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Editor's Comments

In this issue of *Physics and Society* we begin by asking you for help. Each year FPS nominates members for Fellowship and for the Burton and Szilard awards. Our Nominating Committee is always looking for outstanding candidates and if you have a suggestion, please send them in before the deadlines. Also, one of the highlights of the year are the sessions we sponsor at both the March and April meetings. Our Program Chair, Arian Pregenzer, would love to hear from you if you have an idea for an upcoming session or if you would like to help organize a session.

Speaking of sessions, we have summaries of some of the talks from both March and April. For those of you who could not attend, FPS Chair Micah Lowenthal summarized both the "Keyhole to the World: Public Access to Satellite Data for Environmental, Security, and Social Ends" session in March and the "Popularizing Physics" session in April.

Our Social Media Editor, Matthew Parsons, has an interview with an undergraduate student that recently held an AIP Mather Policy Internship which allows undergraduates to spend time in DC working on science policy.

In our articles for this issue, Rafe Sagarin reminds us that public participation in science is expanding and the power of information technology to empower citizens to participate in the scientific process is increasing. Mycle Schneider shares with us the status of the nuclear industry around the globe. His analysis is that the global nuclear industry is in crisis and that the prospect for a revival seems unlikely.

As always, we end with two recent book reviews that were organized by our Book Editor, Art Hobson.

My deepest appreciation to our Assistant Editor, Laura Berzak Hopkins, our Social Media Editor Matthew Parsons, and our Editorial Board, Maury Goodman, Richard Wiener, and Jeremiah Williams for their ongoing assistance in putting the newsletter together. We are always looking for interesting topics and authors willing to write about the latest advances at the intersection of physics and society. Please contact me with your ideas and consider submitting an article for publication in a future edition of the newsletter.

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IN THIS ISSUE

FORUM NEWS

Please Nominate Fellow and Award Candidates

FPS is responsible for nominating members for APS fellowship and for selecting candidates for the Joseph A. Burton Forum Award and the Leo Szilard Lectureship Award. The list of fellows and awardees is truly outstanding, but the only way that we can maintain this level of excellence and recognize deserving recipients is if you nominate them. See below for brief descriptions of fellowship and the awards. If you need guidance on the process, please contact Micah Lowenthal (mlowenthal@nas.edu) and he will direct you to the right person to answer your questions.

APS FELLOWSHIP

Any active APS member is eligible for nomination and election to Fellowship. The general criterion for election is exceptional contributions to the physics enterprise; e.g., outstanding physics research, important applications of physics, leadership in or service to physics, or significant contributions to physics education. FPS nominates physicists for contributions in some aspect of physics and society. Fellowship is a distinct honor signifying recognition by one's professional peers. More information at http://www.aps.org/programs/honors/fellowships/index.cfm

FPS Deadline for APS Fellowship Nomination:

Monday, June 2, 2014

JOSEPH A. BURTON FORUM AWARD

To recognize outstanding contributions to the public understanding or resolution of issues involving the interface of physics and society. More information at http://www.aps.org/units/fps/awards/burton.cfm

Deadline: Tuesday, July 1, 2014

LEO SZILARD LECTURESHIP AWARD

To recognize outstanding accomplishments by physicists in promoting the use of physics for the benefit of society in such areas as the environment, arms control, and science policy. The lecture format is intended to increase the visibility of those who have promoted the use of physics for the benefit of society. More information at http://www.aps.org/units/fps/awards/szilard.cfm

Deadline: Tuesday, July 1, 2014

Suggestions for FPS Invited Sessions

FPS has several slots for invited sessions at the March 2015 and April 2015 meetings. Some of our past sessions have been standing room only (for example, Secrecy and Science at the March 2013 meeting). If you have ideas for sessions (including speakers), or even better if you want to organize a session at one of the meetings, please contact FPS Program Chair (and FPS Chair-Elect) Arian Pregenzer (apregenzer@gmail.com). Decisions about sessions will be made in the early fall 2014, so please send in your ideas as early as you can.

Ideas for Short Courses or Workshops?

In 2013 and 2014, FPS sponsored two short courses or workshops: one on nuclear weapons and another on sustainable energy. In the short courses, prominent experts provide excellent introductions (as well as depth) to their topics, which makes these courses an excellent way for scientists who are interested in the topics to get up to speed quickly. If you have a topic area on which you would like to see a future short course or workshop, or if you want to organize one, please contact FPS Program Chair (and FPS Chair-Elect) Arian Pregenzer (apregenzer@gmail.com). There is no deadline for proposing short courses.

Perspectives on Policy: The Undergradute Internship

While for many physicists the opportunity to participate in the political process may be a result of their career experience, there is no limit to how early one can find themselves making a contribution. The AIP Mather Policy Internship awarded by the Society of Physics Students is designed to give undergraduates the opportunity to get involved right at the heart of science policy in Washington D.C., and recent intern Nikki Sanford shares some of her experience with us here.

Please tell us a little bit about yourself (education, research experience, etc.).

My name is Nikki Sanford and I'm currently a student at William & Mary Law School. I graduated in May 2013 from High Point University with Bachelors degrees in Physics, Mathematics, and a minor in Chemistry. I spent a summer at Duke University through the NSF Research Experience for Undergraduates (REU) Program, and worked in the High Energy Physics Group on computer simulations for SNOLab's Helium and Lead Observatory (HALO) neutrino detector. I had opportunities to present at several national conferences, including the American Physical Society--Division of Nuclear Physics and the American Association of Physics Teachers. This past summer I worked at the U.S. House of Representatives Committee on Science, Space, and Technology as a Mather Intern through the American Institute of Physics--Society of Physics Students (SPS) Intern Program.

Why were you interested in pursuing an internship in science policy?

Science and mathematics have always fascinated me because they answer the question "why" and form the basis of all systems and reason. As I got further involved in research, I saw firsthand many of the amazing discoveries and technology that can arise. I also started to see how prevalent and intricately connected these innovations are to our society as a whole. Needless to say, I became interested in science policy in order to explore the relationship between science and society, and their influence on each other. The SPS Internship in the Science Committee matched those interests perfectly, and turned out to be the optimum introduction into the field.

What were the pieces of legislature being examined while you were working in the House?

I had the opportunity to work on pieces stemming from all five Subcommittees: energy, environment, research & technology, oversight, and space. Some topics of Hearings/Markups that I both worked on and attended were the proposed reorganization of STEM education, the NASA Authorization Act, EPA Investigations of Hydraulic Fracturing, the achievability of new ozone standards, and the Dept. of Energy Science & Technology Priorities.

What similarities and differences do you see between the scientific and legislative processes?

In science, an observation sparks a question, which leads to a thoroughly designed experiment and analysis to confirm a hypothesis. The legislative process is nearly identical, but deals with societal observations rather than purely physical ones. After an issue is identified, much research and discussion is generated to determine the best approaches to solve it—the hypothesis. Legislation acts as an experiment, and the outcomes of which will confirm or reject the prediction.

Have your experiences in science policy influenced your pursuit of a law degree? In what way?

My science policy experiences have proved to be extremely beneficial towards my law studies. Researching topics, writing memos analyzing issues, and conducting outreach and interviews are several skills that I gained throughout my work in the Science Committee. Incidentally, those are some of the essential legal skills that are being taught and strengthened in law school. It has been immensely helpful that I've come in with a handle on those basics, and experience with how they are utilized in an fast-paced work environment.

What memory of your work with science policy stands out to you the most?

