

**Bulletin  
of the  
Atomic  
Scientists**



Annual  
Report  
2015

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## The Mission

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 more than 70 years, the *Bulletin* has bridged the technology divide between scientific research, foreign policy, and public engagement.

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# Letter from the Chair

## Lee Francis



In the remarkable year that is reviewed in this report, we completed a major leadership transition and marked our 70th Anniversary—two milestones that bode well for the *Bulletin's* future.

Back in 2005, I was proud to welcome Dr. Kennette Benedict as executive director and publisher. During her 10-year tenure, the *Bulletin*:

- Increased its historic coverage of nuclear issues and the effects of climate change, escalating energy demands, and emerging technologies on global stability.
- Strengthened its ties to distinguished scientists and re-emerged as a “must-read” resource for scientists, policymakers, and concerned citizens.
- Moved to an all-digital format, quadrupled the subscriber base to the bimonthly journal, and launched an open access website that attracted millions more readers than the print-only format had permitted.
- Reaffirmed our powerful alliance with the University of Chicago, moving to offices at the Harris School of Public Policy Studies.

By the time Kennette began a “retirement” of writing and teaching, the board had chosen a most worthy successor. Dr. Rachel Bronson arrived in February 2015 from her most recent post at The Chicago Council on Global Affairs, inspiring the board and staff with a visionary and ambitious view of the *Bulletin's* global role and potential.

With her deep expertise in Middle East and energy issues, collaborative style, marketing smarts, and keen respect for the role of volunteers and board members, Rachel orchestrated a banner year. As website traffic increased, she introduced new features and strategic fundraising, and capped off year one with the annual Clock Symposium and 70th Anniversary Dinner, both of which were oversubscribed. You’ll get a sense of Rachel’s energy and ideas in the letter that follows this one.

During our 70th anniversary events, we heard from the 19th US Secretary of Defense William Perry, California Governor Jerry Brown, and former Australian foreign minister Gareth Evans, among others, and recognized leaders like Marjorie Benton, who has championed this organization for many years, and Victor Rabinowitch, son of the *Bulletin's* great founding editor Eugene Rabinowitch.

Since the *Bulletin's* founding in 1945, a series of talented civic leaders and professionals have accepted the call to advise and support the organization. As a board member since 2001 and chair since 2013, I have been honored to serve with scientists, business leaders, and nonprofit experts to extend the *Bulletin's* capacity and impact.

The *Bulletin's* future is in very good hands—but the global challenges we cover are unrelenting. The board is deeply committed to inviting more people to embrace the opportunity to shape policy decisions on issues of enormous consequence through our unique, cutting-edge resources. For more than seven decades, the *Bulletin* has been committed to ensuring that sciences’ greatest advancements are channeled toward peace and security. It is our great charge to continue this mission.

Lee Francis, MD

# Letter from the Executive Director and Publisher Rachel Bronson



**After my first year at the *Bulletin*, I believe the need for our organization is as great as ever—and perhaps greater. The topics that we cover are tightly defined, and they ripple through almost every dimension of global security.**

The *Bulletin* continues to cover nuclear security and disarmament, as it has for the past 70 years. Added to that focus, however, are climate change, the growing global energy demand that is driving it, and the often-hidden dangers associated with emerging technologies.

What draws these issues together? They all deal with threats that have the ability to end life on Earth as we know it. Also, these issues know no borders and are global in scope. I can't imagine a more consequential set of topics on which to focus.

By covering these issues in an in-depth yet accessible way, the *Bulletin* has carved out a valuable and trusted space that is attracting ever larger and younger audiences. Our articles are regularly cited and reposted not only on traditional media sites, but also in new media, including Slate, Vox, Vice Media's Motherboard channel, Gawker, Gizmodo, Slashdot, Digg, Reddit, and Fark. We must reach out tirelessly to engage new audiences, and create more opportunities for our stakeholders to engage us directly. We will not survive in this ever-changing digital landscape if we passively wait to pop up on screens and devices.

New programs and activities underscore the fact that the *Bulletin's* mission is both public education and policy impact. Our initial efforts at hosting global teleconferences on topical issues such as the nuclear agreement with Iran and the Paris Climate Summit were wildly successful. Joining the conversations were *Bulletin* stakeholders from US government offices, including the US General Accounting Office, the National Nuclear Security Administration, the State Department, the Senate Committee on Natural Resources, and the US national laboratories; from governments—Denmark, Italy, Israel, Kuwait, Australia, Canada, and Chile, among others—and from educational institutions around the world; from the International Atomic Energy Agency and the Norwegian Defense Research Establishment; and from major media outlets.

We are convening more face-to-face encounters, including our annual Clock Symposium this November in Chicago and additional gatherings in Washington, DC and elsewhere. We also have plans to reconnect with our international audience, recognizing that nearly half of our traffic comes from outside the US. In 2016 we will experiment with webcasts and virtual meetings.

The culmination of our outreach efforts will be the opening of an exhibit in mid-2017 that we are creating in partnership with Chicago's Museum of Science and Industry, which attracts some 1.4 million visitors each year. The working title of the exhibit is 'Turning Back the Clock,' and we are targeting it to young people, believing that if we engage them today, they will become committed stakeholders in years to come. Our aim is for the exhibit to travel nationally and possibly internationally to touch even more people.

