

PHYSICS & SOCIETY

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From the Editor

We are pleased to have more contributions than usual in this issue. These include articles on our recent Forum Burton and Szilard award winners (Shirley Jackson and Zia Mian respectively). We also have a contribution by Peter Somssich, who is both a physicist and a member of the New Hampshire legislature. I find the information I get from people that have, so to speak, a foot on each side of the Physics & Society question extremely fascinating. There are three more articles, plus two book reviews: please see the “In this Issue” Table of Contents for details.

In the News section, we have the complete list of talk titles in the Forum sponsored or co-sponsored sessions at the upcoming March and April APS meetings. I won’t be able to make it to Denver, but hope to see you many of you in Boston.

Our Media Editor, Tabitha Colter, whose last name was spelled incorrectly in the News item of the last issue (my deepest apologies!) continues to expand our media presence. Send your suggestions to her at tabithacolter@gmail.com.

We are always looking for contributions from our readership. As explained in the October 2016 issue, we have some length guidelines (which I routinely waive): Contributed articles (up to 2500 words), letters (500 words), commentary (1000 words), reviews (1000 words). There are no minimums. Send contributions to me, except for reviews, which should go

to the reviews editor directly (ahobson@uark.edu). Contributions are reviewed for style and appropriateness, but their content is not peer reviewed and opinions given there are the author’s, not necessarily mine, nor the Forum’s. I am very open as to what is appropriate. Controversy is good. Only articles consisting purely or very largely (as opposed to incidental to the topic) of political opinions and advocacy, or tainted by ad hominem invective, or containing utterly unsound science of the “the world was created a few thousand years ago” variety will undergo summary editorial rejection.

Oriol



Oriol T. Valls, the current P&S newsletter editor, is a Condensed Matter theorist.

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FPS Invited Speaker Sessions at March and April 2019 APS Meetings

FPS Invited Speaker Sessions at March 2019 APS Meeting

The Future of U.S. Nuclear Forces: What Do We Need?

(Boston, March 7, 2:30 - 5:30 pm - chair: Frank von Hippel)

- Steve Fetter (U Maryland) - *Nuclear Modernization, ICBMs, and Launch On Warning*
- Lisbeth Gronlund (UCS) - *US Plans for New Nuclear Warheads*
- Richard Garwin (IBM) - *Current Nuclear Weapons Issues, and Sid Drell's Contributions*
- Stewart Prager (Princeton) - *Engaging the Physics Community in Nuclear Threat Reduction*

The Politics of Science Advising

(Boston, March 8, 8:00 - 11:00 am - chair: Allen Sessoms)

- John Holdren (Kennedy School; President Obama's Science Advisor and head of OSTP) - *Speaking Science to Power: Providing S&T Advice to Governments*
- Celia Mertzbacher (ORNL; former Executive Director, PCAST) - *Federal Policy Making: Inside and Outside Perspectives*
- Andrew Zwicker (Princeton; New Jersey Assembly) - *Advice from a Scientist-Policy Maker on Giving Advice to a Policy Maker*
- Nathan Phillips (BU) - *Science Legislative Fellow Advisors for State Legislatures*

Iran, North Korea, and Nuclear Proliferation

(Boston, March 8, 11:15 am - 2:15 pm - chair: Joel Primack)

- Zia Mian (Princeton) 2019 Szilard Lectureship Award recipient - *Scientists and Today's Struggles Against Nuclear Weapons: What Would Szilard Do?*
- Scott Kemp (MIT) - *Iran, North Korea, and the Renewed Challenge of Proliferation*
- Alex Glaser (Princeton) - *Verification of Denuclearization*
- Rachel Carr (MIT) - *Can Neutrino Detectors Strengthen the Nonproliferation Regime?*
- Frank von Hippel (Princeton) - *Strengthening the Non-proliferation Regime*

FPS Invited Speaker Sessions at April 2019 APS Meeting

New Energy Technologies & Policies

(Denver, April 15, 10:45 - 12:33 - chair: Richard Wiener)

- Dan Kammen (UC Berkeley) - *New Energy Technologies and New Energy Policies*
- Adilson Motter (Northwestern) - *North American Power-Grid Network: Failures and Opportunities*
- Amory Lovins (Rocky Mountain Institute) - *Integrative Design for Radical Energy Efficiency*

New Challenges to International Science Collaborations

(Denver, April 13, 13:30 - 15:18 - chair: Anna Quider)

- Amy Flatten (APS Director of International Affairs; staff, APS Task Force on Expanding International Engagement) - *Long-term Strategic Planning for APS International Activities*
- Bill Colglazier (Science Advisor to the Secretary of State in the Obama administration, now at AAAS Center for Science Diplomacy) - *Challenges and Opportunities for International Science Collaboration over the Next Ten Years*
- Karla Hagan (2015 APS congressional fellow and current Senior Policy Advisor for Science and Innovation at the British Embassy in DC) - *The US-UK Science Collaboration Landscape: Status and Opportunities for the Future*

FPS Prize Session

(Denver, April 14, 10:45 - 12:33 - chair: Joel Primack)

- Shirley Jackson (RPI) - *Burton Forum Award Speech*
- FPS Luncheon 12:45 - 1:30

Secrecy and Espionage in Science

(Denver, April 13, 15:30 - 7:18, co-sponsored with FHP - chair: Paul Cadden-Zimansky, FHP)

- Alex Wellerstein (Stevens Institute of Technology) - *Secrecy and the Control of Science and Technology: Lessons from History and Sociology*
- Audra Wolfe - *Freedom's Laboratory: The Cold War Struggle for the Soul of Science*
- Doug O'Reagan (MIT) - *Allied Scientific Espionage and the Exploitation of German Technology after the Second World War*

Attracting young people to Science and Science Policy

(Denver, April 13, 10:45 - 12:33, co-sponsored with FECS - chair: Kevin Ludwick, FECS)

- Meredith Drosback (AAAS SciLine, Chair APS Cong Fellow selection committee, former APS Cong Fellow) - *Opportunities in Public Engagement: Sharing Your Scientific Expertise with Policymakers and the Media*
- David Maiullo (Rutgers) - *Physics for All: Using Physics Demonstrations to Both Excite and Educate the Public in Science and Science Policy*
- Brian Jones (CO State U) - *A Warm Planet in a Cold Universe: Making Climate Change Concepts Accessible (and Acceptable) to a Wide Audience*

Detecting and Protecting the Earth from Earth-Crossing Asteroids

(Denver, April 16, 10:45 - 12:33, co-sponsored with DAP - chair: David Gerdes, UMich)

- Amy Mainzer (JPL) - *Finding Near Earth Objects from Space with NEOWISE and NEOCAM*

- *Finding Near Earth Objects from the Ground with ZTF and LSST*
- Defending Earth: Lindley Johnson or Lisa Pratt (NASA Planetary Defense Office) *Defending Earth From Asteroids*

Forum Election Results

The results for the election to the Forum's Executive Committee are in. Stewart C. Prager was elected Vice Chair. Tony Feinberg was re-elected as Secretary/Treasurer.

Julliette Mammei and Savannah Thais (both early career physicists) were elected to 3-year member at large terms

In the last election only 10.4% of the Forum membership

voted, a number that we would all like to see increased.

We thank all the candidates and all the voters for their participation. The nominating committee for next year's elections is chaired by Joel Primack and nominations should be sent to him, joel@ucsc.edu

ARTICLES

A Physicist Politician and Renewable Energy

Dr. Peter Somssich, New Hampshire State Representative

Considering how important technology is in our everyday life, I was glad to see that first APS member Russ Holt of New Jersey and then Bill Foster of Illinois became members of the United States House of Representatives.

I remember reading in the APS Newsletter a quote from Congressman Foster: "I have learned that there is a long list of neurons that you have to deaden to convert a scientist's brain into a politician's. When you speak with voters, you have to lead with conclusions rather than with a complex analysis of underlying evidence - something that is very unnatural to a scientist. You also have to repeat your main campaign message over and over again."

I wondered at the time if that is what you need to make yourself heard? But now that I am a New Hampshire State Representative in Concord, NH (not in Washington), I understand and agree with his comments completely. Taking that advice and making it work, however, is challenging.

In the NH House, unlike the US House, I am my own staff, research department and drafter of bills, while the only office I can call my own is my seat in Representative's Hall which includes a slot for mail. As a member of the Science Technology and Energy (ST&E) committee I do receive some minimal administrative support, but primarily I do my own work. During my first 2-year term NH Governor Chris Sununu issued an updated 10-Year NH Energy Strategy plan that concedes our state's near future to fossil fuels and commits NH to supporting and perhaps even increasing our dependence on

nuclear energy, specifically NH's only nuclear power plant, Seabrook Station in Seabrook, NH. In contrast to other neighboring New England states (and most of the world), this NH plan downplays the importance of energy efficiency and the role of renewable energy. The plan also ignores the fact that energy efficiency programs in NH are only minimally funded and that the Gulf of Maine is considered to be one of the best locations in the country to site offshore wind facilities.

When this plan was announced in April 2018, with no significant input from relevant NH state agencies, I decided that there needs to be an alternative plan that both highlights NH's in-state renewable energy resources and also attempts to identify pathways to reach 100% renewable energy goals in the future. Of course, this also had to be accomplished without the help of state resources or any staff help. After a bill that I sponsored to create a study committee that would inventory NH's renewable energy resources and identify possible options to reach a 100% renewable energy goal was voted down both in the ST&E committee and by the House, I decided to tackle the job that this bill was intended to do.

I recruited several members of the ST&E committee along with members of the business community, a total of 10 contributors plus myself. Each contributor was tasked with contributing a section for this white paper on a specific area connected to renewable energy about which they were knowledgeable. While I agreed to function as the editor each contributor was to submit a section of 2-3 pages length. I specifically promised

Energy Efficiency/ Year	Total R+C/I Electricity Use [GWh]	Total R+C/I Thermal Use [GWh]	Total Energy Elec+Ther Consumption [GWh]	Cum EE Savings [GWh]	Effective EE Savings incl. losses with x 2.5 [GWh]	Total Energy Use incl. Loss after Savings (based on 2016 Use) [GW]
2016 Data	11,000	45,107	56,107	0	0	56,107
2025 with 1% /yr. increase	12,031	49,333	61,364			
2%/yr. EE saving				9,705	24,261	37,102
2030 with 1%/yr. increase	12,644	51,849	64,494			
2%/yr. EE saving				14,729	36,823	27,672
2040 with 1%/yr. increase	13,967	57,274	71,241			
2%/yr. EE saving				24,050	60,125	11,116
2050 with 1%/yr. increase	15,428	63,266	78,694			
2%/yr. EE saving				32,480	81,200	-2,506

Table 1: Predications for Future RE-Energy Efficiency (EE)- Revised 11/30/2018, Ver. 4

contributors that I would not change their submissions and we all agreed that we did not have to all agree with each section of the white paper. Every contributor knew that they alone were responsible for the content of their section. Of course, trying to cobble together a cohesive paper that is both readable and that also covers all of the areas associated with renewable energy now and in the future is quite a challenge. To accomplish this, I invested 2 months of my summer vacation to research areas that were not addressed by others in the paper. While I was tracking down answers to many of my questions, it was my good fortune to established contact with Dr. G.P. Yeh of Fermilab, who in addition to authoring a useful review article concerning worldwide energy issues (“World Energy Transformation, July 2018, www.aps.org/units/fps/newsletters/201807/world-energy.cfm) was also gracious enough to provide me with answers to some of my basic questions.

