Vol. 40, No. 4 October 2011

PHYSICS & SOCIETY

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

Editor's Comments

Sadly, we open this edition of P&S with obituaries of two scientists who contributed in significant but very different ways to science-and-society issues: former Presidential Science Advisor John H. Marburger (1941-2011) and Nobel Laureate Rosalyn Yalow (1921-2011). Dr Marburger's career reminds us of the importance of delivering objective scientific information to those in positions of power, and Dr. Yalow's of how personal determination can overcome irrational and discriminatory obstacles to scientific careers. The staff of P&S extends our most heartfelt condolences to the Marburger and Yalow families.

In other news of interest to Forum members, in the April 2010 edition of P&S, we ran an AIP FYI reporting on the appointment of a Blue-Ribbon Commission by Secretary of Energy Steven Chu to provide advice and recommendations on the issue of nuclear waste. The commission has now released a draft report, on which it is asking for public input; we reprint in this edition a recent follow-up FYI.

At the time of this writing the worldwide price of oil is fairly stable, but we know all to well from past experience how quickly that can change. Our feature article for this edition, by Danny Krebs, examines the pros and cons of various possible alternative fuels for personal transportation as petroleum resources dwindle over the coming decades. There are no clear winners yet, and the transition to a reduced-petroleum transportation sector will by no means be easy.

Supplies and prices of petroleum and other commodities are especially sensitive to outbreaks of war, and, in a second feature article, former P&S editor Alvin Saperstein offers a commentary on how the evolution of what he describes as non-provocative defense strategies and weapons can help to minimize hot conflicts.

Our book reviews deal with the life and career of Edward Teller, and the first phases of the International Tokomac Reactor (ITOR) collaboration in the 1970's and 80's. Both of these topics involve questions of the organization and management of big-science projects, albeit in very different venues.

We look forward to your feedback and contributions.

—Cameron Reed

FORUM NEWS

John H. Marburger III (1941-2011)

The American Physical Society notes with great sadness the death of one of its fellows, John H. Marburger III. Jack, as his colleagues called him, died at the age of 70 on Thursday, July 28 at his Port Jefferson, Long Island home following several years of treatment for non-Hodgkins lymphoma.

A native of Staten Island, New York, Dr. Marburger began his physics career at the University of Southern California after completing his undergraduate physics major at Princeton University in 1962 and his doctoral training in applied physics at Stanford University in 1969, where he studied intense laser-field interactions with matter. He quickly ascended the academic administrative ladder, serving as chairman of the USC physics department and dean of the USC College of Letters, Arts and Sciences before being appointed president of SUNY Stony Brook in 1980.

He is widely credited with setting Stony Brook on a path toward growth and excellence at a time of fiscal stringency in New York State. Jack's excellent people skills came to the attention of New York Governor Mario Cuomo, who asked him to chair a fact-finding panel on the contentious Shoreham nuclear power plant in 1983.

His ability to build consensus around positions with which he did not necessarily agree led to his appointment as director of Brookhaven National Laboratory in 1998 in the midst of a local uproar over tritium leaks at BNL's high-flux beam reactor. Jack personally believed the HFBR should remain open, but with the furor having reached Vice President Gore's office, he reluctantly presided over its orderly shutdown, helping the laboratory reestablish good relations with its eastern Long Island neighbors.

In 2001, despite his openly acknowledged Democratic credentials, President George W. Bush selected him as science advisor and appointed him director of the White House Office of Science and Technology Policy. Although the science community often accused the Bush Administration of misusing science to advance its own policy and political goals, it generally did not view Jack as complicit in those actions.

Shortly before his illness sidelined him, Jack helped President Bush develop the American Competitiveness Initiative that put in place major budget increases for the Department of Energy's Office of Science, the National Institute of Standard's core programs and the National Science Foundation's research and education programs.

Although he had critics, Jack never lost the admiration scientists had for him as a highly ethical person, intensely devoted to his profession and his country. Despite his battle with cancer, he continued to advise APS, appearing as recently as March 11 at the meeting of the Physics Policy Committee. His death is a loss for APS, science, and the nation.

His wife, Carol, his two sons, John and Alexander, one grandchild and his younger sister, Mary Hoffman-Habig, survive him.

Rosalyn Sussman Yalow (1921-2011)

Ruth H. Howes

Rosalyn Sussman Yalow, a physicist who was awarded the Nobel Prize for Physiology or Medicine in 1977, died on May 30, 2011, at the age of 89 [1]. Dr. Yalow played leadership roles in three areas of importance to readers of Physics and Society. First, she used her training in physics to develop radioimmunoassay as a technique in endocrinology, the work for which she was awarded the Nobel Prize. Second, she felt an obligation to use the publicity attending her receipt of the Nobel Prize to speak out in support of biomedical research and education as well as on other technical issues that impact society where she had specialized knowledge. Finally, Yalow was an important role model for young women interested in the study of physics, and interacted with women scientists both as a mentor and a mentee.

Yalow was born in New York City to parents who themselves had never finished high school but were determined that their son and daughter would receive a college education. Yalow was educated in the New York Public Schools where she developed a passionate interest in mathematics and chemistry, which switched to physics at Hunter College. She graduated magna cum laude as the college's first physics major at the age of 19 in January, 1941. After a very brief stint in business school, she was offered at teaching assistantship at the University of Illinois where she received her masters in physics and her Ph.D. in nuclear physics in January, 1945.

Rosalyn Sussman met Aaron Yalow when they both started graduate work in physics at Illinois. They married in 1943. After receiving her PhD, she returned to New York without her husband, whose dissertation was delayed. She joined the Federal Telecommunications Laboratory as an assistant engineer - the only woman engineer on the staff. Aaron followed her to New York and became part of the new field of biophysics using radioisotopes in medicine. In 1946, Rosalyn's group from the Telecommunications Lab left New York and she moved to Hunter College to teach physics to returning veterans. She taught full-time at Hunter, and, in 1947, because she held a Ph.D. in nuclear physics, she was hired part-time by the Veterans Administration to establish Radioisotope Services at its Bronx Hospital. She held both the teaching and VA jobs before joining the VA full time in 1950, by which time she had equipped a janitor's closet as a functioning lab and published 8 clinical papers with Dr. Bernard Roswit and other physicians. In July, 1950, she started work with another physician, Dr. Solomon Berson, with whom she collaborated until his death in 1972 [2].

Berson was an expert on diabetes. He and Yalow were interested in measuring how fast the body used insulin, thereby removing it from the blood. To do so it was necessary to accurately measure concentrations of insulin in human blood. Berson and Yalow developed the technique known as radioimmunoassay (RIA), which takes advantage of the fact that an antigen labeled with a radioactive isotope such as iodine-131 binds with antibodies in solution. The binding rate depends upon the concentration of unlabelled antigen in the solution containing the antibodies and the labeled antigen. By comparing the binding rate of a known quantity of labeled antigen in an unknown solution with the binding rate in precisely prepared samples of known concentrations of antibodies, it is possible to measure the concentration of the antigen in the unknown solution. Not only is RIA able to measure concentrations very precisely, it can also single out one particular protein from among many similar ones. In their initial study of diabetes, they discovered that patients using artificial insulin developed antibodies to it [3]. The research used both Yalow's expertise in nuclear counting techniques and Berson's clinical expertise on diabetes. Yalow's work is a textbook example of creative science that crosses the boundaries of traditional disciplines.

