

# Physicists and Effective Public Policy – Science Matters

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**A Talk at Science Salon**  
of the  
New York Hall of Science  
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It's a great pleasure for me to speak at the New York Hall of Science's "Science Salon." I thought I would give a brief presentation and then invite questions and comments, so I hope you will use some of the next 20 minutes<sup>1</sup> to formulate such. I use the term "physicist" to include here also Jerome B. Wiesner, more properly an electrical engineer, eventually to be Science Advisor to President John F. Kennedy, and also President of MIT. And I include William O. ("Bill") Baker, polymer chemist and much more at Bell Telephone Laboratories, a long-time member of the President's Science Advisory Committee (PSAC) and a key person especially in intelligence. Also a real physicist, Emanuel R. (Mannie) Piore, eventually Director of Research and then Chief Scientist of IBM, important in building post-WW-II university science in the United States, from his position in the Office of Naval Research. I played a role in such activities also, with two 4-year terms on PSAC, and other involvements to which I will introduce you.

I received my B.S. in physics from what is now Case Western Reserve University in Cleveland in 1947 and went to Chicago with my new wife for graduate study in Physics. Uneasy without a laboratory, I asked Enrico Fermi to take me on as an assistant and as a Ph.D. candidate, and received that degree in December 1949 for the

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<sup>1</sup> Only a portion of the text was actually spoken, but almost all was exhibited on the projection screen.

first measurements of the angular correlation between a gamma ray and the previous beta ray from nuclear decay. In the course of my thesis work, I invented and published a simple coincidence circuit of few-nanosecond resolving time that became the standard in the field for several decades, and also the “adiabatic light pipe” for scintillation counters that, respecting the limits of physics, did the job of transporting light from a narrow rectangle to a circular detector (phototube).

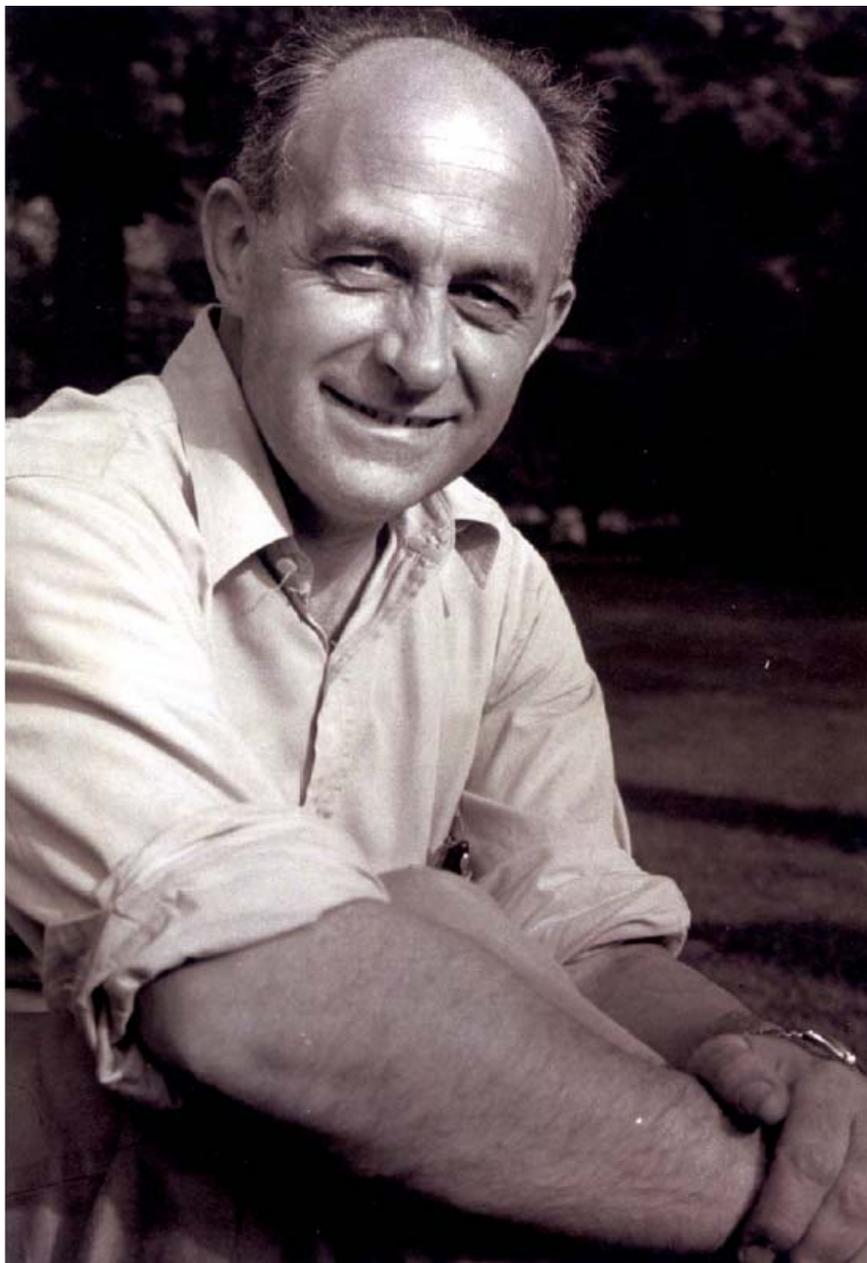
Perhaps my entry into the world of weapons, healthcare, and national technology was the result of an urge to prevent or solve social and national problems. It was at least equally due to my unfamiliarity with the system of obtaining research grants and to the fact that the University of Chicago paid faculty salaries for 9 months, and I and my family ate for 12. I showed an early and largely unwelcome talent for providing advice to my colleagues, which led Fermi to suggest that I accompany him to Los Alamos during his summer consulting stint there in 1950. At the Los Alamos Scientific Laboratory, responsible during WWII from 1943-1945 for actually designing and building the nuclear weapons that destroyed Hiroshima and Nagasaki, and until 1952 the nation's only nuclear weapons laboratory, I learned the technology of nuclear weapons and their testing, and contributed to both.



Little Boy and Fat Man – Hiroshima and Nagasaki bombs  
~13 and 20 kilotons



## Tibbets' copy of Hiroshima destroyed



Enrico Fermi in Los Alamos, 1952. (Photo by Harold M. Agnew)

I spent the first week in the Los Alamos Classified Report Library reading the weekly progress reports back to 1943 of the groups that developed the nuclear weapon.<sup>2</sup> I was fortunate to share a small office with Enrico Fermi, our desks facing one another, his back to the window, mine to the door. I tended the safe and maintained my secret laboratory notebook in which Fermi would occasionally write something for his own record or for my edification. For example, here is his calculation of seismic radiation from a fully contained underground nuclear explosion, perhaps motivated by a question of reducing the intensity of seismic waves at Las Vegas, NV, produced by underground detonations at the nuclear test site some 110 km away.

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<sup>2</sup> I have reported some of this in my papers, “Working With Fermi at Chicago and Los Alamos” <http://tinyurl.com/3b55eqb>, and “Working With Fermi at Chicago and Post-war Los Alamos” <http://fas.org/rlg/010929-fermi.htm>.