The goal of our white paper was twofold: to inventory NH’s renewable energy assets and investigate how these assets could be maximized, and also to identify paths to a 100% renewable energy future for NH. This was not, and could not be a comprehensive or definitive document due to the constraints of time and expert resources. However, I attempted to use the various renewable energy related submissions, as well as information related to energy needs, to project into the future how NH’s energy needs could be met with a combination of in-state renewable energy assets and imported renewable energy.

The outcome was a 55-page white paper (www.psoms-sichnh.com, Links, State Issues) which included many recommendations and tables identifying energy needs and possible energy sources. Some of the recommendations of the paper to NH policy- makers were:

- Set more aggressive goals for NH’s Renewable Portfolio Standard (RPS), a goal of 25% by 2025 renewable energy

for electricity needs is too low a bar,

- Drive down Demand with increased energy efficiency programs,
- Fully fund low-income energy efficiency audits,
- Increase the net-metering cap, allowing more renewable energy generators to feed their energy into the grid and be properly compensated,
- Join other Atlantic coast states on the federal board that awards offshore wind energy leases,
- Join efforts to help create a nationwide carbon pricing system, expanding the current effort in New England of the Regional Greenhouse Gas Initiative (RGGI) states which would put a realistic price on producing energy with fossil fuels.

One of the tables from our white paper shows how modest energy efficiency measures can significantly reduce energy use, while a second table provides predictions from 2030 to 2050 of energy generation that could be available from different renewable energy sources.

Table 1 demonstrates the impact of energy efficiency improvements reducing energy use by 2% each year, while at the same time allowing for overall energy use to rise by 1% a year. The calculations in this table were very simple and straightforward with the results good approximations that come close to numbers that a more sophisticated calculation would provide.

In this table the abbreviation R refers to residential use, while C/I refers to commercial and industrial use. Using data from 2016 which includes 11,000 [GWh] of electricity energy use and 45,107 [GWh] of thermal energy use, the increase in energy use along with the reduction due to energy efficiency is shown from 2016 to 2050. Since the initial total energy in 2016 of 56,107 [GWh] includes the energy that is lost through

Energy Type / Year	Solar [GWh]	Onshore Wind [GWh]	Offshore Wind [GWh]	Small Hydro [GWh]	Large Hydro [GWh]	Biomass [GWh]	Total Energy All Types [GWh]	Total Electricity Energy Use as a % of 2016
2030	583.	10,547.	17,520	320.	3110.	876.	32,953.	300.
CF=1								
2040	1836.	87,600.	21,900.	701.	3110.	876.	116,023.	1054.
2050	3200.	118,672.	26,280.	701.	3110.	876.	152,839.	1389.

Table 8: Predictions for RE-Energy Type and % of Total Energy (based on 2016)

generation and transmission, amounting to approx. 60% of the fuel energy, only 40% of the potential energy is actually delivered to a user. So that if a user saves 1 Wh of energy, the amount of fuel energy saved is 2.5 times that amount, that is 2.5 Wh of fuel energy equivalent. That is why the 6th column is labelled “Effective EE Savings incl. losses with x 2.5, [GWh]”. The impact of both the increased energy savings and the increased energy use is listed in the 7th column resulting in the “Total Energy Use”.

The table shows that by 2025 the total energy use would only be 66% of the 2016 use, and would drop to 20% of the 2016 use by 2040, under the scenario proposed.

Table 8 lists predictions based on the contributions of the various types of renewable energy resources that NH could have available for electricity as a state, compared to electricity energy use in 2016 of 11,000 [GWh]. Since it is assumed that by 2030 battery storage will allow energy generators to provide energy all of the time using storage, a capacity factor of CF=1 was assumed. Table 8 also shows the potential by 2030 of NH generating as much as 300% of the 2016 electricity energy use, and even 1055% by 2040.

After the completion of the white paper, including sign-off by all contributors, a press conference was held at the NH State House on Oct. 12, 2018 with good state-wide media coverage. One important conclusion of our study was that our state should increase its focus on energy efficiency programs, while developing promising renewable energy resources such as offshore and onshore wind energy along with solar and large hydro energy. Small hydropower and biomass energy, while contributing less, serve other important needs of the

state, in particular fuel diversity along with environmental and economic benefits.

The white paper gave a number of political candidates the opportunity to refer to our material during their 2018 NH election campaigns. In addition, we are expecting that the new members of the ST&E committee will use our white paper as a starting point for planning actions on renewable energy issues in the near future.

During my undergraduate and graduate studies at the University of Heidelberg, Germany, our physics professors repeatedly underscored the message (perhaps because of the history of sciences in Germany) that as scientists we have a moral duty to ensure that our science is used primarily to improve people’s lives and not just for commercial benefit.

I believe that as scientists we are obligated to take the lead on scientific issues. Not necessarily to always insist that we are right, but to ensure that important scientific issues and facts are placed in front of the public and policy-makers for consideration and perhaps to help chart the future.

Fortunately, we still have quite a lot of credibility as a profession and the younger scientific generation seems to be very excited about the opportunity to help resolve climate change challenges, promote more renewable energy and energy efficiency and protect the environment for all of us. That is very encouraging.

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Copy of our white paper is available at: www.psoms-sicnh.com/ Links/State issues

Physics and Society is the non-peer-reviewed quarterly newsletter of the Forum on Physics and Society, a division of the American Physical Society. It presents letters, commentary, book reviews and articles on the relations of physics and the physics community to government and society. It also carries news of the Forum and provides a medium for Forum members to exchange ideas. **Opinions expressed are those of the authors alone and do not necessarily reflect the views of the APS or of the Forum. Articles are not peer reviewed.** Contributed articles (up to 2500 words), letters (500 words), commentary (1000 words), reviews (1000 words) and brief news articles are welcome. Send them to the relevant editor by e-mail (preferred) or regular mail.

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Physics and Society can be found on the web at www.aps.org/units/fps.

Leo Szilard Award (2019) for Zia Mian – Why We Must Tilt At Windmills

Pervez Hoodbhoy, Forman Christian College-University in Lahore, Pakistan, hoodbhoy@mit.edu

Nuclear weapons are back in fashion, arms control treaties are being torn up, and global peace appears more distant than ever. What can you do? Shut up because nukes are like furniture now and nobody really likes to waste time thinking about them? You could shrug your shoulders and say, well, the world will go on – and if doesn't, there's nothing I can do about it anyway. The other option is to rush the windmills. A few modern Quixotes keep trying. Even if they haven't succeeded, some have actually made a difference.

Leo Szilard, originator of the nuclear chain reaction and co-designer of the world's first nuclear reactor, must count among them. In his 1939 letter to Albert Einstein, he outlined the possibility of creating a new type of bomb drawing its explosive energy from within the nucleus. This was instrumental in starting off the Manhattan Project. But once Nazi Germany had been defeated, Szilard initiated a petition among fellow top scientists against using the bomb. The giants of physics – Oppenheimer, Fermi, Lawrence, and Compton – rejected it. So did the Project's management, which ensured that President Truman and Secretary Stimson never got to see the petition before August 1945.

Szilard and his colleagues failed to stop the Bomb; Hiroshima happened, then Nagasaki. In 1946, Szilard worked with Einstein to set up the Emergency Committee of the Atomic Scientists but the nuclear genie had floated away by then. Discouraged, many Manhattan scientists gave up and went back to academic research but a few held steady and continued to speak out. Convinced that survival of the planet was imperiled, they helped mobilize citizens into confronting the bomb. In the 1980's, massive anti-nuclear protests swept parts of Europe and the United States. From the old times onward, every generation of scientists has inspired the next and passed on its activism.

[Zia Mian](#), winner of the [American Physical Society's \(APS\) 2019 Leo Szilard Lectureship Award](#), is among those who received the baton and is now running with it as hard as he can. The Award recognizes outstanding accomplishments by physicists in promoting the use of physics for the benefit of society in such areas as the environment, arms control and science policy. His citation reads: “promoting global peace and nuclear disarmament particularly in South Asia, through academic research, public speaking, technical and popular writing and organizing efforts to ban nuclear weapons.”

Mian is passionate and articulate as he speaks to different groups of people within and outside the United States: “The nine nations of the world placing this sword over the life of every person on the planet must change their conduct. Nuclear weapons states should take the weapons off of alert status, lower their numbers, bring the Comprehensive Test Ban Treaty into force by ratifying it, lower the operational

status of the weapons, decouple the warheads from delivery vehicles, strengthen the treaty verification and inspection institutions, and expand the current nuclear weapons free zones which make the Southern Hemisphere virtually nuclear weapons-free.”

At Princeton University, where he has been since 1997, Mian co-directs (with Alexander Glaser) the Program on Science and Global Security (PSGS) at the Woodrow Wilson School. He also directs the Program's Project on Peace and Security in South Asia and is co-chair of the International Panel on Fissile Materials, a group supported by PSGS and comprised of nuclear experts from 16 countries that works to end all production of nuclear weapons materials and eliminate existing stockpiles worldwide. He is the co-editor of *Science & Global Security*, the international journal of arms control, disarmament and nonproliferation science, based at the University.

Mian's advice is often sought at international forums such as those that agreed to the [Treaty for the Prohibition of Nuclear Weapons](#) agreed upon in 2017 by 122 countries at the United Nations. Mian and collaborators at Princeton started the Project on Peace and Security in South Asia – for which Mian has been setting the research agenda every year since 1997. This project is the only one of its kind in the world, bringing physicists from India and Pakistan together to work on technical arms control issues and nuclear energy issues. The project was highlighted by *Nature* in its 10 January 2008 editorial, calling for scientists to become more involved in addressing questions of nuclear disarmament and nonproliferation. It picked out PSGS's South Asia project as an example of the kind of collaboration that is needed.

I first met Zia in 1983 when, prior to his PhD from the University of Newcastle, he joined Quaid-e-Azam University in Islamabad as a lecturer. Not unusually for a person of Pakistani origin who grew up in Britain, he wanted to connect with his roots. The explosion in the 1980's of public worry about nuclear weapons, expressed through large public demonstrations in Europe and the United States, had persuaded this young physics student that he needed to play his part.

This period also happened to be the time when Pakistan was surreptitiously engaged in making nuclear weapons. Only a handful of Pakistanis then (and, regrettably, now as well) felt that such weapons were immoral and needed to be opposed. Zia quickly became a convert and joined our little group of anti-nuclear academics, led by my physicist colleague A.H. Nayyar. He gave the first lecture on the concept of nuclear winter in the QAU physics department in 1985.

Pakistan then was under the boot of dictator General Zia-ul-Haq. It was a period of intense political and cultural repression but, as a very junior lecturer in the Earth Sciences

department, Mian remained undaunted by the hierarchical and authoritarian setting. He returned to Britain for a PhD in 1986 but, after he had completed his post-doc, some of us persuaded him to return to Pakistan in 1993 to work on arms control issues. Thereupon, in 1995, Mian edited the very first book on Pakistan's nuclear program. For this he, and the organization that published it, had to face harassment by the authorities.