Members of the biomedical research community recognized the accuracy and broad applicability of RIA. Hormones in the body have significant physiological effect when they are present in very low concentrations that could not be measured prior to the development of RIA. Today, RIA is a standard technique in a wide variety of biomedical research.

Because his MD carried more weight in medical circles than Yalow's Ph.D., Berson functioned as the public leader of their partnership although they worked as equals in the lab. After 18 productive years of research at the Bronx VA, Berson accepted the chair of the Department of Medicine at Mount Sinai Hospital. Yalow refused to move because she felt she would not have the freedom to choose research topics nor the support for her work that she had found at the VA. Berson spent four frustrating years at Mt. Sinai until his death in 1972. Yalow always acknowledged Berson's contributions to their joint research, even naming her lab for him. However, rumor in the research community held that Berson had been the brains of the collaboration while Yalow was a skilled technician who clearly did not deserve the credit for the work and therefore not a Nobel Prize. Yalow continued her work with other medical collaborators. Five years later it was obvious that her publication rate and quality and her creativity were unabated and the importance of her role in the collaboration with Berson became evident. In 1977, she shared the Nobel Prize for Physiology or Medicine with endocrinologists Roger Guillemin and Andrew Schally, only the second woman to be awarded the prize in medicine or physiology and the sixth for all Nobel Prizes [4].

As RIA became an important tool in biomedical research, drug companies developed commercial kits for RIA procedures. Yalow turned down all offers to become a consultant. She received numerous prestigious awards including the national medal of science, and was elected to offices in professional organizations [3]. After receiving the Nobel Prize, Yalow was invited to speak out on many technical issues that impact society. She served as a consistent advocate for funding of and excellence in basic biomedical research and education. The Nobel Prize brought requests for her to speak out on issues such as nuclear power and the biological effects of radiation, and she felt that she should use her bully pulpit to influence public opinion. She held strong opinions and advocated forcefully for them, often offending those with whom she disagreed. Certainly, she felt a commitment to educate the public about technical issues that impact their daily lives. She served on National and International Boards and Committees where she felt her expertise could serve society.

Yalow was adversely impacted by the fact that she was a woman on any number of occasions in ways that would have stopped a less determined scientist. When she entered the graduate physics program at the University of Illinois in 1941, she was the only woman among the 400 members of the College of Engineering. As usual, she worked extremely hard and received all A's except for an A- in Optics laboratory.

The chair of the department told her, "That A- confirms that women do not do well at laboratory work" [2]. His attitude did not slow Yalow's progress towards a Ph.D.

The Yalows had a son and a daughter. They were able to live close to Rosalyn's work at the Bronx VA Hospital. With the aid of live-in help until her son was 9 and part-time help after that, she managed to work her usual cheerful 80-hour weeks while dealing with two small children. She cites two distinguished women physicists who were particularly supportive of her work, nuclear physicist Gertrude Goldhaber, whose husband Maurice Goldhaber directed Yalow's thesis (Gertrude Goldhaber held no official university position because of nepotism rules), and medical physicist Edith Quimby, in whose Columbia laboratory Yalow volunteered to work in order to learn about the medical applications of radioisotopes and who introduced her to leaders in the field. At Hunter, she began to mentor younger women physicists including Mildred Dresselhaus and Frieda Stahl, a practice which continued during her many years at the VA [6].

Although Yalow consistently supported women scientists, she did not consider herself a feminist. In fact, she refused to accept a woman of the year award from Ladies Home Journal because she felt that by accepting it, she would be making a statement that her work was remarkable for a woman but not equal to that of the best male scientists [5]. She firmly opposed affirmative action. At the same time, she was a supporter of the Equal Rights Amendment and generous in encouraging young women. She consistently stated and demonstrated in her own life that success in science did not require a woman to give up marriage and children. As she put it, "If you want to be a good wife, you have to work a little harder." [6]

As the only woman Nobel Prize Winner in 1977, she was selected to give a special address to students at a banquet. In that speech, she very clearly stated her position on women in science:

We cannot expect in the immediate future that all women who seek it will achieve full equality of opportunity. But if women are to start moving toward that goal, we must believe in ourselves or no one else will believe in us. We must match our aspirations with the competence, courage, and determination to succeed, and we must feel a personal responsibility to ease the path for those who come afterwards. The world cannot afford the loss of talents of half its people if we are to solve the many problems which beset us [7].

The stress on competence and very hard work characterizes Yalow's approach to science. Rumor has it that she kept on her bulletin board a sign that read: "To be considered half as good as a man, a woman must work twice as hard and be twice as good," a standard sentiment, but Yalow had added in script, "Fortunately that is not difficult." Certainly controversy over Yalow centered on her statements on technologies and society and her approach to feminism but not her science.

Aaron Yalow died in 1992. Rosalyn Yalow is survived by their son, Benjamin, of the Bronx, and daughter, Elanna Yalow of Larkspur, California, and two grandchildren [1].

References

1. *Gellene, Denise, "Rosalyn S. Yalow, Nobel Medical Physicist, Dies at 89," www.nytimes.com/2011/06/02/us/02yalow.html?pagewanted=all, June 1, 2011.*
2. *Yalow, R.S., "Autobiography," From Les Prix Nobel. The Nobel Prizes 1977, Editor Wilhelm Odelberg, [Nobel Foundation], Stockholm, 1978 and downloaded from nobelprize.org, the official website of the Nobel Prize.*
3. *Straus, Eugene, Rosalyn Yalow Nobel Laureate: Her Life and Work in Medicine, New York: Plenum Press, 1998.*
4. *Dresselhaus, M.S. and Stahl, F.A., "Rosalyn Sussman Yalow (1921-)," in Out of the Shadows: Contributions of Twentieth-Century Women to Physics edited by Nina Byers and Gary Williams, Cambridge University Press, 2006, pp. 302-314.*
5. *Munson, Judith, "Rosalyn Sussman Yalow: Scientist Without Boundaries," in Celebrating Women in Mathematics and Science edited by Miriam P. Cooney, Reston, VA: National Council of Teachers of Mathematics, 1996, pp. 172-177.*
6. *Biermann, Carol A. and Biermann, Ludwig, "Rosalyn Sussman Yalow (1921-)" in Women in Chemistry and Physics: A Bibliographic Sourcebook edited by Louise S. Grinstein, Rose K. Rose, and Miriam H. Rafailovich, Greenwich, Connecticut: Westwood Press, 1993, pp.626-639.*
7. *Reference 3, pp. 240-241.*

Ruth H. Howes
Emeritus, Ball State University
rhowes@bsu.edu

AIP FYI on Nuclear Waste Report

In the April, 2010, edition of P&S, we ran an AIP FYI reporting on the appointment of a Blue-Ribbon Commission by Secretary of Energy Steven Chu to provide advice and recommendations on the issue of nuclear waste. The commission has now released a draft report, on which it is asking for public input. We reprint here a recent follow-up FYI; the original can be found at http://www.aip.org/fyi/2011/101.html. The draft report and a comment-input form can be found at http://www.brc.gov/.

