

PHYSICS & SOCIETY

A Publication of The Forum on Physics and Society A Forum of The American Physical Society

From the Editor

Following up on what I mentioned in the previous issue, I am pleased to report that the Forum leadership has adopted this year the practice, which is intended to continue, of recording the Forum sponsored talks at the March and April meetings and posting them. Please see the news item on this subject, which includes the links. We intend those links to be 'live' in the .pdf version posted: I hope it works. This is part of our continuing expansion of our media presence. Please contact our Media Editor, Tabitha Colter, at tabithacolter@gmail.com for suggestions and comments.

We have a larger than usual number of articles in this issue. Some of them cover topics related to nuclear arms and disarmament that we have traditionally emphasized, while others branch out in different directions, a thing which we have also been attempting.

Contributions from our readership and their friends are always welcome, as they are suggestions for invited contributions. Suggestions and articles should be sent to me, except for

book reviews, which should go to the reviews editor directly (ahobson@uark.edu).

Content is **not peer reviewed and opinions given there are the author's, only, not necessarily mine, nor the Forum's or, a fortiori, not the APS's either**. I am very open as to what is appropriate. **Controversy is good**. If you object to something, write a letter to the Editor with your comments or, even better, an article with your own point of view.

Oriol



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

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Video Recordings of the 2019 APS Meetings FPS-sponsored Session Talks

The American Physical Society Forum on Physics and Society (FPS) made video recordings of the talks at the FPS-sponsored sessions at the 2019 APS meetings, and they are now posted on YouTube. Here are links to these recordings.

The video recordings of the FPS sessions at the Boston APS meeting in March 2019 are posted on YouTube in the order of talks at each of these sessions:

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

[youtube.com/watch?v=OeMizCqaAHM&t=418s](https://www.youtube.com/watch?v=OeMizCqaAHM&t=418s)

Steve Fetter (U Maryland) - *Nuclear Modernization, ICBMs, and Launch On Warning*

[youtube.com/watch?v=8NDcjXFThC4&t=641s](https://www.youtube.com/watch?v=8NDcjXFThC4&t=641s)

Lisbeth Gronlund (UCS) - *US Plans for New Nuclear Warheads*

[youtube.com/watch?v=VZ1F0126Q5k&list=PLgxD9DiwxLGquMJN-56xTBeYXU_afGyx_&index=4&t=812s](https://www.youtube.com/watch?v=VZ1F0126Q5k&list=PLgxD9DiwxLGquMJN-56xTBeYXU_afGyx_&index=4&t=812s)

Richard Garwin (IBM) - *Current Nuclear Weapons Issues, and Sid Drell's Contributions to Arms Control and Strategic Stability*

[youtube.com/watch?v=9tffRTEBqfo&list=PLgxD9DiwxLGquMJN-56xTBeYXU_afGyx_&index=4](https://www.youtube.com/watch?v=9tffRTEBqfo&list=PLgxD9DiwxLGquMJN-56xTBeYXU_afGyx_&index=4)

Stewart Prager (Princeton) - *Engaging the Physics Community in Nuclear Threat Reduction*

The Politics of Science Advising

[youtube.com/watch?v=IMnGbqXebJk&list=PLgxD9DiwxLGrVkvHUGWxN1-JPlh4dW-Sw&index=2&t=1573s](https://www.youtube.com/watch?v=IMnGbqXebJk&list=PLgxD9DiwxLGrVkvHUGWxN1-JPlh4dW-Sw&index=2&t=1573s)

John Holdren (Kennedy School; President Obama's Science Advisor and head of OSTP) - *Speaking Science to Power: Providing S&T Advice to Governments*

[youtube.com/watch?v=dBznwr0ksJs&list=PLgxD9DiwxLGrVkvHUGWxN1-JPlh4dW-Sw&index=2](https://www.youtube.com/watch?v=dBznwr0ksJs&list=PLgxD9DiwxLGrVkvHUGWxN1-JPlh4dW-Sw&index=2)

Celia Mertzbacher (ORNL; former Executive Director, PCAST) - *Federal Policy Making: Perspectives from Inside and Outside Government*

[youtube.com/watch?v=Ga_ss9GCluM&list=PLgxD9DiwxLGrVkvHUGWxN1-JPlh4dW-Sw&index=3](https://www.youtube.com/watch?v=Ga_ss9GCluM&list=PLgxD9DiwxLGrVkvHUGWxN1-JPlh4dW-Sw&index=3)

Andrew Zwicker (Princeton; New Jersey Assembly) - *Advice from a Scientist-Policy Maker on Giving Advice to a Policy Maker*

[youtube.com/watch?v=ShEt_t9ppUI&list=PLgxD9DiwxLGrVkvHUGWxN1-JPlh4dW-Sw&index=4](https://www.youtube.com/watch?v=ShEt_t9ppUI&list=PLgxD9DiwxLGrVkvHUGWxN1-JPlh4dW-Sw&index=4)

Nathan Phillips (BU) - *Science Legislative Fellow Advisors for State Legislatures*

Iran, North Korea, and Nuclear Proliferation

[youtube.com/playlist?list=PLgxD9DiwxLGqgR6bZSgixc-D5Z4NHyzWN](https://www.youtube.com/playlist?list=PLgxD9DiwxLGqgR6bZSgixc-D5Z4NHyzWN)

Zia Mian (Princeton) 2019 Szilard Lectureship Award recipient - *Scientists and Today's Struggles Against Nuclear Weapons: What Would Szilard Do?*

[youtube.com/watch?v=-Vt2lnZuYX0&list=PLgxD9DiwxLGqgR6bZSgixc-D5Z4NHyzWN&index=3&t=16s](https://www.youtube.com/watch?v=-Vt2lnZuYX0&list=PLgxD9DiwxLGqgR6bZSgixc-D5Z4NHyzWN&index=3&t=16s)

R. Scott Kemp (MIT) - *Iran, North Korea, and the Renewed Challenge of Proliferation*

[youtube.com/watch?v=MgOktbXXlrA&list=PLgxD9DiwxLGqgR6bZSgixc-D5Z4NHyzWN&index=3](https://www.youtube.com/watch?v=MgOktbXXlrA&list=PLgxD9DiwxLGqgR6bZSgixc-D5Z4NHyzWN&index=3)

Alex Glaser (Princeton) - *Verification of Denuclearization*

[youtube.com/watch?v=RaZOfDQCYGM&list=PLgxD9DiwxLGqgR6bZSgixc-D5Z4NHyzWN&index=4](https://www.youtube.com/watch?v=RaZOfDQCYGM&list=PLgxD9DiwxLGqgR6bZSgixc-D5Z4NHyzWN&index=4)

Rachel Carr (MIT) - *Can Neutrino Detectors Strengthen the Nonproliferation Regime?*

[youtube.com/watch?v=RRfYzo7p6X0&list=PLgxD9DiwxLGqgR6bZSgixc-D5Z4NHyzWN&index=5](https://www.youtube.com/watch?v=RRfYzo7p6X0&list=PLgxD9DiwxLGqgR6bZSgixc-D5Z4NHyzWN&index=5)

Frank von Hippel (Princeton) - *Strengthening the Nonproliferation Regime*

Links to the audio/video recordings of the April 2019 FPS sessions at the Denver APS Meeting:

New Challenges International Science Collaborations (FPS)

[youtube.com/watch?v=aRSz_5x08w0](https://www.youtube.com/watch?v=aRSz_5x08w0)

Amy Flatten (APS): *Long-term Strategic Planning for APS International Activities* (Note: a section is missing from the video because of a recording error. Please contact flatten@aps.org for the full presentation.)

[youtube.com/watch?v=3kTIF15B-wE](https://www.youtube.com/watch?v=3kTIF15B-wE)

Bill Colglazier (AAAS): *Opportunities and Challenges in International Scientific Collaboration on Large Scale Projects*

[youtube.com/watch?v=qElz_Q6Z9o](https://www.youtube.com/watch?v=qElz_Q6Z9o)

Karla Hagen (British Embassy, DC): *The US-UK Science Collaboration Landscape: Status and Opportunities for the Future*

[youtube.com/watch?v=o24EyIhEjK8](https://www.youtube.com/watch?v=o24EyIhEjK8)

Panel discussion: *Challenges & Opportunities for International Science Collaborations*

New Energy Technologies and Policies (FPS)

youtube.com/watch?v=jyTVZAPqnn4

Daniel M. Kammen (Berkeley): *An Energy Plan the Earth Can Live With*

youtube.com/watch?v=FOMeRzMrqt4

Adilson Motter (Northwestern): *North American Power-Grid Network: Failures and Opportunities*

youtube.com/watch?v=NkJ5kwFcv0w

Amory Lovins (Rocky Mountain Institute): *Integrative Design for Radical Energy Efficiency*

Attracting Young People to Science and Science Policy (FPS and FECS)

youtube.com/watch?v=skUe4m7OOh8

Brian Jones: *Making Climate Change Concepts Accessible (and Acceptable) to a Wide Audience*

youtube.com/watch?v=k9xqHdQ_FAM

David Maiullo: *Using Physics Demonstrations to Excite & Educate the Public in Science & Sci Policy*

FPS Prize Session: Burton Forum Award

youtube.com/watch?v=Z4xslPu2PmE

Shirley Ann Jackson (RPI President): *Physics the River that Runs Through It All*

In addition, here are two of the talks at the 1st Plenary Session at the April 2019 APS meeting, on **Physics and Society Issues**

youtube.com/watch?v=aL9SIq3kaL8

Amory Lovins (Rocky Mountain Institute): *Disruptive Energy Futures*

youtube.com/watch?v=BLPJdjR7rj8&list=PLgxD9DiwxLGr_5kDIOtWNFYEPO3b5toUo

Katie Mack (NCSU): *Physics and Social Media*

ARTICLES

A Wide-ranging Debate Over US Nuclear-weapons Policy Before the House Armed Services Committee

Frank N. von Hippel, Program on Science and Global Security, Princeton University

When the Democrats took over the House, Representative Adam Smith from Washington State, took over the chairmanship of the House Armed Services Committee (HASC). One of the first hearings he scheduled, on 6 March 2019, was on the US “Nuclear Deterrence Policy and Posture” with non-governmental witnesses.

HASC, which authorizes more than half of the federal discretionary budget, has 57 members organized in six subcommittees. One of the subcommittees focuses on strategic [nuclear] forces but, because of his personal interest, Smith decided to have the hearing before the full committee.

Smith invited two outside witnesses:

- Bruce Blair, currently my colleague at Princeton University’s Program on Science and Global Security. In the early 1970s, Blair served both as a Minuteman Intercontinental Ballistic Missile (ICBM) launch-control officer and as a support officer for the Strategic Air Command’s Airborne Command Post. He became concerned about the danger of accidental or unauthorized nuclear launch and has devoted much of his subsequent career researching and explaining the dangers. He also is a co-founder of Global Zero.

- Joan Rohlfing, President of the Nuclear Threat Initiative, a non-governmental organization, previously worked in the Department of Energy as director of the office of nonproliferation and national security and senior advisor to the secretary on national security.

The minority on the committee got to choose only one witness and chose Frank Miller, of the Scowcroft Group. Most of Miller’s career was in the Pentagon, where he focused on nuclear strategy and targeting. During the Bush Jr. administration, he served on the National Security Council. His Wikipedia profile describes him as “a high priest of nuclear theology.”