The issues that the *Bulletin* takes on every day are daunting, but I see reasons for optimism. In our 2016 Clock Statement, which can be found on page 12 of this report, the Science and Security Board issued a sober warning that the 2016 time of three minutes to midnight "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." Nevertheless, the board also highlighted two bright spots on the international stage: the nuclear agreement between Iran and six major world powers, and the Paris climate accord.

In both of these cases, enlightened leadership made a difference, guided and goaded by public opinion. Leaders were supported by powerful grass roots activity at the climate summit in Paris, and they faced voluble and vigorous public debate in the case of the Iran deal. The *Bulletin* is fully committed to keeping the public engaged by focusing its spotlight on implementation benchmarks on both issues. As California Gov. Jerry Brown noted at the *Bulletin's* Clock-setting event in January, politicians "react to people, to civilians, to interest groups, the media, business, labor, and cultural organizations." The *Bulletin* and its readers play their part, day in and day out, insisting—not just at Clock time, but throughout the year—that leaders around the globe act to address the world's most pressing problems.

The *Bulletin* invites its readers to look behind the headlines, follow the scientific debates that underlie the world's thorniest challenges, and consider policy recommendations offered by those who are not beholden to a particular ideological viewpoint.

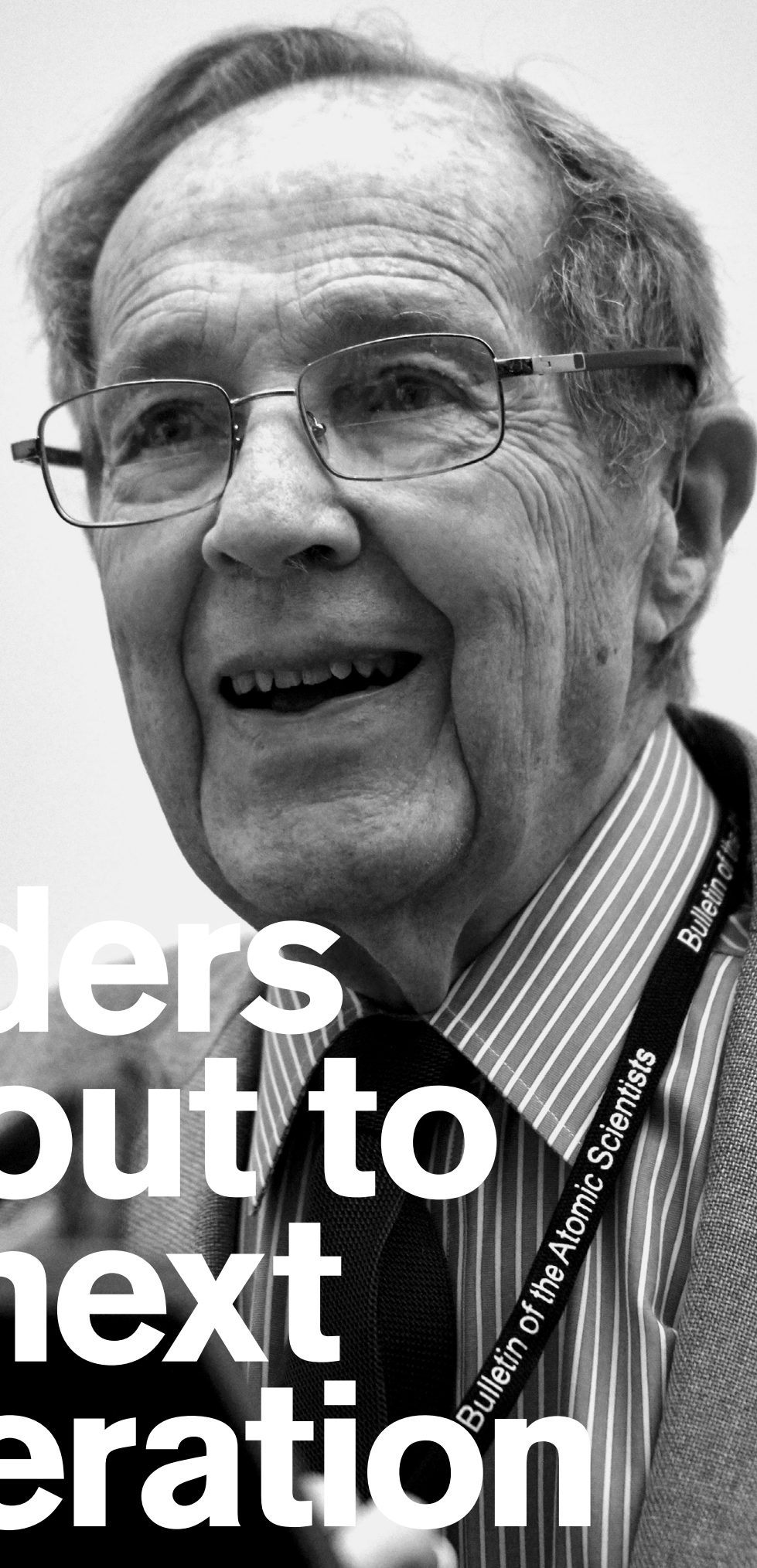
The March 27, 2016 episode of the CBS television show *Madam Secretary* profiled the *Bulletin*; in it, one of the characters argued that the *Bulletin* was "in the pocket of Big Truth." I could not have said it better myself.

