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From the Editor

Welcome to the July issue. I am pleased to have in this issue an article based on invited talks in Forum organized sessions at the last APS April meeting (which this year was in April). This is the article by Schwitters. More such articles will be in the October issue: they are in the pipeline. We have also two additional articles, three letters to the editor, and two book reviews.

This newsletter is dependent on contributions from its readers, and their friends. My definition of what is an appropriate topic is very broad: see past issues, particularly October 2017, for some specifics. Controversy is always welcome.

Oriol

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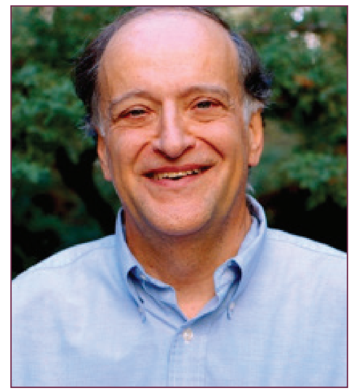

Oriol T. Valls, the current P&S newsletter editor, is a Condensed Matter theorist.

IN THIS ISSUE

A Speculation on the Energy Source of UFOs

Dear Editor,

A recent story in the *Washington Post* related that the Department of Defense has declassified videos documenting encounters between Navy fighter jets and unidentified aircraft capable of flying at speeds much greater than and with maneuverability far exceeding known (or, at least, declassified) aircraft [1]. While the idea that these vehicles are the calling cards of a highly technically-advanced alien civilization strikes me as utter nonsense, it is amusing to speculate as to what might be their source of energy. Call this letter a hypothetical pedagogical exercise.

Presumably any form of conventional rocketry could not provide for such speed or maneuverability. Our other known large-scale sources of energy, nuclear fission or fusion, would likely require structures so massive as to be impractical for such purposes. Is there any source of energy that we know of - at least in theory – which might provide the wherewithal for little green men or their drones to flit about the galaxy? I propose here gravitational potential energy as a candidate.

Just as an electrical field possesses an energy density, so does the gravitational field of any mass. A quick calculation shows the gravitational energy density near the surface of a mass M of radius R is given by

$$U = \frac{GM^2}{8pR^4}$$

In the vicinity of the Earth, this evaluates to an impressive 57.5 *billion* Joules per cubic meter. A cubic meter's worth of such energy would correspond to the kinetic energy of an F-15 jet ($m \sim 20{,}000$ kg) moving at about Mach 7. Perhaps the aliens have found a way to tap into this latent energy, which must pervade the galaxy. They would of course also have to deal with other issues, such as having their craft and themselves withstand the corresponding accelerations, but this might prove a minor issue for the possessors of such technology.

Just a thought.

[1] https://www.washingtonpost.com/outlook/the-military-keeps-encountering-ufos-why-doesnt-the-pentagon-care/2018/03/09/242c125c-22ee-11e8-94da-ebf9d112159c_story.html?utm_term=.fa06ab3a1abd. Accessed March 30, 2018.

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March 31, 2018

Dear Editor,

Pi Day is celebrated annually on March 14 in honor of the frequently used mathematical constant 3.14, which looks similar to 3/14. I propose that Standard Gravity Day be celebrated annually on September 8 in honor of the frequently used standard acceleration due to gravity (abbreviated as standard gravity), 9.8 meters per second squared (m/s^2), which looks similar to 9/8.

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Dear Editor,

Forty-five years ago, the American Physical Society sent its first Congressional Fellow to Washington, D.C., and by all accounts the experiment to increase the scientific and technical capacity of the Federal government has been a success. Since then, dozens of physicists have held Federal government policy positions, three physicists have been elected to Congress and two physicists have been appointed Secretary of Energy, a post typically held by career public servants. But in the US, not all policy is made in Washington. Decisions that affect our lives and our work are made in state houses, county seats, and city halls across the country. That's why I founded Engineers & Scientists Acting Locally (ESAL), an organization dedicated to increasing engagement by engineers and scientists with their local governments and communities.

Today, local governments are dealing with an unprecedented increase in policy issues that require scientific and technical input. To name only a few examples, local governments are considering technology policy ranging from the use of artificial intelligence in criminal justice to the regulation of driverless vehicles. School boards and state education departments across the country must develop curricula and standards to prepare the next generation of Americans for scientific breakthroughs and technology developments we cannot yet imagine. And governments at all levels must develop policies that protect the health of their local ecosystems while maintaining their plans for long-term, sustainable growth.

As physicists, we may wonder whether we have the scientific knowledge to inform related policy decisions. But experience demonstrates that when we choose to engage locally, we have meaningful impact. Today, physicists are serving in state houses from California to New Jersey. We are successfully advocating for statewide voting reforms and changes to municipal residential codes. And we are serving in appointed advisory positions at every level of government.

Despite these successes, however, too few of us get involved. Through a 2017 survey of engineers and scientists across the country, ESAL found that people with backgrounds in science, technology, engineering, and math reported higher levels of knowledge about federal issues and were more likely to engage with the federal government than with their local government. For many people, this participation gap is driven by a lack of information about how to have an impact on local policy. ESAL seeks to fill this gap by giving engineers and scientists the information and tools they need to begin their local engagement journeys.

Through its blog, ESAL shares the experiences of engineers and scientists who are engaging locally. ESAL has also developed a Local Engagement Checklist that provides several entry-points for local policy engagement. And in the coming months the group will announce several new initiatives to help scientists effectively engage with local government, including issue-specific content and curated lists of local resources. ESAL offers a monthly newsletter (sign up) with updates on these efforts.

So, how can you get started making a difference in your local community? For one plasma physicist, it began with an email to his city council members. For myself, through an appointment to a municipal task force. In both these cases, and in many others, such simple first steps opened new possibilities for broader impact. As physicists, we share a long history of policy engagement and advocacy. While we have traditionally participated in the national and global arenas, we may have even greater impact in our local communities. I invite you all to take your first policy step...by staying close to home.

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ARTICLES

World Energy Transformation

G.P. Yeh, Fermilab

Sustainable energy can reduce challenges concerning energy, economy, environment, water, food, health, education, security and peace. The world energy consumption is equivalent to 15,000 Giga Watts (GW), by the world's 7 billion people. The global carbon emission is 10 billion tons per year, or 1 million tons per hour [1]. More than 1 billion people in the world have no electricity. Solar, Wind, and other renewable energies and energy efficiencies will continue their tremendous recent progress. Countries including Saudi Arabia and United Arab Emirates are significantly investing in renewable energies. The 400 nuclear reactors in the world, with an average age of 30 years, provide 2.3% of the world's energy. To significantly provide sustainable energy and help reduce carbon emissions, nuclear power needs fundamental changes. US laboratories, universities, and companies can lead the world towards sustainable nuclear energy. Sustainable Energy is the greatest human challenge, responsibility, opportunity, and endeavor.

1. RENEWABLE ENERGIES

The world needs to reduce carbon emissions as soon as possible. As presented in the Africa Progress Report 2015 [2], renewable energy is the key for African Development and Africa's great historic moment in the next 10-20 years. The world needs to provide electricity and sustainable energy to all people.

In 2016, the world installed 55 GW of Wind Power and 75 GW of Solar, for a cumulative total of 487 GW Wind Power capacity and 303 GW Solar Power capacity [3].Worldwide investment in renewable energies in 2016 totaled US $242 billion (not including investment for hydro power). The United Nations, the World Bank, and partners worldwide are working on Sustainable Energy for All by 2030 [4]. Japan is investing US $300 billion over 10 years towards renewable energy development [5]. China is investing US $277 billion over 5 years to reduce air pollution [6].

1.1 WIND POWER

Wind Power has made tremendous progress in the last decade, adding about 45 GW per year since 2008, for a world total of 487 GW capacity by 2016 [3,7]. In 2016, China added 23 GW resulting in a total of 169 GW, US added 8.2 GW for a total of 82 GW capacity. Germany, India, and Spain had 50, 29, and 23 GW [8] wind power capacity, respectively. Japan, Korea, Taiwan had 3.2,1.0, 0.7 GW. Wind power provides nearly 40% of the annual electricity in Denmark and in the State of Iowa in US. Wind power has become the lowest price electricity in many countries [9]. Each country could benefit greatly by installing more wind power. Offshore wind power has significantly reduced its cost, and is beginning in many countries. Wind power can supply 800 GW by 2021 [7], and thousands of Giga Watts (multi Tera Watts, TW) for world energy by 2050.

