NUCLEAR INNOVATION AND

NATIONAL SECURITY

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**ABSTRACT**

The national security of the United States and the ability of the US government to provide for the nation's common defense has declined since the end of the nuclear innovation age in the late 1980s. Nuclear reactors and nuclear weapons have deteriorated due to political pressure, decreasing oil prices, and apathy toward the America's nuclear infrastructure and community. This thesis examines the US government's inability to guarantee the nation's security from rising powers like China and India due to America's lack of nuclear innovation over the last 30 years. Utilizing historical narratives, scientific examinations, and geopolitical data, this thesis will demonstrate that 21st century security threats from conventional powers arise as a result of stagnant nuclear innovation.

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## CHAPTER I

## INTRODUCTION

Energy is the master resource. Like access to food and water, energy is foundational for economies, governments, militaries, agriculture, and industry. Conflict over energy and resources combined with national sovereignty pursuits has sparked engagements in the South China Sea throughout the 21st Century, Kuwait in the 1990s, and even the Japanese attack on Pearl Harbor. Nations with energy feel powerful and secure, while nations without energy feel threatened and vulnerable. Energy security is either peace or war.

On December 2nd, 1942, an Italian physicist named Enrico Fermi and a team of physicists changed the concept of energy forever by successfully harnessing nuclear power for the first time. They produced the first controlled nuclear chain reaction in their Chicago Pile-1 nuclear reactor, quickly leading to the development of the atomic weapon.[1] This scientific breakthrough prevented a costly Japanese land war and led the conclusion of World War II, the beginning of the Cold War, a race for nuclear power management, and a fundamental shift in international relations and national security. A nation's power and stability quickly became reliant on the pursuit of nuclear technologies.

Simply put, nuclear energy and technology is the essence of a modern, 21st Century nation. This thesis seeks to demonstrate that the presence of nuclear innovation directly correlates to a nation's strategic strength as a world power. Specifically, this thesis identifies

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National Security Law Journal

[1] Richard Rhodes, *The making of the atomic bomb*, (New York: Simon & Schuster, 1986).

complacency toward nuclear technological innovation as negatively affecting US national security placing the nation at risk from the rising 21st Century powers."[2]

After the Second World War (WWII), the advent of nuclear power forced drastic changes. Both the US and Union of Soviet Socialist Republics (USSR) soon entered a period that this thesis has labeled, "the first nuclear innovation age," whereupon these rival superpowers raced to outperform and out-design one another. These nations saw the need to innovate and build bigger, faster, further-flying weaponry to guarantee their national security. In an arms race of such magnitude, new defense requirements were constantly arising, requiring innovation for safety against mutually assured destruction (MAD).

Nuclear power is a complex and often dangerous energy source that requires constant attention so that it does not become unintentionally deadly or unusable. The first nuclear innovation age produced a powerful source of both energy and political power that has become the largest guarantor of national security in the modern age. National security is the "measurable state of the capability of a nation to overcome the multi-dimensional threats to the well-being of its people and its survival as a nation-state, by balancing all instruments of state policy through governance, and is extendable to global security by variables external to it."[3] Typically, the idea of national security is made simple by separating out individual categories or dimensions that ultimately come together to "overcome the multi-dimensional threats" that exist in today's geopolitical climate. National security as a construct involves

[2] National Intelligence Council, *Global Trends 2025: A Transformed World* (2008).

[3] Paleri, Prabhakaran (2008). National Security: Imperatives And Challenges.

military security (offensive and defensive), political security (international balance of power and diplomacy), economic security, environmental security, and energy security.[4]

The single largest factor that links these dimensions together is the presence of a robust, innovative nuclear power program in a nation, or close ties to a nation that has one. This thesis hopes to demonstrate how nuclear power has permeated every dimension of national security. This includes risks to nations without nuclear programs, along with nations that have failed to fund and improve their nuclear programs. Historically, nuclear innovation has furthered national security, and without the constant development of nuclear science and weapons that began following World War II, national security the violate state seen today.

The progression of global nuclear innovation can be categorized into three distinct periods: the first age (1945-1986), the fall (1986-2009), and the second age (2009-present). With the dawning of the first nuclear innovation age, the core dimensions of national security suddenly became solely reliant on a nation's nuclear capabilities instead of the size and competency of its military. The idea of possessing the scientific capabilities to maintain a sustained nuclear chain reaction, has, for the last 70 years, almost exclusively dictated the list of world powers, bringing those powers to the brink of global war on several tenuous occasions, with US nuclear supremacy and fear of Mutual Assured Destruction causing the USSR to back down during the 1961 Cuban missile crisis. This thesis will examine the tenets of national security and the important role that nuclear innovation and nuclear power has played in 20$^{th}$ and 21$^{st}$ centuries.

Rapid nuclear innovation prompted the Cold War's conclusion. Just as the fields within nuclear physics constantly drive one another to improve, so did the Soviet Union and

[4] "Rethinking Security: a Discussion Paper," (The Ammerdown Group, May 2016). https://rethinkingsecurityorguk.files.wordpress.com/2016/10/rethinking-security-a-discussion-paper.pdf.

US. With national security now relying so heavily on nuclear power, nations felt the need to innovate quickly to stay ahead of their rivals and prevent their destruction. However, support for the first nuclear innovation age began its dramatic decline following two nuclear accidents: one in Three Mile Island, Pennsylvania; and a second, more disastrous accident in Chernobyl, Ukraine. With the dissolution of the Warsaw Pact and the disbanding of the USSR, funding for nuclear innovation bottomed out as public fear and domestic focus redirected funding, and focus was shifted onto the cheap alternatives of natural gas and oil.[5] This thesis will examine the downward trend in nuclear expenditures, the need to support nuclear innovation, current nuclear stockpiles, and the pursuit of nuclear reactors.

While the end of the first nuclear innovation age took a severe toll on the global nuclear community, several nations have begun a second nuclear innovation age. The nuclear technologies of China and India have progressed at a staggering rate. For perspective, in 1995, the US nuclear power industry produced approximately 100 GWe from 109 reactors,[6] and China produced 2.1 GWe from 3 reactors. In 2017, the US produced 99 GWe from 99 reactors – while China produced approximately 40 GWe from 38 reactors.[7] China has 20 additional reactors under construction with a projected output of 58 GWe by 2020, and up to 150 GWe by 2030. China's focus on improving their nuclear capabilities will directly translate into an ability to more aggressively posture against the US throughout the Pacific.

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[5] Ahmed Abdulla, "A Retrospective Analysis of Funding and Focus in US Advanced Fission Innovation," (Environmental Research Letters, August 2017). http://static1.1.sqspcdn.com/static/f/356082/27654623/1502645550377/Abdulla_2017_Environ._Res._Lett._12_084016.pdf?token=hY99KQqU96mHKGzeZOixY%2FvviLo%3D.

[6] GWe = gigawatts of electrical output. To clarify, reactors typically make up a power plant, with the majority of nuclear power plants having two or more reactors comprising them.

[7] "Nuclear Power in China," (World Nuclear Association, January 2018). http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx.

India has been pursuing similar, although less extreme growth. Since India is not a signatory to the Nuclear Non-Proliferation Treaty, it has been banned from trade in key nuclear materials for the last 34 years, significantly hampering its development of nuclear energy until 2009, when many restrictions were lifted. India, which possessed 1.7 GWe of nuclear power well into the 2000s, expects to have 14.6 GWe of nuclear capacity on line by 2024 and 63 GWe by 2032, aiming to supply 25% of the nation's total electricity from nuclear power by 2050.[8] India is an important strategic partner of the US and while their growing power is not a direct threat to the US, it is a growing threat to regional and global stability. Although the India-China rivalry is a fairly conventional, historical-style rivalry, the India-Pakistan rivalry is a hate-filled, ethnic, religious, nationalistic rivalry that has the potential to destabilize the entire region at a moment's notice. As India improves their infrastructure and technology, their new confidence could lead to a legitimate conflict in the region.

Both China and India have seen substantial growth in terms of investment in infrastructure, sponsorship of research and development (R&D), and total power output. This growth over the last several decades has put them on course to surpass the US' nuclear capabilities, possibly as early as 2050. Drawing upon recent advancements and future projections, this thesis will also examine US national security in the context of the expanding nuclear infrastructures of foreign powers.

The US deterioration in nuclear innovation over the last three decades reflects apathy among the nation's political and scientific elite. Neglect and complacency has allowed nuclear research, nuclear technologies, nuclear power plants, and nuclear production to

[8] "Nuclear Power in China."

become outdated over time. 19 nuclear reactors have been decommissioned since the Chernobyl disaster and 82% of US nuclear warheads have been disassembled, based on the number of warheads present when the Berlin Wall fell in late 1989."[9] In 2012, the Nuclear Regulatory Commission approved the first construction permit in 34 years, approving construction of four new reactors, two at the existing Vogtle Plant in Georgia, and two at the Summer Plant in South Carolina.[10] While some began declaring that the US nuclear "renaissance" had finally begun, the current state of the two projects demonstrates the state of indifference in the US. The Summer project was entirely abandoned after Westinghouse Electric declared bankruptcy, and the Vogtle project is currently five years behind schedule and $9 billion over budget, and by the time of completion, the new reactor could have a price tag of up to $25 billion.[11]

However, beginning circa 2015, nations beside China and India have shown renewed interest in nuclear weapons and reactors. As Cold War weapons have continued to age, some approaching the 50-year mark, nations look to revitalize their aging stockpiles as new national security threats arise. The potential for newer, safer, more efficient technology may also help catalyze US interest in nuclear development and investment. The current administration, under President Trump, has shown a willingness to acknowledge the need for innovation and expansion of nuclear capabilities, demonstrated in his February 2018 Nuclear Posture Review, but the administration must overcome pressure from the anti-nuclear groups in addition to convincing the general public that new nuclear weapons and an increased focus

[9] "List of All Decommissioned Power Plants in USA," (Public Watchdogs, Sept 2016). https://publicwatchdogs.org/list-decommissioned-nuclear-power-plants-usa/.

[10] "Nuclear Regulatory Commission Approves Construction of First Nuclear Units in 30 Years," (Energy Information Administration, March 5, 2012). https://www.eia.gov/todayinenergy/detail.php?id=5250.

[11] Russell Gold, "Tab Swells to $25 Billion for Nuclear-Power Plant in Georgia," (Wall Street Journal, 2017). https://www.wsj.com/articles/tab-swells-to-25-billion-for-nuclear-power-plant-in-georgia-1501691212.

on nuclear energy is a viable path forward. When comparing its aging nuclear infrastructure with the emergence of foreign nuclear capabilities, the US government must adapt or decline as a world power.

# CHAPTER II:

## THE EARLY DAYS

A significant portion of the initial content in this thesis will be dedicated to presenting the background and direction of nuclear innovation. It will focus heavily on the historical study of the science and experiments that led up to and ultimately drove the first innovation age. Additionally, basic understanding of the science behind nuclear physics is necessary to understand the current state of international security. Whether it is conceptualizing the science behind a nuclear chain reaction or the difference between fission and fusion, context is a foundational component of this scientifically complex topic that includes modern physics, chemistry, and nuclear power. This section of the thesis will include a combination of biographies and narratives to best provide the timeline of events that led to the nuclear innovation age.

Before the US began its own nuclear development project circa WWII, the study of nuclear physics was almost exclusively limited to European nations during the 1910s and 1920s. Scientific powerhouses such as Britain and Germany were joined by brilliant minds from smaller, yet not insignificant nations, such as The Netherlands and Hungary, to pioneer many of the 20th century breakthroughs. However, the story of national security, modern warfare, and modern science actually begins on the British Commonwealth island of New Zealand. Born on a flax farm on an island that had been discovered only 100 years before his birth, future Nobel Laureate Ernest Rutherford would go on to literally change the world.