Characterizing the U.S. approach to the handling of nuclear waste as a “deeply flawed program,” the Blue Ribbon Commission on America’s Nuclear Future has released a draft report recommending fundamental changes in the nation’s management of spent nuclear fuel. The Commission is accepting public comment on its 192-page report through October 31, 2011.

One of the Commission’s central recommendations is for a consent-based approach to be used in the siting of future nuclear waste management facilities. As outlined in the report, Canada, Finland, France, Japan, Spain, Sweden, and the United Kingdom have instituted procedures under which local communities consent to the location of a nuclear waste facility. The Waste Isolation Pilot Plant in New Mexico was also established using a consent-based procedure. This approach contrasts to the mandated, and long-troubled, designation of Yucca Mountain NV as the candidate site for the nation’s sole geologic repository. The Obama Administration is seeking to terminate this repository on the grounds that it is not a “workable option.” There is now approximately 65,000 metric tons of commercial spent fuel in wet and dry storage facilities.

The Administration’s intention to establish the Commission was announced in the FY 2010 budget request for the Department of Energy when it declared its intention to terminate the repository. The Commission, chartered in March 2010, is co-chaired by Lee Hamilton and Brent Scowcroft, and includes among it fifteen members Pete Domenici, Richard Meserve, Ernest Moniz, Per Peterson, and Phil Sharp. After its initial meeting on March 25 and 26, 2010, the full Commission, or its subcommittees, met a total of 25 times in the U.S., Finland, Sweden, Japan, Russia, France, and the United Kingdom. The final report will be presented to President Obama and Energy Secretary Chu on or before January 29, 2012.

The opening paragraph of the report’s Executive Summary aptly describes the current situation:

“America’s nuclear waste management program is at an impasse. The Obama Administration’s decision to halt work on a repository at Yucca Mountain in Nevada is but the latest indicator of a policy that has been troubled for decades and has now all but completely broken down. The approach laid out under the 1987 Amendments to the Nuclear Waste Policy Act (NWPA) - which tied the entire U.S. high-level waste management program to the fate of the Yucca Mountain site - has not worked to produce a timely solution for dealing with the nation’s most hazardous radioactive materials. The United States has traveled nearly 25 years down the current path only to come to a point where continuing to rely on the same approach seems destined to bring further controversy, litigation, and protracted delay.”

The Commission recommends a seven part strategy “to establish a truly integrated national nuclear waste management system” that will ensure institutional and national leadership and respond to concerns about nuclear safety, non-proliferation, and security. It calls for a new organization, outside of the Department of Energy, to manage the nation’s nuclear waste. Declaring “the [Nuclear Waste] Fund does not work as intended,” the Commission recommends that Congress reform the financing mechanism. One or more interim storage facilities should be developed, “without further delay,” with priority given to transferring spent nuclear fuel at closed nuclear generating plants. Of note, the Commission calls for the development of one or more geologic disposal facilities, explaining:

“Deep geologic disposal capacity is an essential component of a comprehensive nuclear waste management system for the simple reason that very long-term isolation from the environment is the only responsible way to manage nuclear materials with a low probability of re-use, including defense and commercial reprocessing wastes and many forms of spent fuel currently in government hands. The conclusion that disposal is needed and that deep geologic disposal is the scientifically preferred approach has been reached by every expert panel that has looked at the issue and by every other country that is pursuing a nuclear waste management program. Moreover, all spent fuel reprocessing or recycle options either already available or under active development at this time still generate waste streams that require a permanent disposal solution. We believe permanent disposal will very likely also be needed to safely manage at least some portion of the commercial spent fuel inventory.”

The Commission’s report does not contain any recommendation about the future of Yucca Mountain, locations for the interim or geologic repositories, nuclear fuel reprocessing, or the future role of nuclear power.

In commenting on the report, House Science Committee Chairman Ralph Hall (R-TX) said "I appreciate the good faith effort put forth by this highly-esteemed Blue Ribbon Commission . . . and look forward to the Committee's close examination of the Commission's recommendations." The Republican leadership of the House Energy and Commerce Committee also expressed general support for the report.

"The overall record of the U.S. nuclear waste program has been one of broken promises and unmet commitments. And yet the Commission finds reasons for confidence that we can turn this record around," the report states. A copy of the draft report, information on five public meetings during September and October in Denver; Boston; Atlanta; Washington, D.C. and Minneapolis and a comment form can be viewed at http://www.brc.gov/ .

Richard Jones
Government Relations Division, American Institute of Physics
rjones@aip.org, (301) 209-3095

ARTICLES

Personal Transportation in the 21st Century and Beyond

Danny J. Krebs

Petroleum Production and Consumption

The original world endowment of conventional petroleum is generally estimated to be less than three trillion barrels, with about a third of that resource having already been pumped [1]. With the world consuming about 26 billion barrels of oil each year, only about 75 years worth of conventional oil remains in the ground. Getting at the last trillion barrels will be a lot harder than getting the first trillion, so production rates will soon decline. One recent study concluded that oil production will peak in 2014 and that by the year 2050, 90% of the recoverable oil on the planet will have been pumped [2]. More optimistic studies forecast a gradual global decline by 2020 or later. Many believe that oil from shale, tar sands, and heavy crude can provide additional petroleum to last well into the 22nd century, but only at increasingly higher prices, and greater environmental peril. The $440 billion in oil payments by the US in 2008 was the largest transfer of wealth in human history. In 2011 we will almost certainly import more than half-a-trillion dollars worth of petroleum. US imports of petroleum account for about 2.4 percent of our GDP and about one third of our balance of payments deficit. In addition to these figures we must also consider the cost of our military posture in the Middle East.

But is petroleum the only energy source able to satisfy our transportation needs? In this article I examine how our transportation system must change to adjust to the realities declining petroleum production, with a particular view to examining possible alternative fuels for private automobiles.

Efficiency and Fuel Options

I believe that we do not have an energy problem so much as a transportation fuel problem. While petroleum provides about 94% of our transportation energy, the total energy derived from petroleum is significantly less than the energy that we derive from coal and natural gas. The mechanical energy necessary for our transportation sector is less than half the useful energy delivered by electric utilities to customers [3]. We rely on petroleum as the least expensive way to derive liquid fuels for transportation. Liquid fuels are generally preferred for vehicles because they store energy more compactly than gaseous fuels or batteries. But gasoline internal combustion engines are far from ideal power sources for transportation. The Carnot efficiency for a gasoline internal combustion engine is about 37%, but actual gasoline engines are only about 20% efficient.