Mian eventually decided to settle in the US, working initially for the Union of Concerned Scientists. There, over the years he acquired a reputation of being a sort of guru for those working on global nuclear disarmament, as well as that in South Asia. He has co-authored scores of articles and books on these subjects with a very diverse group of researchers and activists, including myself. In 2001 he and I produced a video documentary, "Pakistan and India under the Nuclear Shadow". It was the first documentary – and still the only one from Pakistan – that is critical of South Asia's nuclear race. It was followed by a second documentary, "Crossing the Lines – Kashmir, Pakistan, India" which is again the only one from Pakistan that attempts to look at a conflict that has consumed well over 100,000 lives. In my edited book "Confronting the Bomb – Pakistani and Indian Scientists Speak Out", Zia is author or co-author on 8 out of the 17 chapters.

Is it important to be a physicist to be effective in creating awareness of nuclear issues? Once upon a time it absolutely was – the Manhattan scientists were listened to attentively in the years after 1945, and the Pugwash Conference achieved

celebrity status because its membership included both US and Soviet nuclear scientists who had worked on weapons. But that time is well gone; with the passage of decades the making of nuclear weapons has become far simpler and does not represent a high level physics challenge. Nevertheless, knowledge of basic physics is vital for understanding important technical issues related to production, development, and delivery matters. Committees concerned with international policies to reduce stockpiles and end production of plutonium and highly enriched uranium (the key ingredients in nuclear weapons) seek technical advice from experts with a physics background.

No one knows this better than theoretical physicist and citizen-scientist Frank von Hippel, founding director of PSGS and now emeritus professor of public and international affairs at Princeton University. A former assistant director for national security in the White House Office of Science and Technology, and with a lifetime of involvement in nuclear disarmament issues, Hippel had recruited Mian to work in his Princeton group.

It turned out to be a happy choice; the baton continues to move forward: "Mian has carried on the great tradition pioneered by Szilard", Hippel wrote to me after the award was announced, "of warning the public of the danger of nuclear arms races and making creative suggestions to concerned leaders for how to mitigate and ultimately control the danger."

Dr. Shirley Ann Jackson: 2019 Recipient of the Burton Award

Ruth Howes, Ball State University

As most members of the Forum on Physics Society already know, the recipient of this year's Burton Award "For distinguished application of her knowledge of physics to strengthen the use of nuclear power as Chair of the Nuclear Regulatory Commission, advance education as President of Rensselaer Polytechnic Institute and render broad service to government, charitable and corporate boards and committees" is Dr. Shirley Ann Jackson.

Dr. Jackson has a history of firsts as an African American woman physicist (only the second woman of any race to earn a Ph.D. from M.I.T. where her dissertation was in theoretical particle physics), first woman and first African American to head the Nuclear Regulatory Commission, and as the eighteenth president of Rensselaer Polytechnic Institute, the first woman and the first African American to lead a

major research university as well as the first female African American to receive the National Medal of Science. In addition to her list of firsts, Dr. Jackson has served the science community as president of the American Association for the Advancement of Science and the National Society of Black Physicists and as a member and vice chair of the President's Council of Advisors on Science and Technology. Throughout her career she has worked to increase the numbers of women and African Americans in all STEM fields and physics in particular. She has received numerous awards including the Richtmeyer Memorial Award from the American Association of Physics Teachers as well as numerous honorary doctorates. It is difficult to imagine a better-qualified candidate for the Burton Award.

Shirley Ann Jackson was born August 5, 1946 in Wash-

ington, DC to Beatrice and George Jackson (American Men and Women in Science). Her father started working in his senior year in high school following his father's death and then served in a segregated unit during World War II where he saw action in Normandy where he won a bronze star for figuring out how to repair the landing vehicles that carried troops ashore on D-Day thanks to his mechanical ability. He allowed the young Shirley to spend time with him on his projects and strongly encourage her education particularly in science. Her mother taught all her children, including Shirley, to read before they entered kindergarten. Both parents obviously encouraged education. Her father used to tell her, "Aim for the stars so you can reach the treetops." She used to do experiments beginning with the circadian rhythms of the bees in her backyard and she exhibited leadership in organizing the neighborhood children to sweep the sidewalks before the city swept the streets. In 1954, the Brown vs. the Board of Education opened nearby public schools to African American children so Jackson was able to take an accelerated program beginning in sixth grade. She graduated as valedictorian of Roosevelt Senior High School in 1964. (Bryant)

The following fall, Shirley Jackson enrolled at MIT in order to pursue her interest in science, one of two African American women students at the Institute. She lived in a new women's freshman dorm. She remembers that her classmates did not welcome her since at that time there were fewer than 20 African American students enrolled at MIT (O'Connell). As she worked on her first problem set in physics, she noticed the other women in her class working their problem sets in one of the common areas of the dorm. She opened her room door and walked to the group telling them that she had already worked half of the problems and asked to join the group which told her to "Go away!" She went back to her room and cried before she began solitary work and finished the assignment. She needed that trust in herself and her work ethic because other students refused to sit next to her in class or in the dining hall (Schaffer). In order to reduce her isolation, Jackson decided to become involved with the Boston community. She volunteered in the Boston City Hospital pediatric ward which treated children of all races. She particularly remembers one blond boy without a face who was awaiting plastic surgery whom she would visit at the start of each shift simply to hold and comfort him. He in turn taught her that all people have crosses to bear and led her to count her advantages. She also joined the national African-American sorority Delta Sigma Theta, Iota Chapter, which was both a social group of college women in New England and a service organization that tutored math at the Roxbury YMCA. Having found a peer group, Jackson took advantage of academics at MIT such as the Professor Anthony French who interested her in physics during his introductory course. She started research on condensed matter physics in MIT's well equipped laboratory (O'Connell 27-38) and graduated as a theoretical physicist in 1968, having written a thesis on solid state physics (Wiki-

pedia). In her senior year, she applied to several top-ranked physics departments where she was accepted because of her strong academic record (O'Connell 38-39).

The death of a personal hero, Dr. Martin Luther King, Jr. forced her decision to do graduate work in physics at MIT although it would entail a switch to high energy physics since she felt she could make the Institute more welcoming to African-American students. Over the course of her graduate work, she actively pursued this dream, personally mentoring many African-American students, serving on university-wide task force to foster a diverse student body, founding the Black Students Union and directing a six-week summer program to prepare diverse students for the academic demands of MIT. In the first year of recruitment, the number of African-American students rose from 5 to 57. She personally befriended a number of students including future astronaut Ronald McNair (O'Connell 41-53) and current vice president of the APS Sylvester "Jim" Gates who remember Jackson's leadership and friendship at MIT. Gates recalls her saying, "The important thing is to concentrate on your academic performance and don't get distracted." (Schaffer)

In 1973, Jackson became the first African-American woman to earn a doctorate in any field at MIT with a dissertation describing a new way to model collisions (Schaffer). She then accepted a postdoc at Fermilab followed by a fellowship at CERN. She was there when Sam Ting, whom she had known as a professor at MIT, and his group discovered the charm quark. After her stint at CERN, Jackson returned to her position at Fermilab. At an APS Meeting in Atlanta Jackson had a dinner meeting with Maurice Rice, then Head of AT&T Bell Labs in New Jersey, at which she spoke about her work in physics and was invited to give a colloquium at the Lab. She was offered a one-year position there in 1976 and her hard work and talent then made her a full member of the staff of the theoretical physics division (O'Connell 64-89). In 1975, Jackson became a member of the MIT Corporation where she is now a life member (Schaffer).

She switched the focus of her research to the properties of two-dimensional condensed matter systems. Jackson's work on the theory of electrons at the interfaces of layered crystal and density waves would later become important in the theory of high temperature superconductors (Schaffer). About a month after starting at Bell Labs she met Morris A. Washington, a postdoctoral research fellow with a Ph.D. in experimental physics from NYU in 1976, who became a member of the technical staff at Bell Labs in 1978 (Dept. of Physics RPI). They married in 1979 and their son, Alan, was born in 1981 and Jackson stayed home with him for three months and then the Washingtons took joint responsibility for his care (O'Connell 74-75, 96). Alan Washington graduated from Dartmouth College with a BA and then earned a M.S. in Real Estate Development from NYU. He is currently Head of Real Estate Development for Success Academy Charter

Schools which operates 42 schools serving 14,000 students in the New York City boroughs: Manhattan, Brooklyn, Queens, and the Bronx. His projects are in the \$100-180 million range (Linked-in).

In 1985, Governor Tom Kean of New Jersey invited Jackson to become a founding member of the advisory New Jersey Commission on Science and Technology. The purpose of the Commission was to create partnerships between industry and the government to spur investments in research important to the state's economy. In 1986, she was elected a Fellow of the APS and in 1990, she received the Thomas Alva Edison Science Award from New Jersey. In 1991, Jackson was elected a Fellow of the American Academy of Arts and Sciences and joined the faculty of Rutgers University in Piscataway and then in New Brunswick while maintaining her research at Bell Labs as a consultant (O'Connell 76-79). In 1995, President Bill Clinton appointed her as the first woman and the first African-American Chair of the Nuclear Regulatory Commission which was facing public fear of nuclear power reactors. Dr. Richard A. Meserve currently President Emeritus of the Carnegie Institution for Science and Jackson's successor at the NRC when she resigned the chair in 1999, writes:

"Dr. Jackson served as Chairman at a difficult time in which there was significant controversy surrounding the safety of several plants (in particular Millstone and several Commonwealth Edison plants). She helped restore public and Congressional confidence that the NRC was a serious regulator committed to assuring protection of the public and the environment. She recognized that public confidence is essential for the survival of nuclear power and thus the success of the industry is highly dependent on a tough, but fair regulator. She brought the nuclear industry through a difficult period and reestablished confidence in the NRC in the Congress and the public." (Meserve)

Dr. Meserve outlines five specific steps that Jackson took. First she advocated risk-informed, performance-based regulation. Second she advocated the sophisticated techniques of Probabilistic Risk Assessment. Third she used risk assessment to guide the inspection schedule. Fourth she used license renewal protocols to keep existing nuclear power plants in operation. Lastly she founded the International Nuclear Regulatory Association and served as its first chair.

The NRC job forced the Washington family into a commuter marriage where Morris remained in New Jersey as a single parent so Alan could finish high school while Shirley spent week days in Washington, D.C, and devoted weekends to her family, attending swim meets or water polo games frequently. The family talked every night (O'Connell 83).

In 1998, Dr. Jackson was inducted into the National Women's Hall of Fame; in 2001, she received awards including the Richtmeyer Memorial Lecture Award from AAPT and was the first African-American woman elected to the National Academy of Engineering (O'Connell 97).