The issues covered in the hearing included: ballistic-missile defense; the low-yield nuclear warheads the Trump Administration proposes to deploy on some submarine-launched ballistic missiles; “modernization” of US strategic forces; no-first-use of nuclear weapons; the future of US-Russian nuclear arms control; and the vulnerabilities of nuclear command and control.

The prepared statements and bios of the witnesses and a video of the full 2-hour hearing are available on the committee’s website.¹ Below I provide some excerpts, background

and commentary that I hope will be useful to those interested in getting involved in helping to educate their Representatives, Senators and their staffs on these issues. Our Congress was relatively sophisticated on nuclear weapon policy in the 1980s but, with the end of the Cold War and the turnover of Congress, very few members focus on it anymore and big decisions are being made by a relatively small number of people, some of whom are zealots.²

Ballistic-missile defense. Blair was the only one to speak on this issue:

“We pulled out of the ABM Treaty [limiting strategic ballistic missile defense (BMD)] very abruptly in 2002. That was John Bolton’s wrecking ball for arms control. And as a result, today, we’re seeing appear on the scene, all these novel nuclear weapons systems that President Putin has been brandishing over the last several months. The hypersonic vehicles, the cruise missiles, the undersea autonomous nuclear submarine that can travel for 6,000 kilometers. All these systems were stimulated by Putin’s desire to deal with the elimination of the ABM Treaty and develop weapons that could defeat [BMD], and it took them about 15 years.”

Low-yield nuclear weapons. The Trump Administration’s rationale for new low-yield nuclear warheads on submarine-based ballistic and cruise missiles is a supposed Russian strategy to “escalate to de-escalate” a conventional war in Europe. The scenario Miller postulated was one in which Putin would “seize a piece of the Baltics” and then, if NATO assembled an overwhelming force to push his forces back into Russia, use a low-yield nuclear weapon to warn NATO to back off. The Trump Administration believes that the US needs more low-yield options than its bombs and air-launched cruise missiles provide. Freshman Representative Katie Hill of California pointed out that the Trump Administration’s “low”-yield warhead has a yield equivalent to 5,000 tons of conventional explosive, about one-third of that of the Hiroshima bomb, and with one half its potential area of blast destruction.³

Blair interpreted the Russian escalate to de-escalate policy as defensive rather than offensive,

“their escalate to de-escalate strategy’s really emerged in the year 2000 under Putin in response to the NATO bombing of Yugoslavia in 1999... And the Russians looked at that and said, ‘Wait a minute. What if this happens to us? We are inferior. We can’t match NATO. What do we do?’ This was when Russia was on its knees, of course.

“And so they came up with a last-ditch approach to use nuclear weapons under this strategy that has been discussed... that ... highlights ... the weakness of their hand, and the fact that they would only resort to such use of weapons a ... as a last resort, because ... they’re losing a conflict with...NATO.”

Modernization. The primary debate here was over whether the US should “modernize” (replace) the 400 Minuteman III ICBMs that are located in underground silos in the states of Montana, North Dakota and Wyoming. Blair and Rohlfling preferred to retire them because the Minuteman are

postured to be launched on warning in case there appears to be an incoming missile attack. In their view, this creates an accident-prone hair-trigger situation. Blair argued,

“there’s concern that the president, who has only about five minutes under current strategy, to make a decision on whether and how to retaliate to an attack may have to rely on information that has been corrupted.”

Miller argued that it is essential to keep the ICBMs because it would raise the threshold for any Russian attempt at a disarming first strike:

“If an enemy wants to neutralize those [400 ICBMs], that means putting at least 400 to 800 warheads in the air. There is no question that that is a massive attack on the United States which will draw a massive response, and that’s an important indicator of what’s going on in the world at that time.”

No-first use. Blair and Rohlfling argued that the US should raise the threshold for nuclear war by adopting a no-first-nuclear-use posture such as China has. Blair pointed out that, in fact, “the Chinese and the Russians have a no-first-use agreement with each other right now.”

The US had a first-use policy during the Cold War. At the time, the Soviet Union had a big numerical superiority in numbers of tanks along the inter-German border that NATO was unwilling to match. Instead, the US introduced thousands of “tactical” nuclear weapons into West Germany as a signal that any invasion would very quickly trigger a nuclear war. Hundreds of nuclear weapons were introduced into South Korea to send a similar signal to North Korea and China.

This policy was labeled “extended deterrence.” It extended the US “nuclear umbrella” to cover its allies from both nuclear and conventional attack and thereby served the nonproliferation objective of making it unnecessary for allies, such as Germany, Japan and South Korea, to acquire their own nuclear deterrents.

The balance of conventional forces in Europe changed, however, with the disintegration of the Warsaw Pact and the Soviet Union and the retirement of a great deal of Russian hardware under the 1990 Conventional Forces in Europe Treaty. The Bush Sr. administration withdrew all but about 150 nuclear bombs in Europe and all US nuclear weapons from South Korea. President Obama tried to move the US to a no-first-use posture but his Secretaries of State, Defense and Energy all argued that, given Russian and North Korean threats to their neighbors, it was not a good time to do so.⁴

Miller argued that

“our allies have for decades depended on a U.S. policy that we would escalate to nuclear use to end a conventional war in Europe. If we were, in these very tumultuous transatlantic times, to remove that guarantee, we would cause allies to doubt the U.S. guarantee of their safety... if we remove that guarantee, we could well lead to the proliferation of nuclear weapon states in the world.”

Reductions. The US-Russian New START Treaty of 2011 limits Russia and the United States each to 1550 deployed

and counted warheads. The limit is actually somewhat higher because the treaty counts long-range nuclear bombers as carrying only one nuclear warhead although they can carry up to 20 air-launched cruise missiles each.

- US nuclear modernization plans are for:⁵
- 12 new Columbia-class ballistic missile submarines carrying 16 Trident II missiles each, with each missile being able to carry up to 8 warheads for a total of up to 1536 warheads.
- 400 new silo-based ICBMs. The current Minuteman III once carried three warheads but today only carries one. Its successor is likely to have the same capabilities.
- 100 new long-range B-21 bombers plus some of today's 87 B-52H and 20 B-2A bombers. Not all of these bombers would be equipped with nuclear bombs and cruise missiles. Currently, only 60 of the B-52H and B-2As are believed to be nuclear capable. However, 1000 new nuclear-capable long-range standoff (LRSO) cruise missiles are being ordered for the bombers and hundreds of nuclear bombs are being refurbished.

About 3600 warheads are currently available for these systems – about twice as many as are deployed. The extras are available as potential replacements if deployed warheads develop problems. They also could be used to fully load up the strategic missiles and bombers in the absence of limits.

Blair argued⁶ that the US could reduce to a much smaller force – even unilaterally:

“I think the number of primary aim points in our current nuclear planning is on the order of 1,000 ... in Russia, China and North Korea, in total. And we have at sea, in our Ohio-class submarine force, enough warheads to cover all of those aim points...with ... five [ballistic-missile submarines], if you could keep three at sea, that would be sufficient to cover the aim points that I have defined as constituting a fully adequate deterrent threat.”

Three *Columbia*-class submarines could carry up to 384 nuclear warheads, so Blair obviously does not think it necessary to cover all the aim points in the current US nuclear target list. The 1000 aim points is consistent with reports about an Obama Administration study that concluded in 2013 that the US could reduce to about 1000 deployed strategic warheads. Reductions to a “deterrence-only” target set with 500

aim points was reportedly also discussed but resisted by the Chairman of the Joint Chiefs of Staff as too large a reduction to accomplish in a single step.⁷ President Obama hoped that bilateral reductions to 1000 might be possible but Putin was unwilling to consider further reductions without constraints on US BMD, which he sees as threatening the deterrent capabilities of the Russian nuclear forces that might survive a US first strike.⁸

Miller commented,

“A force of 12 [ballistic missile submarines] gives you 10 operational boats. That's enough to have a Pacific base and an Atlantic base. I think if that number came down much smaller, we would be driven to one base, which means we would lose an ocean's worth of patrol area.”

Indeed, Blair's notional five-submarine deterrent would be a big step toward the British and French postures. Both have four ballistic missile submarines with 16 multi-warhead missiles each with at least one submarine on patrol at any time.

Nuclear arms control. Both Rohlffing and Blair called for extension of the New START Treaty which will otherwise expire in 2021, and a renewed dialogue with Russia on nuclear arms control. New START could be extended for five years by a simple executive agreement between Trump and Putin. Miller responded,

“The Russians have violated, are violating as we sit here, nine arms control agreements. I think that we need to proceed ahead to try to get our arms around their strategic weapons, their novel weapons and their non-strategic weapons.”

It is also the Trump Administration's view that, rather than extend New START, the US should try for a broader treaty that would capture all of Russia's nuclear weapons. Unfortunately, the Trump Administration has not engaged in serious nuclear arms control discussions with Russia. If it did, Russia too would want to broaden the agenda and include US BMD, which the Republican-controlled Senate ruled out of bounds for negotiation as a condition of ratification of the New START Treaty.

With less than two years before the New START Treaty expires, it looks increasingly as if it will expire without a successor. Given the Bush Administration's 2002 decision to take the US out of the ABM Treaty and the Trump Administration's February 2019 announcement that it was giving the

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required six-month notice of its decision to take the US out of the Intermediate-Range Nuclear Forces (INF) Treaty, the expiration of the New START Treaty⁹ would leave the US and Moscow without any bilateral nuclear arms control treaty for the first time since 1972.

Vulnerability of nuclear command and control. One thing all three witnesses could agree on was the need to invest in a more survivable command-and-control system for US nuclear weapons. Blair stated,

“every now and then, we conduct a study and we find new and worrisome vulnerabilities in this arena. The last study that I’m aware of happened after a squadron of 50 ICBMs went black in 2010 because of a breakdown in our obsolete command and control systems. No one could monitor those weapons, no one could launch them on authority or prevent their unauthorized launch.

“So when President Obama ordered a study of the possible cyber-vulnerability of Minuteman, it took a year and they came up with some pretty interesting findings, including the fact that we had actually wired our nuclear launch facilities -- our silo complexes -- with the internet, and created a vulnerability to outside hackers.”...

“I think we need to completely relook at the architecture of our command-and-control system. Airplanes don’t last nearly as long as our forces. [Ballistic-missile] submarines can operate for months at sea, and our command system collapses in 24 hours.”

Miller agreed,

“The nuclear command-and-control system is the backbone of the Triad. If you can kill the nuclear command-and-control system, the forces don’t work. The [airborne command posts] are old. The communication systems are old. The satellites are old and vulnerable. And so one of the key elements of the [Trump Administration’s 2018] Nuclear Posture Review is to modernize the nuclear command-and-control system.

They may have had different motivations for wanting to strengthen command and control, however. Blair would like the President or a successor to have time to consider a decision on how to respond to a warning of attack or an actual attack. Miller would like to preserve the ability of the US to fight a nuclear war to the end.

In any case, Representative Garamendi of California was happy that all three witnesses could agree on one thing, “command and control. Put the money there, put the emphasis there and get on with it.”