1.2 SOLAR ENERGY

Solar Energy is abundant, everlasting, and available to all worldwide, connected to an electricity power-grid or off-grid. The cost of Photo-Voltaic (PV) cells and Solar panels have decreased substantially, especially in last several years. In 2016, China, USA, Japan, India, and UK added 34.5, 14.7, 8.6, 4, and 2 GW installed solar power capacity, respectively. China, Japan, Germany, USA, and Italy had 78.1, 42.8, 41.2, 40.3, and 19.3 GW cumulative installed solar power capacity [3,8]. China is adding 50 GW in 2017, and already has 120 GW solar power. India plans 100 GW solar power capacity by 2022. The world is adding 100 GW solar power capacity in 2017.

The cumulative solar water heating capacity was 456 GW-thermal in 2016 [3,8]. Concentrating Solar Power (CSP) can also provide utility-scale electricity. Solar energy will provide multi Tera Watts for world energy by 2050.

1.3 HYDRO POWER

Well planned water system, including hydro power, can provide drinking water, flood control, irrigation, and electricity for the society. Hydro power capacity reached 1096 GW in 2016 [3] and supplied 16.6% of world electricity generation. Small Hydro can benefit local communities. Hydro power can provide 2000 GW for world energy by 2050. Ocean Tidal, Wave, and Ocean Current Power are being developed, and will provide additional sustainable energy for the world.

1.4 BIO ENERGY

Bio energy can be close to carbon neutral. Bioenergy, including Biomass heating, Bio power, Ethanol and Biodiesel provide 14.1% of the world's energy [4]. Global Bio power generation was 112 GW in 2016 [4]. To reduce food consumption for biofuels production, Cellulosic Ethanol has been in production in the last few years. Biodiesel development includes using algae. Bio jet fuel has been well tested by Boeing, Airbus, airlines, and military jets. Bio jet fuel is already being used, and will become increasingly important in the future.

1.5 OTHER RENEWABLE ENERGIES

Geothermal heat pumps can be used to heat and/or cool buildings. Geothermal heat can also be used as a heat source for various applications. Geothermal electricity power generation can be utilized in many countries worldwide.

Hydrogen produced from water electrolysis with wind power or solar power would be a clean fuel with zero Green House Gas emissions. Hydrogen fuel could be used for energy storage for wind power or solar power and/or replace fossil fuels. Germany and Japan have strong support for developing hydrogen vehicles.

Renewable energies, including Wind Power and Solar Power, now have competitive prices compared to the price of fossil fuels or nuclear power. Many companies, government branches, cities, states, institutions, universities have been purchasing renewable energies for up to 100% of their electricity consumption, including Microsoft, Intel, Kohl's, Apple, Cisco, IKEA, Dallas, Houston, Starbucks, and Washington DC [10]. Microsoft is purchasing 4.5 billion kilo-Watt-hours of Wind and Solar Power and Intel is purchasing 4.1 billion kilo-Watt-hours of Biomass, Small-hydro, Geothermal, Solar, Wind, Green Power for 100% of their annual electricity needs. Wind Power or Solar Power can also be used for seawater desalination to provide fresh water.

The Headquarters of the International Renewable Agency is in Abu Dhabi. Saudi Arabia is changing its economy to become less dependent on oil. France, UK, and Volvo expect to stop producing gasoline combustion engine cars by 2040s. Electric Vehicles (EV) have been making progress [11], with networks of large numbers of solar power or wind power charging stations in many countries. Most car manufacturing companies now also make electric and/or hybrid cars. Tesla is investing US $5 billion building a battery Giga-factory. Batteries for EVs will also be used for electricity storage for homes, businesses, utilities, and electric grids.

Improving energy efficiencies is the most cost effective component of energy solutions. LEDs, with 40-50% efficiencies which are 10 times the efficiencies of incandescent light bulbs in converting electricity to light, can save most of the energy used for lighting. Energy efficient appliances, buildings, power plants, factories, vehicles, public transportation, recycling, Smart Cities could reduce energy consumption by multi Tera Watts.

1.6 WORLD RENEWABLE ENERGY PROSPECTS

Wind Power in 2016 provided 4% of the world's electricity or 1% of the world's energy. Solar Power provided 1.5% of the world's electricity. The annual increase of electricity from wind, solar, hydro, and other renewable sources is equivalent to electricity from adding ~50 nuclear reactors per year. Research and development continue to advance efficiencies, reduce costs, and further utilization of renewable energies. Solar, Wind, Hydro, Biofuels, each will provide multi Tera Watts by 2050. Geothermal, Ocean, Hydrogen, each will also provide additional energy.

2. NUCLEAR ENERGY

The 403 nuclear reactors in the world together in 2016 provided 351 GW, which was 10.5% of the world's electricity [12] or 2.3% of the world's energy [3]. Nuclear power has not had significant effect on the reduction of global carbon emissions. About 100 existing nuclear reactors will be decommissioned in the next 10 years because of their age [12].

Especially because of the Fukushima nuclear crisis, Germany, Sweden, Switzerland, Italy, Belgium, Japan, Korea, Taiwan, Kazakhstan, Lithuania have reduced or minimized reliance on nuclear power. The world energy demand and consumption will increase in the next decades. To make significant contributions to world energy, nuclear power needs fundamental changes. The nuclear power inertia since 1950s is changing from conventional nuclear power to developing new generations of reactors including Molten Salt Reactors, Thorium Energy, and Accelerator Driven Systems.

2.1 NUCLEAR POWER CHALLENGES

Nuclear Power has 5 fundamental challenges: Safety, Proliferation, Waste, Cost, and Sustainability. The public is concerned about nuclear safety, especially after the Fukushima incident. Nuclear weapons should not be exploited again. Including the 2017 Prize, 9 Nobel Peace Prizes have been awarded to stop nuclear weapons. The world needs a permanent solution to eliminate nuclear waste. The cost of constructing new nuclear power plants is too high, except for a few countries, mainly China. The existing nuclear power plants and nuclear power technologies are not sustainable. To become one of the significant sources of energy for the world, nuclear power needs fundamental changes.

2.2 MOLTEN SALT REACTORS

Aircraft Reactor Experiment at Idaho developed the first Molten Salt Reactor in 1954-1955. Molten Salt Reactor Experiment [13] at Oak Ridge National Laboratory successfully operated in 1964-1969, including using U233 as fuel which can be obtained from Thorium. Molten salt coolant instead of water enables operation at lower pressure for better safety and at higher temperature for higher thermal efficiency, in comparison with conventional Pressurized Water Reactors. Molten salt fuel instead of solid fuel would provide additional safety. Liquid expansion due to unexpected higher temperature would reduce reactivity, and the liquid would be automatically and safely drained to an external container. There are laboratories, institutes, universities, and companies in US, China, Canada, and other countries developing and commercializing Molten Salt Reactors, including at Oak Ridge National Laboratory [14] in the US and at Shanghai Institute of Applied Physics in China.

2.3 THORIUM ENERGY

Thorium Energy could also provide multi TW of energy for the world for thousands of years. Thorium 232, chemical element 90, has a half-life of 14 billion years. Some of the advantages of Thorium Energy [15,16] over Uranium nuclear reactors are:

I. Naturally Safe: Thorium is not fissile, cannot have chain reaction by itself.

II. Thorium needs a supply of neutrons to initiate and sustain nuclear chain reaction. Thorium reactors can be safely stopped.

III. Proliferation Resistant: No Plutonium in the process; more difficult to make weapons.

IV. In the Thorium fuel cycle, the intermediate decay process providing the fissile U233 also results in accompanying U232 which radiates, requiring extra handling and can be more easily detected.

V. Small amount of waste: 10,000 times smaller from Thorium than from Uranium.

VI. Thorium 232 is element 90, with fewer protons and neutrons than U-235, U238, much less probability to produce trans-Uranic elements and isotopes.

VII. Lower cost, scalable, easier and faster to build.

VIII. Thorium reactors can be Mega Watts small and modular, or large Giga Watts size. Thorium reactors will be safer, and can be simpler and more cost effective than conventional reactors using Uranium fuel.

IX. Sustainable: can supply world energy for thousands of years.

X. Thorium is several times more abundant than Uranium. The world has millions of tons of Thorium reserve available at low price. The conventional reactors use U-235 as fuel. U-235 is only 0.7% of the Uranium from the mine. The other 99.3% of the natural Uranium is U-238, which is fertile but not fissile. Also, only 70% of the U-235 in the reactor is consumed in the power generation. U-235 remains in 1% of the spent nuclear

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fuel. In contrast, the ability to use the fertile Thorium enables using essentially all of the extracted Thorium. Thorium fuel is many hundred times more abundant than U-235 fuel.