### Explosion in underground cavity

(E. Fermi in R.L. Garwin's notebook LANS 3616)

Total energy =  $5 \times 10^{21}$  ergs =  $W$

Initial radius  $R = 33$  m

Initial volume  $\frac{4\pi}{3} R^3 = 1.25 \times 10^5$  m<sup>3</sup>

$$p = \frac{W}{V} (\gamma - 1) = \frac{5 \times 10^{21}}{1.25 \times 10^5} \cdot \frac{2}{3} = 2.7 \times 10^{10}$$

From p. 6

Assume equation of state of rock

$$E = \frac{1}{2} k (v_0 - v)^2 = \text{ergs per cc}$$

$$p = (v_0 - v) k$$

$$c = \sqrt{k v_0^2}$$

$$v_0 = .4 \quad c = 5 \times 10^5 \quad k = 1.57 \times 10^{12}$$

From 3rd Hugoniot

$$\frac{1}{2} k (v_0 - v_1)^2 = \frac{1}{2} p (v_0 - v_1)$$

$$v_0 - v_1 = \frac{p}{k} = \frac{2.7 \times 10^{10}}{1.57 \times 10^{12}} = .0172$$

$$v_0 = .4000$$

$$v_1 = .3828$$

"Explosion in underground cavity" seven pages by Enrico Fermi in R.L. Garwin's Los Alamos notebook (LANS 3616), calculating the radiated wave from an explosion in an underground cavity of initial radius 33 m, and total energy 100 kt. (070050.EF)

30

From 2nd Hug

$$U^2 = \frac{v_0^2}{v_0 - v_1} p = \frac{.4^2}{.0172} \cdot 2.7 \times 10^{10} = 25.1 \times 10^{10}$$

From 1st Hug

$$u = \frac{v_0 - v_1}{v_0} U = \frac{.0172}{.4} 5 \times 10^5 = 2.15 \times 10^4$$

radial expansion  $q' - 1$   $q = \text{new radius}$   
 lateral "  $\frac{q}{r} - 1$

Density of elastic energy

$$\frac{\alpha}{2} [(q' - 1)^2 + 2 \left(\frac{q}{r} - 1\right)^2] + \beta \left[ \left(\frac{q}{r} - 1\right)^2 + 2 \left(\frac{q}{r} - 1\right) (q' - 1) \right]$$

Elastic energy =

$$W_{el} = \int 4\pi r^2 dr \left\{ \begin{array}{l} \text{radial expansion} \\ \text{lateral expansion} \end{array} \right\}$$

[sequelae in my 11/03/2011 talk]

That first summer I was attached to the Physics Division at the Lab, headed by Jerry Kellogg, who in 1952 advised his friends at Columbia University and IBM, when they proposed to offer me a job, “If you hire him, you will regret it, but you will regret it more if you don’t.”

At Los Alamos in June 1950, I began to build an apparatus for the measurement of d-t and d-d cross sections down to 10 keV or so (useful for the thermonuclear weapon work), and although I couldn’t complete the experiment, by far, before the end of summer, the Lab decided that this was a necessary and reasonable approach and created a team to carry out the measurements. Fermi recalled an ingenious British physicist, Jim Tuck, who had been at Los Alamos during the war, and brought him first to Chicago while his clearance was restored, and then to LASL to head the team, which published in 1954<sup>3</sup>.

At the same time, I was interested in applying my new-found knowledge of shock waves and the phenomena of nuclear weaponry, and devised several approaches for obtaining detailed information in nuclear weapons tests, publishing secret lab documents, including the proposal to use stable isotopes at particular points in a 1951

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<sup>3</sup> "Cross Sections for the Reactions  $D(d,p)T$ ,  $D(d,n)He^{*3}$ ,  $T(d,n)He^{*4}$ , and  $He^{*3}(d,p)He^{*4}$  below 120 keV," by W.R. Arnold, J.A. Phillips, G.A. Sawyer, E.J. Stovall, Jr., and J.L. Tuck in Physical Review Vol. 93, No. 3, pp. 483-497, Feb. 1, 1954.

nuclear explosion test in order to determine position, neutron spectrum, and fluence (time integrated flux) by the amount of the resulting radionuclide.<sup>4</sup> This became a standard technique. I also identified a long-range, long-time interaction between nuclear explosions -- a matter of growing importance at that time, with larger numbers of nuclear weapons that might be used on the battlefield, and also in view of the use of nuclear-armed defenses against bombers and missiles. This novel result was quickly verified by Alvin and Elizabeth Graves, at the Nevada Test Site.

In August or September I returned to Chicago to take up my regular duties of research and instruction, working with the 100-MeV betatron and preparing experiments for the 450-MeV synchrocyclotron being built at Chicago. Here I provided more unwelcome suggestions and advice to my colleagues, while I worked to build external targets containing liquid hydrogen or liquid deuterium for the meson beams from the cyclotron.

But I should talk about more important matters on which I have some knowledge and not necessarily those to which I contributed. As an aside, over many decades I have tried to persuade individuals and organizations that innovation and not only invention should be prized and rewarded. Too often, one finds a person so wrapped up in

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<sup>4</sup> The proposal was published August 11, 1950, and a status report October 12, 1950.

creating something new that he or she ignores what has been done outside. Further, there is little reward for bringing into an organization best practices or for licensing a patent that would solve the problem at affordable cost. Early on, I felt, perhaps naturally, that getting credit for one's ideas was important. But in 1953 I learned from Jerome B. Wiesner, "You can either get credit for something or get it done, but not both."

During the summer of 1950, from a distance of about two meters, I watched Enrico Fermi and mathematician Stan Ulam, morning after morning, do their best to calculate the performance of a propagating fusion burn in an infinite cylinder of liquid deuterium. This required attention to the local temperature, with the cylinder zoned axially and radially, the resulting d-d (and d-t) reaction rate, the loss of energy from ions to the electrons, and from the electrons by Bremsstrahlung. There was also the deposition of energy locally from alpha particles and, at a distance, from the neutrons from the reaction, with resultant energy density contributing pressure gradients that led to the hydrodynamic disassembly of the burning stick of deuterium.

Except that it would not burn without being enriched with more tritium than would ever be possible. Ulam would sit next to Fermi's desk, while Fermi would fill out "cells" on a paper spreadsheet, with the time going down the page. He had

transformed the differential equations to first-order equations, so that from one time step to the next there would be the calculation of quantities and the addition of an increment. Multiplications and exponentials Fermi did on his slide rule, and additions and subtractions on a motor-driven Marchant desk calculator. After filling in six rows or so on the spreadsheet, Fermi and Ulam would call in their computer, Miriam Caldwell, who would day after day take away the spreadsheet with its equations and bring it back the next morning filled in for the two scientists to plot, diagnose and to prescribe different parameters.

Fermi was rightly famous. He was modest about his accomplishments, except for his physical stamina. He had received the Nobel Prize December 1938 for his 1934 work with slow neutrons, including the discovery of transuranic elements, most of which were recognized in January 1939 to be, instead, fission products from the irradiation of uranium with neutrons. Fermi was known also for his four-field theory of beta decay, a manuscript rejected by *Nature* magazine in 1933, much to their later dismay.

Fermi had used the opportunity of the Nobel Prize Award to leave Italy with his wife and two children, concealing his plan not to return but to take a position at Columbia University. Within weeks after the Nobel Prize, Lise Meitner and Otto Frisch

conceived and published the concept of nuclear fission. When the news reached Fermi at Columbia he naturally wanted to study fission as a physical phenomenon, but was persuaded by Leo Szilard that fission had the potential to lead to nuclear weapons and that it was important for Fermi to study this instead. His work on “exponential piles” of uranium (or uranium oxide) lumps in a graphite lattice led to the first self-sustaining nuclear reactor at the University of Chicago December 2, 1942.