Ernest Rutherford and the students he taught over the decades, nine of whom would go on to win Nobel prizes of their own, discovered or inspired the discovery of nearly every single foundational piece of nuclear physics, nuclear weapons, and nuclear reactors.[12] Rutherford either independently discovered or led the team that discovered radioactive half-life, alpha and beta particles, the proton, the neutron, the ability to split an atom, and the existence of the atomic nucleus. Migrating from New Zealand to Canada, and ultimately to Great Britain allowed Rutherford and his teams to make use of the robust European scientific infrastructure where they focused on experimental physics. Rutherford's discoveries during his life were so significant that German theoretical physicist Albert Einstein, widely regarded to be the greatest theoretical physicist ever, often described Rutherford to his contemporaries as "the second Newton."[13]

In 1911, while testing the validity of the accepted atomic model, Rutherford accidently discovered the nucleus, and nuclear physics, the study of the atomic nuclei was born. Later in his life, Rutherford said of the experiment, "It was the most remarkable event of my life. It's as if you've fired a large, heavy shell at a piece of tissue paper and it came back and hit you."[14] The next science-altering discovery that Rutherford contributed to is a phenomenon called nuclear transmutation. Historically, transmutation has been a feature of mythology and the object of desire for alchemists. The story of King Midas, the mythical Greek king that turned objects into gold by touch being the most well-known example of transmutation. Rutherford and physicist Frederick Soddy first discovered natural nuclear

[12] Rutherford's Nobel-winning students included: Otto Hahn, James Chadwick, C.F. Powell, Ernest Walton, Niels Bohr, Patrick Blackett, Frederick Soddy, John Cockcroft, Edward Appleton. Historians have described the Cavendish Laboratory as a "Nobel prize factory," but Rutherford's tutelage is what ultimately created the Nobel prize factory.

[13] Richard Reeves, *A Force of Nature: The Frontier Genius of Ernest Rutherford*, 1st ed., Great discoveries, (New York: W. W. Norton & Co., 2008).

[14] Malcolm Longair, "When Rutherford split the atom," interview by Ricky Nathvani, 2017, https://www.thenakedscientists.com/articles/interviews/when-rutherford-split-atom. In his experiment, Rutherford shot alpha particles at a thin piece of gold foil. He expected the alpha particles to pass straight through the foil, due to no knowledge of the nucleus, but instead, the alpha particles bounced off in all directions, with only some passing through.

transmutation in 1901 when they observed radioactive decay in a piece of Thorium that was naturally turning itself into radium through radiation. Reportedly, upon Soddy identifying the process as transmutation, Rutherford said "...don't call it transmutation! They'll have our heads off as alchemists."[15]

The majority of scientific research in Britain came to a grinding halt when much of the scientific community was poached for the war effort in 1914. Rutherford himself was acquired by the British Navy and worked with the anti-submarine division, contributing to the invention of early sonar devices to be used against the German U-boats.[16] While he worked on sonar technologies, he continued minor experiments by himself in the laboratory. During his spare time one day, Rutherford noticed some previously unexplained radiation in the air around alpha particles, which he identified as nitrogen. He began experimenting with the relationship between alpha particles and nitrogen until the war ended. On January 9, 1919 he bombarded pure nitrogen atoms with alpha particles, which broke down the nucleus of the nitrogen atoms, releasing hydrogen and oxygen atoms in the process. As a result, he had successfully split the atom and became the first true alchemist in history, artificially changing one element into another.

Out of this groundbreaking experiment, he also realized that the hydrogen atom, split off of the nitrogen atom, had further implications. The hydrogen atom, he discovered, was the missing ingredient in the makeup of the atom, and Rutherford labeled it as the "proton.". But he quickly realized there was a problem with his view of the atom; the new mass still didn't add up. There was still an unexplained weight missing from the total mass of the atom, even with the electrons and protons in place. With this in mind, in 1920, he proposed in a

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[15] Francisco Doménech, "The True Alchemists," (The Open Mind, September 2015). https://www.bbvaopenmind.com/en/the-true-alchemists/.

[16] Rhodes, *The making of the atomic bomb*.

lecture that there could be a neutral component to the nucleus, which he preemptively labeled as the "neutron". For the next 10 years, Rutherford's primary goal was to prove the existence of the neutron with the help of his former student, James Chadwick.

In conjunction with Chadwick's work on and eventual discovery of the neutron, two more of Rutherford's students, Ernest Walton and John Cockcroft began combining several of Rutherford's discoveries. They intended to create a prototype particle accelerator that would speed up protons in order to artificially split the nucleus of a lithium atom.[17] Rutherford's 1919 experiment with nitrogen had broken off a piece of the nucleus, but not truly split the atom. To split the atom would require something traveling at much higher speeds. The particle accelerator allowed protons to achieve those high speeds and the lithium atom was successfully split, producing two alpha particles, and confirming all the theories of Rutherford and his team. In 1933, Rutherford published an article and gave his now-famous lecture that confirmed to the scientific community and general public that the atom was fully discovered and had been successfully split.[18]

Sitting in the audience at Rutherford's 1933 speech was a man who would turn Rutherford's concepts into actionable science and help kick start US involvement in nuclear physics. Throughout his largely unknown career, Hungarian physicist-inventor Leo Szilard proved himself a master at turning Rutherford's theories and models into actionable physics. Rutherford's article and lecture stated that splitting the atom was not an effective method for generating energy and that "anyone who looked for a source of power in the transformation of the atom was talking moonshine."[19] Shortly after fleeing to England from Hitler's rise in

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[17] Rhodes, *The making of the atomic bomb*.

[18] Rhodes, *The making of the atomic bomb*.

[19] Rhodes, *The making of the atomic bomb*.

Germany, Szilard, irritated about Rutherford dismissal of atoms as a source of power, realized that a nuclear chain reaction, like a chain reaction in chemistry, could theoretically be generated in order to create huge quantities of energy. Splitting one atom would generate two neutrons, which would split two atoms, generating four neutrons, and so on.

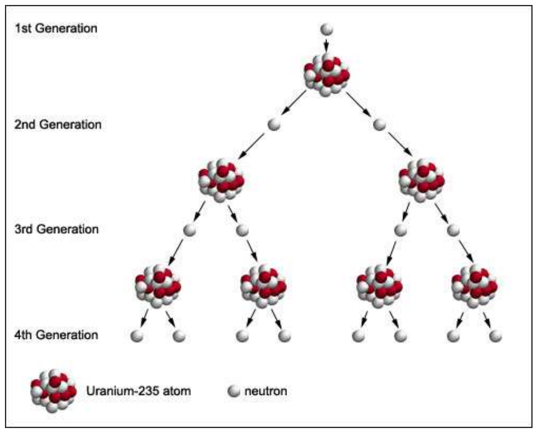


*Figure 1 Nuclear Chain Reaction*[20]

Szilard conducted his first chain reaction experiment at Columbia University, using a simple radium-beryllium source to bombard a small quantity of Uranium. For a nuclear chain reaction to be sustainable, the chain reaction must produce more than 2 neutrons, on average, per fission.[21] During the experiment, he observed a significant increase in neutrons, demonstrating that his chain reaction theory was possible. After proving the feasibility, he was able to convince Enrico Fermi, an Italian physicist considered to be the expert on Uranium at the time, to join him and conduct the experiment on a larger scale

[20] "Nuclear Chain Reaction," in *Encyclopedia Britannica* (2015). https://www.britannica.com/science/nuclear-chain-reaction.

[21] The verbiage "on average" is commonly used because a fission is not always perfect, sometimes 1 neutron is produced, or sometimes 3 or 4 neutrons are produced. In U-235, 2.5 neutrons are produced. Meeting this average makes a material "fissile," a term only applicable to U-233, U-235, and Pu-239.

Once Szilard's theory on the possibility of nuclear reactions was proven valid, he became concerned that the Nazis could easily replicate the experiment with Uranium and water and begin developing nuclear energy and nuclear weapons of their own. In an attempt to prevent the Nazis from re-creating the experiment, Szilard and another physicist, Eugene Wigner, penned a warning letter to the Belgian embassy.[22] At the time, the Belgian Congo was the best source of raw Uranium in the world, and Szilard wanted to guarantee that the Belgians would not supply the Germans with Uranium. In order to legitimize the letter, Szilard had his long-time friend and former business partner, Albert Einstein, who had connections to the Belgian royal family, sign the letter. An acquaintance of Szilard's, economist Alexander Sachs, also suggested that a letter also be presented to President Roosevelt, to warn him of the possible danger posed by Germany. The letter and explanation that Sachs presented to Roosevelt was so compelling that the President began setting up committees, eventually solidifying into the ambiguously-named "Development of Substitute Materials" project.[23]

The President ultimately decided to have the new nuclear project run by the Army instead of the Navy, since the Army had more experience with large-scale construction.[24] The Army Corps of Engineers Construction Division, under Colonel Leslie Groves, was chosen to lead Roosevelt's new project. Colonel Groves, wanting to draw upon the best architectural minds in the US, moved from his old position at the Syracuse Engineering

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[22] Rhodes, *The making of the atomic bomb*.

[23] Vincent C. Jones, *Manhattan, the Army and the Atomic B omb*, United States Army in World War II Special studies, (Washington, D.C.: Center of Military History For sale by the Supt. of Docs., U.S. G.P.O., 1985).

[24] Jones, *Manhattan, the Army and the Atomic B omb*.

District[25] to the newly formed Manhattan District located in downtown New York City. Groves soon moved his headquarters to Washington D.C., but since he was already informally referring to the Development of Substitute Materials project as the "Manhattan Project", the name stuck and was officially changed. The race against the Nazi physicists for the nuclear bomb had officially begun.

[25] Corp of Engineering districts typically carry the name where they are located.

# CHAPTER III:

# BUILDING A BOMB

"I think it is important to emphasize the role of industry in the Manhattan Project, because I deplore the tendency of myself and my colleagues to pretend that, with our own hands, we actually did this job. We had something to do with it. If it had not been for scientists, there would have been no atomic bomb; but if there had been only scientists, there also would be no atomic bomb."[26] J. Robert Oppenheimer, director of the Los Alamos Laboratory and "father of the atomic bomb," voiced this during a testimony before Congress in 1945, after two of his bombs were dropped on the nation of Japan. A common misconception that has always existed among the general public regarding the Manhattan Project was that it was primarily a large science experiment with minor engineering elements. However, the Manhattan Project was the "building of a weapons production system, as opposed to the building of three individual bombs."[27]

The government diverted huge quantities of money and manpower away from the front-line war effort to fund the project, going "all in" in a relatively short period of time. This section of the context portion will demonstrate the length at which the government was willing to go to beat the Germans to the atomic bomb. Overnight, the US changed nuclear physics from a scientific curiosity into a national project, and eventually a global pursuit. Physicist Neils Bohr summarized the industrial efforts when he reportedly told physicist

[26] Alex Wellerstein, "The Price of the Manhattan Project," (RESTRICTED DATA: The Nuclear Secrecy Blog, May 2013). http://blog.nuclearsecrecy.com/2013/05/17/the-price-of-the-manhattan-project/.

[27] Wellerstein, "The Price of the Manhattan Project." Three full bombs were constructed during the course of the project: the Gadget, Thin Man, and Fat Man.

Edward Teller upon seeing Los Alamos: "You see, I told you it couldn't be done without turning the whole country into a factory. You have done just that."[28]

With Colonel Groves at the helm of the project, construction began at an explosive rate. The five primary sites that Groves and his team selected were: the Chicago Met Lab, for Plutonium research and nuclear reactor design; the Hanford Site, for Plutonium production; the Clinton Engineer Works,[29] for enriching Uranium; the P-9 heavy water production plant; and Project Y, or "Los Alamos Laboratory," for designing the bombs.

The resources that the government put into constructing the sites alone demonstrate its commitment to the project:

Table 1 Manhattan Project Economic Layout[30]

| SITE/PROJECT | 1945 DOLLARS | 2012 DOLLARS | % |
|---|---|---|---|
| **OAK RIDGE** | $1,188,352,000 | $18,900,000,000 | 63% |
| —K-25 GASEOUS DIFFUSION PLANT | $512,166,000 | $8,150,000,000 | 27% |
| —Y-12 ELECTROMAGNETIC PLANT | $477,631,000 | $7,600,000,000 | 25% |
| —CLINTON ENGINEER WORKS HQ | $155,951,000 | $2,480,000,000 | 8% |
| —CLINTON LABORATORIES | $26,932,000 | $430,000,000 | 1% |
| —S-50 THERMAL DIFFUSION PLANT | $15,672,000 | $250,000,000 | 1% |
| **HANFORD ENGINEER WORKS** | $390,124,000 | $6,200,000,000 | 21% |
| **SPECIAL OPERATING MATERIALS** | $103,369,000 | $1,640,000,000 | 5% |
| **LOS ALAMOS PROJECT** | $74,055,000 | $1,180,000,000 | 4% |
| **RESEARCH AND DEVELOPMENT** | $69,681,000 | $1,110,000,000 | 4% |
| **GOVERNMENT OVERHEAD** | $37,255,000 | $590,000,000 | 2% |
| **HEAVY WATER PLANTS** | $26,768,000 | $430,000,000 | 1% |
| **GRAND TOTAL** | $1,889,604,000 | $30,060,000,000 | |

[28] Wellerstein, "The Price of the Manhattan Project."
[29] Often referred to as "Oak Ridge" because of the nearby town where the staff lived.