At the *Bulletin*, we are thankful to our many partners, including the Harris School of Public Policy at the University of Chicago, and our new publisher, Taylor and Francis, who—along with many others—continue to help the *Bulletin* advance its mission. And we couldn't accomplish a fraction of what we do without the generosity of our Governing Board, Science and Security Board, Board of Sponsors, and growing list of donors. We also deeply appreciate the good work of former board member and renowned designer Michael Bierut and his colleagues at Pentagram, for their design of this annual report.

The *Bulletin's* staff remains grateful for all the support we receive, hopeful that we are improving the safety and security of our shared planet. There is much work to do, but we are building on a strong foundation. I expect you will see both the accomplishments we have made and the task yet before us as you look through this annual report.

Rachel Bronson, PhD

# Leaders call out to the next generation



**“Our only hope is that Clock; you better tend it well.”**

Jerry Brown



**On November 16, 2015, to mark 70 years speaking knowledge to power, the *Bulletin* organized an afternoon Clock Symposium of serious presentations, followed by an elegant evening of reflections, tributes, and ideas for the future.**

As part of the Symposium, we also showcased N Square’s interactive exhibit, “Boldness and Opportunity: Innovators Tackle Nuclear Threat,” based on the idea that the risks we face require a wide variety of creative problem-solvers and collaborators.

Board of Sponsors member The Honorable Gareth Evans, chancellor of Australian National University and Australia’s former Minister of Foreign Affairs and Minister of Resources and



Opposite page: 19th US Secretary of Defense William Perry; far left: California Governor Jerry Brown; top: from left, Northwestern University’s Brian Hanson, *Bulletin* editor Lucien Crowder, and Lynn Eden of the *Bulletin*’s Science and Security Board. Below: Peter Ogden from the University of Chicago’s Energy Policy Institute and Sivan Kartha of the Science and Security Board.



Energy, opened the proceedings with a keynote address titled “Restoring Reason to the Nuclear Debate.” Evans emphasized how the *Bulletin*, with the powerful symbolism of the Doomsday Clock, had gained respect over seven decades for its ability to educate leaders and the public.

Adele Simmons, president of the Global Philanthropy Partnership, moderated a panel on “Climate Change: What to Expect from Paris 2015 and Does it Matter?,” featuring comments from experts who would be participating in the subsequent climate talks.

California Gov. Jerry Brown took the podium to address “Climate Change, Nuclear Weapons and the Public Disconnect,” listing some of his state’s efforts to combat global warming. *Bulletin* author and former board member Robert Socolow commented that “California is the place to be right now, when it comes to dealing with climate change, even more so than Germany’s Energiewende,” before outlining his own thoughts on our

collective near and far futures. Science and Security Board co-chair Robert Rosner directed a timely panel discussion titled “After the Iran Deal, What’s Next for Nuclear Security,” in which *Bulletin* senior advisor Kennette Benedict termed the stopping of Iran’s 60-year-old nuclear program “an historic achievement.”

Concluding remarks by 19th US Secretary of Defense William Perry were directed especially at students in attendance. Maintaining that issues such as nuclear terrorism were getting short shrift among millennials, he called for new means of communication to convey the threat, including animations and graphic novels. Regarding the likelihood of nuclear terrorism, Perry said he would set the Doomsday Clock at “one minute to midnight.”



**“Nuclear terrorism, while not as catastrophic as a large-scale attack, is much more likely to happen ... For that version of Doomsday, I would put the Clock at one minute before midnight.”**

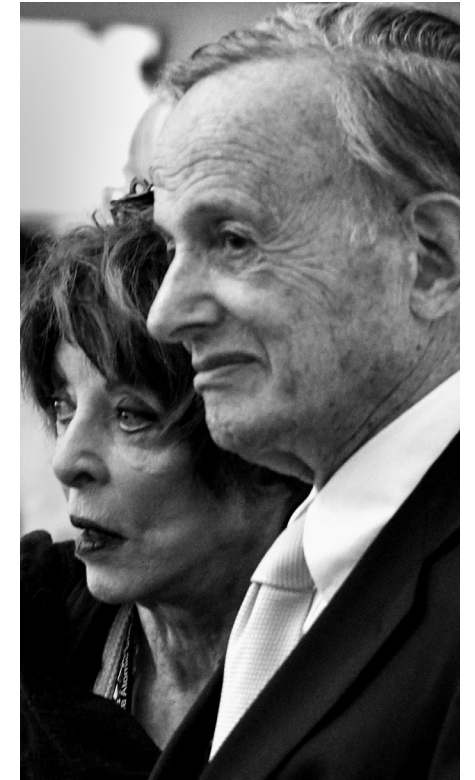
**William Perry**



Top far left: Board chair Lee Francis; top: from left, Morgan Matthews of N Square and Tara Drozdenko from the Outrider Foundation; above: Science and Security Board Member Ramamurti Rajaraman and Nuclear Threat Initiative President Joan Roling; left: Robert Meyers; bottom: Board member Austin Hirsch with Sue Baird on sofa in center, with other Symposium participants.

