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FACTORS PROMOTING WEAPONS RESEARCH IN COLD WAR AMERICA: THE CASE OF MIRV

A Thesis

Presented To

The Faculty of the Department of History

San Jose State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Arts

by

Allison Lee Morgan

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ABSTRACT

FACTORS PROMOTING WEAPONS RESEARCH IN COLD WAR AMERICA: THE CASE OF MIRV

By Allison L. Morgan

This thesis examines the technological climate and process of innovation in America after 1945. The discussion is centered on weapons technology and the factors promoting the development of the sophisticated, high-profile MIRV (multiple independently-target reentry vehicle) technology. The analysis includes a review of public attitudes about technology, the reaction of America to Russian technological achievements, and the personal motivations of the scientists involved with nuclear weapons development.

Research in these areas shows that a technology like MIRV was the result of the iterative process of technological innovation in postwar America. The scientific community and its insatiable drive to innovate was the driving force behind new weapons technologies, including MIRV. Within the environment of the Cold War, the resources to accelerate the process were abundant.

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Introduction

One has to look out for engineers - they begin with sewing machines and end up with the atomic bomb.
- Marcel Pagnol (French playwright, 1895 - 1974)

MIRV (multiple independently-targetable re-entry vehicle) was one of the most important technological innovations of the Cold War. MIRV provided a single intercontinental ballistic missile with the ability to carry multiple nuclear warheads that could each be targeted at separate destinations. The MIRV capability has had serious ramifications for global offense, defense, disarmament negotiations and the arms race. Because of security classification and because MIRV had not yet acquired its appellation, the public was not aware of the capability until the late 1960s, when hearings on deployment began to take place. The primary justification for deploying MIRV at that time was the need to penetrate the Soviet Union's Anti-Ballistic Missile (ABM) System.[1] It was then assumed by many that "MIRV was originally conceived … as a means for penetrating ABM defenses and thus preserving the deterrent

[1] The Soviet Union first implemented the Talinn Air Defense system and later an actual missile defense system in the early 1960s that was referred to as Galosh.

value of strategic missile forces."[2] This assumption is incorrect. The multiple technological innovations required for MIRV were the result of an iterative process of innovation over a longer period of time than that in which MIRV was specifically being discussed. The core of the innovative process was not driven by the Soviet ABM system, by the direct need for money of the labs, or by any other obviously quantifiable force. The scientific community itself, against the backdrop of the Cold War and one of the most intense arms races in history, drove the technological innovation that led to MIRV.

Ted Greenwood's approach in *Making MIRV: A Study in Defense Decision Making* is representative of the false notion that weapons innovations in postwar America can be treated as independent events. In fact, weapons innovations, and for the purposes of this study, the MIRV innovation, must be treated as one project on a list of many inside a larger environment influenced by the Cold War. Greenwood claimed that MIRV was "not the inevitable result of the inexorable march of new technology."[3] He adheres to

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[2] Thomas W. Wolfe, *Statement by Dr. Thomas W. Wolfe at Hearings of the Subcommittee on National Security Policy and Scientific Developments, House Foreign Affairs Committee, July 22, 1969* (Santa Monica, CA: The RAND Corporation, 1969), 9.

[3] Ted Greenwood, *Making the MIRV: A Study of Defense Decision Making* (New York: University Press of America, 1975), 28.

the notion that the early innovators of the fundamental technologies required for MIRV "did not actively seek to match the mission concept to technical realization" and therefore "cannot be considered the inventors" of MIRV.[4] Like many who are unfamiliar with the process of scientific progress, he fails to understand that innovation does not happen as an independent event only when there is a clearly identified requirement. It is an iterative process comprised of collections of often diverse ideas.

Greenwood acknowledged in his own work that MIRV was "invented" by five different parties in the same time period.[5] He then concluded: "To adopt any of these partial explanations, the determination of technology, the inexorable drive of bureaucratic process or the preeminent role of central decision makers, as the explanation of MIRV programs is to miss the richness and diversity of the decision-making process. All were involved and all must be included if an accurate explanation of the MIRV programs is to be given."[6] It is in fact Greenwood, and those with similar approaches to analyzing innovation, who have missed

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[4] Ibid.

[5] Ibid.

[6] Ibid., 81.

the richness and diversity of the decision-making process in their attempts to extricate the MIRV innovation from the larger, technological environment of the Cold War. Weapons innovation in postwar America cannot be adequately explained outside of this context.

The scientific mind drives discovery and innovation. As the great David E. Lilienthal, first director of the Atomic Energy Commission, noted:

> Science is not an abstract, disembodied force; it is the work of men, of individuals. It is, in its finest form, an expression of man's determination to understand the natural world. In this the scientist is driven by much the same force that torments and fulfills the artists and the poet. His work springs from the highest, purest and most creative impulses in man.[7]

This concept is critical to understanding the process of innovation in which MIRV and thousands of other weapons were designed and built in America after 1945. However, while the scientific spirit is a constant throughout history, the environment in which that spirit thrives is not. Scientists innovating in postwar America were in a unique position in history.

The success of the Manhattan Project and the beginning of the Cold War permanently altered the technological climate in America. America's scientists were suddenly in a

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[7] David E. Lilienthal, *Change, Hope and the Bomb* (Princeton: Princeton University Press, 1963), 60.

position of influence over a very broad range of policies including defense policy. Behind the global technological stage was the backdrop of the arms race in the Cold War. In front of this backdrop, multiple dynamics were influencing the larger technological climate.

First there was a sense of competition with the Germans during the war and with the Soviet Union following the war. The Soviets and their technological prowess rose to a larger-than-life status in the minds of the American public, government and military. The ongoing lack of information on Soviet activities further fueled speculation and the arms race. "Better safe than sorry" was the attitude of the day, and the process of technological innovation accelerated accordingly.

Second, the success of the Manhattan Project facilitated the dawn of big science in America. It catapulted American technological programs to new levels of global importance. As a result, the scientists that embodied that success became increasingly important and technology came to be viewed as the cure-all for social, economic, medical and defense challenges. The race with the Soviets and the nature of the Cold War revolved around technological superiority.

Third, the increasing importance and complexity of technology required more and more scientists to get involved with policy advising and decision-making. In general, political and military decision-makers did not feel that they could grasp the continually advancing complexities of the development and uses of technology without panels and committees of scientists as advisors. In addition, scientists were also called upon by non-government organizations such as the press and corporations. One must remember that scientists brought their expertise to these roles but they also brought their innate scientific motivations to discover and innovate.

Each of these factors deserves detailed examination for its role in shaping the technological climate in which a technology as sophisticated as MIRV could be developed.

Chapter 1

The Arms Race and Innovation: The Case of the Ten-Foot Tall Russian

The environment in America in which the scientists were conducting their research and development was one of anxiety and uncertainty. The anxiety stemmed from a succession of events that seemed to confirm everyone's worst fears about Soviet intentions to rule the world: Soviet behavior at the end of the war, the Berlin Crisis, the Korean War, Soviet oppression in Eastern Europe and worst of all for American confidence - the successful launch of *Sputnik* on October 4, 1957. The uncertainty stemmed from the Soviet practice of being "secret[ive] about what they are and are not doing."[8] This lack of information led to worst-case scenario analysis and the myth of the "ten-foot tall Russian doing everything better than we can."[9] The American public was unaware of

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[8] Herbert F. York, *Making Weapons, Talking Peace: A Physicist's Odyssey from Hiroshima to Geneva* (New York: Basic Books, 1987), 99.

[9] Physicist Herbert F. York, interview by author, 6 November 1999, La Jolla, CA, tape recording (hereafter noted as *York Interview*, 6 November 1999). York's extensive career includes participation as a physicist in both the Manhattan Project and the hydrogen bomb project. He went on to become the first director of Lawrence Livermore National Laboratory, the first appointed Director, Defense Research & Engineering, and later an ardent participant in disarmament policy and negotiation.

the many secret projects being undertaken in rocket and guided missile development and thus reacted very strongly to the news of *Sputnik*.

In the months following the launch of *Sputnik*, *The New York Times* and *Time Magazine* were filled with concern over Russian domination of the world and with criticism of United States' scientific programs and efforts in education. On November 18, 1957, *Time Magazine* reported, "Now the U.S. has to live with the uncomfortable realization that Russia is racing with clenched-teeth determination to surpass the West in science – and is rapidly narrowing the West's shielding lead."[10] Physicist Edward Teller predicted, "The Russians may be able to manage the weather within the next decade even."[11] On Saturday, October 5, 1957, *The New York Times* reported that the Museum of Natural History and the Hayden Planetarium began to receive up to one call per minute for more information regarding the facts and meaning of the Soviet launch.[12] Senators Stuart Symington of Missouri and Henry M. Jackson of Washington said, "The development [*Sputnik*] is further evidence of Soviet superiority in the

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[10] "National Affairs," *Time Magazine*, 18 November 1957, 21.

[11] "Defense," *Time Magazine*, 9 December 1957, 27.

[12] *New York Times*, 5 October 1957, page 1.

long-range missiles field."[13] The Soviet Union itself further fueled the fire when it reported "that it had put a scientific instrument into space before the United States."[14] The belief in this obvious demonstration of Soviet scientific superiority, fueled by the launch of a second satellite led to an examination of the American educational system. Senator Lyndon Johnson told the newly formed Preparedness Investigating Subcommittee, "With the launching of *Sputnik I* and *II* and with the information at hand of Russia's strength, our supremacy and even our equality has been challenged. Our goal is to find out what is to be done."[15]

The majority of the criticism took aim at an alleged lack of emphasis on science and math both in education and in government programs. The National Student Association warned: "If the nation fails to improve not only the scientific but all aspects of education, the U.S. educational system might be reduced to a satellite of the Russian system, spinning in an orbit dictated by Russian scientists."[16] Edward Teller told *Time Magazine*, "They [the

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[13] Ibid.

[14] Ibid.

[15] "National Affairs," *Time Magazine*, 9 December 1957, 27.

[16] "Education," *Time Magazine*, 25 November 1957, 99.

Soviets] caught up with us because they work harder. A Russian boy thinks about becoming a scientist like our young girls dream about becoming a movie star."[17] Dr. Vannevar Bush, wartime director of the Office of Scientific Research and Development, urged revamping the Armed Forces Unification Act in order to further eliminate inter-service competition. Lt. General James Doolittle called for an overhaul of the United States educational system so that "the scientist and the educator [would] be given more prestige and more pay."[18] Former President Herbert Hoover noted: "We are turning out … fewer than half as many scientists and engineers. The greatest enemy of all mankind, the Communists, are turning out twice or three times as many as we do."[19] The overwhelming alarm, according to physicist Donald Hughes, was that " [the Soviets] are training more people, making their students spend longer hours at work, and putting more money into science than we are."[20] Both the criticism from the public and a sense of alarm inside the administration, spurred

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[17] "Defense," *Time Magazine*, 9 December 1957, 27.

[18] Ibid.

[19] "Education," *Time Magazine*, 2 December 1957, 53.

[20] Ibid., 76.

President Eisenhower to react with governmental programs and an emphasis on science and technology that would have far-reaching effects.

President Eisenhower wrote in his memoirs that he was surprised at the intensity of public concern.[21] However, while he wrote, "the Soviet space ambitions had been no secret," he reacted by taking the *Sputnik* "warning [and] ... taking added efforts to ensure maximum progress in missile and other scientific programs."[22] Between October 1957 and the end of his term in 1961, President Eisenhower recommended a fivefold increase in spending for the National Science Foundation for science education, signed the National Defense Education Act into law, and recommended a number of scholarship and funding programs specifically for science and math education. In addition, he appointed a Special Advisor to the President for Science and Technology and created the President's Science Advisory Committee. He approved the establishment of the Advanced Research Projects Agency (ARPA) and also appointed a cabinet-level equivalent as Director Defense Research and Engineering to sit in the Pentagon and supervise all defense research projects.

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[21] Dwight D. Eisenhower, *The White House Years: Waging Peace, 1956 - 1961* (New York: Doubleday & Company, Inc., 1965), 206.

[22] Ibid., 205-6.

Eisenhower made it clear that science and technology were going to be emphasized as a key component of America's security. Eisenhower used his 1958 annual address to speak specifically and exclusively about America's position regarding scientific and military strength and about the pursuit of peace, in order to calm the public's fears and improve confidence in the nation.[23]

While the arms race had its roots in 1940 when America was afraid that Germany would develop the atomic bomb first, it was accelerated after 1945 and throughout the 1950s. As discussed above, it stemmed, in part, from a fear of what the Soviets *appeared* to be doing but there was also an element of competition between the services. Herbert F. York points out that the air-launched ballistic missile project, referred to as *Skybolt*, was a direct result of competition between the Air Force and the Navy, the latter of which was already developing the submarine-launched *Polaris* ballistic missile. If the Navy had the capability of moving up closer to the enemy and firing a short-range missile from a submarine then the Air Force wanted to be able to do the same, launching the *Skybolt*.[24] Henry A. Kissinger wrote in 1957 that it was the lack of strategic doctrine for the

[23] Ibid., 240.

