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Editor's Comments

Our feature articles for this edition deal with a variety of interesting topics. Nuclear non-proliferation remains in the headlines as the world continues to monitor developments in Iran and North Korea, and we are pleased to be able to run a very timely article on enhancing the resilience of the nuclear nonproliferation regime by Arian Pregenzer, recipient of the 2012 Joseph A. Burton Forum Award. Dr. Pregenzer's article is based on her presentation on the occasion of the award ceremony held during the APS Atlanta meeting earlier this year. James Williams offers an appreciation of the life of Fang Lizhi, the Chinese astrophysicist and political dissident, who passed away earlier this year. The story of Lizhi's perseverance in an environment of politicization of science is an inspiration – and a reminder that the scientific community needs to remain on guard against such madness. (Indeed, one of our book reviews deal with fighting against the political assault on science in America.) Longtime *P&S* contributor Dave Hafemeister offers a very readable tutorial on estimating the insulative R-value of Earth's atmosphere based on some fundamental heat-transfer considerations; I will be showing this to my freshman-level physics students when we come to the thermal-physics unit of their course later this year. A group of mechanical engineers offer a commentary and a proposal on the basic versus-applied research funding debate. Our other book review examines a physics-based analysis of the future of sustainability.

AIP State Department Fellowship Program Deadline

The American Institute of Physics is now seeking applicants for its 2013-2014 State Department Science Fellowship. The application deadline is November 1. Through this program, the AIP offers an opportunity for scientists to make a unique and substantial contribution to the foreign policy process by spending a year working at the U.S. State Department. Qualified scientists at any stage of their career are encouraged to apply. Applicants must be U.S. citizens, have a PhD in physics or a closely related field, be members of one or more of AIP's ten Member Societies, and be eligible to receive an appropriate security clearance prior to starting the Fellowship. Final interviews will take place early in 2013 and the 12-month Fellowship term will begin in September 2013. Details can be found at the AIP website, http://www.aip.org/gov/fellowships/sdf.html.

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ARTICLES

Enhancing the Resilience of the Nuclear Nonproliferation Regime

Arian L. Pregenzer

[Dr. Pregenzer, recently retired from Sandia National Laboratories, was the recipient of the 2012 Joseph A. Burton Forum Award "for her intellectual and managerial leadership in creating centers that allow international technical and policy experts to explore confidence building measures and other arms control regimes." We are pleased to present here an article based on Dr. Pregenzer's remarks made at an FPS-sponsored session at the APS April meeting held in Atlanta earlier this year – Ed.]

Introduction

The Treaty on the Nonproliferation of Nuclear Weapons, generally known as the NPT, is the heart of the international nuclear nonproliferation regime. The NPT is intended to limit the spread of nuclear weapons. Parties to the NPT are categorized either as nuclear weapon states (those countries that already had nuclear weapons when the treaty entered into force in 1968 – the United States, the United Kingdom, Russia, France, and China) or as non-nuclear weapon states (all other states party). Nuclear weapon states (NWS) commit not to assist other states to acquire or develop nuclear weapons, and non-nuclear weapon states (NNWS) commit not to develop or acquire nuclear weapons and to implement International Atomic Energy Agency (IAEA) safeguards for all civilian nuclear material and facilities. In addition, all states party agree not to export nuclear equipment or material to NNWS except under IAEA safeguards, but to facilitate the exchange of peaceful nuclear technology and to work towards future nuclear (and total) disarmament. Over the longer term, Article VI of the treaty requires that all parties undertake to pursue negotiations in good faith on nuclear disarmament

In addition to the NPT, the nuclear nonproliferation regime includes a broad range of multilateral and bilateral measures, most of which are voluntary. Examples include international export control, border security to detect illicit transfers, physical security for nuclear material and weapons, detection and interdiction measures, sanctions on countries in violation of treaty requirements, and nuclear arms control.

The regime is considered to have played an important role in limiting nuclear proliferation, even though India, Pakistan and Israel never joined the treaty, and North Korea withdrew from it in 1993 and again in 2003. A few states, such as Iran, Libya, and Iraq, joined the NPT but violated some of its provisions. Now, given the interest in nuclear energy worldwide and the increased availability of sensitive nuclear technology, i.e., uranium enrichment and plutonium reprocessing technology needed for making nuclear weapons material, there are concerns about the future of the regime. Figure 1 depicts trends in acquisition of nuclear technology and weapons in the past and raises questions about possible futures.

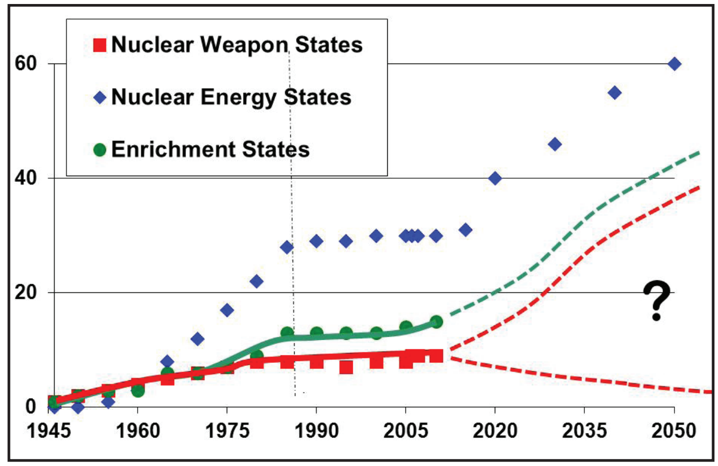

Figure 1. Number of states with nuclear weapons (squares, red), uranium enrichment technology (circles, green), and nuclear energy (diamonds, blue).

The purpose of this article is to introduce the concept of systems resilience as a new framework for thinking about the future of the nonproliferation regime. First, I introduce key concepts from the literature on systems resilience as developed for other disciplines. Then I review the evolution of nonproliferation efforts and analyze them from the perspective of systems resilience. Finally, I suggest some strategies for enhancing the resilience of the nonproliferation system in the future.

Systems Resilience

The study of "systems resilience" seeks to understand how complex systems respond to major disturbances. It has been the subject of significant research in the last thirty years for systems as diverse as electrical grids, transportation infrastructure, and social-ecological systems [1]. In the context of nonproliferation I suggest that the set of actors, instruments, and strategies focused on preventing the spread and use of nuclear weapons can be thought of as a complex system. Actors include states party to the NPT, states outside the NPT, and non-state actors such as terrorist groups. Nonproliferation instruments would include treaties, export control regimes, United Nations Security Council resolutions, and other less formalized efforts, such as the Proliferation Security Initiative. Nonproliferation strategies fall into three broad categories: controlling supply of nuclear weapons relevant technology, material, and expertise; reducing motivation for acquiring nuclear weapons; and responding to proliferation events as they occur. I also suggest that the most important function of the nonproliferation system is to maintain strong international norms against the spread and use of nuclear weapons.

Several themes from the discipline of systems resilience are particularly relevant to the nonproliferation system:

- The difference between resilience and stability,
- The need for evolution to maintain function (by which is meant maintaining an international norm against the spread and use of nuclear weapons) in a changing environment,
- The importance of functional and demographic diversity.