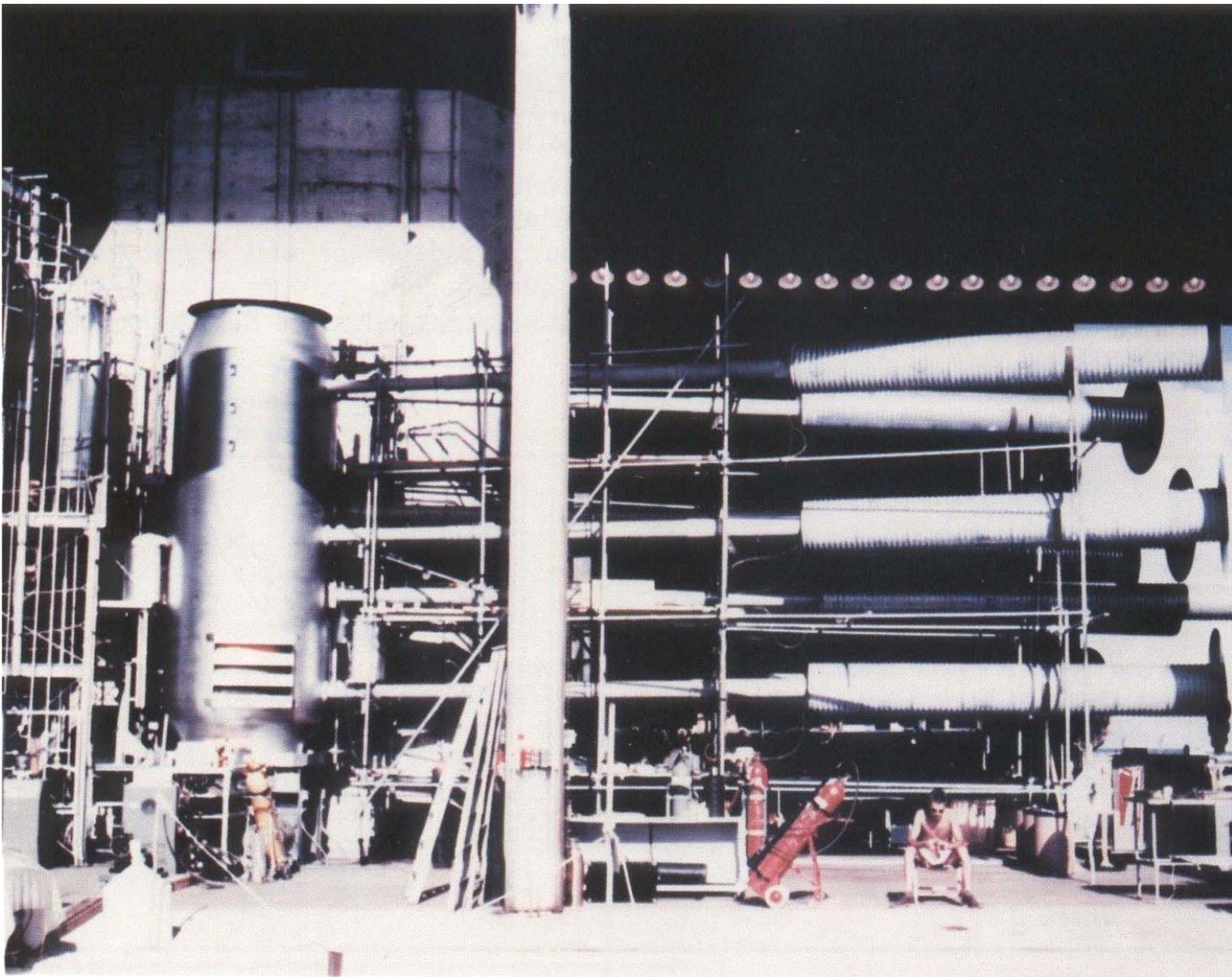
The Los Alamos Scientific Laboratory (“Site Y” of the Manhattan project) was founded in March 1943 in order to build bombs of the enriched uranium to come from Oak Ridge and the reactor-produced plutonium to come from Hanford, Washington. Fermi, with Eugene Wigner and others remaining at Chicago, was designing the 200 megawatt (thermal) production reactor at Hanford, on the basis of data from the 2-watt Chicago pile. When Fermi did go to Los Alamos in 1944, staying until December 1945, he was referred to as “The Pope,” for the infallibility of his predictions and the accuracy of his estimates. Rather than answer a question directly, Fermi would often ask, “Have you considered the influence of X?” But, if pushed, he would give the answer and an estimate of the magnitude of the quantity involved.

When I returned to LASL in May 1951, Edward Teller told me what had been going on at the Lab, particularly the Teller-Ulam invention of radiation implosion. He asked me to provide the design of an experiment that would be absolutely persuasive of the correctness of this principle. It seemed to me easier to achieve and most persuasive to demonstrate this principle at full scale. After I had sketched the design of MIKE, published at LASL July 25, 1951, I still had a month or so that summer at the Lab, and so designed flyable versions of the liquid-deuterium thermonuclear weapon, which I learned much later were actually built and deployed by early 1952, as yet untested, under the name, JUGHEAD.

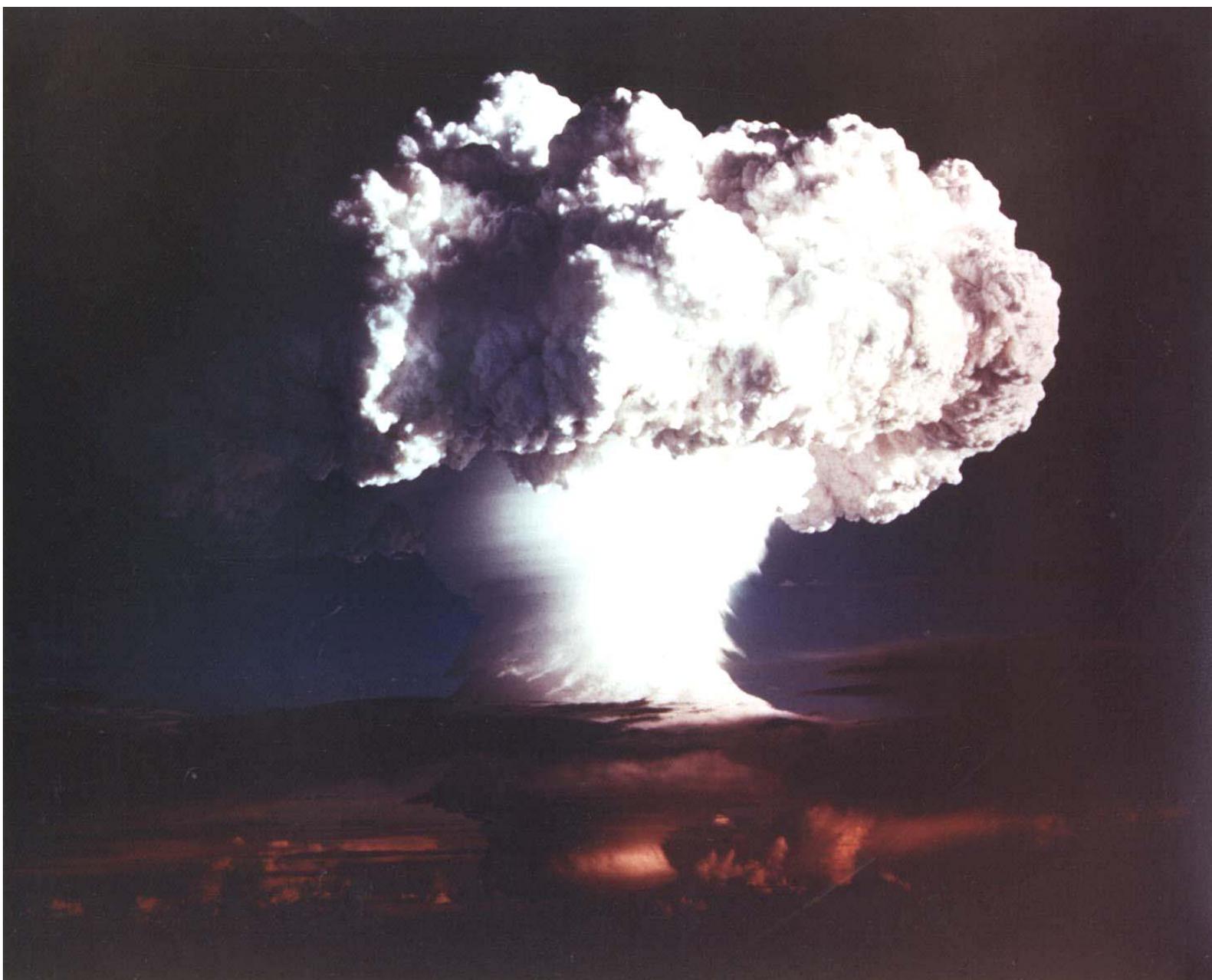
MIKE was tested November 1, 1952 with a yield of 11 megatons, almost 1000 times the yield of the Hiroshima bomb. As Teller later wrote, *“Garwin's blueprint had been criticized by many people, including Hans Bethe. In the end the shot was fired almost precisely according to Garwin's design, and it worked as expected.”* The Los Alamos website<sup>5</sup> now states, *“Shortly after President Truman's directive to proceed with the hydrogen bomb program in January 1950, research began to bear fruit. Edward Teller and Stanislaw Ulam came up with a promising design, involving radiation implosion, which was translated by Richard Garwin into a working design.”*