[24] *York Interview*, 6 November 1999.

combination of the forces that led each to develop its own complete set of weapons, including strategic striking weapons.[25] It is also reasonable to assume that the competition stemmed from pride and even hubris in each of the services. Whatever the reason, the services were each open to new scientific ideas and innovation for how to make themselves more critical to United States security and to further their effort at being the most important service. This caused additional budget allocation to scientific research and development, which in turn made resources available for new experiments. This competitive element was also present when the Air Force and the Navy developed MIRVed missiles around the same time.

In addition to the public and government reaction to *Sputnik*, a lack of concrete information about Soviet activities caused the most alarm in the administration and the military. Herbert Scoville, deputy director of the CIA, gave a speech in front of an open scientific forum on October 4, 1957, in which he said, "The Soviets could launch a satellite this month, this week, or even today."[26] Worst-case analysis and the concept of mirror imaging would remain

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[25] Henry A. Kissinger, *Nuclear Weapons and Foreign Policy* (New York: Harper & Brothers, 1957), 18.

[26] York, *Making Weapons, Talking Peace*, 101.

strong components of the planning process. In this case, mirror imaging assumes that the Soviets have all of the same technologies and capabilities that the United States has. Worst-case analysis goes a step farther and assumes not only that United States capabilities are mirrored by Soviet capabilities, but that the Soviets must also be farther along in effectively deploying current technologies and developing new technologies that the United States is just beginning to conceptualize. Worst-case analysis can also assume that the Soviets are ready to use those capabilities in a hostile manner toward the United States.

Beginning long before the development of the technologies required for MIRV, the pattern of reacting to what *might* be happening in the Soviet Union was already firmly established. Secretary of War, Henry Stimson commented to President Truman in August of 1945, that United States possession of the atomic bomb would "almost certainly stimulate feverish activity on the part of the Soviets toward the development of this bomb."[27] Later, when full-scale development of the hydrogen bomb was being discussed, the General Advisory Committee (GAC) of the Atomic Energy Commission (AEC) argued that building the "Super" might

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[27] Richard Rhodes, *Dark Sun: The Making of the Hydrogen Bomb* (New York: Simon & Schuster, 1995), 209.

unleash unlimited destruction. According to Richard Rhodes, with its argument opposing full-scale development of the hydrogen bomb, the GAC "unwittingly enlarged the scope of its opponents' fears and encouraged them to pursue the project with even greater urgency, because they immediately translated the weapon's destructive potential into a threat and imagined the consequences if the enemy should acquire it first."[28] Retired nuclear physicist Herbert F. York wrote in his memoir, "Could the development of the hydrogen bomb have been avoided? Even in the full light of retrospection, I do not see how. Even if there were no other reasons - and there were others - the almost total lack of communications between Stalin's Russia and the rest of the world would alone have made its avoidance impossible as a practical political matter."[29] This pattern continued until the United States, with limited information about what the Soviets were actually developing, was in an arms race with itself. Richard Rhodes was correct when he wrote, "An arms race is a hall of mirrors."[30]

With the Soviet Union constantly in the nation's consciousness, the United States technological race was not

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[28] Ibid., 402.

[29] York, *Making Weapons, Talking Peace*, 69.

[30] Rhodes, *Dark Sun*, 402.

so much between weapons that were for the same purpose as between offensive and defensive capabilities. When asked to comment on the arms race, York said, "There's essentially your imagination about what they can do which usually is that they can do what we can do and in that sense our ABM and our strategic missiles are in competition with each other even though we think our missiles are in competition with their ABMs."[31] This circular thinking permeated all the way to the Office of the President. When John F. Kennedy took office in 1961 he instructed Secretary of Defense Robert S. McNamara to review all defense research and development projects. In the subsequent cabinet meeting, McNamara recommended canceling two high profile projects, the *B-70* supersonic bomber and the *Skybolt* air-launched ballistic missile. Kennedy replied, "No, I need the *Skybolt* to shoot down the *B-70*."[32] This prevailing attitude of being better safe than sorry in technological development trickled down to the nation's labs and development centers and influenced the direction of scientific innovation. The embedded urge of the scientists to discover and innovate combined with the prevailing fear and uncertainty driving the Cold War and the arms made a

[31] *York Interview,* 6 November 1999.

[32] Ibid.

very powerful combination. This combination formed the basis for the environment in which the technologies necessary for MIRV capability were developed and in which scientists and technology came to the main stage.

Chapter 2

Elements Contributing to the Operational Philosophy of the National Laboratories

The rise in the importance of the role of scientists took place in a relatively short amount of time. In the late 1930s, scientists were heavily recruited to work on radar and wireless communications for immediate pre-war effort. However, the success of the Manhattan Project and subsequent detonation of atomic bombs over Hiroshima and Nagasaki in August 1945 catapulted the scientists to an unprecedented role of importance in American culture. The influence of this role in the process of innovation directly helped to spawn the technologies that would be used to build MIRV. In order to understand how scientists and technology reached this pinnacle, it is necessary to take a step back to the Manhattan Project and the immediate postwar activities of the scientists to examine the elements of the technological climate that most characterized the project and how scientific efforts after 1945 would be conducted.

The Manhattan Engineering District, or MED, was the official name of the project whose goal was to construct an atomic bomb for use in World War II. This bomb would be more powerful by many orders of magnitude than anything the world had seen. Before that time, weapons of such enormous power only existed in science fiction novels and in the backs of the minds of those relatively few physicists who were exploring the structure of the atomic nucleus. The success of what we now know as the Manhattan Project marked the dawn of a new era in weapons, diplomacy and scientific discovery.

Mentioned above, the complex process of scientific discovery deserves special attention. The scientific mind does not operate as a machine; its creativity cannot be turned on when needed and off when unnecessary. Nor does it function in the fashion of an assembly worker who can perform a routine task regardless of whether or not he or she feels good or bad, fulfilled, or unfulfilled. Scientific discovery is rarely routine by its very nature and requires an intellectually stimulating environment with sufficient opportunity for personal recognition and growth. The influence of these essential requirements combined with a wartime urgency and a critical need for security formed the technological climate in which the world's first atomic bomb was designed, tested and manufactured. The project which consumed the war year efforts of tens of thousands of people, including many of the world's most brilliant physicists, created a new concept of "big science" and left a lasting impression on scientific discovery in America.

The core of the Manhattan Project was the scientific drive of the world's nuclear physicists from Germany, Italy, Hungary, England, France, Denmark and the United States to unlock every last secret of the atomic nucleus. Their discoveries, done both serially and in parallel, led to the idea of nuclear energy and then to the possibility of an atomic bomb.

For most of these physicists, science and the process of doubting and discovering had been part of their emotional fabric since childhood. Leo Szilard wrote, "As far as I can see, I was born a scientist. I believe that many children are born with an inquisitive mind, the mind of a scientist, and I assume that I became a scientist because in some ways I remained a child."[33] Edward Teller, who would later be considered the father of the hydrogen bomb, recalls his scientific upbringing and shows that the grave political situation notwithstanding, his overriding goal was

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[33] Leo Szilard, *Leo Szilard: His Version of the Facts* ed. Spencer R. Weart and Gertrud Weiss Szilard (Cambridge: MIT Press, 1978), 3.

scientific discovery. "I started my scientific work in Germany during the declining years of the Weimar Republic. For as long as I could remember, I had wanted to do one thing: to play with ideas and find out how the world is put together."[34] Physics Nobel Laureate Emilio Segre, writing about his mentor, physics Nobel Laureate Enrico Fermi wrote: "Physics was the essence of his life. Although he lived in a time of great human drama, and, through his work, became a major actor in it, his personal involvement was with the intellectual adventure of scientific discovery."[35]

Segre wrote of Fermi without a trace of reticence to show his reverence for the man as a physicist. Along with inquisition and doubt being innate to the scientific mind, "science has a hero system."[36] "Younger scientists regard, older, successful scientists as heroes," said York, physicist at the Berkeley Radiation Laboratory during the Manhattan Project. [37] "Fermi is an enormous hero … I knew that soon after I met Segre. Even though Segre is twenty years older than me, he's got this hero who is older than

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[34] Edward Teller with Allen Brown, *The Legacy of Hiroshima* (New York: Doubleday & Co, 1962), 8.

[35] Emilio Segre, introduction to *Enrico Fermi: Physicist* (Chicago: University of Chicago Press, 1970), ix.

[36] *York Interview,* 6 November 1999.

[37] *York Interview,* 6 November 1999.

him!"[38] York went on to explain that when teaching nuclear physics, it is not about explaining generic equations and principles but that " you teach it in terms of these people and how they did it." York then delivered the most poignant comment on the "hero system":

> The relationship between Ph.D. supervisors and Ph.D. students in one-third or one-half of the cases remains like a father-son relationship through their whole life. I didn't see Emilio that often but we saw him every once in a while and it was always very pleasant; even though he was a difficult person, I loved to see him.[39]

This "hero system" affected young nuclear physicists as well as those that are thought of today as the greatest in their fields. The famous physics Nobel Laureate Richard Feynman remarked much later in a speech about his attendance at a conference during the Manhattan Project, "… there were so many of them that it's one of my great experiences in life to have met all these wonderful physicists. Men that I had heard of ... the greatest ones were there."[40] And, in talking about a visit of the famous scientist, Neils Bohr, to Los Alamos, where Feynman worked during the war, he said, "all the big shot guys [the famous, lead scientists at Los

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[38] Ibid. Emilio Segre was PhD advisor to York at the University of California, Berkeley after the war.

[39] Ibid.

[40] Richard P. Feynman, *The Pleasure of Finding Things Out: The Best Short Works of Richard P. Feynman* ed. Jeffrey Robbins (Cambridge: Perseus Books, 1999), 85.

Alamos], to them, he was even a great god. … We were at a meeting and everybody wanted to see the great Bohr."[41] Segre and Fermi were from Italy, Bohr was from Denmark, and York and Feynman were from the United States. It did not matter where these great physicists originated, they inspired younger and older in the global nuclear physics community.

The global nuclear physics community was characterized by competitive cooperation.[42] The physicists all knew of each other through publication in journals, attendance at conferences, and work at the universities. For each, their work depended on publication for review, challenge, correction, and improvement from their peers. William Lanouette wrote of Leo Szilard, "His true excitement with physics came in the seminars and colloquia, the often noisy meetings where scientists discussed and debated their latest ideas."[43] The practice of publication catalyzed the continuation of a thread of work by graduate students of the

[41] Ibid., 87.

[42] David Reynolds, *The Creation of the Anglo-American Alliance 1937 - 41: A Study in Competitive Cooperation* (London: Europa Publication Limited, 1981). Competitive cooperation is a phrase derived by David Reynolds in discussing the creation and character of the wartime alliance between the United States and Great Britain.

[43] William Lanouette with Bela Szilard, *Genius in the Shadows: A Biography of Leo Szilard, The Man Behind the Bomb* (Chicago: University of Chicago Press, 1992), 58.

physicists and by peers of the physicists. It was perfectly natural for a graduate student to continue the same thread of work or an augmentation of the work that his or her Ph.D. advisor was working on. In the case of Leo Szilard, his thought process for conceiving of the nuclear chain reaction was facilitated by work that had been published by his European colleagues, Ernest Rutherford and the Curie-Joliots. Until the early 1930s when Hitler was revealing his intentions and capabilities, these interwoven relationships between physicists transcended national boundaries and formed a fabric of scientific discovery and innovation.

This is not to say, however, that these physicists were altruists uninterested in receiving proper credit for their ideas and experiments. Although they cooperated with each other in order to further the community's practice of nuclear physics they were also competitive with each other. This competition revolved around making sure that if one conceived an idea, he would publish it immediately in order to receive priority for that idea. This "rock star" mentality is an important concept to understanding how the environment of scientific discovery was driven more from within itself than from any outside stimulus. The physicists were racing ahead to explore this "sexy" new area of nuclear physics.

Nuclear physics was a budding new area where significant discoveries could still be made. While mechanics and electromagnetism were fairly well understood by the early 1930s, "... the great surprises in the first half of the twentieth century would come in physics. ... The atom's time was at hand."[44] Segre wrote of Fermi, "Even though the purpose was grim and terrifying, it was one of the greatest physics experiments of all time. Fermi completely immersed himself in the task."[45] York explained, "We were very happy to be part of that and to be part of the whole world of nuclear science which a great many saw as the most exciting part of science at that time."[46] Each of the scientists brought with him or her a seemingly boundless quest for discovery and innovation, a reverence for those who had come before them in the field, experience with competitive cooperation within the global nuclear physics community, and excitement about meeting the immense scientific challenge of creating the world's first atomic bomb. Upon arriving at

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[44] Richard Rhodes, *The Making of the Atomic Bomb* (New York: Simon & Schuster, 1986), 36.

[45] Segre, *Enrico Fermi: Physicist*, 45.