My interactions with several inspiring and influential leaders are extremely memorable. I had the opportunity to have breakfast in the Capitol with physicist and Congressman Bill Foster and the Nobel Laureate Physicist Dr. John Mather to discuss their work and the influence/importance of their science backgrounds. I also was fortunate enough to meet and speak with NASA Administrator Charlie Bolden, Ranking Member Eddie Bernice Johnson, and Bill Nye the Science Guy!

Furthermore, the Hearings and Markups that I participated in definitely stand out as well. I directly saw how some of my work influenced the topics raised, or questions asked by Congressmen, and it was incredible to see them and the legislative process in action.

For more on Nikki's experiences, and those of other Society of Physics Students interns, please visit http://www.spsnational.org/programs/internships/2013/index.htm.

FPS-Sponsored Session Reviews

Micah Lowenthal

MARCH 2014 MEETING | DENVER, COLORADO

At the APS March meeting FPS sponsored a session titled Keyhole to the World: Public Access to Satellite Data for Environmental, Security, and Social Ends. In this session we had earth scientists, environmental watchdogs, and nuclear arms control analysts who use publicly available satellite imagery in their work. Jeff Dozier from U.C. Santa Barbara presented "40 years of Landsat images: What we learned about science and politics," in which he described the substance of a recent National Research Council study on the future of Landsat. John Amos, president and founder of SkyTruth, described the work of his independent, environmental non-profit organization in "Bringing the Crowd to Environmental Investigation and Monitoring." Irmgard Niemeyer gave a talk titled "Nuclear Verification from Space? Satellite Imagery in Support of Non-Proliferation and Arms Control," which explained her research group's work at Forschungszentrum Jülich GmbH. And Lawrence Friedl gave a survey of NASA's Earth observation satellite capabilities in "Earth Science Serving Society: Using NASA Earth-observing Satellites for Policy, Management, and Capacity Building." At the end of the session, the group held a panel discussion led by the session chair, Micah Lowenthal.

In addition to asking them to tell us about their work, we also asked them to provoke the audience into thinking about the problems the speakers work on by giving us some unsolved challenges in their work, a kind of wish list. We asked them to do this because physicists are a smart, knowledgeable, and creative bunch and it would be a wasted opportunity not to seek input from the physicists.

Dr. Dozier described the unique and extensive data set that Landsat provides dating back to 1972. The Landsat images have moderate spatial resolution (pixel size 10-100m), which provides useful environmental and other data while still being able to provide coverage of the whole earth. Higher resolution imagery takes much longer to cover the same area. The several Landsat sensors cover many of the wavelengths from blue to infrared that are transmissible through the atmosphere, and one in a range that is not. By fusing data from different sensors, analysts can obtain enhanced images to track regional carbon emissions, land-use patterns, and other applications. In 2008, the U.S. government made the Landsat data available for free and the number of images accessed per year rose from very few to approximately 2.6 million. But the future of the Landsat mission is in some doubt as Congress does not wish to spend the $1B it typically costs to design, construct, and launch new satellites for the mission (the Senate wished to limit costs to $650M and the House wished to spend nothing). Dozier noted several options to create a less costly, more robust program: Acquire satellites differently (committing to a series at once); integrate with other data sources; increase the swath width; or create a constellation of smaller satellites. Speaking for himself, Dozier underscored the value of the satellites and the importance of maintaining the Landsat mission.

John Amos began with the early history of earth observation from space, displaying the first photograph of earth taken from 65 miles above the surface by a tumbling V2 rocket captured from Germany shortly after the end of the war and launched by the United States. He then jumped to the current state of satellite affairs with over 1000 operational satellites giving us useful and unique information about the behavior of oceans and clouds, and how people are changing the landscapes, habitats and ecosystems through processes like mining, drilling, deforestation, pollution, and climate change. In 2001, he started the nonprofit SkyTruth to use satellite imagery and data to promote awareness about environmental issues. Within the first week of the BP/Deepwater Horizon blowout, SkyTruth used publicly available images to calculate that the spill was at least 20 times larger than official BP and Coast Guard estimates at the time. Later, the U.S. government determined that SkyTruth's estimate was low by a factor of 3. Amos and his colleagues have combined satellite and ground-based radio-collar tracking data to assess disruption of Mule Deer habitat by gas development in Wyoming and have used satellite imagery to map flaring of natural gas at oil wells worldwide. They have assessed how much of the Appalachian landscape has been directly impacted by mountaintop removal coal mining, which supported evaluations of whether a tipping point has been reached in the environment's capacity to accommodate the practice. Satellite data will increase dramatically in the coming years, which affords many opportunities to utilize those data in new ways. To take advantage of those opportunities, Amos argued that we need new techniques, not only in automated image analysis and information delivery, but in harnessing the power of the crowd to help us continuously monitor environmental changes all over the Earth. Amos described SkyTruth's use of crowdsourcing to check on fracking in Pennsylvania. He closed by noting that automation and crowdsourcing are not alternative approaches, but reinforcing approaches for image analysis, because one ultimately needs human eyes to evaluate images and the automation can allow people to focus only on the ones that need human evaluation.

Irmgard Niemeyer described her work developing tools that can use satellite imagery to monitor and verify current and proposed nuclear nonproliferation and arms control agreements, such as the the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the Comprehensive Nuclear Test Ban Treaty (CTBT), or a Fissile Material Cut-Off Treaty (FMCT). If onsite verification is not feasible, then satellite imagery provides one of the few opportunities to gather direct (and indirect) evidence. Niemeyer's group has partnered with other groups on projects for the European Union like G-SEXTANT, which uses Earth Observation (EO) products to address needs associated with humanitarian crises, natural resources, land conflict situation awareness, monitoring of nuclear sites and activities, illicit crops; and border surveillance. Automated change detection of optical imagery enables tools to identify new facilities and using synthetic aperture radar data, they can construct 3-D models of sites and facilities.

Satellite imagery analysis currently is not included in the CTBT verification regime, although it is considered as an additional technology whose verification potential should be examined (Article IV, paragraph 11). It is anticipated that satellite imagery would be used in the preparation of on-site inspections and when combined with in situ measurements, satellite imagery can contribute to better verification. Niemeyer closed with a wish list, noting that thermal infrared and hyperspectral sensors with improved spatial and temporal resolution; very high resolution optical sensors with enhanced spectral resolution, and high spatial resolution SAR sensors offering polarimetric data would all be valuable additions.

Lawrence Friedl described NASA's Earth Science Division, which aims to characterize, understand, and improve predictions of the Earth, a complex, inter-related system of environmental phenomena, human activities, and ecological effects. As noted by other speakers, the sensors on the satellites utilize a broad range of the electromagnetic spectrum. The 14 current NASA satellite missions provide multiple approaches to measure phenomena and yield valuable analyses concerning air quality, water resources, agriculture, climate, weather, disasters, energy, and ocean phenomena. GRACE, a pair of satellites that uses ultra sensitive distance measurements between the two to observe gravitational fluctuations, measures groundwater abundance over large regions. SERVIR is a NASA-USAID partnership to improve environmental management and disaster resilience in countries that have little capacity for environmental data observation and forecasting. SERVIR linked JASON-2 altimetry data to flood forecasts, increasing the flood prediction times from three days to eight days in northern India and Bangladesh, which can save thousands of lives. The *Terra* and *Aqua* satellites possess sensors to identify thermal anomalies and active fire locations in remote African areas (among other places), and notices are sent via SMS to fire managers in areas. Also in Africa, satellite data are being used to identify the locations with the greatest risk of malaria transmission. NASA continues to seek new tools and better ways to use the increasingly extensive data the satellites generate.