When petroleum fuels are burned, we recover energy stored millions of years ago by photosynthesis of carbon dioxide from the atmosphere, that is, we are tapping into and perturbing the world's carbon cycle. Gasoline is the primary fuel for cars and light trucks in the US and diesel fuel is the primary fuel for heavy transport. Liquefied Petroleum Gas (LPG) is a mixture of propane and butane which is liquid at room temperature if compressed. It is a by-product of petroleum refining, and so is plagued by the same supply issues as other petroleum fuels. Natural gas, which is predominantly methane, the simplest hydrocarbon, is an excellent fuel, can be readily burned in internal combustion engines, contributes least to global warming, and is about two-and-one-half times cheaper per unit of energy than gasoline. World proven reserves of natural gas are roughly equivalent to a trillion barrels of petroleum with much of the proven reserves located in the Middle East and Russia. Natural gas can be liquefied for international shipment in cryogenic tanker vessels. There are terminals in the US for receiving liquified natural gas, but only about 1% of our natural gas is imported this way.

Vehicles store natural gas as a compressed gas. I have personal experience of driving a natural gas car on a 300 mile round trip without having to use the gasoline backup tank. Some public figures advocate much more use of natural gas in US transportation. Completely replacing gasoline consumed in the US with natural gas would cut our estimated domestic reserve of natural gas from 90 years worth to about 50 years worth.

Alcohols like methanol, ethanol and butanol are also potential replacements to gasoline. Methanol has the disadvantages of lower energy content, higher volatility, and toxicity, but is more easily produced. Ethanol is the most developed non-fossil fuel, but its energy content is about 39% less than gasoline, it cannot be transported in pipelines designed for gasoline, and its production has an effect on food prices. Butanol is generally compatible with gasoline infrastructure, but is more difficult to produce than ethanol or methanol.

Hydrogen has received a great deal of attention as a potential alternative fuel. Produced from water using electrolysis, hydrogen can fuel internal combustion engines directly, or power fuel cells to make electricity for electric motors. When hydrogen is burned in an engine or utilized in a fuel cell, water is produced, thereby reversing the electrolysis reaction. Because the electrolysis process is currently too costly, hydrogen is commercially produced from natural gas. Technical improvements to the electrolysis process are being developed, as are biological and solar/catalytic approaches that could also enable hydrogen production from water [4]. While this sounds promising, but there are significant problems with hydrogen. Hydrogen manufacture requires other energy sources, such as electricity, solar energy, or natural gas. Hydrogen does not liquefy at reasonable temperatures, so bulk distribution would probably need to be done in the gaseous state. Distribution is problematic due to the low volumetric energy content and high reactivity of hydrogen [5]. Despite the drawbacks, there is considerable allure to the prospect of a “hydrogen economy”. Honda will lease 200 hydrogen-fuel-cell vehicles to California residents for $600 per month, and has developed home refueling stations that plug into domestic natural gas lines. The Honda vehicle stores its hydrogen in 5000 psi tanks and has an advertised range of 200 miles.

Using ammonia as a fuel has attracted some adherents. Complete combustion of ammonia yields only water and nitrogen, so in principle, ammonia engines can be non-polluting. Production methods for ammonia either require methane or large inputs of electrical energy. Another problem with ammonia is its toxicity. The permissible exposure limit is 35 parts per million, and extremely high levels of exposure can result in death [6]. Nonetheless, one study has concluded that the risks of ammonia transport are no greater than the risks of transporting gasoline or LPG [7].

What about synthetic fuels?

Gasoline, diesel fuel, natural gas, jet fuel, ethanol, methanol, butanol, and hydrogen can all be manufactured synthetically. Chemical methods of manufacturing liquid fuels from coal have been known since the 1920’s. The Fischer-Tropsch process, or similar methods, can be used to synthesize liquid fuels from coal, tar sands, or biomass. The current worldwide production capacity of synthetic fuels is about 240,000 barrels per day, equivalent to about 0.3% of the world crude oil production of about 70 million barrels per day. Germany produced up to 120,000 barrels per day of synthetic fuel during World War II. The US had an active synthetic fuels program in the early 1950’s with a plant in St. Louis, Missouri, producing 1.5 million gallons of synthetic gasoline from coal between 1949 and 1953. The program was de-funded by Congress in 1953, partly as a result of lobbying by the National Petroleum Council. A recent study concluded that a 50,000 barrel per day, coal-to-synthetic-diesel plant could produce a return on investment of almost 20% [8]. One drawback to these processes is that they typically consume other finite resources like coal. While the US has about 250 years worth of coal reserves at current consumption rates, conversion to a coal-based transportation system would put a strain on reserves and greatly damage efforts to limit greenhouse-gas emissions.

What about Biofuels?

In a sense, biofuel technology converts solar energy into fuel using biological processes. There is enough solar energy falling on an area 40 miles by 40 miles to substitute for the energy expended by all the cars in the US, so it is not totally crazy to search for practical biofuel technologies. Biofuel technology has the additional advantage that it need not contribute to greenhouse gas emissions and may actually serve to reduce them. Biofuel technology can be lumped into three general approaches: (1) crop based, which uses only the kernel from the plant; (2) cellulosic, which uses the whole plant; and (3) photo-bioreactor, which grows simple organisms in ponds or containers. The best developed biofuel is ethanol, which has reduced the Brazilian need for gasoline by an approximate factor of two. The US ethanol program, which is based on ethanol production from corn, produced about 10 billion gallons in 2009, or about 2.6% of the US consumption of gasoline. Although this program has many detractors, it has reduced importation of crude oil to some extent. Both the US Navy and Air Force have aggressive programs to develop biofuel mixtures for jet aircraft and ships.

The technology for producing large quantities of ethanol or methanol from cellulosic materials like switch grass or wood chips is not mature. One approach involves breaking the cellulose down into glucose with mild acids, enzymes, or fungi; followed by fermentation. A company in Canada produced about 150,000 gallons of ethanol from straw using an enzyme process in 2009. Despite significant funding from the Department of Energy and private investors, a plant to synthesize ethanol from wood chips recently closed its doors without producing any ethanol [9].

The production of liquid fuels from micro-algae has attracted some adherents, chiefly because the processes appear to be scalable. The Department of Energy estimates that the US requirement for liquid fuels could be satisfied by dedicating 15,000 square miles of land to micro-algae farming, which is less than one-seventh the land currently dedicated to corn production. Unfortunately, production of fuel from micro-algae is not cost competitive; the ponds or bioreactors are difficult to keep clean and harvesting is problematic.

Electric "fuel" Options

Electricity is a serious contender as an alternative fuel, particularly for urban commuting. Electric motors can have efficiencies close to 90%. Therefore, the amount of energy that must be stored by a fuel cell or battery-powered vehicle is about a factor of four less than the energy that is required for an internal combustion engine vehicle (although not necessarily in volume or weight). A distribution system for electrical energy already exists, and the per-mile fuel cost for electricity is about a factor of four to five times less than for gasoline. The electrical generating capability of the US would not have to undergo a drastic expansion to accommodate electric cars, partly because charging can be done off-peak.