Difference between Resilience and Stability

Strategies to promote system resilience will be fundamentally different than strategies to promote stability. Strategies for stability are directed at avoiding danger and controlling both system elements and the external environment. They focus on development of detailed plans to prevent a broad range of hypothetical threats. On the other hand, strategies for resilience acknowledge the inevitability of change and focus on establishing general capabilities to respond to unknown hazards as they occur. Rather than seeking to control the environment, strategies for resilience use an experimental approach to probe the environment, continuously seeking to test strategies against new scenarios.

Successful systems management will require a mix of strategies for both stability and resilience. However, because stability measures are easier to quantify, they are often overemphasized. Strategies to develop the energy, endurance, and skills that are essential to recover from major disasters may seem unfocused and therefore be harder to justify. The willingness to invest in activities that provide more general benefits is a sign of a management strategy that incorporates resilience.

The Need for Evolution to Maintain Function

Systems must continuously evolve to maintain their function in a changing environment, much less to improve. Evolution includes two types of change: strengthening existing capabilities, and developing new ones. Continued strengthening of existing capabilities without adding new ones is likely to be insufficient over the long run.

The Importance of Diversity

Diversity is essential for resilience. For example, the resilience of ecological systems is enhanced if different organisms performing the same ecological function respond differently to environmental perturbations, thereby enhancing the likelihood that the service will be maintained throughout a wide range of conditions. Loss of diversity increases the chances for ecosystem collapse. In the business world, diversity in workplace skills, personalities, and perspectives is believed to enhance creativity and innovation and to improve decision-making and problem-solving, leading to better products. A demographically diverse workforce also may have a better understanding of the demographics of the marketplace, enhancing its competitive edge.

Evolution of Nonproliferation Strategies

The nonproliferation system has evolved over several decades in response to a changing international environment, as depicted in Figure 2. After the failure of the Baruch Plan to win international support for control of nuclear weapons in 1946, the primary U.S. nonproliferation strategy was classification of information related to the nuclear fuel cycle and nuclear weapons. When Soviet and British nuclear weapons tests in the late 1940s and early 1950s demonstrated the weakness of this approach, classification guidelines were modified, but not abandoned. The IAEA was created to promote nuclear power for peaceful purposes and to safeguard civilian nuclear material. IAEA safeguards coupled with diplomacy (mostly bilateral) were the prevailing nonproliferation strategies until the Indian nuclear test in 1974, which triggered much more intensive efforts on international export control and the formation of the Nuclear Suppliers Group.

The breakup of the Soviet Union in 1991, which resulted in fears of unsecured nuclear weapons and material, was a significant shock to the nonproliferation system, and resulted in creation of a broad range of cooperative threat reduction efforts to improve nuclear security. Cooperation with the Russian Federation to protect nuclear weapons and weapons-useable material was unprecedented and involved a high degree of innovation. It also set the stage for a broad range of cooperative nonproliferation efforts with other countries, such as the states of the former Soviet Union, Iraq after the second Gulf War, and Libya after it gave up its nuclear weapons program. In the same time frame, the failure of the IAEA to detect the Iraqi nuclear program eventually led to the IAEA Additional Protocol, which provides mechanisms for detecting nuclear activities at undeclared locations.

The shock of the September 11, 2001 terrorist attacks in the United States, together with revelations about the A.Q. Khan black-market, raised the specter of nuclear terrorism and stimulated the development of a number of new approaches. These range from building capacity to implement nonproliferation and nuclear security commitments to the Proliferation Security Initiative aimed at interdicting illicit shipments, to limited ballistic missile defense, to preemptive war in Iraq. The Obama administration has embraced yet another strategy: reducing the salience (and numbers) of nuclear weapons. The

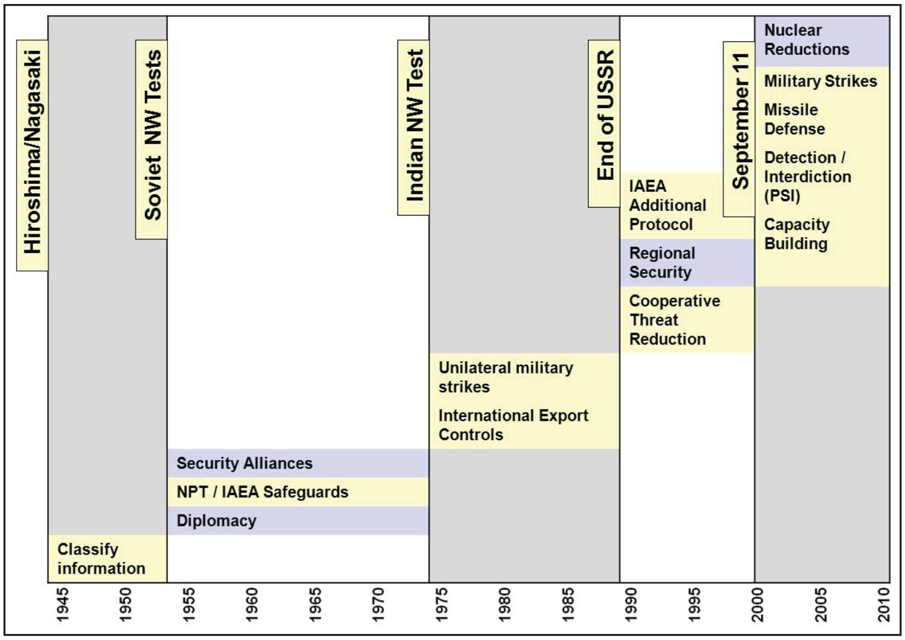

Figure 2: Evolution of nonproliferation strategies. Those strategies aimed at limiting capability to make nuclear weapons are color coded yellow. Those aimed at reducing motivation to develop nuclear weapons are color coded blue.

idea is to demonstrate U.S. commitment to NPT Article VI, and thereby increase support by nonnuclear weapon states for implementation of stronger nonproliferation measures [2].

Most of the nonproliferation strategies discussed above are focused on prevention, and therefore could be categorized as strategies for "stability" rather than strategies for "resilience." As strategies have evolved in response to system shocks, most change has strengthened capabilities to control supply of nuclear material, technology and expertise. Few qualitatively new strategies have evolved. The Proliferation Security Initiative is one example of a new approach. As a "coalition of the willing" it lies outside the bounds of the traditional international nonproliferation instruments and has no formal secretariat. Although nominally focused on preventing proliferation, its emphasis on international interdiction exercises builds capacity that could also contribute to general response capabilities [3].

In addition to a lack of diversity in nonproliferation strategies, the diversity of nonproliferation "champions" is also low. Western states and their allies are the most vocal champions of nonproliferation, with the United States the most prominent. Other states, such as China, Russia, and Brazil are supporters of nonproliferation, but may not prioritize it as highly as does the United States. In fact, some may see nonproliferation as a proxy for U.S. interests.

Enhancing Resilience of the Nonproliferation Regime

I previously suggested that the vital function of the nonproliferation system is maintaining strong international norms against the spread and use of nuclear weapons. If this is the case, the system would be considered resilient as long as this norm is maintained, even if one or two additional states acquire nuclear weapons. Such events would be considered "point failures" within the nonproliferation system, rather than system failures.

Therefore, strategies aimed at enhancing the resilience of the nonproliferation system should focus on sustaining this norm, rather than focusing solely on preventing additional states from acquiring nuclear weapons. Suggestions below are organized into four categories: increase international participation in setting the nonproliferation agenda; develop general international response capabilities, focus on non-coercive approaches to decreasing demand, and apply systems thinking more rigorously to nonproliferation.