Molten Salt Reactor Experiment [13] successfully operated from 1964 to 1969, including using U233 fuel produced from Thorium. US, China, India, Russia, Netherlands, Denmark, Belgium, Germany, Turkey, other countries and some companies are developing Thorium Energy and Molten Salt Reactors [14]. Russian President Putin in July 2016 ordered Russian nuclear institutes to develop Thorium technologies. Thorium Molten Salt Reactors may be demonstrated soon.

2.4 ACCELERATOR DRIVEN SYSTEMS

Particle accelerators have many applications [17]. Low energy linear electron accelerators provide X-rays and MeV photons for radiation therapy. Higher energy electron accelerators can be synchrotron light sources or can provide X-ray free electron lasers for studying bio or nano materials. Proton, Antiproton, Heavy Ion, Electron and Positron accelerators have enabled Particle Therapies, Neutron Sources to study materials, nuclear physics studies, and high energy physics studies of quarks, leptons and other elementary particles and the fundamental forces of Nature.

2.4.1 PROTON, HEAVY ION, NEUTRONPARTICLE THERAPY FOR TREATING PATIENTS WITH TUMOR

Protons and "Heavy Ion" nuclei ionize atoms along their path, with energy deposition described by the Bragg peak. Thus, Protons and Heavy Ion nuclei can deliver with higher precision more dosage to the tumor and less damage to normal cells in comparison with conventional (X-ray/photon) radiation therapy. This electromagnetic effect is proportional to the square of the charge of the particle. Heavy Ions are more effective than Protons. Nuclear effects are stronger and more effective than the electromagnetic interactions. Protons and Heavy Ion also have small amount of nuclear interaction with the nuclei along their path. This also adds effectiveness to the charged particle therapy, in comparison with conventional radiation therapy. The world has 70 large Proton Therapy and Heavy Ion Therapy Centers. The US has 20 large Proton Therapy Centers each with multiple treatment rooms and a few hospitals each with one room for Proton Therapy treatments. By 2016, Heavy Ion Carbon Therapy had treated 21,800 patients, and Proton Therapy had treated 149,000 patients [18].

Neutrons interact only with the nuclei along their path. "Fast" energetic (> MeV) neutronscan split the nuclei along their path. Neutron therapy has 3 x Relative Biological Effectiveness in comparison with conventional radiation therapy. Neutron therapy for each patient consists of a few to twelve 2 minute treatment sessions. Neutron Therapy has treated more than 10,000 patients.

Particle Therapy can also treat some of the inoperable and/or radiation resistant tumors.

2.4.2 ACCELERATOR NEUTRON TRANSMUTATION OF NUCLEAR WASTE

High energy neutrons interacting with nuclei can split the nuclei, while lower energy thermal neutrons or epithermal neutrons can be captured by the nuclei. Larger quantities of neutrons with slightly higher energies (than neutrons for Neutron Therapy) can transmute nuclear waste by splitting the nuclei to become safer materials, with the same physics and similar technologies as Neutron Therapy for treating patients with tumors. To be more efficient in reducing high radiation level nuclear waste, partitioning should be applied to separate high level waste from lower radiation level nuclear waste before transmutation. Laboratories, institutes, universities, and companies in US, EU, Japan, and other countries have research and technologies for partitioning.

Accelerator Transmutations of Nuclear Waste was proposed in 1990 by a team at Los Alamos National Laboratory [19]. Low Energy Demonstration Accelerator with 100 mA, 6.7 MeV protons was built and operated successfully [19]. A team at Brookhaven National Laboratory also proposed Partitioning and Accelerator Transmutation of Nuclear Wastes [20]. US Department of Energy reported to the Congress in 1999: A Roadmap for Developing Accelerator Transmutation of Nuclear Waste Technology [19]. Partitioning and transmutation of nuclear wastes have been studied also at Argonne National Laboratory [21]. Neutron cross sections for materials including Thorium, Uranium, Neptunium, Plutonium, Americium, Curium actinides for advanced reactor systems have been measured at the Nuclear Data Center at Brookhaven National Laboratory [22].

The Spallation Neutron Source (SNS) [23] at Oak Ridge National Laboratory is upgrading from 1.4 MW to 2.8 MW beam power, with 38 mA average beam current, 1.3 GeV protons. The European Spallation Source (ESS) [23] with 62.5 mA average pulse current, 2 GeV protons and 5 MW beam power is expected to deliver first beam in 2019 and full design beam energy and intensity by 2023. Numerous other high intensity proton accelerators and neutron sources worldwide enable studies and advances in sciences and technologies.

The Multi-purpose hYbrid Research Reactor for High-tech Applications, MYRRHA Project [24], in Belgium is expecting soon the final approval from the European Union. One of the top priorities for MYRRHA is the demonstration and studies of transmutation of nuclear waste. The EU Guinevere VENUS-F [25] Projects have been testing in preparation for MYRRHA. Kyoto University Critical Assembly also has been doing ADS experiments and studies [26]. The Japan Proton Accelerator Research Complex, j-PARC, has Accelerator Driven Transmutation Experiment Facility and Transmutation Experiment Facility under construction. China has a program for Accelerator Driven System including transmutation of nuclear waste, and has selected a site. India and other countries also have research and programs for Accelerator Driven Systems.

2.4.3 ACCELERATOR DRIVEN THORIUM ENERGY SYSTEM

In Accelerator Driven Subcritical System (ADS), the accelerator can provide neutrons to use Thorium as fuel in a reactor for "cleaner and inexhaustible nuclear energy production" [27, 28]. The ADS eliminates the need for reprocessing in the Thorium fuel cycle. ADS for transmutation of the conventional nuclear waste, and even generate electricity from nuclear waste, can also use Thorium fuel. ADS systems can operate in the sub-critical mode for additional safety. Advances in accelerator technologies have enabled new accelerators to provide sufficient beam intensity and stability for ADS. Each 10 mA proton beam at 1 - 1.5 GeV can provide 10 – 15 MW power to supply sufficient neutrons to continuously run a reactor generating hundreds of Mega Watts of electricity. Belgium/EU, China, India, Japan, US, Korea are developing ADS [28]. The ADS demonstration systems are expected by 2030.

3. SUMMARY

The 21st Century is the Century of Sustainable Energy. Science, organizations, leaders, governments, policies, investments, corporations, foundations, institutions, communities, and public support have enabled tremendous advances toward sustainable energies. The world energy consumption is 15 TW, and is expected to increase. Solar, wind, hydro, bio energies each will provide multi Tera Watts of energy. The energy solutions also include geothermal, other renewable energies, improving energy storage, energy efficiencies, and energy conservation.

Nuclear sciences, technologies, and nuclear energy can greatly benefit society. To contribute significantly to world energy, nuclear power needs fundamental changes. Molten Salt Reactors, Thorium energy, and Accelerator Driven Systemscan also provide multi Tera Watts of sustainable energy for thousands of years. ADS can also transmute nuclear waste.

Tremendous advances in sustainable energies for all people will be achieved in the next decade. The world is moving forward in the energy transformation from using fossil fuels to using sustainable energy and providing sustainable energy to all people worldwide.

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Scientists and Public Forums

Alvin Saperstein

Two of the major concerns expressed at the Business Meeting of the *Forum on Physics and Society*, held at the recent Columbus, Ohio meeting of the *APS,* were the growing lack of support for science on the part of the present American government and the apparently swelling disinterest of the American public in the processes and results of science as they relate to public policy. Both of these concerns, are, of course, strongly coupled. Traditionally, the professional bodies of science have concentrated on lobbying governmental bodies for support, assuming that enhanced governmental interest would filter down to the general public. For the most part these scientific groups have ignored direct interactions with the "man in the street." This "filtering down" has apparently not been very successful recently. Thus, it seems important at this time for individual scientists, or small groups of them, to endeavor to interact locally with groups of fellow citizens, emphasizing process, results, and public and private implications of their science.

As an illustration of what can be productively done, a small group of us have created a traveling "road show" for the Detroit metropolitan area. This panel includes a physicist and political scientist from Wayne State University, a political scientist and an ethicist from Henry Ford College, and a physicist from the University of Detroit Mercy. (The real world is not easily divided into the traditional academic disciplines and this interdisciplinary panel approach recognizes different disciplinary approaches and concerns but connects them together for the public – and for each other!)

We have put on panel discussions – roughly 20 minutes by each presenter, some with power-point slides - followed by audience questions and response – on the subject "Nukes in Your Future". We have presented at area Colleges, Senior Citizen complexes and Community Centers, with audiences ranging from about a dozen to well over 100 people in the audience. We continue to seek further venues, especially in the "out-county" areas. We have found the senior audiences concerned about the prospects of nuclear conflict though with little factual basis for their concerns, the youthful audiences oblivious to this problem. We think we have buttressed the concern of the "seniors" and awakened the "juniors". The younger audiences are mostly used to interactions with academics and so remain quiet on the whole; the elders find it novel to being addressed by professors and so respond very actively. Hopefully the knowledge and concerns we impart will have some immediate effect on voting behavior and eventual impact on public policy.