A number of types of electric vehicles are now available. Hybrid vehicles provide a way to recapture some of the energy that would otherwise be lost in braking, and apply it to the next cycle of acceleration. Because of the power boost provided by the electric motor, the gasoline engine can be smaller than it would otherwise need to be, and smaller engines require less fuel. The Toyota Prius and some other hybrids have designs that allow the electric motors to contribute power over a wide range of vehicle speeds. Other hybrids use a simpler, but less beneficial scheme that utilizes the electric motor only at low speeds. Currently, hybrid vehicles use nickel-metal-hydride batteries, which are better developed and less expensive than lithium ion batteries.

The weight of batteries has traditionally been a problem for electric vehicles. The EV1 built by GM and Honda in the 1990's had 1200 pounds of lead acid batteries, which was almost half the weight of the vehicle. Lead-acid batteries store only 35 watt-hours per kilogram. Lithium-ion batteries achieve about 150 watt-hours per kilogram at the cell level. The Chevrolet Volt uses about 400 pounds of lithium ion batteries to achieve its 40 mile (electric only) range. Other battery technologies, such as lithium-air and lithium-sulfur are theoretically capable of storing up to 5000 watt-hours per kilogram [10]. But those batteries are in a very early stage of development. It is possible that greatly improved battery technology will be available for cars in the future. At current gasoline prices the fuel cost for an electric vehicle is about three to five times cheaper than a gasoline powered vehicle with similar characteristics.

Plug-in hybrids allow some energy to be stored in the battery from a charging station or normal household plugs. After-market kits for adapting the Prius for plug-in operation are available. GM calls the Volt an extended-range electric vehicle; its electric motors and batteries are sufficient to support electric-only operation for a significant distance. The EPA rating for gasoline-only operation of the Volt is 37 miles per gallon. Nonetheless, owners who only occasionally take more than short trips could see an effective gas mileage of over 200 miles per gallon. The keys to success for these vehicles in the market place will be reliability and acquisition costs.

If the motor-generator system in the extended range electric vehicle is replaced with additional batteries, one then has an all-electric vehicle (EV). Tesla Motors in California has been producing a high performance all-electric sports car since 2008. That vehicle is one of the fastest accelerating production cars in the world: zero to 60 mph in 3.9 seconds. It has a range of 236 miles and costs about $101,500, mainly due to the high cost of its lithium-ion batteries. In 2011 Tesla will introduce a sedan that will cost around $50,000 and have a range of 300 miles. Nissan is introducing an all-electric vehicle called the Leaf that will cost about $25,000 after a $7,500 federal subsidy is deducted from the cost. The Leaf has an advertised range of 100 miles.

At this point, all-electric vehicles do not make a lot of economic sense for most people. Even hybrid owners are not likely to recoup the difference in initial cost from fuel savings. With improvements in battery performance, reductions in battery cost, and likely rises in the cost of gasoline, all-electric vehicles will soon become cost competitive for cars and light trucks.

Summary and Outlook

Synthetic fuels and electric vehicles could help us to avoid the worst consequences of diminishing oil supplies and contribute to reducing carbon emissions. The availability of petroleum from tar sands and oil shale will allow us some "breathing room". Natural gas could also provide some relief from petroleum shortfalls, but domestic supplies are finite and probably should be preserved for other uses.

The technical alternatives to petroleum fuels are all problematic, and it is not clear when or if the hoped-for breakthroughs will occur. The one thing that we can most readily do to reduce petroleum imports is conservation. Since 1980 the average horsepower of American light vehicles has doubled and the fuel economy has remained relatively constant [11]. While this is a remarkable engineering achievement, one must ask what improvements in fuel economy would have been possible if the average horsepower had not doubled. The Corporate Average Fuel Economy (CAFE) regulations enacted by Congress in 1975 were largely ineffective in improving the average fuel economy of American vehicles. Those regulations counted SUV's as light trucks and then promulgated very modest improvements for the "light truck" category. In 2007 more aggressive standards were put in to place by Congress. In 2009 the Obama administration proposed even tougher CAFE standards: 39 mpg and 30 mpg for cars and light trucks respectively by 2016. As much as many of us prefer large vehicles or high performance cars, our preference for those vehicles is costly, both personally and collectively. A few decades ago we were able to satisfy personal and business needs without "Super-Duty" pickups, SUV's, and "sport sedans" with 300-plus horsepower engines. There are a number of options for improving the fuel economy of gasoline driven vehicles at reasonable costs [12].

Shifting to a hydrogen-based transportation system seems unlikely. There appear to be too many issues with hydrogen for it to be a viable fuel in the 21st century. Despite likely advances in battery technology, liquid fuels will continue to be necessary for heavy transport. The power and energy requirements for trucks and locomotives are too great to contemplate replacement with battery technology. One hopes that synthetic fuels can eventually be available for heavy transport and air travel. Synthetic fuels from micro-algae, genetically modified bacteria, or normal crops are attractive possibilities, but the costs will be high and the past failures in this area have been many. Whatever approach is taken, synthetic fuels are likely to be more expensive than petroleum fuels.

With planning and foresight, civilization can survive the depletion of petroleum resources. It is up to the next few generations to manage the transition to a low-petroleum world economy. The U.S. is particularly vulnerable to disruptions in petroleum supply because our dispersed geography, our current infrastructure, and our mindset of expecting cheap fuel to be available indefinitely. There are those who see efforts at moving the US toward conservation and alternative fuels as naive or unpatriotic. They advocate more domestic production to lessen dependence on foreign sources. Increasing domestic production can lessen our dependence on foreign oil in the short term, but only exacerbates the long-term problem. Transitioning to a low-petroleum transportation sector will not be easy, but it is the only long-term solution. I hope that I have conveyed how difficult it will be. By doing good technical development and laying the groundwork now, we can leave an appropriate legacy for future generations.

References

[1] Thomas S. Ahlbrandt, Global Resource Estimates from Total Petroleum Systems (AAPG Publication ISBN 0-89181-267-5, 2005). Different values can be found in other sources; Wikipedia, for example, cites a "proven reserve" of 1.2 trillion barrels for the top 17 national reserves.

[2] Ibrahim Sami Nashawi, Adel Malallah and Mohammed Al-Bisharah, "Forecasting World Crude Oil Production Using Multicyclic Hubbert Model," Energy Fuels, 24(3) 1788–1800 (2010); Michael Moyer, "How Much is Left?," Scientific American, 30(3), September 2010.

[3] Energy Information Administration, Annual Energy Review 2009.

[4] A. Regalado, "Reinventing the Leaf," Scientific American 303(4), October 2010.

[5] R. Muller, Physics for Future Presidents, (W.W. Norton and Company, 2008), pp. 302-304.

[6] Airgas Material Safety Data Sheet No. 001003, May 2011.