APRIL 2014 MEETING | SAVANNAH, GEORGIA

At the APS April meeting FPS sponsored a session titled *Popularizing Physics*, where scientists and science communicators shared some of their expertise on the subject. The session opened with a talk from science writer David Lindley, titled "Explaining today's physics through history and biography." Physicist and science communicator Diandra Leslie-Pelecky followed up with a presentation on "Stealth Physics: Sneaking in Science Where People Least Expect It." The session concluded with a talk by Mats Selen of the University of Illinois at Urbana titled, "Everyone Loves Science."

David Lindley talked about not just what physicists think but how they came to think that way. How did they come to such a peculiar conception of the universe: particles are vibrations of strings, there are 10 dimensions but six of them are bound up so tightly that you can't see them, and so on. Lindley uses history to explain, starting with theories that turned out not to be correct—vortex atom theory, luminiferous Aether and moving to modern theories—superstrings and branes - where the jury is still out. What these have in common is the attempt to explain observations consistently and predict behavior. Scientists' beliefs, acknowledged or not, about scientific thinking and the "correct" aims of science have a powerful influence on how their ideas develop. Physicists have some of the same disquiet and skepticism about new physics ideas that the public does. Telling that story illustrates that scientists are interested in finding the truth.

Diandra Leslie-Pelecky, author of *The Physics of NASCAR*, explained that she got interested in NASCAR when she saw a replay of a NASCAR race accident that had no obvious cause. She started looking into it and found that a bunch of people in NASCAR have science and engineering degrees. They worry about friction, balances of forces, aerodynamics, and other physics problems. Carl Edwards won a 2008 race but his crew chief was fined $100k for a violation because the car's oil tank was modified resulting in lower lift on the car and greater friction. People wanted to know why, so there was an appetite for technical discussion. The explanation reached many thousands of people. Social media is a forum for discussions on the science of crashes. She also does spots on a radio show dedicated to NASCAR (SIRIUS XM Speedway). One spot focused on a major crash that removed the front end of a car. The driver was fine, but the engine went through the catch fence and the tire ended up in row 19, hurting some people severely. Why, the audience asked, didn't the race officials know that this would happen? Even when Leslie-Pelecky was not on the program, the show's host, who is not a technically trained person, said "the overriding point is that scientists often learn what works from observing what doesn't work". Working with the radio host has given science an advocate who reaches millions of listeners. Leslie-Pelecky had some brief takeaway messages: (1) We can explain what we think is interesting, but we really need to figure out how to show them the science in what they already find interesting. (2) Long-term relationships have more impact than hit-and runs. (3) They (the public) are more scared of us than we are of them. They appreciate experts taking the time to explain. And (4) We can't wait for them to come to us; we have to go to them. NASCAR reaches a lot of people whom we can't reach through science magazines.

Mats Selen talked about outreach activities at the University of Illinois at Urbana Champagne. He noted that kids are born curious, teachers love having science activities, adults are fascinated by science, and scientists love to talk about science, so there's an obvious matchup. You just need to get it started, and as a college professor, Selen notes that college students are an amazing resource for making that happen. UIUC introduced Physics 123: Physics for elementary education students, because many elementary school teachers are not confident in science. The course is wildly popular and the students exit the class with a set of lessons for hands on exploration using cheap everyday materials. Selen has also done weekly spots on local television as "the Whys Guy." He explained to the APS audience that getting on local TV is easy because viewers love it and it's free content for the station. The key is to come up with crisp, clear explanations (and to wear bright, engaging colors). UIUC has also established a physics van, a traveling science show run by undergraduates (a club) targeting elementary schools, which was modeled on a project done at Purdue. Over the many years that the physics van has been operating, they have reached over 70 schools and over 100,000 students. The program is self-sustaining because the students run it and are passionate about it. Do kids remember what they learn? In a non-representative survey of his introductory mechanics students at the college, Selen found that most respondents said they had been exposed to the physics van or something like it, that they didn't remember the details, but they thought it was cool. Finally, Selen and colleagues have run a Q&A website for science inquiries from the public. It is hard to get quality answers from students or young faculty members because of the time it takes to do it, so they enlisted emeritus faculty. One of those professors then added a section debunking bad explanations elsewhere on the web ("baloney websites"). There are many opportunities for such outreach.

ARTICLES

Citizen Science: Convergent Evolution Across the Sciences

Rafe Sagarin

Public participation in science, or citizen science, is finding a foothold in all branches of science, from ecology to climatology to astronomy. Citizen science can be informal and isolated, as in the amateur astronomer who identified the first asteroid of 2014 (and only the second incoming object ever to be identified before it hit Earth), or part of an organized event with a specific goal in mind such as the National Parks' "BioBlitzes" to record all the species in a particular Park unit, or even regular ongoing programs of monitoring and discovery, such as the LiMPETS program which works with students and volunteers to monitor coastal animal populations in National Marine Sanctuaries. Citizen scientists are now making significant contributions to our understanding of climate change, emerging infectious diseases, and potentially hazardous near-Earth objects.

The number and diversity of projects that have emerged over the last decade is astounding, but they are all rooted in, and reflective of, larger trends occurring across science over this same time period. While my perspective on these trends is from the field of ecology, I believe readers of this journal will find echoes of these trends within their own fields. Specifically, three emerging trends: 1) the renewed power of, and respect for, discovery-driven observational studies; 2) the increasing openness to, and acceptance of, non-institutional knowledge holders; and 3) the rise of crowdsourcing, are aligned to make citizen science a powerful source of scientific insight. And while citizen science isn't new (it was, in fact, the way that science started long before it became institutionalized), the power of information technology to help us collect, connect, analyze and provide feedback upon large collections of citizen science data is the catalyst allowing for unprecedented uses of citizen science data.

The trends in science I refer to above, although facilitated by recent advances in technology, are borne out of very old, even ancient, practices. In particular, the renewed power of observation is rooted in the practice of natural history, which probably co-evolved with us as an essential function of the human species. Natural history is the interdisciplinary study, classification, and interpretation of the living Earth and its inhabitants [1]. Natural history can be separated from merely strolling in the woods, or obsessively pinning butterflies to shadow boxes by its reliance on carefully engaged, multi-sensory observation—what the paleobiologist Geerat Vermeij (who happens to be blind) describes as "the increasingly ignored role of sensation—of observation with the brain in gear".

Yet natural history has long been thought of as wholly within the domain of amateurs, even hobbyists. The amateur tinge of natural history has tainted it and its practitioners for much of the history of modern, professional, and institutionalized science. Charles Darwin was told by his father, "you care for nothing but shooting, rat-catching, and dogs, and you will be a disgrace to yourself and all your family." Consider the fate of one of America's greatest natural historians, Teddy Roosevelt. He entered Harvard as an eager young naturalist, hoping to be trained by the great biologists there to become a professional naturalist, but he soon became discouraged, noting the tendency to "treat as not serious, as unscientific, any kind of work that was not carried on with laborious minuteness in the laboratory." The disdain for natural history became particularly acute in the decades following the discovery of the structure of DNA. Watson and Crick's discovery provided the tantalizing promise that biology could finally become as orderly and predictable as biologists always assumed physics and chemistry were - so much for the fanciful musings of natural historians. The great naturalist E.O. Wilson, who started at Harvard at the same time as young James Watson, was largely forgotten in the shadows of his colleague's more brilliant prospects for scientific immortality.