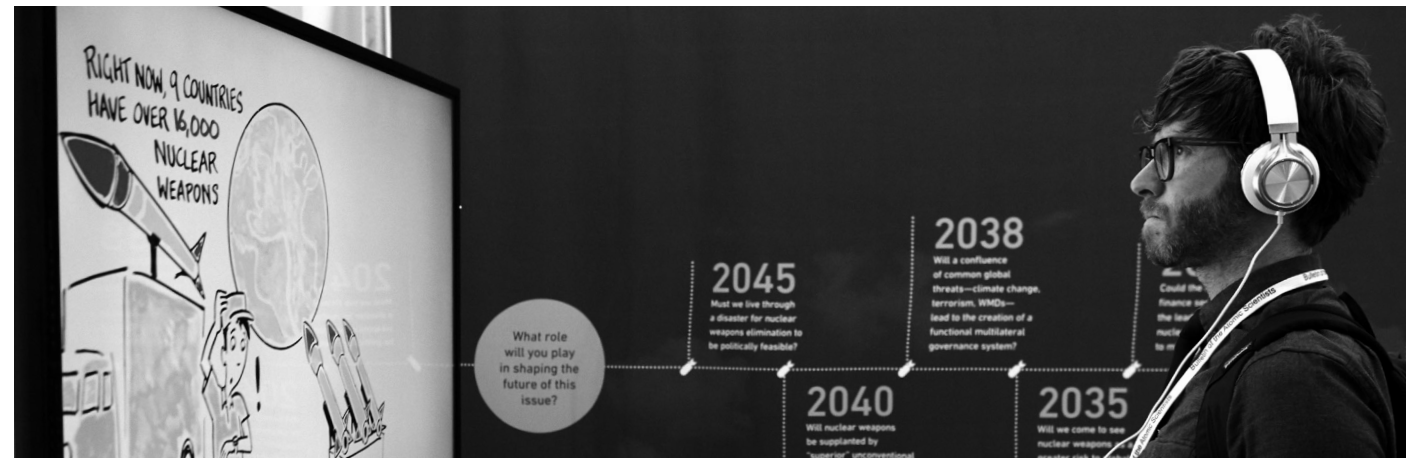


Above: Board of Sponsors Member and Keynote speaker Gareth Evans, Chancellor of Australian National University; right center: Nivien Saleh of Houston; far right: Canadian artist Brenda Bury and Board of Sponsors member and 1986 Nobel Laureate John Polanyi; below right: *Bulletin* senior advisor Kennette Benedict and Sissy Farenthold of Houston; below: Science and Security Board member Sharon Squassoni; and bottom: Andy Adams of the Outrider Foundation.



**“What policy makers need to be persuaded about are the rational, strategic arguments against nuclear weapons: that in fact they are at best of minimal, and at worst of zero, utility in maintaining stable peace.”**

**Gareth Evans**



**After the Clock Symposium the *Bulletin of the Atomic Scientists* hosted a sold-out 70th Anniversary Dinner at Chicago's Museum of Science and Industry, on November 16, 2015.**

Governing Board Chair Lee Francis first welcomed back to the podium California Governor Jerry Brown, who ruefully observed that, after a lifetime in politics, he has become an expert on triviality—and contrasted the triviality that assaults him daily with the seriousness of the *Bulletin's* mission. "You've got a lot of credibility," he said. "Use it wisely to protect our country and the world."

David Mosena, the museum's president and CEO, graciously welcomed more than 250 board members and guests, who then heard more about the major display the *Bulletin* will open at the museum in 2017, exploring how the world has changed through the nuclear era, and how the Doomsday Clock has moved along with it.

Before dinner was served, Secretary Perry again described for the larger audience a planet in deep nuclear peril. Despite the grim topics discussed, guests circulated, dined, and toasted the *Bulletin's* distinguished history, and took time to recognize past leaders and generous sponsors.

The high point of the evening came when Julia Stasch, president of the John D. and Catherine T. MacArthur Foundation, described her organization's commitment to nuclear security and climate issues. She then recognized Marjorie Craig Benton, the 70th Anniversary Honoree, for her longstanding support of the *Bulletin* and, in particular, for her leadership at critical times in the *Bulletin's* evolution. Benton served on the *Bulletin's* Governing Board from 2006 to 2010, helping to guide the organization through a period of increasing national and international visibility as a highly respected voice of scientists and policy leaders.

Concluding the evening with a powerful speech, celebrated theoretical physicist and chair of the *Bulletin's* Board of Sponsors Lawrence Krauss said that the *Bulletin* is more necessary today than at the time it was founded. "We are going to have to live on Earth 2.0," he said. But the *Bulletin's* "dedication and impact over 70 years are worth celebrating."



Top left: Former Board member Jay Harris applauds as Honoree Marjorie Craig Benton (right) is recognized; center left top: Board member Lew Watts and Christie Hefner; center left below: Marti Rabinowitch, Peter Rabinowitch, and Board of Sponsors member Victor Rabinowitch; below: Board of Sponsors member Lawrence Krauss; bottom left, US House of Representative from Illinois Jan Schakowsky.



**"The *Bulletin* represents the best about what it means to be human."**

Lawrence Krauss

## 70th Anniversary Sponsors

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Top: Eleanor Revelle, Caroline Herzenberg, and former Illinois State Representative Julie Hamos; above left, Editor-in-Chief John Mecklin and Sunshine Menezes of the University of Rhode Island; above right, former board members Joan Winstein and Joan Shapiro, Marsha Rosner, and Science and Security Board Member Robert Rosner; left, Michelle Gittler, Board Chair Lee Francis, Honoree Marjorie Benton, and Science and Security Board Member Suzet McKinney; below, Laura Tucker, Sunny Fischer, Julia Garg, and *Bulletin* Governing Board Member Sonny Garg.