[7] N. J. Duijm et al, Safety Assessment of Ammonia as a Transport Fuel, Riso Report No. 1504(EN), Risø National Laboratory, Roskilde , Denmark, February 2005.

[8] L. Van Bibber, Baseline Technical and Economic Assessment of a Commercial Scale Fischer-Tropsch Liquids Facility (DOE/NETL-2007/1260, April 9, 2007, p. 5).

[9] David Biello, "The False Promise of Biofuels," Scientific American 305(2), August 2011. As an example of some of the research being conducted in this area, see http://www.jbei.org/biofuels/index.shtml.

[10] J. Markoff, "Pursuing a Battery So Electric Vehicles Can Go the Extra Mile", New York Times, 14 September 2009.

[11] U.S. Environmental Protection Agency, Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2009, November 2009.

[12] Ben Knight, "Better Mileage Now," Scientific American 302(2), February 2010.

Danny J. Krebs
Department of Physics, Saginaw Valley State University
djkrebs@svsu.edu

Danny Krebs is retired from the NASA Goddard Space Flight Center in Greenbelt, MD where he was a lead engineer for space flight laser and detector systems. Previously he was at McDonnell Douglas Electronic Systems Company in St. Louis, where he did research leading to the first all-solid-state, pulsed high power laser. He has a B.S. in Engineering Physics from the Colorado School of Mines, M.S. degrees in Engineering Management and Physics, and a Ph.D. in Physics, all from the University of Missouri-Rolla (now Missouri University of Science and Technology). He has taught physics at Saginaw Valley State University as both an Adjunct Professor and full time faculty. This paper is adapted from a talk presented by the author to the Torch Club International Annual Convention, 25 June 2011.

COMMENTARY

Reflections on New Technology and “Non-Provocative Defense”

Alvin M. Saperstein

The United States has had its armed forces in combat for the past decade in intra-nation fighting rather than inter-nation war. The casualties suffered by U.S. troops have been primarily from small-arms fire and improvised roadside bombs, not from high technology weapons. While “high-tech” drones (remotely controlled aircraft) are often featured in the news media and have had major political impacts, it is not clear that they have had decisive impacts in changing the course of war or conflict. Focused on “low-tech” combat within nations, where the conquering of territory is not the main motive, modern readers may have forgotten the role of “high-tech” equipment in wars between states, where the seizing of territory is a paramount objective. The purpose of this commentary is to provide a reminder from recent history of the often-decisive role of science and technology in altering the course of armed conflict. We have no guarantees that the ages of inter-state warfare are over. And the concept of “provocation” – and how it may lead to mutually undesirable conflict - must be kept foremost in mind when considering any potential conflict, intra- or inter- state.

That innovations in science and technology can produce major changes in the course of war and even bring war to conclusion is well known. Examples often cited are the introduction of the English long-bow at the battle of Agincourt in the 15th century – which decimated France’s armored chivalry (perhaps forcing the end of the “age of chivalry”); the introduction of the tank in World War I – ending the age of trench warfare; the application of radar in the Battle of Britain and in the Pacific theater of war; the proximity fuse, and, of course, the use of A-bombs against Japan to hasten the end of World War II. In this paper I reflect upon the role of new scientific technology in preventing the outbreak of “Hot War”. New science-based personal armament technologies, such as anti-tank rocket launchers which could be stored in ordinary civilian homes and deployed and operated by one or two person teams, made the “non-provocative defense” of Western Europe feasible, thus making possible the end of the Cold War and the subsequent demise of the Soviet Union.

The end of the Second World War saw very rapid and extensive demobilization of the western powers, leaving very little military power deployed in Europe between the extended borders of the Soviet Union and the English Channel. Fears were expressed that there was nothing to stop Stalin’s vast tank armies from rolling west; many feared that he had the inclination to order them to do so. Presumably, the only thing that prevented the “Soviet hordes” from rolling west was the existence of the A-bomb. The western allies had “the bomb”; the eastern allies did not. The threat of the atomic incineration of Moscow in retaliation for the Soviet overrunning of Berlin (and points west) presumably held the eastern armies in check. The west’s atomic defense was cheap and so the west could relax behind its growing atomic shield and concentrate on building its own prosperity.

But by 1949 the Soviets had their own atomic weapons, and the nuclear arms race began. The concept of “Mutually Assured Destruction” took hold. Deliberate initiation of “defensive” nuclear war became unthinkable, and so the inexpensive nuclear barrier against the eastern tank armies was no longer viable. It became vital to match tank against tank, to expensively build up the mechanized armies of the west to match those of the east. Of course, the possible resultant mechanized war in Europe – accompanied by the planned use of tactical and nuclear weapons – would devastate all of Europe. As seen from the west, the massive build-up of western tank armies was purely “defensive” to counter the offensive character of eastern tank armies. (It was commonly said that only a tank could defend against a tank.)

But from a Warsaw Pact perspective, the NATO tanks looked offensive, ready and able to roll eastwards. And so each increase in mechanized arms by one side was matched – and then raised – by the other side. The result was an increasingly expensive –and unstable- conventional arms race, diverting human and material resources from the race for prosperity and frightening many with the prospect of some incident setting off World War III. The resulting dangerously unstable “peace” – called “Cold War” - was the tension between the massive strategic nuclear armaments of both sides and the large provocative conventional armies in Europe.

The west announced that its new tank armies were intended to defend the west on western soil – but as close to the inter-zone border as possible. But tanks are inherently mobile – they can go forward as well as backwards. There is nothing to prevent them, given appropriate orders from higher authorities, from charging across the border to continue, or begin, their defense on their opponent's territory. There is no practical way of distinguishing a defensive mechanized army from an offensive one. A highly mobile army is inherently a highly provocative force, and when stationed near a border it necessarily provokes the creation of a symmetric response force, as the eastern tank armies did provoke the creation of the NATO tank armies.

What was needed was an unsymmetrical response – a non-mobile force, able to defend its territory and people on its own turf but incapable of readily moving on to its opponent's turf. Hence, if the opponent truly had no aggressive intentions, there would be no need to build up its inherently aggressive mobile forces. Such a non-mobile force would be a "non-provocative defense"; its existence would not provoke the opponent to counter it or surpass it. But such a non-provocative defense had to have the potential of being effective. It had to have the capability of stopping the opponent's mobile armies long before they could overrun the defending country. Stopping tanks implies destroying tanks!

Several European nations, for example, Sweden and Switzerland, have a long tradition of maintaining civilian militias. These consist of civilians who maintain light weapons (rifles, machine guns) in their homes, periodically meeting to train to defend their neighborhoods with their light weapons. This is certainly a non-mobile non-provocative defense force. But how could they stop an invading tank army?