Increase International Participation

Despite the success of U.S. and western leadership of nonproliferation efforts in the past, more international participation in setting the nonproliferation agenda will be required in the future. The global economy has contracted substantially, and the West has many fewer resources to invest. Future success will depend on genuine international commitment and capabilities to manage risks that are both ubiquitous and diffuse in an increasingly "dual-use" world. This, in turn, will require that challenges are defined from a local and regional perspective. Regional approaches should be encouraged in addition to the current bilateral approach. Regional efforts will add credibility to the process, increase available resources, and help to ensure broad support. As more and more countries benefit from nuclear technology, they must also assume greater responsibility for establishing and maintaining the culture required to assure the safety and security for all.

In January 2011, a Memorandum of Understanding between the United States and China to establish a Center of Excellence (COE) on Nuclear Security in Beijing was signed. This agreement represents a substantial investment by both countries and is an example of a new approach to international engagement. The COE will have extensive training facilities, analytical laboratories, and facilities to test and evaluate a wide spectrum of nuclear security technologies. The scope of cooperation will include: nuclear safeguards, nuclear material physical protection, control, and accounting; nuclear detection technology; nuclear measurement; and nuclear emergency preparedness and response. It is intended as a forum for exchange of best practices, development of training courses, technical collaboration, technology demonstrations and field testing of physical security and related technology. It will serve as a focal point to promote multilateral nuclear security throughout the Asia/Pacific region as well as the broader international community.

Develop General International Response Capabilities

The Proliferation Security Initiative offers features that would be valuable in a general response capability. The mission of the PSI is to stop shipments of nuclear, biological or chemical weapons and associated delivery and production capabilities to terrorists and potential state proliferators. Participating countries aim to interdict cargo at sea, in the air and on land. The PSI is designed to make it more costly and risky for proliferators to acquire the weapons or materials they seek, thereby (hopefully) dissuading them from pursuing weapons in the first place or at least significantly delaying in their acquisition efforts. Only 11 countries signed up to the PSI in 2003, and many others expressed concerns about its legality. Since then, however, an additional 73 countries, including Russia, have committed to it. PSI participants have conducted nearly 30 interdiction exercises, which include mock ship boardings. The exercises are intended to increase the participants' capabilities to cooperate with one another. They are also intended to put a public face on the initiative and act as a deterrent to potential proliferators.

Another type of international response capability would be nuclear incident response teams. International capabilities could be based on domestic programs, such as the U.S. Department of Energy's Nuclear Emergency Support Team (NEST), which provides technical assistance to coordinate search and recovery operations for nuclear materials, weapons, or devices; and assistance in identifying and deactivating radiological devices [4]. An international nuclear incident response capability which includes regular exercises to test procedures and technologies could be valuable not only for proliferation or terrorism incidents, but could also provide a framework for responding to civilian nuclear disasters. The recent experience with the Fukushima reactor in Japan demonstrates the need for more effective international coordination and response in the civilian sector. Although the IAEA provides training in emergency response, it does not include international exercises that allow full-scale simulation of response operations [5].

Multilateral missile defense would be another example. However, to contribute to the resilience of the international nonproliferation system, it would need to contribute to the security of more than a small subset of countries. Understanding potential unintended consequences of missile defense (such as alienating China and Russia) and taking steps to reduce them would be essential to its making a positive contribution to the international nonproliferation system. Recent discussions between NATO and Russia on cooperative missile defense are a positive development [6]. In addition to nuclear threats, missile defense could be used against conventional threats.

Focus on Reducing Demand for Nuclear Weapons

Motivation to pursue a nuclear weapons program is generally thought to stem from a combination of several causes: national security concerns, domestic politics, and prestige derived from the symbolic value of nuclear weapons [7]. However, few nonproliferation strategies are intended to impact these factors. In fact, some nonproliferation strategies may inadvertently contribute to the sense that nuclear weapons convey both security and status.

To the extent that security concerns are the primary motivators behind a nuclear weapons program, reducing regional tensions and increasing the number of states that are covered by security assurances could be considered [8]. Positive security assurances, a feature of many security alliances, are widely believed to have been instrumental in preventing proliferation in Europe and Asia. However, if positive security assurances are understood to carry the promise of a nuclear response, they might inadvertently increase the perceived value of nuclear weapons as the ultimate security guarantor. In addition, unless countries such as Russia and China were included in development of new security arrangements, it could exacerbate their own security concerns.

Reducing the salience of nuclear weapons in national security strategies could reduce both their perceived security value as well as their symbolic importance. In the final analysis, however, as long as the most powerful states in the world (including all permanent members of the U.N. Security Council) continue to view nuclear weapons as indispensable to their security, it will be hard to convince all others that such weapons are not worth pursuing. This is why many argue that the two-tiered approach that is inherent in the existing nonproliferation system must end.

Apply Systems Thinking More to Nonproliferation

Because of the complexity of the nonproliferation system, it is difficult to predict (or even understand) the ultimate impact of nonproliferation strategies. However, analysis tools and methodologies have been developed to understand the behavior of complex adaptive systems in other disciplines and could be applied to nonproliferation. This first step would be to develop a graphical conceptual model of the process of proliferation and strategies that are intended to influence it. The graphical model could include a representation of states' motivations for seeking nuclear weapons and the methods for acquiring them. It would also include a graphical representation of nonproliferation strategies, along with their intended and unintended impacts on the process of proliferation [9].

Such a model would allow practitioners to clarify their thinking about system processes and explicitly account for feedbacks among strategies and unintended consequences. This in itself could be highly beneficial. Going beyond a simple graphical model might be possible but would require caution. Not only are the interactions in the nonproliferation system difficult to quantify, many interactions remain unknown. The results of a mathematical model of the nonproliferation system might be significantly less valuable than the simple graphical model.

Final Thoughts

Although developing a better understanding of feedbacks among nonproliferation strategies will be needed to enhance the resilience of the nonproliferation system, it is important to keep in mind that the nonproliferation system interacts constantly with other systems on larger and smaller scales. In the United States, nonproliferation traditionally has been an element of broader security policy, not necessarily the highest priority. Larger international security issues have sometimes driven policies that seem inconsistent with the strict goals of nonproliferation. The so-called U.S. / India nuclear deal that implicitly places a higher priority on a strategic partnership with India than on India's acceding to the NPT is an example.

The nonproliferation system interacts with smaller-scale systems as well, such as domestic energy policy and nuclear weapons policy. Implications of the interaction between nuclear energy policy and nonproliferation have been recognized and analyzed since the 1950s, but the latter is much less understood. For example, the 2010 U.S. Nuclear Posture Review Report states that the greatest threats to U.S. national security are nuclear proliferation and terrorism, and articulates the goals of reducing numbers of U.S. nuclear weapons and their salience to U.S. security strategy while maintaining a safe, secure nuclear deterrent as long as other states possess them [10]. It also establishes ambitious goals for both nonproliferation and modernizing the U.S. nuclear weapons complex. However, modernizing the U.S. nuclear weapons complex in a way that is consistent with possible future arms control and nonproliferation requirements will be a challenge [11]. During the implementation process, much care will be needed to avoid sending the wrong message and undercutting international nonproliferation commitments.

Finally, although many worry about the repercussions of a nuclear capable Iran or developments in the North Korean nuclear program, it is impossible to predict the nature or timing of the next major challenge to the nonproliferation regime. In the past, shocks have come from events directly related to proliferation, such as the Soviet and Indian nuclear tests. In more recent years, shocks have tended to be associated with broader international developments, such as the dissolution of the Soviet Union and the September 11 terrorist attacks. Acknowledging both the inevitability and unpredictability of future shocks and relaxing the urge for control may be the most important steps to foster a climate for continued innovation that will underpin any ultimately resilient system.