[30] Stephen I Schwartz, "The U.S. Nuclear Weapons Cost Study Project," (The Brookings Institution, August 1, 1998). https://www.brookings.edu/research/u-s-nuclear-weapons-cost-study-project/.

Additionally, there were approximately 130,000 people involved with the project, approximately 1% of the US's 1945 population of around 140 million.

Physicists like Szilard and Fermi, who just five years before were unable to conduct their experiment because of budget constraints, were suddenly provided with a blank check. Groves' massive construction projects began taking shape, and after 4 months, Fermi and Szilard got to test their hypotheses on a large scale. Nuclear historian Richard Rhodes summarizes the event:

> "On the cold winter afternoon of 2 December 1942, in a disused doubles squash court under the stands of the University of Chicago football stadium, the Nobel laureate physicist Enrico Fermi, a refugee from Fascist Italy, calmly initiated the world's first controlled nuclear-fission chain reaction. Other than hand-operated cadmium control rods, nothing visibly moved in the garage-sized graphite and natural uranium assembly Fermi and his crew had stacked up by hand over the preceding two months. (Fermi called the assembly a "pile" in amused reference to its stacked arrangement.) The reactor required no radiation shielding. The energy it produced by splitting—"fissioning"—uranium atoms, held to a mere 200 watts, was not even enough to warm the unheated court.1 Yet the experiment was transformative, presaging both nuclear power and atomic bombs."[31]

After the Chicago-Pile 1 success, innovation in the Manhattan Project was the top priority. Since many of the components and elements required to build the new atom bomb could not be purchased, the 130,000 person workforce had to invent and build the numerous ingredients and components. The largest was the K-25 gaseous diffusion project at Oak Ridge, accounting for almost one-third of the entire Manhattan Project budget, approximately $8.5bn in 2012 USD.[32]

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[31] Richard Rhodes, *Energy : A Human History*, First Simon & Schuster hardcover edition. ed., (New York: Simon & Schuster, 2018).

[32] Wellerstein, "The Price of the Manhattan Project."

*Figure 2 K-25 superimposed next to the Pentagon, for scale*[33]

The work at K-25 was largely separate from the rest of the Manhattan Project's work. The level of secrecy and compartmentalization meant that, in addition to being cut off from the Manhattan Project, the employees were cut off from the world itself. To put into perspective the vast amount of employees isolated at the Oak Ridge complex, the local intramural sports program there included: badminton, shuffleboard, bowling, golf, tennis, horseshoe tournaments, hiking, casting, riding, roller-skating, mini-golf, 26 teams of touch football, a baseball league with 10 teams, and 10 softball leagues with 81 teams.[34] The majority of the employees working at K-25 and the attached facilities had no idea on what they were actually working. All the employees were told was that: it involved building very large buildings; there were various health hazards involved; and it was an important war project.

[33] Alex Wellerstein, "Inside K-25," (RESTRICTED DATA: The Nuclear Secrecy Blog). http://blog.nuclearsecrecy.com/2013/05/24/inside-k-25/.

[34] Wellerstein, "The Price of the Manhattan Project."

The purpose of the plant specifically was to extract U-235 out of U-238 for use in weapons and piles (which are now called “reactors”). Naturally occurring Uranium is a combination of two different forms, which are called isotopes: U-238 (92 protons + 146 neutrons = 238) and U-235 (92 protons + 143 neutrons = 235). “The isotope that both fissions and chain-reacts, releasing energy, is U235. But most of natural uranium is U238; U235 is only about 1 part in 140, or .07 percent—seven-tenths of 1 percent. Even more troublesome, the two isotopes are chemically identical, which means they can’t be separated using chemical means.”[35] This is where K-25 came in.

In a gaseous diffusion enrichment plant, Uranium hexafluoride (UF6) gas was fed into the pipes where it was pumped through special filters called porous membranes. The holes in the membranes were so small that there was barely enough room for the UF6 gas molecules to pass through. The isotope enrichment occurred because the lighter UF6 gas molecules (with the U-235 atoms) diffused faster through the barriers than the heavier UF6 gas molecules containing U-238.36t took hundreds of barriers, one after the other, before the UF6 gas contained enough U-235 to be used in nuclear fuel. At the end of the process, the enriched UF6 gas was withdrawn from the pipelines and condensed back into a liquid that was then poured into containers. The UF6 was allowed to cool and solidify before it was transported to fuel fabrication facilities.[37]

[35] Rhodes, *Energy : A Human History*.

[36] Rhodes, *The making of the atomic bomb*.

[37] Wellerstein, "Inside K-25."

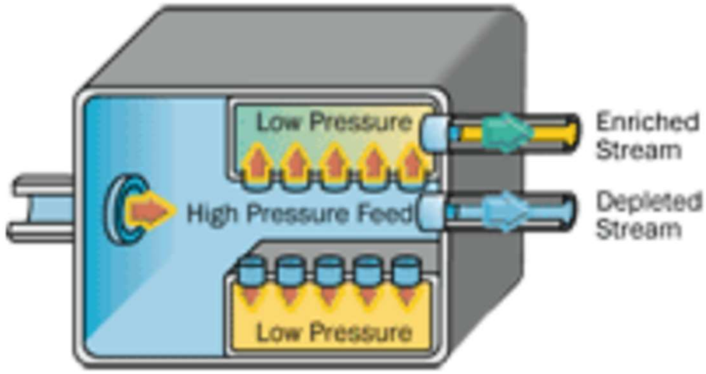


*Figure 3 Gaseous Diffusion Diagram*[38]

While the Oak Ridge K-25 plant was the largest and most costly of all the Manhattan Project efforts, the science and design project at Los Alamos was the most secretive and has become most commonly synonymous with the "Manhattan Project" name. The original intention was for the lab to be located with the other facilities at Oak Ridge, but Director Oppenheimer pushed for a separate lab location in the desert of New Mexico, near a more isolated area where testing could be more easily conducted. The government acquired 45,000 acres of land near the abandoned Los Alamos Ranch School, and Groves allocated $300,000 for its construction.[39] The sole responsibility of the Los Alamos Laboratory was to design a bomb based on the principles of a nuclear chain reaction.

The scientists were tasked with creating a fission bomb using Plutonium as the primary ingredient. Through theory and experimentation, physicists discovered that a concept called "supercriticality" was required for a bomb. Whereas criticality is simply the presence of a sustained nuclear chain reaction, as in the Chicago Pile-1 or in any nuclear reactor,

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[38] "Uranium Enrichment ",  (Nuclear Regulatory Commission, August 2017). https://www.nrc.gov/materials/fuel-cycle-fac/ur-enrichment.html#diffusion.

[39] By the end of construction, $7 million would eventually be spent on building Los Alamos Lab

supercriticality is an exponential increase of neutrons in the chain reaction able to create an explosion. If the right conditions and the proper quantity of fissile material exists (called critical mass, "proper" is an important word here because critical mass is not a specific number), the natural tendency is for Uranium or Plutonium to go supercritical, tearing itself apart, ending the reaction, and returning to a stable state.[40] In Chicago Pile-1, for example, the physicists were able to slow down and control the flow of neutrons with control rods, making the Uranium critical, but avoiding supercriticality. In Los Alamos, the physicists were tasked with not only creating a supercritical reaction, but maintaining a reaction long enough to generate a large explosion before the Uranium or Plutonium tore itself apart and ended the reaction early.

The initial design method was a "gun-type" bomb, using Plutonium, that the lab dubbed, "Thin Man."[41] The basic premise of Thin Man was that a hollow, subcritical Plutonium cylinder "bullet" would be propelled down a "gun barrel" by cordite, a gunpowder-like substance used in munitions.[42] The hollow bullet would collide with a subcritical Plutonium "target spike" at the other end of the barrel. As the bullet traveled down the 6 foot-long barrel, the two would achieve criticality when they were 9.8 inches apart, building up neutrons that would generate supercriticality and then an explosion. However, the scientists quickly realized that, while this design would work in theory, they had selected the wrong material. In the experiments, the Plutonium would generate too many neutrons while traveling down the barrel, achieving supercriticality too early and leading to a pre-

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[40] Rhodes, *The making of the atomic bomb*.

[41] The naming conventions of the nuclear bombs is a point of contention. Some believe that the bombs were named solely on their physical appearance, while others believe that Thin Man was named after President Roosevelt and Fat Man after Prime Minister Churchill.

[42] Rhodes, *The making of the atomic bomb*.

detonation, causing the materials to rip apart before a large explosion could occur. Additionally, the scientists realized that an explosion produced by this method would be very inefficient, with the reaction ending before the majority of the energy could be expelled, even if pre-detonation were somehow avoided.[43]

*Figure 4 Gun-Type Bomb Model*[44]

The final iteration of the gun-type bomb developed by Los Alamos, but never tested until “Little Boy” was dropped on Hiroshima, used Uranium as the fuel instead of Plutonium. The Uranium was able to generate just enough neutrons traveling down the barrel that a large explosion was generated while pre-detonation was avoided.

An alternative bomb that a small group of physicists had begun working on in the early days of Los Alamos was called the, “implosion bomb”. Due to the perceived simplicity of the gun-type bomb, the implosion bomb had been regarded as more of a scientific curiosity at Los Alamos. Physicist Seth Neddermeyer and a team had begun conducting research into an alternate Plutonium bomb using similar physics concepts to the gun type bomb, but vastly different munitions principles. The idea behind Neddermeyer’s bomb was that a solid sphere of Plutonium (called a core) could achieve the desirable critical mass - using substantially less material of lower purification - by detonating non-nuclear chemical

[43] The relative crudity of the gun-type bomb meant that only about 1% of its fissile material reacted — it was many times less powerful, even though it had roughly 10x more fissile material its alternative design**.**

[44] John Coster-Mullen, "Atom Bombs: The Top Secret Inside Story of Little Boy and Fat Man," (2002).

explosives in a spherical pattern around the subcritical core.[45] The inward explosion, precisely timed in order to be symmetrical, would so compress the core that critical mass would be achieved, and a substantial nuclear explosion would occur.

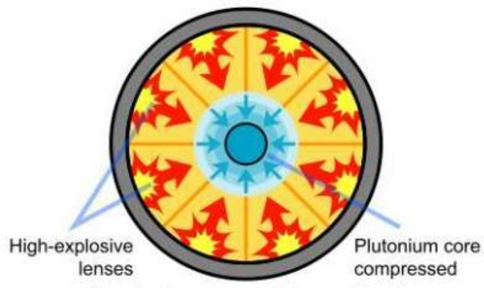


*Figure 5 Implosion Bomb Model*

The biggest difficulty that the team faced in legitimizing their design was the requirement that the explosives must fire at a precise time, or else the bomb would not work. Los Alamos was temporary home to many of the world's best chemists and physicists, but mathematicians were in short supply. Before the invention of modern computers, explosives were one of the most difficult phenomena to model and predict mathematically. Los Alamos enlisted the help of possibly the only man alive that could provide the mathematical calculations to accurately model and design the implosion bomb, Hungarian mathematician John von Neumann. Von Neumann, regarded as one of the all-time smartest men in history in terms of raw brain power,[46] developed the modeling for the explosive lenses that would be instrumental in creating the bomb. These lenses function similar to optical lenses, however, instead of focusing light waves, they focus and shape detonation waves. With von Neumann's aid, Los Alamos' work was nearly completed, and it was up to the other Manhattan Project sites to build the bomb and its components.

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[45] Rhodes, *The making of the atomic bomb*.