[46] *York Interview,* 6 November 1999.

the various laboratories of the Manhattan Project, the scientists and their collections of experience and motivation were met with the new urgency of wartime.

The United States physicists approached the wartime urgency from a different perspective than did the European-born physicists. The United States physicists were anxious to take part in helping to bring a more rapid end to the war. "We were very optimistic about all of this and its influence on the war. We were very optimistic. … We didn't have any doubt it was going to end the war," commented York.[47] However, while the United States physicists were driven in part by this general enthusiasm for ending the war, they did not possess first hand experience with the increasing horrors of the Nazi regime as did many of the European-born scientists.

A.H. Compton, in discussing this subject, says that the European scientists were more alert to the Nazi danger than the American scientists and thus were anxious to be ahead of Germany in the making of any decisive weapon.[48] The European physicists had at the forefront of their minds Hitler's obvious and apparently growing capacity for evil.

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[47] Ibid.

[48] Segre, *Enrico Fermi: Physicist*, 110, quoting Arthur H. Compton, *Atomic Quest* (New York: Oxford University Press, 1956), 28.

They saw the Manhattan Project as a critical race against the Germans for the atomic bomb. Because of the international community in physics, each was familiar with the accomplishments of famous German scientists such as Werner Heisenberg and Werner Von Braun. "If a chain reaction would work in graphite and uranium, Szilard assumed, then a bomb was probable. And if he had managed these conclusions, he further assumed, then so had his counterparts in Nazi Germany."[49] This wartime urgency compelled all of the scientists to diverge from their theoretical heritage to a more practical approach to building a bomb that would actually work.

This more practical approach was called the Edison Method. With the Edison Method, scientists discover and innovate while emphasizing the practical. The focus of the scientists had to transition from understanding to use and from general conceptions to particular materials and apparatuses.[50] In effect, they had to be much more practical than academic and had to try solutions until one worked whether it matched the theoretical prediction or not.

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[49] Rhodes, *The Making of the Atomic Bomb*, 302.

[50] Lillian Hoddeson, Paul W. Henriksen, Roger A. Meade, and Catherine Westfall, *Critical Assembly: A Technical History of Los Alamos during the Oppenheimer Years, 1943-1945* (Cambridge: Cambridge University Press, 1993), 5.

It may seem like a rather haphazard approach to development but as Richard Feynman once put it: "It would have been unscientific not to guess."[51] The process also yielded important results. First, the scientists knew that whatever solution was arrived at was going to work because it had been derived with an emphasis on concrete phenomena rather than complete theory. Second, experiments could be carried out in parallel to save time. Third, often, the diversity of the experiments yielded valuable information that could be leveraged to solve other indirectly related or future problems. When the Hungarian-born Teller asked a friend of his how he could abandon pure mathematical research to work on airplane designs, the friend replied: "With Hitler on the rise, we scientists can no longer be frivolous. We cannot play around with ideas and theories. We must get to work."[52] York summed up the combination of the scientific drive with wartime urgency: "I would say that the priority and the competition and 'I want to get there ahead of you so I can be more famous,' which is a standard stuff of science, was set aside, and the race, instead of being with one's

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[51] Richard P. Feynman, *The Meaning of It All: Thoughts of a Citizen-Scientist* (Reading: Perseus Books, 1998), 25.

[52] Teller, *Legacy of Hiroshima*, 8.

friendly competitors, was with the enemy or with time."[53] This combination necessitated changes in the traditional academic approaches and the result was the more practical Edison Method.

The Edison Method also required that physicists work closely with chemists, engineers, metallurgists and ordnance staffs in order to build a complete, operational solution. Without interdisciplinary cooperation, each individual group would have only a piece of the solution. Because an atomic bomb involves every major physical, biological and chemical principle, it was critical that these teams work together. This requirement created a need for open communication channels between the teams for ideas exchange and problem solving. However, an open forum for communication violated every military security principle governing highly classified projects.

Brigadier General Leslie M. Groves of the United States Army was responsible for overseeing the Manhattan Project. He supervised the operation of the national laboratories and oversaw the training program for the pilots of the *B-29* bombers, *Enola Gay* and *Bock's Car,* that would drop the atomic bombs. Groves also advised on targets in Japan, and

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[53] *York Interview,* 6 November 1999.

worked on post-war policy regarding atomic energy. He was the connection between the Manhattan Project and the policy makers at the top of the United States government. The wide range of his responsibilities reflected the high level of security on the project. Because of the President's reluctance to let others in on the secret, Groves was involved in almost every aspect of the bomb's development and use. Groves, however, was no stranger to large, expensive, classified projects. His previous assignment had been to oversee the construction of the Pentagon where security and compartmentalization of information was essential to maintaining the integrity of what would be the nerve center of our nation's military decision-making system.

The rules of information compartmentalization in standard security practice, however, were contrary to the fundamentals of scientific discovery and created much friction with the scientists working on the project. Groves summarizes his position on security and the scientific discovery process as follows:

> This flow [of information between scientists] had to stopped, if we were to beat our opponents in the race for the first atomic bomb. Compartmentalization of knowledge, to me, was the very heart of security. My rule was simple and not capable of interpretation - each man should know everything he needed to know to do his job and nothing else. Adherence to this rule

> not only provided an adequate measure of security, but it greatly improved overall efficiency by making our people stick to their knitting. And it made quite clear to all concerned that the project existed to produce a specific end product - not to enable individuals to satisfy their curiosity and to increase their scientific knowledge.[54]

There are two problems with Groves's position in relation to the scientists. The first is that compartmentalization does not allow the scientists to brainstorm together and challenge and check each other's work in order to ensure high quality solutions. "No one should be surprised that a group of independent scientists found General Groves and his regulations irritating. Secrecy runs contrary to the deepest inclinations of every scientist."[55] As mentioned earlier, scientists built not only from their own ideas but also from the work of others in the field. If the physicists were cut off from other work going on in the field, the discovery process would be inhibited. In addition, interaction between disciplines was critical for a complete solution for the bomb. Although General Groves knew this to a degree because his military people had to work with the scientists directly on

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[54] General Leslie M. Groves, *Now It Can Be Told: The Story of the Manhattan Project* (Reading: Perseus Books, 1962), 140.

[55] Edward Teller, introduction to *Now It Can Be Told: The Story of the Manhattan Project* by General Leslie M. Groves (Reading: Perseus Books, 1962), v.

operational issues, he still felt that somehow these problems could still be efficiently solved in a compartmentalized environment.

The physicists saw compartmentalization as a detriment to the efficiency of finding the solution. In complaining about Vannevar Bush's[56] reorganization in the fall of 1941, Leo Szilard felt it a grave error to compartmentalize a scientific effort "that could thrive only on intellectual interchange. … We knew in August 1939 how to make a power plant with graphite and uranium."[57] Szilard suggested that if memos and papers written by himself and Albert Einstein had been adequately shared among team members that "the war would have been over by now [May 1942] if those recommendations had been acted upon."[58] The most challenging aspect of the Manhattan Project was obtaining fissionable material. Likewise, Segre wrote of a situation in the summer of 1940 where experiments had been done that showed that there was an alternative to the slow, inefficient processes of uranium isotope separation to

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[56] Dr. Vannevar Bush was President of the Carnegie Institution of Washington and Chairman of a policy panel at the National Academy of Sciences (NAS). In June of 1940, he was appointed by President Roosevelt to run the National Defense Research Committee that would later be renamed the Office of Scientific Research and Development and would direct scientific work for military use.

[57] Lanouette, *Genius in the Shadows*, 232.

[58] Ibid.

obtain fissionable material. He continued, "These ideas had been in the air, so to speak; and they sprung up at several places, but wartime secrecy forbade their promulgation."[59]

The second problem with Groves's position on secrecy was one that he articulated himself in his own memoir of the Manhattan Project:

> The big problem in getting good people arose from the fact that the scientific resources of the country, particularly for this general area, were already fully engaged on important war work. Because they were civilians, the scientist[s] [had] complete freedom in their choice of jobs.[60]

The value of a scientist in the employment market is based on what he or she knows. It is based on intangible, intellectual property. Therefore a scientist, in order to maintain both marketability and the innate motivation of scientific discovery, must be able to continue his intellectual growth. This would not be possible in an environment that is totally cut off from other scientists and scientific freedom of speech with one's peers. With this in mind, the hesitancy on the part of members of the scientific community to embark on such a venture is understandable. Even Groves and his team were able to understand this, although they perhaps didn't agree, and

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[59] Segre, *Enrico Fermi: Physicist*, 118.

[60] Groves, *Now It Can Be Told*, 150.

they furnished J. Robert Oppenheimer, Director of Weapon Design and Los Alamos National Laboratory, with a letter to present to recruits conveying that "by joining us [Los Alamos National Laboratory] they would not be cut off from the rest of the scientific world."[61] This letter indicated that although there was friction between the policies of the military and the needs of the scientific community, there was room for a solution to attempt to address the needs of both.

Discussion of scientist resistance to militarization and strict security is not to suggest that they felt no need whatsoever to maintain security. In fact, when Leo Szilard first conceptualized the chain reaction and then its possible application to military weapons and the ramifications of the Germans getting it first, he initiated an effort for self-censorship in the nuclear physics community. An intense discussion resulted in the community about the absolute necessity of the fundamental practice of peer review on one hand and the extreme danger if the Germans figured out how to build a bomb first on the other. Neils Bohr felt very strongly about publishing and:

> … had worked for decades to shape physics into an international community, a model within its limited franchise of what a peaceful, politically united

[61] Ibid., 151.

> world might be. Openness was its fragile, essential charter, an operational necessity, as freedom of speech is an operational necessity to a democracy. Complete openness forced absolute honesty. … Secrecy would revoke that charter and subordinate science to a political system.[62]

There was not an easy solution to reconciling the needs of peer review, individual recognition and world security. In the case of Fermi and Szilard and their secondary-neutrons experiments, they mailed the reports to the *Physical Review* in order to establish priority, but they asked the editor to delay publishing them until the new security issues could be resolved.[63]

According to Richard Rhodes, Szilard was right to be concerned. When the French trio of Joliot/von Halban/Kowarski published two papers on secondary-neutrons in *Nature* in March and April of 1939, a German physicist alerted the Reich Ministry of Education. A secret conference in Berlin immediately followed and as a result Germany took the bold steps of initiating a research program, banning uranium exports and obtaining radium from the Czechoslovakian mines at Joachimsthal.[64] At the time, Szilard was alarmed at the French transgression and began to

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[62] Rhodes, *The Making of the Atomic Bomb*, 294.

[63] Ibid., 293.

[64] Ibid., 296.

construe ways to take responsibility himself for reaching the right authorities. This led to his contact with Albert Einstein, living on Long Island, and for whom Szilard grew to harbor tremendous respect. A rewarding relationship resulted. The pair's exploration of a number of possibilities and pathways culminated in the famous letter from Albert Einstein to Franklin D. Roosevelt on the possibility of an atomic bomb.

The concerns of all parties involved in the security debate were valid and compromises were made to address the issues. Oppenheimer insisted:

> We needed a central laboratory devoted wholly to this purpose, where people could talk freely with each other, where theoretical ideas and experimental findings could affect each other, where the waste and frustration and error of the many compartmentalized experimental studies could be eliminated, where we could begin to come to grips with chemical, metallurgical, engineering, and ordnance problems that had so far received no consideration.[65]

Oppenheimer finally obtained his open scientific community at Los Alamos, New Mexico, but in return, General Groves strictly isolated Los Alamos, generally cutting off its residents from outside life. This compromise is representative of the workable solutions to the complex problem of maintaining security on a project of such magnitude where both tangible and intangible issues had to

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[65] Ibid., 448.

be dealt with. Neither group was completely satisfied with the solutions. There was still a general feeling among the scientists that the security measures retarded the success of the project, while General Groves believed that the scientists had no regard for his all-important security system. At one point Groves tried to have all foreign-born scientists taken off the project for security reasons. While this might have been prudent in respect to standard security practice, it clearly made no sense for the Manhattan Project given that a significant number of the lead scientists were born in Europe. The ongoing contentious relationship was a combination of the scientific drive, the wartime urgency and the needs for security and would exist until the end of the war and into the post-war period. These elements of character that the scientists brought to the Manhattan Project and subsequently to the technological climate in America are very important for understanding how that climate would be conducive to developing a technology like MIRV.

Scientific discovery and the postwar period in America were heavily influenced by the Manhattan Project and its success. Among the most important immediate changes were the emergence of the United States as a leader in physics, the dawn of "big science" and multi-disciplinary cooperation, a heightened relationship between the federal government and the scientific community and a political and social awareness of scientists concerning the ramifications of their scientific discovery.