1. docs.house.gov/Committee/Calendar/ByEvent.aspx?EventID=109017, [youtube.com/watch?v=lUm4qXTQFNs](https://www.youtube.com/watch?v=lUm4qXTQFNs).
2. Steve Fetter, Richard L. Garwin and Frank von Hippel, “Nuclear weapons dangers and policy options,” *Physics Today*, April 2018, 32-39.
3. *The blast area goes as the two-thirds power of the yield.*
4. David Sanger and William Broad, “Obama Unlikely to Vow No First Use of Nuclear Weapons,” *New York Times*, 5 September 2016, [nytimes.com/2016/09/06/science/obama-unlikely-to-vow-no-first-use-of-nuclear-weapons.html?searchResultPosition=1](https://www.nytimes.com/2016/09/06/science/obama-unlikely-to-vow-no-first-use-of-nuclear-weapons.html?searchResultPosition=1).
5. “U.S. Nuclear Modernization Programs,” *Arms Control Association*, August 2018, armscontrol.org/factsheets/USNuclearModernization. For current US nuclear forces see, Hans M. Kristensen and Matt Korda, “United States nuclear forces, 2019,” *Bulletin of the Atomic Scientists*, 2019, doi.org/10.1080/00963402.2019.1606503.
6. See also Bruce Blair, *The End of Nuclear Warfighting: Moving to a Deterrence-only Posture (Program on Science and Global Security, Princeton University, 2018)* globalzero.org/wp-content/uploads/2018/09/ANPR-Final.pdf.
7. Jeffrey Smith, “Obama Administration embraces major new nuclear weapon cuts,” 9 February 2013, updated 19 May 2014, publicintegrity.org/national-security/obama-administration-embraces-major-new-nuclear-weapons-cut/.
8. See the Putin quote in Ref. 2.
9. “The Intermediate-Range Nuclear Forces (INF) Treaty at a Glance,” *Arms Control Association*, February 2019, armscontrol.org/factsheets/INFtreaty.

DOE and NIST Long Range Reactor Plans

Will Thomas, AIP, wthomas@aip.org

Momentum is building behind efforts to plan for the future of research reactors in the United States. Currently, there are two major reactor-based user facilities in the U.S. that provide researchers with access to high-flux neutron beams: the Department of Energy’s High Flux Isotope Reactor (HFIR) and the National Institute of Standards and Technology Center for Neutron Research (NCNR). Both reactors are about five decades old. Although they are expected to continue operating for many years, calls to develop a long-term strategy for them are beginning to propagate.

Much of the current discussion draws from a [report](#) the American Physical Society issued last year, spotlighting a

shortage of capacity for neutron research in the U.S. relative to other global regions. Among its recommendations, the report urges the design and construction of a “new generation” of research reactor.

Work on a new reactor would only begin after an extensive planning process and, if approved, it would likely take many years to complete. In the meantime, the neutron research community must deal with a more immediate problem: the effects of extended unplanned shutdowns at both HFIR and NCNR. While unrelated to the facilities’ long-term prospects, the situation has put already highly subscribed resources for neutron research under unusually acute strain.

DOE ASKS ADVISORY COMMITTEE FOR REACTOR STUDY

At its meeting in March, the Basic Energy Sciences Advisory Committee (BESAC) received a [charge](#) from DOE asking it to assess “the scientific justification for a U.S. domestic high-performance reactor-based research facility, taking into account current international plans and existing domestic facility infrastructure.”

The study is to explore the significance of science that can be performed using a research reactor and to consider the full range of capabilities that reactors can provide. These include neutron-beam experiments as well as materials testing by irradiation, radioisotope production, neutron activation for trace element analysis, and dark matter research. The study will also consider the role of reactor-based neutron sources versus spallation neutron sources. DOE is currently planning [major upgrades](#) to its Spallation Neutron Source (SNS) facility that will increase both its capabilities and its capacity.

DOE stipulates the study should also offer advice regarding the department’s “long-term strategy concerning HFIR.” The charge explains, “With HFIR entering its sixth decade, its long-term future requires careful thought and planning, especially in the context of the U.S. domestic high-performance neutron research facilities.” It notes that one avenue the study should explore is whether there are “feasible upgrade paths for HFIR to provide world-leading capabilities ... well into the future.”

The charge also asks BESAC to consider whether low enriched uranium (LEU) could be used in a reactor without significantly diminishing its utility. Currently, HFIR and many other high-performance research reactors around the world use highly enriched uranium (HEU). It has long been U.S. policy to tamp down the use of HEU to mitigate the risk of its theft by rogue actors who could use it to make nuclear weapons. However, efforts to convert HEU reactors, including HFIR, to use LEU have been [inhibited](#) by the difficulty of fabricating suitable LEU fuels.

In considering upgrades to HFIR, BESAC is instructed to look to the experience of Europe’s premier reactor-based user facility, the Institut Laue-Langevin (ILL) in Grenoble, France. Commissioned in 1972, the facility underwent a [series of upgrades](#) from 2000 to 2018 and is now beginning a second series scheduled to continue through 2023. Although ILL [agreed](#) to convert to LEU 20 years ago, the facility continues to use HEU fuel and there are no immediate plans to abandon it.

There would be fewer difficulties in fabricating LEU fuel for new reactors if they are specifically designed to accommodate it, as the APS report recommends. The U.S. has not seriously considered building a new multipurpose high-performance research reactor since the 1990s, when DOE [planned](#) a large, HEU-fueled reactor called the Advanced Neutron Source that was ultimately cancelled in the face of

rising cost estimates. The APS and BESAC reports could prepare the way for a new proposal to be put on the table.

NATIONAL ACADEMIES PANEL BROACHES NIST REACTOR REPLACEMENT

A recommendation for a new reactor would also have to take into account the future of NCNR, which underwent a [routine National Academies assessment](#) last year. While the assessment found the facility is well run and delivers a high return on investment, it stated, “The nuclear reactor on which the NCNR depends is 50 years old, and as a matter of simple prudence, a plan needs to be developed that will ensure that NCNR users have the neutrons they need into the indefinite future.”

The assessment pointed to three options for the long-term future of NCNR: continuing to operate its existing reactor, upgrading it, or replacing it completely. Suggesting the first two options are “inferior” to the third, the assessment points to an internal NCNR report from 2017 that found a new reactor would cost about \$1 billion and take more than 15 years to complete. “A project of this magnitude will not be undertaken without a substantial planning effort and support from the neutron and the general scientific communities,” it observed. Accordingly, it recommended NCNR “commission a detailed assessment of the current facility and begin the conceptual design of a new reactor.”

NIST has not announced a response to the recommendation, but at the meeting of its primary advisory panel in June, NIST Director Walter Copan said that the agency is working on jointly sponsoring a National Academies study with DOE and the National Science Foundation. In Congress, Rep. Randy Weber (R-TX) is now sponsoring a bill that, among its other provisions, would endorse efforts to plan for NCNR’s future.

REACTOR SHUTDOWNS HAMPER NEUTRON RESEARCH COMMUNITY

Even as planning begins for the long-term future of HFIR and NCNR, both facilities have recently had to deal with the short-term effects of unplanned shutdowns. NCNR was offline for more than one month at the beginning of this year due to the partial shutdown of the federal government. According to a [story](#) in the *Los Angeles Times*, during that time more than 100 experiments were cancelled, causing considerable disruption to the facility’s users. Schedule reshuffling continued even following the restoration of operations on Feb. 5 in order to accommodate cancelled experiments.

HFIR, meanwhile, has been shut down since November, following the [detection](#) of slightly elevated radiation levels in its primary coolant system following a routine refueling. Harriet Kung, director of DOE’s Basic Energy Sciences program, [told BESAC](#) that 45 of the 540 plates within the

reactor's newly installed fuel elements were discovered to be "deflected." She reported that no radioactivity was released from the reactor and no personnel had been exposed. The reactor facility itself was undamaged.

In an [update](#) on Feb. 14, Paul Langan, who directs the neutron sciences program at Oak Ridge, reported the incident is still under review and procedures are being developed to prevent it from happening again. Kung said that 252 experiments will have been cancelled by May 1 and that Oak Ridge is aiming to restore operations by the end of the fiscal year on Sept. 30.

It remains unclear exactly how much the HFIR shutdown is affecting researchers' ability to obtain time at SNS and NCNR, which were already heavily subscribed. Langan told BESAC that Oak Ridge has worked to accommodate HFIR users at SNS where possible, but that not all experiments are transferrable. Another question is how the shutdown is affecting the supply chains of the isotopes HFIR produces, which are employed in medical applications and as [fuel on interplanetary science missions](#), among other uses.

Counter-Force and Counter-Value: The End of War?

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Ever since humans have gathered together in groups there have been occasional conflicts between the groups. As these groups became nations, these conflicts became wars, hierarchically organized conflicts, with kings – or their equivalents – at the top way down to single warrior. The purpose of the war was to obtain power – the ability to control – over the important resources of the opponents: = their land, people, mineral and agricultural resources and water, ports, transportation and commercial routes and their hubs. To attain this power, one had to overpower the opponent's power, using your military power to destroy that of the opponents. This would be accomplished by killing their fighting people, disorganizing their units, fragmenting their will to fight, and/or depriving them of effective allies or military supplies and provisions. In other words, to win, your military forces had to defeat those of the enemy, your *force* had to successfully *counter* the *force* of the opponent. There was no need to inflict damage to the opponent's non-combatants ("civilians" or other resources); in fact, they were the "*value*" you were fighting to achieve. Certainly civilians - and their resources - were often hurt or killed in large numbers, but this was rarely – if ever - the goal of the war. Civilians were the "innocent bystanders"; they suffered "collateral damage". Even in religious wars, the goal was more often to "convert" the unbelieving civilians rather than to kill them. Very often, the defeated society survived, left with enough resources and will to eventually re-create its military strength and again try to achieve power over others. And so, further wars developed a long chain of wars throughout the history of "mankind." Nations developed the ability to exert "counter-force" against potential future opponents but spent little time, effort, or resources to develop the ability to counter the *values* of these future enemies. Nations did not

usually go to war to kill people. They went to war to achieve power over people and their resources. Even if the occasional war was for revenge over some slight or insult, revenge was much "sweeter" with power over defeated opponents than with their dead bodies.

A significant change occurs in World War I. Cities far from the battle lines were deliberately bombed or shelled; large masses of civilian refugees were driven from their homelands. Military force was exerted against objects of "value" – people and their necessary resources. There certainly was a great deal of "*counter-force*" capability developed on the battlefields of Europe and the Middle East, but nascent "*counter-value*" abilities and desires began to grow first in Europe. And they blossomed in World War II. Millions of civilians were killed by "conventional bombing" of the cities of both sides in Europe and Asia (in addition to those slaughtered by gassing and traditional means). There is considerable debate, among historians, as to how much the considerable tonnage of conventional bombs (millions of tons of explosive energy) dropped by Allied aircraft upon German and Japanese cities contributed to the eventual Allied success. But the large amount of aviation fuel required to kill one person - civilian or military – by aerial bombardment implied no end to the future chain of wars for there was, potentially, a large number of people in the future; the fuel would run out long before the "value" targets did.