Science-based technical developments, starting at the end of WW II, and accelerating afterwards, changed the nature of "light weaponry", making it possible for a home-based militia to be an effective as well as non-provocative defense system. Shaped charges, radar and infra-red guidance systems, laser aiming devices, lighter and more powerful rocket motors, micro-electronic control systems and computers, and enhanced communication systems, made it possible for a dispersed group of well-trained individuals, using hand-held rocket launchers, to destroy attacking tanks and their ground-support aircraft. Instead of pitched battles between groups of mechanized warriors, there would be attrition of the invading tank columns by local civilian launched rockets and mines. Given sufficient attrition, the remaining aggressors could be pushed back by the smaller, non-provocative professional armed defenders. The organization and training of such local civilian based defense forces was not new. The novel "high-tech" weaponry that made them potentially effective against invading "panzer" forces was new, and became generally available in the 1970's.

Thus, during the late 1970's, the possibility of "non-provocative defense" (often referred to as "alternative defense" in the west, as "sufficiency" in Warsaw pact discussions) spread throughout Europe (and to a much lesser extent, in the U.S.) Starting in academia, it spread through military think tanks and soon reached the highest governmental circles in Europe. It was discussed by the West German Foreign Minister in 1986 and by General Secretary Gorbachev of the U.S.S.R. in 1987. (See, for references, Alvin M. Saperstein, "Primer on Non-Provocative Defense", Arms Control, Vol. 9, No. 1, May 1988, and notes therein.) Such thinking influenced military training and procurement as well as political and diplomatic activity, easing tensions and enhancing civil influence over the military. The prospect of worldwide strategic nuclear war initiated by minor provocations frightened everybody, and so strategic nuclear arms limitation started being discussed by the U.S. and U.S.S.R. in the 1970's. The Intermediate Range Nuclear Forces Treaty, limiting the nuclear weapons that might actually be used in a European war, was negotiated in 1987. Provocative non-nuclear armaments of both sides were significantly limited in Europe by the CFE (Conventional Forces in Europe) Treaty in 1990. The Berlin Wall fell in 1989, thus signaling the beginning of the end of the "Cold War", and two years later (1991) the Warsaw Pact, and the Soviet Union itself, dissolved.

Fear of a nuclear Armageddon certainly contributed to the failure of the Cold War to become hot. But a "rational fear" of war will not prevent" incidents" from escalating into war. Provocative defense postures by the two opponents in the Cold War in Europe offered many opportunities for such incidents. It took the spread of non-provocative defense thinking to diminish the probability of such incidents. This new thinking was made possible by the increasing anti-armor effectiveness of personal weapons, which, in turn depended upon the post -WW II evolution of science and technology.

Alvin M. Saperstein
Wayne State University
ams@physics.wayne.edu

REVIEWS

Judging Edward Teller: A closer look at one of the most influential scientists of the Twentieth Century

By Istvan Hargittai, with foreword by Peter Lax and afterword by Richard Garwin (Prometheus Books, Amherst, NY, 2010), 575 pages, $32.00; ISBN 978-1-61614-221-6.

This book is a must-read for anyone wishing to understand the principal problem facing the world inherited from the work of physicists in the last century. Although it focuses on the life of Edward Teller (1908-2003), the biography is unlikely to change the views of those who already have an opinion of Teller since there is plenty of detail to support either a positive or negative judgment.

The spectrum of perceptions includes this from Hungarian-American physicist and Nobel laureate Eugene P. Wigner: "Teller's imagination was more fertile than that of anyone else I have ever known," which he reinforced by adding that he also knew Albert Einstein. There is also this negative observation by American Nobel laureate Isidor I. Rabi: "He is a danger to all that is important. I do think it would have been a better world without Teller. I think he is an enemy of humanity."

Teller and Wigner are two members of the famous group of five Jewish Hungarian-American scientists designated informally as "the Martians," (Teller, Wigner, Leo Szilard, John von Neumann, and Theodore von Karman). Teller, though in no sense religious, was the only one who did not convert. The four conversions almost certainly were for career reasons in anti-Semitic Hungary.

The author attributes the Martian designation to a joking exchange between Enrico Fermi and Szilard during the days of the Manhattan Project. Fermi, who was dubious of intelligent life originating outside of the Earth, received a rebuttal from Szilard to the effect that it had already happened. Hungary, a nation with a small population of only ten million, had given an unlikely rise to a brilliant group of gifted scientists and mathematicians including, of course, Szilard himself. However, there is an earlier source for this legend that credits the accomplished German physicist Friedrich Georg Houtermans [1].

Teller is best known as "father of the hydrogen bomb." There is no evidence that he resented the prestige of being associated with the alleged paternity, but usually light-heartedly protested when confronted with the characterization by an interviewer saying "I am the father of Paul and Wendy," his children. In an article Teller correctly called the weapon "the work of many people."

In my judgment, although Teller and Stanislaw M. Ulam came up with the radiation implosion design that finally made the bomb possible, a more suitable candidate for the questionable "father" distinction is American physicist Richard L. Garwin. The first actual hydrogen bomb design was included in a four-page technical memorandum and sketch delivered to Teller by Garwin on July 25, 1951. The design was the basis for the MIKE shot detonated November 1, 1952 as part of the Pacific nuclear tests. The device was exploded on the small one-mile diameter island of Elugelab and had a yield of 10.5-11 megatons TNT equivalent. Garwin discusses why his design of the MIKE device was unknown to the public and not even to most scientists at Los Alamos: "The detailed proposal was presented in early 1951 to the appropriate Los Alamos committee chaired by [Hans] Bethe and as Teller states was thoroughly criticized and then endorsed and built essentially as I had proposed. It was important what was being achieved and not who proposed it and I had by then sensed what had been a guiding principle in my own life: You can either get something done or credit for it but not both."

Teller was born in 1908 in Budapest and given the name Ede, later anglicized to Edward. He attended the Minta Gymnasium and Budapest Technical University where his initial studies were in chemistry. He continued his academic work in Germany at the Karlsruhe Technical University in 1926 and the University of Munich in 1928. That year he experienced a serious accident when he fell beneath a trolley car that severed his right foot and required a prosthesis which he wore the remainder of his life. It did not interfere with his later activities and was not even noticed by some of his associates.

In 1929 he transferred to the University of Leipsig where he studied for his PhD under the renowned Werner Heisenberg. Heisenberg was the object of Teller's lifelong affection and warmest respect, sentiments not wholly reciprocated by Heisenberg. As with Teller, there were aspects of Heisenberg's life considered egregiously deplorable. On the positive side, though urged to do so by the Nazis, he refused to condemn Einstein's and other Jews' physical theories and was even labeled a "white Jew" by the Nazi press and may well have ended in a concentration camp or worse except for the intervention of his mother who had a long friendship with the mother of the savage Nazi SS leader Heinrich Himmler. Himmler's mother persuaded her son to leave Heisenberg in peace.