In the early 1900s, the United States was not considered a hotbed for physics, but in the late 1920s and early 1930s the field began to develop. Many of the newer American physicists had been trained in Europe and were considered better educated than their predecessors. The American *Physical Review,* however, was still considered a backwater publication.[66] Furthermore, in the late 1930s and early 1940s, while new discoveries about the atomic nucleus were being pursued in Europe, many of the United States' brightest physicists at the prestigious Lincoln Laboratories at MIT were focused on developing radar.[67] But as the grim events in Germany and in Europe began to unfold, the United States physics community benefited. European physicists began to protest the Nazi regime by publishing in English instead of the usual German and Italian. Many of the non-German European physicists had colleagues and friends in Germany and were thus aware not only of the difficulties of their friends but also of the degradation of physics in

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[66] Ibid., 141.

[67] Segre, *Enrico Fermi: Physicist,* 110.

Germany due to the persecution of many scholars. This resulted in more and more physicists turning to the United States and England in order to prevent physics from being degraded further.[68]

This turn, which later most heavily impacted the United States, led to an immigration of the European physicists. Most of the motivation for seeking immigration was fear of the Nazi regime on the part of those physicists who were Jewish, or as in the case of Enrico Fermi, had a Jewish spouse.[69] Many non-Jewish scientists and intellectuals also immigrated to avoid Nazi persecution or to protest the regime. A significant number of these physicists would later become Nobel Laureates. This infusion of talent filtered into universities and labs in the United States and "by the time Project Y [the program at Los Alamos] was underway, the American physics community had matured sufficiently to handle the challenge of building the atomic bomb. It was no longer scientifically or institutionally backward in comparison to Europe."[70]

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[68] Ibid., 92.

[69] Notable immigrants include Albert Einstein, Leo Szilard, Edward Teller, Hans Bethe, Enrico Fermi, Emilio Segre, Neils Bohr, John von Neumann, and Stanislaw Ulam.

[70] Lillian Hoddeson et al, *Critical Assembly*, 7.

To complete the transition from backwardness to preeminence in physics, the Alsos Intelligence mission, led by General Groves, entered Germany behind the United States Army. They were there to capture German physicists and laboratory data on a number of topics, including nuclear physics. This mission yielded valuable insight into how close the Germans were to building an atomic bomb and also furnished the United States with yet another infusion of scientific talent from Germany. One of the physicists, Werner Von Braun, would go on to play a critical role in launching the first American artificial satellite into orbit. The German physicists were not unhappy to see the United States Army because "nobody wanted to surrender to the Russians."[71] Thus the United States was fully established as a physics powerhouse after the war.

The second and most widespread change motivated by the Manhattan Project was the dawn of big science and multi-disciplinary cooperation. Big science is the concept of large groups of scientists working together on projects and in laboratories. It is a departure from the traditional structure of a senior researcher and four to six graduate students in his lab. Big science involves cross-

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[71] *York Interview*, 6 November 1999.

disciplinary projects in which physicists work with chemists, engineers, machinists, etc. in order to accomplish a large goal. In the early 1930s, Ernest O. Lawrence was one of the first laboratory directors to practice group science in his laboratory at the University of California, Berkeley, but this was by no means a widespread practice in the physics community before the war. During the war, these cross-disciplinary groups necessarily had to work together. The result was a fast, efficient development method that was adopted for postwar projects both in the United States and internationally.[72]

When these cross-functional teams were faced with the wartime urgency of having to build a working, atomic bomb that would explode predictably, they necessarily had to adopt the Edison method. As Richard Feynman remarked in a speech long after the war was over, "I think that to keep trying new solutions is the way to do everything."[73] This more practical approach, emphasizing concrete research products rather than pure theory, has influenced the research methods of laboratories and technology firms up to the present day. It is probably safe to suggest that this influence was a building block in the close relationships

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[72] Lillian Hoddeson et al, *Critical Assembly*, 405.

[73] Feynman, *The Meaning of It All*, 9.

that exist today between the military, the research laboratories, and the military contractors' laboratories. The critical vehicle for spreading this influence, however, was the dispersion of the talent after the war.

"The valuable thing was not the big projects; the valuable things were the numerous teams, which somehow crystallized during the war, of men who had different abilities and who liked to work together with each other."[74] This statement by Leo Szilard contains two important points. The first is that as the projects began to dissolve after the war, the scientists dispersed to various universities and laboratories, some back from whence they came and some to new places. With them, they took their Manhattan Project experience and spirit. As York remarked: "It's the formative years syndrome. For somebody who does that when I'm [*sic*] twenty, that's the rest of my life. … I have to think of what I was doing before, because the war overwhelms everything."[75] These scientists built enduring relationships during the war and these relationships influenced how the postwar community would form. "Graduate students who had been recruited from Los Alamos, the

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[74] Szilard, *Leo Szilard: His Version of the Facts*, 183.

[75] *York Interview*, 6 November 1999.

metallurgical laboratory, and similar places represented the future," wrote Fermi.[76]

The second point that Szilard's statement makes regards leadership. He wrote that these teams "somehow crystallized during the war." This crystallization was in part due to leadership. The Manhattan Project brought to the surface those leaders in the scientific community who could inspire and motivate teams to innovate and develop while, at the same time, work with administration to accommodate the political and practical goals of the project. J. Robert Oppenheimer is a good example. He was not a Nobel Laureate and had never run a large-scale operation like Los Alamos before, but he was highly regarded both by his superiors and his subordinates as a leader in the scientific community. His teams were inspired by his manner of presence and his strength of intellect. According to York, Ernest Lawrence was another of this type. His inspirational presence was further augmented by his large physical stature. As a result of the filtering process of the Manhattan Project, a new group of leaders skilled in managing large-scale, multi-disciplinary projects with responsibilities to policy

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[76] Segre, *Enrico Fermi: Physicist*, 167.

committees and government leaders was dispersed back to the broader scientific community.[77]

New labs were formed, new university physics programs were initiated, old labs were infused with new and different talent, and American science was restructured, "opening new vistas in both applied and pure science, from the space program to research on subatomic elementary particles to numerical studies of astrophysics."[78] With all of these new programs and excitement in the scientific community, the need for fiscal and laboratory resources increased.

In prewar times, scientists were hesitant to accept federal monies. As Fermi said, "It is not that we will not work for the government, but rather that we cannot work for the government. Unless research is free and outside of control, the United States will lose its superiority in scientific pursuit."[79] During the war, however, the scientists had a mostly positive experience in using over two billion dollars in federal monies during the Manhattan Project. With the increased scientific talent available and the heightened scientific spirit, the demand and acceptance of federal projects rose. According to York, this also

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[77] Lillian Hoddeson et al, *Critical Assembly*, 7.

[78] Ibid., 11.

[79] Segre, *Enrico Fermi: Physicist*, 158.

brought back the individual competition that was suppressed during the war. With limited budget, a finite number of hours on laboratory equipment, and only so many supporting staffers like machinists available, a prioritization process began and scientists had to start competing based on the merits of their projects. The goal was for the scientist to make sure that he or she was doing the work of the most value to advancing science in order to ensure that he or she continues to get time and resources in the laboratories.[80] This competitive process has merit in making sure that laboratory resources are used efficiently and effectively. It also contributed to the model still being applied today of the continual development of newer, more capable, more sophisticated technologies that are often worked on independently of any stated requirement.

The last major change stimulated by the Manhattan Project was the introduction of a profound sense of social responsibility and debate over the results of scientific achievement. On July 16, 1945, the initial thoughts of the scientists after the first test, called Trinity and conducted at Alamogordo, New Mexico, were filled with elation. "Our satisfaction and pride was great," wrote

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[80] *York Interview,* 6 November 1999.

Segre.[81] "The feat will stand as a great monument of human endeavor for a long time to come," he elaborated. The "great monument of human endeavor" however was not necessarily seen as a positive endeavor after the initial exuberance of a successful test wore off.

"Our first feeling was one of elation, then we realized we were tired, and then we were worried," scientist Victor Weisskopf remembered.[82] "Now we are all sons of bitches," scientist Kenneth Bainbridge told J. Robert Oppenheimer after the test.[83] Why did the atomic bomb have such an impact on these scientists? Norris Bradbury, postwar director of Los Alamos National Laboratory, summed it up best: "Most experiences in life can be comprehended by prior experiences, but the atom bomb did not fit into any preconceptions possessed by anybody."[84] The scientists were now in the middle of a charged discussion with each other and with the government about where their innate scientific drive and the needs of the war had taken them and the world. Richard Feynman held the perspective that "a power to do something is of value. Whether the result is a good thing

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[81] Segre, *Enrico Fermi: Physicist*, 148.

[82] Rhodes, *The Making of the Atomic Bomb*, 675.

[83] Ibid.

[84] Ibid.

or a bad thing depends on how it is used, but the power is of value."[85] The dependence on how it is used mentioned by Feynman is the key thought that prompted many scientists to action.

Before the bomb had even been tested, Leo Szilard, circulated petitions against testing the bomb and using it against Japan. His efforts were to no avail but it was clear even before the war was over that the scientists' reservations about the use of the bomb ranged from minor to grave. In 1945, the Federation of Atomic Scientists was formed in an effort to publicly address the implications and dangers of the nuclear age. A year after the war ended, on August 1, 1946, the President Truman formed the United States Atomic Energy Commission (AEC), which transferred control of atomic energy from military to civilian control. Its mission was to foster and control the peacetime development of atomic science and technology. J. Robert Oppenheimer chaired the General Advisory Committee (GAC) of the AEC. The committee was comprised mostly of scientists who had now made their way into influencing atomic energy policy.

[85] Feynman, *The Meaning of It All*, 6.

The scientists on the Manhattan Project had come full circle. Their project had begun with the fundamental scientific practice of doubt and it had ended with a new kind of doubt about the results of their achievement. They had come together from different points on the globe with a common scientific thread to join them. They plunged into one of the largest government development projects ever and were motivated by the urgency of war and constrained by a critical need for security. Their approach to the endeavor and its subsequent success compelled permanent changes to the scientific community and how it accomplished its future development and project goals. Their success and the circumstances of the war in Europe accelerated the United States transition to world importance in physics. The evolution of American physics with the dawn of big science and the growth scientific social responsibility are important changes to remember for the later discussions on the operational philosophies of the labs and the scientists' move into policy making. All of these pieces influenced the environment in which MIRV technologies were developed.

Chapter 3

Establishment Tradition and the Dawn of the Cold War

When the war was over, many scientists, like Enrico Fermi at the University of Chicago, left the national labs and went back to the universities from whence they came. Others took appointments at new universities, like Herbert F. York who followed Ernest O. Lawrence back to Berkeley to earn a Ph.D. and to become a member of the Physics Department of the University of California. However, even though the war was over and many of the scientists scattered, the scientific spirit continued to drive both the scientists themselves and the innovative process for weapons design. Further examination of the attitudes of the scientists and the method by which those who remained working directly for the government will show that their primary motivation was still basic science and a sense of adventure.

A frequent misconception among critics of the national laboratories is that the scientists were involved in weapons development for economic enrichment. For example, Ted

Greenwood, in *Making MIRV: A Study in Defense Decision Making*, wrote, "Large organizations have been created that owe their continued existence solely to their ability to invent or design new weapon and sell them to political decision makers."[86] As discussed above, an important result of the Manhattan Project was a much closer relationship between scientific academia and the government.

In the case of the pursuit of technology, the government brought its huge coffers to the relationship. However, this budget was attractive to the scientists from a scientific perspective not from that personal enrichment. *Time Magazine* reported in November of 1957, twelve years after the war was over, that a government/university scientist could make $10,000 to $20,000 per year but, "Scientists in industry can do a lot better than that."[87] While this may have been a decent living at the time, it was certainly not an astronomical amount of money and many of the nation's most brilliant scientists did not go to industry. In 1951, Herbert F. York was looking to stabilize his own financial situation when Ernest O. Lawrence secured him a position in the Berkeley Physics Department for one-third time. The other two thirds of the time "would continue to be as

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[86] Greenwood, *Making the MIRV*, 13.

[87] "National Affairs," *Time Magazine*, 18 November 1957, 22.

'physicist in the radiation laboratory,' the job title that Lawrence insisted was the best in the world."[88] The funding from the government allowed the scientists the resources to conduct experiments that would otherwise have been too expensive for the individual to take on. David Lilienthal wrote, regarding the prospect of the Manhattan project, "For the physicist who had waited for years to test his theories on equipment too expensive for anyone to buy, [the Manhattan Project] was a dream come true. National laboratories were established, universities were liberally supplied with scholarships and grants and the university research work of scientists was greatly expanded by government contract."[89]

After the war, more competition did develop because there were a limited number of hours in a day in which to use expensive equipment to test ideas and theories. As York stated, "There were more ideas about how to use it than could be fit into sixteen hours a day, so there was a competition for time on the machine."[90] However, this competition increased the quality of work that was being done. "These competitions are settled by committee, which allocates time. … In order to be sure you'll continue to get

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[88] York, *Making Weapons, Talking Peace*, 60.

[89] Lilienthal, *Change, Hope and the Bomb*, 71.