Then came the American dropping of atomic bombs (releasing kilotons of explosive energy) on Hiroshima and Nagasaki, vastly increasing the amount of civilian death and destruction, ("value") per gallon of fuel expended and, apparently, bringing the war with Japan in the Pacific to a successful conclusion for the Allies. But fear of Soviet expansionism

brought on the “Cold War”, with the increasing involvement of the world’s governments in the nurturing of the physical sciences, and the development of increasingly powerful nuclear fission-fusion weapons (now capable of releasing megatons of explosive energy). Equally important was the creation, by the major competing nation states, of the means for their efficient intercontinental delivery; by missiles launched from aircraft, and from land and underwater (submarine) based silos. As the mass-killing power of these weapons increased, the prospect of war inevitably shifted from “counter-force” to “counter-value”. The only way to protect one’s nation from devastating value destruction was a pre-emptive strike against the enemy’s missiles. These initial strikes could not be guaranteed to be effective in preventing massively destructive counter-strikes because of the increasing probability of “launch on warning” – increasing space-based detection and communication capabilities meant that the incoming pre-emptive warheads would explode over empty silos. (There were many attempts to counter missile attacks with “anti-missiles” but the possible number of attacking warheads and the weakness of the defensive technology seemed to preclude any successful defense.) And the “launched-on-warning missiles” would not be aimed at the pre-empting adversary’s empty silos, but at his major value sites, such as cities, destroying major fractions of the adversary’s society.

Thus, the foundational concept of MAD – “Mutually Assured Destruction” arose and spread. As Einstein is reputed to have said: the war after the next war would be fought with sticks and stones – if there was anybody left to do the fighting. No sane person or political body liked that prospect! MAD meant that you had to be “mad” to contemplate going to war. And so, with and without formal agreement, the probability of wars between the major powers decreased, as did their stocks of nuclear weapons and the “Cold War”.

But technology marched on; with increasing missile accuracy and smaller warheads, perhaps the destruction of “value” could be minimized and the prospect of future “counter-force” war enhanced. Nations could go back to the

pre-nuclear age, but with shorter and more destructive, (but hopefully) not universally destructive, wars. Concurrently, the societies of the major nation states were increasingly dominated by their “military-industrial complexes”. The prospect of a no-war future was not universally desired. And so, currently, we find the breaking of missile control treaties, increasing nuclear weapons (as well as conventional military) budgets, and an increasing number of nuclear armed states. Current governments, and their militaries, seem increasingly disinclined to accept the MAD concept as their primary means of dealing with each other in an increasingly competitive world. So now nations are engaged in expensive campaigns to “modernize” their stocks of nuclear weapons by increasing their command and control capabilities, and accuracies, even further, decreasing the size of their explosive power (though many in our present stocks already have “dial-down” options), and by bolstering their numbers and possible launch possibilities.

But nuclear weapons, no matter how small and accurate they may be, have much longer-ranged kill capacity than conventional weapons (longer -ranged in both space and time). Given the large numbers of “small” nuclear weapons contemplated (“small” = roughly the destructive power of the Hiroshima bomb = “kilotons”), the havoc they would create, if used, it’s hard to believe that the massive city busters (*i.e.*, “megatons”) would not also come into play. Certainly, the losing side would likely use them. And so, the universal destruction envisioned by MAD would come about, even without planning for it. Thus, a counter-force strategy, which we are presently contemplating adopting, would most probably lead to a universal counter-value outcome. A counter-force strategy, if successfully adopted and executed (extremely unlikely!) would result in a continuation of the international chain of wars. A counter-value strategy – MAD – if stuck to, is likely to break that chain. There still may be “small wars” – terrorist “attacks – but a universal holocaust would be avoided, a very desirable outcome.

Economic Performance Through Time: A Dynamical Theory

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Why are there rich countries and poor, or colloquially, why do the haves have and the have-nots haven't? Herodotus (Herodotus 440 BCE) wrote that civil war, worse than war among a united people, would bring a country to ruin. Aristotle (Aristotle 350 BCE) wrote that the Greeks' political system and the bountiful life it bestowed was a product of its climate, neither too hot nor too cold, neither too wet nor too dry. And, can anyone have failed to notice that natural resources and geography contribute to prosperity? Nevertheless, quantitative assessment of the relative significance of these and other factors has been elusive. So the haves have and why the disparities of having are persistent are the central questions of Development Economics and Economic History, two disciplines whose names announce their common interest in economic performance through time. The prevailing view is that institutions—for instance the informal rules of social convention on the one hand, or transportation networks, health care systems, guilds, and formal legislation on the other—impose order, reduce transaction costs, and facilitate economic growth. Douglass North encapsulated this with an epigram, Institutions are the rules of the game, tipping his hat toward game theory as the means to characterize a dynamical system which he imagined lay beneath the observed world of economies evolving over time. If the 65,000 citations of his monograph *Institutions, Institutional Change, and Economic Performance* (North 1993) are any indication, the 1993 Nobel Prize winner has been influential. Yet, 50 years into the program of this so-called New Institutionalism, there is no game theoretic formulation of why the haves have, nor has any dynamical theory surfaced at all, a fact that he lamented in his Nobel acceptance speech to which he gave the title, Economic Performance Through Time. We address that deficit in this article, and in so doing, we show that institutions are not the rules of the game.¹

North described the underlying dynamical system in persuasive prose; “Together with the standard constraints of economics, [institutions] define the choice set and therefore determine the transaction and production costs and hence the profitability and feasibility of engaging in economic activity. They evolve incrementally, connecting the past with the future; history in consequence is largely a story of institutional evolution in which the historical performance of economies can only be understood as a part of a sequential story.” Latent in these words is not game theory, but a pair of coupled, linear,

¹ A longer version of this work with more thorough testing of its predictions is available on [arXiv.org](https://arxiv.org/abs/1905.02956) arXiv1905.02956. Daniel Seligson, Anne McCants. (2019) Economic Performance Through Time: A Dynamical Theory.

first order differential equations whose solutions were fully explicated centuries ago.

Using E^i to denote the economic performance of a polity i , and I_N^i for its institutions as they are defined by North and others, we write

$$\dot{E}^i = -\lambda_E * E^i + \alpha_I * I_N^i + f(\vec{x}^i)I_N^i = \alpha_E * E^i - \lambda_I * I_N^i + g(\vec{x}^i) \quad (1)$$

The argument, \vec{x}^i of the differentiable functions f and g is a vector of exogenous factors that source (or sink) economic and institutional growth; for instance, climate, geography, natural resources, civil war, colonial history, and so forth. The constants α_I and α_E , both positive by definition, couple rather constrain I_N and E . By a transformation of scale, we may equate the couplings without loss of generality. The dissipations, λ_I and λ_E again positive by definition, are the constraints on growth. Without dissipation, this model economy would be unstable, and real economies are not unstable, as we will confirm later. There is no *a priori* reason that $\lambda_I = \lambda_E$, yet on the other hand, there is no reason for them to be much different. We ask the reader to accept that we have measured their ratio and found it to be unity.

Before we move on to the solution and validation of Eq. 1, let us take a look at I_N . I_N is a hodgepodge of slowly changing taboos and of laws that can change overnight. Defined in this way, I_N is not suited for use in a time-dependent theory. If we are going to capture its full effect in the dynamical system, we must break it into components with different time dependences and follow them accordingly. We propose $I_N = I + N$ where I , Institutions, are the infrastructure and systems of governance that evolve with the economy, and N , Norms, are the ethics, codes of conduct, conventions, and unwritten rules of the game. Exploiting the fact that $N \ll I$, equating the couplings and dissipations, and redefining α such that $\alpha \rightarrow \alpha/\lambda$, Eq. 1 becomes

$$\dot{E}^i = \lambda * (-E^i + \alpha * I^i) + f(\vec{x}^i, N^i)I^i = \lambda * (\alpha * E^i - I^i) + g(\vec{x}^i, N^i) \quad (2)$$

In this rewriting, Eq. 2 describes the motion of a polity in a phase space of I and E . Along the system eigenvectors, $\mu = I + E$ and $\kappa = I - E$, the time constants are

$$\tau_{\mu\kappa} = \frac{-1}{\lambda} \frac{1}{1 \mp \alpha} \quad (3)$$

The state flows to a fixed point ϕ_0 if $0 < \alpha < 1$. If $\alpha \cong 0$, then the coupling to the economy is imperceptibly small, and if $\alpha \cong 1$, then the coupling is imperceptibly slow. Neither corner case provides the incentives for people to invest in the Institutions, therefore we argue that $\alpha = O(0.5)$. What may we

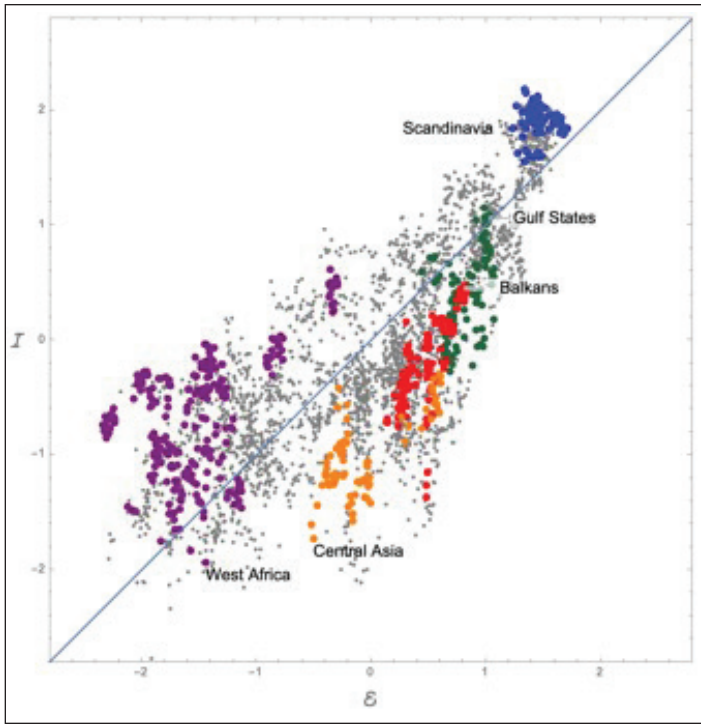


Figure 1: The global economy in phase space, 1996-2016. 3210 observations of E , the UN's Human Development Index and of I , the Worldwide Governance Index. Any theory of the global economy must have verisimilitude: it must predict the co-locality of "like-states", the dominance of variance along the +1 sloping diagonal, and the persistence of this distribution. The theory described here demonstrates all three of these.

say about λ ? It is the size-dependent constraint on growth. The more infrastructure a polity possesses, the more maintenance it requires, lest that infrastructure decay to inutility. The bigger an economy, the harder it is to manage efficiently, therefore the greater the difficulty in growing. North estimated that the cost of institutions constituted a 40% tax on all transactions. Let us assume $\lambda = 0.2$. Eq. 3 tells us that the time constants for convergence to ϕ_0 are less than or equal to 10 years, a value that is small compared to the age of the global economy. So, not only is the motion converging, but theory says it has converged and that contemporary observations of ϕ are representative of the phase space equilibrium whose value is determined by f and g evaluated at the polity-specific \vec{x} and N . Thus, I is a dependent variable, equivalent in this sense to E . Institutions are not the rules of the game. They are an outcome of the game.

If this is correct, then $\phi \cong \phi_0$ and measures of ϕ over time would be very nearly constant. Are they? Before we can answer that, we must put some flesh on the bones of I and E . For E , we use the UN's Human Development Index,² HDI, a composite of currency-weighted income, life expectancy, and education. (UnitedNations 2019) For I , we use the Worldwide

² Gross Domestic Product (GDP) is the most commonly used measure, but ordinal anomalies, for instance the near equivalence of GDP in Israel and Equatorial Guinea, make clear that it is not suitable for inter-polity comparisons.