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[2] *NPT Article VI requires that all treaty parties undertake to pursue negotiations in good faith on nuclear disarmament. For full text, see: http://www.fas.org/nuke/control/npt/text/npt2.htm.*

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[8] *See, for example, C. Paul Robinson, "Developing a Realistic Strategy to Control the Spread of Nuclear Weapons." Nature 432 (November 25, 2004), pp. 441-442.*

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[10] *The 2010 Nuclear Posture Review can be read at: <http://www.defense.gov/npr/docs/2010%20nuclear%20posture%20review%20report.pdf>*

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Fang Lizhi: An Appreciation

James H. Williams

[A version of this article ran in the Fall 2012 edition of the Forum on International Physics Newsletter, and in the British journal China Quarterly. We are grateful to FIP and CQ for their permission to run this version – Ed.]

Fang Lizhi (1936-2012)

Courtesy Wikimedia Commons; http://commons.wikimedia.org/wiki/File:Fang_Lizhi.jpg

Fang Lizhi, the Chinese astrophysicist and political dissident, died on April 6, 2012, in Tucson, Arizona. He left China in 1990 after a year spent inside the U.S. consulate in Beijing. Fang and his wife had gone to the consulate for refuge following the violent suppression of the 1989 democracy movement, which the Chinese authorities accused him of fomenting. In 1992 Fang took a position teaching physics at the University of Arizona, where he worked until the time of his death at age 76. He never returned to China.

Fang Lizhi's life story is remarkable, and provides a unique window into recent Chinese history. He was born in 1936 in Beijing, where his father was an accountant for the national railroad. He grew up under Japanese occupation, and joined an underground Communist youth organization during the Nationalist interlude. At the age of sixteen, Fang was admitted to Beijing University in physics, the premier department in China's premier university. Fang's professors included many of China's top foreign-educated physicists, who also served as government advisors and research institute directors. While at Beida [a colloquial term for Beijing University – Ed.], Fang was admitted to the Communist Party, and met physics classmate Li Shuxian, his future wife. He graduated at the top of his class in 1956 and was assigned to the CAS Institute of Modern Physics, where at age 21 he led a team doing calculations – sometimes by abacus, in the absence of computers – to optimize nuclear reactor design for production of plutonium for weapons.

In May 1957, during the Hundred Flowers movement, Beida became ground zero for criticisms of the Party. Physics students played a leading role, due partly to their prestige and partly to their privileged access to foreign news sources which made them aware of events in the Soviet bloc, such as Khrushchev's criticism of Stalin and the Hungarian uprising. Though he had graduated, Fang was frequently on campus visiting Li Shuxian, who had been posted there after graduation as a translator for a Soviet expert. The two took part in the Hundred Flowers criticisms, and as a result became targets the following month when Mao Zedong reversed course and launched the Anti-Rightist campaign. Li was labeled a rightist, dooming her physics career. Fang avoided the worst consequences simply because the Party required CAS to purge five percent of its personnel as rightists, and this quota was met before Fang's activities came to light. Nonetheless, he was removed from classified weapons research and expelled from the Party.

The Anti-Rightist campaign was the beginning of a twenty-year odyssey during which Fang, like many other Chinese scientists and intellectuals, sought to pursue a career and raise a family in the midst of political upheaval and frequent assignments to manual labor in China's hinterland. At various times Fang grew millet, raised livestock, planted trees, dug railroad tunnels, and worked in electronics and camera factories. He was reassigned to a teaching position at the newly formed Chinese University of Science and Technology in Beijing, and was also able to unofficially join the CAS Institute of Physics research team that built China's first laser. While his political status prevented him from publishing articles using his CUST affiliation, he slipped through the cracks of official censorship by using his informal affiliation with the Institute of Physics, and despite his manual labor stints became one of the most widely published physics researchers in China in the early 1960s. Fang and Li married in 1961 in the depth of the post-Great Leap Forward famine and had their first child in 1963. During the Cultural Revolution, students on the CUST campus engaged in violent confrontations wearing makeshift armor. Fang stayed clear of the fray initially but was denounced during the Purify the Class Ranks campaign in 1968, and sentenced to confinement in a "cowshed" dormitory room with other professors for a year, during which time 10 of his colleagues committed suicide. In 1969, as part of the "third front" mobilization that relocated strategic assets into China's interior, students and faculty physically moved CUST to its new home in Hefei, Anhui. Fang was later part of a work team that made the bricks from which the new CUST campus buildings were constructed.

A pivotal point in Fang's life and career came during a 1969 assignment to a May 7th cadre school in Huainan, Anhui, where his responsibilities included mining coal and carting the dead victims of the campaign against May 16th elements (a conspiracy later shown never to have existed) in a wheelbarrow to the morgue. While deep in the coal mine, Fang heard bitter complaints by ordinary miners who felt victimized by Mao and the Communist Party. This was a political epiphany for Fang, who up to that point had retained hope that the Party's policies were at least benefiting the majority of peasants and workers. After a day's work in the mine, Fang would hide beneath the mosquito netting in his dorm and read a secreted copy of the Soviet physicist Lev Landau's text on classical field theory, which led to a fascination with general relativity and cosmology. As Fang later described it, "during those months Landau's book became my... only sustenance. When night fell and I lay in my netting exhausted from the day's labor, my soul would roam the expanding universe... It was from this time that I fell in love with astrophysics."

In 1972, as Nixon's visit to China led to a rapprochement in the U.S.-China relationship, scientists returned from manual labor to the lab, and scholarly journals resumed publication. In December, Fang became the first Chinese physicist to publish a research article on modern relativistic cosmology; specifically, Big Bang theory. Fang's article was technical and straightforward, but its political context was not. Einstein and the Theory of Relativity had been strenuously denounced in China during the Cultural Revolution; the substance of this campaign drew heavily from similar campaigns under Stalin in the 1930s and 1940s. As a result, even though as Fang said "there could not have been more than one hundred persons in China who really understood relativistic cosmology," his article became a centerpiece of the factional struggle surrounding Mao's succession, in which the Maoist left accused the pragmatists associated with Zhou Enlai and Deng Xiaoping of pursuing reactionary policies in science – "the satellites may fly to the sky, but the Red Flag falls to the ground." From early 1973 until Mao's death in 1976, at least thirty articles criticizing Big Bang theory in general and Fang's paper in particular were published by the Maoist left in the national news media (including People's Daily) and in academic journals. The thrust of the criticism was that Big Bang cosmology contradicted the dialectical materialist doctrine of the infinite universe contained in such Marxist-Leninist classics as Engels's *Anti-Dühring and Dialectics of Nature,* and Lenin's *Materialism and Empirio-Criticism*.

Fang stood his ground in the face of these attacks, publishing several new papers arguing that recent developments such as radio-telescope observations had created an empirical basis for cosmology to be studied through the usual methods of science, rather than through philosophical discourse. The campaign against the Big Bang had the unexpected result of allowing Chinese astronomers to hold scientific conferences to conduct "mass criticism"; under this pretext, nationwide astronomy meetings were resumed in 1974, and Fang's resistance became widely known among China's scientific community. A showdown of sorts occurred at a national astronomy conference held at CUST in the summer of 1976, after Deng was purged and his "Outline Report" on science policy attacked by the resurgent Maoist left. With representatives of the Party's ideology departments attending, senior Chinese astronomer Dai Wensai declared publicly that he supported Big Bang theory. The threat of repercussions for the conference leaders ended when Mao died in September and the Gang of Four were arrested a month later.