[46] *JJ O'Connor*, "John von Neumann " (University of St Andrews, Scotland, October 2003). http://www-history.mcs.st-andrews.ac.uk/Biographies/Von_Neumann.html.

As the Manhattan Project began approaching a completed product, the discussion of testing began in mid-1944. There was large-spread support from the scientists involved, but General Groves was hesitant to move forward with testing due to financial concerns. Groves' worry was that the bomb was not near completion, and if they tested too soon they could potentially destroy the Plutonium if the bomb was a failure. This Plutonium represented the entire worldwide quantity at the time and was worth up to $1 billion 2012 USD[47]. The other concern presented was the obvious safety and security required for a large test of such an unknown weapon. The scientists required a flat area with minimal wind, and eventually selected Alamogordo Bombing Range, 230 miles south of Los Alamos, and began construction in December 1944. The sparse working conditions there forced the inhabitants to build many of their amenities from scratch, and the base camp was accidentally bombed twice in May 1945 due to its proximity to the existing bombing range.[48]

On April 12, 1945, less than three months after being inaugurated for his fourth term, President Roosevelt died of a cerebral hemorrhage, leaving a country who was at war, in the hands of the uneducated Missouri farmer who had been Vice President for 82 days, Harry S Truman.[49] Truman was sworn in at 7:00pm on the 12th, and promptly attended a cabinet meeting, where the Secretary of War, Henry Stimson, said that Truman needed "to know about an immense project that was under way – a project working on the development of a new explosive of almost unbelievable destructive power."[50] On April 25th, Truman received

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[47] Wellerstein, "The Price of the Manhattan Project."

[48] Alex Wellerstein, "How to Die at Los Alamos," (RESTRICTED DATA: The Nuclear Secrecy Blog, February 2015). http://blog.nuclearsecrecy.com/2015/02/13/how-to-die-at-los-alamos/.

[49] President Truman is commonly referred to as "uneducated" because he was the only 20th century U.S President that did not graduate from college.

[50] Harry S Truman, *1945: Year of Decision*.

the first of many briefings informing him of the existence of a multi-billion dollar weapons program to build an atomic bomb.

With the new President sworn in and the Germans bowing out of the war on May 7th, the preparations for the nuclear test continued in earnest. The test was scheduled between July 18th and July 21st due to favorable weather predicted for the dates. However, President Truman specifically requested that the test be conducted earlier, on July 16th, due to the Potsdam Conference beginning on the same date.

The majority of the scientists present for the test estimated that the bomb would generate a detonation of approximately 5,000 tons of TNT, or 5kT. Scattered between the test tower and the three observation bunkers 10,000 yards away were various structures and objects that were placed so that the bomb's effect on certain objects at specific ranges could be observed. Many of the 250 observers, and all of those closest to the blast lay on their backs with their feet toward the tower, due to the total uncertainty of the power of the bomb.

At 05:29:20, the Gadget (the nickname for the assembled nuclear weapon) detonated with a force of 21kT, exceeding the estimates by four-fold, and the structures set up throughout the test range were incinerated. The desert sand around the detonation was instantly transformed into green glass, the detonation felt over 100 miles away, and the cloud reached 7.5 miles in height.[51] After the celebration of this overwhelmingly successful test wore off, Kenneth Bainbridge, the lead of the Trinity test, turned to Oppenheimer and somberly told him "now we are all sons of bitches."[52] More famously, Oppenheimer later recalled: "We knew the world would not be the same. A few people laughed, a few people

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[51] The famous green glass, or Trinite was formed from sand drawn up inside the Gadget's atomic fireball and then rained down in liquid form, cooling into the glassy substance.

[52] Rhodes, *The making of the atomic bomb*.

cried, most people were silent." Oppenheimer says, "I remembered the line from the Hindu scripture, the Bhagavad-Gita. Vishnu is trying to persuade the Prince that he should do his duty and to impress him, takes on his multi-armed form and says, 'Now, I am become Death, the destroyer of worlds.' I suppose we all thought that one way or another."[53] After almost 40 years of research, Pandora's Box had finally been opened.

Before the test, throughout April and May, various high-level committees had begun meeting to discuss possible targets in Japan. Five Japanese targets were selected: Hiroshima, Kokura, Yokohama, Niigata, and Kyoto. After selection, US air forces ceased bombing these five cities so that the psychological effect would be more substantial for the Japanese. Secretary of War, Henry Stimson, voiced displeasure at Kyoto's nomination as a target on the grounds of historical, cultural, and religious significance, as well as the fact that he had visited Kyoto on his honeymoon and had grown attached to the city. President Truman agreed with the decision to remove Kyoto from the strike list, and the seaport of Nagasaki was put in its place.[54]

The first atomic bombing mission began on August 6, with Hiroshima set as the primary target, and Kokura and Nagasaki as the secondary targets. Upon arrival at Hiroshima from Tinian, the aircrafts involved were greeted with clear visibility of the target. *Straight Flush*, the B-29 providing weather reconnaissance for Hiroshima, advised the crew of the primary bomber, *Enola Gay*, to proceed with the bombing. The bombardier released the gun-type bomb, Little Boy, from 31,000 feet at 8:15am to detonate 1,900 feet above the city. The untested bomb variant successfully yielded 16kT of energy, only fissioning 1.7% of the

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[53] J Robert Oppenheimer, "1965 TV Broadcast," 1965, https://www.shmoop.com/quotes/become-death-destroyer-of-worlds.html.

[54] Mariko Oi, "The Man Who Saved Kyoto from the Atomic Bomb," (BBC, August 2015). http://www.bbc.com/news/world-asia-33755182.

Uranium inside, but instantly killing approximately 30% of Hiroshima's population, or 80,000 people.[55]

While the Japanese government was stunned by the size and effect of the bomb in Hiroshima, they refused to meet the Allies' demands for unconditional surrender, and therefore the US decided to strike again. It was decided that the target for "Fat Man", the implosion-type bomb, would be the city of Kokura, the site of major Japanese munitions production. Due to an unfavorable weather forecast beginning on August 10th, Col Tibbets, the mission commander, decided to reschedule for August 9th. On the 9th Weather reconnaissance aircraft at both Kokura and Nagasaki, the secondary target, reported that the weather was ideal at their location. *Bockscar*, the B-29 carrying Fat Man, was supposed to rendezvous at an assembly point off the coast of Japan with *Big Stink*, the strike observation and photography B-29. But *Big Stink* was delayed, causing *Bockscar* to wait 30 additional minutes, thereby delaying the bombing.[56] By the time that *Bockscar* arrived on station in Kokura, clouds and black smoke from a previous bombing raid had obscured the target, causing the crew to make three separate passes, placing the aircraft in the way of Japanese antiaircraft fire.

With *Bockscar's* fuel running low due to a mechanical issue with its fuel pump, the convoy decided to head for the secondary target, Nagasaki. Due to the fuel levels, the crew initially decided that if Nagasaki was obscured upon their arrival, they would fly back to Okinawa and dump the bomb in the ocean, however, en route, they optioned for bombing

[55] Rhodes, *The making of the atomic bomb*.

[56] Craig Collie, "How A Last-Minute Decision Led To The Nuking Of Nagasaki," (Business Insider, Aug 2012). http://www.businessinsider.com/how-a-last-minute-decision-led-to-the-nuking-of-nagasaki-2012-8.

regardless of visibility, utilizing radar.[57] Once over the partly clouded target, the bombardier was able to visually sight the target through a break in the clouds and dropped Fat Man at 11:01am onto a tennis court 1,650 feet above the ground.[58] Fortunately for many of the residents, Nagasaki's location within the Urakami Valley saved much of the city as the blast was contained by the surrounding hills. Three days later, the Japanese emperor notified the imperial family that Japan would surrender, and two days later announced surrender to the world, citing the two atom bombs as well as the recent Soviet invasion, thus ending WWII.

The decision by US leadership to drop the atomic bombs on Japan, killing around 100,000 people, was defended by policymakers who argued that "defeating Japan would have required invading the island nation and spilling a vast quantity of American blood,"[59] possibly leaving up to an additional million dead on both sides. A land invasion accompanied by conventional bombings would have crippled the island of Japan more significantly than the two atomic bombs, likely creating an even larger humanitarian crisis.

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[57] Collie, "How A Last-Minute Decision Led To The Nuking Of Nagasaki."

[58] Collie, "How A Last-Minute Decision Led To The Nuking Of Nagasaki."

[59] Truman, *1945: Year of Decision*.

# CHAPTER IV:

# NATIONAL SECURITY TRANSFORMED

The Japanese surrender concluded the war and accelerated the nuclear innovation age. The USSR's own innovation age would further drive the ever-growing role that nuclear power would come to play in national security. With the dropping of the first bomb on Hiroshima, the dimensions of national security literally changed overnight. The next segment of this thesis will explore how emerging technologies from the nuclear innovation age drastically changed the specific dimensions of national security: military, political, energy, economic, and environmental security.

## Military Security

Traditional military (sometimes called physical) security implies the capability of a state to both adequately defend itself against foreign powers while also deterring foreign military aggression.[60] Specifically, this means that a nation's military must protect its citizens through offensive (deterrence, counter-terrorism) and defensive (standing armies, anti-ballistic missile) action. The most important role of the US government is to "provide for the common defense," a task that has been interpreted and executed in a variety of ways since the country was founded in 1787. In the 230 years of America sovereignty, leaders and administrations of the nation have acted against a wide range of threats to the common defense.

Military security has evolved with changing warfare, but from the perspective of the US as a superpower, it began in the early 20th century. With the US's rise to power in the

[60] "National Security Council Report," (Executive Secretary to the National Security Council, March 1956). https://history.state.gov/historicaldocuments/frus1955-57v19/d66.

early 1900s, its military became internationally formidable and relied on “gunboat diplomacy” for its military security strategy. As Theodore Roosevelt liked to quote from the West African proverb, gunboat diplomacy was "speak softly and carry a big stick."[61] This one-sided policy historically relied on powerful naval demonstrations to frighten weaker opponents into submission or neutrality. However, this form of military security is viable only when a single nation is substantially stronger than the others.[62] In the cases of both WWI and WWII, the common defense of the US was attacked by nations of similar military caliber: German U-boats besieged US shipping in WWI and Japanese aircrafts attacked the US homeland in WWII. Towards the end of the devastating WWII, the US returned to gunboat diplomacy, dropping two atom bombs on its stubborn Japanese enemy. As the sole owner of nuclear weapons, the US could once again frighten weaker opponents into submission or neutrality. That period, however, only lasted for four years, until the USSR detonated their first implosion-type atom bomb.

With help from US spies like Julius and Ethel Rosenberg, the USSR was able to speed up the timeline of their nuclear weapons program through the procurement of top-secret nuclear weapons designs. “Physicist Hans Bethe estimated that the Soviets would be able to build their own bomb in five years, but thanks to information provided by their agents, they did it in four."[63] When the USSR tested First Lightning on August 29, 1949, modern military security was born. With the US and USSR both in possession of nuclear weapons, the nuclear innovation age finally began, and military security took on a new identity. Having nuclear weapons in their possession, both had the means of carrying out

[61] Editors of Encyclopedia Britannica, "Big Stick Policy," (December 2017). https://www.britannica.com/event/Big-Stick-policy.

[62] https://www.idsa-india.org/an-feb-4-01.html

[63] Daniel P. Moynihan, *Secrecy : the American experience*, (New Haven: Yale University Press, 1999).

gunboat diplomacy, with devastating results. This new, two-sided variant of gunboat diplomacy colloquially became known as "mutually assured destruction," whereby both countries could now speak softly and carry a big stick, while deterring their rivals from waging a land war against them.

