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Chapter 3

Science, Society and the State:
The Nuclear Project and the Transformation of the American Political Economy

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Introduction

The first official U.S. government action regarding atomic research was the establishment of a national advisory committee by President Franklin Roosevelt in October of 1939. Roosevelt was responding to a warning contained in a letter signed by physicists Albert Einstein, Enrico Fermi and Leo Szilard, identifying the destructive possibilities obtainable from the emerging scientific discoveries related to the structure and properties of atoms.

The physicists' warning and the U.S. president's response triggered a set of events that eventually brought science and the state together as the patricians of a new era of "technological authoritarianism" (Byrne and Hoffman, 1988). Joined by the American military and the corporate sector, this partnership assumed the role of restructuring society around what were, and are, staunchly believed to be the progressive powers of science and technology. The last half of the 20th century has been shaped by and, some argue (e.g., Schell, 1982), traumatized by the Manhattan

Project. What is difficult to dispute is that this project and its institutional legacy utterly changed our world.

By most accounts, the significance of the "nuclear age" has been its revolutionary impact on international military and foreign policy. However, the transformation of political economy was no less revolutionary. In this respect, it is argued here that the Manhattan Project's institutional and organizational structure was the prototype for other scientific and technological ventures central to the Cold War experience. Far from being simply a military success, the Project was offered as a means to take American society to an even higher level of economic and technological development. The institutional transformations necessary to complete the research, development and construction of an atomic bomb set in motion a series of events which resulted in a highly centralized and hierarchical system of scientific endeavor.

Early Science Interest

Physicists Fermi and Szilard were only the most recent contributors in a cadre of international scientists that stretched back to Marie and Pierre Curie and others that were experimenting with subatomic structure and behavior throughout the late 1800s and early 1900s. Moreover, the linkage between the destructive power of a nuclear reaction and the possibility for creating usable energy was recognized early on. As Hewlett and Anderson note, the physicists reasoned from virtually the outset that "if the process [of fission] could be controlled, a new source of heat and power would be available. If it were allowed to progress unchecked, an explosive of tremendous force might be possible" (1962: 11). Given the stage of theoretical physics at the time, however, neither the physicists, and therefore Roosevelt, knew with any degree of certainty whether an atomic bomb or a nuclear power plant was feasible.

Still, the possibility that a superweapon *could* be constructed was enough to motivate the President to initiate a series of governmental actions. Roosevelt, in consultation with his military attache General "Pa" Watson, immediately created a governmental Advisory Committee on Uranium and charged it with the official duty of investigating whether and how atomic research should proceed. Initial members of the Advisory Committee included Lyman Briggs (then Director of the National Bureau of Standards) who served as its chair, Commander Gilbert C. Hoover (U.S. Navy), and Colonel Keith C. Adamson (U.S. Army).

Within the month, the Committee had completed its charge and reported back to Roosevelt that a chain reaction was a plausible, if as yet unproven, possibility. Over the next six months, both Fermi and Szilard continued to conduct their experiments, keeping both the Committee and Admiral Harold Bowen (director of the Naval Research Laboratory) abreast of their work. Supplied with this information, both Bowen and Advisory Committee chair Briggs reached the conclusion that the progress Fermi and Szilard were making was sufficient to recommend government support of a laboratory-scale investigation into the physics of a chain reaction. This recommendation propelled the first of a series of public actions over the next five years that created a government-university-corporate complex which would eventually succeed in achieving what President Truman later called, "the greatest scientific achievement in history".

The Institutional Integration of Nuclear Weapons Research and Development

Central to the Manhattan Project and subsequent development of nuclear technology was the integration of science, the academy, the military, and industry in a common effort. While American scientific and industrial cooperation in weapons development had historical precedence dating back to the Civil War, this effort had been sporadic and largely an individual and product-specific engagement. Similarly, university relations with U.S. industry had mostly been centered on curriculum and cooperative education programs. For example, industrial concerns about the degree to which universities had been providing relevant and useful knowledge to the industrial economy had resulted in the development of new technical fields such as engineering and business (Chandler, 1977; Noble, 1977). Yet for most of the early part of the century, industry had created and maintained its own internal research and development infrastructure independent of universities. Indeed, industrial laboratories such as those at DuPont, Westinghouse, General Electric, AT&T, and General Motors had been the locus of industrial R&D and the envy of most university laboratories since the turn of the century. Funding for research within the Bell system alone amounted to over $2.2 million in 1916, and with substantial annual increases this figure reached over $23 million in 1930, an amount far larger "than any single university in the country" (Maclaurin, 1949: 156, 159).

In order to proceed with the Bowen and Briggs recommendations for laboratory-scale research, it was therefore necessary to establish a new organizational basis for cross-institutional collaboration, since no single institution was capable of handling the complexities and scale of an atomic research project on its own. The initial basis for this collaboration was provided through the establishment of the National Defense Research Council (NDRC) in May 1940. The NDRC was created by Roosevelt through an executive order with support from scientific as well as military leaders. The NDRC was distinctive in that it was the first time the national government would be directly engaged in defining and funding research in support of military requirements *outside* of a war context. Among the several prominent university supporters advocating the creation of a governmental organization that could integrate the activities of universities and industry were Carnegie president Vannevar Bush, Harvard president James B. Conant, and MIT president Karl Compton. The university group was joined by America's national science spokesman — the National Academy of Sciences president, Frank B. Jewett (also vice-president of AT&T) who similarly called for creation of a national government organization to direct the nuclear effort. The impact on research created by the new Council was both immediate and substantial: within six months, the NDRC had contracted 126 projects at 32 academic institutions and 19 corporations (Kevles, 1987: 298).