In 1999, at the end of her second term as chair of the NRC, Rensselaer Polytechnic Institute (RPI) recruited her

to serve as its 18th President, the first African-American Woman to lead a national research university. Her mission was to promote both first class research and diversity at RPI. In 2000, Morris Washington left his job at Bell Labs (now run by Lucent Technologies) and joined the Department of Physics, Applied Physics and Astronomy at Rensselaer (RPI) as a Clinical Professor of Practice and Associate Director of CIEEM (Center for Integrated electronics and electronic manufacture). He had earned a Master Certificate (Project Management) from George Washington University, School of Business and Public Management in 1997 (Dept. of Physics RPI). With Alan at Dartmouth, the family was complete although the next few years were busy ones as Jackson raised standards for P&T at the university over objections of faculty (she would survive a no-confidence vote in 2006) and worked to raise money and recruit diverse students (Schaffer). In 2004 Jackson launched the Renaissance at Rensselaer campaign which met its goal of \$1.4 billion nine months ahead of schedule in 2008. Jackson promoted programmatic efforts in computational science and engineering, biotechnology and the life sciences, nanotechnology and advanced materials, energy, the environment and smart systems, media arts, and science and technology. During her tenure as President, Rensselaer has seen a tripling of sponsored research expenditures, the hiring of 325 new tenure track faculty members, advances in curriculum, increase in scholarships, growth of undergraduate research and several improvements in student life on campus which support all students, particularly minority students (Office of the President RPI). In 2010, Rensselaer offered her a ten-year extension on her contract and she is one of the best paid university presidents in the country (Wikipedia).

These years also saw Dr. Jackson serve the scientific community in a number of positions, as the first African-American woman elected to the National Academy of Engineering in 2001, as president of the AAAS in 2004 and later as chair of the AAAS Board of Directors (2005), as a regent of the Smithsonian as a member of Obama's President's Council of Advisors on Science and Technology from 2009-2014, the President's Intelligence Advisory Board from 2014-2017, Vice Chair of the Board of Regents of the Smithsonian, University Vice Chair of the U.S. Council on Competitiveness from 2008 to 2013 (Schaffer).

Dr. Jackson has received numerous awards including 53 honorary doctorates over the years and the National Medal of Science in 2016. She is a fellow of the American Physical Society, the American Academy of Arts and Sciences and the AAAS (Schaffer). She is also an International Fellow of the Royal Academy of Engineering (2013), and received a Candace Award from the National Coalition of 100 Black Women in 1983, obviously in recognition of her work at Bell Labs. She has served on numerous committees of the NSF and the National Research Council, been inducted into the National Women's Hall of Fame (1998). She is a Trustee of the Brookings Institution and on the Board of Directors of

the Hyde Collection and the Council on Foreign Relations (Wikipedia). She sits on the Board of Directors of IBM, FedEx, Medtronic, and Public Service Enterprise Group as well as the board of the World Economic Forum. From 2006-2013, she served as chair of the Board of the New York Stock Exchange (Schaffer).

In summary, it is difficult to imagine a candidate who is better qualified for the Burton Award.

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REFERENCES

- American Men and Women of Science*, entry on Shirley Ann Jackson, 22nd edition (2003).
- Bryant, Adam (May 27, 2016) "Shirley Ann Jackson: Keep Your Eye on the North Star". *Corner Office* column, business section of the New York Times, <https://www.nytimes.com/2016/05/29/business/Shirley-Ann-Jackson-keep-your-eye-on-the-north-star.html>, accessed 11/24/2018.
- Department of Physics, Applied Physics, and Astronomy, Rensselaer Polytechnic Institute, "Morris A. Washington", <https://science.rpi.edu/physics>, accessed 11/20/2018.
- Linked In Profile for Alan Washington, accessed on 11/20/2018.
- Meserve, Richard A. (July 12, 2017), *Letter of Support for the Nomination of Shirley Jackson for the Burton Award of the Forum on Physics and Society*.
- O'Connell, Diane, *Strong Force: The Story of Physicist Shirley Ann Jackson*, Washington, D.C.: Joseph Henry Press (1956).
- Office of the President RPI, Biography of Shirley Ann Jackson, 18th President of Rensselaer Polytechnic Institute, <https://president.rpi.edu/president-biography>, accessed 11/26/2018.
- Schaffer, Amanda (December 19, 2017) "The Remarkable Career of Shirley Ann Jackson." MIT News magazine, January/February 2018, Issue, <http://www.technologyreview.com>, accessed 11/24/2018.
- Wikipedia, "Shirley Ann Jackson" <https://en.wikipedia.org/wiki/>, accessed 11/24/2018.

Cyber Vulnerabilities and Nuclear Weapons Risks

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In October 2018, the United States Government Accountability Organization (GAO) reported that "mission-critical cyber vulnerabilities" had been found in many weapon systems being developed by the U.S. Department of Defense (DOD). These vulnerabilities allowed testers to "take control of systems and largely operate undetected" [1, p. 21], and could allow hackers to do the same.

The GAO report identified three underlying reasons for this problem. First, computers have proliferated in the designs of almost all weapon systems and enable many of their functions and communications. Second, the DOD has only recently prioritized cybersecurity in its weapon systems; in many cases, cybersecurity was not even a consideration when earlier weapon systems were designed. Finally, the DOD has a shallow understanding of how to construct secure weapon systems after ignoring them for many years. As a result, the GAO report said, the DOD has fielded a generation of insecure weapon systems, which could jeopardize military networks for years to come.

The report did not name specific weapon systems or describe faults in detail; however, its authors confirmed that their study included the systems that can cause the most destruction: nuclear weapons [2]. Concerns about the cybersecurity of nuclear weapons have also been raised by outside researchers [3]–[6], and the warning comes at a time when many states

are planning large modernizations of their nuclear arsenals.

This article will discuss some of these risks. It will start with a description of the basic principles of cybersecurity, their application to the U.S. nuclear arsenal, and how these principles are being challenged by the modernization of nuclear forces. It then describes a key policy choice that increases the risk that a cyberattack on some elements of the nuclear arsenal could result in accidental or inadvertent nuclear weapons use, and ends with some recommendations for improving safety.

GENERAL CYBERSECURITY PRINCIPLES

Academics studying computer science and the computer industry have identified many principles to create secure computer systems [7]. Ideally, these principles should be incorporated during the design of any digital network that supports critical infrastructure, such as those used to control the electrical grid, send financial information, or, more importantly, to command and control nuclear arsenals. Implementing these principles after the design stage, when the system is being tested or deployed, could lead to costly and incomplete fixes for faults and bugs.

The six basic principles of secure computing are availability, reliability, safety, integrity, maintainability, and confidentiality.

- Availability describes a system that readily offers the intended function. A system that lacks availability will experience intermittent outages in service, such as a cell phone service that is only available if the user is close to particular cell towers.
- Reliability is the ability of a system to offer the correct function. Systems that are not reliable will not perform the intended service some of the time, such as a cell phone that sometimes connects to a different number than the user dialed.
- Safety refers to a system whose operation, intended or otherwise, does not cause harm. Unintended actions can also be considered when assessing safety; a system that fails in a manner that does not cause harm is called fail-safe.
- Integrity describes a system that prohibits nonauthorized users from altering its functions or data. Electronic banking services are used because people trust that the numbers they can view online reflect the balances in their accounts. The integrity of this system would break down if these numbers could be changed by hackers or rogue bank employees.
- Confidentiality is a property of a system that does not disclose information to unauthorized parties. If online banking were to allow people other than the owners of the bank account and authorized bank employees to access the user account numbers and balances, it would no longer be confidential.
- Maintainability refers to a system that can be repaired or updated. Systems that can only be updated during certain periods or under certain circumstances have poor maintainability.

While it is clear that all of these principles are desirable, achieving them simultaneously within a single system is challenging. The Mars Polar Lander, which crashed into the surface of Mars in December 1999, is an example of a system that was reliable but not safe [8]. The crash occurred because the landing software mistook turbulence from the Martian atmosphere as confirmation that Polar Lander had reached the planet's surface. The software, performing according to its specifications, turned off the engines slowing the Polar Lander's descent [9]. Prof. Nancy Leveson from the Massachusetts Institute of Technology, who specializes in building reliable and safe software systems, points out that, in some cases, safety and reliability can be in conflict: "making the system safer may decrease reliability and enhancing reliability may decrease safety" [8, p. 7].

CYBERSECURITY PRINCIPLES AND U.S. ICBMS

The United States operates a triad of delivery vehicles for its nuclear weapons. One component of this triad is the "land-based ballistic missile force (ICBMs)" consisting "of 400 land-based ICBMs, each deployed with one warhead"

[10, p. i]. These ICBMs are stored inside hardened missile silos, which are controlled by a network of launch control centers. Each center directly controls, on average, about ten missiles, and a secondary launch control center monitors the commands sent by the primary center [11]. Each ICBM contains a missile guidance computer, which is responsible for directing the nuclear-armed missile to its intended target [12]. The missile guidance computer can store multiple target locations according to what is called for by the U.S. nuclear war plan [13]. To launch a nuclear attack, the launch control centers specify both a target location and an execution order by either selecting one of the pre-stored options or manually entering different information [14].

It is not straightforward to apply the previously described principles to assess the cybersecurity of the U.S. ICBM force because publicly available information on these systems is greatly limited. One indirect approach is to examine measures of general security and there it is clear that the United States does seem to apply the principles of availability, reliability, safety, integrity, maintainability, and confidentiality to its ICBM force [15]. That being said, there are certain differences between physical- and cyber- security measures, and the incorporation of security measures in the physical realm should not be taken as confirmation of these principles in the cyber realm.

As described in the case of the Mars Polar Lander, there are conflicts between these different principles. A particular problem for nuclear weapons is the need for confidentiality, which can and does impact their safety or reliability. Because of the sheer complexity of the computer systems involved, the design of the hardware and software will have to be carried out by teams of engineers, often involving people who may not be allowed to handle confidential or secret data. Thus, specifications for how the system should operate must be communicated in a non-classified manner. But that is usually incomplete, and the inadequacy of information available to software and hardware professionals can lead to problems.

An illustration of the affect this problem can have was the replacement in 2007 of the internal guidance computers inside U.S. land-based nuclear missiles [16]. During testing, the new system gave inaccurate guidance [17]. These inaccuracies were eventually traced to errors in rounding and truncation in the software of the guidance computer [18]. The most likely reason for this underlying error is that design specifications were not properly outlined, as was the case with the Mars Polar Lander [19].

MODERNIZATION BRINGS NEW CHALLENGES FOR CYBERSECURITY

When it comes the U.S. nuclear arsenal, one particular cybersecurity concern pertains to the system for nuclear command and control, a term given to the infrastructure,

procedures, and policies used to direct and control nuclear forces. This system involves a vast network of computers that are interconnected and in constant communication with each other. As a result, there are many points of attack for potential hackers. Other aspects of the nuclear arsenal are also computerized and thus susceptible to cyberattacks. If left unaddressed, some of the weaknesses identified could lead to the accidental launch of nuclear weapons and even inadvertent nuclear war [3]–[6].

Worsening the cybersecurity problem, the United States [20] is modernizing its nuclear arsenal by developing new weapon systems and investing in improvements in their command and control networks. If modernizations of nuclear arsenals are to follow the precedent established by other military weapon systems, the use of computers and digital electronics in these systems will greatly expand, accentuating cyber risks to nuclear command and control.

Not only does modernization involve the introduction of computers into hitherto uncomputerized parts of the arsenal, it also brings in new challenges to older parts of the system that have already incorporated computers and digital systems. Many of the components inside the nuclear command and control system are decades old; one instance of such an old system that has been often discussed in public is the use of floppy discs to direct nuclear forces [21]. New components will therefore be drastically different from those currently in use. That might seem like an advance, but the change will bring safety and security challenges. For instance, using floppy discs, an outdated technology, is definitely inconvenient and compromises maintainability, but, because of their relatively small capacity for data storage, they are less susceptible to computer malware and thus enhances integrity.