In the post-Mao era, Fang's scientific career blossomed. He published prolifically and became China's youngest full professor in 1978, a CAS academician in 1981, president of his professional society in 1983, and vice-president of CUST in 1984. He traveled abroad extensively to take up visiting scholar positions and establish scientific relationships between foreign and Chinese institutions; his first trip to a scientific conference in 1978 was so novel that his departure required direct approval from Hua Guofeng, Mao's interim successor. His CUST Center for Astrophysics was in turn visited by foreign luminaries such as Cambridge physicist Stephen Hawking, who complimented the center as being "state of the art in astrophysics and cosmology." Fang also participated in the de-Maoization of science, writing articles about the Cultural Revolution experiences of Chinese scientists that were sharply critical of political and ideological repression, likening Chinese cosmologists to Galileo and their Maoist oppressors to the Inquisition. For a time, these criticisms were compatible with the aims of the Dengist leadership, who wanted to normalize and reward scientific work in support of their technology and economic goals. But a chasm eventually developed between the authorities, who criticized the Cultural Revolution's chaos and privation in order to bolster the Party's political monopoly and economic development focus, and Fang, who criticized the Cultural Revolution's tyranny and mind control as an argument for intellectual and political freedom.

Publicly contradicting Party theorists such as Hu Qiaomu, who insisted that dialectical materialism continue to play a "guiding role" in scientific research, Fang said bluntly that Marxist philosophy was useless to science, claiming (some would say gleefully) that he could find a scientific error on every page of Engels's *Dialectics of Nature*.

As the 1980s unfolded, Fang's public critique of Chinese politics and culture extended far beyond the realm of scientific research. He charged that the greatest obstacle to China's development was not "material shortcomings" that could be bridged through "purchases and acquisitions," but rather "cultural traditions and habits of mind." In contrast to the official scientism of the Party's modernization drive, Fang argued that the greatest value of science was not as a technical discipline in the service of a technocratic state, but rather in its role as a "cornerstone of modern thought." Fang almost singlehandedly revived the May 4th movement theme of "science and democracy," which many early-20th century intellectuals, including CCP founder Chen Duxiu, had embraced as guiding principles for China's modernization. The Party's "Four Modernizations" campaign, by contrast, aimed far too low: "In the beginning we were mainly aware of the grave shortcomings in our production of goods, our economy, our science and technology, and that modernization was required in these areas. But now we understand our situation much better. We realize that grave shortcomings exist not only in our 'material civilization' but also in our 'spiritual civilization' — our culture, our ethics, our political institutions — and that these also require modernization." For Chinese intellectuals, Fang told students, modernization started with "straightening our bent backs" and speaking truth to power. He set a clear example, speaking plainly, criticizing leaders by name, and shining a spotlight on corruption and malfeasance. When asked by a reporter if his "four principles of academic freedom" might be seen as contradicting the regime's "Four Upholds" (the socialist path, dictatorship of the proletariat, CCP leadership, and the leading role of Marxism-Leninism-Mao Zedong Thought), Fang responded: "Is it possible that science, democracy, creativity, and independence are in conflict with the Four Upholds? If so, it's because the Four Upholds advocate the opposite of science, which is superstition; the opposite of democracy, which is dictatorship; the opposite of creativity, which is conservatism; and the opposite of independence, which is dependency."

Fang's themes featured prominently in street protests by college students against corruption and rigged local elections in late 1986. Though he worked behind the scenes to urge the students to return to their campuses, the Party's crackdown on the protests required official scapegoats, and Fang, journalist Liu Binyan, and writer Wang Ruowang were chosen. The Anti-Bourgeois Liberalization campaign had a paradoxical effect: as 500,000 copies of his selected writings and speeches were disseminated to Party branches throughout the country for study and criticism, Fang gained a much wider audience and became a folk hero. He was removed from his CUST post and transferred to the Beijing Observatory, but efforts to control or silence Fang invariably came back to embarrass the Party. Revoking Fang's travel privileges resulted in a torrent of international protest, including a letter from fellow physicist and dissident Andrei Sakharov.

In January 1989, Fang sent a hand-written note to Deng Xiaoping, asking for the release of Democracy Wall activist Wei Jingsheng and other political prisoners. (Wei said recently, "My gratitude to Fang remains immense… for the person whom Deng Xiaoping hated most to openly offend the dictator required enormous courage.") Fang's note in turn precipitated two open petitions of support from prominent intellectuals, including the senior nuclear weapons physicist Wang Ganchang. In March, authorities used heavy-handed tactics to prevent Fang from attending a barbecue to which he had been invited by visiting U.S. president George Bush, focusing worldwide media scrutiny on human rights violations in China. In the democracy protests that erupted spontaneously in April and May of 1989 following the death of Hu Yaobang, Fang avoided playing a direct role, concerned that his involvement would provide a pretext for the authorities to suppress the movement. His views, however, remained influential among the protesters; Beijing University students wore shirts with the legend "science and democracy." After the tragedy of June 4th, Fang and his wife were placed at the top of the public enemies list. At the urging of friends they took refuge in the U.S. Embassy in Beijing, where their presence became an impediment to the normalization of relations between the U.S. and China for more than a year. After lengthy negotiations, Fang and Li were released, and following stays in Cambridge and Princeton, ultimately settled in Arizona.

In exile, Fang remained engaged with China, participating in human rights campaigns, giving talks and interviews, publishing articles, and writing letters on behalf of political prisoners. He worked with many organizations including Human Rights in China, the International League for Human Rights, the Committee of Concerned Scientists, and the Committee on International Freedom of Scientists. He received honors for both human rights and scientific work, and was named a fellow of the AAAS and the American Physical Society. He retained his passion for science, and for teaching science and training young people. Of the 340 scientific journal articles, book chapters, and conference papers in his *curriculum vitae*, more than half were published between 1990 and 2012, an average of about eight papers per year. He worked with more than 125 co-authors, served on international scientific committees, helped to organize major conferences, and continued to build linkages between China and the rest of the scientific world, including the Beijing-Arizona-Taipei-Connecticut

(BATC) survey project, one of China's most significant collaborations in astronomy.

Fang's research focused on the structure and evolution of the early universe, the formation of galaxies, and the role of dark energy and dark matter. The range of phenomena he was conversant with was extremely broad, from quantum processes to the expansion of the universe. The bulk of his papers might best be characterized as observational cosmology, in that they took the limited data available from astronomical observations – mostly, the spectral lines of light emitted eons ago from impossibly distant objects – and applied many kinds of rigorous mathematical analyses to them, to tease out the patterns and test which theoretical models were consistent or inconsistent with the data. One of Fang's great skills in science was to recognize the patterns and underlying dynamics of the universe given the observed data, and then to explain it to people in a very simple and direct way. This was perhaps his greatest skill as an observer of Chinese society as well.