The NDRC was only a few months old when the Nazis invaded Belgium in the summer of 1940. This and other German actions provoked fears by scientists, as well as the military, that the Nazis might secure access to one of the world's largest known sources of uranium located in the Belgian Congo. Such a possibility, along with speculation about Germany's own progress on atomic bomb research, sparked another round of demands for increased national control of science in the atomic field. Two separate committees of scientists, which had been appointed by NDRC chairman Vannevar Bush to review the situation, recommended the immediate establishment of a government program in fission research. But mounting such an effort required a much larger and more certain funding source than the emergency funds that had been underwriting the NDRC at the time. A new executive order creating the Office of Scientific Research and Development (OSRD) was issued in May of 1941 in response to these concerns.

This time, Roosevelt's order established a new agency with a full-time director (former NDRC head Vannevar Bush assumed this role) and a Congressionally appropriated budget. While the mission of the OSRD was still to provide the military with advanced weapons research capability, its creation instituted a scientific research agency with relative leadership autonomy from the military on the organization and direction of research. OSRD director Bush was given the primary responsibility and authority to, as Kevles notes, "advance ideas for weapons from the germinal to the production stage" with direct reporting responsibility to the President (1987: 300). In addition, the OSRD provided for the consolidation of all atomic related projects under one agency roof. James Conant (president of Harvard University) replaced Bush as head of the NDRC, which was itself located within the OSRD, and the Committee on Uranium then became the OSRD Section on Uranium, or S-1.

Even though the physics of a chain reaction, and hence the feasibility of an atomic weapon, still remained a purely hypothetical possibility, the OSRD under Bush's direction continued to mobilize the nation's university and corporate resources. Bush undertook action to accelerate atomic research under the OSRD and to investigate the development of pilot plant operations. With respect to research, the OSRD was already simultaneously sponsoring a variety of programs, including the theoretical physics of an atomic weapon, power production, isotope separation, heavy water and graphic moderators, and nuclear fission (using uranium 235 or 238, and plutonium). In order to facilitate work on the development of a pilot plant, a Planning Board was created to specifically investigate the industrial engineering and manufacturing questions related to the production of an atomic bomb. For membership to the Planning Board, Bush recruited corporate and engineering expertise from among the largest U.S. companies, including officials from Standard Oil, the Kellogg Company, Union Carbide, and Westinghouse.

Thus, before the attack on Pearl Harbor in December 1941, the United States had already assembled an institutional structure to investigate the science and technology of atomic weapons. This structure had integrated university, industrial and military research and engineering, and had devised production and supply lines to ensure delivery of everything from uranium to flow meters and thermometers. Approximately 1,700 physicists were engaged in government-sponsored atomic research by the time the U.S. officially entered the war. A year and a half after the establishment of an advisory committee to study the status of atomic research and its implications for the production of a bomb, atomic science had become a matter of national policy.

The Manhattan Project: Science-Based Industrial Development of a Nuclear Weapon

With the entrance of the U.S. into World War II, the atomic project acquired a new urgency of mission and organizational purpose. Consequently, an effort within the OSRD to pursue a more efficient and focused program of research was instituted. A week after the Pearl Harbor attack, Vannevar Bush divided the bomb project into two areas: engineering issues to be investigated by the Planning Board; and physics and chemistry questions to be researched at the universities. Six months later, in June 1942, Roosevelt authorized Bush to go forward with a full-scale effort to build the atomic bomb. With this mandate the OSRD reorganized the bomb project and authorized the newly created Manhattan District of the Army Corps of Engineers to assume management responsibilities. Brigadier General Leslie R. Groves (who had managed the building of the Pentagon) was given command of what became known as the Manhattan Project (Lauren, 1988: 60).

Before the Manhattan Project, the military-science-industry partnership had relied upon a somewhat fragmented organizational structure. University laboratories, industry representatives and high-ranking military officers had been loosely organized in "committees," "planning boards," and so on. After December 1942, however, this was no longer acceptable. With Roosevelt's approval of an "all-out effort", Groves was put in charge of a half-billion dollar budget and a "giant industrial complex" (Hewlett and Anderson, 1962: 115).

The NDRC and the OSRD had made substantial contributions in the policy and planning of a national atomic science program, but the scope of the research, engineering, and manufacturing required for an atomic bomb superseded the ability of these organizations. The Manhattan Project demonstrated a research and development scale and complexity which had not yet been experienced in the industrial world. Emphasis on organization at this stage was absolutely critical since many of the components of atomic bomb research and production were not yet understood. The Manhattan Project set out to simultaneously engage in theoretical physics research, the engineering and design of multi-facility pilot plants for the production of bomb grade material, and the manufacture and testing of the bomb itself. To successfully build the bomb, Groves would require the assistance of some of the nation's largest corporations, the cooperation of the country's most prestigious universities and the governmental authority to plan, coordinate, and administer the effort.

Of critical importance to the design of the Manhattan Project was the issue of management over industrial activities. Although the Project's objective was obviously military in nature, the question of subatomic behavior was scientific in character. Few in government or universities had the experience of building and managing large-scale production facilities needed to bring the project to fruition. Groves therefore looked to the industrial sector for the solution and ultimately settled on the DuPont Company for the job. DuPont was selected not only because of "its size and experience," but also because it had developed an internal organizational structure capable of integrating "all the complex activities of the company . . . around the manufacture of products" (Hewlett and Anderson, 1962: 187-188). Given the multiple activities of the Manhattan Project, this was considered essential to its success. In addition, the company was a veteran of military production and the War Department had already assigned to it the construction and operation of several explosive plants. DuPont acted immediately and personnel from its Explosives, Ammonia, Chemicals and Engineering Departments were assembled to supervise manufacturing and engineering operations of the Manhattan Project. On these matters the company had insisted, and received, complete management control in order to avoid "the many headaches of co-ordination and administration which plagued most joint enterprises between university research groups and industry" (Hewlett and Anderson, 1962: 188).