# Letter from the Editor-in-Chief

## John Mecklin



### In recognition of a major publishing milestone—its 70th anniversary of publication—the *Bulletin* published two special issues to mark the start and end of 2015.

The first focused on our storied past, which included contributions from, among many luminaries, Albert Einstein, Edward Teller, J. Robert Oppenheimer, and Mikhail Gorbachev. In our second anniversary issue, an array of today's top public intellectuals—including Pulitzer Prize-winning historian Richard Rhodes; Eric Schlosser, author of the acclaimed and terrifying book about nuclear weapons accidents, *Command and Control*; and renowned Princeton University climate change expert and polymath Rob Socolow—looked forward, to a future that will include not just the threat of thermonuclear catastrophe, but an array of other global dangers, from climate change to the potential misuses of advances in synthetic biology, information technology, and artificial intelligence.

In the year bracketed by these intellectual bookends, the *Bulletin* was highly successful, by most any measure one could choose. On the quantitative front, readership of our website grew by 84 percent in 2015 as compared to the previous year. The site drew 1,000,000 more page views than in 2014, and many of our new readers came from the Web-native social media and news aggregation sites that attract a younger audience. At the same time, the *Bulletin* continued to expand the attention it receives from thought-leading publications and top-tier think tanks like *The New York Times*, *The Atlantic*, *The Los Angeles Times*, the *Guardian*, the Council on Foreign Relations, and Harvard's Belfer Center for Science and International Affairs.

These increases in readership and impact were powered by a continuing emphasis on 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.

In the nuclear realm, the *Bulletin's* coverage of the historic agreement between six major powers and Iran featured what many observers consider the most comprehensive array of top experts to comment on the subject, from Stanford's Sig Hecker to Princeton's Frank von Hippel and Zia Mian to Harvard's William Tobey, to Georgetown's Ariane Tabatabai and on and on.

On climate change, we published articles by and interviews with Penn State expert Michael Mann of "hockey stick" graphic fame, Rocky Mountain Institute co-founder Amory Lovins, California Gov. Jerry Brown, and award-winning journalist Naomi Klein, to mention just a few in a top-flight roster of authors. In a move that acknowledges the power of religion to influence the making of earthly public policy, we also published a trio of articles examining the relationship of Islam, the Catholic Church, and evangelical Christianity to climate change.

Looking to the future, we have already begun expanding our coverage of climate change and emerging technological threats to humanity by expanding our roster of columnists to include additional top-rank experts in those subjects. We are in the process of producing special issues that focus on bringing information about nuclear weapons and climate change to younger people, and on understanding and reducing the heightened tensions that have arisen between the United States and Russia. And in coming months we'll of course be reporting on the US presidential elections, in hopes of persuading candidates to address nuclear weapons, climate change, and other global threats to humanity in a realistic manner.

As I noted in my introduction to one of our anniversary issues, at the age of 70, the *Bulletin* considers itself young, and our primary emphasis in the coming year will be on addressing current threats to the continuation of humanity, and on making sure that younger readers understand the dangers they, and their children, face. We have never been better positioned to make real progress in reducing those dangers, thanks to your longstanding and continued support, for which the entire *Bulletin* staff thanks you.

John Mecklin



**Save the time**  
2016 Annual Dinner  
Monday, November 14  
Chicago  
Cultural Center

# It is still three minutes to midnight

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**From: The *Bulletin***  
**To: Leaders and citizens of the world**

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**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 Governing Board and the 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. This statement reflects the conclusions of our board members, reached on November 17, 2015.**

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 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.



# 1 Nuclear Weapons

## 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 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 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.