Governance Index, the average of 5 Worldwide Governance Indicators collected by the World Bank. (Kaufmann 2019) In combination, these give us 3210 measurements of ϕ for 189 countries over the period 1996-2016, shown in Figure 1.

We digress briefly to note two significant features in the figure. First, we see that the variance is principally along the $\mu=I+E$ axis. Theory predicts the ratio of variances is $((1+\alpha)/(1-\alpha))^2 = 9$ for $\alpha = 0.5$. The actual is 8.2. Second, we see that clusters of states that are geographically, climatically, and culturally alike are also economically and institutionally alike. Our theory teaches that the equilibrium condition, ϕ_0 , depends only on polity-specific \vec{x} and N . In as much as we expect that \vec{x} and N are geographic, climatic, and cultural, our theory predicts that states of a feather flock to together; that is, it predicts regional homophilies.

Returning to the question of stability, if $D(t)$ is the distribution of μ in a given year, then the autocorrelation function of $D(t)$ tells us about the relative stability of $D(t)$. It is well approximated by the function $P(\tau) = (1-\delta)^\tau$ where τ is the time interval in years and $\delta = 0.00212 \pm \sigma = 0.00043$. We call P the Persistence. Its half-life is over 300 years. It may be argued, especially by historians, that 20 years of phase data is insufficient to be making pronouncements about the wealth of nations over centuries. To that, we note that though we do not have long term data on governance as a measure of institutions, Leandro Escosura in Madrid has produced a time series of HDI over the period 1870 to 2015. (Escosura 2015) Examining the Persistence of this HDI, that is of E only, we obtain $\delta = 0.00141 \pm \sigma = 0.00045$ and a half-life of nearly 500 years. Though we may speculate whether this 145-year time series tells us anything quantitative about the impact of the Industrial Revolution or of the Spanish or Islamic Conquests, it confirms the predictions based on the two most recent decades, and we assert that the distribution of polities in phase space has been stable over at least this past century. This persistence is consistent with Institutions not being the rules of the game. North's epigram is an impediment to understanding persistence.

Since, we may write

$$\mu = f(\vec{x}, N)$$

(4)

This does not derive from a statistical correlation. It follows from the description of the underlying dynamics. It is a causal equation on the basis of which we may make causal queries of the data. (Pearl 2009) Though we don't yet know the relevant \vec{x} and N , we may construct an ensemble of models and interrogate them with the question, "The world is the best evidence of which among you?" If it turns out that the 3210 observations of μ are good evidence of a model based on geography and natural resources, Herodotus's civil war, Aristotle's climate, and some of our Norms, then we may say that we have made good progress towards solutions of the



Figure 2: A world map of the global economy assessed by μ . The $-$ component of 3025 observations of ϕ (Figure 1) is time averaged by country and represented here on a scale from low (dark green) to high (white).

two central problems of Economic History, and that we have addressed North's lament over the absence of a dynamical theory of economic performance through time. Here we report only on a two-factor model based on climate and geography.

In the 14th century, Ibn Khaldun identified latitude as a proxy for climate in the context of its contribution to social norms and the fortunes of Man. (Khaldun 2015) This was a practical choice in an era before geo-gridded databases. Today, we use the country-averaged, mean monthly high temperature over 1900-2016, a variable we call T_- . (CRU 2018) The correlation of T_- with PET, a measure of precipitation, evaporation, and transpiration, is 0.94, and so T_- captures much relevant behavior of the water cycle. As for geography, we observe that elevation presents obstacles to a polity's development of trade, agriculture, and human capital, suggesting mean elevation, h , as its proxy. Time averaging 3025 observations of ϕ in 177 countries, we get the map of Figure 2, and we approximate μ^i in the spirit of Eq. 4 to obtain

$$\mu^i = -0.15 * T^i - 1.5 * h^i + f(\vec{x}^i, N^i)$$

(5)

Not quite 50% of the global variance of μ is explained by these two variables. The t-statistic of each coefficient exceeds 7. Coefficients of second order terms, e.g., T_-^2 , which would signal an Aristotelian optimum, are insignificant.

How might we interpret this, notwithstanding the obvious truth that a bivariate model of the global economy is likely to suffer from omitted variable bias? μ is the sum of the quality of life (HDI) and the infrastructure of governance (WGI) under whose umbrella that life is lived. It is a measure of the total economy. HDI itself is the geometric mean of the log of Gross National Income, GNI, and of measures of education

and longevity. This logarithmic contribution to HDI makes μ linear in log GNI, too, thus the coefficient of T_- in Eq. 5 effects a 10% reduction in GNI per 1°C increase in T , and the coefficient of h effects the same reduction for a 100-meter increase in mean elevation. In a still-under-development 6-variable model, M , at the Bayes Information Criterion minimum, the revised coefficients for T_- and h are $-0.11/^\circ\text{C}$ (-7% GNI/ $^\circ\text{C}$) and $-0.75/\text{km}$ (-5% GNI/100m), respectively, and their contribution to the observed variance of μ falls to about 20%. For comparison, we note that Dell, Jones, and Olken, in a study of the GDP of 134 countries, find an $-8\%/^\circ\text{C}$ variation, (Melissa Dell 2009) and Acemoglu, Johnson, and Robinson find a $0\%/^\circ\text{C}$ variation in a very influential study of 40 countries, all of them former European colonies. (Daron Acemoglu 2002)³

The model M , for which $R^2 > 0.83$, suggests the potential for a Standard Model of the global economy. Imagine the mess we'd be in if a physicist had to generate her own model of the solar system every time she wanted to answer a question about planetary motions. A Standard Model is a much-needed institution that would create order in Development Economics and Economic History and reduce transaction costs in the policy and foreign aid worlds where tens of billions of dollars are spent annually on the basis of suspect or even provably wrong theory.

CONCLUSION

To social scientists, North's epigram, Institutions are the rules of the game, is definitional. We construct a dynamical

³ We will discuss the methodological shortcomings of the latter work in a forthcoming presentation at the 2019 Annual Meeting of the Social Science History Association.

theory based on the more fundamental mechanism he posits, that of the co-evolution of institutions and the economy. That action of construction surfaces a problem with the definition of institutions, and its resolution upends the epigram itself. The theory generates a causal model of the total economy, obviating the prevailing understanding that all that separates Norway and Somalia is their Institutions. Rather, it follows that the addition of exogenous Institutions crowds out endogenous ones, leaving the total fixed at a level set by x^* and N . The high degree of verisimilitude between our theory and the global economy—and the absence of same between the New Institutionalism and the global economy—favors our understanding. Thus, though North Korea could become South Korea within a few decades, we see no path, short of global calamity, for Somalia to become Norway.

The colloquial definition of institutions fails us in dynamical theory. The success of even the toy model tells us that we are on a promising track with Eq. 2, and leads us to a new definition; Institutions are the humanly devised systems that promote economic growth, that are costly to build, costly to maintain, and that themselves scale with the economy. Thus, a law, for instance one ensuring property rights, is not itself an Institution, but an ever-revised code of laws with a judiciary and enforcement behind it is. Practically speaking, Institutions are growth-promoting infrastructure.

The theory presented here is simple and powerful, but elaboration is inevitable. Physicists have much to offer in this arena moving forward. For instance, on a theoretical level, we should look at international couplings. This might help us understand how civil war systematically affects a neighbor's

economy. At the modeling level, the observed linearity of μ over the full range of earthly T_e is only possible if it is the sum of a multiplicity of factors, each of which operates over a smaller temperature range. This needs elucidation. The door is open for collaboration and perhaps even better, for independent scrutiny and approaches.

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The Dynamics of Human Society Evolution

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INTRODUCTION

Is the phenomenon of man different fundamentally from that of inanimate nature? Indeed there are some differences, however, there may not be a fine line separating animate from the inanimate at the fundamental level. Here, we summarize an article [1] about the evolution of human society that builds a case based on the foundation of classical mechanics and Niels Bohr's Atomic Theory. New energy, identical in the form of that defined through the classical field theories, may be at play for the evolution of human society. The large-scale social collective and societies might be effectively understood from the perspective of energy flow; energetics in general.

Some argue that Bohr gave biologists a new conceptual tool. But many aspects of his Atomic Theory are still being

integrated into human knowledge. About three-quarters of a century ago, Bohr wondered whether there exist unexplored aspects of epistemology in the analysis of natural phenomena. The dynamics of human society seems an obvious phenomenon for the authors to examine. This is why one of us proposed a new theory on the epistemology of Atomic Theory. The social field theory may also shed light on a better understanding of the dynamics of human society on the basis of physical experience. The theory helps define social force, social energy and the Hamiltonian of an individual in a society. The theory, however, may run counter to the flatland physics of an isolated system. Human society, after all, is an open and evolving system that may be understood better using thermodynamic principles.

The social dynamics may be understood better in terms of kinetics expressed in terms of the Hamiltonian of an individual in society. Kinetics considers movement in tandem with the underlying forces or the source term in general. What is the source term in social dynamics? According to Bertrand Russell, it is power: “The fundamental concept in social science is Power, in the same sense in which Energy is the fundamental concept in physics.” This observation is in accordance with one of the fundamental thermodynamics equations governing an open system – the rate of change of energy (E) is equal to power (P), or $dE/dt = P$. Human being/society is an open system in which matter, energy, entropy, and information flow in and out of the system’s boundaries. We expand the thermodynamic equations in order to develop provisional “equations of motion for social systems” in the way Wolfgang Weidlich [2] has long sought for. Obviously, the equations we have developed for the social system are based on kinetics. The equations are energetic descriptions of the social system that takes into account the power dynamics in the hierarchical society.

There are quite a bit of open-ended problems in social dynamics including the one ‘How Did Cooperative Behavior Evolve?’ [3] A monolithic culture, be it either natural science or social science, finds such questions elusive. If we follow the suggestions of Anthony J. Leggett, a 2003 Noble Laureate in Physics, it becomes important first to distinguish various levels of the problems we encounter in any disciplines. As is the case with condensed matter physics, [4] the open problems in social science may also be classified into the following three categories:

- i) Hamiltonian known and tractable
- ii) Hamiltonian partially known but intractable
- iii) Hamiltonian not even known.

We placed social dynamics in one of the last two categories depending on the lens we choose to wear. Economic science registers money as the proxy for the Hamiltonian of an individual in society. For many of us with a background in the natural science, the arguments economic science make do not seem to provide enough direct evidence but economic science has supplied us with many interesting problems to solve that go beyond its boundaries. ‘It is not the load that breaks it down, it the way you carry it’ says Lou Holtz. Economic science may be carrying the dynamic load of human society the wrong way, it may need to be adjusted. Physicists are joining hands in the form of Econophysics; many engineers [5, 6] are also joining the fray. We offer Thermodynamics 2.0. Thermodynamics 2.0 is about bisociation [7] of thermodynamics with other academic disciplines such as physics, chemistry, biology, economics and many more. In a nutshell, Thermodynamics 2.0 is all about the coevolution of sciences - identifying and connecting dots of scientific revolutions in natural and social sciences.

Likewise with Leggett, the last categories (iii) are in many

ways the most fascinating to us. We proposed an analogy between Niels Bohr’s Atomic Theory and human society- the phenomenon of poverty to be precise. The social field theory may not yet have experimental rigor though it adheres to most of our observations of societies in the East and West. The theory leads to the Hamiltonian (H) of an individual in the society.