International military security evolved during the nuclear innovation age via three different technologies: the hydrogen bomb, ballistic missiles, and nuclear submarines. While the new military security strategy was "mutually assured destruction," the atom bomb was not yet truly capable of "assuring destruction". In 1950, President Truman approved research to create an even larger nuclear weapon, called a "super," which would utilize hydrogen in addition to the typical elements of the atom bomb.[64] The idea of a nuclear weapon using hydrogen as a primary ingredient was first discussed in Los Alamos during the Manhattan Project, but was abandoned in favor of the fission bomb. However, after the success of the Soviet atomic bomb, the idea of building a hydrogen bomb received new support in the US. For this type of bomb, deuterium and tritium (hydrogen isotopes) were fused into helium, thereby releasing energy. This fusion created in a hydrogen bomb mirrors the process by which the sun produces its energy. Due to the incredible heat required to start a fusion reaction, the physicists quickly realized that a fission detonation, which reaches temperatures exceeded 100 million degrees, would be the ideal kindling for a fusion bomb.[65]

The physicists also realized that theoretically, there would be no limit to the yield of this weapon, as energy output could be increased until it caused significant atmospheric damage or global fallout. Physicists such as Oppenheimer and Fermi opposed its development, writing, "Since no limit exists to the destructiveness of this weapon, its

[64] Richard Rhodes, *Dark sun : the making of the hydrogen bomb*, Sloan technology series, (New York: Simon & Schuster, 1995).

[65] Rhodes, *Dark sun : the making of the hydrogen bomb*.

existence and knowledge of its construction is a danger to humanity as a whole."[66] Disregarding all warnings, the US and USSR both developed hydrogen bombs with ever-increasing potency. Hydrogen bomb research reached its pinnacle on October 30, 1961, when the USSR dropped a 57mT hydrogen bomb, Tsar Bomba, which had a yield of 1500 times the power of the bombs dropped on Japan. Sensors registered Tsar Bomba's shockwave orbiting the Earth three times and the flash from the detonation could be seen up to 630 miles away, or the distance from Washington D.C. to Orlando, Florida.[67]

To deliver Tsar Bomba to its target, the 27-ton bomb had to be attached underneath a Tu-95 bomber as it was too large to fit in the bomb bay, and the pilots were only give a 50% chance of surviving the blast.[68] With technology that could destroy a major city in seconds, the US and USSR both required more efficient means than an aircraft for delivering their massive weapons. Short range ballistic missiles had been preliminarily developed during WWII, and the US and USSR began pouring money into their development after the war's end. With the construction of the new hydrogen bomb, the USSR became the first nation to build a true intercontinental ballistic missile (ICBM), the R-7, which flew 3,700 miles in its first successful test, and would eventually launch both the first satellite and the first man into space. The US Air Force was initially uninterested in developing an ICBM due to their air superiority and intercontinental bombers, but after the first hydrogen bomb test by the USSR, the government was forced to develop the Atlas ICBM.

[66] Stephen Dowling, "The Monster Atomic Bomb that was Too Big to Use," (BBC, August 2017). http://www.bbc.com/future/story/20170816-the-monster-atomic-bomb-that-was-too-big-to-use.

[67] Dowling, "The Monster Atomic Bomb that was Too Big to Use."

[68] Dowling, "The Monster Atomic Bomb that was Too Big to Use."

Since the two nations could not launch the missiles against one another without triggering global war, they sought other avenues to demonstrate their technical proficiency to provide for the common defense. The most peaceful and public way to demonstrate the capabilities and reliability of their missiles were with manned spaceflight. By placing a human atop their ICBM and accurately launching them into space and returning them safely, the US and USSR showed each other, very publicly, that they could assure the destruction of their rival.

With hydrogen bombs to destroy cities and ICBMs to get them there, the US and USSR now needed a hidden, mobile platform from which to launch the ICBMs to avoid being easily targeted, and submarines were the logical answer. However, the submarine's usefulness and stealth were limited by fuel consumption, constantly needing to return to base to refuel. Therefore, the US Navy formed the Naval Reactors Branch to devise a solution around fuel limitations by riding the wave of nuclear innovation.

The Naval Reactors Branch, the Atomic Energy Commission, and Westinghouse Electric Corporation then came together and invent what would become the universally used modern nuclear reactor, under the direction of Captain Hyman Rickover. They needed to miniaturize the existing reactor technology, incorporate steam generation for powering the submarine, and create extensive safety mechanisms to protect the sailors, all while planning for the unique physical limitations of operating on a submarine as well as under the ocean.[69] The complexity of this new technology is easily demonstrated through a diagram of a submarine's reactor:

[69] Sherie Mershon, "A Century of Innovation," (Department of Energy). https://www.netl.doe.gov/File%20Library/NewsRoom/NETL-A_Century_of_Innovation.pdf.

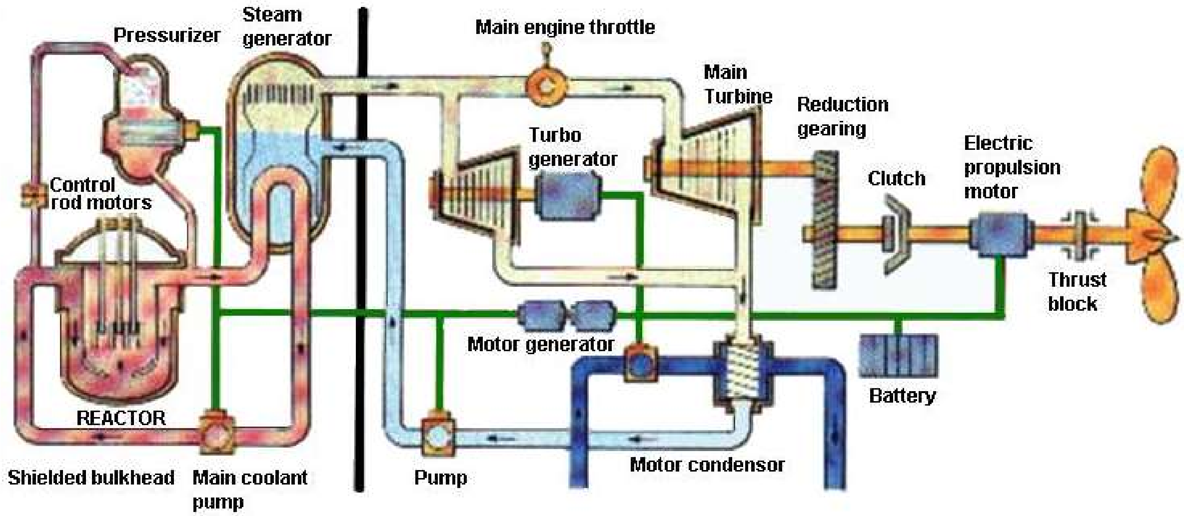


*Figure 6 Pressurized-Water Naval Nuclear Propulsion System*

The necessity for innovation drove the teams to develop technology that used pressurized water for cooling as well as steam generation, the method still used as the primary means of nuclear power generation all over the world today.

The nuclear propulsion on submarines proved to be a critical component of nuclear age military security. The nuclear reactor's independence from air that diesel engines required, meant that submarines no longer needed to surface, staying under water for considerably longer periods of time. Additionally, these nuclear reactors only require refueling approximately every 25 years, meaning that the only time they are required to return to port would be for food or maintenance.[70] In terms of military security, the largest advantage of the nuclear submarine is its mobility. With traditional ICBMs, missiles are permanently tethered to their silos, and their poor maneuverability makes for a desirable target for an enemy. With nuclear submarines, the ICBMs they carry can be anywhere in the ocean, hidden from view of concerned nations, ever providing for the common defense.

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[70] Loz Blain, "A Modern Engineering Masterpiece " (New Atlas, May 2007). https://newatlas.com/go/7292/.

This improvement of military security through nuclear innovation has had a positive cyclical effect internally on nations, whereby the military, private industry, and research institutes all work together to stimulate the economy and encourage academic pursuits at all levels of learning.[71] Externally, however, this change in military security has led to the largest, most powerful, most expensive arms race in history.

**Political Security**

Political security has historically been defined by global stability and is based on "the rule of international law, the effectiveness of international political institutions, as well as diplomacy and negotiation between nations and other security actors."[72] However, with the rise of nuclear superpowers, political security has also been defined by "the capability of a nation-state to enforce its international policy choices by use of its military and nuclear capabilities."[73] This type of coercion has always played a role in political security, but with the rise of nuclear innovation, it has become one of the primary drivers in international politics.

While military security was the national security dimension most immediately effected by nuclear power, the weapons also heavily affected the nature and content of international relations. Its rise was responsible for transforming the traditional international balance of power into a "balance of terror."[74] While nuclear weapons have been a source of

[71] "The Economic Benefits of Nuclear Technologies," (Management Information Services, March 1980). https://www.nrc.gov/docs/ML0037/ML003719644.pdf.

[72] Vladimir Petrovsky, "Diplomacy as an Instrument of Good Governance," (DiploFoundation, 1998). https://www.diplomacy.edu/resources/general/diplomacy-instrument-good-governance.

[73] Samuel W. Bodman, *National Security and Nuclear Weapons in the 21st Century* (2008).

[74] Albert Wohlstetter, "The Delicate Balance of Terror," (Foreign Affairs, January 1959). https://www.foreignaffairs.com/articles/1959-01-01/delicate-balance-terror.

"stability" and deterrence for guaranteeing military security, they have been a major source of instability on the international power structure. For the first few years after WWII, the US monopoly on atomic weapons made it the only superpower in the world, capable of blackmailing or pressuring any rival. When the USSR successfully developed nuclear weapons several years later, it led to bipolarity in international relations and the rise of two true superpowers. Then, with the rapid entry of Britain, France and China as nuclear powers, the bipolar power structure was transformed into a confusing, unstable multipolar structure.

Before the nuclear weapons age, the international standing of a state was determined by elements such as geography, population, natural resources and industrial capacity. In the nuclear age, nuclear technology and nuclear power quickly became the only important factors in achieving international political power. Any state that found itself outside the nuclear powers list, or without a protector under a "nuclear umbrella," found itself in immediate danger.[75] NATO, the North Atlantic Treaty Organization, is a commonly cited example of non-nuclear nations banding together under a nuclear umbrella, provided by the US, UK, and France, in an attempt to guarantee their national security under the new international order.[76] Additionally, under the new international order, small, previously insignificant states were suddenly capable of becoming formidable powers in international politics by acquiring nuclear technology and weapons. North Korea, a nation the size of Mississippi, with inhospitable geography, minimal natural resources, and a weak, starving population, has managed to propel themselves onto the international stage through their procurement of nuclear technology.

[75] Gro Nystuen, "Nuclear Umbrellas and Umbrella States," (International Law and Policy Institute, April 2016). http://nwp.ilpi.org/?p=1221.

[76] Wolfgang Ischinger and Ulrich Weisser, "NATO and the Nuclear Umbrella," (New York Times, Feb. 15, 2010). http://www.nytimes.com/2010/02/16/opinion/16iht-edischinger.html.

Also, under the old system of international order, power scarcity was the common trend, with “nations participating in major wars against their enemies for only minor gains in power.”[77] This traditional balance of power typically prevented large changes in the status quo, since there was only a finite amount of power available. Throughout Western civilization, several dominating nations in Europe historically controlled and manipulated the level of power of weaker nations, and whenever any nation tried to upset the balance or accumulate too much for itself, the other nations took action against the offender, typically in a coalition of sorts, using threat or force of war.[78] More recently, throughout the 100-year period following Napoleon's defeat, from 1815-1914, this method successfully regulated international relations, for the most part, with the European powers maintaining peace through the threat of war, until Germany's unification and subsequent rise.

In the nuclear age, instead of power scarcity, power surplus came to be the distinguishing trend. Nuclear nations came to acquire what some call an "overkill capacity," that is, the capacity to destroy the entire world several times over.[79] Once the nuclear age began, no coalition of non-nuclear powers could be formed against any single nuclear power. Even a nuclear power found it difficult to force a balance of power against a nuclear power through threat of war, since such a step could have led to its own destruction. The US and USSR came to have an extreme level of overkill capacity, meaning they were theoretically capable of achieving their interests anywhere in the world in complete disregard of the

[77] Gro Nystuen and Kjolv Egeland, "A ‘Legal Gap’? Nuclear Weapons Under International Law," (Arms Control Association, March 2016). https://www.armscontrol.org/ACT/2016_03/Features/A-Legal-Gap-Nuclear-Weapons-Under-International-Law.

[78] Nystuen and Egeland, "A ‘Legal Gap’? Nuclear Weapons Under International Law."

[79] Nystuen and Egeland, "A ‘Legal Gap’? Nuclear Weapons Under International Law."

opinion and wishes of other states. Both began flexing their newfound total power by attempting intervention as a means of imposing their wishes on small nations.