[90] *York Interview,* 6 November 1999.

time, you have to do good work that produces good results," York explained.[91]

As further clarification that money is not the primary goal of the scientist, the fact that scientists do not stop the process of innovation and experimentation in the absence of necessary equipment and sufficient funding is important. As discussed previously, the scientific mind is not turned on and off depending on resources, but it is continually questioning and discovering. When Ernest O. Lawrence was early in his career, he lacked sufficient resources to test his theories of ionization. Instead of stopping his experiments because he had no money, "He first demonstrated it with a crude but scientifically overwhelming do-it yourself kit: a kitchen chair, clothes tree, toy-sized four-inch magnet, pie-sized vacuum chamber made of window glass, brass, and sealing wax."[92] It was also reported that he invented a color television tube in his garage. J. Robert Oppenheimer summarized this idea well, "If you are a scientist you believe that it is good to find out how the world works; that it is good to find out what the realities are; that it is good to turn over to mankind at large the

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[91] Ibid.

[92] "The Atomic Age," *Time Magazine*, 18 November 1957, 25.

greatest possible power to control the world. …"[93] Oppenheimer was explaining the basis for why scientists believe in science. There is no mention of yearning to discover only when there is ample funding.

The scientists involved in the Manhattan Project explained this personal belief in fundamental science from a deeper level in their experience after the war. York wrote in his memoir, "When the war ended I was demobilized, so to speak, and I began what I hoped and thought was going to be a normal peaceful career in pure science. It was not to be. After only three and a half years, major external events, including the explosion of the first Soviet atomic bomb and the Korean War, brought me back into the nuclear arms race."[94] Even a scientist like Edward Teller, who is usually characterized as being very hawkish, had aspirations to continue his practice in pure science. When he went to Columbia to work with Leo Szilard on an atomic-energy project, Teller intended to go back to George Washington University "someday and resume his pure-science investigations into the minute structure of matter. That day never came."[95] Glenn Seaborg, a famous nuclear chemist

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[93] Rhodes, *The Making of the Atomic Bomb*, 761.

[94] York, *Making Weapons, Talking Peace*, xi.

[95] "The Atomic Age," *Time Magazine*, 18 November 1957, 23.

who is also a veteran of the Manhattan Project, said, "The inner rewards are very great. Science is the new frontier."[96]

Clearly personal wealth was not the motivation of these scientists. As *Time Magazine* reported, "Asked what he is doing, the scientist is likely to reply that he is having 'fun' – a word that recurs again and again, along with 'adventure,' when scientists talk about their work."[97] That science is a truly creative, artistic process, not motivated directly by money, is reiterated by former President Eisenhower, "When a science and engineering program is going ahead flat-out and 100 percent capacity, more money cannot speed it up, any more than all the water in the Mississippi can speed the growth of a tree."[98]

While the pure spirit of scientific discovery and innovation was the primary motivator for these brilliant minds, there was also a tense competition between the United States' national laboratories after the war. The competition stemmed from pride in scientific achievement and contribution to the nation's security as well as from

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[96] Ibid., 25.

[97] Ibid., 22.

[98] Eisenhower, *Waging Peace*, 217.

personalities. The most high profile and intense competition was between Los Alamos National Laboratory, founded in 1942, and Lawrence Livermore National Laboratory, founded in 1952. Herbert F. York was charged with directing Lawrence Livermore when it was established. When asked whether the competition between themselves at Livermore and Los Alamos was friendly or unfriendly, he replied, "It was a tense competition. So it was an unfriendly competition but that's what people wanted when they set up the second laboratory. Teller had it in mind that we needed competition for Los Alamos because they were too stuffy and complacent. Of course, they [Los Alamos] didn't think so."[99]

York contended that even though a competition existed, that Norris Bradbury, successor to J. Robert Oppenheimer as Director of Los Alamos, "Did everything right. We had to ask them for a lot of help."[100] When Lawrence Livermore was established, their development process was not up to full speed. They had to constantly ask Los Alamos for significant pieces of technology in order to conduct their field tests on what are called two-stage weapons. For the first several years, Lawrence Livermore did not have the

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[99] *York Interview,* 6 November 1999.

[100] Ibid.

capability of making what is referred to as the primary stage of these two-stage nuclear weapons. What York didn't know until just several years ago, was that throughout the time that Norris Bradbury and his team of scientists "were behaving just right," Bradbury was writing a series of letters to Washington that were highly critical of the Lawrence Livermore capability and productivity.[101] He went on to explain that Teller was "bad-mouthing" the Los Alamos team at the same time and that there was an "element of personal insult involved."[102] These complex, scientific personalities certainly helped to amplify the competition between the labs.

The more overt competition between the two labs came in the form of the weapons count. Each lab would claim that they had more bombs in the stockpile. Regarding the weapons count, York said, "Of course it's like a lot of things, it depends on how you count."[103] Both labs were developing and enhancing nuclear weapons. Los Alamos boasted of having developed the highest number of different types (each different type is considered one "mark number") of nuclear weapons, while Lawrence Livermore boasted of developing the

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[101] Ibid.

[102] Ibid.

[103] Ibid.

most warheads of the same mark numbers. As time went on, similar competitions would develop between the Berkeley Radiation Laboratory (Rad Lab) and the Brookhaven Laboratory and between Oakridge Laboratory and the Argonne National Laboratory.

York also addressed the competition between the labs from a monetary standpoint. He explained that there was some worry about budgets "as a question of support and the support being divided," but on the other hand, "they [Los Alamos] were already big enough so it [the budget] didn't really interfere."[104] While some companies have to work hard to sell a new project in order to maintain their business, the national labs and associated university programs did not. York said, "We always assumed … we had the budget to pay for them [the staff]. And then after that, we would figure out what to do."[105]

This thought process, of considering science and innovation as the primary goal, was a very important element in how the laboratories were operated after the war. It was a critical element of the environment that facilitated the development of capabilities such as MIRV. To reiterate, scientific discovery and innovation revolves around people.

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[104] Ibid.

[105] Ibid.

The core of the laboratory is the intellectual property of the people who work there. Unlike a factory with machines that can run twenty-four hours a day, the laboratory cannot be productive at the end of each day when the core of the laboratory goes home. It is, therefore, very important to the success of the mission of the lab to ensure that the scientists come back each morning to continue their work. In addition to executing the mission of the laboratory, attracting and retaining people was one of the primary operational goals of the lab.

Laboratory directors and team leaders used intellectual adventure as the primary hook to keep the scientists interested in remaining employed. They emphasized three areas which are related but can be examined separately. The first area of emphasis was basic science. In the case of nuclear physicists, it is the study of matter down to the level of the atomic nucleus and how the elements of the nucleus behave under various conditions. In the case of the nuclear physics, applied science would be how to apply the fundamental properties of the nucleus to achieve an end, i.e. release nuclear energy in the form of an atomic bomb. Basic science is what drew most of the scientists into science in the first place.

The Manhattan Project, the Cold War, global tension and other external events made it prudent for the scientists to redirect their efforts to emphasize more applied science, but it was in basic science that they were interested at the start. Therefore, the laboratory directors had to make sure that the scientists could continue studies in basic science because, "It provided the kind of intellectual stimulus and prospect for adventure that young scientists usually find only in basic research."[106] York conceded, "We wanted to keep them and attract more besides."[107] It was important that the scientists did not feel as if they were missing the academic community's momentum of discovery by choosing to work in a national laboratory instead of the pure science environment of a university, for example. As for the importance to the nation of basic science, Edward Teller summed it up best when he told *Time Magazine*, "The science of today is the technology of tomorrow."[108] This statement is very important to understanding why lab directors like York felt that research on basic principles and other scientific areas that are only indirectly related to the specific task at hand was valuable. They did not know what

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[106] York, *Making Weapons, Talking Peace*, 76.

[107] Ibid.

[108] "The Atomic Age," *Time Magazine*, 18 November 1957, 21.

types of discoveries they could make that might help them on a different project or at a later date. They felt that none of the experiments were a waste of time. This relates back to the Edison Method in the sense that if a scientist tries something and it does not work, that he still learned valuable information in the process about why the experiment did not work or about related phenomena.

The second area of emphasis that the lab directors used to attract and retain their scientific talent was the technological extreme. As former director of Lawrence Livermore, Herbert F. York said, "In order to make applied science as interesting as pure science, we always pushed the limits. In other words, we created frontiers; pure science has them naturally and we made artificial frontiers"[109] The scientists did not wait for the government or military to outline a requirement, but they set out from the start to construct nuclear explosive devices that had the smallest diameter, the lightest weight, the least investment in rare materials, the highest yield-to-weight ratio, or that "otherwise carried the state of the art beyond the currently explored frontiers."[110] This working philosophy was outlined at the very beginning and readily accepted by the entire

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[109] *York Interview,* 6 November 1999.

[110] York, *Making Weapons, Talking Peace,* 75.

staff. As York explained, "We were completely confident the military would find a use for our product after we proved it, and that did indeed usually turn out to be true."[111]

It did indeed usually prove to be true. The *Polaris* warhead started out as "simply the lightest weight thermonuclear warhead we could build."[112] After development was well under way, the Navy did issue a requirement for an extremely lightweight warhead for its first submarine-launched missile and the *Polaris* program was established. York said with a smile, "They were a perfect match."[113] An example that was not such a perfect match but still yielded plenty of useful information was the *Davy Crockett*. The *Davy Crockett* began as a project to develop the smallest nuclear weapon of any kind. It was a combination of the need to feel engaged in basic science and the philosophy of pushing at the technological extremes. It was " a way of recreating the kind of intellectual spirit that we thought of as being the stimulus for pure science," York explained.[114] York admitted that the *Davy Crockett* was not the laboratory's most brilliant idea and thus was never

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[111] Ibid.

[112] *York Interview,* 6 November 1999.

[113] Ibid.

[114] Ibid.

adopted as the mortar-based nuclear weapon it was conceived as. However, the design idea did find application in other small and lightweight delivery systems. Similarly, the task of John S. Foster's B-Division at Lawrence Livermore was to build better fission bombs by exploiting new principles and novel design ideas.[115] York said that although few of B-Division's designs were adopted in their entirety, "The work of Foster's group paid off handsomely and many of their ideas opened up new horizons in weapons design and later made their way into the American nuclear stockpile."[116] Even when projects were not adopted in their entirety, they yielded valuable scientific capital for future work.[117]

The third area of emphasis that the lab directors focused on in order to attract and retain scientific talent was the constant improvement of existing weapons. This open, intellectual invitation to innovate and improve was not new to the postwar period in which MIRV technologies were developed. Even during the Manhattan Project, before

[115] A fission bomb, like the Hiroshima and Nagasaki devices, use the splitting of an atomic nucleus to release energy. A thermonuclear bomb, also called the hydrogen bomb, uses the process of fusion - two Hydrogen nuclei are fused together to release an immense amount of energy. A hydrogen bomb requires a fission bomb as a trigger to provide enough force to push the two hydrogen nuclei together.

[116] *York Interview,* 6 November 1999.

[117] Scientific capital is a term coined by Vannevar Bush. Vannevar Bush, Director of OSRD, *Science, The Endless Frontier: Report to the President on a Program for Postwar Scientific Research* (Washington: United States Government Printing Office, 1945).

the world's first atomic bomb was detonated, physicists were conceiving of ways to make more efficient fission bombs, fission bombs with less radioactive fallout, and more powerful bombs in the form of thermonuclear explosions. In the case of Edward Teller, "the theoretical complexity of the Super challenged Teller as the fission bomb had not."[118] James B. Conant in the fall of 1944 learned that "the technological imperative, the urge to improvement even if the objects to be improved are weapons of mass destruction, was already operating at Los Alamos. Under intense pressure to produce a first crude weapon in time to affect the outcome of the war, people had found occasion nevertheless to think about building a better bomb."[119] Of his Manhattan Project experience, Herbert F. York wrote, "Even after construction was under way back east [of the cyclotron that separated uranium isotopes], experiments with prototypes continued at Berkeley for the purpose of optimizing the process and improving both the quantity and the quality of the product."[120] In the summer of 1942, three years before the first atomic bomb test, J. Robert Oppenheimer chaired a

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[118] The term "Super" was commonly used to refer to the hydrogen bomb. Rhodes, *Making of the Atomic Bomb*, 540.

[119] Rhodes, *The Making of the Atomic Bomb*, 563.

[120] York, *Making Weapons, Talking Peace*, 13.

secret seminar, attended by such famous names as Hans Bethe, Edward Teller, and Robert Serber, on atomic-bomb development at which the possibility of creating a thermonuclear bomb (also called the hydrogen bomb) was discussed at length.[121] The prospect of being able to recreate, on earth, a hydrogen fusion reaction that only occurred on the sun was thrilling to these physicists. This constant improvement and enhancement of existing technologies continued on after the war and to the present day.

In the case of *Polaris*, York said, "You've got to get it out there into the fleet, but it didn't quite meet the exact size and yield requirements they [the Navy] had. So we put something out there that would do and started working on the next one."[122] The philosophy of constant improvement was very natural to the laboratory teams. However, this process does not go on indefinitely and unchecked. When York was director of Lawrence Livermore between 1952 and 1958, it was his annual responsibility to tell the administration what the laboratory would be working on. This included nuclear weapons development and tests. Because the President of the United States was the only person who could authorize a nuclear explosion for the United States, President

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[121] Rhodes, *Dark Sun*, 248.