There is no need for FPS members to struggle through the creation of an interdisciplinary colloquial traveling group. There are many community groups – churches, synagogues, mosques, alumni groups, book and discussion clubs, community centers – made of up senior and/or middle-aged citizens who would welcome scientific insight into current important public issues from locally based professional scientists. (They are more likely to think about and/or accept local expertise than public expertise from distant sources.) Many colleges have such knowledge within their ranks – active and retired faculty, students, alumni – and should be strongly encouraged to publicly announce their availability to their communities. The political aspects of the issues cannot be avoided, but the presenting scientist should be careful to avoid the appearance of being partisan.

I have given a number of well-received talks at a Detroit area group called SOAR (Society Of Active Retirees). This group was initially an off-shoot of Wayne State University, known as the "Society of Alumni Retirees". It became an independent organization as alumni of other educational institutions indicated that they too wanted to participate in such informational presentations. The group offers a wide variety of "courses", ranging from history, politics, arts, cinema and theater, humanities, social, biological and physical sciences. The "courses" range from single one-or-two-hour sessions to multiple sequential sessions over several weeks. People in the area, mostly seniors, sign up in advance, upon receipt of the course catalogue which is published twice a year. I have given Power-Point slide presentations on two separate topics: The "science of climate change" and the "science of nuclear weapons and their use". I do not claim to be an "expert" on either of these topics, but I am much more informed about the basics and their applications than most of my audiences, which usually number about 50 people. My talks usually go for about an hour-and-a half, and there is never any difficulty filling the scheduled two-hour sessions with audience questions and responses – even from those on the opposite side of the "political fence." My talks are strictly neutral, presenting the history, technology, and strategy of all sides of each issue. If asked during the question period, I will briefly give my own opinion (and make sure it is clear that it is a personal opinion, albeit based on the facts and information I presented earlier in the session.)

There are many other important topics which can be similarly productively addressed: climate, population, public health, natural resources, ground, air and water pollution, general matters of environment, war and peace. Science and scientists can greatly aid the public in reaching productive rational decisions on these pressing matters. They should strive to be actively involved in the public discussions. The public policy "theater" takes place on a physical stage whose pitfall can best be elucidated -and thus avoided –by the scientific community. These public presentations are one more way to do this interactively – and also for the scientists to learn from the public what they, and the public, need and want to know.

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U.S. Nuclear Weapons Modernization*

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INTRODUCTION

The United States conducted the last of its more than 800 underground[1] nuclear tests (UGTs) on September 23, 1992. Codenamed "Divider", that test produced a yield reported [1] as less than 20 kt (kilotons TNT equivalent), compared to 21 kt for the world's first nuclear test, "Trinity", in 1945. Coincidentally, the Rocky Flats plutonium fabrication facility, which produced most of the pits—primary fission triggers—for today's U.S. nuclear weapon stockpile, was permanently closed in 1992; its capabilities have since been partially reconstituted at Los Alamos National Laboratory (LANL). Underground testing and the capability to produce large quan- tities of plutonium pits (along with other components) were, by then, established cornerstones of the U.S. nuclear deterrent at the same time the Cold War with the Soviet Union and its emphasis on nuclear weapons was ending. In response, the U.S. launched the science-based Stockpile Stewardship Program (SSP) in 1995 under the Department of Energy (DOE) to ensure the safety, security, and effectiveness of what- ever nuclear weapons stockpile it would require in the post Cold War world *without* nuclear testing.

Today, a generation after the cessation of underground testing, the U.S. nuclear stockpile is assessed annually and meets requirements for safety, security, and effectiveness. Particular stockpile systems are being or will be modernized through "lifetime extension programs" (LEPs) to address changes in requirements and component aging, informed by advances in scientific understanding and engineering practice since they entered the stockpile. DOE's SSP responsibilities are conducted through its National Nuclear Security Administration (NNSA)[2] and associated facilities comprising national scientific and engineering laboratories, production plants, and assembly operations located at ten major sites around the United States.

Of particular importance to SSP, was the early and sustained priority assigned to developing new computer modeling and simulation capabilities for comparing archived results of

[1] The U.S. also conducted 210 atmospheric nuclear tests[1] until stopped under the 1963 Limited Test Ban Treaty.

[2] NNSA is directed by Presidential and DOE policy documents and performance requirements established by the U.S. Department of Defense (DoD).

UGTs with modern predictions of weapon performance. This talk describes technical advances made during the first generation of SSP, looking forward to what comparable scientific opportunities and corresponding investments can be expected over the next generation of SSP to better understand the U.S. stockpile and respond to new requirements.

For context, the number of nuclear warheads in the U.S. stockpile since Trinity through the first generation of science-based Stockpile Stewardship is shown in Figure 1. Notice that since the end of the cold war and closing of Rocky Flats, the average age of the U.S. stockpile has increased essentially by one year per year to the present.

All warheads in today's U.S. stockpile are two-stage devices, which function through similar physical processes, but which are tailored to meet different military requirements depending on delivery system and other operational considerations. The primary stages of U.S. stockpile weapons employ: 1) chemical high explosives to implode a hollow plutonium (Pu) pit filled with deuterium-tritium (D-T) gas to achieve the critical density where: 2) neutrons initially supplied by timed neutron generators, are multiplied through Pu fission, heating the compressing gas: 3) to the temperature where D-T nuclei fuse, forming an intense burst of neutrons that: 4) causes most of the Pu nuclei from the pit to fission rapidly in a process called "boost." The net result is an efficient release of the energy stored in Pu nuclei of the primary in the form of energetic electromagnetic radiation—x-rays and gamma rays. This radiation is transported to the secondary stage of the weapon where it compresses and heats that stage, creating a thermonuclear "burn" that provides most of the explosive energy—yield—of the device.

The science and arts of nuclear weapon design, engineering, construction, and underground testing advanced substantially during the cold war, resulting in the science and technology base on which today's stockpile and SSP are based, with a strategic focus on the Soviet/Russian threat of limited anti-ballistic missile (ABM) defenses coupled with a massive offensive or retaliatory capacity.

An annual series of Stockpile Management plans prepared for Congress by NNSA[2] form an unclassified, historical picture of SSP, including its developments of new scientific tools and methods to better understand the performance of U.S. nuclear weapons and to modernize them accordingly. Technical reports available through websites at the NNSA national laboratories, Lawrence Livermore (LLNL), Los Alamos (LANL), and Sandia (SNL) also provide information on technical developments achieved through SSP.

U.S. nuclear weapons policy for the stockpile is outlined in periodic "posture" reviews; today's stockpile follows closely the *2010 Nuclear Posture Review* [3] and the new administration's policy is outlined in the *2018 Nuclear Posture Review* [4]. Much of the content related to U.S. stockpile requirements are similar, but their descriptions of current threats are different: the 2010 review stresses terrorist threats and aging infrastructure of the nuclear weapons complex, while the 2018 review describes an overall security situation more complex and demanding than anytime since the end of the cold war, in which significant *modernization* of U.S. nuclear forces is highlighted as being needed to preserve a credible nuclear deterrent.

