically viable. In the longer term, entrepreneurs will have to design and test new types of nuclear power plants that can be built quickly, as well as having to prove to regulators that those new reactors are at least as safe as the commercial nuclear plants now operating.

It is likely that leaders in different parts of the world will make different decisions on whether their countries will or will not include nuclear power in their efforts to combat climate change. Where nuclear power is used, at a very minimum, leaders must ensure that truly independent regulatory systems and safe geological disposal repositories are created.

Emerging Technologies

Potential threats multiply

In December, US intelligence agencies concluded that Russia had intervened in the 2016 US presidential campaign to help Donald Trump in ways that highlight the vulnerability of critical information systems in cyberspace, information microcultures, and news media, and the hacking and release of politically sensitive emails may have had an illegitimate impact on the US presidential election, threatening the fabric of democracy, which relies on an informed electorate to decide the direction of public policy—including policy relating to existential threats such as nuclear weapons and climate change. If not controlled, these types of electoral attacks could be launched against democracies around the world, undermining the belief in representative government and thereby endangering humanity as a whole.

Such attacks on the democratic process, however, represent just one threat associated with the modern world’s increased reliance on the internet and information technology. Sophisticated hacking—whether by private groups or governmental entities—could lead to potential to create grave and large impacts, threatening financial activities and national electrical power grids and plants (including nuclear power plants) and the freedoms that are based on the privacy of the core of democracy.

Beyond cybersecurity, the increasing potential of autonomous machine systems—which could, for example, allow the development of efficient, self-driving cars—also opens up a new set of risks that require thoughtful management. Without good governance, including appropriate regulation, these threats could emerge in coming decades as existential—that is, dangerous to the whole of humanity or to modern civilization as we know it. Lethal autonomous weapons systems that make “kill” decisions without human input or supervision, for example, would be particularly worrisome. Advances in synthetic biology, including the Crispr gene-editing technology, could present real potential—and a dark side that includes the possible creation of bioweapons and other dangerous manipulations of genetic material.

Technological innovation is occurring at a speed that challenges society’s ability to keep pace. While limited at the current time to nuclear weapons, existential threats posed by a host of emerging technologies need to be monitored, and to the extent possible anticipated, as the 21st century unfolds.
Technology continues to outpace humanity’s capacity to control it, even as many citizens lose faith in the institutions upon which they must rely to make scientific and innovation work for rather than against them. Expert advice is crucial if governments are to effectively deal with complex global threats. The Science and Security Board is extremely concerned about the willingness of governments around the world— including the incoming US administration— to ignore or discard sound science and considered expertise during their decision-making processes.

Wise men and women have said that public policy is never made in the absence of politics. But in this unusual political year, we offer a corollary: Good policy takes account of politics but is never made in the absence of expertise. Facts are indeed stubborn things, and they must be taken into account if the future of humanity is to be preserved, long term.

Nuclear weapons and climate change are precisely the sort of complex existential threats that cannot be properly managed without access to and reliance on expert knowledge. In 2016, world leaders not only failed to deal adequately with those threats; they actually increased the risk of nuclear war and uncontrolled climate change through a variety of provocative statements and actions, including reckless rhetoric about the use of nuclear weapons and the Watson’s defiance of scientific truths. We call on these leaders— particularly in Russia and the United States— to retrace in the coming year on reducing existential risks and preserving humanity, in no small part by consulting with top-level experts and taking scientific research and observed reality into account.

Because we know from experience that governmental leaders respond to public pressure, we also call on citizens of the world to express themselves in all the ways available to them— including through use of the powerful new tools of social media— to demand that:

• US and Russian leaders return to the negotiating table to seek further reductions in nuclear arms and to limit nuclear modernization programs that threaten to create a new nuclear arms race. The world can be more secure with much, much smaller nuclear arsenals than now exist. Political leaders are truly interested in protecting their citizens from harm.

• The United States and Russia reduce the alert levels of their nuclear weapons and use existing crisis stability mechanisms to avoid inadvertent escalation of conflict. Provocative military exercises increase the possibilities for accidental war and should cease.

• Governments around the world sharply reduce their countries’ greenhouse gas emissions and fulfill the Paris Accord promise of keeping warming to 2 degrees Celsius above preindustrial levels, or less. This temperature target is consistent with consensus views on climate science and is eminently achievable and economically viable, provided that poorer countries are given the support they need to make the post-carbon transition.