A further complication is the ongoing globalization of the supply chain for commercially-available computer components. Today's computer components are often designed, fabricated, and assembled in many different nations. Even if a country has set up in-house fabrication facilities, it is likely that these will use machinery produced in other countries. The usage of equipment from multiple countries increases the possibility that malicious design features or hardware components might be covertly embedded into devices. Once they have been built in, these covert features are almost impossible to detect [22].

As nuclear systems are modernized, the tendency is to use commercially-available products, because developing new components from scratch will require more testing and resources. An example of the use of commercially-available, also called off-the-shelf, products includes the set of instruments that communicate flight data during missile flight tests. A U.S. Air Force budget justification document said that the replacement effort for this component “will maximize the use of off-the-shelf components to meet mission requirements” [23, p. 7].

The cybersecurity of the nuclear arsenal is also challenged by the lifecycle of modern computer components, which require more frequent updates and replacement. For computer systems used in everyday life, these updates are an inconvenience, but most people realize that undertaking these routine updates lowers their chances of being infected by malware or viruses. Weapon systems are different and incorporating such updates in a timely fashion might be difficult because of various constraints. For example, U.S. nuclear missiles are expected to be in continuous use and, as a result, missile maintenance requires prior approval by higher authority [24]. Nuclear command and control systems are also likely to have similarly constrained maintenance schedules. As a result, known vulnerabilities will likely persist much longer in weapon systems than in other systems that can be updated more frequently. These known vulnerabilities will certainly continue to compromise security.

The WannaCry ransomware attack, which crippled the British National Health Services, illustrated the dangers of infrequent software updates. The attack used a vulnerability that affected systems that had not yet installed the most recent Microsoft patch [25]. Replacing parts in the U.S. land-based missile system often stretches over many years, from design to fielding. Because of this, there is a chance that components might have become obsolete by the time they are fielded.

CONCERNS DUE TO POLICY CHOICES

U.S. nuclear weapons policy exacerbates the existing cyber security vulnerabilities as well as those caused by modernization. If the United States military were to get information from the many sensors it has deployed that there was an incoming nuclear attack, its stated policy allows the President to launch nuclear weapons against the country that is believed to be attacking. This launch could take place within a few minutes, before the arrival of the attacking missiles. The hope is that countries will be less likely to launch a preemptive strike, because, in theory, retaliation is always guaranteed and this would decrease the value of a hypothetical first strike.

Because its nuclear command and control system must comply with the short decision-making times necessary for such rapid launch, the system is configured for quick use. This way of deploying missiles increases the risk of accidental or inadvertent use. For example, storing nuclear warheads inside missiles that are fueled with combustible materials leads to the potential for accidental explosions [26]. In 1980, an accidental leak of liquid propellant from a U.S. ICBM led to an explosion that ejected parts of the missile, including the nuclear warhead, from its reinforced silo. Thankfully, the nuclear warhead did not detonate [27].

There are also other precursors to potential nuclear war, sometimes due to computers from an earlier era. On June 3, 1980 at 2:26 am, a computer screen in a command post of the U.S. Strategic Air Command began indicating incoming

Soviet-launched ballistic missiles. Within a few seconds, more missiles appeared [28]. Bomber pilots were notified to start their engines and await orders on the tarmac. U.S. ICBMs were prepared for launch as well. Fortunately people realized that something was amiss—the number of incoming missiles fluctuated wildly with no clear pattern of attack. A threat assessment conference dismissed the signals as spurious, and the nuclear bombers and missiles were told that the alert had ended. An investigation revealed that a computer chip failure had led to the erroneous readings [29]. However, if the spuriousness of the warning had not been realized with the roughly 30 minutes it takes for a missile to fly from the Soviet Union to the United States, the U.S. President might have decided to launch missiles at the Soviet Union.

A MODERN NUCLEAR ACCIDENT

As more digital components are built into the nuclear command and control network and the weapons themselves, the potential for cyber related problems will increase. New problems will also present themselves as more components become digital or older components are modernized. Computer components introduce more uncertainty into the already complex task of controlling and directing nuclear forces. When combined with the short timescales for decision making put into place by launch on warning policies, problems introduced by digital components could lead to unpredictable accidents with catastrophic consequences [30], [31]. Knowing that modern technology makes small errors more likely, it is important to take steps to ensure that these malfunctions do not lead to catastrophe.

Without access to classified data, it is difficult to prescribe specific steps that can increase the overall safety of the system. However, one can argue in general that measures that enhance safety, even if it comes at the cost of availability, are desirable from the viewpoint of reducing the chances of accidental or inadvertent nuclear weapons use. One example is to store the nuclear warheads separately from the ballistic missiles that carry them. Such measures would lower the risk of inadvertent or accidental nuclear war.

Lowered risk, of course, doesn't mean no risk. In the longer term, the only way to eliminate such a risk is to eliminate nuclear weapons altogether.

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REFERENCES

- [1] GAO, "Weapon Systems Cybersecurity: DoD Just Beginning to Grapple with Scale of Vulnerabilities," *United States Government Accountability Office*, Washington, D.C., GAO-19-128, Oct. 2018.
- [2] "New U.S. Weapons Systems Are a Hackers' Bonanza, Investigators Find - The New York Times." [Online]. Available: <https://www.nytimes.com/2018/10/10/us/politics/hackers-pentagon-weapons-systems.html>. [Accessed: 12-Oct-2018].
- [3] B. G. Blair, "Global Zero on Nuclear Risk Reduction: De-Alerting and Stabilizing the World's Nuclear Force Postures," *Global Zero*, Apr. 2015.
- [4] A. Futter, "Hacking the Bomb: Cyber Threats and Nuclear Weapons," *Washington D.C.: Georgetown University Press*, 2018, p. 208.
- [5] B. Unal and P. Lewis, "Cybersecurity of Nuclear Weapons Systems: Threats, Vulnerabilities and Consequences," *The Royal Institute of International Affairs Chatham House, London, Research Paper*, 2018.
- [6] P. O. Stoutland and S. Pitts-Kiefer, "Nuclear Weapons in the New Cyber Age," *Nuclear Threat Initiative*, Sep. 2018.
- [7] A. Avizienis, J.-Laprie, B. Randell, and C. Landwehr, "Basic concepts and taxonomy of dependable and secure computing," *IEEE Trans. Dependable Secure Comput.*, vol. 1, no. 1, pp. 11–33, Jan. 2004.
- [8] N. Leveson, *Engineering a Safer World*. MIT Press, 2011.
- [9] "NASA Reveals Probable Cause of Mars Polar Lander and Deep Space-2 Mission Failures." [Online]. Available: <http://www.spaceref.com/news/viewnews.html?id=105>. [Accessed: 25-Nov-2018].
- [10] CRS, "U.S. Strategic Nuclear Forces: Background, Developments, and Issues," *Congressional Research Service*, Washington, D. C., Nov. 2018.
- [11] B. Blair, *Strategic Command and Control*, 1st edition. Washington, D.C: Brookings Institution Press, 1985.
- [12] T. S. ICBM Prime team, "Minuteman Weapons System History and Description." *Intercontinental Ballistic Missile (ICBM) System Program Office (SPO)*, Jul-2001.
- [13] B. G. Blair, "Mad Fiction," *Nonproliferation Rev.*, vol. 21, no. 2, pp. 239–250, Apr. 2014.
- [14] *Minuteman Systems Engineering*, "WS-133A-M Upgrade Wing III and V: Integrated Minuteman Command and Control Systems," *Boeing Aerospace Company*, Seattle, WA, D2-19944-1, Feb. 1978.
- [15] L. J. Borja, "The Price of Modernization: Cyber Vulnerabilities in the Nuclear Arsenal," in preparation.
- [16] "Team Malmstrom first to accomplish missile guidance system replacement," *Malmstrom Air Force Base*. [Online]. Available: <http://www.malmstrom.af.mil/News/Article-Display/Article/348943/team-malmstrom-first-to-accomplish-missile-guidance-system-replacement>. [Accessed: 18-Nov-2018].
- [17] "MINUTEMAN III GUIDANCE AND PROPULSION REPLACEMENT PROGRAMS (GRP)," *The Office of the Director, Operational Test and Evaluation (DOT&E)*, Annual Report, Jan. 2001.
- [18] "Minuteman III Guidance and Propulsion Replacement Programs," *The Office of the Director, Operational Test and Evaluation (DOT&E)*, Annual Report, Jan. 2003.
- [19] N. Leveson, "Engineering a Safer World," *MIT Press*. [Online]. Available: <https://mitpress.mit.edu/books/engineering-safer-world>. [Accessed: 30-Jan-2018].
- [20] H. M. Kristensen and R. M. Norris, "United States nuclear forces, 2018," *Bull. At. Sci.*, vol. 72, no. 4, pp. 120–131, Mar. 2018.
- [21] "Information Technology: Federal Agencies Need to Address Aging Legacy Systems," *US Government Accountability Office*, GAO-16-46, May 2016.
- [22] S. Bhasin and F. Regazzoni, "A survey on hardware trojan detection techniques," in 2015 IEEE International Symposium on Circuits and Systems (ISCAS), 2015, pp. 2021–2024.
- [23] "ICBM - EMD FY2013," *Air Force*, Exhibit R-2, RDT&E Budget Item Justification 0604851F, Feb. 2012.
- [24] *Commander of the Air Force Global Strike Command*, "Intercontinental Ballistic Missile (ICBM) Operational Test and Evaluation (OT&E)," *Air Force*, Test and Evaluation 99–102, Mar. 2011.

- [25] C. Graham, “NHS cyber attack: Everything you need to know about ‘biggest ransomware’ offensive in history,” *The Telegraph*, 13-May-2017.
- [26] Z. Mian, M. V. Ramana, and R. Rajaraman, “Plutonium dispersal and health hazards from nuclear weapon accidents,” *Curr. Sci.*, vol. 80, no. 10, pp. 1275–1284, 2001.
- [27] E. Schlosser, *Command and Control: Nuclear Weapons, the Damascus Accident, and the Illusion of Safety*, Reprint edition. New York: Penguin Books, 2014.
- [28] D. Hoffman, “The Fear Factor,” *Foreign Policy*, 08-Jul-2010.
- [29] “False Alarms in the Nuclear Age — NOVA | PBS.” [Online]. Available: <http://www.pbs.org/wgbh/nova/military/nuclear-false-alarms.html>. [Accessed: 27-Aug-2018].
- [30] C. Perrow, *Normal Accidents: Living with High-Risk Technologies*, Revised ed. Princeton, NJ: Princeton University Press, 1999.
- [31] S. D. Sagan, *The Limits of Safety: Organizations, Accidents, and Nuclear Weapons*, 1st ed. Princeton University Press, 1995.

Neutrinos May Have a Practical Niche in North Korea Diplomacy

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Before Chairman Kim and President Trump met in Singapore last June, two nuclear policy veterans surveyed the “long and complicated process” ahead [1]. Reflecting on their experience with post-Soviet republics in the 1990s, former U.S. Senators Sam Nunn and Richard Lugar wrote that securing a peaceful Korean Peninsula “will require unconventional thinking and steps that are much broader than denuclearization.”

