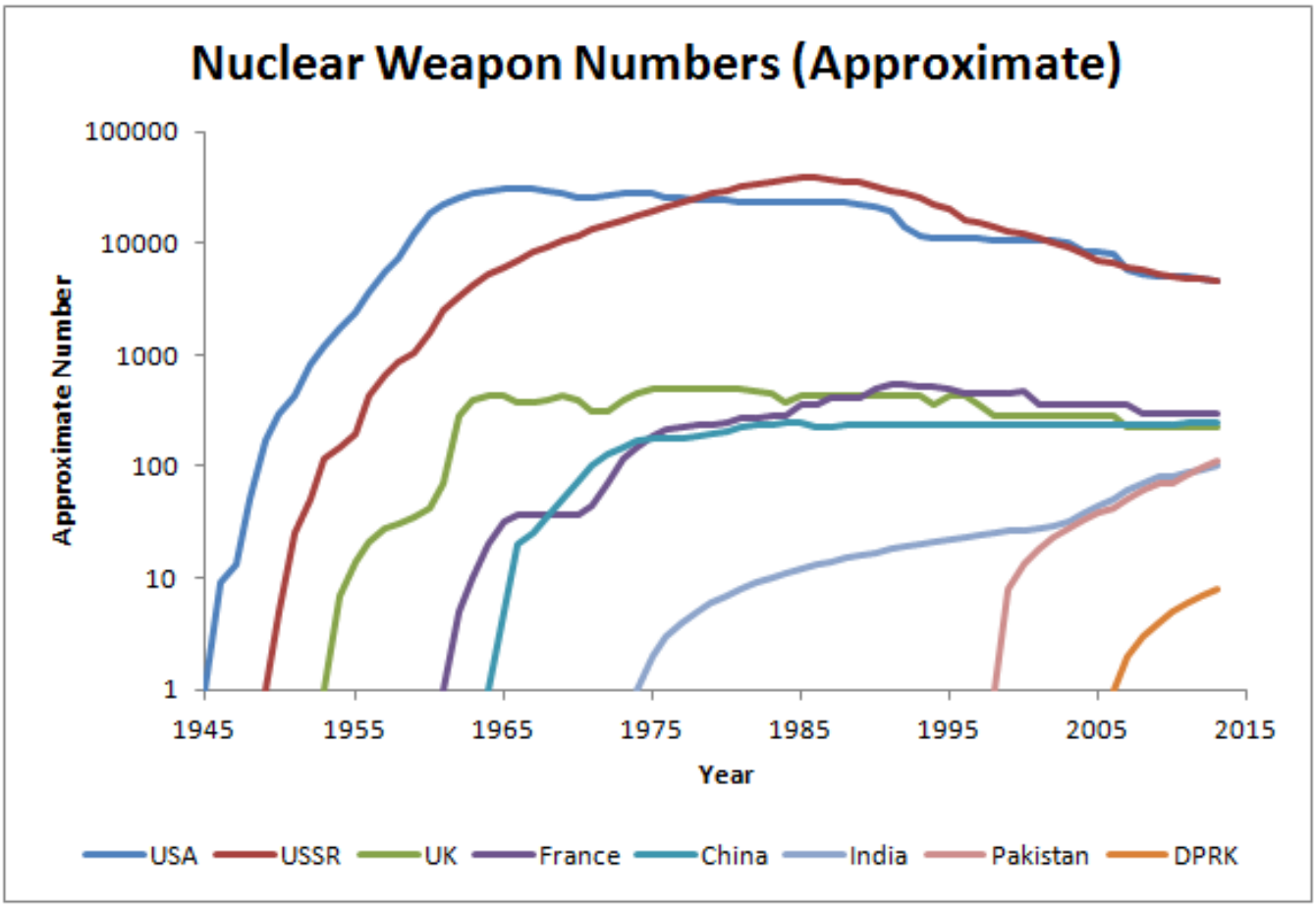


BOOK SYNOPSIS

'Nuclear Proliferation and Terrorism in the Post-9/11 World,' by David Hafemeister