Finally, because centralized decision-making was considered critical, it was decided that overall decisions would be exercised by only three individuals: General Groves, MIT President Compton and the DuPont Company's Roger Williams. In this way, the Manhattan Project provided a merger of two modes of "efficient" organization: the multidivisional, horizontally and vertically integrated production structure of the modern corporation; and the command and control structure of the military system. The university's role was the supply of specialists to the new organization. Indeed, efficiency and organization would *have* to guide the project if and until the technical, military and political "ends" were resolved. The Manhattan Project became the prototype of contemporary technocratic order: a large-scale, multi-dimensional organization that embodies hierarchy *and* the flexibility of innovation-oriented R&D.

The physical and engineering accomplishments of the Manhattan Project were indeed impressive. Three major production and research facilities in Oak Ridge, Tennessee, Hanford, Washington and Los Alamos, New Mexico were constructed in three years. Entire new towns, and their accompanying infrastructure of houses, roads, rail lines, schools, commercial and retail establishments, water and power plants, as well as the experimental research pilot plants themselves, were built literally from the ground up. By 1945 the Manhattan Project employed thousands, from assembly workers to physicists and managed large complexes with an annual budget of approximately $2 billion (in 1995 dollars, this would be equal to almost $18 billion, an enormous sum for that period).

However impressive its size and sophistication, the truly remarkable accomplishments of the Project lay in its organizational triumphs. From the University of California, Berkeley to the University of Chicago and Columbia University, and from International Nickel and American Harvester to General Electric and DuPont, the Manhattan Project was able to integrate vastly disparate, autonomous and geographically distant organizations for one common purpose.

On July 16, 1945, five and a half years after the Fermi-Szilard letter had been delivered to Roosevelt, the consortium achieved its objective — the explosion of a twenty kiloton plutonium bomb. The first test was conducted in Alamagordo, New Mexico, and the blast was visible in the city of Albuquerque approximately 125 miles from the test site. The "release of nuclear energy," the principal goal of the atomic bomb R&D (Hewlett and Anderson, 1962: 377), was so violent that J. Robert Oppenheimer, the lead scientist in the project, was moved to quote from the Hindu Bhagavad-Gita: "I am become Death, the shatterer of worlds" (Kevles: 1987: 333).

In one of the politically most interesting debates of the modern era, and one which still causes public dissension to this day, the technical, corporate and military elites of the Manhattan Project indulged in a protracted discussion in the spring of 1945 over the proper use of this new weapon. Their ultimate decision was memorialized on August 6, 1945. On that day the prophecy which Oppenheimer had spoken of less than a month earlier came to a fiery rest for over 200,00 Japanese people in the city of Hiroshima. The world learned about the bomb blast from a statement delivered by President Truman (1945: 4):

> Sixteen hours ago an American plane dropped one bomb on Hiroshima . . . It is an atomic bomb. It is a harnessing of the basic power of the universe. . . We have spent two billion dollars on the greatest scientific gamble in history — and won.

On August 9, 1945, "the force from which the sun draws its power" was loosed again, this time upon the people of Nagasaki. Within a month, opposite sides of the earth had each witnessed the "unforgettable fire" of atomic energy (Nippon Hoso

Kyokai, 1977). But their reactions, not surprisingly, were markedly different. The U.S. account was documented by William L. Laurence, the sole "official" Manhattan Project reporter designated to record the Project by General Groves (1945: 1, 16):

> It was as though the earth had opened and the skies had split. One felt as though he had been privileged to witness the Birth of the World — to be present at the moment of Creation when the Lord said: Let There be Light . . . A great cloud rose from the ground and followed the trail of the Great Sun. . . For a fleeting instant it took the form of the Statue of liberty Magnified many times.
>
> They clapped their hands many times as they leaped from the ground — earth-bound man symbolizing a new birth in freedom . . . The dance of the primitive man lasted but a few seconds during which an evolutionary period of 10,000 years had been telescoped. Primitive man was metamorphosed into modern man — shaking hands, slapping each other on the back, laughing like happy children.

The Birth of the Nuclear World had indeed brought about a profound changes, the nature of which the Project cadre could not yet even imagine. But the exuberance with which most in the U.S. first greeted the arrival of modern man was not to be replicated in Japan. There, the exodus of primitive man was bid only in silence (Hiroshi, 1984: 60):

> No one wept
> no one screamed in pain
> none of the dying
> died noisily
> not even the children
> cried
> no one spoke

A New Technological Order

With the bombing of Hiroshima and Nagasaki, U.S. society had indeed realized a new Technological Order with many, both inside and outside the realm of the new technological elite, lauding the physicists for inaugurating a "Pax Atomica" (Kevles, 1987: 392). It was clear that, henceforth, any consideration of the national interest would take place within a nuclear context. The work of the Manhattan Project was not limited to the production of a bomb; rather, it had brought into being a new social reality governed by scientific and technological values. Science, industry, the state and the military had worked together to uphold and promote the value of "the one best means" (Ellul, 1964: 21), and hence had achieved their common goal.

In addition to the creation of the atomic bomb, the nation's scientific and technological resources had been mobilized to deliver a host of other technologies, from advances in biological and chemical warfare to microwave radar. The military, in particular, which prior to World War II had been skeptical about the intrusion of science and scientists into the business of war, had become convinced of their indispensability in maintaining U.S. control in the post-war era. A counsel to Army Chief of Staff Eisenhower expressed the issue succinctly in 1946 (quoted in Allison, 1985: 290):

> The lessons of the last war are clear. The military effort required for victory threw upon the Army an unprecedented range of responsibilities, many of which were effectively discharged only through the invaluable assistance supplied by our cumulative resources in the natural and social sciences and the talents and experience furnished by management and labor . . . This pattern of integration must be translated into a peacetime counterpart which will

> not merely familiarize the Army with the progress made in science and industry, but draw into our planning for national security all the civilian resources which can contribute to the defense of the country.

It is important, however, to note that the reach of this apparatus was never narrowly construed as a military one. Quite the contrary, the civilianization of the Manhattan Project was embraced after the war as a model to guide science- and technology-based national economic development. Indeed, the appeal of the new Technological Order was, according to Seymour Melman, its promise of general prosperity (1974: 16):

> From their experience with World War II, Americans drew the inference that the economy could produce guns and butter, that military spending could boost the economy and that war work could be used to create full employment. They observed that these results had not been achieved by the effort of President Franklin Roosevelt's civilian New Deal.