For at least 40 years, physicists have explored the unconventional idea of using neutrino detectors to monitor nuclear reactors [2]. Neutrino emissions from a reactor core can indicate an anomalous reactor startup or, in some cases, diversion of plutonium from the core. Compared to other fission signatures, neutrino signals are virtually impossible to mask, alter, or mimic. In the last year, physicists have demonstrated detectors that can observe these signals without needing an underground site. Meanwhile, neutrino physics has become a frontier in basic science, particularly among North Korea’s neighbors, South Korea and China.

Motivated by the renewed international dialogue with North Korea, we joined physics colleagues from South Korea, China, Japan, Russia, Europe, and the United States to outline how neutrinos could play a small role in diplomacy on the Korean Peninsula [3]. Beyond verifying the shutdown of plutonium producing reactors, neutrino-based projects could support broader steps to reintegrate North Korea into the international community.

METER-SCALE NEUTRINO DETECTORS COULD VERIFY SHUTDOWN OF REACTORS AT YONGBYON

A key part of North Korea’s nuclear weapons program is the Yongbyon Nuclear Research Center. Yongbyon hosts the 5 MWe gas-graphite reactor that produced plutonium for

the North Korea’s weapons program, a newer Experimental Light Water Reactor, older reactor projects, fuel processing facilities, and a uranium enrichment facility [4, 5, 6]. Since the Singapore summit, North and South Korea [7] and the United States [8] have suggested the dismantlement of Yongbyon as a possible step in reducing tensions.

If leaders agree to eliminate one or more reactors at Yongbyon, the U.S. and others may seek assurance that the reactors remain shut down during the long cool-down period preceding dismantlement. Traditional monitoring tools include onsite inspections and satellite observation of the site. Neutrino detectors could complement these approaches, perhaps as an early step toward more comprehensive action at Yongbyon. Unlike full reactor inspections, installing neutrino detectors would not require access to the most sensitive parts of the site. Compared to satellite imaging, neutrino detectors offer more persistent and precise reactor observations and an opportunity for cooperative engagement on the ground.

The technology to perform neutrino-based reactor monitoring is well demonstrated. Physicists have observed reactor on-off transitions in neutrino detectors since the 1980s [9, 10]. As of 2018, many groups worldwide are observing reactor neutrinos in meter-scale systems [11-17]. These detectors are largely motivated by searches for new physics in the neutrino sector, but they also demonstrate practical features for reactor monitoring. Instead of using an underground site to control backgrounds, several detectors now use design features and analysis techniques to allow on-surface operation. Some groups have built detectors inside shipping containers or trailers, indicating feasibility for rapid field deployment. Reactor neutrino detectors now operate for months or years with little onsite maintenance, continuously sending data offsite for analysis.

At Yongbyon, we and our colleagues estimate that a meter-scale scintillator detector could provide timely notice of unauthorized reactor startups following a shutdown agreement [3]. A capable detector could fit inside a standard shipping container. As a basis for sensitivity estimates, we use the efficiency and backgrounds measured in the 4-ton PROSPECT detector, currently observing neutrinos from a reactor at Oak Ridge National Laboratory [11]. If placed 20 meters from the 5 MWe reactor core, a similar detector could identify a reactor startup at 95% confidence level within 2 days. At the larger Experimental Light Water Reactor, a detector could identify a startup within 2 hours and potentially monitor the fuel evolution (see [3] for more details). Neutrinos could be observed from a standoff distance longer than 20 meters, but the required detector size scales with the square of the distance. The PROSPECT detector was constructed in less than a year for about \$5 million.

NEUTRINO PHYSICS IS AN OPPORTUNITY TO ENGAGE NORTH KOREAN SCIENTISTS AND ENGINEERS

Deploying neutrino detectors at Yongbyon would require coordination between technical teams from North Korea and other nations. However, it would not require exchange of classified or militarily sensitive information. Details on the design and use of reactor neutrino detectors are available in the open scientific literature. Neutrino detectors are therefore a low-stakes opportunity for scientists and engineers from North Korea and other nations to work together. As in former Soviet republics, such cooperative work could help to rebuild trust and redirect scientists and engineers from the weapons program to non-military applications.

Cooperative deployment of neutrino detectors at Yongbyon could open the door to wider scientific engagement in and beyond the region. The physics communities in South Korea, China, Japan, Russia, Europe, and the United States could support the effort from multiple angles. For example, scientists from North Korea could receive initial training in neutrino physics in China. Detectors at Yongbyon could be paired with detectors at power reactors in South Korea, furthering North-South unity. Major new neutrino experiments in East Asia, such as Hyper-Kamiokande in Japan [19] (and possibly South Korea [20]) and JUNO in China [21], are natural opportunities to strengthen peaceful regional ties. With time, other countries could consider student and scientist exchanges with North Korea in the area of particle physics.

NEUTRINO DETECTORS CAN BE A SMALL STEP, AMONG WIDER EFFORTS

Of course, neutrino physics can be only a small part of reducing nuclear risks on the Korean Peninsula. The enrichment and reprocessing facilities at Yongbyon are not amenable to neutrino-based monitoring. In North Korea, a full program

of Cooperative Threat Reduction—the term Nunn and Lugar coined for multilateral efforts in the former Soviet Union—would include many other components. Still, it bears some reflection that neutrino physics as an experimental science began with former weapons scientists at a plutonium production reactor [22]. On another continent, the 1954 founding of CERN was one of the first diplomatic agreements between Germany, France, and their neighbors following World War II.

Seven months after the Singapore summit, Nunn and Lugar’s prediction of a “long and complicated process” for the nuclear talks seems correct. It may be much longer before joint objectives become clear, including the future of the reactors at Yongbyon. Nonetheless, policymakers could consider preparing neutrino-based tools, among others, in case further steps become possible. The final engineering work for a field-ready neutrino system could begin immediately. We encourage policymakers to consider this unconventional idea within the broader pursuit of a stable, secure Korean Peninsula.

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REFERENCES:

- [1] S. Nunn and R. Lugar, “What to do if the talks with North Korea succeed,” *Washington Post* (2018).
- [2] A. A. Borovoi and L. A. Mikaelyan, “Possibilities of the practical use of neutrinos,” *Soviet Atomic Energy* 44, 589 (1978).
- [3] R. Carr et al., “Neutrino-based tools for nuclear verification and diplomacy in North Korea,” *arXiv:1811.04737 [physics.soc-ph]*.
- [4] D. Albright and K. O’Neill, *Solving the North Korean Nuclear Puzzle* (ISIS Press, 2000).
- [5] S. S. Hecker, “A return trip to North Korea’s Yongbyon nuclear complex,” *Center for International Security and Cooperation, Stanford University* (2010).
- [6] K. K. R. Lai, W. J. Broad, and D. E. Sanger, “North Korea is starting up a reactor that could upset Trump’s talks with Kim,” *New York Times* (2018).
- [7] DPRK and ROK, “Pyongyang Joint Declaration of September 2018” (2018).
- [8] U.S. Department of State, “On the Outcome of Summit Meeting between President Moon and Chairman Kim” (2018).
- [9] A. I. Afonin et al., “Neutrino experiment in the reactor of the Rovno atomic power plant: cross-section for inverse beta decay,” *JETP Lett.* 41, 435-438 (1985), [*Pisma Zh. Eksp. Teor. Fiz.* 41, 355 (1985)].
- [10] N. S. Bowden et al., “Experimental results from an antineutrino detector for cooperative monitoring of nuclear reactors,” *Nucl. Instrum. Meth.* A572, 985-998 (2007), *arXiv:physics/0612152 [physics]*.
- [11] J. Ashenfelter et al. (PROSPECT), “First search for short-baseline neutrino oscillations at HFIR with PROSPECT” (2018), *arXiv:1806.02784 [hep-ex]*.
- [12] Y. J. Ko et al. (NEOS), “Sterile Neutrino Search at the NEOS Experiment,” *Phys. Rev. Lett.* 118, 121802 (2017), *arXiv:1610.05134 [hep-ex]*.
- [13] I. Alekseev et al. (DANSS), “Search for sterile neutrinos at the DANSS experiment,” (2018), *arXiv:1804.04046 [hep-ex]*.

- [14] A.P. Serebrov et al. (Neutrino-4), “The first observation of effect of oscillation in Neutrino-4 experiment on search for sterile neutrino,” (2018), arXiv:1809.10561 [hep-ex].
- [15] H. Almazan et al. (STEREO), “Sterile Neutrino Constraints from the STEREO Experiment with 66 Days of Reactor-On Data,” Phys. Rev. Lett. 121, 161801 (2018), arXiv:1806.02096 [hep-ex].
- [16] N. van Remortel, “Commissioning and calibration of the SoLid experiment,” (2018), XXVIII International Conference on Neutrino Physics and Astrophysics. DOI:10.5281/zenodo.1287001.
- [17] J. Carroll et al., “Monitoring Reactor Anti-Neutrinos Using a Plastic Scintillator Detector in a Mobile Laboratory” (2018), arXiv:1811.01006 [physics.ins-det].
- [18] A. Haghighat et al., “Observation of Reactor Antineutrinos with a Rapidly-Deployable Surface-Level Detector” (2018), arXiv:1812.02163.
- [19] K. Abe et al. (Hyper-Kamiokande Proto-Collaboration), “Hyper-Kamiokande Design Report” (2016), arXiv:1805.04163 [physics.ins-det].
- [20] K. Abe et al. (Hyper-Kamiokande), “Physics potentials with the second Hyper-Kamiokande detector in Korea,” PTEP 2018, 063C01 (2018), arXiv:1611.06118 [hep-ex].
- [21] T. Adam et al., “JUNO Conceptual Design Report” (2015), arXiv:1508.07166 [physics.ins-det].
- [22] F. Reines, “The neutrino: From poltergeist to particle,” Nobel Lecture (1995).

Sovereign Nations as Interacting Molecules

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This is a time of growing populist nationalism in the U.S. and in several European nations, a time of growing unilateralism and suspicion of multilateralism or internationalism, a time of growing emphasis on the concept of national *sovereignty*. But emphasis on sovereignty in the past has frequently led to war -which, for many, was an acceptable outcome. The growing international destructiveness of war, caused by the “progress” of technology, human ingenuity, has led many to seek ways of avoiding deadly international conflict and hence trying to put limits on national sovereignty. Some have sought to achieve these limits via the creation of an overarching world power – a “world government”, either by force of arms, by peaceful mutual agreement, or by some combination of the two. Many doubt the feasibility of this hope. Is it possible for the many independently sovereign nations to reach a stable, mutually comfortable, arrangement without an overpowering external force? This is a “social science” problem, but it may be that some productive insight into its resolution may be derived from the “physical sciences”.

The word “science” in the designation of “political science” implies that this academic discipline wishes to apply the scientific methods pioneered by the “natural sciences”: observation; experiment; theory creation; further observation and experiment to test, modify, extend or reject the theories;

application of the theories to practical problems. As a physical scientist, I am in no position impartially to judge the success of political science as a science. I can, however, suggest analogies to concepts that have proven useful in physics and hope that they will prove heuristically useful to some of the conceptual or practical problems facing the political science of international relations. I suggest that a collection of ideally “sovereign” nations acts much like the elastically colliding molecules of an “ideal gas”—chaotically and violently interacting with each other. However, the constraints of our modern, nuclear-armed world modify this ideal sovereignty so that a collection of “real” nations, like a set of real molecules, which may condense into a liquid and then an ordered solid, may undergo a spontaneous transition to an ordered system which rules out the violent interactions that have been so characteristic of the international system of the past.