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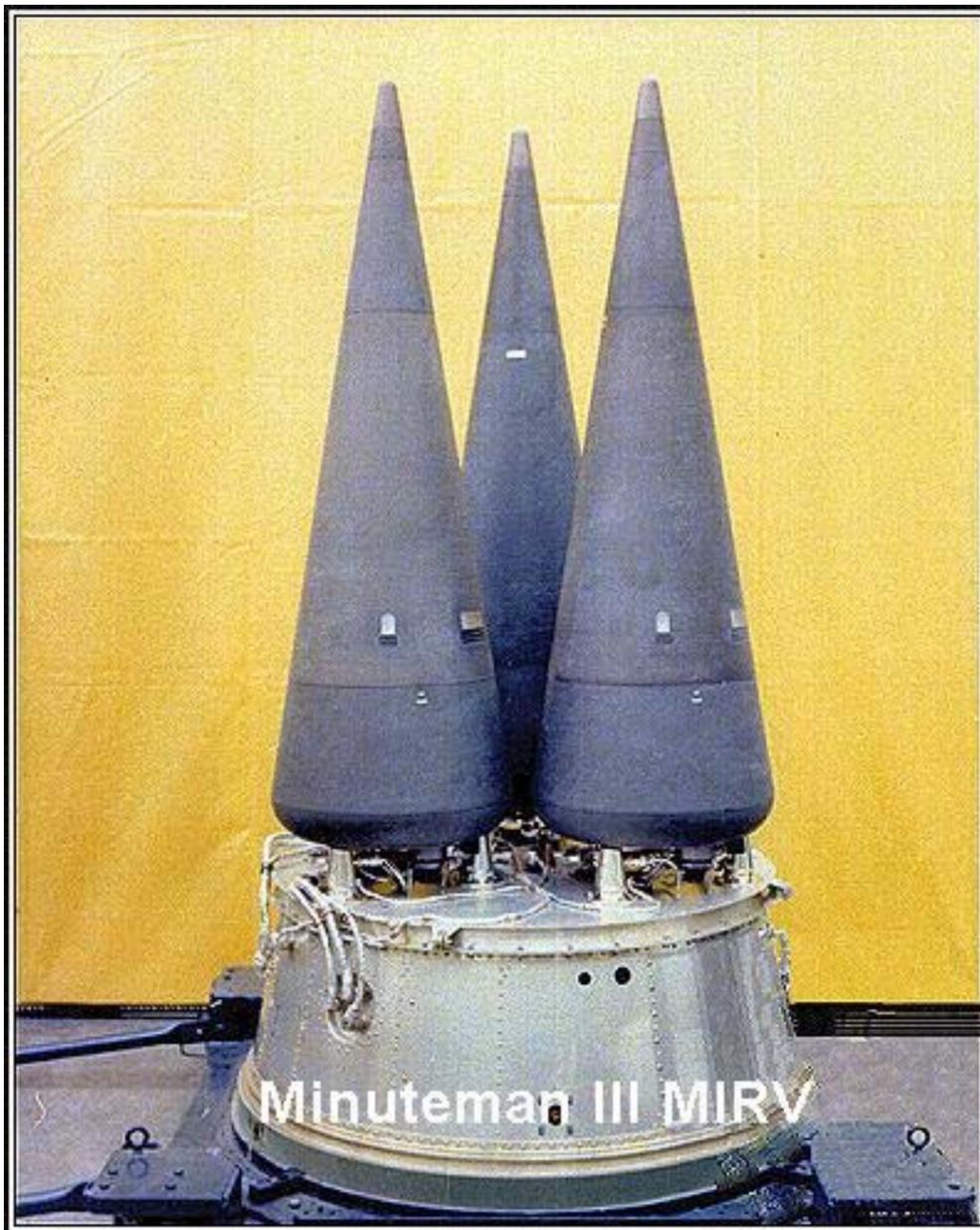
<sup>5</sup> [http://www.lanl.gov/history/story.php?story\\_id=19](http://www.lanl.gov/history/story.php?story_id=19)



Ivy Mike in preparation



Ivy Mike mushroom cloud, 11 megatons



Modern U.S. nuclear warheads-- ~330 kt each

When I moved to New York December 1952 to join the IBM Watson Scientific Laboratory at Columbia University, it was with a clause in my employment contract that permitted me to spend one-third of my IBM time working with the U.S. government on matters of national security and technology, and IBM would have no access to the substance of my involvement. This was to hold until my retirement from IBM more than 40 years later.

I moved from Chicago because I was more interested in conducting my own research than in working in particle physics as a member of a group of six, with the necessity to say what one was going to do six weeks in advance. Little did I know that it would become groups of 600 and a time horizon of six years. At IBM I began to work in low-temperature physics (condensed matter) with thin-film superconductors and superfluids and other aspects of He-3 and He-4.

At my new laboratory and in my new field I had much more control over topic and schedule than in arranging for time on a shared particle accelerator, and there was an excellent atmosphere for research and invention under the directorship of Wallace J. Eckert, astronomer from Columbia University, who was the person who had introduced the punched card into scientific computing in the 1930s.

Not long after I arrived in New York, and at about the same time as the birth of our second son in March 1953, I was asked by the top echelon of IBM to work for a year with the Project LAMP LIGHT study group of MIT, which was a collection of physicists and electrical engineers exploring the extension of the air defense system of the United States and Canada to the sea lines of approach of Soviet bombers. This is not what I had signed up for at IBM, but I had intended to involve myself in the technology of information storage and transmission, so I was, in fact, quite interested in the subject. I managed to negotiate spending half-time for the year, at LAMP LIGHT three days a week, while my already long-suffering wife managed with two young sons at home at our apartment in Riverdale, NY.

This did introduce me to Jerome B. Wiesner, in 1961 to become President John F. Kennedy's Science Advisor and PSAC chair, and Jerrold Zacharias, Professor of Physics at MIT. It was from Zacharias that I learned, "Don't get it right, get it written!" And from the other members of the study group the science and engineering of radar and communication systems, including "meteor-scatter radio communications" and the like. I was introduced to a whole additional semi-secret world of technology but also to the overall weapon delivery systems and contest of offense vs. defense of strategic nuclear weapons.



**Jerome Wiesner**

**Jerrold Zacharias**

Wiesner and Zacharias brought me into the advisory circles in the White House-- PSAC and the Office of Science & Technology-- OST. It does not serve the presidency well for his or her science and technology advisory apparatus to wait until asked to provide advice on some matter. First, when there is policy or legislation, the Science Advisor should take a pro-active role, routinely considering how S&T could be used to achieve goals or reduce cost or minimize hazard. The policy staff in the White House often have not understood the extent to which S&T could help in the evaluation or the conduct of some program.

I proposed during the Johnson Administration that the newly created Department of Housing and Urban Development (HUD) should model and simulate response to any legislation and programs that it intended to initiate, and, further, that because of the federal responsibility for Washington, DC, that the government should create at least one working model (administration and accounting) for each program for which it would be responsible nationwide, so that local governments or states could, but need not, adopt that model by default and avoid the delay and cost of creating their own. It was far from a “rogue” Office of Science and Technology, though, because every significant activity was done with the approval of the President or of White House staff or that of the Office of Management and Budget-- OMB.