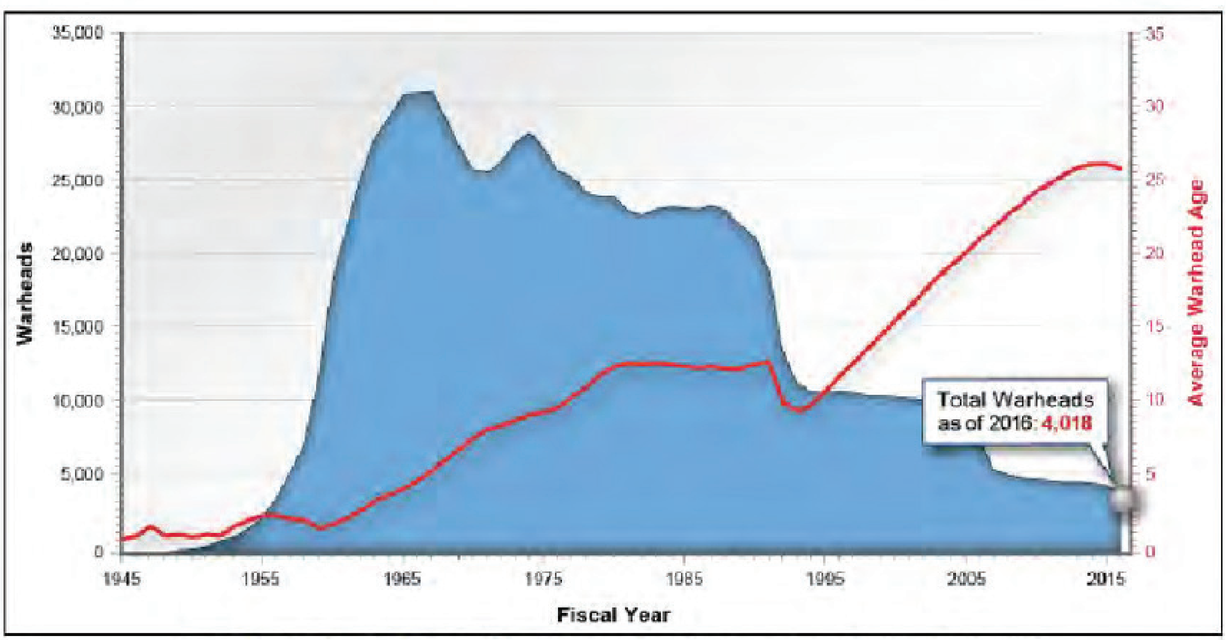

Figure 1: *Size and average age of the U.S. nuclear weapons stockpile, 1945–2016. Reproduced from Figure 6-1 of the 2018 NNSA Stockpile Management Plan[2], page 1-10. The red curve indicates the average age of weapons in the stockpile. The number of weapons indicated for 2016 was based on operational requirements to support the New START treaty between the U.S. and Russia that went into force on Feb. 5, 2011.*

I shall describe "modernization" of U.S. nuclear weapons in a more abstract way than the arguments, convincing to me, put forward for replacing delivery systems—ballistic missile submarines, ground-based ICBMs, and aircraft—when they reach the end of service life. Engineering expectations on service life, generally well understood before those systems come into service, truly determine the end of service life. In contrast, the lifetimes of nuclear weapons are known to be measured in decades, can be confirmed through surveillance and laboratory tests, but have uncertainties. Aside from special subsystems employing limited life components that are exchanged periodically, as long as today's weapons are judged to continue to meet military requirements and our treaty obligations, they have remained in service and are refurbished as needed through LEPs. A more nuanced approach to address an apparent proliferation of non-strategic weapon types and inefficiencies in fielding different weapon designs among strategic missile warheads, called the "3+2 Strategy" was approved by the Nuclear Weapons Council (NWC)[3] in 2013 and adopted as a "program of record", as described in DOE's 2018 stockpile management plan.[4]

The 2018 NPR states:

> The current threat environment and future uncertainties now necessitate a national commitment to maintain modern and effective nuclear forces, as well as the infrastructure needed to support them. Consequently, the United States has initiated a series of programs to sustain and replace existing nuclear capabilities before they reach the end of their service lives.

I wish to argue that when it comes to U.S. nuclear weapons, it is the knowledge base of nuclear weapon design and engineering, gained through testing and, now, by means of stewardship without nuclear testing, that constitutes the critical DOE/NNSA capability that must be continually modernized to maintain future confidence in the U.S. deterrent as threats evolve and weapons age.

RECENT STATEMENTS ON FUTURE THREATS AND RESPONSES

Before describing U.S. stockpile stewardship, we note two interesting commentaries reported in the press recently regarding nuclear modernization in Russia and the U.S., one by the Russian president and the other by a former U.S. Secretary of State. In a March 1, 2018 address [6] to "Citizens of Russia, members of the Federation Council and State Duma", Vladimir Putin stated: "Todays Address is a very special landmark event, just as the times we are living in, when the choices we make and every step we take are set to shape the future of our country for decades to come." He goes on:

> Russia's advanced arms are based on the cutting-edge, unique achievements of our scientists, designers and engineers. One of them is a small- scale heavy-duty nuclear energy unit that can be installed in a missile like our latest X-101 air-launched missile or the American Tomahawk missile a similar type but with a range dozens of times longer, dozens, basically an unlimited range. It is a low-flying stealth missile carrying a nuclear warhead, with almost an unlimited range, unpredictable trajectory and ability to bypass interception boundaries. It is invincible against all existing and prospective missile defense and counter-air defense systems. I will repeat this several times today.
>
> In late 2017, Russia successfully launched its latest nuclear-powered missile at the Central training ground. During its flight, the nuclear-powered engine reached its design capacity and provided the necessary propulsion.
>
> Now that the missile launch and ground tests were successful, we can begin developing a completely new type of weapon, a strategic nuclear weapons system with a nuclear-powered missile.
>
> Roll the video, please. (Video plays.)[5]

Putin also describes a doomsday nuclear powered torpedo that "enabled us to begin developing a new type of strategic weapon that would carry massive nuclear ordnance."

Significantly, the 2018 NPR calls for new types of nuclear weapons to be added the the U.S. nuclear stockpile for *non-strategic* missions:

> Additionally, in the near-term, the United States will modify a small number of existing SLBM warheads to provide a low-yield option, and in the longer term, pursue a modern nuclear-armed sea-launched cruise missile (SLCM). ... a low-yield SLBM warhead and SLCM will not require or rely on host nation support to provide deterrent effect. They will provide additional diversity in platforms, range, and survivability, and a valuable hedge against future nuclear "break out" scenarios.

Large numbers of "low-yield" nuclear weapons have been a mainstay of the Soviet, now Russian arsenal. In testimony [7] on Global Challenges before the Senate Armed Services Committee on January 25, 2018, former Secretary of State George Shultz addressed current nuclear challenges relevant to Putin's threats and new low-yield weapons described in the 2018 U.S. NPR. In part, Secretary Shultz observed:

> A nuclear weapon is a nuclear weapon. You use a small one, then you go to a bigger one. Nuclear weapons are nuclear weapons, and we need to draw the line there. One of the alarming things to me is this notion we can have something called a small nuclear weapon, which I understand the Russians are doing, and somehow that is usable. Your mind goes to the idea that nuclear weapons become usable, and then we are really in trouble... And we need to get rid of them. Personally, I think the way to get rid of them is on the one hand, maintain the strength of our arsenal, but then we need to somehow get rearranged with Russia.

[3] From its charter: "The NWC is a joint DoD-DOE activity responsible for facilitating cooperation and coordination, reaching consensus, and establishing priorities between the two Departments as they fulfill their dual-agency responsibilities for U.S. nuclear weapons stockpile management."

[4] An independent, unclassified analysis of the 3+2 Strategy was conducted by the Union of Concerned Scientists [5].

[5] Actually, a computer animation.

TODAY'S STOCKPILE

Today's U.S. nuclear weapons and associated delivery systems are listed in Table 1. The W78 and W87 are reentry vehicle warheads carried by Minuteman III ICBMs that comprise the ground leg of the U.S. strategic triad; W76-0/1, W88 are reentry body warheads carried by Trident II submarine-launched ballistic missiles, comprising the sea leg of the triad; and B61-7,11 and B83-1 are strategic bombs carried by various long-range bombers, which along with the W80-1, a air-launched cruise warhead, comprise the air leg. The remaining B61 variants would be employed in non-strategic roles.

It is instructive to note the "tail numbers" that identify stockpile weapon-types.

The two-digit number following the warhead (W) or bomb (B) designator approximately— to various degrees— represent the year in which the weapon family first came into service. The most recent addition occurred in 1988. This is *not* to say that these devices are relics from distant cold war design. They are continually being "touched"by SSP through annual assessments, surveillance where units are disassembled and inspected on a regular basis, maintenance where limited-life components are exchanged, and modernization by means of alterations, modifications, and lifetime extension programs. Furthermore, their designs are based on established scientific and engineering principles that were tested extensively in laboratory experiments and underground explosions before 1992; the data from large numbers of these UGTs have been captured on modern media forming an invaluable resource that is used extensively within the SSP to compare with and challenge computer models of stockpile systems.

SELECTED HIGHLIGHTS OF STOCKPILE STEWARDSHIP

1995 to the Present

The founder of SSP at DOE (Reis) and two scientists who joined DOE/NNSA to help manage the enterprise (Hanrahan and Levidahl) wrote a knowledgeable overview of the first generation of SSP that was published in 2016 in the American Physical Society's magazine, *Physics Today* [8]. I will try not to repeat their descriptions of some of the many important ongoing technical efforts supporting SSP, but do want to highlight some, which I consider to be most significant:

- The central accomplishment during this period—certifying the U.S. nuclear deterrent without explosive nuclear testing—was accomplished in large part by means of new computing capabilities developed under the Accelerated Strategic Computing Initiative (ASCI) and its follow-on, Advanced Simulation and Computing program (ASC). The impetus provided by science-based stockpile stewardship rejuvenated high performance computing

Table 1: Current U.S. nuclear weapons and associated delivery systems.