SOVEREIGN MOLECULES

In an ideal gas, molecules are entities that interact with each other only upon direct contact (“collision”) as they move among each other through physical space. The only forces between molecules occur at the peripheries of the molecules at the instant of collision: the individual molecule extends no force, exerts no influence, at any distance from itself. Further-

more, the collisions are elastic: they exert no influence upon the interiors of the molecules participating in the collision and are completed at the instant they commence. Excepting the instantaneous moment of impact, these ideal molecules do not “know” of each other’s presence; the interior of each of these molecules is never “aware” of the existence of the others. The result of these *elastic collisions* among many molecules, confined in a finite enclosed space, is *molecular chaos*—completely disordered motion of the individual molecules (no discernible pattern). In an unbounded space, the molecules rapidly distance themselves from each other. Appropriate averages over these random motions lead to the usual ideal gas laws (Boyle’s Law – at a constant temperature, the pressure of a gas is inversely proportional to its volume; Charles’ Law – at a constant pressure, the volume of a gas is directly proportional to its absolute temperature). These laws successfully describe the behavior of real gasses at sufficiently high temperatures—that is, when the average energy, per real molecule, is sufficiently great.

Real molecules exert long range forces upon each other—their influence extends far beyond their individual peripheries. This influence extends to the interior of the interacting molecules and is also extensive in time—the influence both over external motions and internal affairs extends over finite durations of time. When the temperature is high enough, the motions of these real molecules cannot be distinguished from those of ideal ones. The energies of their individual motions so far exceed the energies of their mutual and internal interactions that the latter cannot be noticed. They still display the random violent motions of ideal gas. However, as the mean molecular energies are lowered (that is, as the temperature is decreased), the extended mutual influences of the molecules allows the spontaneous occurrence of order. The energies of mutual attraction begin to countervail against the energies associated with the random flying apart of the molecules. They begin to “clump” together rather than strive to fly apart; the gas begins to liquify. At sufficiently low temperatures, structural patterns of molecular position and motion are formed—patterns commonly described as “crystals” – the gas has “frozen” into a solid. These intrinsic, ordered, patterns are not the result of any imposed templates or overall “planning and negotiation.” They just “happen” when the circumstances are right. The ordered motion of molecules in a crystal is “collaborative”—all move together: “all for one and one for all,” though it must be kept in mind that all relative motion does not cease in a real crystal at a finite temperature. The molecules still “jiggle” around their respective equilibrium positions.

SOVEREIGNTY OF NATIONS

Webster’s Third New International Dictionary defines “sovereignty” as a “supreme power, especially over a body politic”, or “freedom from external control.” The power of sovereign government over its people or territories is “unlim-

ited in extent.” A sovereign nation can treat its people and its territories as it wishes. The government of the People’s Republic of China, or of Myanmar, can hence legitimately complain about infringement upon their sovereignty by a world that enunciates horror at those government’s massacre of their own citizens. A sovereign United States, “of an unqualified nature,” can shrug its shoulders with legal impunity as the acid rains generated in its territories destroy the lakes and forests of a sovereign Canada, “having undisputed ascendancy” over its land and waters. Sovereign nations, ideally, have absolute authority of their own territory and no authority at all over the territory of others. There is no overlap of sovereignty except by the deliberate projection of force onto the territories of others—which, of course, is an act of war. War does not respect sovereignty.

A collection of such ideal sovereign nations, on the finite surface of the Earth, is a group of non- influencing entities, immune in their interiors to the activities of others, interacting only briefly and violently at their peripheries. Such a system is chaotic—without order: “The international systems, whether it is dominated for a time by six Great Powers or only two, remains anarchical—that is, there is no greater authority than the sovereign, egoistical nation-state” (Kennedy, Paul. 1987. *The Rise and Decline of Great Powers*. New York: Random House, page 440; emphasis added). The analogy between such a system and an ideal gas, as described in the previous section, seems very close, including the tendency of both systems to push out to fill the entire available space: the gas pushes to its container walls, exerting a pressure upon them; the nations push out over the non-nation territories of the globe, colonizing or incorporating them. Also, like ideal molecules, the definitions of the ideal sovereign nation give no hint as to the origin of its sovereign nature: sovereignty just “is.” Actually, of course, molecules are created by intermolecular collisions—chemical reactions; sovereignty also is created by interactions—wars—between states or “tribes”, between feudal lords and warriors, between peoples and states or lords.

LIMITS TO SOVEREIGNTY

In the nuclear age, even small nations may challenge the viability of the interior capital cities of distant superpowers. (Israel may be able to threaten Teheran with nuclear devastation delivered by its own Jericho II ballistic missiles or by its US supplied F-16 aircraft; eventually it may be able to similarly strike Moscow. Similarly, Pakistan can threaten New Delhi and India can threaten Karachi. Even now, France or Great Britain possess the capability of destroying Moscow or Beijing with ballistic missiles launched from underground silos or submarines. Of course, the major nuclear powers, possessing large stocks of immensely powerful nuclear weapons with the means to project them anywhere in the world regardless of natural or man-made defensive barriers, have

the capacities to destroy each other., all the rest of the nations, and perhaps all of humankind as we know it via radioactive fallout and/or “nuclear winter”. A nation that cannot even guarantee the survival of its own citizens, much less its own survivability as an entity, cannot be said to be free “from external control.” Even without nuclear weapons, nations can inflict grievous harm upon each other via the long-range delivery of potent chemical and biological weapons as well as with the precision placement of “conventional” explosives (e.g., Seoul remains at the “mercy” of North Korea’s massive conventional artillery stocks). And how can we say that its power over its territories is “unlimited” when the nation, big or small, may not even be able to protect its peacetime commercial air—land—and waterways from death and disruption at the hands of “terrorists” representing other nations, or not nations at all? The 2016 U.S. national elections have shown how difficult it is to guarantee the validity of its own political processes from the interference of other nations. (Supposedly, there were also recent attempted international interferences in French and German national elections.)

Given the destructiveness that even a very small, “weak” nation can inflict upon its neighbors, nations who themselves are firm believers in national sovereignty do not willingly extend that concept to neighbors. And these neighbors, and the rest of the world, may accept these restraints—giving up the “good” of sovereignty for the “good” of peaceful quasi-sovereignty. If the Palestinians ever hope to achieve statehood without destroying Israel, it will only be by the acceptance of severe restrictions as to what military power they may create and maintain upon their national territory, surely a great limitation on the usual “undisputed ascendancy” over its lands and peoples. (And Israel will have to give up some of its absolute authority over the surface and sub-surface waters of the region and its sea coast.)

But “acts of war,” whether in “peace” or wartime, nuclear or otherwise, are not the only infringement upon conventional “sovereignty.” Can a nation be free “from external control” when a good part of its land, resources, communication facilities (such as “Facebook”), and productive capacities, belong to other nations, when many of the tools necessary for defense and economic well-being in a modern, technological age, must be acquired from other distant nations, when many of its people can only be productively employed and gain a livelihood under the direction and control of citizens of “foreign” nations?

Economics and long-range projection of weapons are not the only constraints upon traditional sovereignty. In a finite world, the resources—for example, oil from internal or external sources—used by one nation in advancing its comfort and well-being, are used up and no longer available to other people’s when they become capable and wish to exploit the same portion of the earth’s goods. Fish caught in the Pacific by Japan are no longer available in Peru; in fact, with the prevalent over-fishing, they may not be available

to anybody! Nations can, and do, poison the air, waters, and lands of their neighbors either intentionally, or inadvertently via usual economic activities.

Furthermore, the harm may not come from a neighboring nation—the source may be “generic”! The fluorocarbons leaking from an automobile air conditioner in an American city contributes to the “hole in the ozone layer” over an Australian citizen. The burning of rain forests in Brazil contributes to the global “greenhouse effect”, warming the atmosphere, melting the polar icecaps, thus contributing to droughts in the farmlands of the American Midwest and floods in the impoverished sea plain of Bangladesh. The generation of peaceful Ukrainian nuclear-electric power in the then Soviet Union has led to the destruction of the livelihoods of peaceful Lapp reindeer herders in northern Sweden.

Hence even without war (the customary creator and destroyer of the nation-state and the usual accomplice of the system of sovereign states) or warlike acts, sovereignty—as customarily defined—is a fiction of the modern age. Nations do have profound influences upon each other even in peacetime, upon the peoples as well as the governments of the rest of the world. The completely anarchic system of states, which is the corollary of the existence of the individual sovereign state, is also fictional. Many actions, having significant impact upon domestic life, are done “in concert” by the various nations—even competing ones. (Even in the midst of deadly combat, Iraq and Iran met to discuss oil production quotas and prices.) There is already considerable “order” and restraint—some things are “just not done” even though the “power” to do them exists. And the ordering is becoming stronger.

ORDER OF NATIONS

It is usually assumed that the alternate system to the present anarchic system of completely sovereign states is one of order through world government. Such a single government could come about with the planned conquest of all other states by one of the super-powers. However, given the fact that even one of the smaller nations, acting in its own defense, could destroy a superpower, admittedly committing suicide in the process, it seems unlikely that a viable world order will result from military conquest.

An alternative to military ordering is economic domination of the many by the one. But the modern “high tech” world is very unstable. Today’s small nations become tomorrow’s economic superpowers while the economic giants of today fritter away their tomorrows via the uncontrolled accumulation of debt, the disintegration of their societies’ physical, cultural, and educational infrastructure, and the growth of domestic disorder. Hence a planned economic ordering also seems unlikely.

Many assume that a formal ordering of the world will come about as a result of diplomatic negotiations among governments if not by conquest or economic domination.

After reaching agreement on the templates for world order via long, tedious, and agonizing negotiations, nations would presumably diminish their individual sovereignties in a carefully orchestrated, step-by-step, non-spontaneous process. But there is no evidence that such a process is under way, and no reason to believe that any foreseeable government would acquiesce to such a process or such a resulting constraint upon their dignities and perquisites. It seems very unlikely that the nations of the UN are going to get together, like the states of their post-revolutionary American Confederation, in a deliberately planned surrender of sovereignty to a greater sovereign whole. In fact, at present, there is much evidence that some nations are striving to go in the opposite direction.

And yet order grows—apparently spontaneously. Citizens' groups create ties among themselves that function even when their respective governments are not in communication. There are groups that share common cultural and environmental interests across national borders: international art associations, chess groups, scientific collaborations, music societies, whale watching associations, and so on. These groups engage in no governmental activities, but in meeting to share their activities they also share and intertwine their national commitments to some extent. Other citizen groups may engage in governmental activities but meet internationally on a nongovernmental basis: international associations of police, firemen, game wardens, bankers and financiers, manufacturers, natural resource producers, and so on. In the process of non-officially aligning their professional activities and outlooks, they create ties among their nations in spite of the wishes of their respective governments. Then there are the activities of international commerce and industry that transcend national boundaries in manifold manners, many of which are unknown to their formal governing bodies but create strong constraints on the sovereign nature of these governments. Finally, there are the quasi-governmental interactions in which citizen groups meet and negotiate in parallel to, sometimes instead of—official governmental delegations: United Nations support groups for

example. And, of course, there are the citizen groups of one nation set up explicitly to influence the citizens and governments of another nation: differing groups of Guatemalans in the United States to manipulate American policy towards that unhappy nation, Polish American organizations lobby for greater American participation in Poland's economic recovery, and so on. There is no overarching plan to all of these diverse processes, no formally preconceived model of the end of the process, no explicit template to which the international structure is being shaped.