• The Trump administration acknowledge climate change as a science-backed reality and redouble US efforts to limit carbon dioxide emissions and support carbon-free energy sources, including, when economically reasonable and safe over the long term, nuclear energy. It will be past time to move beyond arguments over the reality of climate change and on to solutions, including fiscal measures such as carbon markets and carbon taxes or fees that encourage efficiency and put a price on carbon emissions.

• The United States, China, Russia, and other concerned nations engage with 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. As we said last year and repeat here: New is not the time to tighten North Korea’s isolation but to engage seriously in dialogue.

• Leaders of countries with commercial nuclear power programs deal responsibly with safety issues and with the commercial nuclear waste problem. Top experts disagree on whether an expansion of nuclear-powered electricity generation can become a major component of the effort to limit climate change. Regardless of the trajectory of the global nuclear industry, there will be a continuing need for safe and secure interim and permanent nuclear waste storage facilities and for ever-safer nuclear power plants.

• The countries of the world collaborate in creating institutions specifically assigned to explore and address potentially malign or catastrophic misuses of new technologies. Scientific advance can provide society with great benefits. But as events surrounding the recent US presidential election show, the potential for misuse of potent new technologies is real. Governmental, scientific, and business leaders need to take appropriate steps to address possibly devastating consequences of these technologies.

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. It is two and a half minutes to midnight, the Clock is ticking, global dangers loom. 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.

Bulitett editors produced a remarkable array of essays in 2016—ranging from brief columns, multimedia presentations, and interactive features to roundtable discussions and long-form articles. A healthy segment of our material appears in our subscription-based journal, which has won numerous honors throughout the years, including the 2007 National Magazine Award Society for General Excellence from the American Society of Magazine Editors. By any measure, the annual subscriptions, offered through our publishing partners Taylor & Francis, are a bargain for individuals and institutional subscribers. Also, we normally “lift the paywall” for several articles in each issue, providing free access to the special issues: interviews, analysis, and graphics that have garnered international respect for more than seven decades.

Every issue also includes open access to installments of the renowned Nuclear Notebook, an authoritative accounting of world nuclear weapons arsenals produced by Federation of American Scientists experts Hans M. Kristensen and Robert S. Norris.

And since May 2016, an additional bonus of an annual subscription is access to the John A. Simpson Archive—a fully searchable cache of every single article published by the Bulletin since it was founded in 1945. It is a unique chronicle reflecting the belief of our founders that the atom bomb would only be the first of many dangerous presents from “Pandora’s box of modern science.” It remains a record of the Bulletin’s sustained efforts to educate people about the realities of the scientific age.

(above, the photo shows the Lizard Island section of Australia’s Great Barrier Reef, before and after the recent coral bleaching event; image courtesy of the XL Catlin Seaview Survey.)

January-February 2016: In the first special issue of the new year, “Nuclear Energy in the Middle East,” Executive Director and Publisher Rachel Bronson wrote the lead article “Power shift in the Middle East.”

May-June 2016: This special issue discussed many aspects of US-Russia relations, including arms control, current statistics on the Russian nuclear arsenal, and the geopolitical significance of Russia’s oil and gas exports.

July-August 2016: This special issue illustrated the rapidly changing power equations on display across—and beneath—the world’s oceans and how those changes could soon affect everything from global internet access to the nuclear determent strategies of the world’s nuclear powers.

November-December 2016: International security in the age of renewables was the focus of the final special issue for calendar 2016, which included articles on Saudi Arabia, the impact on relations between Russia and the European Union, and complex financing issues.
2016: Journal Highlights

Interviews and Long-form articles

Editor-in-Chief John Mecklin published two key interviews in 2016: one with former covert CIA operations officer Valerie Plame, who spoke on howmillennials can be encouraged to become active in dealing with the threat posed by nuclear weapons and nuclear proliferation, and the other with former US ambassador to Russia Michael McFaul, who discussed howUS-Russia relations might be improved, given Russian President Vladimir Putin’s suspicious views of US intentions.

Associate Editor Dan Drollette talked to Steven Chu, former US Secretary of Energy about his latest research; the reasoning behind the decisions he made in office; and how to make progress in the current, anti-regulatory political environment.