Some of these activities, though unheralded, were significant, as with a one-day workshop in 1965 that I helped organize on the topic of airport noise. I had chaired the Military Aircraft Panel of PSAC for years, and that Panel had now taken up civil aviation and even the Northeast-corridor transportation question. Among the problems of commercial air transport were airfield acceptance rates, both land side and ground side, airport noise, and the like. OST staff and I looked at the available technology for quieting aircraft and thus making airfields better neighbors for commercial and residential neighborhoods and decided that much could be done. There were, of course, comments from industry and their contractors that, “noise was

wasted energy,” and that manufacturers and operators in the pursuit of lower cost and profits would automatically minimize noise. However, the amount of energy required to provide unbearable noise is a tiny fraction of the operating cost of aircraft, and the power loss to noise not a significant incentive toward noise reduction.

I remember being, somewhat later, at a reception on the top-floor terrace of the Department of State building at 22nd and C, NW, in Washington, talking with former IBM Chairman and CEO Vin Learson. Our chat was interrupted by aircraft coming in to land at nearby Washington National Airport, and I explained how it would soon be much better in view of the OST airport noise workshop of 1965. In fact, the improvement has been remarkable. Now aircraft whisper in over the State Department terrace—an example of how much can be accomplished in the longer run (not a result of a decline in my hearing acuity).

Although I did not know it in 1953, Wiesner and Zacharias were members of the Science Advisory Committee of the Office of Defense Mobilization, nominally advising the President of the United States, although he had never met with it. That is, until September 1954, when President Dwight D. Eisenhower asked the SAC to formally initiate the Technological Capabilities Panel (TCP) in response to the first Soviet test of a nuclear weapon containing fusion fuel, and the March 1, 1954, U.S.

test, CASTLE BRAVO, of a 15-megaton deliverable (i.e. solid-fuel-- lithium hydride) nuclear weapon.

The exceptional performance of the TCP under James Killian led to the highest priority being given by President Eisenhower to the Air Force ICBM program and then to the mid-range ballistic missile program, to the first flight of a fleet of Top-Secret U-2 reconnaissance aircraft<sup>6</sup> over the Soviet Union in 1956, to the development of the Top Secret CIA OXCART A-12 (later dubbed the SR-71) Mach-3 titanium reconnaissance aircraft, and to the CORONA film-return satellite system that with its first operational flight in August 1960 dispelled the myth of Soviet superiority in deployed long-range missiles—one of the elements of the Kennedy presidential campaign to which Wiesner was a technical advisor.

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<sup>6</sup> <https://www.cia.gov/library/center-for-the-study-of-intelligence/csi-publications/books-and-monographs/the-cia-and-the-u-2-program-1954-1974/u2.pdf>



## The SR-71 OXCART Mach-3 Recon Aircraft

Not until 1957 were the SAC and the TCP elevated to the Eisenhower White House 18-person President's Science Advisory Committee (PSAC) of which Wiesner and Zacharias became members, and to which I was a consultant. I then had two 4-year terms on PSAC under Presidents Kennedy and Johnson, and Nixon.

An Eisenhower passion was a ban on explosive testing of nuclear weapons; in his May 29, 1961 statement to the American people he characterized the failure to obtain a universal ban on nuclear weapon tests as “the greatest disappointment of any administration—of any decade—of any time and of any party.”

For PSAC I chaired several of the military-oriented panels, which like the parent committee, typically met for two days a month and took their tasks very seriously. I was a member also throughout the PSAC era of the Strategic Military Panel, SMP, together with Hans Bethe of Cornell, “Pief” Panofsky of Stanford, and others, where my background in nuclear weapons, radar, and intelligence was helpful. I was impressed by the seriousness and dedication of these people, and their commitment to informing the President and his staff, and to providing not arguments in favor of a preconceived program, but potential solutions with their positive and negative aspects.

I mention my copying and distributing the Rachel Carson *New Yorker* articles, later published in book form as “Silent Spring,” that led to the creation of the PSAC Panel on Insecticides and Pesticides, under the chairmanship of John Tukey, statistician and extraordinary contributor from Bell Labs and Princeton University. I used to sit next to John at PSAC meetings, in part to eat some of his supply of dried prunes.

Panofsky, in particular, was a phenomenon of energy and words. He would use his flight from Stanford (San Francisco Airport) to draft position papers, and his flight home to do more. He recounts that after his return from a two-day PSAC (or Panel) meeting in Washington, he and his wife, Adele, would take the laundry from their

home with five children to a local laundromat, then proceed to the university where she would help him set up physics demonstration equipment for the early-morning lecture the next day. Then back to the laundromat to pick up the dried clothes. And, of course, Panofsky's secretary would then be busy transcribing his in-person dictation into lucid and technically competent prose for circulation to his PSAC colleagues or to those on the Strategic Military Panel.

This was complicated by the very secret nature of much of the work, but fortunately Pief and Sid Drell had an authorized security-cleared facility for defense secret and Atomic Energy Commission Restricted Data ("RD") documents.



“Pief” Panofsky

The PSAC SMP was concerned with both U.S. offensive and defensive strategic weapons, although the long-range bombers were handled in the PSAC Military Aircraft Panel (MAP) which I chaired. We dealt also with Soviet ballistic missiles and bombers and with the creation of a Ballistic Missile defense (BMD) system in the United States for countering the missiles. And with the Soviet BMD system, particularly sites deployed around Moscow, which were revealed to be equipped with SA-2 interceptor rockets for defense against U.S. bombers, and later with the nuclear-armed exo-atmospheric interceptors (GALOSH) to counter U.S. ballistic missile

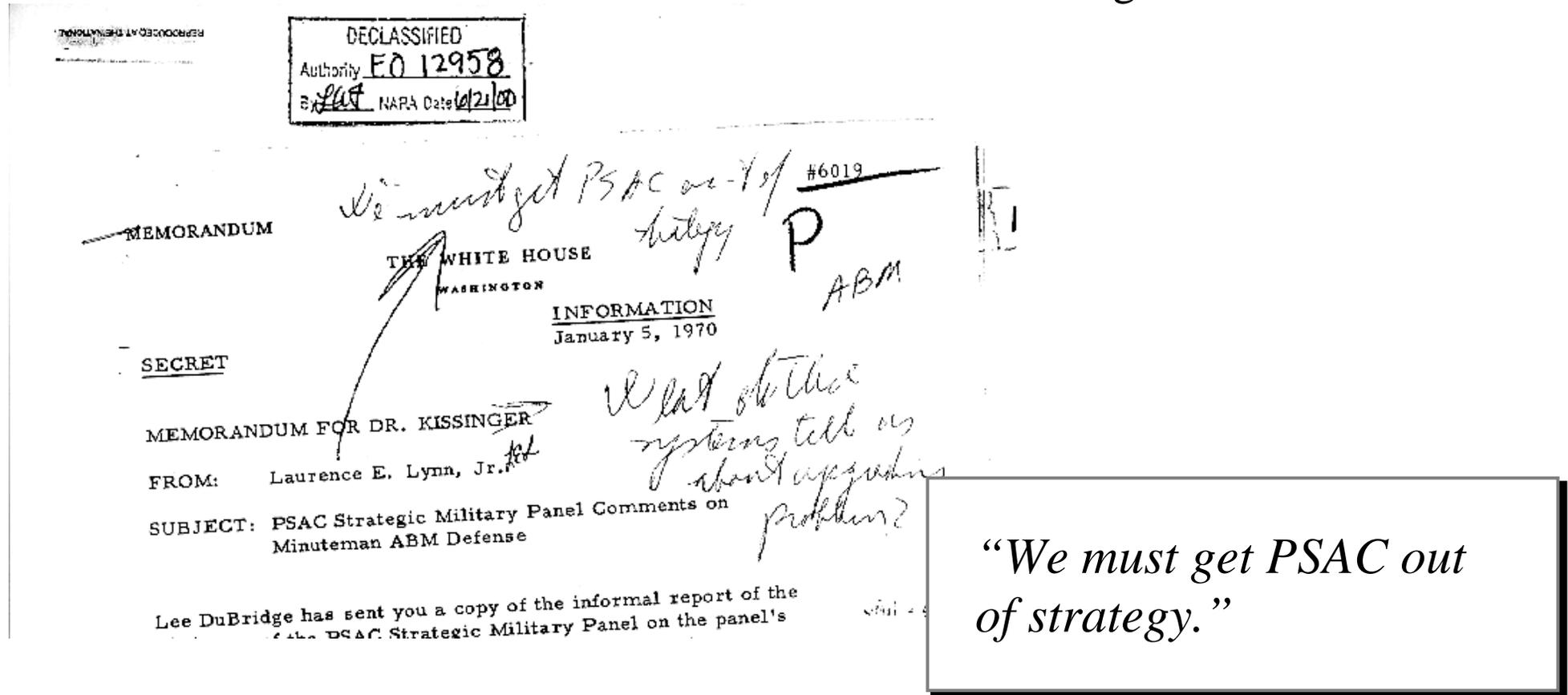
warheads. On May 1, 1960, an SA-2 rocket shot down Francis Gary Powers's U-2 near Sverdlovsk, scuttling a planned 4-power summit meeting in Paris.