# 2 Climate Change

## 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.

# 3 Nuclear Power

## 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.

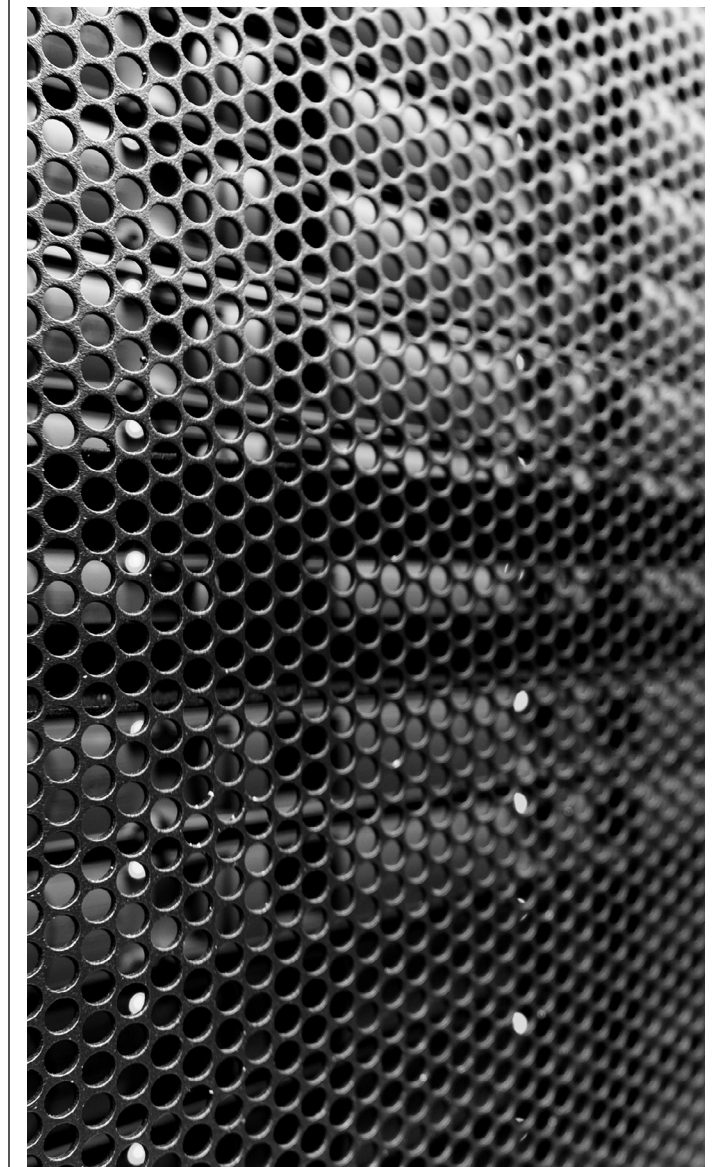
Because of such problems, in the United States and in other countries, nuclear power's attractiveness as an alternative to fossil fuels has decreased, despite the clear need for carbon-emissions-free energy in the age of climate change.

# 4 Emerging Technology

## More attention to new 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.



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 about their constituents and their countries.

# Three minutes is too close. Far too close.

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.

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.**

# 2015 in review: We've been very busy

## Climate

It was a record-setting year for average global temperatures. A chemist-turned-pope issued an encyclical in favor of the scientific evidence behind human-induced climate change. And almost 200 nations came to some kind of agreement—however flawed—on reducing the carbon emissions that lead to global warming. Below are our highlights.

### The IPCC's shifting position on nuclear energy

Suzanne Waldman  
What role should nuclear power play in combating climate change?

### The Serengeti strategy: How special interests try to intimidate scientists, and how best to fight back

Michael Mann  
The scientist behind the famous “hockey stick” graph that shows the link between increased temperature and rising levels of carbon dioxide gives a behind-the-scenes view of the resulting controversy—and what others can learn from his experiences.

### Climate change: Irreversible but not unstoppable

Dawn Stover  
Some people think that climate change is a far less disastrous threat than nuclear war because it is reversible. This is a gross misconception.

### A religious nature: On Islam and the environment: Interview with philosopher Seyyed Hossein Nasr

A theology professor from a different faith liked this interview with an Islamic religious authority so much, she considered making it assigned reading.

### Climate change makes for a hotter and meaner world

Interview with Naomi Klein  
Climate change is not just about things getting hotter, it's about things getting meaner and more divided. Still, the best-selling author of *This Changes Everything* sees cause for hope.

## Emerging Technologies

The gap between scientific progress in dual-use technology and humanity's capacity to grasp and control the related risks is an issue of increasing concern to some experts who have published with us in the past year.

### Emerging technologies and the future of humanity

Brad Allenby  
Emerging technologies are not the danger. Failure of human imagination, optimism, energy, and creativity is the danger.

### Is artificial intelligence really an existential threat to humanity?

Edward Moore Geist  
The extraordinary claim that machines can become so intelligent as to gain demonic powers requires extraordinary evidence, particularly since artificial intelligence researchers have struggled to create machines that show much evidence of intelligence at all.

### Learning from the Sony hack attack

Herbert Lin  
Let the most recent high-profile cyber assault guide the US government's planning for future strikes.

### The bioweapons convention: A new approach

Sonia Ben Ouagrham-Gormley  
In a welcome but little-noticed development, the United States recently encouraged fellow members of the Biological Weapons Convention to take a deeper interest in “tacit knowledge,” a key determinant of bioweapons development, but one that nonproliferation efforts have largely ignored.

### Stopping killer robots and other future threats

Seth Baum  
The campaign against fully autonomous weapons may be a road map for confronting tomorrow's dangerous technologies.



## Roundtables

This year, the Development and Disarmament Roundtable series examined issues ranging from plutonium reprocessing to lethal autonomous weapons, from nuclear modernization to the link between technology and climate mitigation. These complex, demanding themes cry out for expert treatment—but not the sort of expert treatment that simply makes you cry out. What's needed is seriousness enlivened by passion, command of the facts matched with a clarifying instinct. That can be a tough bill to fill, but the authors below delivered the goods.

### Climate: Just one more reason for Africa to slow its population growth

Alex Ezeh  
Nigerian demographer Ezeh argues that African nations—through improving girls' education, encouraging delayed marriages, and providing universal access to family planning—should seek to slow population growth. But climate change, he explains, has little to do with the wisdom of such policies. A compelling and deeply informative piece.

### Reprocessing in China: A long, risky journey

Zhang Hui  
Improbably, Zhang discusses China's plutonium reprocessing efforts in a way that makes you want to know what happens next. This piece is stuffed with information that you're unlikely to find elsewhere—but it's all in the service of a forceful argument that Beijing should put the brakes on its entire reprocessing project.