This period of late 20th century science was marked by an increasing interest in controlled, hypothesis-driven science. Buoyed by Karl Popper's philosophical conjecture that science could be reliably separated from non-science by the degree to which a question was falsifiable, a standardized acceptable method of achieving scientific inference emerged. The "scientific method" that most of us were taught in grade school is a reflection of this, as is the fairly standard format for journal papers and grant applications.

But late 20th and early 21st century realities of our natural world have shone light on some of the limitations of this conception of scientific methodology, and science as an institution is adapting (in some fields faster than others) to this new reality. Specifically, large scale changes in the environment present complex realities that are impossible—logistically or sometimes ethically—to replicate in laboratories or controlled experiments. At the same time, advances in technology that allow us to observe the natural world at both its largest and smallest scales with unprecedented acuity are making observations of the world—the basic building blocks of natural history—more useful and powerful than they have ever been before. Why try to make an incomplete simulation of a natural phenomenon in the laboratory or on a computer when you can observe the same phenomenon as it occurs in real time and real space? Why limit our investigations to those that can falsify a limited set of pre-determined binary hypotheses, when we can discover unexpected and explanatory patterns across the full spectrum of reality by observing as broadly as possible?

These are large and debatable philosophical questions, but just in being able to seriously ask them has a trickle down effect on what we perceive to be "scientific" and, by extension, who we perceive to be scientists. Accordingly, we have seen a slowly emerging respect for both natural history and for amateur observers of the natural world. In part, the practical limitations of what credentialed scientists are able to observe forces our hands to look beyond the ivory tower for knowledge, but the quality, breadth, and utility of this amateur knowledge is what keeps us coming back.

The third trend, the rise of crowdsourcing, is also technologically facilitated, but is a novel and emergent effect of the first two. Crowdsourcing is essentially a societal hack for mimicking a powerful biological adaptation for observing change [2]. Namely, biological systems rely on decentralized observational agents to sense and respond to change. The exemplar of this organization is our immune system. It features millions of cells running around our body identifying and attacking pathogens, with virtually no control from our brain. The system and its agents still serve our brain and our body, and are likewise given a home and nutrition, but they act independently. It is their collective action, then, that solves the challenge of how to keep a body protected from dangerous foreign invaders.

As a societal parallel of this adaptive process, crowdsourcing has helped to solve all sorts of complex challenges—from long-standing mathematical puzzles to thorny problems in protein configuration—and there are more than a few personal computers still employed in the search for extraterrestrial life in their down time. More primitive, yet effective forms of crowdsourcing can be found at any horse track. Pari-mutuel betting essentially assigns probabilities to the wisdom of crowds. Today's crowdsourcing is a technological mutation of this more primitive form, allowing for much more widespread, instantaneous, and multi-directional sharing of decentralized observation.

Citizen science, in its best manifestations, brings together all these trends and beneficial mutations in science, into a positive feedback cycle. As we increasingly respect the power of observation to understand a complex world, we increasingly seek out observations and observers. In recruiting new observers—as either lone natural historians or participants in formalized citizen science programs—we both educate ourselves as scientists about the skills of amateurs, and provide science education for new observers. And as these observers increasingly come into meaningful and mutually beneficial contact with institutional scientists, the number, quality, and utility of citizen science observations will likely improve.

For those scientists interested in delving into the world of citizen science, there is a large and growing literature codifying and analyzing best practices. Additional reading is recommended below which considers citizen science from several angles, most fully generalizable to many fields of professional science.

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References and Additional Reading

[1] http://naturalhistorynetwork.org/about/

[2] Sagarin, R. 2012. Learning from the Octopus: How Secrets from Nature That Can Help Us Fight Terrorist Attacks, Natural Disasters and Disease. Basic Books

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The Status of the Nuclear Industry in the World – Dawn or Dusk?

Mycle Schneider

Germany phases out nuclear power. Easy enough, many thought, the country will import nuclear power from neighboring France. Three years after German Chancellor Angela Merkel, a former Environment Minister in charge of nuclear reactor safety and a physicist by training, decided to shut down half of the nuclear fleet in the country, reality is dramatically different. Germany never exported more power than in 2013, about 33 TWh[1] net. Amongst Germany's best customers… France. In fact, France, while also a net power exporter, imported throughout the past year almost 10 TWh more electricity from Germany than it exported to its eastern neighbor. These German exports are partially generated by renewables but also by polluting coal and lignite plants, a side effect of the shale gas revolution in the US that led to massive coal imports to Europe and to the shutdown or mothballing of about 50 GW of much cleaner natural gas fired power plants throughout the EU. This trend is a perfect illustration of the lack of an appropriately designed and regulated carbon market but has nothing to do with nuclear plants being taken off the grid. Germany has built up a huge renewable energy capacity of over 75 GW, roughly equivalent to its peak load, mainly wind and solar. But the four traditional large utilities E.ON, RWE, EnBW and Vattenfall that operate the nine remaining nuclear power plants, hold only 5 percent of the renewable capacity. The big four clearly missed the renewables train—so far. There are now over 1.3 million electricity generators in the country, including households, farmers, coops and municipalities. In 2012, for the first time, renewable sources provided more electricity than nuclear plants in Germany. The same happened in China, India and Japan. Thus three of the four largest economies in the world generated more power from wind, solar and biomass than from nuclear fission. In 2013, at least one more country joined the club, Spain, which generated more power with wind turbines alone than with any other energy source. In the EU as a whole a total of 23 GW of renewables have been added to the grid in 2013 alone, while 11 GW of coal, oil and natural gas plants were closed for good.

France, nuclear dreamland *par excellence,* is under increasing pressure. The French nuclear industry, which has profited from unlimited and uninterrupted public support for the past forty years, is struggling with high debt loads, increasing costs, potent competitors and stagnating electricity consumption. State controlled EDF has to deal with a € 35.5 billion ($49bn) debt burden and increasing operational costs, estimated by the national Energy Regulatory Commission at 4.5 percent annually since 2007. In 2012, tariffs did not cover the costs, which created a loss of € 1.5 billion ($2bn). That does not include yet massive additional post-3/11 (post-Fukushima) upgrading requested by the Nuclear Safety Authority. As a consequence the regulator asked for large power price increases—a measure about as popular as increasing the price of the baguette—which are expected to reach around 30 percent between 2013 and 2017. At that point, Enercoop, a 100-percent renewable power provider that used to be the most expensive distributor in France but never increased its tariffs, will sell power at a lower price than nuclear EDF. In addition, the largest nuclear operator in the world is struggling with a rapidly widening skills gap as about half of the nuclear staff is eligible for retirement over a five-year period up to 2017. EDF admitted that it will be confronting an extremely difficult period with a "forecasted doubling of expenditures between 2010 and 2020 (operation and investment)" and with "a peak of departures for retirement coinciding with a peak in activities".[2] AREVA, the pride of the French State-controlled nuclear establishments and largest nuclear builder in the world, filed a loss for the third year in a row. After a staggering € 2.5bn loss in 2011, and € 100m in 2012, another € 0.5bn were lacking to break even in 2013. The main cause for last year's meager result is the lasting saga of the EPR[3] construction site in Olkiluoto, Finland. A decade ago planned to cost hardly more than € 2bn a piece, estimates have skyrocketed to € 8.5bn. In the latest developments, AREVA refused to come up with a new projected startup date, originally planned for 2009, delayed to 2016 two years ago. A follow-up project in Flamanville, France, is not doing any better. Even the third and fourth EPR, under construction in Taishan, China, for a long time believed to be on schedule, is now reportedly delayed for 13 and 15 months respectively.