The classical field theories define the potential energy of an object within the field of other objects that shares the same properties such as mass or charge or (di)pole strength. A force is a gradient of the potential energy. Many phenomena in nature can be interpreted in terms of four fundamental forces: electromagnetic, gravity, strong and weak nuclear forces. Are the myriad phenomena in nature governed by just these four fundamental forces? Many of us assume such a notion to be true. These forces were uncovered in order to explain various phenomena in natural science, and thus do not provide enough clues to explain social dynamics. We think a new type of force exists, especially among social beings. Earlier, we have made a case for the social field theory through a generalization of the classical field theories.

There is an inherent challenge to extend classical mechanics into the social system. This challenge led curious minds like Alfred J. Lotka to rely on energetics to understand evolution. In energetics, Lotka saw a physical principle competent enough to extend our systematic knowledge to natural selection. This is unfinished business; something that has yet to take off the ground. We go around this challenge in order to combine classical mechanics with Atomic Theory in order to come up with the equation for the evolution of human society. This is an effort to apply concepts arising from thermodynamics to areas outside of classical thermodynamics.

The portrait of an atom that Bohr’s theory presents resembles certain characteristics of our own solar system. Nature doesn’t differentiate sciences, but we do for good and bad reasons. In this theoretical approach, based on energetics, we argue that human society evolves following the laws of energy along with underlying forms and structures that human ingenuity develops and sustains over time.

SOCIAL FIELD THEORY

There are many types of field theories in social science. None of these theories are in the language of energy. The social field theory that we summarize here was born out of an effort to understand the link between energy access and poverty dynamics. We have formalized it based on Bohr’s theory of the H-atom, which connects classical and quantum mechanics in a way many engineering students may find easy to understand.

The social field is characterized in terms of Social Strength (S), Individual Strength (I) and social distance (r). The variables S and I have a bearing on the pole strength in a magnetic field. The social distance is the relation of social

entities to other entities measuring the degree of their contact or isolation. We define the Trust Vector (Γ) as being reciprocal to social distance, i.e. $r \times \Gamma = 1$. The two hypotheses of the social field theory are:

HP1: Social Field is a quasi-conservative field, defined as a field for which total energy is a monotonic function of time.

HP2: Energy levels in the social field are quantized in similar notions to how they are in established models of an atom, for example Bohr's theory of the hydrogen atom and Schrödinger's equation.

To some of us trained in a monolithic culture, the idea of a social field could easily be a "The Blind Man and the Elephant." One of the internal reviewers wrote: "I don't believe a single variable can be an adequate measure of the "social strength" of an individual, nor do I believe that "social distance" can be described by a single variable." We understand the frustration of the reviewer. However, social strength (S) is an n-dimensional variable, and so is the social distance (r) or the trust vector (Γ). The social field is a non-inertial field characterized in terms of energy. We define the non-inertial field as the field for which terms like acceleration keeps evolving. Human societies evolve in steps as some anthropologists have made the case for [8]. These steps may well be conceived by the energy levels following HP02.

The total energy of an individual is composed of two forms of energy, Potential Energy (PE) $-SIT$, and Kinetic Energy (KE) $= \frac{1}{2} SIT$. The same expression of kinetic energy can also be derived based on the Virial theorem. In the social field, we equate the potential energy to capabilities C_2 , and kinetic energy to capital C_1 of an individual. The total energy in the social field is the Hamiltonian of an individual, $H = H(C_1, C_2, t)$. Entropy in the social field turns out to be $I \log(SI)$. The social field is a non-inertial field that autonomously evolves with time. HP02 provides a structure for the hierarchical social field.

This theory may provide an additional clue about the operations of 'animate agencies' with reference to the Second Law of Thermodynamics along the line of reasoning proposed by Prigogine for an open system.

EQUATION OF MOTION

Equations of motion (EOM) describe the time evolution of the state of a system. In fact, the equation we propose for the social field is a power equation, power $P = \text{Force (F)} \times \text{velocity (v)}$, where power is defined as the rate of change of energy. The change of energy is expressed in terms of the total derivative of the Hamiltonian $H = H(C_1, C_2, t)$ in the framework of the Navier-Stokes equations. The EOM for an individual in the social field turns out to be,

$$\frac{\partial H}{\partial t} + \frac{\partial H}{\partial C_1} \frac{dC_1}{dt} + \frac{\partial H}{\partial C_2} \frac{dC_2}{dt} = (F_{en} + F_{ex}) \frac{1}{r^2} \frac{d\Gamma}{dt} \pm \dot{Q}_s \quad (1)$$

In Eq. (1), \dot{Q}_s includes both the generation and dissipation terms. The Hamiltonian of a society can be aggregated in terms of the probability distribution function H_s . Hence for society, EOM will be

$$\frac{\partial}{\partial t} H_s(n, t) = - \sum_{i=1}^n \frac{\partial H_s(n, t)}{\partial C_i} \dot{C}_i + (F_s(n, t) + F_b(n, t)) r'_n \pm \dot{Q}_s \quad (2)$$

An aggregated multi-body equation in the social field leads to an implicit multivariate Fokker-Planck equation. We propose Eq. (2) as a stopgap to knowledge about "equations of motion for social systems" Wolfgang Weidlich [2] claimed this to be non-existent in the literature. Lotka-Volterra type of equation can be derived from it when some additional assumptions are made [1]. One of the field theorists in sociology, Pierre Bourdieu has implied three major forms of capital. Accordingly, we propose to contract the n-dimensional social field to \mathbf{R}^3 . These three reduced dimensions are i) economic ii) cultural and iii) social. This contracted description may provide logical reasoning to interpret the trends in social capital [9] in many societies.

It may be inappropriate to talk about social dynamics without linking it to money, a concept of paramount significance to economic science. The energetics framework conceives of money in accordance with original insights of Howard Odum: money flows in circles, but energy flows through a system and ultimately comes out in a degraded form.

The article presents how classical mechanics and quantum mechanics (especially Atomic Theory) may complement each other in order to explain some phenomenon that is not understood well in terms of physical principles. Obviously, these are half-backed ideas still awaiting criticisms from scientific communities. As Bohr argued, complementarity also has a place in social sciences. Ernst Mayr offered another example of complementary perspectives in biology. He emphasized two broad types of causation in biology: ultimate (i.e., evolutionary) and proximate (i.e., physiological). In the words of Bohr, both types of explanations have their uses, but not necessarily for addressing the same questions. Here, classical mechanics meets with quantum mechanics in order to make some more sense of social dynamics and the evolution of human society within the framework of energetics.

In the same manner by which Bohr defended his case, we would like to invoke the precedence: "The test of any theory is not whether it contradicts preconceived philosophical notions, but only whether it contradicts the experimental fact." Our natural science instincts, obviously, leads us to aspire being rigorous about testing the theory with more available facts. Unfortunately, there is not much high-quality data on how societies are related to one another. Hence, it is difficult to draw quantitative conclusions. The best things we can do at this stage is to wait curiously to see which working alternatives to the ideas of human society evolution are in tune with the observations of many conscious minds in the 21st century.

We end this summary with Philippe Nozieres' quote "only simple qualitative arguments can reveal the underlying physics". Some might see it as a light in the qualitative argument that social field theory brings forth. While others may easily consider it a misplaced analogy. Many of us are filled with preconceptions about the world around us; we are not exceptions either. Nonetheless, if a true opinion accompanied by reason is knowledge, this transgression by a duo of engineers may contribute to an essential advance in human knowledge, especially about the evolution of human society and the integration of the sciences. We are all spectators and actors in an evolving human society. Together we can understand 'The Elephant' better!

ACKNOWLEDGEMENTS

We benefited from the input of participants at multiple conferences. We would also like to mention [Energy for Capabilities Development Partnership](#), and Complex Systems Group at Worcester Polytechnic Institute (WPI) in Worcester, MA.

A Workable Moral Strategy for Achieving and Preserving World Peace

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Assumption: The reader thoroughly understands what happened within seconds to more than 210,000 people of Hiroshima and Nagasaki in August, 1945.

It has become clear that nuclear weapons are only a symptom of an all-pervasive malignancy of the spirit of the world and of adult humankind. Some Japanese have an expression for this period of human history; they call it "the era of nuclear madness." It is the purpose of this essay to show one way that era can be brought to a remarkably peaceful end. Einstein, Oppenheimer, and others have suggested means to that end.

Since 1945 there have been no conflicts which could have justified using nuclear weapons. International business conflicts seem to regularly arise with major trading partner China, and with Russia, usually a U.S. trading partner. Some politicians speak of possible war with North Korea or Iran or other Middle Eastern nations. We doubt there exist any American politicians, any "deciders," or "dividers," qualified to order the use of nuclear weapons to remedy international conflicts. Likewise there probably is no single person in the world, nor any cabal, qualified to make such a decision to indiscriminately murder hundreds of thousands within seconds; it would be morally unjustifiable.

But some people have considered nuclear explosives to be useable weapons of war; after all, in 1945 the Allies actually used two which many believe ended that war. Then,

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during the 1946 Bikini "Able" and "Baker" nuclear tests, U.S. congressmen, invited to witness the tests, were located so far away (for their safety) that many came away naively expressive. "Like a giant firecracker," said one. Another, "In the next war I hope we don't have to throw atomic baseballs." The Bikini "Charlie" was cancelled. More recently from the White House, "If we have them, why can't we use them?" "My button is bigger than theirs."

Apparently members of the U.S. Congress and policy creators of many nations pay little heed to wiser minds. For example, early on, Albert Einstein in 1947, "We scientists believe that a clear and widespread understanding of the facts and implications of the atomic discoveries is indispensable to a reasonable public stand on questions of international politics. Given this understanding, men and women will recognize that only international cooperation through effective institutions can ensure security against humanity's destruction." [1]

Carroll Quigley (former Professor at Princeton, Harvard, and the School of Foreign Service at Georgetown) – "The powers of financial capitalism had a far-reaching [plan], nothing less than to create a *world system of financial control in private hands* able to dominate the political system of each country and the economy of the world as a whole." [2] Obviously they did not seek creation of a peaceful world, a world free from wars; they sought a different goal.

Albert Einstein, 1949 – “The result of these developments is an oligarchy of private capital the enormous power of which cannot be effectively checked even by a democratically organized political society. . . since the members of legislative bodies are selected by political parties, largely financed or otherwise influenced by private capitalists who, for all practical purposes, separate the electorate from the legislature.” Einstein again, “. . . unless by common struggle we are capable of new ways of thinking, mankind is doomed.” “At present we are bound by political thinking, much of which seems dictated by private financial interests, not human or necessarily moral interests.” [3]

In the 20th century the annual average of war-killing was more than one million people. [4] We believe a great deal of it was brought about by political thinking dictated by private financial interests or at least supported by them. Unless there are changes we can expect such slaughter to continue. But the admonition of Albert Einstein was, “We can’t solve problems by using the same kind of thinking we used when we created them.” Until the war problem is solved this world will continue training our youngest adults, men and women, to be mass murderers, to continue bloody wars until financial control of the economy of the world is in private hands, undoubtedly not yours. The stupidity of people, not of policies, continues the wholesale killing.