Above: Numbers of nuclear weapons from 1945 to 2012 for eight nations. We define a weapon as either deployed or in reserve, giving the total stockpile. The 8 curves are plotted in the following order, left to right, keyed to the date of the first nuclear test for the state: US (2015 totals; 4650 stockpile, 2150 operational), Russia (5000 stockpile, 1800 operational), UK (225), France (300), China (250), India (90–110), Pakistan (100–120), Israel (80) and N. Korea (5–10). The logarithm of the number of nuclear warheads is used in order to display the large differences in numbers between states. The US curve peaked in 1965 and the Soviet/Russian curve peaked in 1985. The US and Soviet/Russian curves show the drop in numbers over time. [P. Corden and D. Hafemeister, *Physics Today*, April 2014. Pierce Corden and Derek Updegraff (AAAS), adapted for graphics from the warhead numbers from Hans Kristensen (FAS), 2014-15.]

THREE MAIN THRUSTS

Arms Control: "Both sides in the arms race are confronted by the dilemma of steadily increasing military power and steadily decreasing national security. It is our considered professional judgment that this dilemma has no technical solution. If the great powers continue to look for solutions in the area of science and technology only, the result will be to worsen the situation."

[Jerome Wiesner and Herb York, *Scientific American* 211(4), 27 (1964)]

Proliferation: "Pakistan will fight, flight for a thousand years. If India builds the (atomic) bomb… (Pakistan) will eat grass or (leaves), even go hungry but we (Pakistan) will get one of our own (atom bomb). We (Pakistan) have no choice."

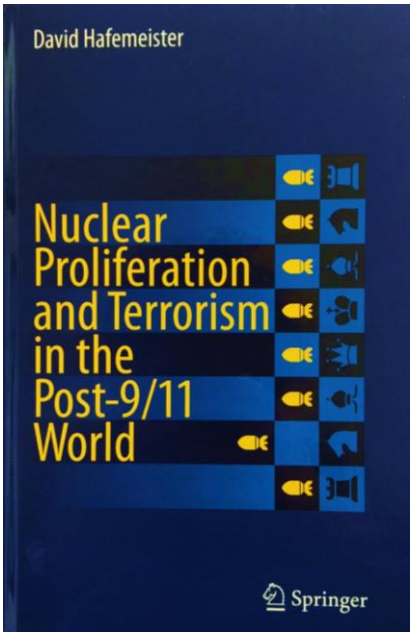
[Pakistani Prime Minister and Foreign Minister, Zulfikar Ali Bhutto, 1965]

Terrorism: "I am in charge of the 19 brothers…. I was responsible for entrusting the 19 brothers…. with the raids"

[Osama bin Laden, 23 May 2006]

These quotations point to the three main themes of *Nuclear Proliferation and Terrorism in the Post–9/11 World* (Springer, 2016).

1. ***Major–power arms race***: US, Russia, UK, France, China, and others (Ch. 1-7). This issue continues.
2. ***Proliferation of nuclear weapons*** to additional states: India, Iran, Israel, North Korea, Pakistan, and others (Ch. 8–11). Who will be next?
3. ***Terrorism after 9/11 attack:*** Fossil fuel explosives, dirty nuclear bombs, improvised nuclear devices, drones, cyber attacks, biological and chemical weapons, and more (Ch. 12–15). If ISIS had these weapons of mass destruction, they would use them.



I have a t-shirt that shows a picture of Earth's Western Hemisphere, with the caption, "Still in Beta?" There is much we don't know about our untested experiment on Earth. We do not have the luxury of doing accurate computer simulations to determine the future. What appears to be an excellent move can turn out to be horrible in the future. We can all suggest an event that should not have been done in the past, but continues to live with us in negative ways every day. The chessboard, illustrated by Julie Frankel, depicted on the cover of my book implies that logic is supreme. But the quote by Jerome Wiesner and Herb York tells us the opposite, that "this dilemma has no technical solution. If the great powers continue to look for solutions in the area of science and technology only, the result will be to worsen the situation."

The lack of permanence becomes evident when reading *Nuclear Proliferation and Terrorism*. Cal Poly University in San Luis Obispo, California is a technocratic university, requires its students to take one upper–division course on *science and society issues* to graduate. One science and society course is only a beginning, but

it is a journey that must begin somewhere. The impacts from technology are huge. It pays for society to use technology assessments in order to understand what the future may hold.