What Melman called "pentagon capitalism" would succeed, supposedly, where the New Deal had not.

In the years following the war, the influence of the atomic bomb complex would have on the American political economy was already evident. Only a few corporations and an even smaller number of universities would dominate the postwar technological and economic order, as they had during the war period. Spending on the plants and laboratories of the Manhattan Project had catapulted the federal government into a leadership role as its proportion of total science expenditures (public and private combined) increased from 18 to 83 percent. The dramatic increase in society's scientific investment had been concentrated in only a few organizations: "sixty-six percent of wartime contract dollars for research and development went to only sixty-eight corporations, some 40 percent to only ten. OSRD spent about 90 percent of its funds for principal academic contractors at only eight institutions" (Kevles, 1987: 342).

The highly concentrated and hierarchical research and development system that emerged out of the Manhattan Project raised significant questions: were these traits to be accepted as the necessary accompaniments of a postwar political economy? And relatedly, was the high degree of military participation in scientific and economic affairs an unavoidable consequence of the Nuclear Age? The answers to both of these questions became clear soon after the war.

The cooperative effort of the Manhattan Project had proven itself by the significant advantages it produced for science, industry, the military and the state: the average annual federal investment in research grew from $68 million in 1938 to $706 million in 1944; a market for parts and equipment as well as federally subsidized research and development was virtually guaranteed to corporate industry (in addition to special consideration in antitrust matters); an infrastructure necessary for the support of the military R&D system had been created; and, of course, the nation had put an end to the war in the Pacific.

Initial resolution of how to ensure the continuation and viability of the massive atomic energy and weapons research and manufacturing system was secured after brief but intense public discussion and congressional debate. Preliminary agreement on the matter was reached with the passage of the Atomic Energy Act in 1946. The enabling legislation of the Act formally established the Atomic Energy Commission (AEC) as the governing body for the nuclear program and put in place a "peacetime" administrative structure for the atomic energy industry. The Act granted the AEC sole ownership and control over the production and use of fissionable materials; authorized it to sponsor basic and applied research as well as the development of militarily necessary nuclear projects; and, finally, vested it with responsibility for the promotion and commercialization of nuclear-generated electrical power. It was also decided that the atomic energy-weapons complex must be governed by those few who were in possession of the requisite scientific expertise, under a military umbrella meant to ensure the nation's security. The Commission, composed of five members serving six-year staggered terms and representing leaders of both the public and private sectors, was to constitute the leadership of this elite system of national technology development and management.

The complete "civilianization" of the atomic energy complex was, of course, considered impossible. Yet, with atomic weapons now the basis of national and international security, operating and, and most importantly, maintaining control, of a weapons research and manufacturing system was considered essential. Only the wartime Manhattan participants, as David Lilienthal, the first AEC chair, later explained, knew and understood the "official mystery and complexity of atomic energy. They were the experts; they knew it all; it was over the heads of the public and public critics were viewed . . . as a 'bunch of housewives'" (1980: 30).

But the significance of the AEC model of governance was, and has been, its transformation of U.S. capitalism and its elevation of scientific and technocratic interests, at times even over democratic aims and aspirations. The new institutional structure of the AEC encouraged a transformation comparable in political terms to the technical and scientific achievements of nuclear fission, namely, a modern state in which democratic processes and structures would now be expected to adapt to scientific and technocratic realities. Not only did the governance and administrative structure of the AEC blur public-private distinctions, it also legitimated government by expert, and acknowledged the permanent centrality of the military in a nuclear world.

The Atomic Energy Act accomplished this, in part, by authorizing the creation of the AEC General Advisory Committee (GAC). The Committee, which was composed of scientists with knowledge and expertise of the atomic field, was charged with "advis[ing] the Commission on scientific and technical matters relating to materials, production, and research and development" (Sylves, 1987: 16). But the GAC was not confined in its advisory role to purely technical matters. Indeed, the GAC was often called upon to consult and advise on military and national security issues, as well as private and public nuclear research and development.

But, perhaps the clearest political impact of atomic energy was the creation of the Joint Committee on Atomic Energy (JCAE) by the Congress. This body recognized as early as October 1945, that in regard to atomic matters "an extraordinary legislative device was essential" (Green and Rosenthal, 1963: 3). Because of the secrecy requirements and issues of national security surrounding atomic research and development, traditional ideas of democratic governance, based on an informed citizenry and public consent, were judged to be inappropriate for atomic decision-making. As a result, a new and innovative legislative device, the JCAE, was created by the Atomic Energy Act, and given "full jurisdiction" over all matters relating to the AEC and to the atomic program. Henceforth, only members of the JCAE, on behalf of Congress, would be privy to the details of AEC policy, and only they would have partial access to information in several areas of atomic energy and weapons research and development. It was also explicitly decided that members of the congressional military committees would *not* be allowed to exercise oversight responsibilities regarding the program. In lieu of public accountability and participation, the hallmarks of a democratic society, expert bodies integrated with limited congressional oversight had become an institutionalized in American government (Green and Rosenthal, 1963: 199):

> (T)he JCAE did not conceive its mission to be one of informing Congress, or of stimulating congressional and public discussion of atomic energy. On the contrary, the Committee's attitude seemed to be that the atomic-energy program could be debated in Congress only by those with immediate responsibility who were already privy to atomic secrets . . . The Committee took its commitment to preserve security so seriously that almost no information of substance was communicated to the rest of Congress.