The smaller non-nuclear nations quickly came to live in a state of defenselessness, finding themselves powerless in securing their own interests, not only against a nuclear power, but against any power.[80] If they pursued an interest in a manner that a nuclear power simply disproved of, their country could be placed in danger of annihilation. With such a power surplus, it was difficult to protect their people from a nuclear power, and they had no means to prevent nuclear blackmail, which nuclear nations could impose at any time.

The feeling of defenselessness that consumed international relations eventually transformed into what some have called the "balance of terror," where nations fear one another's capabilities to such an extent that they have become anxious to avoid war and hesitant to pursue any national interest. "The fear of total destruction has acted as a blessing in disguise, in so far as it checked the states from thinking in terms of war."[81] The balance of terror has created an unusual situation in international politics and indirectly helped preserve peace. While the nuclear age provided a power surplus to the nuclear nations, it has made the actual exercising of power very difficult. Since the balance of terror prevents the use of their nuclear weapons, nuclear powers engaged in several unsuccessful conventional proxy wars during the Cold War to indirectly fight each other and maintain the balance. The US was unable to use nuclear weapons in Vietnam and was forced to withdraw from it. Similarly, the USSR was forced to pull their punches against their enemies and failed to successfully control Afghanistan. The rise of nuclear weapons also confused politicians and diplomats.

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[80] A Dinesh, "Impact of Nuclear Weapons on International Relations." http://www.yourarticlelibrary.com/international-politics/impact-of-nuclear-weapons-on-international-relations/48526.

[81] Dinesh, "Impact of Nuclear Weapons on International Relations."

“They possessed weapons of unimaginable destruction that could eliminate an enemy in seconds but remained unsure of the legality and public opinion toward using them.”[82]

The final impact that nuclear weapons have had and continue to have on international relations is in the realm of international law. The basic premise of nuclear weapons subverts some of the fundamental tenants of international law and, at times, entirely defeats the purpose of having the laws. Nuclear weapons fundamentally changed the character of war from simple war to total war, thereby eliminating the historical difference between military personnel and civilians. In the new "modern" war, every person is treated as a combatant since nuclear weapons can't make the distinction that a human can.[83] This change in warfare evolved into a situation in which no state could hope to use or even rely on the traditional laws of war.

Advocates for humanitarian law often point to the "1977 Additional Protocol I to the 1949 Geneva Conventions" when discussing the relationship between nuclear weapons and international law. The Protocol focuses heavily on the proper method for conducting hostilities and outlines five basic rules that describe proper warfighting. The first, and most important rule in the Protocol is distinction. According to distinction, members of a conflict may not “employ a method or means of combat the effects of which cannot be limited as required by this Protocol; and consequently, in each such case, are of a nature to strike military objectives and civilians or civilian objects without distinction.”[84] Essentially, the rule states that, when conducting war, nations are to only focus their efforts on military targets and personnel, not civilians. For example, the WWII fire bombings of Dresden would

[82] Dinesh, "Impact of Nuclear Weapons on International Relations."

[83] "Protocol Additional to the Geneva Conventions of 12 August 1949," ed. International Red Cross (8 June 1977). https://ihl-databases.icrc.org/ihl/INTRO/470.

[84] "Protocol Additional to the Geneva Conventions of 12 August 1949."

not be permissible under this provision. Similarly, the basic definition of a nuclear weapon is in direct contrast to this rule, as its goal is to destroy absolutely anything in its path.

After the atrocities of both World Wars, a variety of weapons were explicitly prohibited from use in conflicts. Many of the weapons violate several of the five Protocol rules, but all were banned specifically because of their violation of the rule of distinction. This is the case with biological weapons and chemical weapons, as well as anti-personnel landmines and cluster munitions.[85] Nuclear weapons, however, were not ever formally described as violators of the rule of distinction, a fact that has garnered much criticism from non-nuclear states and demonstrates obvious favoritism toward the nuclear states that laid down the post-war international rules and created their exclusive nuclear club.

In addition to distinction, the four remaining rules relate to items such as the unlawful targeting of non-military buildings, precautions that minimize “incidental loss of civilian life," conducting warfare which causes "superfluous injury and unnecessary suffering," and prohibition of warfare that causes "widespread, long-term, and severe damage to the environment."[86] Formal, diplomatic committees have constantly debated the legality of nuclear weapons within the context of these rules, and the general consensus is that nuclear weapons are clearly illegal per international law. However, no gathering of non-nuclear powers, no matter how large (120 currently) nor how much international power they possess, can force nuclear powers to give up their weapons, thus far. Nuclear weapons' most lasting role in international relations is to nullify the credibility of international law, giving modern states the ability to pick-and-choose international laws they want to follow, and disregarding those they disfavor.

[85] "Protocol Additional to the Geneva Conventions of 12 August 1949."

[86] "Protocol Additional to the Geneva Conventions of 12 August 1949."

**Energy, Economic, and Environmental Security**

Energy security, "the uninterrupted availability of energy sources at an affordable price,"[87] first earned its place as a fundamental dimension of national security in the 1970s. "When the price of oil on world markets increased dramatically in 1973, countries which were major energy importers reviewed their energy policies and took steps to reduce their vulnerability to political and economic uncertainties."[88] With populations rapidly expanding and technology relying ever more on a reliable, unbroken power source, nations began acknowledging that energy was becoming as important as powerful militaries and robust economies. As the oil crisis showed, "there are significant geopolitical, economic and availability implications of a country relying on energy imports. Today, much of the internationally-traded oil and gas comes from relatively few sources, and political instability there or in countries traversed by pipelines is a constant risk to supplies and hence a major economic vulnerability."[89] For some nations, the most obvious solution to this problem was to invest more heavily in the extraction of fossil fuels. However, the problem with fossil fuels is: they only occur in certain regions of the world, they are clearly finite, and they pose a hazard to a nation's environmental security. Therefore, nuclear power is the most viable solution for providing a nation with carbon-free, base load power.

"It is impossible to imagine sustainable international development without an increase in the role of nuclear power in global energy production. Nuclear power has the potential to limit greenhouse gas production, to conserve fossil fuel, and to increase nations' energy

[87] "Energy Security," (International Energy Agency, Feb 2018). https://www.iea.org/topics/energysecurity/.

[88] "Energy Security," (World Nuclear Association, April 2014). http://www.world-nuclear.org/information-library/economic-aspects/energy-security.aspx.

[89] "Energy Security."

independence. Without the continued improvement of nuclear power, achieving energy security will be much more difficult."[90] Nations like France have already converted much of their energy production to nuclear power, but many world powers are still relying on fossil fuels to power their lives while wrestling with the implications of a conversion to "green energy." Green energy produced from solar and wind has seen a micro-innovation age as nations move toward carbon-free energy producers. However, the problem presented by solar and wind is their role as a non-base load power source,[91] Due to the weather-based nature of solar and wind power generation, they cannot exclusively provide power to the grid without enormous batteries and long-range power lines. The basic notion of base load power is a topic of debate among green energy strategists, but the size and varying climates of the US makes a non-base load power system difficult to overcome

A national security dimension that closely relates to energy security is economic security. Economic security is the "increasing dependency on the flow of goods and services, people and capital, and information and technology across nation's borders, safeguarding the systems that make this flow possible from exploitation by adversaries, including terrorists and criminals."[92] As the role of modern technology in society continues to grow, economic and energy security have become increasingly intertwined. For a nation to have robust energy security, it must rely on a strong and secure economy to provide the constant resources for cost-effective, highly available power. In the same way, a strong economy simply cannot

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[90] Laura S. H. Holgate, "Linking Energy Security and Nuclear Security," (International Conference "G8 Global Security Agenda: Challenges and Interests Towards the St. Petersburg Summit" Nuclear Threat Initiative, April 2006). http://www.nti.org/analysis/speeches/linking-energy-security-and-nuclear-security-laura-holgate/.

[91] Mark Diesendorf, "Do We Need Base-Load Power Stations?," (EnergyScience Coalition, December 2015). http://energyscience.org.au/BP16%20BaseLoad.pdf.

[92] "Economic Security Overview," (Department of Homeland Security, July 2015). https://www.dhs.gov/topic/economic-security-overview.

exist in the 21st century without stable and secure energy that is the lifeblood of the modern flow of goods and services internationally.

The newest dimension of national security that continues to grow in prominence is environmental security. “The security of ecosystems has attracted greater attention as the impact of ecological damage by humans has grown. The degradation of ecosystems, including topsoil erosion, deforestation, biodiversity loss, and climate change, affect economic security and can precipitate mass migration, leading to increased pressure on resources elsewhere.”[93] The short-term solution that addresses part of the ongoing ecological degradation is clearly green energy. Simply moving away from the burning of fossil fuels to a carbon-free power source would make a huge impact on the overall health of the Earth. Companies like Tesla Motors are trying to decrease the burning of fossil fuels by building cars that operate on electricity stored in on-board batteries. However, unless a Tesla owner has solar or wind connected to their place of residence, Tesla vehicles rely almost exclusively on electricity produced from the burning of fossil fuels, as 76% of the US electrical grid comes from fossil fuels.[94]

[93] Elizabeth Chalecki, "Environmental Security: A Case Study of Climate Change," (Pacific Institute for Studies in Development, Environment, and Security, 2001). https://www.pacinst.org/reports/environment_and_security/env_security_and_climate_change.pdf.

[94] Dianne Dunn, "Monthly Energy Review April 2018," (U.S. Energy Information Administration Office of Energy Statistics, Ap ril 2018). https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf.

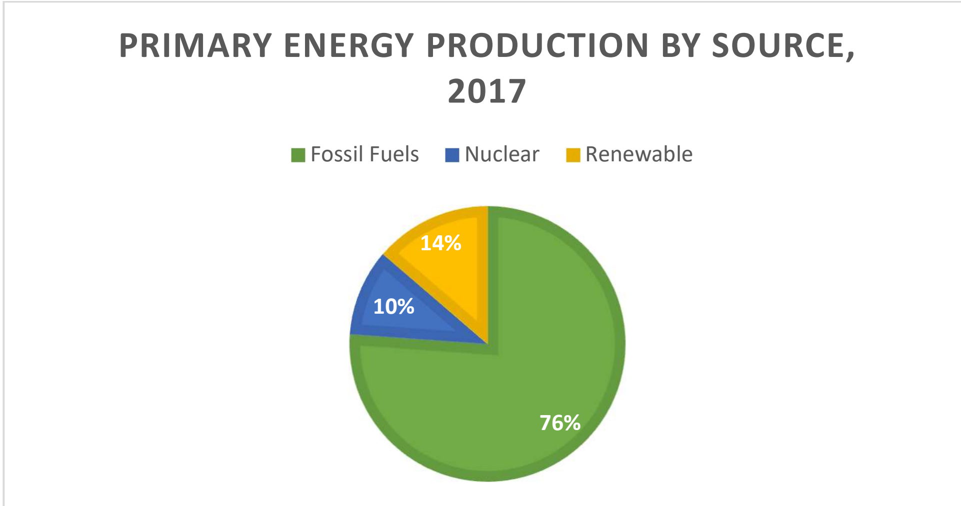


*Figure 7 Primary Energy Production by Source, 2017*[95]

Energy, economic, and environmental requirements will only increase in their reliance on nuclear power. In order to support growing energy and economic demands while safeguarding the environment from fossil fuels, nuclear power is a vital necessity for guaranteeing a nation's national security. Both the public and private sector have acknowledged the need for a move away from fossil fuels to green energy, but in order to do this in the coming decades, solar/wind will have become the new norm with nuclear power as the overall backbone of the electrical grid.

[95] Dunn, "Monthly Energy Review April 2018."

# CHAPTER V:

## FROM CAUTION TO FEAR TO COMPLACENCY

The nuclear innovation age brought the power surplus to unstable levels, as superpowers were now able to destroy their enemies several times over. Governments' focus on nuclear innovation meant that technology continued advancing at a rapid pace, always with the goal of outclassing a rival power. The peak in US nuclear innovation came in the late 1960s, culminating in the largest-ever warhead stockpile, employing then-advanced technology that is still widely used in 2018. In just 10 years of increasing production at an extreme rate of growth, the US went from approximately 500 nuclear warheads to over 31,000.[96]


*Figure 8 Quantity of US Nuclear Stockpile (1945-2009)* [97]

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[96] Hans Kristensen, "United States Discloses Size of Nuclear Weapons Stockpile," (Federation of American Scientists, 2010). https://fas.org/blogs/security/2010/05/stockpilenumber/.