This text is intended for upper division undergraduates (juniors and seniors) of all majors, including the liberal arts. It also is a useful reference book, but that is not its primary purpose. The chapters contain ample homework questions and seminar topics. It is a lone *text of this type*. The text describes technical devices, but without the use of mathematics; it is reduced to that which would be needed by a foreign–service officer in the State Department with a bachelor's degree in history. Foreign service officers are expected to be knowledgeable in many areas, from culture to history to politics to economics to geography to military affairs, with basic science. Finally, we are human beings trying to learn, no matter what your major or your role in life.

This text evolved over my 43 years of teaching a course at Cal Poly that has been variously named *the Nuclear Arms Race* or *Nuclear Weapons Proliferation and Terrorism in the Post-9/11 World*. Most students were initially concerned about having to learn some science in a general education science class. They calmed down when they learned that the students were going to present 25% of the course material in the seminar portion of the class. My students knew little of these matters, but they were able to look quite sophisticated with the help of Google and Wikipedia. And they liked to hear each other deliver seminars to the class as it became less threatening. We do have a society that is shy about science and more lecturing won't solve it. A four–minute talk once a week is not a great burden. If you can't verbalize the issue, you won't understand the issue.

STRATEGIC ARMS CONTROL (CH. 1–7)

The strategic arms race is not just an issue from the past. If nations are too isolated, they will consider reaching for more nuclear weapons to feel more secure, even when these weapons may in fact make them less secure. At one point, there were 70,000 nuclear weapons between the US and the Soviet Union. This number cannot be justified on the basis of science and logic. With a lack of agreement between Obama and Putin during the Ukraine invasion, it is difficult to develop new agreements.

Politically, it is important to be strong and strident. It is difficult for someone to run for president if it appears that the candidate would compromise too easily. If we display more military prowess, Iran would probably ignore it. When we show strength through financial sanctions, Iran does not ignore us. But alternatively, mindless rigidity maintains the status quo, as the decades pass. If we display unbending strength, that does not necessarily mean that Iran will do all that we desire.

Chapter 1 describes the historical underpinnings of nuclear weapons. The main issues are summarized, along with a lengthy chronology for those wishing for more details.

Chapter 2 describes fission and fusion weapons, and some that are more exotic. Impacts from nuclear explosions are discussed, along with the Stockpile Stewardship program, meant to ensure confidence in the reliability of weapons under a global testing ban.

Chapter 3 describes nuclear reactors; their proliferation, safety issues and nuclear waste. The biological effects of low-dose radiation are also discussed.

Chapter 4 describes missile systems and the triad of land–, sea–, and air–based nuclear weapons. The potency of nuclear weapons is defined in terms of their parameters.

Chapter 5 describes ballistic missile-defense systems, including President Reagan's *Star Wars* program and the present approach to defend against smaller attacks or accidental launches.

Chapter 6 describes the complex fabric of arms control treaties, including the ways to monitor compliance with the terms of treaties.

Chapter 7 describes the wind–down of the Cold War with the Soviet Union. The annexation of Crimea by Russia in 2014 and other events show problems between the East and the West.

PROLIFERATION OF NUCLEAR WEAPONS (CH. 8–11)

In 2015, seven decades after Hiroshima and Nagasaki, there are 9 generally recognized nuclear weapon states: the P5 of the Nuclear Non–Proliferation Treaty (China, France, Russia, the UK, and the U.S.) and the four *defacto* nuclear states (India, Israel, North Korea, and Pakistan). Over 27 nations started nuclear weapon programs, although many of these have stopped. Will we be able to constrain states striving to become nuclear weapon states in an era of easier uranium enrichment? It could be worse than nine nuclear states, if you consider that over 27 nations began this journey.

Chapter 8 describes the incentives and disincentives of various nonproliferation policies. The first six Articles of the NPT are described, revealing a more complex situation than bilateral arms control. Sanctions can only be effective if the vast majority of nations participate.

Chapter 9 describes proliferation technologies, particularly the enrichment technologies, monitoring technologies, and the missile technology control regime.