[122] *York Interview,* 6 November 1999.

Eisenhower had to personally approve each test explosion. York and his team proposed to build a bomb which was about twice as big as had been previously built: "about thirty megatons."[123] York said one of his more memorable moments was when word came back to him regarding the request to test the thirty megaton bomb, that "The President says, 'No, they're already too big'."[124] Most of the time, however, the administrations would agree with the laboratories development and design plans. As will be explained in the next chapters, this was partly due to the new critical role of technology and technologists.

The method of operation of the national labs was a result of the combination of the scientific experience of the Manhattan Project, our nation's need for security and the personalities of the scientists and directors. Directors were faced with the challenge of accomplishing the mission of the laboratories in their role in national security. In order to accomplish that mission, the laboratory directors had to have talented people. To attract and retain talented people, they had to formulate

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[123] *York Interview*, 6 November 1999. As a point of reference, the bomb that exploded over Hiroshima was 12.5 kilotons. The first U.S. thermonuclear bomb was the Mike Shot in November 1952, which yielded 10.5 megatons - 1000 times the yield of Hiroshima.

[124] Ibid.

the operation of the laboratories such that they could satisfy the professional and personal goals of the scientists they depended on. Thus, the underlying operation of the labs was governed by the scientists' need to innovate and discover. York wrote, "In essence, Lawrence firmly believed that if a group of bright young men were simply sent off in the right direction with a reasonable level of support, they would end up in the right place. He did not believe that the goals needed to be spelled out in details or that the leadership had to consist of persons already well known."[125] About himself, York wrote of his encounter with a senior scientist at Berkeley Radiation Laboratory, "I took the whole matter to heart and determined that never again would I simply wait for a boss to tell me what to do."[126] Such personal experiences, both as human beings and as scientists, influenced the labs and the technological climate of the United States. The emphasis on basic research, pushing technological extremes and constant improvement of existing weapons led to an aggressive research and development program that "pushed against

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[125] York, *Making Weapons, Talking Peace*, 67.

[126] Ibid., 16.

technological frontiers without waiting to be asked" and in turn provided the United States with "a qualitative edge."[127]

Given this technological environment, largely driven by scientists and their thrill of science and discovery, it is easy to see how innovation moved very quickly from the atomic bomb (1945), to the thermonuclear bomb (1952), to more efficient nuclear bombs, to nuclear devices small enough that more than one could fit on the same rocket (late 1950s). In the scientists' minds, these were very natural progressions. The labs were mindfully continuing at a pace that was ahead of the requirements for the government and the military in order to satisfy their national security requirements as well as their own personal ambitions as a scientist. At the same time that innovation was moving forward for nuclear devices, improvements were being made in other government labs in rocket technologies, guidance technologies and materials technologies. When the combination of technologies in these areas came together, one had the ability to build a missile with multiple independently-targetable reentry vehicles (MIRV) even though the stated requirement from the administration and the official program did not come until 1964.

[127] Ibid., 77.

Chapter 4
Science and Technology as the Cure-All

> It [science] should be brought to the center of the stage - for in it lies much of our hope for the future.[128]

How did science and technology achieve this position of importance? Penicillin helped to save many lives from death by bacterial infection, radar helped the Allies to see the enemy before he attacked, and the atomic bomb apparently ended one of the deadliest wars the world had ever seen. By the time Japan surrendered in the fall of 1945, science and technology looked like they might be a key to many of the nation's problems. In his report on the potential of science to President Truman, Vannevar Bush espoused, "Advances in science when put to practical use mean more jobs, higher wages, shorter hours, more abundant crops, more leisure for recreation, for study, for learning how to live without the deadening drudgery which has been the burden of the common man for ages past."[129] This was quite a diverse list of issues for science and technology to address. After

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[128] Bush, *Science: The Endless Frontier*, 7.

[129] Ibid., 5.

the war in Europe ended, Army Air Force General Curtis LeMay felt at first "out of his depth technically in research and development, 'but it didn't take me long to become mighty interested.'"[130] He helped to organize Operation Paper Clip after the war in order to collect German technology and technologists for the benefit of the United States.[131] With the success of the Manhattan Project, the United States experienced a significant increase in power and prestige. The estimates for how long it would take the Soviet Union to detonate their own atomic bomb and challenge United States power and prestige ranged from a few years to twenty years. In the meantime, with nuclear war too terrible to instigate, the United States continued its efforts to further and to exploit its technological advantage.

In addition to the government administration and the scientists, the public was also looking to science and technology to provide a path to future success. As Vannevar Bush reported, medicine, agriculture, and the economic situation of America were all vulnerable to the positive impact of science and technology for fighting disease, raising farm productivity and creating jobs in new industries spawned by the latest discoveries. The

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[130] Rhodes, *Dark Sun*, 228.

[131] Ibid.

application of science to domestic challenges even went as far as the lumber industry and how to exploit wood more efficiently. A headline in the *New York Times*, in October 1957, read, "Science is in Search of New Items for Home, Industry." The article interviewed researchers about the current state of American wood technology both at home and abroad. The Director of the Forest Products Laboratory of Agriculture's Forest Services said, "The stage now has been reached in which forestry recognizes the necessity for continued research in its products in order to keep them abreast of and in balance with the total field of technology."[132] It might be hard to conceive that the problems of the forestry industry and their current state of technology could be spoken of with the same seriousness as those of the national security establishment, but just about every group seemed to believe that technology held some promise for them. Even in the case of morality, where it seems perfectly natural to speak in qualitative, subjective terms, a group of scientists and philosophers got together at the Massachusetts Institute of Technology in October 1957 to discuss bringing "systematic scientific analysis" to

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[132] *New York Times*, 5 October 1957, front page.

"bring order to the chaos of human relations."[133] Clearly, science and technology were on the public's mind.

Science and technology, to be expected, were also on the minds of the military establishment and the government leadership. Michael Hogan wrote, "American leaders emerged from the Second World War absolutely convinced that science had saved the day by achieving dramatic breakthroughs in military technology."[134] Former President Eisenhower wrote that in 1947, as Chief of Staff of the Army, he reported at a hearing before the House Military Appropriations Subcommittee that "in the field of guided missiles, electronics and supersonic aircraft we have no more than scratched the surface of possibilities which we must explore in order to keep abreast of the rest of the world. Neglect to do so could bring our country to ruin and defeat in an appallingly few hours."[135]

After the war and into the 1950s, this trend of thinking continued. "The successful detonation of the first, and seemingly revolutionary, superbomb [hydrogen bomb] – [codenamed] Mike – only days before Eisenhower's election

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[133] Ibid., front page, second section.

[134] Michael J. Hogan, *A Cross of Iron: Harry S. Truman and the Origins of the National Security State, 1945 – 1954* (Cambridge: Cambridge University Press, 1998), 220.

[135] Eisenhower, *Waging Peace*, 207.

reinforced both he idea that technology could provide us with the answer to our security problems and the idea that a thorough rethinking of how to go about exploiting it was needed."[136] Eisenhower recalled, "Deeply concerned in 1953 at the previous lack of attention given to missile development, my administration quickly turned to outstanding scientists and engineers to determine the feasibility of developing effective weapons of this character."[137] With all of this focus on technology, it is no surprise that technology began to move into the infrastructure of decision making in the United States.

The entrenchment of technology into the decision-making infrastructure began during the war in 1940 with the National Defense Research Committee, which in 1941 became the Office of Scientific Research and Development headed by Vannevar Bush, an electrical engineer from the Massachusetts Institute of Technology. Also under Dr. Bush's direction was the Advisory Committee on Uranium under which the formal Manhattan Engineering District was recommended and established. In January 1958, President Eisenhower convened the first meeting of the President's Science Advisory Council. In February 1958, Secretary of Defense McElroy

[136] York, *Making Weapons, Talking Peace*, 86.

[137] Eisenhower, *Waging Peace*, 208.

established the Advanced Research Projects Agency (ARPA). ARPA's sole mission was to explore leading edge technologies for our nation's military. Herbert F. York, while continuing his role as Director of Lawrence Livermore National Laboratory, was appointed as the Agency's Chief Scientist. President Eisenhower, from November 1957 to April 1958, recommended and established the position of Director Defense Research and Engineering (DDR&E). In 1958, York left his post as Director of Lawrence Livermore National Laboratory and accepted the appointment as the first DDR&E. This position was a giant step toward elevating the importance of technology in the military and Presidential decision-making process. To show its importance, Eisenhower purposely established the DDR&E at a salary level equal to the service Secretaries. The DDR&E was tasked with supervising all expenditure on defense research and engineering projects across all three services. This move and others by Eisenhower demonstrated that technology and the process of weapons innovation was an important element and was here to stay in defense decision-making. As Hogan pointed out, "The same man who would later warn against the dangers of a military-industrial-scientific complex began urging the Army to utilize the country's industrial and technological resources as organic parts of our military structure.'"[138] During his Presidency, Eisenhower was well on his way to making technology an integral tool for the services and for the nation.

However, not everyone believed that technology was the answer to the world's problems. Henry A. Kissinger, a professor at Harvard University, was critical of the management of technology as the cure-all for United States security in his 1957 book, *Nuclear Arms and Foreign Policy.*[139] While he did not did not dispute the value of technology and the need to compete with the Soviets, he did believe that the administration ignored the value of formulating solid strategic doctrine. Regarding the immediate post war he wrote, "Ever since the end of the Second World War brought us not the peace we sought so earnestly, but an uneasy armistice, we have responded by what can best be described as a flight into technology: by devising ever more fearful weapons."[140] Kissinger insinuated that the administration chose to pursue a strong strategy in technology because it was easier than devising an effective strategic doctrine that would incorporate all three of our nation's services and the security goals of the United

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[138] Hogan, *A Cross of Iron,* 228.

[139] Kissinger, *Nuclear Weapons and Foreign Policy,* 18.

[140] Ibid., 3.

States. "In these circumstances it is not surprising that there exists more concern with technology than with doctrine. The penalty for miscalculation in the technical field is obvious and demonstrable. The penalty for falling behind in the field of strategic doctrine, though catastrophic, is not immediately discernible."[141] Regarding the position of the services, he believed that the lack of strategic doctrine meant that their role was not clear and that each felt a need to pursue the entire range of functions from strategic striking power to tactical maneuver. He noted also, "The technological race also multiplies the choices which must be made by the military services. The obverse of this multiplicity of choices is an unparalleled specialization of functions."[142] Kissinger indicated here that advanced and abundant technology can create more confusion and complexity than capability.

Even with this dissenting opinion, technology was at the forefront of the effort toward security for the United States. In the climate of such rapid technological advancement, the already natural inclination to innovate constantly was amplified and facilitated.

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[141] Ibid., 18.

[142] Ibid., 17.

Chapter 5

Scientists As Policy-Makers

The third dynamic influencing the technological climate of the period leading up to the development of technologies for MIRV was the dramatic move of scientists from the laboratory into policy-making. This move had a large impact on decision-making in the United States and was facilitated by the new role of importance of the scientists. David Lilienthal described the phenomenon best when he wrote, "The atom became all important, and so therefore did the men who had called it into being, the atomic scientists."[143]

After the success of the Manhattan Project and the apparent victory of technology over a murderous foe, the scientists were catapulted into the spotlight. They were seen as great saviors and as those who were able to understand complex scientific principles, the significance of which seemed intellectually unavailable to the layman. Lilienthal expounds:

[143] Lilienthal, *Change, Hope and the Bomb*, 63.

> Military men, politicians, business leaders, teachers - all categories of men who dealt with the more ornery and unpredictable affairs of human beings - were dwarfed by comparison. The scientists seemed to take on some of the attributes of his world-shaking creation; there was, in the public mind, something unearthly, something superhuman, something uncanny about him.[144]

Vannevar Bush's report to President Truman gave evidence of the high leadership's faith in science and technology, but the faith was apparent down through the ranks.[145]

> As 'master of the Atom', the scientist had transformed the world. His views on all subjects were sought by newspapermen, by Congressional committees, by organizations of all kinds; he was asked in effect to transfer his scientific mastery to the analysis of the very different questions of human affairs: peace, world government, social organization, population control, military strategy and so forth.[146]

With technology in a new role of unprecedented prominence, the scientists' primary calling was to the various scientific committees and as advisors to top policy makers.

Aside from the respect the success of the Manhattan Project generated for science and technology, a significant element of the demand for scientific advice stemmed from the complexity of technology. The scientists simply knew more about the technology than any politician or military

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[144] Ibid., 64.