Realizing the Nuclear Vision

During the 1950s through the 1970s, the entire atomic energy and weapons R&D program, insulated from public scrutiny and criticism, became a dominant model of national science technological development. Its position in energy R&D alone was such that by the "outset of the 1970s, 86 percent of all federal energy R&D policy funds that had been spent since World War II had gone to [the AEC]" (Lambright, 1976: 33). Few, if any, questioned this new "integrated" model for achieving scientific and technological progress. Universities not only appealed to the AEC for greater access to the expensive machinery in operating laboratories, but they also entered the competition for their own AEC funded high-energy research equipment. New laboratories modeled after Oak Ridge, Hanford and Los Alamos were created, including Lawrence Livermore Laboratory, Berkeley Radiation Laboratory, Argonne National Laboratory and Brookhaven National Laboratory.

The most valuable of the AEC's assets were the various laboratories and production facilities assembled for the Manhattan

Project. Their importance was recognized by political, military and scientific leaders alike as essential for U.S. technological development. At the same time, however, these leaders also suggested that a new age of science as social possibility was being forged. "(I)f progress in nuclear physics is important to the nation, to the world," Lee A. DuBridge, a GAC member, advised, then the national laboratories "are not whims of crazy scientists but are part of the necessary fabric of the atmosphere in which science flourishes" (DuBridge, 1946: 13).

By the early 1950s the AEC was devoting significant attention to the non-military applications of atomic research. Thus, in addition to research on the application of atomic weapons, AEC laboratories were busy conducting research on reactor development and basic research in high-energy physics. While the development of atomic reactors presented the Commission with a problem of high technical order, both the GAC and AEC regarded development of nuclear power as necessary and thus proceeded to develop a nuclear program based on what they believed to be "the ultimate possibility" for science in service to society (Hewlett and Duncan, 1969: 115).

In the wake of the successes of the Manhattan Project, the reality of a limitless source of energy seemed only a matter of time, given proper organization of scientific and engineering effort. The confidence which existed both within and outside of the AEC suggested that the nation's scientific and industrial elite would be equally successful in providing a nuclear generation system as it had been in building the bomb. President Eisenhower publicly inaugurated the atomic energy program in his December 1953 address to the United Nations. There, he unveiled his Atoms for Peace Program, declaring that "this greatest of destructive forces can be developed into a great boon, for the benefit of all mankind" (quoted in Clarfield and Wiecek, 1984: 184). Eisenhower was not alone in his proclamation. Even before the first prototype nuclear power plant was in operation, Alvin Weinberg, then director of the

Oak Ridge National Laboratory, was celebrating "the unborn technology" of atomic energy as the "solution to one of mankind's profoundest shortages" (1956: 299). AEC Chairman David Lilienthal echoed these sentiments when he stated, "atomic energy [is] not simply a search for new energy, but more significantly a beginning of human history in which this faith in knowledge can vitalize man's whole life" (1949: 145).

In order to achieve the goal set forward by Eisenhower, an institutional transformation as extensive as the one invoked by the Manhattan Project would be required. Among the most important elements in this transformation was the redefinition of "private enterprise" and the critical role that the state would play in maintaining and assuring the success of the private sector development of nuclear power.

Redefining the Enterprise

By the mid-1950s, leaders of several corporations had begun to challenge the publicly-led monopoly over commercial nuclear energy development. The criticism, however, was never intended to disengage the federal government from investment in nuclear energy. To the contrary, it was expected that state sponsorship would continue in this area. Instead, private industry complaints were directed at the structural difficulties they were encountering as they confronted the unique attributes of nuclear technology and the failure of the state to relieve them of these burdens.

To some extent, this debate was intertwined with both Cold War ideological arguments as well as earlier differences over the proper mix of public versus private systems of electrical generation and delivery. The latter arguments had surfaced periodically since the 1930s, most notably over the creation of the Tennessee Valley Authority and the Bonneville Power Administration. Cries of socialism in the power industry had been used to limit large-scale public power, as well as to thwart small-scale cooperative and municipal projects all around the country. But the issue of private versus public power was radically transformed with the prospective integration of nuclear power into the nation's energy system.

Before Lilienthal's term as AEC Chairman ended, he and Phillip Sporn of American Electric Power initiated the establishment of an industrial advisory committee for the purpose of making recommendations on the relevance of nuclear power to the industrial sector. Additionally, communication between those working on power reactor development within the AEC and corporate officials led to the formation of study groups aimed at developing proposals for private industry participation. Not surprisingly, the corporations involved in these study groups were veteran Manhattan Project/AEC partners. Members included the Monsanto Company, Union Electric Company, Dow Chemical and Detroit Edison. Soon after, in 1951 the AEC announced the creation of an Industrial Participation Program aimed at furthering the corporate role in nuclear power. Proposals came forward immediately, including two submitted by the study groups, two others offered by Commonwealth Edison of Chicago, and a joint venture proposed by Pacific Gas and Electric and the Bechtel Corporation.

Notwithstanding these proposals, it soon became clear that further participation by the private sector was at a stalemate. The Atomic Energy Act had been designed in a period dominated by the development of atomic weapons rather than the potential civilian use of nuclear fission. Issues of national security had preoccupied legislative discussion and, as a result, the 1946 Act essentially mandated that the atomic program be a government monopoly. By the early 1950s, revision of the Act became a priority in Congress and within the AEC. Both Congress and the AEC, as well as nuclear proponents within the private sector, agreed on the necessary thrust of the revisions: to create the institutional conditions and guarantees that would lead industry to take on a more substantive and authoritative role in the development of nuclear power. Among the immediate roadblocks to this end were "questions regarding patents, use of source material, international cooperation, use of classified information, and monopolization by those companies that had gained competence by holding AEC contracts" (Mazuzan and Walker, 1984: 25).