On the other side, Heisenberg became head of the German atomic bomb project. Despite his post-war claim that his lack of success was attributable to moral considerations against such a weapon, Heisenberg and his colleagues continued working on the project after the Nazi leadership had given up confidence in achieving the bomb as a meaningful weapon in the war. This misrepresentation was further advanced by Teller: "I believe the idea of putting the power of an atomic bomb into Hitler's hand was consciously or unconsciously repellant to many of the scientists involved, but most especially to Heisenberg." [2]

One of the controversial and important subjects treated carefully in Hargittai's book was whether the atomic bombings in the populated cities of Hiroshima and Nagasaki were justified in terms of the massive numbers of immediate and long-term civilian deaths. With the prior history of fiercely determined Japanese resistance in the South Pacific and the home island of Okinawa, President Truman and his military advisors came to the conclusion that far more American and indeed Japanese lives would have been lost in a required full scale invasion than was lost in the atomic bombings.

There is much to be learned from this book aside from details associated with Teller such as his rejection by a large segment of the scientific community following his devastating testimony at the 1954 Atomic Energy Commission on security clearance hearings for the Manhattan Project's scientific director, J. Robert Oppenheimer. Important is the author's debatable conjecture that the breakup of the Soviet Union was at least in part attributable to Teller's vigorous defense of President Ronald W. Reagan's (1911-2004) famous Strategic Defense Initiative (SDI) speech of March 23, 1983, in which the President proposed a total "non-nuclear" defense against nuclear weapons. Teller, though supportive of the SDI concept, visualized not a non-nuclear but a sophisticated nuclear x-ray laser defense system. To this day neither Reagan's SDI or the x-ray laser itself has been achieved. According to the theory, developing its own SDI represented an insupportable economic and indefensible burden to the continued existence of the Soviet Union.

With his political antagonism toward the Soviet Union during the years of the Cold War, Teller's advice and support were sought by major American military elements. Teller's opinion of the wickedness of the Soviet Union was derived in substantial measure from the writings of author Arthur Koestler, particularly his famous novel Darkness at Noon.

This reviewer deduces from this book the conclusion that humanity may be on the precipice of destruction. Consider the large distribution of nuclear weapons already held by nation states or others who either have the capacity or the desire to make them. Also, in the last century, there were two occasions when only the restraint of political leaders or a changing military situation prevented nuclear weapons use. The first was the 1962 Cuban missile crisis. The second was the authorization by Israel's Prime Minister Golda Meir to her military chief-of-staff Moshe Dayan to use nuclear weapons if necessary against the invading armies of Egypt and Syria during their near success in the 1973 Yom Kippur war.

Some of the best American and Russian scientific minds of the last century proposed the preemptive use of nuclear weapons. Russian physicist Andrei D. Sakharov, characterized as the father of the Soviet hydrogen bomb, suggested exploding a thermonuclear device in an enemy port, presumably New York City [3].

According to Hargittai, Oppenheimer considered the possibility of using atomic bombs in the Korean conflict. Though regarded as the most aggressive "hawk," Teller did not support either Oppenheimer or his good friend and fellow Martian, von Neumann, who had advocated nuclear strikes on Moscow.

One must conclude that the START treaties and non-proliferation agreements, though useful, are not at all adequate. A think tank should be established dedicated exclusively and with sufficient resources to address the issues involved.

References

[1] *Physics Today, July 1992, p. 29.*

[2] *Edward Teller with Judith Shoolery, Memoirs: Twentieth Century Journey in Science and Politics (Perseus Publishing, Cambridge, MA, 2001), p. 230.*

[3] *Andrei Sakharov, Memoirs, translated by Richard Lourie (Alfred A. Knopf, New York, 1990), p. 221.*

Leonard R. Solon, Ph.D
Former member of U.S. Atomic Energy Commission
crsolon@aol.com

The Quest for a Fusion Energy Reactor

by Weston M. Stacey, Oxford University Press, New York, 2010, 160 pages, ISBN 978-0-19-973384-2, $25 hard cover.

The technology of thermonuclear fusion with magnetic containment progressed through construction of ever larger and more expensive devices until, by 1978, the magnitude and cost of future devices suggested need for a large international collaboration. This book is about the first phases of that collaboration, called the INTOR (International Tokomac Reactor) project, led by the U.S., USSR, European Community, and Japan. Author Weston Stacey led the U.S. effort.

The first half of the book is about the "Zero Phase," December 1978 to January 1980, for deciding on the scope of the project. Half of the remainder deals with Phase 1, extending until August 1981, for developing a conceptual design, and nearly all of the rest describes Phase 2A, 1981-1988, for refining some details of the conceptual design but mainly keeping the program alive while trying to work out severe political problems that threatened to halt further progress until the problems were suddenly overcome by a Gorbachev (USSR) initiative at a summit meeting with Reagan. The book concludes with a four page epilogue on how INTOR was transformed into ITER (International Thermonuclear Experimental Reactor), construction of which began in 2009 at Cadarache (France) with scheduled completion in 2018.

INTOR consisted of a series of international workshops, mostly in Vienna with some support from International Atomic Energy Agency, at which various specific problems were laid out to be studied as "homework" by each of the four participating nations. The results were reported at the next workshop where differences among the four presentations were reconciled or re-assigned for further study and reporting at the following workshop. The U.S. homework was spread among many groups, with frequent meetings among them.

For example, the zero phase for determining the scope of the project originally divided the problems into plasma heating, magnets, plasma confinement, impurity control, plasma stability control, start-up, burn, shut-down, energy storage and transfer, fueling and exhaust, tritium production and storage, materials, first wall, shielding, mechanical design, remote maintenance, blanket, diagnostics, cost and schedule, and facilities and personnel. After several cycles of studies, reports, and workshops, a 650 page Phase Zero final report was published including contributions from over 500 engineers and physicists. It recommended a device for demonstrating the physics and engineering components needed for a commercial reactor (without electricity generation) and serving as a test facility for tritium breeding.

The book deals with the many problems in arriving at consensus agreements. Each participating country had its own program with ambitions for constructing a competing, albeit less elaborate device, so INTOR participants had difficulty (and were frequently unsuccessful) in selling these agreements to national authorities such as the U.S. Department of Energy. There were various frictions between and within the national groups. The author describes social activities that succeeded in smoothing these, including details of the coffee breaks, restaurants, and banquets utilized. Eventually, a spirit of international camaraderie and trust took root among the participants, which in itself was one of the most important achievements of the INTOR program

This book contains little of value for a reader interested in technical issues, aside perhaps from very brief discussions of alternative methods for plasma heating and of diverters for keeping impurities out of the plasma. There are a few diagrams which are small and condensed, with marginally adequate explanation. Appendix B gives tables of contents of INTOR reports which contain the technical details, and Appendix D lists the 65 Tokomaks in the World with their dimensions and properties. But the book is essentially about personal and political relationships. Long lists (in one case covering nearly two pages) of participants at each meeting and their professional connections are given. The author earned my admiration for how he managed those relationships. Personally, I was much impressed with the progress and success of the often maligned idea of "design by committees," especially committees of such diversity.

The book is short and easy to read. It describes rapidly moving activities, which maintains interest and avoids boredom. I would recommend it to anyone for whom the problems of organizing and developing a large international scientific project is of interest.

Bernard L. Cohen
Physics Dept., University of Pittsburgh
Pittsburgh, PA 15260
blc@pitt.edu