### How I changed my mind on reprocessing

Klaus Janberg  
Janberg, writing alongside Zhang, recounts his evolution from a young nuclear engineer convinced that “[b]reeder reactors and plutonium recycling would provide the world with unlimited cheap electricity” into

a mature man convinced that “[b]reeders without a commercial fuel cycle just don't make sense.” A disarmingly personal and charming piece of writing.

### Modernization and “zero”: Compatible tendencies?

Eugene Miasnikov  
Miasnikov offers a clear-eyed, subtly rendered argument: Nuclear modernizations are probably inevitable, but it's possible to structure them so that they don't interfere with disarmament in the long run. What's really worrisome, Miasnikov maintains, is that the United States will pursue ballistic missile defense and conventional precision weaponry without regard for threat perceptions in other nuclear-armed states.

### Hiroshima and Nagasaki: Lessons learned?

Akira Kawasaki, Mustafa Kibaroglu, and Suvrat Raju  
In this roundtable marking the most solemn of anniversaries, three authors reach the regrettable, unsurprising conclusion that the world has not absorbed the lessons of Hiroshima and Nagasaki. But then something out of the ordinary happens—a spirit of self-reflection emerges, a willingness to examine one's own nation and admit hypocrisy where it exists. A humane response to human tragedy.



## Nuclear Weapons

The *Bulletin's* extensive cast of top experts analyzed current and historical events in a panoply of wide-ranging articles across the nuclear weapons landscape. Here is a far-from-complete summary list of their best efforts:

### The harrowing story of the Nagasaki bombing mission

Ellen Bradbury and Sandra Blakeslee  
A typhoon was coming, the fuel pump failed, they had to switch planes, things were wired incorrectly, they missed their rendezvous, they couldn't see the primary target, they ran out of gas on the way home, and they had to crash-land. And the crew members of the plane tasked with the second atomic bombing of Japan had one other problem: The Fat Man atomic bomb started to arm itself, mid-flight.

### What would happen if an 800-kiloton nuclear warhead detonated above midtown Manhattan?

Steven Starr, Lynn Eden, and Theodore A. Postol  
Three top experts explain in overpowering detail what would happen if a standard Russian nuclear missile warhead exploded over New York City: At least 90 square miles of firestorm would extinguish all life and destroy almost everything. And that's not to mention the radioactive fallout.

### Iran's invisible opportunity

Amory B. Lovins  
The cofounder of the Rocky Mountain Institute explains how energy efficiency and renewable energy could move Iran from the nuclear path—and maybe even reinvigorate the Non-Proliferation Treaty.

### How the next US nuclear accident could happen

Hugh Gusterson  
When an 82-year-old nun with a heart condition and two confederates old enough to be AARP members can breach security at a supposedly impregnable storage facility for highly enriched uranium, you know you have a problem.

# 2015 Milestones

## The Next Generation Initiative Launched

The Next Generation Initiative was created to ensure that new voices, steeped in science and public policy, have a trusted platform from which to address the world's existential challenges. The Next Generation Initiative is generously supported by the John D. and Catherine T. MacArthur Foundation, scientists, members of the Leonard Rieser family, and donors who are dedicated to supporting tomorrow's scientific leaders and policymakers.

### Voices of Tomorrow

The program features new authors and rising stars who write with distinction about at least one of the *Bulletin's* core issues: nuclear weapons, climate change, the changing energy landscape, and threats from emerging technologies.

### 2015 articles

#### China's nuclear submarines: The end of "No First Use?"

Richard Woolgar-James  
Submarines armed with nuclear missiles give China a more credible nuclear deterrent, but undermine the credibility of China's "No First Use" pledge.

#### The nuclear verification technology that could change the game

Kelly Wadsworth  
Antineutrino detection could help monitor Iranian compliance with its nuclear agreement, and eventually transform nonproliferation worldwide.

#### Bad chemistry: ISIS and mustard agents

Gabrielle Tarini  
Chemical warfare is still alive and well in Syria and Iraq, because of an enduring belief among regional actors that chemical weapons will get the job done.

#### Bioweapons ... for dummies?

Zian Liu  
Ignore the hype. Novice biologists aren't likely to construct advanced weapons any time soon.

#### Drawing a line between conventional and nuclear weapons in China

David Cromer Logan  
Analysts believe that China operates conventional and nuclear missiles at the same locations, and under the same command systems, increasing the risks of nuclear war. Here's how to disentangle the two missile types without putting China at a strategic disadvantage.



### 2015 Leonard M. Rieser Award

The Rieser Award is the capstone of the *Bulletin's* Next Generation Initiative, recognizing outstanding emerging science and security experts passionate about advancing peace and security in our time. The award is given annually and is selected by the *Bulletin's* editorial team from among our Voices of Tomorrow authors.

The 2015 recipient was Moritz Kütt, a doctoral candidate in the Physics Department at the Technische Universität Darmstadt, in Germany, and a member of the university's Interdisciplinary Research Group on Science, Technology, and Security (IANUS). His thesis involves researching the role of open source simulation tools for nuclear disarmament and nonproliferation verification and developing an open source application that could be used for nuclear warhead authentication.

Kütt's award-winning essay, "Arms-control lessons from the Volkswagen scandal," examined the recent Volkswagen emissions test cheating scandal and what it means for arms control regimes.