In 1954, a revised Atomic Energy Act was passed by Congress, paving the way for further public-private integration. The revised Act provided for private ownership of nuclear reactors and the licensing of nuclear materials, enabling at least some corporations to adopt their own initiatives for nuclear power (Green and Rosenthal, 1963: 13) The provisions strengthened the role of corporate industry in the nuclear program, and by 1963 AEC contracts and subcontracts to private vendors for materials, supplies, and equipment totaled approximately $3.4 billion. Yet, even as the atomic energy (and weapons) program became more and more linked with the national economy, the highly concentrated and hierarchical character of the complex remained essentially unchanged. Through most of the 1960s, over half of AEC expenditures were distributed to only five industrial giants (Union Carbide, General Electric, Bendix, Westinghouse and DuPont) and two academic contractors (University of California and University of Chicago) (Orlans, 1967: 13).

The 1954 Act demonstrated how far the integration of the public and private sectors in the political economy had come. Private and public leaders alike had acted on a common definition of the legislative challenge, articulating free-market arguments in criticizing state control as the problem facing the future development potential of nuclear power. At the same time, the Act enlisted the state as the principal investor in the development of the technology as well as making it responsible for fuel procurement. Both of these were unusual roles for a piece of legislation casting nuclear power's development in the language of free enterprise.

The ability to treat commercial nuclear power as an invention of enterprise, despite all evidence to the contrary, was captured in statements made by Walter L. Cisler, president of the Detroit Edison Company, during the course of legislative hearings on the revision of the Act (quoted in Mazuzan and Walker, 1984: 29):

> The question Congress must consider is whether at this critical period in the development, industry using its own funds, will be given the opportunity to perform its natural function of seeking out economic methods of utilizing this natural energy resource and making the resulting benefits available to all in a normal manner, or whether industry is to be restricted in its opportunities by a continuation of the existing law. In our minds we must proceed along natural and traditional lines.

In addition to calling for greater industrial participation in nuclear power development, all parties had agreed that a commercial nuclear power program could only be realized "if the basis of participation is made sufficiently attractive for investment of private capital" (Alfred Iddles of Babcock and Wilcox Company, quoted in Mazuzan and Walker, 1984: 29). The most important of the conditions necessary for such investment were the public underwriting of research and development and governmental protection against corporate liability and exposure in the event of a catastrophic accident.

Though a landmark in the development of the industry, the revised Act only satisfied the first of these financial pre-conditions. It did so by vesting the AEC with a unique governmental charter: the authority and responsibility to simultaneously act as both a promotional *and* regulatory agency. Promotion was, among other things, understood to mean responsibility for conducting basic research and for developing many of the components necessary for the operation of a nuclear power plant.

If the Act satisfied the research and development concerns of private enterprise, it left unresolved the issue of liability. Throughout the mid-1950s, a variety of study groups, commissions and panels had been assembled to review the insurance and liability problems posed by an emerging, but yet to be developed, industrial technology. Francis K. McCune, general manager of the Atomic Products Division of GE had been the first to bring the issue up during the hearings on the revised Act of 1954 (Mazuzan and Walker, 1984). The problem was described succinctly by McCune, who stated that liability in atomic power "is bigger than any that business has ever had to face." If an accident were to occur, it was, he suggested, "entirely possible for damage to exceed the corporate assets of any given contractor or insurance company" (quoted in Mazuzan and Walker, 1984: 94). In June 1955, after a more in-depth study of the problem, an Insurance Study Group established by the AEC agreed with McCune's early assessment. In a preliminary report they noted that the "fundamental difficulty" of insurance for a nuclear power industry would be that "the catastrophe potential, although remote, [is] more serious than anything known in industry" (quoted in Mazuzan and Walker, 1984: 97).

The 1957 Price-Anderson Act was the legislative resolution to the problem of nuclear liability. Yet, its passage was merely the culmination of changes which had already occurred in the process of making nuclear power an "economically viable" industry. The structure of the insurance industry as it existed until 1955 was incapable of providing the extent of coverage needed to adequately address the risks of nuclear power. The amount of insurance required could not be underwritten at the time by any single or joint company effort. Leaders of the industry, under the guidance of the study group, called for the organization of syndicates or pools. In response to these recommendations, three syndicates were formed by May of 1956: the Nuclear Energy Property Insurance Association, the Nuclear Energy Liability Insurance

Association, and the Mutual Atomic Energy Insurance Pool. In creating these pools, the insurance industry had organized itself in a way meant to meet the unique demands of nuclear accident liability. Working together, the insurance industry was prepared to offer the nuclear industry total private property and liability insurance of approximately $65 million. "This represented an unprecedented undertaking by the insurance companies," according to Mazuzan and Walker, "[in that] the largest amount made available to other American industries had never exceeded fifteen million" (1984: 100).

Still, despite this effort by the insurance industry, and despite the lack of operating experience which, in usual circumstances was the basis for developing actuarial information, it was recognized that $65 million was hardly enough to address the risks of nuclear power plants. Utility and reactor vendors responded to the insurance industry initiatives by suggesting that because the limits of possible damage were "incalculable, nothing short of complete indemnification would be adequate if private development was to proceed expeditiously" (Mazuzan and Walker, 1984: 107). New Mexico Senator Clinton P. Anderson took the Congressional lead and began developing legislation which would accommodate the needs of partners in both the insurance and nuclear power industries.

A major obstacle in developing appropriate insurance coverage was the hypothetical nature of the process. Decisions on liability and property damage were being estimated without any experiential evidence and in advance of the development of the technology itself. Consequently, the free-market rationales offered during the debates over the Atomic Energy Act were unsuited to the proposed Price-Anderson Act. Without objection from industrial leaders, Harold P. Green, attorney for the JCAE, suggested that it was necessary to "preclude reliance upon forces of the marketplace as determinants of the rate of nuclear power growth" (Clarfield and Wiecek, 1984: 198). As was so often the case in the development of this technology, the role of the state was clearly recognized: in this case, to establish a state supported insurance and liability infrastructure sufficient to make nuclear power an attractive investment option for private capital.