Each year, in preparation for the budget decisions, the SMP would provide the President an assessment of the current proposal of the U.S. army for ballistic missile defense of the country or, in some cases, of the strategic offensive retaliatory missile force. As befits elements of the government, the Army had a program every year ready for deployment. It had excellent contractors for the radar and interceptor in the AT&T Bell Telephone Laboratories, and for phenomenology of reentry physics, the MIT Lincoln Laboratory. The SMP assessed much work by Lincoln and Bell Labs on measurements of reentry phenomenology, both optical and radar, which might be used in discriminating real ballistic missile warheads from decoys.

Every year we would write the President in a Top Secret memo that the missile-defense system would have this or that performance, but that it could be nullified with technical countermeasures, with tactics, or it could be overwhelmed by numbers of incoming reentry vehicles. Or destroyed by a small fraction of the warheads.

The enthusiasm with which the President's National Security Advisor (Henry Kissinger for President Nixon) received these substantive highly classified reports is

clear from the note on this declassified memo<sup>7</sup> from Kissinger's aide:



Conflict between supporters of the BMD systems and the objective analysis of PSAC probably contributed to Nixon's eliminating PSAC in early 1972, at the end of my second four-year term. PSAC members, including Jerry Wiesner, then a consultant-

<sup>7</sup> “Missile Defense Thirty Years Ago: Déjà Vu All Over Again?” Edited by William Burr, December 18, 2000. <http://www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB36/index.html>

at-large, had asked the PSAC chair, President's Science Advisor Lee Dubridge, whether they should resign from PSAC in order to provide their own personal testimony to Congressional hearings on the antiballistic missile (ABM or BMD) system. Dr. Dubridge conveyed the President's advice that PSAC members should not resign—that it was important for the Congress to have the personal views of the members. But other White House staff were undoubtedly unhappy with such testimony, and with my own on the commercial Supersonic Transport (SST) program that I had studied for both the Johnson and Nixon administrations.

This BMD story extends to the present day, with the evolution of technology and the proclamation by President Ronald Reagan, March 23, 1983, of the Strategic Defense Initiative (“Star Wars”) that would use orbiting directed energy weapons (laser or neutral particle beams--NPB) to destroy Soviet ballistic missiles in their boost phase. The intent was to provide an impenetrable shield so that not one of the 6000 Soviet reentry vehicles armed with nuclear warheads could strike the territory of the United States. This fantasy is not beyond the laws of physics, but taking account not only costs and technology and time on the United States side but also the vulnerability of a system to being overwhelmed, underflown, deceived, or destroyed, meant that it was a waste of funds that it could otherwise have been employed in the economy or in other military programs.

Some have it otherwise, asserting that the recognition by Mikhail Gorbachev that the Soviet Union could not compete in a Star Wars race led to the dissolution of the Soviet, but I disagree. Even administrations recognizing the futility of BMD to protect the country against the deterrent/retaliatory nuclear force of the Soviet Union (now Russia) nevertheless were moved to deploy such a system in order to counter political criticism. However, the Nixon Administration, to the credit of Richard Nixon and his National Security Advisor and later Secretary of State, Henry A. Kissinger, had negotiated the Moscow ABM Treaty of 1972 that limited each side to 100 interceptors, nuclear armed, but deployed in such a fashion that it they could not form the basis for the defense of the national territory.

At present, the Obama Administration has, with the agreement of the Department of Defense, modified and improved the deployment plans of the George W. Bush Administration for very large ground-based interceptors (GBI) in Poland and elsewhere, to the deployment of hundreds of smaller interceptors on naval ships and on land, in a phased adaptive approach (PAA) to BMD.

This far more feasible task is not to destroy 6000 warheads in a raid by the Soviet Union or even a few thousand warheads in a nuclear attack by Russia, but to counter

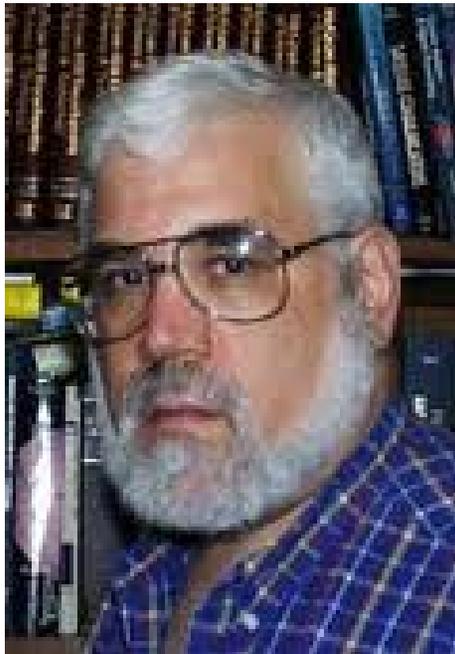
a few or a few tens of ballistic missiles from Iran or North Korea. However, as I and my colleagues, particularly Dr. Theodore A. Postol, have emphasized repeatedly over the years, this mid-course defense system is fundamentally useless because of the feasibility of mid-course countermeasures—particularly the surrounding of the missile warhead by a large enclosing aluminized balloon that is opaque to radar, visible, and infrared sensors, and that would have no effectiveness against a nuclear-armed interceptor, but defeats handily a hit-to-kill interceptor of the current and recent past proposals for BMD.



Figure 8-1 of “Countermeasures,” photograph of NASA Air Density Explorer balloons, first launched in 1961

Ted Postol has provided incisive, technically competent testimony and papers and has been a major force for rationalizing military programs. He should be listened to more attentively. I first encountered Ted in 1980 when Sid Drell and I helped to put together a team of three young outside physicists for the Office of Technology

Assessment study of the basing options for the ill-fated MX missile—a 95-ton replacement for the Minuteman missile, twice its size, that would contain 10 independently targeted reentry vehicles (MIRVs) in comparison with the three warheads of the Minuteman-III. Ted Postol then joined the government after this fine and exhaustive study, in the role of Advisor to the Chief of Naval Operations (particularly in regard to the Navy strategic ballistic missile force—Polaris/Poseidon/ and now Trident).



Ted Postol



Ashton B. Carter

Ashton Carter has been professor in the Kennedy School at Harvard and served in the Clinton administration in the Department of Defense, where is now Deputy Secretary of Defense to Leon Panetta.

At a time when the massive reductions in strategic nuclear forces of the United States and Russia are indeed in progress, an ineffective BMD can derail this improvement in U.S. security. Indeed, it is widely recognized that having more nuclear weapons than is needed (and how many are “needed”?) is a great threat to society and, in particular, to U.S. society, in the form of nuclear terrorism. Henry Kissinger once demanded to hear how a system could be both ineffective and destabilizing; I replied that he should think about using a toy pistol to threaten a police officer.