Edward Moore Geist argued that an Artificial Intelligence (AI) arms race is already well under way, due to the historical connection between AI research and defense applications, despite campaigns for an agreement to ban autonomous weapons before they become the next domain of military competition.

In Putin: The one-man show the West doesn’t understand by Fiona Hill, the director of the Center for the United States and Europe at The Brookings Institution explained what the world is missing when it deals with the Russian president.

And a bevy of top experts—including Princeton’s Frank von Hippel and Stanford’s Sig Hecker—suggested a series of penetrating questions about nuclear weapons that should have been asked of the 2016 presidential candidates. And should now be put to the experts on nuclear weapons, climate change, and other existential threats to humanity comment on how they think the expert community can best respond to Donald Trump’s election.

Preparing the country for nuclear terrorism Jerome M. Hauer

The presidential candidates must do more than accept the possibility of a terrorist attack with an improvised nuclear device. They need to plan an effective response that reduces the mass morbidity and mortality such an attack inevitably will cause.

The double-edged sword: US nuclear command and control modernization Andrew Futter

Even in this digital age there are many reasons to be careful about what we wish for when it comes to modernizing the nuclear command and control system. More technological capability will not necessarily create a more secure world.

Below are some of the Bulletin’s best articles on nuclear weapons from 2016, during which, in countries around the world—from North Korea to Pakistan to India and Russia and on to the United States—people who ought to know better suggested that more nuclear weapons should be built, and some might be used.

On tickling the dragon’s tail Victor Gilinsky

The moral restraints that prevent Armageddon are flimsier than one might think, because humans have a self-destructive defect. They like to tickle the dragon’s tail.

The experts, and the Trump administration John Mecklin

Top experts on nuclear weapons, climate change, and other existential threats to humanity comment on how they think the expert community can best respond to Donald Trump’s election.

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2016: By the Numbers*

*Calendar 2016 through January 2017, following the Clock Announcement

2,400,000
website visits

3,700,000
page views

2,500,000
viewers watched

53% of the Bulletin’s audience in 2016 was under 35 years old. 70% was under 45

Nearly half of the Bulletin’s audience is from outside the United States

+20%

+26%

Our interactive tools were used more in 2016 than ever before

Doomsday Dashboard
Nuclear Notebook
Nuclear Fuel Cycle Cost Calculator
Doomsday Clock Timeline
Global Nuclear Power Database

+80%

Financials

Ordinary Income/Expense 2015 2016

Income
Foundation Grants 332,638 154,983
Individual & Corporate Contributions 448,958 528,878
In-kind Contributions 507,433 536,968
Earned Revenue 214,890 165,812

Total Revenue before Restrictions 1,503,919 1,366,241
Released from Restrictions 421,817 623,137
Total Unrestricted Revenue 1,925,736 1,988,378

Temporarily Restricted
Temporarily Restricted Revenue 1,171,602 127,455
Released from Restriction (421,817) (623,137)

Total Revenue after Release of Restrictions 2,675,521 1,492,696

Expense
Salaries and Benefits 747,750 882,155
Program Expenses 1,023,085 975,210
Administrative Expenses 112,026 123,458

Total Expense 1,882,862 1,980,823

Net Operating Income before Restrictions 42,874 7,555

Expenses
Salaries and Benefits
Program Expenses
Administrative Expenses

Ordinary Income/Expense 2015 2016

Income
Foundation Grants 36%
Individual & Corporate Contributions 28%
In-kind Contributions 27%
Earned Revenue 8%

Expenses
Salaries and Benefits 45%
Program Expenses 49%
Administrative Expenses 6%
We welcomed another sold-out crowd for the second year in a row to the Bulletin’s 2016 Annual Dinner on November 14 at the Chicago Cultural Center. Keynote speakers were Career Ambassador and Board of Sponsors member Thomas Pickering, who has served as US ambassador to the United Nations, El Salvador, India, Israel, Jordan, Nigeria, and the Russian Federation, and award-winning climate scientist and member of the Science and Security Board Richard Somerville of the Scripps Institution of Oceanography at the University of California San Diego.

The highlight of the evening came when former Vice President Al Gore delivered a videotaped tribute to honorees William and Eleanor Revelle for their early recognition that climate change poses a threat to humanity, and for their long-standing commitment to the Bulletin.