[97] Kristensen, "United States Discloses Size of Nuclear Weapons Stockpile."

Additionally, in 1966, the US began improvements to the third-stage of the Minuteman ICBM, building the Minuteman III. This upgrade improved distance and accuracy, however much of the justification for the upgrade was for newly developed technology called, "multiple independently-targetable re-entry vehicles," or MIRVs. Upon re-entry, the MIRVs would separate from the top of the missile and direct toward separate targets, decreasing the number of missiles necessary to fire. Specifically, MIRVs would be used to reduce collateral damage "by matching the yield to the target."[98] Since MIRVs could accurately hit point targets, such as a missile base or silo, only a small nuclear warhead would be necessary to achieve the anticipated destruction. Collateral damage, therefore, would be significantly reduced from the destruction caused by larger warheads.

The 1970s were a period of stagnation in nuclear innovation, with decreases in quantities of warheads, as well as lower production of new missile systems. While the innovation slowed, the US government's support for the nuclear community remained high as the Cold War continued. However, the first signs that the nuclear innovation age's end was in sight appeared in 1979. (The next several pages will attempt to simplify extremely complex nuclear reactor functions down to paragraphs with some amplifying notes, but in summary, nuclear reactors are dangerous when poorly designed or poorly attended it.)

Around 4:00am on March 28, 1979, a mechanical failure in the main feedwater pumps for the secondary system's steam generators caused an automatic shutdown of the turbine-generator and reactor in Unit 2 of the Three Mile Island nuclear power plant in Middletown, Pennsylvania.[99] The rapid shutdown led to a quick increase in pressure in the

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[98] David Buchonnet, "MIRV: A Brief History of Minuteman and Multiple Reentry Vehicles," (Lawrence Livermore Laboratory, February 1976). https://nsarchive2.gwu.edu/nsa/NC/mirv/mirv.html.

[99]James A. Mahaffey, *Atomic Accidents : A History of Nuclear Meltdowns and Disasters : From the Ozark Mountains to Fukushima*, First Pegasus Books edition. ed., (New York: Pegasus Books, 2014). Most nuclear

primary system, and plant technicians responded by opening the pressure relief valve to correct the issue. However, the pressure relief valve became stuck open, while the main control panel showed it had re-closed, not indicating that cooling water was now pouring out the relief valve. The stuck valve then caused the system to lose so much pressure that the coolant levels were lowered, and the reactor core began overheating. The heat from the core melted the Zirconium plating on the Uranium fuel and the incident was officially declared a "severe core meltdown," the 2nd most severe accident rating on the nuclear regulatory commission's (NRC), meltdown scale.[100]

Fortunately, the reactor vessel remained intact, which meant the external effects were low, and there was no detectable health effect on the workers or local populace.[101] However, the entire nuclear community, regardless of their affiliation, was now under intense scrutiny. The mechanical and safety failures that allowed the meltdown to occur brought public skepticism upon the nuclear industry, and people were reminded of the dangers that radiation and nuclear power posed if not handled properly. Because of the increase in public fear and distrust, the NRC's regulations and oversight became broader, stricter and more robust, with the operation and constructing of nuclear plants becoming highly politicized and bureaucratic. Large-scale changes, because of the meltdown, led to both increased reactor

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reactors have a system that relies on two separated water feeds to produce steam, which turns a turbine and produces energy. The primary feed is a close loop that contains the irradiated water from the core which converts the heat from the nuclear reaction to steam, and the secondary feed contains unradiated water that is responsible for spinning the turbine and cooling the water in the primary feed.

[100] David Biello, "Nuclear Mishap or Meltdown?: It's All a Matter of Degree," (Scientific American

July 2007). https://www.scientificamerican.com/article/nuclear-mishap-or-meltdown-a-matter-of-degree/.

[101] The famous meltdown at Fukishima-Daichi in 2011had a very similar meltdown sequence, but under very different circumstances. The difference in severity there was that the build-up of hydrogen in the containment vessel exploded, rupturing the containment vessel and releasing radiation. The hydrogen build-up at Three Mile Island was contained and dissipated.

safety and the end of much of the government and public's support of the nuclear community.

The next nail in the coffin of the nuclear innovation age was a more global event, one that horrified the international community and helped lead to the collapse of a superpower. In the early morning of April 26, 1986, undertrained workers conducted a poorly planned test in Unit 2 of the Chernobyl power plant in modern-day Ukraine. Before a routine shutdown was scheduled to occur late on the 26th, the workers at the plant decided to conduct a test to determine the reactor's behavior during an unscheduled power loss.[102] The workers had to make several changes to the reactor configuration before beginning, famously disabling the automatic shutdown feature on the system in order to run the system at lower power.

The test first required that the reactor run at very low power levels before the power was actually shut off, an unadvisable requirement due to previously identified concerns with the design, but the crew decided to proceed with the test anyway.[103] Initially, the reactor, which was only running at 50% power (approximately 1500 MW), began plummeting in power once the test began, dropping down to 30 MW and making the reactor highly unstable. The shift leader called off the test due to safety concerns, but the deputy chief engineer overrode him, and approximately 30 minutes later, managed to stabilize the reactor at 200 MW.[104]

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[102] Mahaffey, *Atomic Accidents : A History of Nuclear Meltdowns and Disasters : From the Ozark Mountains to Fukushima*.They wanted to determine if the slowing turbines had enough momentum to keep powering the water pumps for the 30-45 seconds it took to fully power on the backup generators.

[103]Mahaffey, *Atomic Accidents : A History of Nuclear Meltdowns and Disasters : From the Ozark Mountains to Fukushima*. A previous test in 1983 run had very low power levels had almost become derailed, but the technicians were able to resolve the problem.

[104] Mahaffey, *Atomic Accidents : A History of Nuclear Meltdowns and Disasters : From the Ozark Mountains to Fukushima*.

As the workers shut down the power, and the turbine for the water pumps began slowing while they waited for the backup generators to start, the water pumps began pumping with irregular power, creating bubbles in the system. The presence of the bubbles meant there was less overall coolant in the system to absorb neutrons, and the workers suddenly noticed a spike in power. Until this point, the computer had been compensating for the bubbles, adjusting appropriately. However, possibly scared by the sudden spike in power, a worker initiated the emergency shutdown, causing the system to automatically insert every control rod simultaneously.[105] At this point, the blame for the accident is shifted from the operators to the faulty reactor design. Among its many design flaws, the largest flaw with the Chernobyl reactor (an RBMK) was that the control rods had graphite moderators attached to their tip to help the reactor increase power as it was starting up and when the rods were being withdrawn. With the rods now being inserted in an emergency situation, there was another power spike due to the introduction of the graphite into the system. Before the control rods could be fully inserted, thereby shutting down the reactor, the core began overheating, causing fuel rods to break apart and block the control rod tunnel, leaving them only one-third inserted, and their graphite tips exposed, raising the power output in the reactor to 5300 MW.

The further power increase led to temperatures and pressures high enough to rupture the fuel channels and introduce the overheated fuel to the water coolant, which immediately flashed to steam. The flashing of the water to steam rocketed the power output in the reactor from 5300 MW to 33,000 MW, ten times the normal operational output.[106] This rapid increase caused a steam explosion that tore off the 1000-ton reactor lid and sent it through the

[105] Control rods are long sticks made of various metals and mixtures that are designed to absorb neutrons.

[106] Mahaffey, *Atomic Accidents : A History of Nuclear Meltdowns and Disasters : From the Ozark Mountains to Fukushima*.

roof of the building. This explosion also further ruptured the fuel channels as well as severed the coolant lines, causing the remaining coolant to flash to steam.

This explanation of the first explosion has been the scientifically accepted explanation for the Chernobyl meltdown for the last 32 years. However, in November 2017, a Swedish report was published that speculates that the first explosion may have actually been nuclear. The report presented three pieces of evidence which gives credibility to the claim that the explosion was nuclear: isotopes found further north than a steam explosion could have propelled them, temperatures hot enough to melt the two-meter thick bottom reactor plate, and a reported “bright blue flash” observed at the time of the explosion, characteristic of nuclear reactions.[107] While the nature of the explosion does not change the fact that it occurred, it does place even more fear and skepticism on the nuclear industry and its ability to conduct operations safely.

Approximately three seconds after the first explosion (whether it be nuclear or steam), a second, larger explosion occurred, destroying the remainder of the reactor core and ending the nuclear chain reaction. This explosion caused numerous large-scale fires to break out throughout the building. The fires, in conjunction with the now-open roof, were a major cause of the widespread radiation that occurred, with the updraft from the powerful fires further propelling the radiation upward into the atmosphere.

The accident caused the "largest uncontrolled radioactive release into the environment ever recorded for any civilian operation," and large quantities of radioactive substances were released into the air for about 10 days.[108] The Chernobyl accident's severe

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[107] Lars-Erik De Geer, Christer Persson, and Henning Rodhe, "A Nuclear Jet at Chernobyl Around 21:23:45 UTC on April 25, 1986," *Nuclear Technology* (2017), http://dx.doi.org/10.1080/00295450.2017.1384269.

[108] Naim Hamdia Afgan, *Resilience of Sustainable Power Plant Systems in Catastrophe Events*, (Hauppauge, New York: Nova Science Publishers, Inc., 2014).

radiation effects killed 29 of the site's 600 workers in the first four months after the event. Another 106 workers received high enough doses to cause acute radiation sickness, two technicians died directly from the explosion and the falling debris in the control room, and another 200,000 cleanup workers in 1986 and 1987 received toxic doses of between 1 and 100 rem.[109]

The events at Chernobyl caused a shift, from fear toward nuclear power to one of horror and hatred, with some European nations outright banning any nuclear power production in their nation in the aftermath. The international community witnessed another example of the dangers of nuclear power if not properly controlled, and it terrified them. This disaster, however, was not quite the end of the nuclear innovation age, but some think that it ultimately led to it.

"The Chernobyl explosion was perhaps the real cause of the collapse of the Soviet Union." While this phrase may sound absurd and contrary to common history, it was uttered by the man that ended up dismantling the Soviet Union, Mikhail Gorbachev.[110] According to Gorbachev, the Chernobyl explosion was a “turning point” that “opened the possibility of much greater freedom of expression, to the point that the system as we knew it could no longer continue.” Chernobyl, represented a transition in the relationship between the Soviet public and the government. Before the explosion, most Soviets were not yet discontented dissidents; “they believed in the Soviet system, forgave its flaws, and hoped for a better

[109]Afgan, *Resilience of Sustainable Power Plant Systems in Catastrophe Events*. The average annual radiation dose for a US citizen is about 0.6 rem.

[110] Mark Joseph Stern, "The Nuclear Theory of the Fall of the USSR.," (Slate, January 2013). http://www.slate.com/articles/health_and_science/nuclear_power/2013/01/chernobyl_and_the_fall_of_the_soviet_union_gorbachev_s_glasnost_allowed.html.

future within its confines."[111] But after Chernobyl, the system seemed scary, unredeemable, and entirely unsafe. For them, it represented everything the Soviet Union was becoming, and their hope for Soviet prosperity went up in flames with Chernobyl.

Once the Warsaw Pact dissolved and the USSR disbanded, the nuclear innovation age was officially over, and the US was once again the sole superpower. Following the collapse of the USSR, the role of nuclear weapons in national security decreased immediately, due to an overwhelming lack of support for innovation. The US then turned to security in international relations through more traditional means, focusing on economy and trade deals, while national defense became focused on terrorism, with the nation's common defense under attack from an untraditional enemy.

The first indication that nuclear innovation in the US ended was the dramatic drop in the Department of Defense's expenditure on nuclear weapons. Spending was at the highest during the peak of US innovation, when the Minuteman III and MIRVs were coming online in the 1960s. After dipping back down, spending spiked again in the early 1980s as tension with the USSR was approaching a high. After the Chernobyl explosion, there is a very clear, rapid downward trend in spending, from 11% to around 3% in only a decade, signaling the fall.

Next, global nuclear warhead inventory was dramatically reduced, which had the most immediate effect in ending the nuclear innovation age. As the USSR began its decline as a direct result of Chernobyl, the global stockpile was impacted by this transition.