Ultimately the Price-Anderson Act established $500 million in federal coverage. In addition to the $65 million provided by the private insurance industry, total coverage available was set at $560 million. Senator Anderson's staff had arrived at the $500 million figure by selecting the halfway point between zero and $1 billion since no hard evidence existed upon which to estimate a more realistic number (Mazuzan and Walker, 1984: 108). In JCAE hearings on the bill, Harold L. Price, director of the AEC's Division of Civilian Applications, discussed the agency's objective in dealing with the insurance question. The AEC, he stated, had "not approached this from the standpoint of disaster insurance to protect the public . . . We are trying to remove a roadblock that has been said to interfere with people getting into this program" (quoted in Clarfield and Wiecek, 1984: 199). As an additional incentive to industry, the Price-Anderson Act also contained a ten year statute of limitations on claims. This provision was (and is) included despite the fact that the latency period associated with exposure to radioactive material oftentimes will exceed ten years.

Big Science and Nuclear Power

With the Atomic Energy Act and the Price-Anderson Act in hand, the AEC was well on its way to achieving its goal of "privatizing" nuclear power. The AEC was equally aggressive in its efforts to reconstitute the nation's scientific endeavors through its system of national laboratories. Indeed, AEC's laboratory system had become what one writer has referred to as the home of "Big Science," where multidisciplinary teams could be assembled to address almost any scientific and technical problem (Seidel, 1986: 164). Seidel characterized the capability of the laboratories by the end of the 1950s as follows: "whether the object of study was photosynthesis, reactor materials, or nuclear propulsion, they were equipped to bring to bear a range of expertise on the question" (1986: 165). In this respect, the AEC had produced a highly flexible and easily mobilized scientific research apparatus whose role was to support the emerging national political economy.

In its 1959 report to the JCAE entitled *The Future Role of the Atomic Energy Laboratories*, the AEC identified its new responsibility as "strengthening free enterprise on the one hand, and the universities as centers of education and learning on the other." Its resources, it advised, were "held in trust for the nation as a whole," poised for deployment in those times when "national needs . . . called for out-of-the-ordinary arrangements, efforts, and ability." The atomic energy field was only one area of national interest that had been and could be served by the AEC. In fact, the Commission pledged in its report, "to make room for new projects and undertakings" (quoted in Seidel, 1986: 165).

The AEC's effort to expand its role was based on the argument "that it was not what the laboratories did, but how they did it" (Seidel, 1986: 166). Examined in this context, the organization was highly successful. By the end of the 1960s the AEC had all but shed its traditional (i.e., nuclear) mission as the basis for its funding. In doing so, the agency saw its budgets increase significantly and its client list grow to include the Department of Commerce, the National Academy of Sciences, the National Institutes of Health, and a host of corporations. It was also engaged in research on such diverse topics as desalination, civil defense and carcinogenesis. The "Big Science" model, as practiced by the AEC, was so successful that its proponents were able to suggest that it was capable of providing all the necessary ingredients for the mass production of scientific and technological development in nearly all areas of society.

Thus, in its mature form, the AEC represented a new model of industrial organization and production method. While the early rationale for its existence had been predicated on national security needs, Big Science constituted a model of scientific-industry-state cooperation that was at the very center of the nation's transformation from its traditional manufacturing base to its present technology base. Seidel has suggested that the national laboratories acted as the "factories of [a] cerebral American System of Manufacturing," (Seidel, 1986: 135) and that the nuclear power program served as the "pilot" case for the high technology era. Both were fundamental in the transformation of the national political economy. Through state sponsorship, a "scientific estate" had been assembled to collaborate with industry in the production of highly expensive scientific goods (including a system of fully equipped national laboratories) and sophisticated technologies, such as power reactors, nuclear submarines, ballistic missiles and a host of laser related inventions (Price, 1965).

The AEC model in fact served its purpose so well that it was duplicated in a number of other science-based industrial fields, including that of aeronautics. A federally-sponsored science organization for research in aeronautics dates back to 1915 in the form of the National Advisory Committee for Aeronautics (NACA). NACA conducted research on aerodynamics and missiles and had enjoyed "long, close working relationships with the military services in solving their research problems, while at the same time translating the research into civil applications" (Anderson, 1976: 17). In 1958, the agency was renamed the National Aeronautics and Space Administration (NASA), and along with NACA's research staff and facilities, assumed control of all appropriate space and aeronautics projects from the Army, Navy and Air Force. Along the lines of the AEC model, NASA was charged with operating aeronautics and space research and development facilities, integrating this research with appropriate military projects, and engaging in joint ventures with industrial contractors (Anderson, 1976: 24-28). Many of the same corporations doing business with the AEC were among the largest NASA contractors, including among others, General Electric and Westinghouse. As for its university linkages, by 1970 NASA had contributed over $32 million for university laboratories and equipment, and $50 million in university research grants.

During the height of the Cold War, U.S. R&D was largely military-sponsored, with university and chemical/engineering industry partners working in conjunction with the national laboratory system to guide national technological development. As shown in Table 1, between 1954 and 1970, for instance, no less than 90 percent of public R&D funds went to DOD, AEC and NASA in support of the Big Science-Big Industry technology model.

Table 1

Federal R&D Expenditures by Agency, 1940-1971 (millions of dollars)

Year	DOD	MED/ AEC	NACA	NSF	NIH
1940-1950	4,643	2,279	256	-	-
1951	823	242	62	0.1	-
1952	1,317	250	67	0.5	-
1953	2,454	378	79	2	53
1954	2,487	393	89	3	52
1955	2,630	385	74	8	-
1956	2,639	474	71	15	-
1957	3,371	656	76	30	125
1958	3,664	804	89	33	154
1959	4,183	877	145	54	224
1960	5,653	986	401	64	256
1961-1971	80,272	16,450	41,260	2,625	7,216

DOD: Department of Defense
MED: Manhattan Engineering District
NACA: National Advisory Committee on Aeronautics (Reorganized as the National Aeronautics and Space Administration in 1958)
NSF: National Science Foundation
NIH: National Institutes of Health

SOURCES: National Science Foundation, 1958, 1971, and 1972.