“The Revelles have never stopped working to make the world a safer and healthier place.”
2016: With Gratitude

For more than seven decades, a dedicated network of board members, advisors, foundations, and donors have sustained the Ploughshares Fund. We extend our deepest gratitude to the board leaders, individuals, and institutions who made contributions between January 1 and December 31, 2016. Their names are listed here, with our sincere thanks for making everything we do possible.

Norwegian Ministry of $100,000-$250,000 making everything we do possible.

Governing Board member John Balkcom and Carol Balkcom

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In honor of Esther Green:  
Molly Weiner Cooper and B.igeleisen

In honor of the Bulletin Team:  
Molly Weiner Cooper and B.igeleisen

Honor gifts  
in honor of Konnedi Benedict:  
Anonymous

In honor of Marjorie Benton:  
K. Sujata and Lawrence Marks

In honor of Alan Beyerchen:  
Barbara Reeves

In honor of Paige Bonk:  
Kendall and Kenneth Gladish

In honor of Rachel Bronson:  
Helen and Robin Losh

In honor of Betty Wein:  
Molly Weiner Cooper

In memory of Ruth Adams:  
Megan Adams

In memory of Charles Benton:  
Sunny and Paul Fischer

In memory of Dr. Rosalie Bertelli:  
Catherine Euler

In memory of Christine Brady:  
Catherine Euler

In memory of Harry Palevsky:  
Mary Palevsky

In memory of Wolfgang K. K. Panofsky:  
Margaret Panofsky

In memory of Owen Chamberlain:  
Senta Pugh

In memory of Esther Green:  
Michael Green

In memory of Austin Hirsch:  
Joan Gomberg

In memory of Harold Maier:  
Alicia Kru\n
In memory of William Law:  
Margaret Janner

In memory of Dr. Nolen Levine:  
Sara Pantaleo and Courteney Wright

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In memory of and Eleanor Revolles:  
Paul and Mary Firminger

In memory of Charles Fosdick:  
Laura Jones and Paul Ginsparg

In memory of Jack Kyger:  
Nora Kyger

In memory of Marilyt Landsdogel:  
Suzanne Landsdogel

In memory of Martin and Eva Melker:  
E. C. Scorsy and Philip Fischer

In memory of Dennis Norwood:  
Joseph Grech

In memory of Harry Palevsky:  
Mary Palevsky

In memory of Marguerite Panofsky:  
Margaret Panofsky

In memory of Owen Chamberlain:  
Senta Pugh

In memory of Cathryn Cranston:  
Thomas Rosenbaum and Katherine Faber

In memory of Sidney Drell:  
Renee de Nerves and Herman Winkin

In memory of Ervino Fermi:  
Joseph Lach

In memory of James Franck:  
Frank and Patricia von Hippel

In memory of Edward Michael Fuller:  
Susan Bader

In memory of Joseph X. (and Anne L. Gretch):  
Joseph Grech

In memory of Paul S. Hesey:  
Donald Hees

In memory of Charles Buford Jones:  
Laura Jones and Paul Ginsparg

In memory of Jack Kyger:  
Nora Kyger

In memory of Martha Landsdogel:  
Suzanne Landsdogel

In memory of Otto and Greta Hone:  
Christopher Strass

In memory of Martin and Eva Melker:  
E. C. Scorsy and Philip Fischer

In memory of Dennis Norwood:  
Joseph Grech

In memory of Mary Frances Vasaly:  
Nora Kyger

With sadness we noted the passing of Helen Thom Edwards, an outstanding physical who was known the world over, and who was a generous friend to the Bulletin.

In memory of Leonid Rieser:  
Barbara Barnes
Margot De L'Estoile

In memory of my wife:  
Suzanne Langsdorf

In memory of Charles Fosdick:  
Suzanne Landsdogel

In memory of Martin and Eva Melker:  
E. C. Scorsy and Philip Fischer

In memory of Dennis Norwood:  
Joseph Grech

In memory of Harry Palevsky:  
Mary Palevsky

In memory of Margaret Panofsky:  
Margaret Panofsky

In memory of Owen Chamberlain:  
Senta Pugh

Keynote Speaker Thomas Pickering and Governing Board members

Steve Fadem and Lee Watts

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