Interestingly enough, it was first *Business Week*[4] that reported that EDF "is having to cut production from its reactors to accommodate higher European wind and solar output, potentially curbing future earnings from atomic power". In a more spectacular manner, on 26 March 2014, the government's most senior administrator for energy, Laurent Michel, Director General for Energy and Climate at the Ministry of Ecology, told a stunned enquiry committee at the National Assembly, the country's parliament, that current projections for stagnating or even decreasing electricity consumption could lead to the "non-need or electric uselessness of about 20 reactors" by 2025. What is somewhat awkwardly expressed here is that the increase in other areas, and notably renewables inside and outside the country, combined with low consumption levels render these reactors obsolete or uneconomic.

1 *terawatt-hours*

2 *EDF, "Les grands chantiers du nucléaire civil – Le 'grand carénage' du parc nucléaire de production d'EDF", 14 January 2014.*

3 *EPR stands for European Pressurized water Reactor in Europe, while it has been branded as Evolutionary Power Reactor in the US. One is tempted to call it European Problem Reactor.*

4 *Business Week, "EDF Curbs Nuclear Generation to Allow for Wind and Solar on Grid", 19 March 2014.*

These projections are perfectly in line with the French President's target of reducing the share of nuclear power from the current three quarters to about half in the generation mix by 2025. However, the task—which dwarfs the German nuclear phase-out commitment for nine units by 2022—will be economically, socially and organizationally challenging. On the other hand, whatever the French policy will finally look like after a new energy bill is voted on likely before the end of the year, the competitiveness of operating nuclear power plants is increasingly threatened by rising costs and rapidly changing market conditions. This is also true for the US as well as for Europe as a whole. German operator E.ON just announced its intention to shut down the Grafenrheinfeld unit in Bavaria in May 2015, seven months earlier than scheduled. Just as a number of coal- and gas-fired plants, the reactor is not anymore economic to operate. In fact, the German nuclear phase-out might go faster in practice than required by law.

The comparison between France and Germany is interesting in many ways. While French electricity prices generally remain below the average in Germany, the situation confronted by consumers is quite different. If "cheap nuclear electricity" was to allow for the competitiveness of the French industry, Germany produces the world's largest trade surplus approaching staggering € 200bn ($275bn) in 2013 outpacing even China, France stumbles from one record trade deficit to the next, reaching over € 60bn ($84bn) in 2013. Ironically, France is Germany's largest trading partner and contributes 18 percent of its surplus or, in other words, the trade deficit with Germany represents over almost 60 percent of France's deficit. The French industry now complains about market disadvantages over their German competitors. Indeed, energy intensive industries in Germany profit of a number of advantages over average consumers and other large industries profit of a spot market price that has constantly decreased since 2011 and is now significantly lower than in France. French households have access to lower average electricity prices but have higher bills because they consume more their German counterparts. Electric space heating, hardly existing in Germany, installed in 30 percent of French dwellings, is driving households into poverty.[5] An estimated four million households in France have troubles paying their energy bills, most of them for electricity. Electric space heating and hot water supply was massively promoted starting in the 1980s to drive up consumption when EDF realized that it was in the course of significantly overbuilding their nuclear generating capacity. The winter peak load in France is around 100 GW compared with Germany's 75 GW and a population that is 15 million people larger. When the thermometer drops by 1°C in France, the capacity need increases by 2.4 GW, a temperature sensitivity that renders the French power system very fragile. In February 2012, during a cold weather wave, France imported power from all six neighboring countries, including the UK, to save the grid from collapsing.

Developments in France and Germany, in 2012 the world's second and fifth largest nuclear power generators, reflect a global trend. The role of nuclear power has been on the decline for a long time. As of 1 January 2014, there were

5 *Electric space and water heating is extremely inefficient. You lose up to two thirds of the primary energy in the fuel as waste heat in a thermal power plant and another ten percent in electricity transport and distribution just to reheat air or water. Central or urban heating systems limit losses to 15 percent or less, compared with the three quarters of the electric heating system. The environmental implications are obvious*

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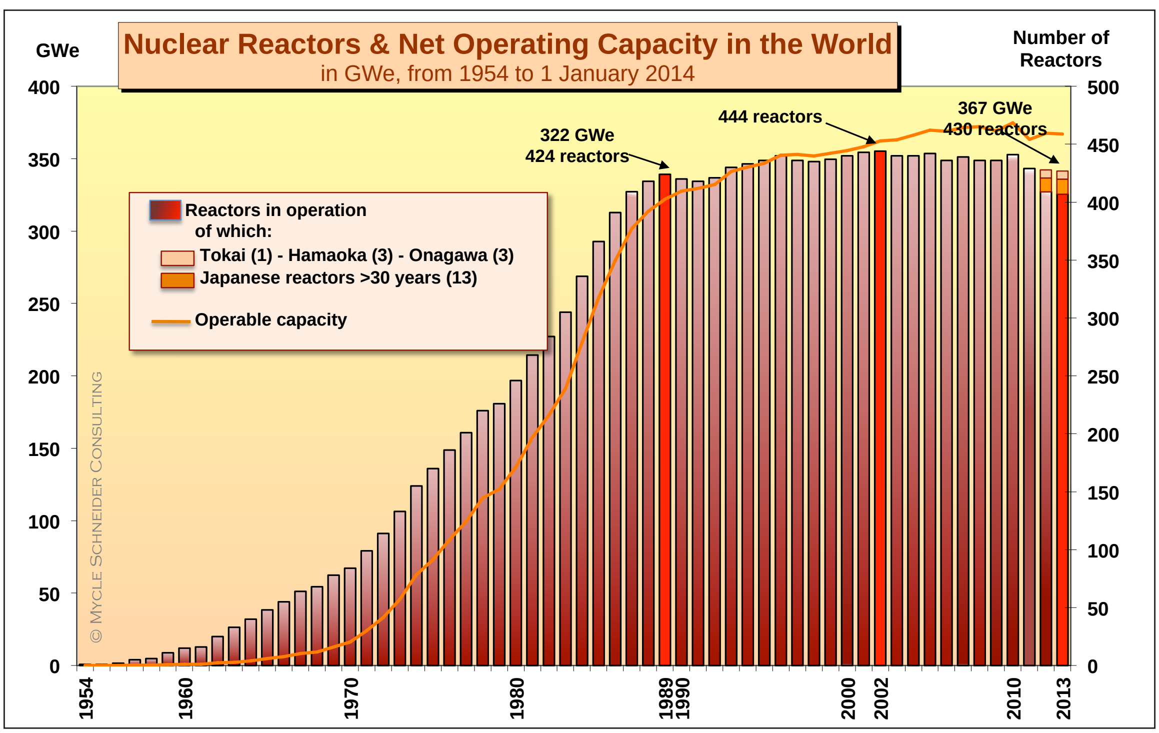

Figure 1.

Source: IAEA-PRIS, MSC, 2014

430 nuclear reactors considered "in operation" in the world[6], preliminary analysis indicates (see Figure 1.).

The number is identical to the situation one year ago but 14 below the historic peak in 2002. In the European Union, the number of operating reactors reached its maximum with 177 in 1988 and dropped by 46 to 131 today.