The death of a hero in exile is as tragic in real life as in mythology, and there is immense pathos for those who admired Fang to realize that he will never return home. Yet he did not pass quietly into obscurity, he did not become bitter, and he did not lose his humility, his honesty, his sense of humor, or his passion for the things he cared about. These are great triumphs in the midst of a tragic situation. For China on the other hand, the tragedy of Fang's exile – and the exile and imprisonment of others like him, from Wei Jingsheng to Liu Xiaobo, who have spoken with a clear voice and without fear about the observable reality around them – is not mitigated by its emergence as a superpower. Since Fang's path and China's path diverged in 1989, there has been prodigious progress in China's material modernization, but not in its political culture, evidenced most recently in the Bo Xilai affair's exposure of corruption, cynicism, and lack of accountability within the Party's highest ranks. This is unlikely to change until the spirit of truth-telling that Fang Lizhi embodied is finally invited home to a hero's welcome.

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Estimating the R-Value of Earth's Atmosphere

David Hafemeister

Raymond Pierrehumbert, Director of the Climate Systems Center at the University of Chicago, has pointed out an interesting parallel between heat transfer through planetary atmospheres and heat-transfer from ordinary buildings [1]:

"The temperature of your house is intermediate between the temperature of the flame in your furnace and the temperature of the outdoors, and adding insulation shifts it toward the former by reducing the rate at which the house loses energy to the outdoors. As Fourier already understood, when it comes to relating temperature to the principles of energy balance, it matters little whether the heat-loss mechanism is purely radiative, as in the case of a planet, or a mix of radiation and turbulent convection, as in the case of a house—or a green-house. Carbon dioxide is just planetary insulation."

Motivated by Pierrehumbert's analogy, we can determine the insulative R–value of the Earth's atmosphere with a very straightforward calculation. This has a personal connection for me: As a young father I almost burned down our house. We lacked shelf space, so I put a shelf in the closet for the kid's winter clothes, ignoring basic physics. The trouble was that the light bulb above the shelf was accidently covered as my kid's winter coats were thrown willy-nilly on the shelf. A covered light bulb raised the temperature to start a smoldering fire. Luckily I smelled smoke in time and saved the day. I had forgotten that the R-value for heat transfer from buildings is defined as

$$dQ/dt = (A/R)\Delta T, \qquad (1)$$

where dQ/dt is thermal power passing through the medium in Watts, A is surface area, R is the thermal resistance "R–factor," and ΔT is the temperature drop across the medium. Solving for ΔT, we obtain

$$\Delta T = (R/A)(dQ/dt) \qquad (2)$$

If the R–value is doubled, it takes a twice the temperature differential $2\Delta T$ to push the constant heat flux (Watts/m^2) through the medium. This is analogous to doubling the voltage to push a constant current through a doubled electrical resistance.

The MKS unit of the R-value is m^{2}K/W. In customary English units this transforms to (ft^2 hr ^{o}F/BTU); the conversion is $R_{\text{English}} \sim 5.68 R_{\text{MKS}}$. R is related to the thermal conductivity k of elementary textbooks through $R = L/k$, where L is the thickness of the medium. Good insulators have high R-values; polystyrene boards, for example, have $R \sim 0.9$ m^{2}K/W per inch of thickness.

In the case of Earth's atmosphere, it is necessary to radiate the absorbed solar flux at the surface through the atmosphere to space. Earth's average absorbed solar flux $s_{\text{absorbed}} = [(dQ/dt)/A]$ is mostly absorbed at the Earth's surface, giving

$$\Delta T = R\,(dQ/dt)/A = R\, s_{absorbed}. \qquad (3)$$

To obtain the R-value, begin with the fact that the solar flux s_o at Earth's orbit is 1367 W/m^2. This is reduced because the albedo (a) reflects about 30% of the incoming flux. Since Earth's perpendicular absorbing area πr^2 is one-fourth the radiating area of $4\pi r^2$ (r = Earth radius), we divide the solar flux by a factor of 4 to get the average flux. This gives a surface-averaged solar absorbed flux of

$$s_{absorbed} = (dQ/dt)/A = (1 - a)(s_o)/4 = (0.7)(1367\ W/m^2)/4 = 239\ W/m^2. \qquad (4)$$

The out-going heat flux is transferred from Earth's surface at a mean temperature of 287 K to the middle of the troposphere at 255 K. Combining these facts and using Equation (3) gives the R-value for Earth's atmosphere as

$$R_{atmosphere\text{-}SI} \sim \Delta T/s_{absorbed} = (T_{troposphere} - T_{surface})/s_{absorbed}$$

$$\sim (287\ \text{K} - 255\ \text{K}) / (239\ \text{W/m}^2) \sim 0.13\ \text{m}^2\text{K/W}. \qquad (5)$$

In English units this corresponds to $R \sim 0.76$ ft^2 hr ^{o}F/BTU. The atmosphere is not a terribly good insulator, equivalent to only about one-seventh of an inch of polystyrene!

Finally, how might global warming affect the R-value? The variation in solar flux over its 11-year cycle is only 0.1% and the average solar constant over the past decades has been very constant. Thus, we will ignore solar corrections. The 2007 Intergovernmental Panel on Climate Change (IPCC) best estimate for Earth's surface temperature rise is 3 K by the year 2100, which is about 10% of the 33 K greenhouse temperature rise before industrialization [2]. Since R is proportional to ΔT, a 10% rise in ΔT will mean the same percentage increase in R.

Calculations along this line appeared in the author's *Physics of Societal Issues* [3]. The second edition will include this work.

[1] R. Pierrehumbert, "Infrared Radiation and Planetary Temperature," Physics Today 64, January 2011, p. 33-38, and Physics of Sustainable Energy, AIP Conference Proceedings 1401, 232-243 (2011), ed. by D. Hafemeister, D. Kammen, B. Levi and P. Schwartz.

[2] Intergovernmental Panel on Climate Change, Climate Change 2007: The Physical Science Basis, Fourth Assessment Review, www.ipcc.ch.

[3] D. Hafemeister, Physics of Societal Issues (Springer, New York, 2007), 282.

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COMMENTARY

A New Take on the Research Funding Debate

J. R. Saylor, J. D. Summers, G. M. Mocko

Introduction

The relative importance of basic and applied research is the subject of fierce debate in academic circles. The intensity of this debate is, while understandable, somewhat peculiar since researchers of all types tend to agree that science and engineering research ultimately should, and does, benefit society. This being the case, it would seem that the debate should not be about basic research versus applied research, but rather about how, and how fast, the knowledge obtained in basic research should be, and can be, transitioned toward applied research and the development of new technologies and products that benefit society. In other words, the important question is not how much funding basic research receives, but rather "how quickly should we expect these basic research results to be transitioned into products?"; "who should do the transitioning?"; and "what is the most effective way to make this transition?"

Efforts by funding agencies to improve the effectiveness and speed of the transition from basic research to products inevitably take the form of highly structured funding programs designed to connect a basic researcher with an entity (usually a company) interested in taking that one, clearly-defined step needed to move the research into the realm of a product. An example of this is the NSF Small Business Technology Transfer Program which is focused on bridging "…the gap between performance of basic science and commercialization of resulting innovations." This is a laudatory goal, but these programs only provide funding when it is relatively obvious how the basic research will result in a product. This point is typically reached long after the basic research was conducted – viz too long, in our opinion. Such programs also close off avenues of exploration that arise during the conduct of the research/development, but are unrelated to the proposed work. This is a significant limitation, since curiosity is a very significant motivation for the basic researcher (indeed, NSF often refers to basic research as "curiosity-driven research").