Nuclear terrorism has replaced nuclear attack by a state as a principal threat to the United States, even though it would involve, probably, only a few nuclear explosions instead of hundreds or thousands. Much effort is going into countering nuclear terrorism, especially the threat of stolen or otherwise acquired nuclear weapons, or the creation of improvised nuclear explosive devices (IND) from the hundreds of tons of highly enriched uranium (HEU) or plutonium (military and “civil”) now available in the world. But that is another story.

The TCP had an intelligence Panel under Edwin H. Land, the inventor of polarizing film and of the Polaroid process for instant photography. The Land Panel, evolved from its TCP era as a group advising the President's science advisor, the director of the CIA and the deputy secretary of defense, was much involved with the details of "overhead reconnaissance," including satellite imagery and satellites performing invaluable roles in the acquisition of radio signals from communication systems, radars, and telemetry. The film reconnaissance satellite flew in August 1960, the first of 145 film capsules returned to Earth in the CORONA program, which terminated in 1972. The CORONA program and its imagery, at best about 2-m ground resolution, was completely declassified in 1995. It had been created as a CIA "black program" response to the technical and programmatic recommendations of the Land Panel and the intelligence panel of the TCP before it. The Land Panel was involved with optical imagery, but other information from space was important, and I worked as an independent consultant to the relevant U.S. agencies that were developing and deploying such systems.

The Land Panel was a key element in the definition and selection of two CORONA follow-on film-return systems, HEXAGON and GAMBIT, which were much more capable and which were largely declassified on September 17, 2011. The enormous HEXAGON spacecraft is on public exhibit at the Air and Space Museum of the

Smithsonian—a vehicle the size of a large school bus, 60 feet long and 10 feet in diameter. It had four large film-return buckets. HEXAGON had a resolution on the order of 0.7 m, and GAMBIT, not a panoramic camera like CORONA or HEXAGON, a resolution measured in centimeters, but, of course, over a small field of view.

The first HEXAGON flight was in 1971; the last in 1986. The vehicle was on orbit for as long as 129 days. Each image of the stereo +/- 60-deg scan captured a “bow tie” ground patch 300 nautical miles cross-track and 17 nm along track, repeated as desired to have continuous along-track coverage of a strip 300 nmi wide<sup>8</sup>.

In all this, physicist Edward M. Purcell was a key player, as evidenced by this footnote in an official history of the HEXAGON program, declassified September 17, 2011. In 2000, he was named, posthumously, one of ten Founders of National Reconnaissance, along with Edwin Land, Sidney D. Drell, Richard L. Garwin, Wm. J. Perry, Wm. O. Baker, Merton E. Davies, Amron H. Katz, James R. Killian, and Frank W. Lehan.

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<sup>8</sup> <http://www.nro.mil/foia/declass/GAMBHEX%20Histories.html>

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The "Purcell Panel," headed by E. M. Purcell, included A. F. Donovan, E. G. Fubini, R. L. Garwin, E. H. Land, D. P. Ling, A. C. Lundahl, J. G. Baker, and H. C. Yutzy--perhaps the most distinguished group of authorities on reconnaissance, space, and photography ever to be collected in one study group. Many of the

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The HEXAGON photographic satellite vehicle. Length 60 ft; diameter 10 ft



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As was indicated in the 1995 speeches and documents accompanying the declassification of CORONA, the film-return systems have been replaced by a “near-real-time electro-optical system” which came on line in January, 1977—the predecessor of the commercial satellite imaging systems that feed Google Earth.

I have discussed mostly the role of advisors and consultants to the Executive branch. In fact, there are many, many advisory committees not only to the government but also to the National Academy of Sciences—boards and commissions and individual *ad hoc* and standing committees. For instance, there is the Board on Effects of Ionizing Radiation, which in 2007 published BEIR VII-Phase 2, the latest estimate of health effects of ionizing radiation—primarily latent cancers, amounting to about 0.1 latent cancer per sievert (Sv) of weighted whole-body energy deposition. One gray of minimum ionizing radiation contributes 1 Sv, and, in physical units amounts to about 1 J/kg of tissue. With the present state of medical science and treatment, about half the cancers are fatal, so that an overall dose response coefficient for minimum ionizing radiation is one lethal cancers per 20 Sv.

In 1981, the National Academies of Science created the Committee on International Security and Arms Control, primarily for semi-annual bilateral sessions with a corresponding group of Soviet scientists. Of course, there is very little similarity between the Soviet Academy of Sciences (now the Russian Academy of Sciences (RAS)) and the U.S. National Academies of Science (NAS). The RAS now has 130,000 employees, of whom 65,000 are researchers. It has 165 institutes under the RAS; the NAS has none (despite the name of the Institute of Medicine, which is a sister of the NAS).

The RAS can be very influential in decisions of the Russian government, and the CISAC emphasis on nuclear weapons and military technology have, at times, been highly beneficial, as in providing technical views of the prospects for the Strategic Defense Initiative.

Now a bit of philosophy, although I am much better at problem solving by the use of elementary physics or, as former Secretary of Defense William J. Perry put it, “Just plain good sense.” Why is it that outside advisory groups or individual consultants can have a disproportionately beneficial influence on U.S. government programs, in particular? Well, it is not always that easy, and not always of that sign, but let that pass for the moment. Sometimes, as is the case with determining the position of

three radar-sensing aircraft by means of three tiny pseudo-radar generators (ground beacons) rather than precision tracking radars deployed in the theater of conflict, it is just a matter of seeing the problem overall, and of applying the principle that if something can be eliminated, one doesn't need to worry about its schedule, cost, or reliability.

Or it could be phrased: if you assume that the system you are working on actually works, what else can it do (in this case determine with extreme accuracy the position of the sensing aircraft themselves). How is the utility of outsiders consistent with the discovery by Herb Simon (Carnegie Mellon University) that it takes about “40,000 facts” to make an expert? That is, until one has about that many facts and concepts at one's disposal—at the tip of tongue, so to speak-- it is not easy to correlate anything new with everything that is already known. Similar conclusions are recounted, for instance by Malcolm Gladwell, that 10,000 hours of practice are required whether one is a musician, a public speaker, or a professor of physics. How, then, can an occasional consultant help?

Individual members of a high-function group such as PSAC in its glory days are chosen because of their demonstrated record of accomplishment, scientific integrity,

and constructiveness. In general, they not only get along, they often like one another and are bound in a common mission.

Given the option of constituting an advisory committee of recognized experts, or an advisory committee of recognized accomplishment in their own fields, the second is by far preferable. The first is too likely to encounter inherent conflicts of interest, and to limit itself to the conventional wisdom.

Then there is the frequently experienced concept of “hybrid vigor,” which in this context comes about because a person accomplished in one field is intimately familiar with concepts and tools in that field, and can immediately see the mapping of problems in a new field onto the tools of the old field.

Still, someone needs to know enough about the field (the current problems of the government or its agencies and departments) to understand them and transform them into questions and goals. In the late 1950s, it was apparent that the scientists who had worked so effectively in the wartime laboratories of the United States under the National Defense Research Council (NRC) aegis and developed radar, the proximity fuse, underwater sound (antisubmarine warfare) and the nuclear weapons, would die

off, and that it would be good to involve researchers of the highest caliber in their advisory work with these important government programs.

It had been hoped that bringing young scientists on to PSAC panels would provide this needed expertise and familiarity, but the panels themselves did not do enough concentrated work to generate new knowledge, although in many cases the pooled knowledge and expertise of the members was extremely valuable, as in the case of the Military Aircraft Panel's strong influence on what was to become the Global Positioning System, GPS. Among the experts of the MAP was Luis W. Alvarez who, beyond his Nobel-Prize winning feats in physics, had invented and developed Ground-Controlled Approach (GCA)—a technique perfected for U.S. and British aircraft in Britain during WW II, that allowed landing under all weather conditions on British airfields, without adding any equipment and very little training to the aircraft and its pilot.