The main changes in world nuclear statistics during the year 2013 include four new units connected to the grid—three in China (Hongyanhe-1 & -2) and Yangjiang-1, and one in India (Kudankulam-1)—while four units were announced as shutdown definitely. In comparison, in the pre-Chernobyl years 1984-85, a total of 33 new reactors were connected to the grid (see Figure 2).

Thus, in 2013, the number of units considered "operational" remained stable, while in 2012 retirements outweighed the number of startups. An entirely new development lies in the fact that all four shutdown reactors (Crystal River-3, Kewaunee and San Onofre-2 and -3) are located in the US and are the first retirements of nuclear units in the country in 15 years. An additional unit in the US, Vermont Yankee, is scheduled to be disconnected from the grid in 2014 because, just like in the case of Kewaunee, the unit is not anymore economic to operate. These cases are particularly significant as both units had obtained a license renewal for operation up to 2032 and 2033 respectively.

The number of reactors in the world generally considered as "in operation" is increasingly misleading because of the situation in Japan, resulting from the Fukushima events in March 2011. In 2013, only two of the then officially 50 "operating" reactors[7] have generated electricity and no unit in Japan has produced any power since September 2013. The global number of 430 units does not include the ten Fukushima reactors, but incorporates the remaining 44 Japanese units, most of which have not generated electricity for two years and more.

The generation of nuclear electricity in the world reached its historic maximum in 2006 with 2,660 TWh. Mainly due to the decline in output in Japan and Germany, nuclear generation had dropped in 2012 by 12 percent to 2,336 TWh. The relative share of nuclear power in the electricity mix peaked already in 1993 at 17 percent and slowly declined to around 10 percent in 2012 (see Figure 3). Only one country, the Czech Republic, peaked in 2012, all other countries reached the maximum share of nuclear power in the grid often many years ago, the US in 1995 with 22.5 percent and even China already in 2003 with… 2.2 percent. The nuclear share in world commercial primary energy dropped to 4.5 percent, the lowest level in 30 years.

New developments can also be reported on reactor construction. For the first time in three and a half decades concrete was poured for new build projects in the US (Virgil C. Summer-2 and -3, Vogtle-3 and -4). However, at this point, these seem to remain exceptions in the country that are implemented under specific conditions (legal possibility to pass on cost increases to the consumer, loan guarantees, etc.). Construction on Belarusian-1 started in Belarus, the first nuclear plant in a country heavily impacted by fallout from the Chernobyl

6 *One additional Chinese reactor, Ningde-2, started up later in January 2014.*

7 *In January 2013, the Japan Nuclear Energy Safety Organization (JNES) placed 47 of the Japanese units in the IAEA's "Long-term Shutdown" category. But the operation was reversed two days later (see "IAEA-Japan Reactor Status Incident: 'Clerical Error' Explanation Not Credible" and linked preceding articles on the issue).*

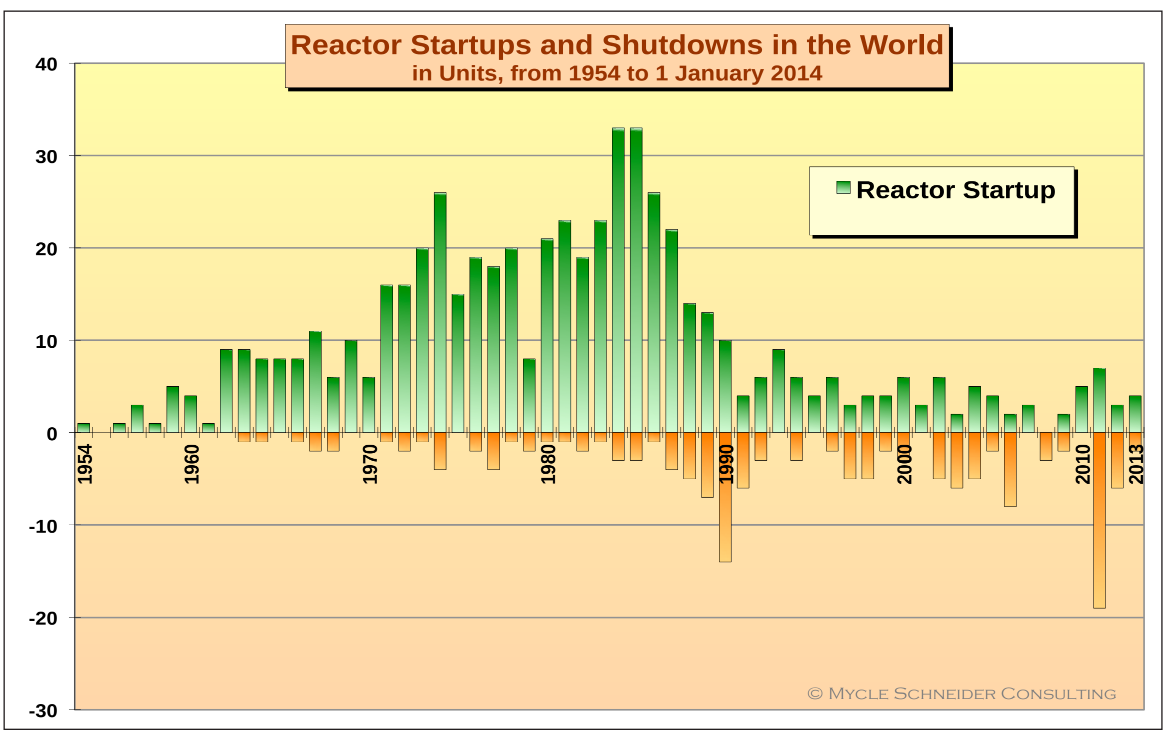

Figure 2. This chart represents grid connections and withdrawals from the grid. Therefore, while their definitive shutdown was only decided in 2013, the San Onofre units are added to the 2012 closures as they did not generate any power in 2013.

accident in 1986. Three more units got underway in China (Tianwan-4, Yangjiang-5 and -6), while the UAE started work on Barakah-2 and South Korea on Shin-Hanul-2. This brings the total of nuclear reactors "under construction" to 69 as of 1 January 2014[8], compared to 64 a year earlier.

As illustrated in subsequent *World Nuclear Industry Status Reports*, most of the building projects are subject to considerable delays. This is no doubt one of the explanations why the increase in numbers of construction sites does not automatically translate into increasing numbers of operating nuclear power plants. The current number of reactors "under construction" compares with the highest historic level of construction registered in 1979 with 234 units, 48 of which have been abandoned at various stages of advancement.

For the first time, there is now an official admission that all of the reactor building projects in China started prior to 2011 are also behind schedule (see Figure 4). The most significant delays are reported for the Westinghouse AP1000 projects Sanmen-1 (21 months) and -2 (>9 months), as well as Haiyang-1 (21 months) and -2 (18 months).

The *World Nuclear Industry Status Report* also looks into comparative data for the development into renewables. It is remarkable to see that the only country massively investing into nuclear power is China with 29 of the 69 units under construction at the beginning of the year is also the country that invests by far the most into the development of renewable energies. China is leading the top-ten renewable energy investors with an estimated $61.3bn outpacing the US with $48.4bn spent in 2013. Wind power alone, with an estimated installed capacity of 90 GW outpaced nuclear production again and the targets are 100 GW by 2015 and stunning 200 GW by 2020. The Chinese solar photovoltaic (PV) target has been raised by a factor of seven since 3/11 to 35 GW by 2015. Some analysts expect annual additions in China on the order of close to 10 GW of PV in the near future.