We think there is much room for improvement in the speed and effectiveness with which basic research results are transitioned into products. Herein we propose an alternative funding model. The proposed model involves two PIs (or groups of PIs), a basic researcher(s) and an applied researcher(s), in an academic setting. The goal of the proposed program is to: (1) minimize the time between attaining a new basic research result and the development of a product, while (2) expanding the degree of intellectual freedom for both the basic and applied researcher, thereby (3) turning the academic research enterprise into a product development incubator. The hallmark of the proposed program, and we expect the controversial aspect of it, is the absence of a commitment by the PIs to a specific research topic, or to a specific product to be developed, as long as both fall somewhere within the funding agency's portfolio. The PIs would be expected to commit only to the development of new basic knowledge (by the basic researcher), and the development of a technology based on that research (by the applied researcher). This would be done in a co-evolutionary fashion, whereby early results from the basic research are evaluated by the applied researcher and together, both researchers modify (if appropriate) the direction of the research so that a product actually results. A critically important aspect of the proposal is a detailed, well-researched, and thoughtful means for interaction between the applied and basic researcher. Another critically important aspect is an annual workshop/review, wherein funding is withdrawn if satisfactory collaboration between the PIs is not explicitly demonstrated.

The Proposal

Basic and applied researchers both face challenges in justifying their work. Basic researchers must justify spending taxpayer dollars on work that *a priori*, cannot be guaranteed to result in a useful application. Applied researchers, on the other hand, benefit from being able to explicitly state how their research will benefit society, but in so doing tend to establish the limits of their work. That is, by showing how their research will solve a specific problem, applied researchers limit the scope of their work. In a nutshell, basic research has the potential to transform society, but with low probability and in ways that cannot be predicted, while applied research has a benefit that can be easily predicted, but is almost guaranteed not to be transformative. How can these two types of research be combined to eliminate their respective weaknesses while maintaining their strengths?

As noted above, attempts to address the aforementioned problem typically result in funding programs where researchers who do basic research are expected to partner with those who do applied research or, in some cases, to go it alone and transform their basic research results into something more applied. Sometimes this is in the form of technology transfer, where a basic researcher teams with or forms a startup company. In other cases, funding programs are developed seeking to address a specific problem, and basic researchers are encouraged to apply their knowledge to this problem.

Other approaches have been explored as well. However, in our opinion, the weakness of all these programs is the *specificity* of the research. A *specific* type of basic research is to be transformed into a *specific* type of technology. There are milestones, goals and deliverables that are all laid out before a dollar is spent. This, we think, is a problem.

The National Science Foundation has a research portfolio that spans all aspects of science. Research on metallurgy, cancer, and arctic environments all exist within the purview of a single agency. This notwithstanding, there is little cross-fertilization within the NSF. The NSF would almost certainly disagree with this statement and would cite its long list of interdisciplinary programs. However, regardless of the interdisciplinary program, the following remains true: one has to write a proposal with specific deliverables. At first blush this makes nothing but good sense; the NSF is, and should be, committed to good stewardship of taxpayer dollars. However, it seems to us that there is room within the NSF for at least one program where the deliverables need only fall within the overall scope of the agency. The elimination of specific deliverables would eliminate a huge obstacle to true innovation. Accordingly, we propose a new program where a (self-selected) basic and applied researcher team together with the only commitment being that they (1) do research in an area that falls within the domain of the NSF; (2) that important basic research is done; and (3) that the basic research result in intellectual property that is economically viable at the end of the funding period. Such a program would increase the freedom of the basic researcher, but with the restriction that s/he works with an applied researcher in such a way that the research results in something with concrete benefits.

The obvious risk of the proposed program is that, once funded, the two researchers will each head in their own direction, doing what they want to do, but without interacting in any meaningful way. To prevent this from occurring, the proposed program would require attendance of both PIs at an annual workshop run by the program manager. The PIs would be required to make a presentation that focuses on the characteristics of their interaction. Their research would also be presented, but the emphasis of the presentation would be on how they interacted. For example, questions to be addressed would be, "how is each PI's research informing the other?"; and "how has the direction of the research evolved during the funding period?" The presentations would serve to both provide the program management panel with information needed to determine whether to continue funding, as well as to provide lessons-learned for the other attendees of the workshop.

The proposed program would be of three years duration and would include the usual final report. However, a potential fourth year of funding would be included for the top research groups (say the top 25%) who demonstrated exceptional promise at the annual workshops. These groups would be given the fourth year of funding for purposes of patenting and further developing the technology.

Like all funding programs, the one proposed above is imperfect (and incomplete, as many details would need to be added). The aforementioned checks notwithstanding, it is still possible that the PIs will not work together. It is likely that the program itself will have to evolve to develop methods for effectively ensuring that those groups who are not collaborating have their funding eliminated. Other problems may arise. In spite of these risks, we feel that the proposed program, or something similar to it, is worth an attempt. If innovation and technologies are what we hope to obtain from federal dollars, then such a program should be explored.

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The Poised Century: On Living Today As If Tomorrow Mattered

By David A. Robinson (Tower Press, 2011) ISBN 978-1-46633-883-8, 240pp, $21.

Most will agree with David Robinson that America is moving in a "frenetic, complex and unsustainable economic social order." This book is Robinson's contribution to the evolution of a new sustainable era in which the community plays a key role. It is written by a physicist, but it is not a book expressly designed for physicists. There are no equations or graphs. Stories, his and others, feature strongly in the development. Early on, Robinson introduces the physical concepts of work and the laws of thermodynamics, and uses them in a novel way as bases for the transition to his primary and unexpected focus on social issues. For example, he makes much use of an increase in entropy corresponding with the increase of disorder of the system. To restore order, which we do each time we make our beds, work has to be done and energy expended. Along with the laws of nature he emerges with three laws of life. First Law, *Life is Work*; Second Law, *Work is required to reduce the difficulties of life*; Third Law, *No amount of work can reduce our difficulties to zero*.

Robinson makes a vital distinction between convergent and divergent problems. Convergent problems can be solved by consulting one good specialist, as happens frequently with technological problems. Divergent problems cannot be solved by a specialist in one field, and require consultations between several specialists. Each has his or her own conflicting personalities and prejudices. These problems frequently involve social and political issues, require compromise, and can only be ameliorated but not completely solved.

Robinson then argues that people are averse to doing excessive work and try to avoid it by taking short cuts, which use more energy than if the task was completed in the hard but most efficient way; or, people avoid work by handing it to a committee where it becomes a divergent problem with the associated compromises. He asserts that today we need leaders –servant leaders--whose understanding is deeply directed by the laws of nature and the laws of life, and who do not offer simple and short term solutions - in contrast with many of our leaders and public who promise or expect immediate satisfaction without obligation to the community and the future.

In Chapter 5, "The New Work," Robinson discusses the continuing need for the third sector - a nonprofit sector, including religious institutions. The work of the third sector is the work of social transformation that builds secure communities through the nurturing and renewing of people. His "challenge of today" is not to produce more things but to transform people and build communities. The servant leaders' task is to direct the required self-organization around the capabilities of the members of the group they represent, by letting each member bring to the task those skills that best match what needs to be done.

The next chapter is a surprising and perhaps unexpected chapter in a book by a physicist. Robinson asserts that "of all the third sector nonprofit organizations in America it is those that bring spiritual consciousness to our communities that are of the most importance and that through the radical teachings of Jesus, the Christian churches of America can be powerful organizations for social transformation." The Jesus he refers to is Jesus the man, and not Jesus the Christ with centuries of embellishments inflicted on him. Robinson himself was brought up in orthodox theology from which he is now far removed into what is broadly known as progressive Christianity. For the next 30 pages he gives a well informed and very readable description of this philosophy and how it applies to today's situation. Jesus to him becomes the model servant leader.