Let us attempt some “new ways of thinking,” based upon human and moral interests. Consider the following: It must be true that in an ideal peaceful world, a world without the conventional weapons of war, without tanks, missiles, bombers, warships, drones and cyber-threats, there would be no need for nuclear weapons. In contrast to the treaty negotiated by the International Campaign to Abolish Nuclear Weapons, (ICAN, 2017 Nobel Peace Prize), the inverse of the above proposition is not true. For example, year 1941 and the absence of nuclear weapons, conventional armaments were abundant and in use.

We believe a world without conventional weapons of war, a world without need for nuclear weapons, can be achieved.

World initiatives for action need to be taken away from the military-industrial establishment and from the war mongers of the world with their insidious subversions, their mythological belief in their superiority and cause, and their assumed destiny to dominate nations, to rule the world, or their part of the world. World initiatives need to be directed not toward war, dominance, and conquest, but toward peace, for all those nations which are ready for peace, ready for the promised advances of the 20th and 21st centuries. At present U.S. and many nations foreign and military policies are subverted and corrupted by events abroad, corrupted often by private financial interests that seek great personal and private gain. *National and international discourse needs redirection toward peace and away from war.*

J. Robert Oppenheimer, “father” of atomic bombs, told us 73 years ago in 1946, that “. . . wars might be avoided by:

universal disarmament; limited national sovereignties; provision for all people of the world: of a rising standard of living, better education, more contact with and better understanding of others, and equal access to the technical and raw materials which are needed for improving life. . .” [5] For the avoidance of war we will show how this could be managed.

In the following, a plan or strategy is proposed that, if adopted: would put “everyone” back to work; bring peace and stability; end war-sacrificed lives; and ensure corporate profits, growth, and cooperation; and would allow people to return to peaceful opportunity-laden homelands.

This *workable moral strategy* seems the only approach, for decades or centuries to come, by which people of the Less Developed world, in peace, without war, can become masters of their own nation, can create a sensible path to their own peaceful destinies, as so many other nations have done. *This workable moral strategy exports no United States’ or other nation’s money.* It fosters the expressed desires of all people and nations seeking: peace, justice, opportunity, and a better life. This strategy has been referred to by one as “brilliant.” Well, certainly; the strategy incorporates ideas advocated by J. Robert Oppenheimer, Albert Einstein, Philip Morrison & Kostas Tsipis [6], and James C. Warf [7], some very bright fellows. We describe and recommended a workable moral strategy that might well be referred to as the “incentivization” of world peace. (You may wish to compare it with the world peace plan of the United States, or that of Russia or China or the United Nations.) Incentivization is an element lacking in the ICAN treaty.

Niels Bohr remarked to colleagues who were stumbling over a particularly onerous mathematical problem, “No, no, you’re not thinking, you’re just being logical.” He was suggesting new ways of thinking.

A WORKABLE MORAL STRATEGY FOR WORLD PEACE

Since the United States is the world’s major arms supplier it makes moral sense that the U. S. should have the privilege of leading the way. Thus the United States would announce a strategy, that starting one year from now it will revise the manner by which it provides aid to all other nations and particularly to those of the Less Developed world, provides aid using tax-wealth created by American and other taxpayers. It will no longer be *direct aid*. All other Developed nations are encouraged to similarly participate so that they would also obtain the benefits that will accrue to them just as benefits will accrue to the United States.

Henceforth, rather than direct aid, the United States will provide the United Nations with \$165 billion per year in “credit chits” (promissory notes) for use by Less Developed nations. Other Developed nations are invited to contribute *in total* an additional \$165 billion in “credit chits” to the UN; more if they wish. *No actual money leaves any nation.* The credit chits originating in the U.S. will only be redeemable in

cash by American businesses and industries from the United States Treasury. With cooperation from other nations it means \$330 billion or more per year of development aid to the Less Developed world, much more than what is now provided by the U.S. alone, a great deal of which we know under the current system is wasted, corrupted, or spent on tools of war.

It seems affordable. On April 10, 2009 the small nation of Japan, not at war with anyone, announced a \$150 billion government stimulus package. In 2009 Japan thought it could afford to do this. You can hear a conservative United States Congress complaining that we cannot afford to do something like that. But financial resources are always found for wars. We can be smart enough to find them for a peace which eliminates wars and *the costs* of wars. We will show reference that the workable strategy we are proposing will lead to more than 500,000 U.S. peacetime manufacturing jobs in the first year – with more to come, and *greatly more than 500,000* other peacetime jobs throughout the world.

The United Nations makes the “credit chits” available to *peaceful democratic* nations of the Less Developed world. Additionally, chits will also be very cautiously offered to those nations which are verifiably peacefully evolving toward equitable nondiscriminatory constitutional democracy. The chits are made available to Less Developed nations based on solicited application of: development proposals from them, verifiable need, and guarantees against misuse or corruption.

These chits to be offered by the United Nations may be utilized *only* for social and economic development, six specific self-sufficiency goals:

- 1) modern appropriate agriculture, food, and fresh pure water production;
- 2) good sheltering and its basic amenities, including electricity, plumbing, sewage;
- 3) health care, with hospitals, clinics, electronic communication, and well-trained doctors;
- 4) national wealth creation and infrastructure from their own natural and human resources;
- 5) civilian security, and;
- 6) education and training at all levels to support goals 1-5.

The solicited development proposals submitted to the United Nations will be carefully evaluated, in terms of the proposed societal, cultural, economic, and environmental impact, and in terms of protection against abuse and corruption. The UN will aid revisions of unacceptable proposals until they are in line with this UN sanctioned strategy.

Administering this program, the United Nations will not grant chits to nations where war exists or is likely, or where violations of rights: gender, religious, human, or ethnic, are active or not being remediated. Repressive and military governments and martial law governments will not qualify for participation in this program, nor will any nation, chit donor or receiver, regardless of its size, power and influence,

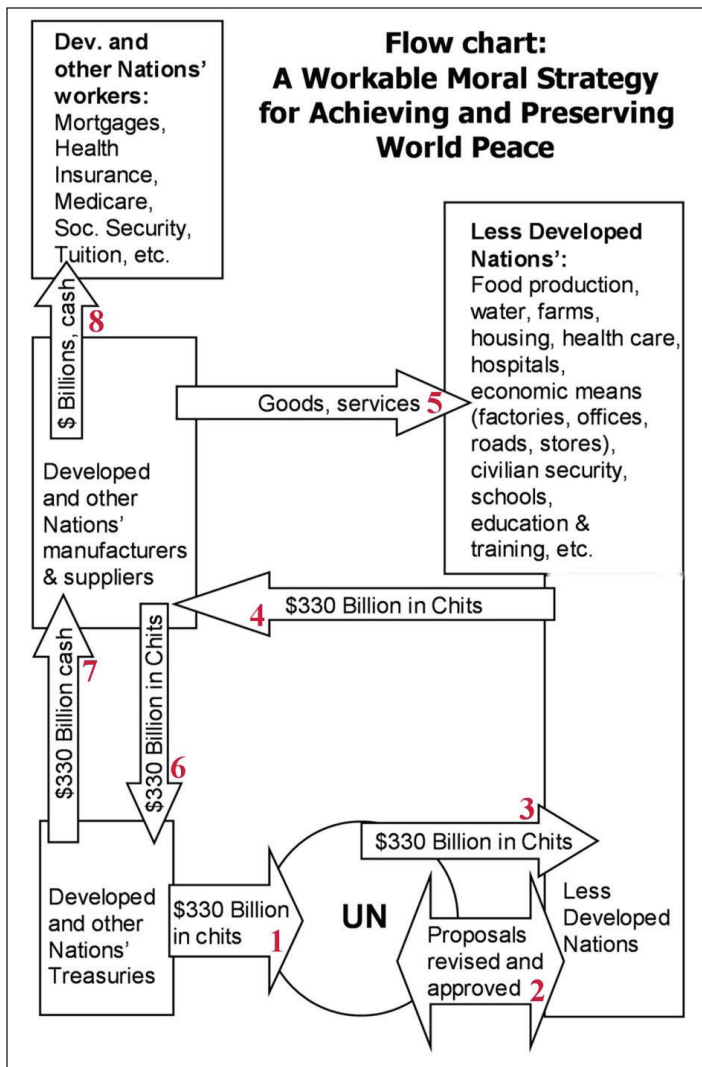
which is not fully and actively transparently participating and cooperating in the worldwide elimination of: armaments of war, nuclear weapons, terrorism, and the illicit drug trade. Chits may pass through other nations on their way back to their origin nation, that is, pass through nations which also must be in abidance with the conditions of this paragraph. In democracies seeking peace and advancement the people will not choose continued corruption and wars.

All the above are the essential specifications to this workable moral strategy for achieving and preserving world peace. There are three additional “recommendations” in Chapter 5 of the author’s book* from which this document has been extracted and abridged. Chapter 5 also responds to reader’s other possible concerns.

There will be great advantages to all nations that make chit deposits into this program, and considerable disadvantages to those who can, but do not. The more chits deposited, the greater productive economic value accrues to the depositor nation.

Each year this workable and moral program will see returned to the nonmilitary economies of the Developed nations, in total, some US\$330 billion or more, to be used solely for deliverance of peacetime goods and services! Hence, this proposed program should greatly reduce unemployment in any nation participating, supplier or receiver. This program will put workers, the original creators of wealth, back on the job. We estimate that the first year could create in the U.S. alone some 500,000 or more jobs, and at least that many outside the U.S. Here is a source of an estimate of the number of jobs to be created or restored: David Swanson in *Roots Action*, Sept. 9, 2011; Political Economy Research Institute at the University of Massachusetts (Amherst). (rootsaction.org/news-a-views/232-i-just-found-29-million-jobs)

When this plan is activated individual citizens of participating Developed nations would come to understand that they are active participants, creating tools, equipment, materials, and know-how, making possible peace and justice onto all regions of the world, and doing it without guns, bombs, and missiles, without destruction and killing thousands. Citizens of the Less Developed world will finally begin to see their hopes and dreams of a peaceful homeland coming true. Their long sought homes, employment opportunities, health care, utilities, schools, society, foods and water, etc., all coming into being, and *by their own work and efforts*, with the tools, equipment, materials and know-how provided by all the participating UN Developed nations who committed themselves to such obligation with their UN Charter signature. [8] When the “chits” are allocated the field is leveled; Less Developed nations can then negotiate with all participating Developed nations to gain the best advantage for themselves. Political and financial obligations to “powerful” nations become unnecessary.



Consider what 3,500,000,000 people of the Less Developed world do not have, and who is capable of supplying it! There are abundant opportunities for all! Chit donors and receivers. This proposal has the potential of bringing together the people of possibly 190 nations for the purpose of ending wars and creating a peaceful, cooperative world. This plan is “*The Incentivization of World Peace.*” Billions of people worldwide would be able to have jobs and greatly improved lives. If you think that this approach to world peace could become quite costly, compare it to the cost of “attempting” to recover from a war that could involve the United States (and Allies) and Russia, China, and stateless terrorists. Such a war could result in hundreds of millions of deaths as well as physical destruction of the major cities on the surface of a radioactive earth.

Adoption of this strategy would result in an exchange being made:

- With self-sufficiency and self-defined but true democracy growing in a protected Less Developed world and the elimination there of poverty, illiteracy, malnutrition, disease, neocolonialism, rights deprivation, indebtedness, exploitation, and slavery;

- The entire world could have full economic recovery, elimination of the possibility for international nuclear catastrophe, and the practical elimination of war.
- In a world at peace the refugee problem is solved. The killing stops and solutions to global problems can be found. The basic tool is cooperation and proper incentives, not sanctions, boycotts, deadly threats, regime changes, and wars; but instead, justified benefits, not penalties; advantages for all. As promised, no money would leave any nation or pass through the UN, and the credit chits never pass through the World Bank, or any bank, or the International Monetary Fund.