Nuclear power is being driven out of the global market place, too big, too expensive, too slow. System costs per installed solar kilowatt have decreased in Germany by three quarters in only seven years, while operating and new nuclear plants become increasingly expensive. The record quantity of PV connected to the grid in one month is 3 GW, while the average construction times for nuclear reactors is on the order of 10 years. Countries like Germany and China still rely heavily on coal and considerable challenges in grid and system upgrading remain ahead. But the current dynamic is clearly most favorable to small and medium size natural gas and renewable energy plants, including in the US, where both sources combined account for 88 percent of the new capacity connected to the grid in 2013. And only a handful of projects exceeded 0.2 GW in size. In the European Union, net additions of new plants in 2013 were almost 100 percent renewables.

The events of Fukushima did not trigger the crisis of the international nuclear industry but made it considerably worse. While there is a lot of talk about plans and projects, potential newcomer countries and the revival of the nuclear industry, a reality check shows that many of these plans have been dreams for decades and are likely to remain in the realm of fantasy. Current concrete projects are far from able to reverse the global trend. The global nuclear industry is well in the dusk with little prospect of seeing the dawn again.

8 *One additional plant started construction in February 2014, a small 25 MW reactor in Argentina. However, since the reactor that started up in January 2014 is not under construction anymore, the total number of units under construction as of early 2014 remains at 70.*

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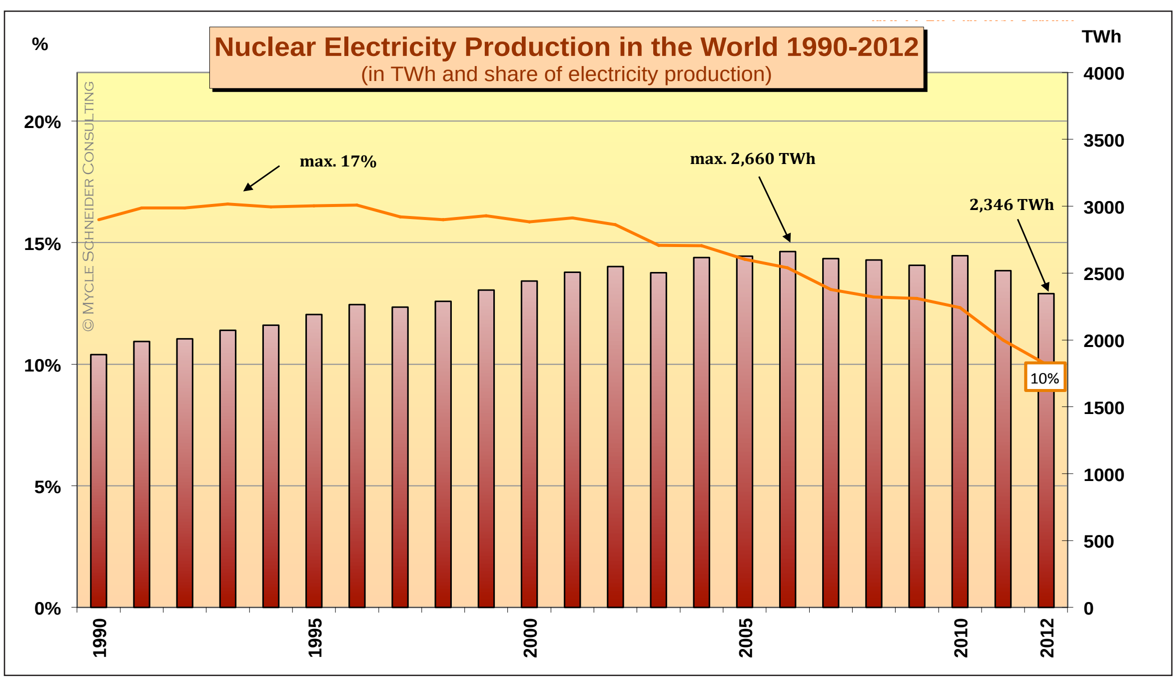
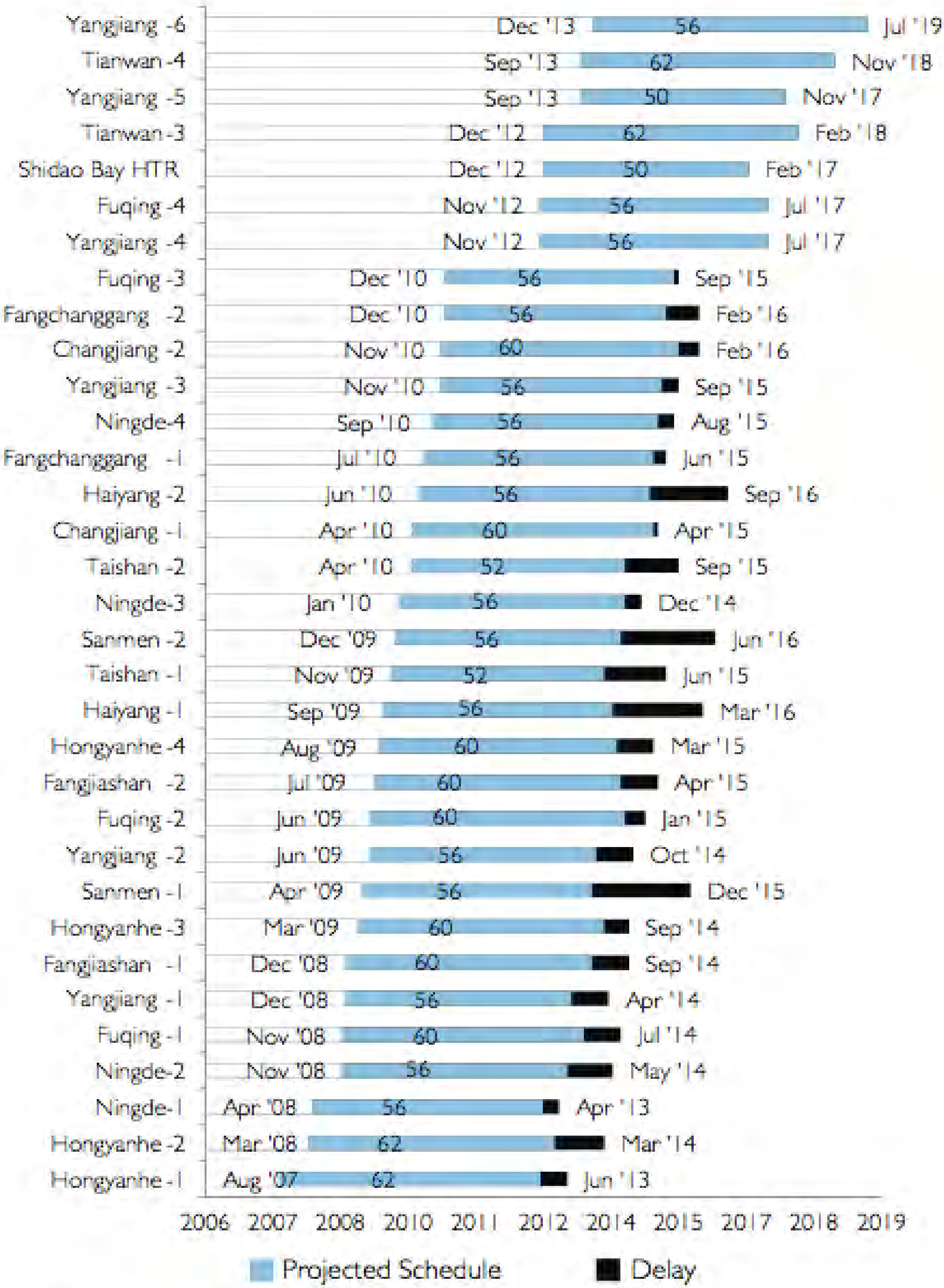


Figure 3.