[145] Bush, *Science: The Endless Frontier.*

[146] Lilienthal, *Change, Hope and the Bomb*, 64.

personnel could hope to. The pace of technological innovation during the period immediately after the war up until a formal decision for MIRV development was made, was extremely rapid. President Truman, for example, could have taken the time to understand technically how the atomic bomb worked. But his job as President required that he make a wide range of decisions on domestic, foreign, military and economic issues. Neither President Truman, nor any President during that time (or any time), had the time to keep up with all of the technical aspects of military technology advancement in light of his other duties. He had to rely on people whose training and experience lie in technology to advise him of the advantages and disadvantages of the latest technological advancements.

Regarding the technological capabilities of the labs, York said, "We didn't always get it [capabilities] right but even so, we knew more than they [the military] knew."[147] Dean Acheson's personal representative to the Atomic Energy Commission, Herbert Marks, laid bare the incredible challenge facing the non-scientific person when he was touring the Los Alamos facility after the war. He was noticing the high security measures at the laboratory.

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[147] *York Interview,* 6 November 1999.

"And supposing I had got away with one [materials receptacle], what could I, an ordinary layman, have done with it? In a way, the same was true of so much of the whole Manhattan District."[148] Even when the project and the materials were arranged before him, the layman would not be able to assemble them into a weapon of mass destruction. This complexity exists with many of the weapons in the United States' arsenal. The decision-making process is equally complex.

On November 7, 1957, President Eisenhower appointed Dr. James R. Killian as his first Special Assistant to the President for Science and Technology. Dr. George B. Kistiakowsky later succeeded Killian, also in the Eisenhower administration. In his memoir, Eisenhower could not speak highly enough of these two assistants and attributed the utmost importance to their help in making what he considered critical national security decisions involving technology.

> In character and accomplishment they could not have had superiors. Whatever the task - to build an airframe for the enormous B-70, or solve the metallurgical problem of ways to dissipate heat for nose cone re-entries into the earth's atmosphere - the scientific advisor kept me enlightened. My "wizard" helped me ... without such distinguished help, any President in our time would be, to a certain extent, disabled.[149]

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[148] Rhodes, *Dark Sun*, 231.

[149] Eisenhower, *Waging Peace*, 224.

Eisenhower feeling as if he would be disabled without an understanding of technology emphasizes the importance of technology and clarifies one way in which scientists were called upon to help form policy.

The number of policy committees that scientists were invited to sit on was enormous. Many scientists sat on two or more committees simultaneously. The committees and their specific members are too numerous to record in detail, but a few examples will be helpful to clarify the influence of the scientists on policy. Having had the high-profile role of directing the actual design, assembly and testing of the atomic bomb, J. Robert Oppenheimer was one of the more prominent scientists participating in policy-making. Along with Ernest O. Lawrence, Arthur. H. Compton and Enrico Fermi, Oppenheimer began, even before the war was over, on the scientific panel that advised Secretary of War Stimson's Interim Committee for considering the postwar disposition of atomic energy.[150] Later he was appointed Director of the Institute for Advanced Study at Princeton as well as the first Chairman of the General Advisory Committee (GAC) of the United States Atomic Energy Commission. Participating on multiple policy committees and testifying before

[150] Rhodes, *Dark Sun*, 203.

Congress, "Oppenheimer had begun to work his way into the corridors of power."[151] A significant portion of many of the general committees like the GAC was comprised of scientists and, as would be expected, almost all of the scientific committees were composed completely of scientists.

Each service formed its own scientific advisory board and every new weapon system seemed to need its own scientific advisory panel. For example, the Air Force formed the Air Force Scientific Advisory Board (SAB) Nuclear Panel in 1953 on which such distinguished scientists as John von Neumann served. Von Neumann also served on the Strategic Missile Evaluation Committee (SMEC) put together by the Assistant Secretary of the Air Force, Trevor Gardner in February 1954.[152] The SMEC was later renamed the von Neumann Committee and several more scientists were added to it.[153] Dr. John S. Foster, Jr. simultaneously served on both the Air Force SAB and the Atomic Energy Commission GAC. In this situation he had the opportunity to transmit ideas and plans between the two committees.

> He liked high-ranking military officers and got along very well with them. If anyone during that crucial period in the early and middle-fifties can be said to

[151] Rhodes, *The Making of the Atomic Bomb*, 760.

[152] York, *Making Weapons, Talking Peace*, 93.

[153] Ibid., 95.

> have enjoyed more "credibility" in national defense circles than all the others, that person was surely Johnny. Both Jimmy Doolittle and General Bernard A. Schriever, at that time deputy chief for advance planning, made it clear to me that it was Johnny's personal projections about the future of thermonuclear weapons, and no other individual or institutional source, that first convinced them of the new possibilities and cause the Air Force to initiate the actions that eventually led to a high-priority program to build intercontinental ballistic missiles.[154]

As if the web of relationships was not complex enough, Foster would later succeed Herbert F. York and Harold Brown as both Director of Lawrence Livermore and as DDR&E.

The scientists' influence over policy and weapons development programs was firmly entrenched by the early 1950s. In February 1955, a scientific committee headed by Killian recommended that the United States develop an intermediate-range ballistic missile (IRBM) in addition to the intercontinental ballistic missile (ICBM). Following the recommendation, Eisenhower wrote, "By December, we [Eisenhower administration] concluded it wise to assign highest priority to programs for … two IRBMs, Jupiter and Thor."[155] Many more committees comprised of accomplished scientists were formed and directly influenced research and development. With several exceptions, the Presidential and

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[154] Ibid., 90.

[155] Eisenhower, *Waging Peace,* 208.

military administrations would accept the recommendations of the scientific advisory panels. Gradually, the military began to understand the spectrum of possibilities and "got much more sophisticated about what they wanted," according to York who worked directly with the military in various technology advisory roles.[156] Even though the administrations began to play an increasing role in generating requirements, the scientists were here to stay as policy makers.

It is reasonable to say that scientists who can discover and understand complex physical, chemical and biological principles are generally intelligent people who can think and derive opinions of their own. Although scientists try to remain as objective as possible in their discussions of research and development, it is unrealistic to believe that they would not formulate their own perspectives on the advantages and disadvantages of the technologies their community builds. Early on at the Berkeley Radiation Laboratory, York remembered Lawrence saying, "Scientists, especially young ones, cannot waste precious working time on extraneous issues for which they had no special training."[157] In 1954, Edward Teller described his reaction to the GAC's

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[156] *York Interview,* 6 November 1999.

[157] York, *Making Weapons, Talking Peace,* 25.

recommendation in 1949 against proceeding with a crash development of the hydrogen bomb. "The important thing in any science is to do the things that can be done. Scientists naturally have a right and a duty to have opinions. But their science gives them no special insight into public affairs. There is a time for scientists and movie stars and people who have flown the Atlantic to restrain their opinion lest they be taken more seriously than they should be."[158] This is an interesting viewpoint for Teller to espouse since he was primarily reacting to disagreement with his viewpoint on what the policy should be. Herbert F. York expressed a more insightful perspective in his memoir. He wrote, "Given my position as head of one of America's two nuclear labs, it was natural that I would be drawn into the broader process of rethinking the United States' approach to national security."[159] Similarly, in 1954, J. Robert Oppenheimer testified in front of the Atomic Energy Commission, "In the early days [of the AEC] we [scientists on the GAC] knew more collectively about the past of the atomic energy undertaking and its present state, technically and to some extent even organizationally … than the commission did. … It was very natural of us not merely

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[158] Rhodes, *The Making of the Atomic Bomb*, 770.

[159] York, *Making Weapons, Talking Peace*, 86.

to respond to questions that the Commission put, but suggest to the Commission programs it ought to undertake."[160] Leo Szilard felt that he was being wrongly excluded from influencing policy. "As the man who had thought longer and harder than anyone else about the consequences of the chain reaction, Szilard had chafed at his continued exile from the high councils of government."[161] Szilard was in good company; Einstein was also largely excluded. As mentioned above, thought about the consequences and policies of weapons technology was a dynamic that was most firmly established after the Trinity Test in July and the subsequent atomic bombing of Hiroshima. Scientists could not help but to bring their opinions on the effects of technology to their advisory and decision-making roles.

Not all scientists were included in the dynamics of influencing policy but many were. They were considered "stars" after the war and the technical explanations of their art were not widely comprehended. Only the obvious demonstrations of their power to control nature could be appreciated by the masses and even the non-scientifically educated. With the personal motivation to conduct leading edge pure science, the new role of technology for solving

[160] Rhodes, *Dark Sun,* 308.

[161] Rhodes, *The Making of the Atomic Bomb,* 635.

problems, and the permeation of scientific talent into decision-making, the environment was ripe for the iterative process of innovation that brought about MIRV capability.

Chapter 6

MIRV: The Perfect Case Study

Those who assert that MIRV was designed as a response to the Soviet Union's ABM system, like Thomas Wolfe above, or that MIRV was not the "inevitable result of the inexorable march of new technology," as Ted Greenwood wrote, have missed the larger picture of the innovative process and the environment in which it took place.[162] MIRV was a product of the technological climate in the United States after 1945. That climate was grounded by a diverse group of scientists that had each brought their common scientific motivations to the success of the Manhattan Project, the largest and probably the highest profile technological development project in history. After the war and with their newly acquired fame, the scientists moved into roles in which they operated the nation's ongoing laboratory efforts in weapons and technology development. Also with their new importance, they were invited to influence all types of policy, including domestic, foreign, economic and defense. Of

[162] Greenwood, *Making the MIRV*, 28.

course, the backdrop for this dynamic technological climate was the Cold War and the arms race.

Although controversial in the deployment debate, the MIRV development was just one of many weapons advancements. It was a result of all of the larger dynamics discussed in this work so far and cannot be fairly analyzed outside of that technological climate. Greenwood, author of the most comprehensive study to date of the development of MIRV, attempted to analyze the MIRV innovation outside of these larger factors and within an inappropriately narrow definition of innovation. He claims:

> For technical innovation, the conception phase must involve matching a technology to a desired outcome, a military mission in the case of a weapons innovation. … But neither the availability of the technology nor the awareness of the mission requirements alone can be considered the source of the MIRV innovation. Only by associating one with the other could the MIRV be invented.[163]

There are two problems with Greenwood's analysis as it relates to the present discussion on the innovative process and the arms race as an element of the Cold War.

First, the more expansive of the two problems is that Greenwood seems to have taken MIRV out of the context of the Cold War. If the Cold War was not going on, the money for the research and development would not have been plentiful

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[163] Ibid., 27-28.

and the MIRV innovation would have taken a much longer time or perhaps would not have ever come about. If there had been no Cold War, the overwhelming fear of the "ten-foot tall Russians" may not have driven so much activity either "and we might now only be talking about going to the moon."[164] York reaffirmed, "But in order to say it's not inexorable you have to say in the absence of the Cold War it's not inexorable."[165] Greenwood's implication that innovation does not happen without a need contains two problems. First, the Cold War was the need and it overarched any specific military need. Second, engaging scientific research and development only when there is an identified need is not how the process of innovation works.

Chapter 2 discusses in depth the scientists' fundamental motivation to question and to discover the basic laws of nature. This motivation was built into the operational philosophies of the laboratories. The scientists were continually studying basic principles and new applications. Re-using Edward Teller's statement, "The science of today is the technology of tomorrow," is a perfect explanation for how Greenwood misunderstood the process of innovation in

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[164] *York Interview,* 6 November 1999.

[165] Ibid.

general and for MIRV specifically. To start, the atomic bomb is a good example:

> Some of the dazed publicity that last week followed the unveiling of the atomic bomb gave the impression that it was created from scratch under the terrible urgency of war. Nothing could have been farther from the fact. The urgency of war had indeed hastened the achievement. But the explosive release of atomic energy was clearly foreshadowed by the ferment of atomic physics in 1940.[166]

> The atomic bomb was the creation of France's long-dead Henri Becquerel, who discovered radioactivity, and the Curies, who discovered radium. It was the creation of Albert Einstein, sitting quietly in an old sweater, keeping his speculative pencil always pointed close to the secrets of physics.[167]

Scientific innovation can be likened to building a brick house in which each scientist carefully lays a few bricks into the structure. He knows only that some generation, maybe his own, maybe the one after next, will have a working building. He may not even know what function the building will serve, but he will be satisfied that he has contributed to a portion of a structure that will grow for generations to come. This iterative process of innovation was similar for MIRV.

A reminder of the critical technologies for MIRV will be helpful at this point. In order to achieve multiple independently-targetable re-entry vehicles, one must start

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[166] "The Atomic Age," *Time Magazine*, 20 August 1945, 31.

[167] Ibid., 15.

with a rocket that is capable of launching objects past the atmosphere and into orbit. Next, it requires objects small enough for two or more to fit on a single rocket. Third, the individual objects must have access to guidance and propulsion that is either contained on their own structures or provided to each by the rocket. Fourth, in the case of warheads, they must be contained inside a re-entry vehicle that will allow them to re-enter the atmosphere toward the target without burning. This is not necessary for a satellite, which will stay above the atmosphere and in orbit.