The concentration of federal funds in the hands of a few large federal laboratories and corporations was characteristic of the R&D complex as a whole. In 1967, the 100 largest contractors received 65 percent of all military contracts and the top ten received 30 percent of its sales to military contracts from 1960 to 1967. Others, such as fifth-ranked General Electric, established subsidiary divisions specifically for defense contract work. As a result, nearly 20 percent of all GE sales involved DOD, AEC or NASA during the same period (Melman, 1970: 77-78). Universities likewise found it lucrative to turn their research attention to Big Science topics, ranging from the development of weapons systems to social control techniques (Melman, 1970: 100). Indeed, defense research and production problem-solving became a highly profitable academic enterprise.

Many of the universities applied the AEC model to their own institutions and developed separate laboratories and research centers for federally funded research. As might be expected, the distribution of these resources exhibited similar concentration tendencies. A congressional study revealed that in 1964 ten universities received 38 percent of all federal funds to institutions of higher learning and that 50 universities received 75 percent. Those institutions which were not participants in the elite group found innovative ways to compete for Pentagon, AEC and NASA dollars. One such initiative was Project Themis. Instituted in 1967 with a budget of $20 million, and raised to $30 million in 1969, Project Themis was designed as an effort to incorporate smaller universities into the defense R&D circuit so they might collaboratively compete for research contracts. Subject areas included a range of science and social science topics from detection and surveillance, navigation and control, energy and power, to information systems, environmental analysis, and social and behavioral studies (Melman, 1970: 100). Universities, in the words of former Michigan State University President John Hannah, "must be regarded as bastions of our defense, as essential to the preservation of our country and our way of life as supersonic bombers, nuclear powered submarines and intercontinental ballistic missiles" (quoted in Lens, 1970: 127). In brief, parity in university R&D meant not simply that public funds would be more widely enjoyed, but that the university *system* as a whole would steadily become integrated into Eisenhower's military-industrial complex.

The influence of the Big Science model was so pervasive that even those who sought to propose a different approach to the conduct of science were forced to accept its underlying suppositions. Perhaps the most significant example of this imperative is provided by the National Science Foundation (NSF), which was proposed and implemented by former OSRD director Vannevar Bush. In his well-received report to President Roosevelt on postwar scientific research, Bush outlined his program (Bush, 1980: 31):

> [NSF] should be a focal point within the Government for a concerted program of assisting scientific research conducted outside of Government. [It] should furnish the funds needed to support basic research in the colleges and universities, should coordinate where possible research programs on matters of utmost importance to the national welfare, should formulate a national policy for the Government toward scientific information among scientists and laboratories both in this country and abroad, and should ensure that the incentives to research in industry and the universities are maintained.

Relieved of the "constant pressure to produce in a tangible way," it was suggested that NSF would underwrite the needs of basic science "to explore the unknown" (Bush, 1980: 32). In contrast to the research and development activities already existing in government and industry, NSF was to support only basic research.

Despite formal statements such as these, Bush's vision was never intended to build a science independent of military and industrial considerations. Certainly Bush did not subscribe to a view of science as a source of criticism for the emergent power of the military-industrial alliance. Indeed, Bush proposed that NSF should fund research on new weapons and should support basic research in order to strengthen industrial productivity (1980: 32 and 21). The independence he sought was on the narrow question of who should decide on project funding: NSF (i.e., scientists), politicians, military officers, or industrial officials. In the broader sense, however, NSF seldom questioned the need to collaborate with the military and industry. Instead, the debate was focused then (and many believe still is today) on the relative role of the individual scientist versus scientific organizations.

Conclusion

Less than two decades after the Manhattan Project, there was little doubt, either in the nation's leadership or the public, that the future of the United States depended upon its scientific and technological standing in the international order. As Kevles notes, science as it was constructed in the post-war era, as well as the scientists themselves, were credited with being the progenitors of a progressive technological era. It was an age, according to Kevles when (1987: 391-392):

> [S]cientists were identified not only as the makers of bombs and rockets but as the progenitors of jet planes, computers, and direct dial telephoning, of transistor radios, stereophonic phonographs, and color television; when research and development, in what President Clark of the University of California called this "age of the knowledge industry", was believed to generate endless economic expansion; when electronic and computer firms were assumed to follow close upon the heels

> of local Ph.D. programs; when Governor Edmund G. Brown of California reported that, on the basis of an experiment in his state, space and defense scientists could solve problems of smog, sewage or waste disposal, and transportation.

Given the thrall of science, and the priority assigned to the country's over half-century commitment to atomic weapons and nuclear power, it is not perhaps surprising that the institutions which gave us bombs and electricity played a central role in postwar science-based industrialization. Micro-electronics, communications systems, computer technologies, laser devices, composite materials, computer-aided design and manufacture, robotics, radiology and many other industrial fields are directly indebted for their existence to the efforts of the atomic energy and weapons consortium.

One of the architects of the nuclear age expressed the enthusiasm for science and technology that has pervaded postwar society, and in particular, captured the imagination of the nuclear dreamer (Weinberg, 1956: 302):

> I do not think it unreasonable to propose that much of mankind's social and political tradition will become obsolete with the full flowering of the Scientific Era simply because all of the traditional doctrines were conceived in an economic and technological era which bears little relation to the age of abundance and moderation which I envisage . . . The bitterness which has been assumed to be part of all political struggle — whether intra- or international — will be mitigated because the basic conditions of life have become easier.

The results of the Manhattan Project and the Atoms for Peace Program have failed to coincide with the prospects envisioned by Weinberg. Instead, the technology has produced a litany of social ills, ranging from the nuclear arms race, to the disaster at Chernobyl and near-disaster at Three Mile Island, and the unresolved problems of bomb plant clean-up and civilian plant waste disposal and decommissioning. Equally important, the nuclear dream has resulted in the marginalization of democratic forms of governance. In this respect, the reinvigoration of democracy is, perhaps, the most significant challenge facing society in a post-nuclear age.

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