Charles H. Townes as Vice President of the Institute of Defense Analyses (on leave from his position as Professor of Physics at Columbia University), was key in creating the JASON group of consultants, attached at first to IDA and then administratively housed at SRI International and now the MITRE Corporation. Initially in large part physicists with a sprinkling of chemists and mathematicians,

JASON is now about 60 scientists, engineers, and mathematicians, and works at an eight-week intensive Summer Study in La Jolla, CA, supplemented by a 10-day Winter Study there and a Spring and Fall three-day session in Washington, DC, two days of which are devoted to classified and unclassified talks to JASON and to many of the sponsoring agencies. Study topics are negotiated between the sponsors and the JASON leadership, and are completed during the Summer Study in La Jolla, by early August, with finished reports provided to the sponsoring agency by October of that same year.

About half of the reports are unclassified, and of these most are made available by the sponsoring agency, but some are not. JASON has worked on climate change, underwater sound, deployment of large 10-warhead missiles horizontally on small strategic submarines, and in recent decades especially on maintaining the health and safety of the U.S. nuclear weapon stockpile without nuclear explosive testing.

JASON also has done a good deal of work on intelligence matters—analysis as well as technology. Secretary of Defense Robert Gates spoke to JASON at its 50<sup>th</sup> anniversary dinner, November 2009.

Every talk must end, and this one ends here. Except, as Steve Jobs would say, for “one more thing,” as emphasized in the hand-out,

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ABOUT 1,060,000 RESULTS (0.36 SECONDS)

This afternoon I received an email from Arun Majumdar, which quote, to barely introduce a recent important example of physicists' involvement in important government programs—in this case to help terminate the 2010 BP oil spew in the Gulf of Mexico. In previous talks<sup>9</sup> I have presented the substance of the activity, but Majumdar briefly summarizes the remarkable performance of Energy Secretary Steven Chu in forming and leading the Government-Led Science Team that played a major role in that enterprise. First a single illustration from a mile deep in the Gulf:

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<sup>9</sup> E.g., "[Science \(and Technology\) to Tame a Wild Deep-sea Oil Well](http://www.fas.org/rlg/2010%20Columbia%20STWDOW.pdf)," by R.L. Garwin. Presented at Physics Colloquium, Columbia University, Department of Physics, December 6, 2010. ( at <http://www.fas.org/rlg/2010%20Columbia%20STWDOW.pdf> )



“Slide 4. A still from an ROV video of the gas/oil plume emerging from the clean-cut 21-inch-diameter riser. The oil is orange in color.”

And here is the human side of the story, as narrated by Arun Majumdar,

“...Because there was something else, with much higher urgency and devastating impact, that landed on his lap, and sucked me right into it as well. It was April 20th, 2010 – the Deepwater horizon disaster began with the blowout of BP’s Macondo well approximately a mile deep in the ocean, and produced the largest environmental disaster in US history.

“The President asked Secretary Chu to lead a team of scientists to stop the oil from leaking. I joined the team in early May, and so did a group of super-sharp folks spanning academia, business and national labs. Allow me to paint the picture of what it was like in those 5 months while Sunshot was incubating.

“It was first suggested by BP that the oil was leaking into the Gulf at only 5,000 barrels per day. But our team soon showed that it was a whopping 50,000 barrels per day, or probably even higher. It was on the front page of all major newspapers almost every day. If you turned on your TV, every news channel had a video 24/7 of the oil gushing out. In late May, BP tried to kill the well with mud, but that maneuver failed and oil kept gushing out. Things looked quite grim and the media provided a constant reminder that this was not going away. There were hardly any oil pressure measurements down at those depths – it was a data free zone. Rather, the pressure was on us and BP to stop this disaster.

“Secretary Chu took over the reins and what ensued was truly historic. Following him, we dropped almost everything and immersed ourselves in learning on the job every detail of well design, the blow-out preventer (BOP), reservoir, the damage, etc. From the few measurements that we could get, and a knowledge base spanning

geophysics, multiphase flows, mechanics and various other disciplines, we had to reconstruct what actually happened and how to stop the leak. Within the science team, there were 100s of emails going back and forth each day, and sometimes 4 or 5 1-hour telecons a day. It was all consuming. There were discussions, debates, real-time calculations, risk analysis and decision-making. There were plenty of occasions where we had 2 or 3 different options, and we had to choose one with very little information. The stakes were high, the world was watching, and the longer we took the more oil kept gushing out at 50,000 barrels per day – it was a ticking time bomb. None of us slept very much.

“I say this was historic, because there was one extraordinary incident that I must share with you. There was a suggestion, even in some journal articles, to explode a nuclear bomb deep in the well, and let the well collapse on itself. There was an intense debate within our science team – some folks thought this was a good option, and others were doing calculations showing there were some major risks involved. At one point in this debate, one of our team members, Dick Garwin, sent an unforgettable email. Dick was a former student of Enrico Fermi and was one of the pioneers who helped build the first Hydrogen bomb. He is super sharp as an arrow and has a no-nonsense style. During this debate, he became a bit frustrated that he couldn't convince some of the other members that exploding a bomb was a bad idea.

“So he wrote June 25<sup>th</sup> 2:18am: “*Dear Alex: I hope that I wasn't rude, but this is a topic I know a good deal about (an understatement from someone who built the hydrogen bomb!)*”. Then he wrote: “*Here are 7 pages in Enrico Fermi's hand from my July 1950 Los Alamos Notebook-- an early calculation of such containment.*”

“There it was, a scanned image of Fermi’s handwritten derivation of elastic shock waves from an underground explosion. When I saw that email, my jaw literally fell off. I shot off an email June 25<sup>th</sup> 10:33am to the whole team, and I wrote:

*Stepping back from all the email traffic, the one below is noteworthy on several accounts and will remain in my memory for a while.*

- A. *I never thought I would encounter a historical connection between the oil spill and Enrico Fermi spanning 60 years.*
- B. *I am awed that Dick has his lab notes from 60 years ago!*
- C. *And even more so that he remembers where things are in it!!*

“And in the midst of it all this turmoil and uncertainty was the calmness, the openness, the humor, the technical rigor, the analytical ability, and the decision-making skills of Secretary Chu. We all followed his cue. As a scientist, he used to

do his own calculations and then throw it out there for us to critique. There were no hierarchies, only free flow of information in an open way. He used to say: “This is the way I am thinking, what do you think?” “I am thinking of making this decision. Is there any dissenting opinion?” Now he had the authority from the President to make decisions, and yet he was there with us, fully exposed and inquiring if someone else had a better idea. It takes a lot of guts, humility and self-confidence to do so, especially in this kind of pressure-cooker situation. Many of us had dissenting opinions, and yet once he made the decision, we were all behind him and went on to the next step. What mattered was not who was right, but how could we stop the leak and save the Nation from a catastrophe of a full-blown uncontrolled leak.

“History has shown that crises such as these bring out the leadership qualities in some people that even they are unaware of about themselves. In our Nation’s history, few crises were bigger and more acute than the Civil War. And during that time, President Lincoln’s leadership became well known for the following attributes:

1. Capacity to listen to different points of view
2. Ability to learn on the job
3. Ready willingness to share credit for success and share blame for failure
4. Awareness of own weaknesses

5. Ability to control emotions and know how to relax and replenish
6. Go out into the field and manage directly
7. Strength to adhere to fundamental goals
8. Ability to communicate goals and vision

“As I look back at Secretary Chu’s role in the BP oil crisis, a similar list could be made as well. The Nation owes him an enormous debt of gratitude for his role in saving the Nation from the biggest environmental disaster in US history.”

My thanks to Arun Majumdar for his 2.5 years in government and for his providential email that reminded me of this recent contribution of physicists (and other technical people) to solving public problems.