Type [a]	Description	Delivery System	Laboratories	Mission	Military
Warheads—Strategic Ballistic Missile Platforms					
W78	Reentry vehicle warhead	Minuteman III intercontinental ballistic missile	LANL/SNL	Surface to surface	Air Force
W87	Reentry vehicle warhead	Minuteman III intercontinental ballistic missile	LLNL/SNL	Surface to surface	Air Force
W76-0/1	Reentry body warhead	Trident II D5 submarine-launched ballistic missile	LANL/SNL	Underwater to surface	Navy
W88	Reentry body warhead	Trident II D5 submarine-launched ballistic missile	LANL/SNL	Underwater to surface	Navy
Bombs—Aircraft Platforms					
B61-3/4/10	Non-strategic bomb	F-15, F-16, certified NATO aircraft	LANL/SNL	Air to surface	Air Force/Select NATO forces
B61-7	Strategic bomb	B-52 and B-2 bombers	LANL/SNL	Air to surface	Air Force
B61-11	Strategic bomb	B-2 bomber	LANL/SNL	Air to surface	Air Force
B83-1	Strategic bomb	B-52 and B-2 bombers	LLNL/SNL	Air to surface	Air Force
Warheads—Cruise Missile Platforms					
W80-1	Air-launched cruise missile strategic weapons	B-52 bomber	LLNL/SNL	Air to surface	Air Force

LANL = Los Alamos National Laboratory NATO = North Atlantic Treaty Organization
LLNL = Lawrence Livermore National Laboratory SNL = Sandia National Laboratories

[a] The suffix associated with each warhead or bomb type (*e.g.*, "-0/1" for the W76) represents the modification associated with

Source: Table 1-1 of the 2018 NNSA Stockpile Management Plan[2], page 1-10 through adoption of massively parallel hardware and associated software, largely developed at the NNSA national laboratories, that could be applied efficiently to SSP problems. The resulting computing power—hardware and software—available to SSP grew by an astonishing factor of 200 per decade over the first generation of SSP.

- Knowledge of physical properties of materials employed in stockpile systems is essential to accurate modeling and simulation of weapon performance; new and improved measurements of such properties are regularly conducted under SSP science campaigns and are incorporated into simulation codes as they become validated.
- Archival UGT data are of *strategic* importance to U.S. SSP. ASC computer codes describing weapon performance are evolving to "common" models that can be applied to any type of weapon in the stockpile, drawing on the same algorithms to simulate the relevant physics and common libraries of relevant material properties. Earlier generations of simulation codes relied on weapon-dependent ad hoc "knobs" to manage transitions among the different physical stages—for example, from initiation of high explosive detonation in a weapon primary, to fissioning and boost of a primary pit, to radiation flow to the weapon secondary, etc.—involved in the functioning of a U.S. stockpile weapon. Common models are challenging because they enforce common physics constraints that are inherant in weapons (and everything else), enabling better understanding of all stockpile systems. Last year, FY17, [9] teams from LANL and LLNL successfully completed a "Level-1 milestone" by simulating one to two *dozen* different UGTs, involving different weapon types and "anomalies" where preshot predictions differed significantly from the actual test result. Such results demonstrate that not only do ASC simulations agree with UGT data, but they do so for the right reasons!
- Quantifying performance margins M and associated uncertainties U, generally referred to as QMU, has become the *lingua franca* of SSP and the broader nuclear weapons enterprise. QMU is important because it is *useful* in communicating complex issues in simple ways among the large and diverse community responsible for maintaining the U.S. nuclear deterrent. NNSA requested the JASON group of national security consultants[6] examine the pit assessment programs of Los Alamos and Livermore national laboratories as they approached a Level-1 Milestone in 2006 to estimate pit lifetimes with associated uncertainties. Concern had been prompted, in part, by the closure of the Rocky Flats plutonium facility in 1992. The JASON report is classified, but NNSA released unclassified sections, one of which provides a simple, but useful operational description of QMU:

  The basic idea is to compute a ratio of the margin M to the total uncertainty *U*. The higher this ratio, the higher the level of confidence in the weapon's operation, and, in general, a central goal of Stockpile Stewardship is to continually monitor and assess this ratio and to perform mitigation to increase it should the ratio tend close to 1.
- Surveillance of our nuclear stockpile is a most important function of SSP–it is the only way we can actually *see* how the parts are standing up to their years of readiness. Every year, a small number of weapons are dismantled and inspected for problems or changes. In addition, instruments providing nondestructive inspection have been developed and employed. Given the complexity of modern nuclear weapons, it is not surprising that problems are revealed in inspection of individual weapons and they are. Any anomaly discovered that could affect performance initiates a "significant finding investigation" (SFI) to understand it and respond as needed. The numbers of SFIs opened and resolved by calendar year since 2000 are shown in Figure 2. The point of this figure is to highlight the considerable effort that goes into examining the stockpile for potential surprises. The data show no obvious trends in the numbers of SFIs discovered on this decadal time scale.

[6] The author was chair of JASON at the time of the pit lifetime study.

FUTURE DIRECTIONS

NNSA's 2018 stockpile management plan reveals some qualitatively different experimental initiatives aimed at discovering new knowledge about nuclear weapons science through integrated experiments rather than comparing simulations with archival UGT data. They go by the acronyms NDSE and ECSE which mean Neutron-Diagnosed Subcritical Experiment and Extended-Capability Subcritical Experiment, respectively. The focus is on primary stage performance—basically understanding margins and uncertainties for primaries to achieve boost, including effects of aged materials. The experiments will use plutonium in sub-scale replicas of weapon components and measure the time-development of their hydrodynamic behavior and neutron reactivity with pulsed neutron or electron sources. An important early goal would be to compare the behaviors of "fresh" plutonium with aged material with sensitivity meaningful to stockpile performance requirements. Computer simulation cannot capture the small physical scales thought to be relevant to aging effects in weapons.

These experiments function like other large, integrated experiments common, say, in high energy physics, where simulations link detector responses to physics of interest through "forward computer modeling." In these experiments, one can determine accurately the connections between physics observables—e.g., detection rates, locations, and angular distributions of detected particles—through simulation. The experimental observations are then "unfolded" using the simulated connections to reveal the actual important physics processes present in the experiment, with manageable un-

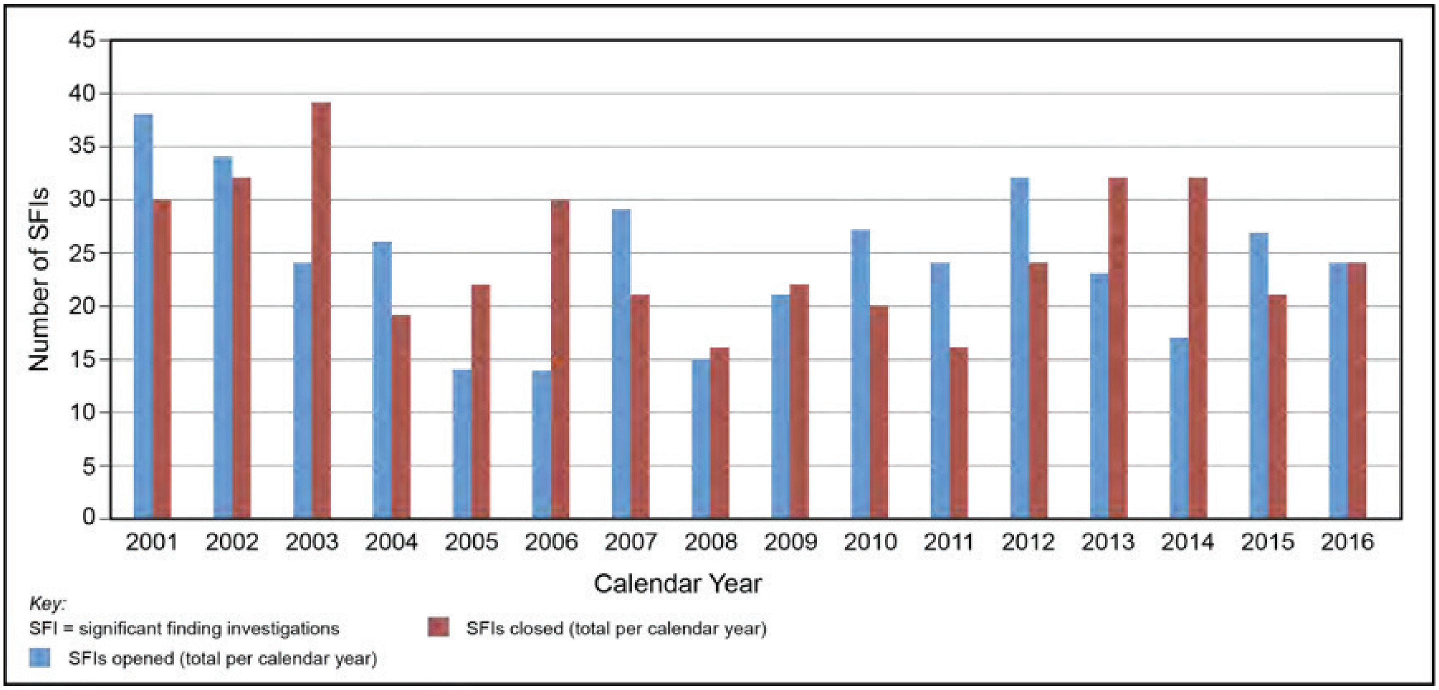

Figure 2: *Annual number of significant finding investigations (SFIs) initiated and closed by calendar year. Reproduced from Figure 2-2 of the 2018 NNSA Stockpile Management Plan[2], page 2-10.*

derstanding of statistical and other sources of uncertainty. Thus definitive results are expected, which can be repeated if needed, an option not available from the UGT data.