Regarding multiple launches with a single rocket, the United States began to think about launching multiple satellites following *Sputnik* in October 1957. *Sputnik* caused considerable alarm at the fact that if the Russians could launch a satellite into orbit, they could be close to having an intercontinental-ballistic missile. As previously discussed, there was not clear information on exactly what the Russian capabilities were, and as a result, mirror-imaging and worst case scenario analysis were utilized. The United States began to think of schemes with which to defend itself from such a threat; thus, ironically, the first thoughts of multiple launches were for the nation's defense, not for offensive penetration of enemy defenses. The multiple satellites could be used to detect and destroy an enemy missile in its boost phase (the phase immediately after takeoff before the missile leaves the atmosphere). These types of systems were collectively known as BAMBI (ballistic missile boost intercept).[168] Fortunately, scientists had not waited until this potential need surfaced before doing basic research on rocket fuels, rocket design and guidance that would be required to achieve a multiple satellite launch. When the concept was brought up, the scientists already had a firm foundation of previous research and development on which to build.

The innovative process is iterative: the Air Force was already working on rockets and satellites. Also, Werner von Braun's group under the US Army was already studying rocket systems. At this same time, in the early 1960s, the Navy was considering multiple warheads for the *Polaris* system. Electronics labs were continuing to enhance guidance control systems and Lawrence Livermore and Los Alamos were working on smaller and more efficient warheads like the ones that would later be used for MIRV. York recalled, "Lawrence Livermore made warheads for MIRV. The whole idea of small warheads was already there. Then you just fit them

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[168] Stockholm International Peace Research Institute, "The Origins of MIRV" *SIPRI Research Report* No. 9. (August, 1973), 9 (hereafter noted as SIPRI, *The Origins of MIRV*).

specially to MIRV."[169] The first United States multiple satellite launch took place on June 22, 1960.[170] Two satellites were launched past the atmosphere and then separated via compressed spring. The smaller of the two satellites then traveled at a different rate than the larger. This was the beginning of independent targeting. From this point, the iterative process toward MIRV moved very quickly.

Two months before the first multiple satellite launch, an *Able-Star* upper stage was the first successful attempt at shutdown and restart of the main engines. This was a critical step toward MIRV in that this system could make orbital adjustments that would be necessary to reposition the vehicle for releasing separate objects. In October 1963, an *Atlas-Agena* rocket successfully placed two satellites into orbits that were 180° apart. In 1966, the *Titan III* rocket with the technologically pivotal *Transtage* post-boost control system successfully launched multiple satellites. The post-boost control system was the system by which the vehicle could repeatedly reposition itself and release objects on the proper paths. It was the "immediate

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[169] *York Interview,* 6 November 1999.

[170] J. S. Butz, "Transit Applies Dual Satellite Technique," *Aviation Week*, 27 June 1960, 26.

technological precursor to the United States Air Force Version of MIRV, " and is often referred to as the "bus".[171] The bus was the key technology that allowed for MIRV. The rocket technology, warhead design, general guidance systems and materials technology needed for reentry were each available by the early 1960s. The critical piece was the bus that had finally evolved.

During the time the United States Air Force was developing multiple satellite launches, the Navy was developing multiple warhead capability of its own. In the early 1960s, the *Polaris* program, the submarine-launched missile system, was almost finished. Following the natural path of constant improvement, the Navy was looking to increase the power of the rockets.[172] "In addition, this was a time of continued and steady improvements in systems for missile guidance and for submarine location. These technical developments, plus the practically automatic conclusion that there would be a new generation of Polaris, meant that the question of warhead design was wide open."[173] The next generation of *Polaris* would be called the *Polaris A-3* and, deployed in 1964, would carry three warheads that

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171 SIPRI, *The Origins of MIRV,* 12.

172 Ibid., 15.

173 Ibid.

were not independently-targetable. York, explained that not only were multiple warheads a natural way to progress for the Navy but also that the element of inter-service rivalry was present. "The idea of multiple launches … was natural because that was what planes always did."[174] The *Poseidon* (a MIRVed missile) program was the next step for the Navy. The Air Force furthered their evolution toward MIRV also in the early 1960s. They were concerned about penetrating missile defense and also about the increasing number of targets that would need to be destroyed in the Soviet Union.[175] The Air Force MIRV program would be known as the *Minuteman III*. There is no need to embark on a detailed chronology of the *Poseidon* and *Minuteman III* MIRV systems after 1964 in this discussion because Greenwood does an excellent job with that task in his book.

For MIRV, there was not a thread of development "but a fabric."[176] The innovative process was following its usual iterative path. "With MIRV, being able to use a single rocket, a single launch for multiple purposes is a natural

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[174] *York Interview,* 6 November 1999.

[175] SIPRI, *The Origins of MIRV,* 18.

[176] York Herbert F., "Multiple Warhead Missiles," *Scientific American* (November 1973), 20.

way to go."[177] The "fabric" was composed of the long history of technological development and its continued evolution as well as a number of disparate uses for the technology and the exchange of personnel between the military, the laboratories, the universities, industry and the administration. The list of uses includes launching multiple satellites into different orbits, inflicting more damage with a single rocket by firing more warheads at a target, hitting more than one target with a single rocket, and potentially overwhelming an enemy's missile defense system. York explained, "There's so many different possible needs that there was no chance there wouldn't be a need. So that's inexorable."[178] In addition, the exchange of personnel helped to facilitate the cross-pollination of ideas and knowledge. For example, the BAMBI satellites were studied in depth by the Advanced Research Projects Agency (ARPA) of the Department of Defense with assistance from the RAND Corporation. Just a few years after ARPA's founding in 1958, "there was an especially rapid interchange of key technical personnel between ARPA and industry, and among the industrial groups most heavily involved in missile and space

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177 *York Interview,* 6 November 1999.

178 Ibid.

technology."[179] According to York, the "fabric" of the evolution toward MIRV "could have been cut in any number of places without seriously impeding the progress of the MIRV system."[180]

Greenwood's study of the Air Force and Navy MIRV programs is very detailed and apparently accurate. He focused the study largely on the period from 1964 to the mid-1970s when MIRVed missiles were deployed to land sites and submarine fleets. Greenwood wrote, "The year of decision for MIRV was 1964."[181] While 1964 was the first year that a program for a specifically designed MIRVed missile was put into the defense budget, it was, as shown in this work, by no means the beginning of the MIRV innovation. Greenwood briefly acknowledged the mirror imaging and worst-case analysis tendencies, the multiple uses for MIRV technology and the fact that independent parties were conceptualizing the capability at the same time. He also briefly acknowledged that laboratories must push the technological extreme in order to attract and retain people and that MIRV was "firmly grounded in the technical

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[179] SIPRI, *The Origins of MIRV,* 10.

[180] York, "Multiple Warhead Missiles," 20.

[181] Greenwood, *Making the MIRV,* 5.

developments of the 1950s."[182] Although he acknowledged these critical dynamics, Greenwood came to the wrong conclusion about their importance by attempting to treat the MIRV innovation as largely independent of the Cold War and the larger dynamics of the technological climate at the time. He criticized other authors for single-factor explanations by referring to their "universal reluctance to deal with historical evidence in all its richness."[183] This author asserts that it is Greenwood that failed to examine the richness of history when he ignored the influence of the greater technological climate in the United States after 1945 and concluded that MIRV was not "the inexorable march of new technology."[184]

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[182] Ibid., 104.

[183] Ibid., 143.

[184] Ibid., 28.

Conclusion

The technological climate in America after 1945 had a very strong foundation from the success of the Manhattan Project. The motivation of the scientists to question and discover was at the very heart of the project. Each had a different background and a different set of experiences to bring to the project, but all shared a common interest in rising to the challenge of harnessing the energy of the very building block of matter, the atom. Their work was accelerated to meet the needs of wartime urgency yet their communication was constrained by the requirements of national security. The successful detonation of the world's first atomic bomb over Hiroshima left indelible changes in the dynamics of technological development in the United States.

Before Churchill gave his "Iron Curtain" speech in Missouri, the United States had seen the dawn of big science. The days of the lone professor working in a tiny office to discover the principles of nature were over. The continuing practice of big science brought teams of scientists from all disciplines together in large, well-funded laboratories. The chemist would work directly with the physicist who would approach the machinist and the engineer together - much the way they had during the Manhattan Project. In this environment, the scientists enjoyed the intellectual adventure of innovation and learned that cross-disciplines could get along with each other and, more importantly, with the government.

Before 1945, scientists had been hesitant to accept federal funding for fear that their paths of discovery and innovation be dictated by biased sources. During the Manhattan Project, they learned that it could be a rewarding adventure to spend over two billion dollars of federal monies. After the war, the government and the scientific community came to arrangements that largely accommodated the needs of both. The scientists were given flexibility and the government was certain of a continuing source of innovation. This relationship gave laboratory directors the opportunity to formulate an operational policy that would allow them to attract and retain talented scientists while still accomplishing the national security goals of the United States.

Scientists embarked on natural patterns of development that constantly pushed at applied technological extremes, continually improved on current technologies and emphasized a practice in basic science. This combination of related but separate areas of practice kept the laboratories at an operational equilibrium that allowed them to sustain a continual outflow of innovative technologies to the defense establishment. To slow the flow the government only needed to stop the funding for experiments, but that would not be possible in the all-encompassing grip of the Cold War and the associated arms race.

The "ten-foot tall Russian" seemed to be on everyone's mind, from the administration, to the military, to the scientific teams, to the public. The intelligence that the United States did not have on Soviet activities seemed to be more powerful than the intelligence that it did have. Scientists and military services were desperately competing with their own capabilities in an effort to be safe, rather than sorry, in the arms race. In the atomic age, nuclear war was too terrible to fathom, thus with the obvious success of technology in ending World War II, the United States began to compete with technology.

Within the country, technology became the probable answer to just about any issue ranging from agriculture, to moral discipline, to national defense. With technology as the path to the future, technologists were in high demand for guidance and decision-making on a wide range of issues, including national defense. To these advisory and policy roles, the scientists brought with them all the trappings of their art, including their appreciation for ongoing innovation and discovery.

In this environment, a capability like MIRV had almost no chance of not being developed. Because of the iterative nature of scientific innovation, the building blocks on which MIRV technology sits were in seemingly infinite cycles of advancement and new discovery. In the case of MIRV, there were several needs for the combination of technologies required to build the capability. Penetrating Anti-Ballistic Missile defenses was only one of these needs. To say that MIRV was developed in response to the Soviet ABM threat is to be ignorant of the larger dynamics of the technological climate at the time. In the natural patterns of innovation and discovery, MIRV was built on discoveries that were made before its time just as it would be the building block of discoveries made after its time.

MIRV was perfectly natural in the progression of weapons innovation. A specific requirement is not necessary for the process of innovation to begin, nor does the process end when the requirement is met. Progression was just considered the normal thing to do given the Cold War and the factors determining the technological climate in postwar America. Herbert F. York cited accuracy as analogous to the natural pathway for MIRV, "My view is that accuracy is a general military good and you're going to work on developing accuracy. You don't need a requirement."[185] This subjective approach by the scientists is where authors such as Greenwood fail to understand that innovation does not begin with a requirement, it begins with science.

Although MIRV was a collection of building blocks in the infinite procession of technological development, debates on deploying the technology brought controversy. However, controversy over weapons systems was not new either. The Manhattan Project was pivotal in causing a large number of scientists, as well as non-scientists, to consider the potential of scientific achievement. The debates spawned about atomic energy, arms control, and the futility of nuclear war continue today, over fifty years later.

Wars have been terrible and have resulted in the death of millions since the beginning of time. Why did the atomic bomb, as another terrible weapon, spark the initial debate? The machine gun was a major advance in a military force's ability to inflict casualties; motorized warfare, air power

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[185] *York Interview*, 6 November 1999.

and armored warfare also mark major advances. Why don't nuclear weapons merely take their place on the list of advancements? Nuclear weapons marked the end of the possibility of a war of attrition. In nuclear war, a battle of attrition could no longer be won by simply adding more war-fighters. With weapons that can destroy, in increments of square miles, all of the people, buildings and inhabitable environment in those spaces, a two-sided battle becomes a stalemate, an impossibility. There is no adequate defense against these indiscriminate weapons even today. It is natural and correct that scientists use their scientific approach of doubting and discovering in order to understand the new world based on their scientific achievement. However, even as they continue through this process and debate political and social issues, they are still scientists.

Enrico Fermi said, "After all, it wouldn't make any difference whether the bomb went off or not because it would still have been a well worth-while scientific experiment. For if it did fail to go off, we would have proved that an atomic explosion was not possible."[186] Perhaps Segre was correct when he wrote, "I sometimes thought Fermi believed

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[186] Groves, *Now It Can Be Told* , 297.

that when the noise and excitement of the hour had long been forgotten, only physics would last and assert its perennial value."[187] The excitement of the hour has not been forgotten, and the political, social and scientific components of the Cold War and the arms race, both positive and negative, are still with us today.

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[187] Segre, *Enrico Fermi: Physicist*, 151.

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