Robinson turns back to physics in a chapter titled "The Chaos Paradigm," where we encounter self–organization and "leaderless work" using foraging ants and flocking birds as metaphors. For humans some leadership is necessary, but leadership fails when we give our leaders the responsibility for work that belongs only to us. Given this, Robinson offers three properties characterizing the work of the servant-leader. The most significant is that he or she keep the purpose of the organization visible to each of a network of workers who share common experiences and values, so that the larger goals of the organization emerge from their collective work. Ideally then he should make the organization's work so self-organizing that his or her leadership becomes unnecessary! In the same section, emerging from a physics background, he talks of fractal life and life on the edge of chaos.

Specific eco-problems, like avoiding the consequences of global warming or mass starvation through overdrawing earth's bounties, are left to the latter part of the book where Robinson devotes a chapter mainly to the oil situation. He respects the opinion of scientists but, at the same time, rather than constantly looking to the scientist, politician or preacher to bail us out with pain-free solutions, he asserts the need to embrace the reality that our problems will require complex and likely messy remedies that will demand as much from us as of the experts to whom we would like to refer. This brings us back to the suggestions earlier in the book.

The foregoing chapters culminate in chapter nine, "The poised century--abundance or despair." This discusses possible ways ahead, and contains headings like "How much is enough," "The social cost of entropy," "Towards a sustainable economy," and "A last lesson from physics" which is a reminder from the second law that any order which comes to our lives must be at the expense of a simultaneous decrease in the order of the world. Consequently planning a sustainable future for the next generation requires a balance that can only come from valuing the whole as much as we value ourselves.

The final chapter offers "Ten remedies for the poised century" Robinson does not prescribe any panacea, and it is indeed best to look at the book as his contribution to a continuing process that is going to be controversial and messy at times. This is not a book primarily about physical hardware or economics, but about a transformation of society to a new social order--a much more difficult task. His approach from physics to social science is novel with many interesting stories and ideas and some within 40 pages of notes. It is well worth reading by physicists and non-physicists alike.

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These contributions have not been peer-reviewed. They represent solely the view(s) of the author(s) and not necessarily the view of APS.

Fool Me Twice: Fighting the Assault on Science in America

By Shawn Lawrence Otto (Rodale Books, 2011), 376 pp, $26, ISBN 978-1-60529-217-5

Fool Me Twice is an ambitious attempt to make the case that (1) citizens in a democracy who wish to govern themselves sensibly must inform themselves about science, especially its process; (2) scientists need to engage much more actively in public policy discussions; and (3) candidates for political office should take part in "science debates." The author, Shawn Lawrence Otto, is a cofounder of Science Debate. This nonprofit organization tried unsuccessfully to get the two major-party candidates to agree to a debate about science during the 2008 U.S. presidential campaign. Science Debate 2008 did elicit written responses from McCain and Obama to fourteen top "science questions facing America" (see www.sciencedebate.org). The organization continues to press for greater attention to science in the public square, especially in political discussions, and for citizens to affirm five "core principles" contained in "the American Science Pledge." This pledge (along with those top science questions as of 2008) appears in the appendix of *Fool Me Twice* as the culmination of the narrative. That narrative is developed through fourteen chapters grouped into five parts: I. America's Science Problem; II. Yesterday's Science Politics; III. Today's Science Politics; IV. Tomorrow's Science Politics; and V. The Solution.

The second chapter of Part I, which bears the title "Is Science Political?," answers its question in the affirmative and also argues that science is inherently antiauthoritarian. In the book's only graphic (on p. 31), Otto depicts politics in four quadrants, using the familiar "left" and "right" wings, but also a "top wing " (antiauthoritarian) and a "bottom wing" (authoritarian). Otto claims that "Any one of the infinite gradations of political thought can be placed on the plane around these axes." Further, he asserts that "When looked at in historical perspective, it's clear that while science and republican democracy are antiauthoritarian systems of knowledge and of governance, respectively, they are neither progressive nor conservative. Both communism on the left and fascism on the right are authoritarian and opposed to the freedom of inquiry and expression that characterize science and democracy, just as fundamentalist and authoritarian religions do."

The author's prose combines clarity with respect for the reader's intellect; in many places it achieves eloquence. Each chapter is divided into several labeled sections (typically 1-3 pages each). For example, the section headings for Chapter 3 (Religion, Meet Science) are "In the Beginning," "God's Natural Law is Reason," "The DNA of Western Thought," "Descartes Versus Bacon," "Puritan Science," "The Scientist-Politician," "How Do We Know Things?" and "The Progeny." This chapter is the author's explication of the intellectual debt owed by America's founding fathers to the writings of Francis Bacon, Isaac Newton, and John Locke.

Chapter 10 (Climate Change: The Money Battle), the longest chapter, uses two display quotes (from Rush Limbaugh and Glenn Beck) and opens "For two generations, scientists have labored under the notion that science is not political." A sampling of Chapter 10's nearly three dozen (!) section headings should give a sense of the author's readiness to use lively (even edgy) tags when it suits his rhetorical purpose: "Of Polar Bears and Profits: A Case Study in Antiscience Propaganda," "The Hockey Stick Attack," "Climategate," "When You're 'Splainin', You're Not Gainin'," "A Hundred Yard Dash Into the Weeds," and "You Got to Be Freakin' Kidding Me."

The book's final section, "The Choice," ends with several questions and a claim: "Will we set aside the left-right skirmishes of identity politics and focus as our founders did on the top-bottom battle for freedom? Will we protect and fund the conditions that encourage diversity, creativity, and prosperity in art and science, not because of what they do for our pocketbooks but because of what they mean to our values as Americans? Will the people, in short, remain well enough informed to be trusted with their own government? In a century dominated by the awesome powers and dangers of science, there is no greater moral, economic, or political question."

Fool Me Twice is not flawless. In its reach for breadth and depth, the narrative trajectory risks excessive twists and turns. There are also several points at which the author makes assertions or draws conclusions (some of which this reader agrees with and some not) that haven't been adequately established by the preceding prose. (For example, Otto seems convinced that the growth and design of American suburbs in the middle years of the 20th Century was a conscious response to nuclear-war fears.) There are also a few minor annoyances: the use of the word "proscribed" when context clearly indicates the intent was "prescribed;" a technically incorrect "explanation" of the period-luminosity relation for Cepheid variable stars discovered by Henrietta Leavitt; describing U.S. Energy Secretary Steven Chu as a "nuclear physicist and climate scientist."

For this reader, *Fool Me Twice* is by turns exhilarating and perplexing. It does not always hit the target, but its aim is admirably high. The book is a detailed and worthy preamble to the American Science Pledge and its five core principles: (1) Public decisions must be based on knowledge. (2) Knowledge is supreme and must not be suppressed. (3) Scientific integrity and transparency must be protected. (4) Freedom of inquiry must be encouraged. (5) The major science policy issues must be openly debated.

This book deserves attention and discussion by individuals and groups who aspire to improve the climate for rational public discussion of science. I strongly recommend it.

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These contributions have not been peer-reviewed. They represent solely the view(s) of the author(s) and not necessarily the view of APS.

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