### Communications Workshops

The *Bulletin* drew on its 70-year history to create a series of six workshops to connect experienced public communicators with emerging science and security experts. *Bulletin* editors engage outside journalists and scholars who speak to and mentor emerging science and security leaders (advanced graduate students, post docs, and assistant professors) who are interested in making their research findings accessible to policy leaders and the interested public.

The first workshop took place at the University of Chicago in November 2015, and next up is Stanford in May 2016 and then Washington DC in July.

## A New Publishing Partnership Announced

The *Bulletin* has chosen Routledge, a division of Taylor and Francis, to produce and increase the circulation of our signature subscriber-access digital journal. Leon Heward-Mills, Taylor and Francis Global Publishing Director, stated that "the *Bulletin* has been tackling critical global issues since its launch and we are delighted to welcome this important publication to our Politics and International Relations journals portfolio."

## Teleconferences Initiated

Because the *Bulletin's* mission is both public education and policy impact, we initiated a series of global conference calls in 2015 on the nuclear agreement with Iran and the Paris climate accords. Stakeholders from US government offices and national laboratories along with government representatives from Denmark, Italy, Israel, Kuwait, Australia, Canada and Chile joined experts from the International Atomic Energy Agency and the Norwegian Defense Research Establishment in the calls, which also included citizens and journalists. In 2016 we are experimenting with webcasts of these virtual gatherings.

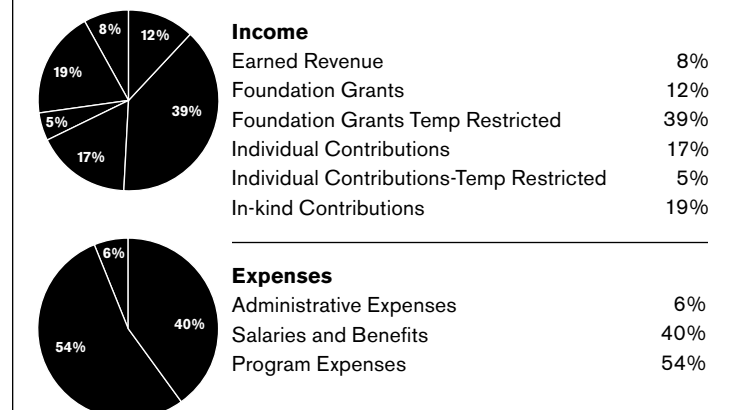
## On Display Soon in Chicago

The *Bulletin* and the Museum of Science and Industry (MSI) are creating a multimedia display to open in 2017 to engage the public, particularly young people, with the challenges and opportunities of the nuclear age. The working title of the display is "Turn back the Clock"

The display is based on the premise that science doesn't speak for itself. It needs informed advocates to help ensure that humanity can benefit from scientific progress and limit the risks. The display focuses on the intersection of science and policy around nuclear weapons, nuclear energy, and climate change, to inform visitors about the immediacy of these issues and engage their ideas and voices.

## Finances

Ordinary Income/Expense	2014	2015
<b>Income</b>		
Contributed Revenue		
Foundation Grants	510,000	332,638
Foundation Grants (Temp Restricted)	80,265	1,030,160
Individual Contributions	420,912	448,958
Individual Contributions (Temp Restricted)	0	141,442
In-kind Contributions	442,374	507,433
<b>Total Contributed Revenue</b>	<b>1,453,551</b>	<b>2,460,631</b>
Earned Revenue	189,372	211,271
<b>Total Income</b>	<b>1,642,923</b>	<b>2,671,902</b>
<b>Expense</b>		
Salaries and Benefits	688,496	747,750
Program Expenses	793,310	1,023,085
Administrative Expenses	99,966	108,389
<b>Total Expense</b>	<b>1,581,772</b>	<b>1,879,224</b>
<b>Net Ordinary Income</b>	<b>61,151</b>	<b>792,678</b>



# 2015 Rising Numbers

# 1,000,000

more page views than 2014

+79%

# 1,600,000

website visits in 2015

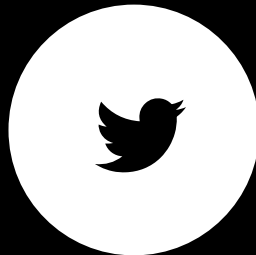
+84%

# 46%

audience from outside the US

# +56%

Twitter followers



# 3 new

cutting edge interactive tools:

- Domsday Dashboard
- Nuclear Notebook
- Nuclear Fuel Cycle Cost Calculator

That attracted

# 125,000+

page views

# +94%

Facebook followers



Increases continued in January 2016 when one Facebook video on the Clock Statement drew

# 700,000+

website visits

# 2015 in Gratitude

We extend our deepest gratitude to the board leaders, individuals, and institutions who made contributions between January 1 and December 31, 2015. Their names are listed here, with our sincere thanks for making everything we do possible.

## \$250,000-\$500,000

Carnegie Corporation of New York  
John D. and Catherine T. MacArthur Foundation

## \$100,000-\$249,999

Norwegian Ministry of Foreign Affairs

## \$50,000-\$99,999

Civil Society Institute  
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## \$25,000-\$49,999

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Invenergy LLC

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Nuclear Threat Initiative

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University of Chicago  
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