Chapter 10 describes the individual proliferation paths of 27 nations. It is a race between technology transfer, the adoption of the NPT/IAEA regime, or a new regime.

Chapter 11 describes the intersection between the NPT Treaty and the Comprehensive Nuclear–Test–Ban Treaty. The P5 called for an NPT without a time limit. The NPT regime would be strengthened if CTBT entered into force without a time limit.

TERRORISM AFTER 9/11 (CH. 12–16)

The 9/11 destruction of the Twin Towers in New York City and the attack on the Pentagon were horrible events. But, the invasion of Iraq in 2003 was a flawed response. The new world of the Department of Homeland Security and the more invasive examination of email and phone messages, as allowed by the Foreign Intelligence Surveillance Act and the Patriot Act, is now a regular fixture in our lives.

Chapter 12 describes vulnerabilities and responses to terrorism. Some of these responses are useful, but others are not, as terrorists learn to change their modus operandi, by using advanced encryption and by avoiding cell phones and email.

Chapter 13 describes radioactive terrorism from radiological dispersal devices (dirty bombs), improvised nuclear devices, improvised explosive devices, and drones. Significant nuclear terror events have not happened over the past 15 years, but the attack on Paris in 2015 shows they can happen with just bullets and smaller explosions.

Chapter 14 describes cyber terrorism, which includes the Stuxnet virus that attacked Iran's centrifuges, denial–of–service attacks, phishing to gain access to internet materials, and attacks to digital infrastructures. Measures are suggested to strengthen the Internet, but these are only as strong as their weakest links.

Chapter 15 describes biological and chemical weapons. The current treaty regimes have made the use of biological and chemical weapons more difficult. Most primary nations (not including Egypt and Israel) are members of the Biological and Chemical Weapon Conventions. But the relative ease of using BW/CW, even if ineffective, makes them a concern. New BW research can complicate this. Chapter 16 is a summary.

QUO VADIS PLANET EARTH?

The United States is the world's remaining military superpower, but with limited financial assets. There will be shifts in how it deals with the global community. What issues will be decided on our watch?

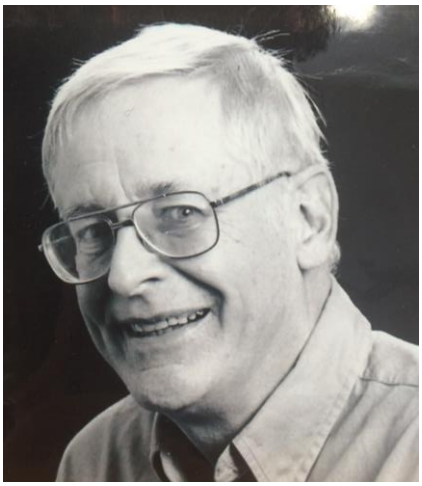
- *Will China equal and then eclipse the U.S. militarily?*
- *Will drones give a lasting edge to some U.S. attacks?*
- *Will cyberwar and struggles over big data lead to stable rules of conduct on information technology?*
- *Will rights to privacy be diminished?*
- *Will the war on terror be a never–ending war?*
- *Will the number of nuclear weapon states expand or contract?*
- *Will the U.S. act unilaterally or multilaterally?*
- *Will reduced dependence on Middle–East oil reduce U.S. military in that region?*
- *What international structures can reduce terrorism by weapons of mass destruction and by conventional terrorism?*
- *Can a two-tiered world of nuclear–weapon states and non–nuclear–weapon states remain viable in the asymmetric NPT?*
- *Will Iran and the P5+1 constrain Iran's nuclear program? Will the Sunni nations be satisfied with the result?*
- *Can religious extremism of the Islamic State be constrained?*
- *Will Russia's foray into Ukraine prevent diplomatic and nuclear cooperation between Russia and the US/EU?*

The advance of technology makes democracy more difficult. Jack Gibbons, former director of the Office of Technology Assessment (1979–1993) and Presidential Science Advisor (1993–1999), was concerned that the public was losing faith in science. His 2003 comments reflect this, as he called for strengthening the role of science to help resolve social ills:

> *"People thought of science as a cornucopia of goodies. Now they have to choose between good and bad….I hope rationality will triumph….but you can't count on it."*

I believe that science and technology, acting together, is a main driving force of history. I hope that *Nuclear Proliferation and Terrorism in the Post-9/11 World* can be useful in presenting facts on the world that we live in.