Source: IAEA-PRIS, MSC, 2014

Figure 4. From Nuclear Intelligence Weekly, March 14, 2014.



Source: China's National Energy Administration, 2014.

REVIEWS

The Second Nuclear Age—Strategy, Danger and the New Nuclear Politics

By Paul Bracken, Henry Holt and Company, 306 pages, ISBN 978-0-8050-9430-5

The author and this reviewer have quite different backgrounds. Paul Bracken worked with Herman Kahn at the Hudson Institute and is now a professor of management and political science at Yale University. From 1941 to 1945 I was a junior physicist in the cyclotron group at the Metallurgical Laboratory. Later I was a professor of physics at Cornell, LSU, and RPI. I became a Quaker in 1987, and seven years later I walked fifty miles in a march protesting nuclear weapons.

Bracken distinguishes between the first and second nuclear ages as follows. In the first nuclear age, the fission bomb (and later the hydrogen bomb) was developed by only five major powers, the permanent members of the Security Council. The cold war between the U.S. and its allies, and the Soviet Union and its allies, involved nuclear threats, and regional wars with conventional weapons in Korea and Indochina. These five powers signed and pushed the non-proliferation treaty (NPT) to try to preserve their special status as nuclear powers. Negotiations between the U.S. and USSR limited the wild escalation of nuclear weapons by these two adversaries. Negotiations also resulted in the l963 ban on tests of nuclear weapons in the atmosphere. (Bracken omits mention of the treaty banning atmospheric testing, but I think it was a significant forward step. We didn't know fifty years ago, and we still don't know, how many lives worldwide were saved by this treaty. At the time, Pauling said tens or hundreds of thousands of lives; but Teller said none. The controversy continues.)

Thirty or forty years ago we slid from the first to the current second nuclear age. Bracken says we must reconsider old strategies and develop new strategies to meet current problems. The doctrine of Mutually Assured Destruction (abbreviated MAD) of the first nuclear age is no longer relevant; nor is the NPT. What are good new strategies? Bracken says the U.S. should follow China and India in proclaiming a no-first-use policy. Bracken proposes adding a 'guaranteed second use'—if any country uses nuclear weapons, we would respond with a nuclear attack. (I favor no-first-use but not guaranteed-second-use. I also advocate a pledge by all members of the nuclear club to keep their weapons secure under military control; we must be sure that terrorists cannot steal or buy nuclear weapons.)

Neither Bracken nor I have many specific proposals for policy in our second nuclear age. Despite the nearly seventy years since Hiroshima, there's still a major industrial effort to produce nuclear weapons. The NPT did not prevent some other countries from producing their own nuclear weapons: Israel (1966), India (1974), Pakistan (1998), and North Korea (2006). South Africa, with Mandela as President, rejoined the NPT by returning its nuclear weapons to Israel. In the past few years we have seen great concern that Iran may be trying to join the nuclear club. There have been only minor changes in the technology of production of U-235 and Pu-239. For U-235, gaseous diffusion and electromagnetic separation have been replaced by ultracentrifuges—lots of them! Plutonium is still produced by giant nuclear reactors. A terrorist group could not escalate from current production of chemical explosives to nuclear weapons without substantial help from a government—or if they have enough money they could try to buy nuclear weapons from a governmental stockpile. Terrorists cannot make nuclear weapons in their kitchens.

Bracken has started a crucial discussion of nuclear strategy and danger in our second nuclear age. I look forward to many of us, of course including Bracken, continuing this discussion.

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Arguments that Count Physics, Computing and Missile Defense, 1949-2012

Rebecca Slayton, The MIT Press, Cambridge, Massachusetts, 226 pages, plus end notes and references. ISBN 978-0-262-01944-6, hardback, no price stated.

As the title suggests, this book is not an easy read. Although it is not "technical" in the sense physicists are used to (that is, using mathematics to explain concepts), it is very technical as a historical reference book. The author's goal is to document and explain the complex and "messy" (author's term) interdependencies between high-level physics and engineering advisors to the U.S. government, and the emerging and evolving fields of computer hardware and software engineering, in the context of efforts to develop air and missile defense systems for the country. This obviously is not an easy task, and the author cites a tremendous amount of reference material and first-person interviews to buttress her arguments. I can foresee this book being used as a textbook for a graduate course in the history of technical policy-making in the U.S.

With such wide-ranging goals dealing with both political and technical subjects simultaneously over a 63-year time period, the author has a challenging task indeed. One method she uses to address this multiplicity of subjects is repetition of key points as she jumps back and forth between the three narratives of missile defense, policy advice, and evolution of software engineering. A major theme throughout the book is the impossibility of creating "perfectly reliable" software for extremely complex systems, and the way physicist and engineer advisors to the federal government consistently underestimated (or were oblivious to) this problem over most of the 50 years from WWII to the mid-1990s. A companion theme is how the search for provably reliable software for missile defenses during this period drove government, industry and academic software developers to evolve the discipline of software engineering.

The author does an admirable job of showing the difficulties inherent in creating a technical discipline from scratch, as was the case with computer programming between the late 1940s and the late 1990s. Within this theme, the differing viewpoints on the reliability issue held by those who stood to profit from government contracts or who were "true believers" (my term) in missile defense, versus those who felt they were "objectively" analyzing the reliability problem are thoroughly reported and carefully referenced.

A consensus that seems to emerge from the software engineering community, is that the reliability of the software for most systems of "arbitrary complexity" can be improved to "almost perfect" through continuous repair of glitches, even (perhaps especially) after the system enters use. The author quotes expert claims that this real-time improvement was/is not possible for nuclear missile defense systems, because those systems are intended for one-time use, and cannot be realistically tested beforehand. While that may have been true in the past, I am not sure it is generally true today, given the variety of missile defenses (for different types of threats) the U.S. has deployed or has in R&D at present.

Another key point the author argues effectively is that complex technological systems of all kinds, not just missile defense systems, by their nature, have social and political components. These components introduce "arbitrary complexity" into the software of these systems, in the sense that in the real world, final, fixed requirements for the software are impossible to define. This is because these requirements are ever changing with the whims of politics, history and technology itself. The author shows that the professional computing community itself is divided over the eventual outcome for this issue: Will "perfectly reliable" software forever be out of reach due to fundamental constraints, or can best practices, continual testing and hard work create reliable software for at least some complex systems?

One addition that would improve the book is a glossary of acronyms. The author is faithful to define every acronym when it is first used, but may not repeat a given acronym for 20 pages or more, and by then the reader has forgotten its meaning. I have spoken in government acronyms for 50 years, and still would have appreciated a listing for some of the acronyms the author used. The book's detailed index helps in this regard, but a separate, single glossary would be an improvement.

While historians are the primary audience for this book, it does contain a cautionary lesson for physicists. When providing analysis and advice on complex, multi-disciplinary systems, we should never assume that the physics is the most difficult or limiting component. Other, possibly newer, disciplines/technologies/human factors may limit a system more than the physics.

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