One can speculate that as experience is gained with the new integrated experiments, it might be possible to *reduce* the uncertainty, *U*, in our stockpile assessments, to below today's estimates arising from limitations of simulation tools and the use of UGT data alone. In situations, where a system's margin *M* may be limited by other constraints, reducing U has value by increasing the ratio *M/U*, thus *increasing* confidence.

CONCLUDING REMARKS

Science-based stockpile stewardship has succeeded to date in validating the safety, security, and effectiveness of the U.S. nuclear stockpile and promises to continue to do so for the foreseeable future. We have discussed how the *knowledge* base provided by SSP has been continuously modernized through implementation of new scientific tools and methods, notably high performance computing and the rich experimental data collected from U.S. nuclear tests is continuing to be used in new ways, such as the common software model studies. We can look forward to the next generation of SSP with modernized approaches to dynamic, subcritical experiments that may provide better understanding and reduced uncertainty in aspects of weapon performance not accessible since the end of underground testing.

Would that NNSA and DoD might find ways to modernize their *management practices* that project today the production schedules shown in Figure 3. LEPs are scheduled over the next 3-4 *decades*, but without clearly demonstrating a continuity in workloads for the various types of expertise needed to accomplish the different demanding tasks! LEPs take the products of SSP and apply them to the actual stockpile! They require intensive involvement of weapon scientists and engineers with production managers and workers to actually create the complex devices modeled in ASC simulations. Fitting such long and intricate schedules into budget reality can and does lead to delays in critical work, say design, for one example, that cannot necessarily be made up later if the designers must work on multiple weapon types simultaneously for a few years and then be furloughed during gaps in design work.

Related management issues plagued efforts to establish a pit production capability with a *known* production rate at LANL. The Secretary of Energy decision to produce a small number of weapon quality pits annually at LANL was made in December 1996.[11] It was more than a decade later that a small quantity of weapon quality pits were produced at LANL for stockpile use. However, sustained production did not follow and efforts languished, a classic case of "use it or lose it". Today, there is a much better organized effort at LANL that is having some success producing 3-5 pits per year, but to what purpose? Unless the teams needed to build these demanding and crucial components see their work contributing to national needs in efficient ways, it will be difficult to establish stable production. Congress demands rates of 30-80 pits be produced per year by 2030, as reflected in the most recent NNSA Management Plan Report. Why not consider taking a different tack and begin producing pits continuously in batches for all weapon types in the stockpile under stable

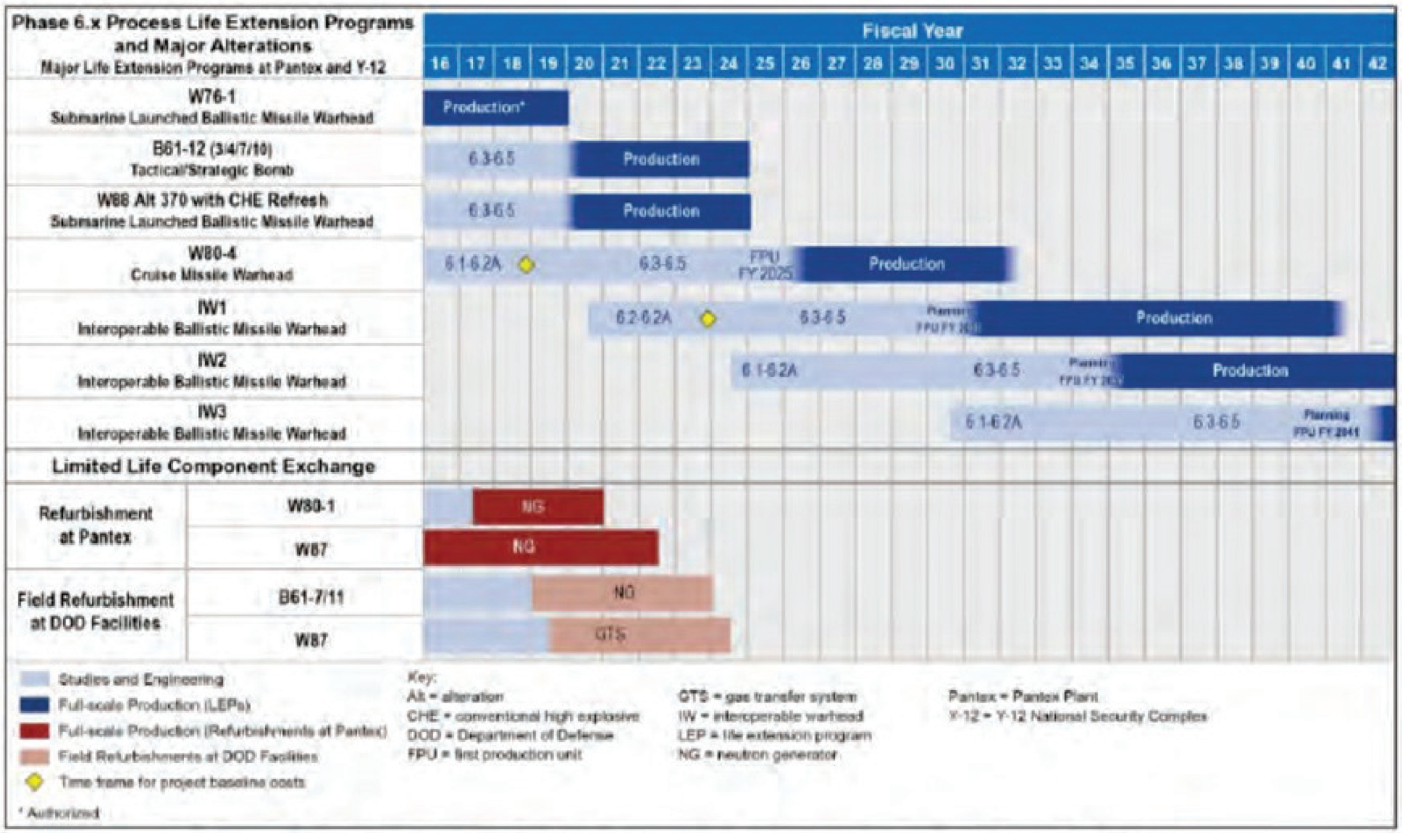

Figure 3: *Gantt chart showing NNSA's warhead modernization activities. Reproduced from Figure 2-5 of the 2018 NNSA Stockpile Management Plan[2], page 2-20.*

work-load conditions and build up a reserve that would serve several upcoming LEPs, when needed? Similarly, particular weapon system LEPs could be produced in interleaved batches to balance the load, sustain, and, even, grow expertise over all critical production capabilities and the design and engineering support needed for them to succeed. The present long blocks of effort shown in the NNSA's production schedules do not guarantee continuity of critical knowledge and skills for several reasons: 1) the schedules tend to be notional beyond the normal DoD/DOE 5-year budget horizon;

LEPs do not necessarily replace all components in the weapon, so multi-year gaps in exercising critical capabilities can occur at individual sites. Consideration should be given to a more holistic approach to stockpile modernization based on continuous productive use of critical capabilities not found elsewhere in the U.S. economy.

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The Grid: The Fraying Wires Between Americans and Our Energy Future

By Gretchen Bakke, Ph.D., Bloomsbury Publishing Plc, 2016, 352 pages, Price$27, ISBN: 978-1-60819-610-4

Gretchen Bakke is not a physicist nor an electrical engineer, she is a cultural anthropologist. In her book, "The Grid" she shows us that the electrical grid is not just a bunch of wires that connect buildings to power plants. Rather it is a byproduct of history, culture, technology, profit and politics. As the societal demands for electricity change the grid must adapt and the path to a high-functioning, cleaner, greener grid will not be straightforward.