A world at peace as described above would aid solution of present day social problems, in particular the immigration problems in Europe, Africa, the Middle East, the United States, and Latin America.

We believe the workers of the world, of the Americas, of Russia, of China, would approve of this plan; unless someone throws a wrench into the works, *for some reason.*

For the Developed World to reject this type of plan implies that the oligarchy of private capital influencing legislative bodies would much prefer to continue structuring a world system of financial control in private hands, through wars, financial obligations, and regime changes.

JUSTIFICATION: A MORAL WORLD VIEW

We believe the Developed World and its people have some responsibility for centuries of: exploitation, poverty, starvation, slavery, disease, displaced refugees, rights deprivation, war-killing and destruction, and illiteracy, etc., as they have existed in the former colonial and Less Developed world, in Africa, in Asia and the Middle East, in Latin America. It is likely that your nation in some manner has taken selfish advantage of people of the Less Developed world. We believe the Developed World has some unfulfilled moral obligations to the former colonial and Less Developed World.

Chapter 5 of Wilson’s book* also suggests specific solutions to the Palestine/Israel problem as well as the Senkaku Islands problem between Japan and China. Similar problems exist elsewhere.

Adoption of this Incentivization of World Peace would go down in history as the turning point which saved the earth and its people from return to a darkest and post-nuclear age. For all nations’ Congresses, Parliaments, and people it would symbolize the wisdom of finally coming to their senses. Otherwise, the world must endure many more centuries of “nuclear madness” and annual mass murders.

But here is a prediction of “Constant Conflict”: “There will be no peace. At any given moment for the rest of our lifetimes, there will be multiple conflicts in mutating forms around the globe. Violent conflict will dominate the headlines, but cultural and economic struggles will be steadier

and ultimately more decisive. The de facto role of the US armed forces will be to keep the world safe for our economy and open to our cultural assault. To those ends, we will do a fair amount of killing.” — Major Ralph Peters of the Office of the Deputy Chief of Staff for Intelligence, 1997, where he was responsible for future warfare. [9]

To such ends any amount of killing would be morally unjustifiable. There are other choices, other options. “War does not determine who is right - only who is left.” — Often attributed to Bertrand Russell, but no sources exist.

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[8] ***The Purposes of the United Nations are:***

1. *To maintain international peace and security, and to that end: to take effective collective measures for the prevention and removal of threats to the peace, and for the suppression of acts of aggression or other breaches of the peace, and to bring about by peaceful means, and in conformity with the principles of justice and international law, adjustment or settlement of international disputes or situations which might lead to a breach of the peace;*
2. *To develop friendly relations among nations based on respect for the principle of equal rights and self-determination of peoples, and to take other appropriate measures to strengthen universal peace;*
3. *To achieve international cooperation in solving international problems of an economic, social, cultural, or humanitarian character, and in promoting and encouraging respect for human rights and for fundamental freedoms for all without distinction as to race, sex, language, or religion; and*
4. *To be a centre for harmonizing the actions of nations in the attainment of these common ends.*

[9] “*Constant Conflict*,” Lt. Colonel Ralph Peters, informationclearinghouse.info/article3011.htm

* Raymond G. Wilson is an emeritus Associate Professor of Physics, Illinois Wesleyan University, who has taught about nuclear war for over 58 years and has spent most of 17 summers of study and exploration in Hiroshima and Nagasaki. This essay is adapted and greatly abridged from Wilson’s 2014 book, where the strategy is developed more completely in Chapter 5. *Nuclear War: Hiroshima, Nagasaki, and A Workable Moral Strategy for Achieving and Preserving World Peace*, Author House, is available in print from Amazon or ebook from the publisher. The book is not for profit and can be downloaded at no cost here, sun.iwu.edu/~rwilson/PNDclass.html There is a “Caution” on the cover.

Energy: A Human History

Richard Rhodes (Simon and Schuster, New York, 2018). xiv + 465 pp. \$30.00. ISBN 978-1-5011-0535-7.

Because my first year of teaching at The Calhoun School was the year of the Iran Oil Embargo, my students and colleagues wanted me to enlighten them on what was then known as the “energy crisis.” The first book I saw on the Calhoun library shelf to turn to was George Russell Harrison’s *The Conquest of Energy*. Harrison broke the history of human energy sources into four “f’s”: *food* (during the food gathering stage, going back two million years), *feed* (for animals, during the agricultural stage, going back twenty thousand years), *fuel* (for the Industrial Revolution, going back two hundred years), and *fission* (for the nuclear age, at that time going back about two dozen years).

In his preface, Rhodes writes “The current debate [about energy issues] has hardly explored the rich *human* history behind today’s energy challenge. I wrote *Energy* partly to fill that void – with people, events, times, places, approaches, examples, parallels, disasters, and triumphs, to enliven the debate and clarify choices.” He writes that he “was surprised and sometimes amazed at how many of [these] stories have been forgotten” and that some of the resources he uses are “histories and biographies that date back two hundred years or more.” But he adds that his book is “more than merely stories” and that “its serious purpose is to explore the history of energy, to cast light on the choices we’re confronting today because of the challenge of global climate change.” He calls global warming “the great challenge of the twenty-first century” and describes the problem as “limiting global warming while simultaneously providing energy for a world population not only advancing in number but also advancing from subsistence to prosperity.”

Rhodes wrote his human history of energy with a focus on what Harrison would call the “fuel” and “fission” stages. He draw his inspiration for the book from a “narrative extension” of a World Primary Energy graph by Italian physicist Cesare Marchetti showing successive peaks of different energy sources from 1850 through 2100, beginning with coal peaking in 1920 as wood declines, followed by oil peaking in 1980, natural gas in 2030, and nuclear in 2085.

Energy is divided into three parts. The first, titled “Power,” tells the stories constituting the Industrial Revolution in England. He begins with the last years of Elizabeth I’s reign, characterized by a wood shortage around London resulting from deforestation to erect buildings and build ships. Mainmasts 120 feet tall required trees that had been growing almost that many years, and 300,000 more trees per year were needed to heat buildings and provide charcoal for 300 iron smelters.

With wood in short supply, people started burning coal

to provide heat. After using all the accessible coal from the ground, chisels attached to rods driven with a levered system by a man with his foot in a stirrup was used to find underground coal seams. Mines below the water table needed to be pumped, initially by systems powered by horses moving in circles. Later, the cyclic motion of a piston with differential gas pressures was preferred. Denis Papin invented the pressure cooker and showed he could use superheated steam to raise water up to 70 feet, but he did not have funding to develop his idea. Meanwhile, Thomas Savery was patenting a new invention for raising of water in 1698.

Unfortunately the steam engine designs of both Savery and Papin required a manual operator. By 1734 Thomas Newcomen overcame this problem, but even his design required external application of water to condense steam, a step he subsequently automated. But since Savery’s patent “covered all engines that raised water by fire,” the only way Newcomen could proceed with his design was in partnership with Savery. Moreover, the limited efficiency of Newcomen’s steam engine limited its use to raising water, but it did so at one sixth the cost of horses.

With the problem of raising water from mines solved, the next problem was transporting coal to market. Roads, being the responsibility of local property owners, were notoriously bad, so the first mines were established near rivers on which the mined coal could be barged. When these mines were exhausted, carts transported coal to rivers. They operated most efficiently on rails, initially made of wood which needed replacement every one to two years. Iron rails could solve this problem, but wood, still in short supply, was needed to make the charcoal to smelt the iron. Rhodes does not say where, given this wood shortage, the wood to make the carts and rails was obtained. Abraham Darby solved this problem by anaerobically heating coal to make coke, which worked as well as charcoal.

As the maker and maintainer of instruments for the then College of Glasgow, James Watt encountered Newcomen’s steam engine and was struck by its inefficiency, some of which he attributed to the energy loss coming from condensing the steam in the cylinder. He circumvented this problem by condensing the steam in a separate condenser, for which he was awarded a patent in 1769 for “Methods of Lessening the Consumption of Steam, and, consequently, of Fuel, in Fire Engines.” Even then, though, the efficiency was only 2%. After Watt partnered with Matthew Boulton in 1775 to mass produce these engines, Boulton persuaded parliament to extend Watt’s patent another ten years, to 1800. By this time steam engines had found an increasing number of uses. Exacerbating England’s air pollution problem, 50% of the country’s energy was provided by coal, a figure that would increase to 75% a century later.

To skirt the Boulton and Watt patent, Richard Trevithick, Jr., in 1795 built a different kind of steam engine. Whereas Boulton and Watt's design was based on the pressure difference between Earth's atmosphere and the vacuum produced by condensing steam, Trevithick used the higher pressure of "strong steam" against that of Earth's atmosphere and filed for a patent in 1802. With horses needed by the military during the Napoleonic War, Trevithick applied his steam engine to pull the carts of coal (now with iron wheels on iron rails) to make the first railroad locomotive in 1801. Two years later he made a steam-driven horseless carriage, but it lacked effective means of control and elicited no interest. Trevithick's mantle as a builder of locomotives and promoter of steam-powered transportation fell to the self-taught George Stephenson. He partnered with his engineer-trained son Robert to build the first steam-powered public railway, between Stockton and Darlington. It opened 27 September 1825, a year before Trevithick's death (in poverty).

More challenging—in terms of both the political and physical environment—was establishing the railway between Liverpool and Manchester. Stephenson's *Rocket*, which placed first in a public competition, ran on it. Thus the need to replace wood by pumping water from mines to extract coal gave rise to machines that burned that coal not only to pump water but also to do other types of work.

The second part of *Energy*, titled "Light," details stories of the various fuels burned to produce light, among them coal gas, whale oil, kerosene (then called "coal oil"), as well as the primary source of light today, electrical energy, and our means of generating it. While these stories are interesting, they form a less tightly-knit unit than the stories in the first part.

The two most interesting stories are: (1) drilling the first oil well in Titusville, PA, in 1859, which is absolutely riveting; (2) the victory of George Westinghouse's AC over Thomas Edison's DC. The latter was really due to William Stanley, Jr., not Nikola Tesla, whose "only contribution to the 'war' [of electric currents] was the alternating current electric motor."

The third part, titled "New Fires," is also not as tightly-knit as the first part. It begins with the automobile and ends with nuclear energy, and emphasizes Hyman Rickover's role in designing American reactors. Rhodes observes that the first American automobiles, made in the last decade of the nineteenth century, used three types of propulsion: electricity, steam, and gasoline. Of these, the last dominated automotive transportation in the twentieth century, and in fact fossil fuels have been our primary source of energy. Mindful that fossil fuels are now threatening Earth with climate change, Rhodes concludes part three by surveying our options for the future.

He begins his last chapter by discussing wind and solar energies but then notes their low capacity factor, in contrast to 92.1% for nuclear in 2016. Along with renewables, he sees nuclear as the only source able to meet the 21st century challenge of limiting global warming. He acknowledges the high cost of nuclear energy and the problem of disposing of its wastes and conducts post-mortems of the nuclear accidents at Three Mile Island, Chernobyl, and Fukushima Daiichi. Yet he feels that nuclear is "easily the most promising single energy source available to cope" with this challenge.

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