…Read on for an exclusive Q&A with Dr. David Hafemeister



AUTHOR SPOTLIGHT

By Allison Feldman, FAS

Dr. David Hafemeister *is a visiting scientist at the Federation of American Scientists during 2015–16. He is an emeritus professor of physics at California Polytechnic State University. He was formerly employed at the US Senate Committees on Foreign Relations and on Government Affairs, the US State Department, the US Arms Control and Disarmament Agency, the National Academy of Sciences, Stanford, Princeton, and MIT. He was the technical-staff lead for nuclear testing issues in the US State Department (TTBT, 1987), the Senate Foreign Relations Committee (1990–92, TTBT, PNET, and 1992 test moratorium), and the National Academy of Sciences (2000–2, Study on Technical Issues Related to the CTBT). He also worked on the ratification of START and CFE at SFRC. Dr. Hafemeister holds a B.S. in Mechanical Engineering from Northwestern University and both an M.S. and Ph.D. in Physics from the University of Illinois.*

1. What made you want to become a scientist or engineer? Were there any particular people or experiences in your youth that inspired you?

At age 18, I didn't know what "science" was. When I took my first job as a design engineer on the 12 BeV accelerator at Argonne National Lab, I didn't choose science as a career for noble reasons. But while there, I met scientists and engineers who did research and I was inspired to follow their role of creatively looking for solutions – I wanted to be like them. After a year, I resigned and went to grad school to study physics. I studied physics with a passion and chose to make it my career.

2. What do you believe is the single, greatest challenge that scientists or engineers have in conveying information to the public and political spheres?

There are many challenges. We must keep our integrity and not jump into overly strong argumentation to be too persuasive. We must not be dull and repetitious; we have to look towards common sense solutions that make sense from many directions. Those that use specious arguments should be confronted. FAS covers the issues with good style and accuracy.

3. What do you believe is FAS's greatest strength and how can the organization take advantage of it?

In answering this, I date back to being the Secretary Treasurer for the Pittsburgh Chapter of FAS in 1966-69. In my view, science is the driving force of history and will affect both the survival and destruction of the Earth. It is our task to study the science impacts, so as to reduce their impacts on the Earth. Many times an issue becomes politicized before it is ready to be discussed. It is easy for everybody to be politically locked into a position before all the facts are known. The nuclear test ban treaty is an example of that. It is hard to find rational people that desire a nuclear testing race between the US, China, and Russia. By avoiding the CTBT, we are doing just that. The fact that FAS represents a huge number of Nobel laureates and other prestigious people helps raise the curtain and shed light on this situation.

It is easy to see that mistakes with science have been made in the past. When extolling the dangers of the Soviet ICBMs, some senators exaggerated the Soviet prowess because of their missile size. The models that represented ICBMs were very graphic. But, it is the accuracy of the missile that is far more important than the yield. If the accuracy of a missile was enhanced from 200 meters to 100 meters, the yield could be reduced by a factor of 8 for the same destructive effect on a silo. Thus, a missile warhead could be reduced from 1 Mt to 125 kt if its accuracy was improved to 100 m. In other words, the small Minuteman and Trident were more capable than the large SS-18 for destroying silos. Those who wanted to put extra fear into our hearts about the Soviets used the argumentation that exaggerated the effect of the size of the missile. Another example of exaggeration was that of the beam weapons that were going to defend the US. The beam weapons were made to look stronger than they were. One needed some kind of technical background to discuss countermeasures and beam prowess in terms of mirror diameters, distance to target, hardness of target, and so forth. FAS has the expertise available from its membership to keep an open mind on topics and examine all sides. What more can you ask?

4. Tell us about a time in your career where you were asked to do something unexpected/you weren't exactly prepared for. How did you overcome those challenges?