Bakke starts the book with Grid Week, a conference for those who make, regulate and transport electricity. The key note speaker is Secretary of Energy Stephen Chu calling for more renewables. Bakke focuses on the people listening to the address and you can feel the tension in the room. This will not be an easy task. Electricity is a unique commodity in that as soon as it is made it is delivered. Renewables are unreliable, at times under-or over-producing at the whim of the weather. Solar panels drop out as a cloud passes over and wind production spikes as a wind storm rolls in. Stability depends on the people running the grid to balance variable consumption with variable generation and that means changing infrastructure.

To understand the grid in its current state Bakke takes the reader back to the 1880's. Electricity was small scale with power plants built for single mansions or with a singular purpose in mind (e.g. running San Francisco's street cars). Evolution of the grid was a co-evolution with the devices, gadgets and machines that needed electricity. Initially there was no single grid, but multiple grids with different voltages for different uses with components that weren't interchangeable. Access to electricity was not a right as we think of it today. It was an elite product.

The consolidation of power and widespread availability was done to increase profits. Samuel Insull, a former assistant to Thomas Edison, realized that it was more profitable to run a power plant close to 100% of the time. This required him to diversify his customer base, sell electricity cheaper during off peak hours and work with politicians trading regulations for a guaranteed customer base. For the decades that followed, bigger meant better. By the 1960s and 1970s American life was inseparable from electric gadget-luxuries were now necessities. Electric utilities were at their peak. This began to change as power plants ran into the Carnot limit and the environmental cost became apparent.

Electric utilities had both a monopoly-as sole producers--and a monopsony-as sole buyers-of electricity. For anyone else who tried to produce electricity the utility set the price. With the Public Utilities Regulatory Policies Act of 1978 the Carter Administration changed that. This required utilities to buy power from small green power plants at a price equivalent to what it would cost them to produce it. This forced smaller producers to produce cheaply. Initially technology wasn't up to snuff but the incentives were enough to spur innovation.

The Energy Policy Act took this separation of electrical generation from distribution a step further. It treated electricity like any other commodity that can be made in one place and shipped to another. Utilities were now the shippers without any control over how the electricity was generated or where it was shipped. Electricity was now "shipped" to farther places, wherever there is demand. This was done without upgrading the grid that carries it. Bakke reminds the reader that nothing lasts forever and recounts several catastrophes and near catastrophes caused by a failing infrastructure. She provides a detailed account of the 2003 Eastern blackout caused by too tall trees and a computer bug.

After identifying the weaknesses of the current grid to meet modern demands Bakke takes some time to look at what is needed in a grid of the future. One important piece of a new and improved grid is information. To balance real time consumption with real time production smart meters need to be incorporated into smart grids. This is not as easy as it sounds and Bakke looks at an attempt to do this in Boulder, Colorado. Ultimately that project failed because of a resistance to smart meters due to privacy concerns, the project being over budget and under "smart" due to poor choices in technology.

A future grid must also be resilient. Things will break but systems must be engineered to get back up and running quickly. To highlight this need Bakke dives into case studies of two great storms: The Great Gale in the Pacific Northwest and Sandy on the East Coast. She provides some ideas on how to recover quickly, such as smaller, more local and more diverse powers stations. Some microgrids-small scale grids that can plug into the macrogrid but that can also work in isolation--have been constructed since Sandy to improve resiliency.

Variable generation from green power necessitates a place to store that power. Some small-scale storage systems currently exist and they show that thinking outside of the box can be beneficial, resulting in such innovations as large battery banks that can provide backup for a few minutes, pumped hydro, forced air in caverns, and molten salt towers. Grid scale battery storage is far off, but small distributed batteries (matching such small distributed green generation as rooftop solar) may be the answer. Electric cars that can give and take from the grid when needed are offered as a possible solution.

Finally, Bakke reminds us of the human side of the grid.

The future grid is not all about the right technology, it is also about the people. The future grid must not only be smart, it must be "wise" by taking into account how people want to generate power and how they want to use or not use it through conservation.

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Cold War Brinkmanshhip: Nuclear Arms, Civil Rights, Government Secrecy

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From 1946 until 1991 the United States and the Soviet Union were engaged in a cold war. The two countries built up huge arsenals of nuclear weapons that could be delivered by airplanes, land-based missiles, and submarine-launched missiles. The two states threatened each other with nuclear annihilation. The preservation of peace depended largely on a stalemate (mutual assured destruction) between the two countries. During the period of the cold war and continuing to the present there were other related developments, including the use of radioactivity in medicine, the development and application of nuclear power, the civil rights movement, the anti-war movement, and attempts to reduce the size of nuclear arsenals.

Alexander DeVolpi discusses these developments in this book that is part history and part memoir. DeVolpi is particularly well qualified to discuss these topics. He served 5 years in the US Navy followed by 20 years in the naval reserve. After leaving the active navy he obtained a Ph.D. in physics and then went to Argonne National Laboratory in Illinois where he worked on the development of nuclear reactors for peaceful uses. However, it was necessary for him to get top-secret security clearance and become familiar with the properties of nuclear weapons. In later stages of his career he worked on the problem of verification of treaties that would reduce the size of nuclear arsenals. In the course of his work DeVopi had contact with other scientists working on nuclear power and nuclear weapons, including visits to other laboratories in the US and the former Soviet Union. DeVolpi also had contact with people in the civil rights and anti-war movements, which led him into these movements. His work, his knowledge of secret materials, and his outside activities led to his being investigated several times by the FBI. His security clearance was even revoked once but was restored after a short time. In addition to his own files from the period, DeVolpi based much of this book on government reports obtained under the freedom of information act.

In the book's nine chapters, DeVolpi discusses the cold war and related events of the second half of the twentieth century. The discussion is primarily from the point of view of his connection with these events. Central to the entire period is the buildup of large stockpiles of nuclear weapons by the United States and the Soviet Union. The confrontation between the US and the USSR was partly responsible for the wars in Korea and Viet Nam. But the most dangerous confrontation was the Cuban missile crisis that nearly produced a nuclear exchange. The wars in Korea and especially in Viet Nam, along with the buildup of nuclear weapons and means of delivery, led to the anti-war and nuclear disarmament movements. At the same time the civil rights movement increased in intensity. Dr. DeVolpi contributed to these movements.

Although DeVolpi is strongly in favor of reducing the size of nuclear arsenals, he feels that total elimination of nuclear weapons is not feasible. Rather he recommends that states be limited to no more than a few hundred nuclear weapons. This is far fewer than the thousands now possessed by the US and Russia and would not present the same danger. A few hundred nuclear weapons would be enough to deter a nuclear or even a conventional attack but not enough to mount a first strike.

DeVolpi makes a strong case for application of nuclear power. He argues that nuclear is the only source that can provide large amounts of carbon free power. Solar and wind are certainly worthwhile and should be pursued but cannot alone replace fossil fuels. He argues that the dangers of nuclear power have been greatly overrated even in the cases of Three Mile Island, Chernobyl, and Fukushima. He also argues that the fear of reactor grade nuclear materials being used for weapons is baseless. These materials are unsuitable for weapons and have never been used in that way. Indeed, he argues that the best way of eliminating weapons grade uranium and plutonium is to use them as fuel in reactors.

Based on his experience with government secrecy DeVolpifeels there is far too much classification. Often it does not involve sensitive material but is being used to prevent government from being embarrassed. Even material already in the public domain has been classified. DeVolpi particularly notes the article on H-bomb design published in *Progressive Magazine* and based on public information. He has co-authored an earlier book on that case, *Born Secret: the H-bomb, the Progressive case, and National Security* (Pergamon Press, New York, 1981). DeVolpi feels the proper government reaction to such cases is to ignore them. Attempts to censor such articles suggest that they contain significant material.

One feature of this book that I particularly like is the index of acronyms. In reading other books one often forgets the meanings of acronyms, leading to great difficulty in locating the original definition.

Unfortunately this book does have several flaws. First, it is quite repetitious. DeVolpi discusses a topic and then, in a later chapter, discusses it again. In a few places he repeats nearly the same sentences within a few paragraphs. The book would be more readable and useful if it were better organized. Second, the text contains very many errors. Most are minor grammatical or typographical errors but some are more serious. In any case there are far too many. The book needed a serious proofreading before publication. Third, in many places the print is so fuzzy that it is nearly impossible to read.

In spite of these flaws I recommend the book. It is an important work that should be read by anyone concerned with the cold war and related matters.

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