And yet, apparently spontaneously, the nations are being shaped to each other, the rough edges which might dangerously abrade each other are, "peacefully", themselves being abraded away. The ability and inclination of the sovereign nation to be sovereign—to behave free of external constraints, as if there were no other nations present—seems to be lessening (in spite of the expressed desires of some present governments pushing in the opposite direction), driven by the greater inclination to survive and prosper. We have not planned the final order of states; we may not be able to anticipate or control the ordering, but an ordered system seems to be replacing the chaos of classical sovereignty. The resultant order will probably not imply the disappearance of conflict—violent or otherwise—between and within states. There may still be considerable "jiggling" about their final equilibrium states, but the jiggling energy will not be enough to destroy the ordered states—if we survive to reach such an order.

Hence, pushing the analogy between molecules and nations beyond ideal gasses to real gasses, spontaneously (without a prior universal agreement upon, and establishment of, an overarching, omnipresent, all-powerful world government), we may see the evolution of order from disorder, and the development of a non-violent world commonwealth from the anarchical threats of nuclear violence. In spite of the apparent occasional pushes to international disorder, multilateralism may still triumph in the end.

Enlightenment Now: The Case for Reason, Science, Humanism, and Progress

By Steven Pinker (Viking, New York, 2018). xix + 516 pp. ISBN 978-0-525-42757-5. \$35.

Although Pinker notes in his preface that “at the time of this writing, my country is led by people with a dark vision of the current moment,” he acknowledges that this book “was conceived some years before Donald Trump announced his candidacy” (p. xvii). “The ideals of the Enlightenment are products of human reason, but they always struggle with other strands of human nature,” he writes in the brief Part I of this book, a book which is “my attempt to restate the ideals of the Enlightenment in the language and concepts of the 21st century” (p. 5).

Pinker portrays the Enlightenment in terms of four themes: reason, science, humanism (which form the basis of a more substantive Part III), and progress (the topic of Part II, which comprises nearly three quarters of his text). To these he adds “entropy, evolution, and information” as “some critical ideas about the human condition and the nature of progress that we know and they didn’t” (p. 14).

Part II consists of a series of chapters charting the progress in various areas pertaining to human life using graphical data, like that used in Pinker’s 2011 book *The Better Angels of Our Nature* where he argues violence has declined in the world both in the long run and the short run. The areas covered in Part II are life, health, sustenance, wealth, (income) inequality, the environment, peace, safety, terrorism, democracy, equal rights, knowledge, quality of life, happiness, and existential threats. Particularly noteworthy are his discussions of “the world’s two most pressing problems” (p. 324) – anthropogenic climate change, which he calls “the most vigorously challenged scientific hypothesis in history” (p. 137) and nuclear war, one of “the four horsemen of the modern apocalypse” (p. 290) (the other three are population, resource shortages and pollution).

Introducing Part III, Pinker reminds his readers that Part I outlined the ideas of the Enlightenment and that “Part II showed they work” (p. 349). Part III is intended to defend them – against “not just angry populists and religious fundamentalists, but fractions of mainstream intellectual cultures” (p. 349). He does so with chapters titled by the three themes of reason, science, and humanism which also comprise his subtitle.

The main thrust of Pinker’s chapter on “Reason” is that “The major enemy of reason in the public sphere today . . . is . . . politicization,” (p. 371) and the fact that it is increasing. This politicization is all the more problematic, because the future of planet Earth is at stake. “A challenge of our era is how to foster an intellectual and political culture that is

driven by reason rather than tribalism and mutual reaction” (p. 375). “The human brain is *capable* of reason; the problem is to identify those circumstances and put them more firmly In place” (p. 375).

After extolling the achievements of science, Pinker announces that the purpose of his chapter on “Science” is to address a hostility to science that goes deeper than opposition from the political left to nuclear power and from the right to evolution. He sees it spring from C. P. Snow’s *The Two Cultures*, from nonscience disciplines complaining that science is encroaching upon their time-honored territories. Deprecating the idea of a “scientific method,” Pinker notes that “Scientists use whichever methods help them understand the world . . . pressed into the service of two ideals” (p. 392): (1) “that the world is *intelligible*” (p. 382) and (2) “that we must allow the world to tell us whether our ideas about it are correct” (p. 393). What science has taught us about the “genesis of the world, life, humans, and societies” (p. 394) undermines “the belief systems of all the world’s traditional religions and cultures” (p. 394). “One of the greatest potential contributions of modern science may be a deeper integration with its academic partner, the humanities” (p. 405). But Pinker acknowledges that skeptical humanists will have to be more welcoming of this consilience.

In his final chapter, on “Humanism,” Pinker formalizes the connection between science and humanism. Although science is the pathway of human progress, he notes that it can bring results that harm humanity as well as to enable it to flourish. To insure that only the latter comes to pass, science must be tempered by humanism, which does not allow the flourishing of any one human at the expense of any other.

He addresses what he sees as threats to humanism, the first of which is theistic morality, especially in “the Islamic world, which by a number of objective measures appears to be sitting out the progress enjoyed by the rest” (p. 439). “Correlation is not causation, but if you combine the fact that much of Islamic doctrine is antihumanistic with the fact that many Muslims believe that Islamic doctrine is inerrant – and throw in the fact that the Muslims who carry out illiberal policies and violent acts say they are doing it because they are following those doctrines – then it becomes a stretch to say that the inhumane practices have nothing to do with religious devotion and that the real cause is oil, colonialism, Islamophobia, Orientalism, or Zionism” (p. 440). “All these troubling patterns were once true of Christendom” (p. 441), he acknowledges, but he observes that the Enlightenment changed that. Can there be an Enlightenment for the Islamic world? Pinker spends a half page listing Muslims in a position to bring it about and adds that “non-Muslims have a role to play” (p. 443), too. In addition to theistic morality, Pinker sees a second threat to humanism in what he calls romantic heroism, epitomized

by the philosophy of Friedrich Nietzsche, who advocated a society ruled by one elevated to the status of *Übermensch*, which served as models for many twentieth-century dictators.

Although Pinker's message can be distilled in his closing words, "there is no limit to the betterments we can attain if we continue to apply knowledge to enhance human flourishing" (p. 453), I was continually awed in reading this book by the amount of information that had to be gathered for it: 37 pages of reference notes, 32 pages of reference listings, and 32 pages of index, all set in what appears to be 4-point type. Covering so many fields accurately is a challenge, and I compliment Pinker that I could find only one statement in my field of physics to quarrel with: "Solar panels made with carbon nanotubes can be a hundred times as efficient as current

photovoltaics, continuing Moore's Law for solar energy" (p. 330). Since efficiency cannot be greater than 100% and the current efficiency of photovoltaics is around 20%, this statement would violate the first law of thermodynamics!

If I were going to quarrel with anything in this book, it is that Pinker gives short shrift to one of his "four horsemen of the modern apocalypse" – overpopulation. On page 324 he states that "Before the century is out, [Earth] will have to accommodate another two billion people." But he doesn't say how.

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Lasers, Death Rays and the Long Strange Quest for the Ultimate Weapon

By Jeff Hecht, published by Prometheus Books (available Jan. 8, 2019)

All of us encounter lasers in every aspect of our everyday lives. When we go to the grocery store, our purchases' prices are scanned by a laser. Laser pointers are ubiquitous at APS meetings and lasers are widely used in construction and by the communications industry. However military applications are far more limited. We read about drones using lasers to target vehicles carrying enemy leaders, but they are still rare as battle field weapons except for designating targets for attack.

This book recounts efforts to develop lasers as defensive and offensive weapons both in space and on terrestrial battlefields, on the oceans and in the air. The author (B.S. Electrical Engineering, California Institute of Technology, 1969 and M.Ed. in Higher Education, UMass. Amherst 1971) is a longtime science writer who has authored a variety of science magazine articles and 13 books and published articles in *Nature* and *IEEE Spectrum*. He is a fellow of the Optical Society of America and a life senior member of the IEEE. He has followed attempts to develop lasers as weapons since the origins of the technology.

This book begins with a brief history of the "lightning bolt" weapons of ancient gods, Archimedes' work, and Tesla's efforts to construct an electric field beam weapon. The author details the story of the origins of the maser, and its development in 1954 into a laser. He states that lasers are clearly suggestive of the eventual development of death rays and reviews early efforts to this end including the fictional stories that incorporated laser weapons. He also recounts the ways in which the Pentagon almost invented the laser and begins

a detailed history of military projects starting at the conclusion of the Cuban Missile Crisis. Most of the initial effort was focused on finding more powerful lasers since a beam weapon had to be powerful in order to damage armored targets such as battlefield missiles or war planes. With considerable effort, military and industrial scientists invented new types of lasers whose power could reach hundreds of kilowatts or even megawatts. Hecht tells this intriguing tale and profiles the men involved, many of whom he interviewed.

Once lasers of sufficient power were available, new problems gained center stage such as the defocusing of lasers by the atmosphere, the need for robust optical systems, and a way to decrease the size and mass of high power lasers so they could be deployed in either spacecraft or airplanes. The Strategic Defense Initiative announced by President Ronald Reagan in 1983 threw huge amounts of money and talent into the search for a useful laser defense against missiles. The program solved problem after problem as detailed in this book, but never managed to produce a working system that could be deployed.

By 1991, Reagan was out of office. The Soviet Union had collapsed and with it the need for space-based lasers for defense against nuclear-armed inter-continental missiles. Nevertheless, President H. W. Bush continued to support the Airborne Laser System as a way to destroy battlefield missiles. The system worked but hit a series of logistic problems, many of which were gradually solved. I found the story of General Ellen Pawlikowski, today the first female four-star general in the Air Force, who was named director of the Program Office of the Airborne Laser System at Kirkland Airforce Base in 2000, especially interesting because it was based on an interview conducted by Hecht and because Dr. Pawlikowski is a pioneering woman in laser technology.

In 1995, Israel and the U.S. began to collaborate on the

development of laser-based defenses against missiles that could be deployed in ground vehicles on the battlefield. This was much easier than developing systems based in space or on airplanes, but it was hampered by many of the same problems. The rest of the book updates the reader on recent developments in types of lasers, including those powered by diesel fuel which might be used on the battlefield against conventional weapons. It finishes with a look at the future of the ultimate beam weapon.

This slim volume provides a remarkable description, including detailed quotations and profiles, of the men and women involved in the quest for laser weapons. It is also remarkable in providing detailed technical descriptions of the lasers and the systemic problems they encountered without

resorting to a single equation. I recommend it to those with a background in physics who are not experts in lasers or optics as well as to non-physicists who are interested in the technologies used in weapons. Unfortunately the version of the book which I read was clearly a prepublication version containing several substantive goofs, for example stating that alkali metals have only one atom in their outer shells. My recommendation of this book is contingent on the publisher correcting these errors prior to publication.

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