As a new science Congressional fellow in 1975, I was asked by Sen. John Glenn and the Senate Government Operations Committee to organize hearings on the diplomatic effects of the 1974 Indian nuclear explosion and US policies. At that time, my main responsibility was to work with the Senate Energy Committee after the oil embargo of '73-74. But the staff person who was to arrange the Indian bomb hearings broke his shoulder and I was given the responsibility to arrange the hearings. In other words, my future background in diplomacy with the Senate Foreign Relations Committee and the State Department happened because of someone else's misfortune. So, you never know where history is going to take you. I did not have a strong background in nuclear history at that point, but I jumped in and invited David Lilienthal, Hans Bethe, and Herb York to be witnesses, with legislation and treaties following from that.

5. You served as a member of the FAS National Council from 1989-92 and again from 1994-98. What were your primary responsibilities in this role?

My most interesting assignment was to travel with the joint US–Soviet scientists and generals to Moscow and Kiev in 1991 and 1992. At the time, I was working on CFE and START in the Senate Foreign Relations Committee. A little-known fact is that the NGO community, led by Frank von Hippel of FAS and Tom Cochran of NRDC, was ahead of the diplomatic game of the State Department, my former employer. The science approach quickly unveiled the problem that the Soviets didn't know how much nuclear material they had and how they were going to protect it. On this trip, in 1991, Minatom Minister Viktor Mikhailov requested financial help to build a large facility near Tomsk to store excess weapon-usable materials under secure conditions. In January 1996, US Secretary of Defense William Perry and Mikhailov agreed on the construction of a storage facility for excess weapon-usable fissile materials at Mayak (Chelyabinsk-65). These facts were quickly deduced on the FAS trip. The new Russian Federation needed help in this area and it was transmitted to our government by way of the NGO community. The back channel worked very nicely. The State Department has enhanced their science-diplomacy skills since those days.

6. What advice would you give scientists and other technically trained people in how to apply their knowledge and experience to societal issues and/or to educate policymakers?

The universities should play a larger role in this area. There is very good science to talk about and we have to find ways not to scare the unscientific listener. The seminar approach has worked for me, in order to involve the students more. But they need a little more hard work and patience as well. At Cal Poly, you need one upper-division science

and society course chosen from the Schools of Science, Engineering, Architecture, or Agriculture. Most universities look the other way and do not require such courses.

7. What advice would you give someone about breaking into your field or the scientific and technical worlds in general?

Please consider a career in science and public policy. This could vary between policy work, design work, legal work, or other topics. It entails much more than basic science. I feel blessed by the wonderful people I've met, coming from the many different sectors of society. It finally does come down to the realization that science means knowledge, not just $E = mc^2$. You would think that science and public policy, being important topics, would have a deep bench of workers in Washington doing this. But the bench is somewhat narrow and it is not that difficult to learn to get something accomplished. I started out just teaching the class on arms and energy matters in California and ended up with FAS in Moscow on the last days of the Soviet Union. So, you never know where life will go.

8. What are the top issues that FAS should focus on in the next five years?

Now that is a good question. I think if we could limit destabilizing military technologies, we will have done a lot. The technologies scheduled to be built must be analyzed with technology assessments. I love my solar collectors on my roof, while I drive my electric car and live 50 miles from 0.9 GWe of solar power. But I also know that to replace over 50% of US electrical power with photovoltaics is not as easy as "falling off a log" and it will take hard work.

9. Complete this sentence: We need science because…

…Science and the humanities, working together, is the only way we will be able to find a stable solution for our Earth. The science process is extremely important in public policy matters. Under this situation, we are to keep an open mind, quantify what we can, avoid exaggerations and falsehoods, and compare the results of the various options. We should not always be looking for political winners, but we should look for solutions that reflect wisdom. The Einstein statue in Washington's Mall bears this inscription:

"The right to search for truth implies also a duty; one must not conceal any part of what one has recognized to be true."

This says it all. We must avoid exaggerations and we must not cover up issues that undercut the argument we are trying to make. It is the true test for a scientist to grow by in order to avoid becoming a political hack.

This *Author Spotlight* is an exclusive spin-off of *Scientist Spotlight,* a regular installment that features Q&As with prominent FAS-affiliated scientists and engineers. Read up on past features here.