[111] Stern, "The Nuclear Theory of the Fall of the USSR.."

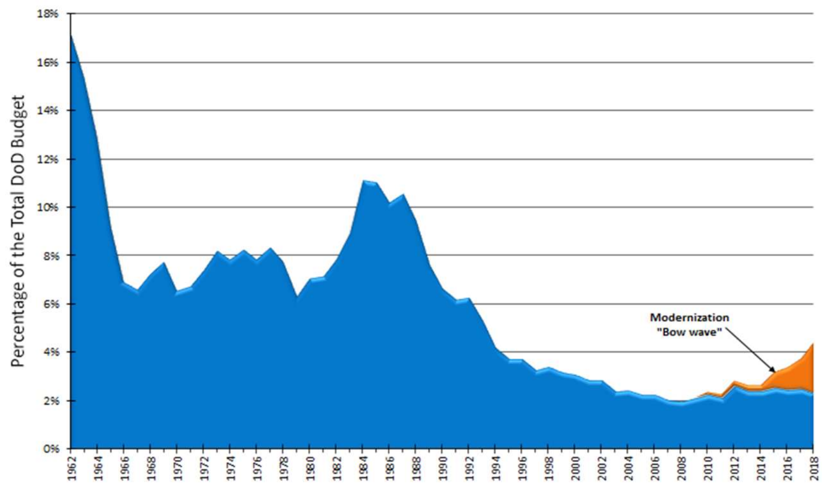


*Figure 9 US DoD Nuclear Weapons Expenditures*[112]

Furthermore, arms reduction treaties like SALT (Strategic Arms Limitation Talks) I and II began to break down the rate of innovation, and the superpowers were now contractually obligated to slow innovation by limiting the quantity and capabilities of their nuclear technologies. Nations began addressing the absurdity of the stockpile sizes and capabilities, and while it was put in place as a measure to de-escalate, it greatly weakened the US nuclear infrastructure and community.

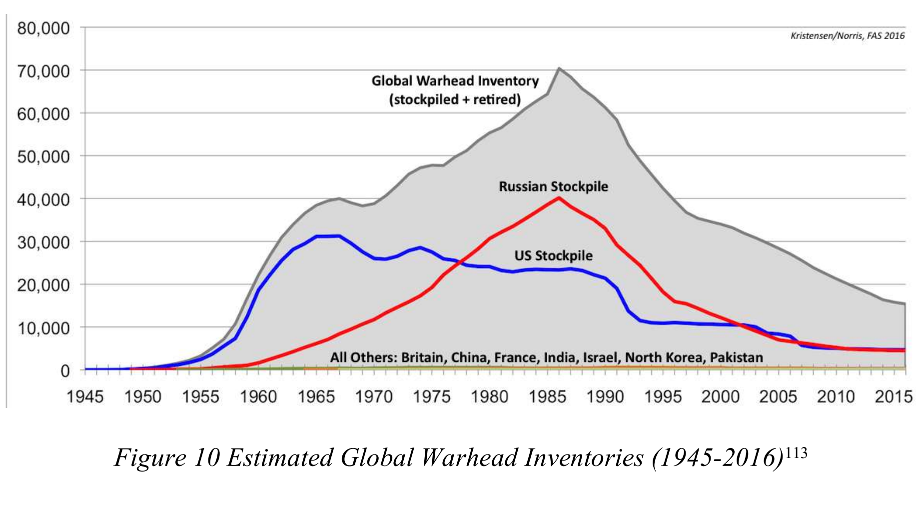


*Figure 10 Estimated Global Warhead Inventories (1945-2016)*[113]

[112] "The 2015 Long-Term Budget Outlook," (Congressional Budget Office, June 2015). https://www.cbo.gov/sites/default/files/114th-congress-2015-2016/reports/50250-longtermbudgetoutlook-4.pdf.

Finally, the category most negatively affected by the end of government-sponsored nuclear innovation was nuclear reactor construction. The global number of "completed and ongoing projects" went from around 200 in 1980, to 60 in 1990, to 30 in 2000, and to 1 in 2010[114]. The industry has begun to make a small recovery with the start of the Asian innovation age that began around 2010, but the combination of fear and complacency has taken a heavy toll on the nuclear reactor industry.

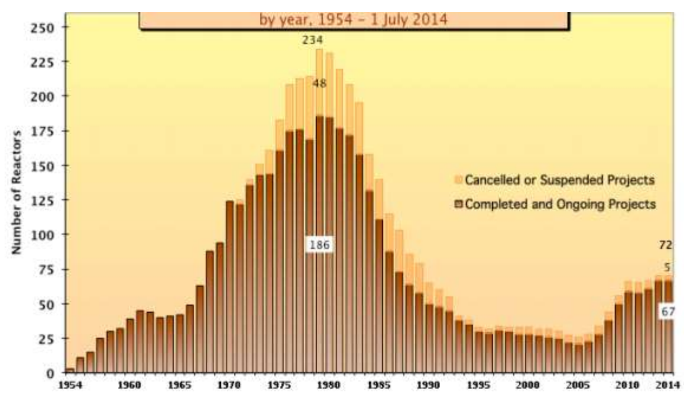


*Figure 11 Reactors "Under Construction"*[115]

**The Wrath of Khan**

With the Cold War over and global focus temporarily shifted away from nuclear energy, a power vacuum of sorts began. A cabal of rogue states became interested in acquiring nuclear weapons programs as a means of national defense as well as legitimizing their existence on the world stage. This second nuclear innovation age, the "rogue innovation age," began as a result to India's successful nuclear weapon test in 1974. Pakistan, India's

[113] Kristensen, "United States Discloses Size of Nuclear Weapons Stockpile."

[114] "Plans For New Reactors Worldwide," (World Nuclear Association, January 2018). http://www.world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx.

[115] Mycle Schneider, "The World Nuclear Industry Status Report 2013." https://www.worldnuclearreport.org/World-Nuclear-Report-2013.html.

bitter rival and neighbor, feared that an Indian nuclear weapon would mean their destruction, but found their security through a Pakistani metallurgical engineer working in The Netherlands making nuclear centrifuges, who would become the father of the rogue innovation age.[116] Abdul Qadeer (A.Q.) Khan recognized the danger that his country faced and stole classified schematics for highly advanced centrifuges from his employer, URENCO, returning to Pakistan with them, ready to build a bomb. In July 1976, Khan founded the Engineering Research Laboratories to set up and operate a centrifuge plant using the URENCO designs.[117] Raw Uranium was to be mined locally in Pakistan, converted to gas (Uranium hexafluoride), and sent to Khan's centrifuges. Khan, recognizing the size of the operation, purchased land, hired over 10,000 employees, and personally laid down the Pakistani national plan for procuring a nuclear weapon.

Famously, Khan also leveraged European contacts he had made both while in Academia and working for URENCO. He set up a continent-wide network for purchasing highly technical components that he could not easily manufacture or buy in Pakistan.[118] In the late 1970s, the export laws in Europe were much looser and more ambiguous than those in the US. For example, an unauthorized entity was not permitted by law to purchase an assembled centrifuge, but anyone could easily purchase the required parts and assemble it themselves.[119]

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[116] Douglas Frantz and Catherine Collins, *The nuclear jihadist : the true story of the man who sold the world's most dangerous secrets-- and how we could have stopped him*, 1st ed., (New York: Twelve, 2007).
[117] Douglas Frantz and Catherine Collins, *The Nuclear Jihadist*, 1st ed., (New York: Twelve, 2007).

[118] Frantz and Collins, *The Nuclear Jihadist*.

[119] William Langewiesche, *The Atomic Bazaar : The Rise of the Nuclear Poor*, 1st ed., (New York: Farrar, Straus and Giroux, 2007).

"Complete centrifuge units were listed, and could only be exported to IAEA safeguarded facilities, which the Pakistani enrichment plant was not. High-vacuum valves were not listed, even if expressly intended for a centrifuge enrichment unit. The valves might be necessary to the centrifuge, but, in the logic of the list, they were not "sensitive."[120] Khan began placing large orders of the required parts from specific companies around Europe. Many of the governments, where these companies were located, began protesting the selling of nuclear-related components to the Pakistani, but law prevented them from actually doing anything. By the time Chernobyl melted down, Khan had a fully operation nuclear supply chain, capable of producing complete nuclear weapons.

Khan then began the process of exporting his technologies and designs to other rogue nations looking to develop nuclear programs. Iran, North Korea, and Libya were all beneficiaries of Khan's nuclear network, developing nuclear networks of their own to some degree, with North Korea being the most successful thus far.[121] During the rogue innovation age, the US attempted to gain international support through several avenues, but proved mostly unsuccessful. States, many of who were close allies, were hesitant to help the US due to the obvious and unfair double standard that was perceived, as the US demanded nations give up their nuclear programs while maintaining a 30,000-warhead stockpile.

Just like the first age, this interim nuclear innovation age had a major effect on national security. The international community now had to face the possibility of nuclear weapons falling into the hands of unstable, irrational actors, who may randomly launch an attack or even sell nuclear weapons to non-government actors, such as radical Islamic

[120] Langewiesche, *The Atomic Bazaar : The Rise of the Nuclear Poor*.

[121] Catherine Collins and Douglas Frantz, *Fallout : the True Story of the CIA's Secret War on Nuclear Trafficking*, 1st Free Press hardcover ed., (New York: Free Press, 2011).

terrorist groups.[122] Since MAD didn't apply to new actors pursuing nuclear weapons, the US had to seek alternate means of national defense. The government sought military options though avenues like missile defense by withdrawing from the 1972 ABM treaty in 2002.[123] They also sought national defense through economic sanctions on the rouge states, but the sanctions only emboldening nations like Pakistan and North Korea.

In international relations, the US government was shocked to find that their nuclear blackmail was becoming less effective against rogue states acquiring nuclear weapons. It could no longer order around the smaller, weak nations that were now developing nuclear capabilities of their own. The new multipolar world continued growing more multipolar as nations tested nuclear weapons and tested the boundaries of international acceptance.[124]

As Pakistan was helping fill the power vacuum of innovation, the US infrastructure and supply chain was slowly sliding into a state of disrepair. Much of the infrastructure that supports the US nuclear weapons programs, including labs, production facilities, and weapons storage complexes have recently passed their sixty-year anniversary. Neither the general public nor the government in the last several decades has demonstrated any interest in the task of maintaining the vast, complex nuclear infrastructure. With prolonged wars in the Middle East, and low oil and natural gas prices, the US has been able to ignore the crumbling nuclear infrastructure. The disaster at Fukishima in 2011, and the occasional

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[122] Jeffrey Richelson, "Nuclear Terrorism: How Big a Threat? ," (National Security Archive Electronic Briefing Book No. 388, Sept 2012). https://nsarchive2.gwu.edu/nukevault/ebb388/.

[123] Wade Boese, "U.S. Withdraws from ABM Treaty; Global Response Muted," (Arms Control Association, 2002). https://www.armscontrol.org/act/2002_07-08/abmjul_aug02.

[124] Noah Rothman, "The Age of Nuclear Multipolarity," (Commentary Magazine, Aug 2017). https://www.commentarymagazine.com/foreign-policy/nuclear-multipolarity-japan-north-korea/.

nuclear tests by North Korea serves to remind the public of the existence of nuclear power, but the interest ends there.

The complacency of US leadership has translated into a “$3.7 billion backlog in deferred essential repairs to the US nuclear weapons infrastructure.”[125] Many of the facilities “date to the Eisenhower Administration and, in some cases, the Manhattan Project era,” Frank Klotz, the administrator of the NNSA recently stated, “I can think of no greater threat to the nuclear security enterprise than the state of NNSA’s infrastructure.”[126] In the 21st century, the most significant threat to US national security comes from apathy toward crumbling infrastructure and an unwillingness to repair it. Because of it, the capability to produce nuclear weapons has been substantially degraded, as well as the capability to efficiently produce baseload nuclear power.

Aside from infrastructure, the complacency has also affected the nation’s aging weapon stockpile. It has been 25 years since the US tested a nuclear weapon.[127] The nuclear test ban was a beneficial treaty for the environment and international stability, but the nuclear programs of the signatories have been significantly impacted by it. The absence of nuclear innovation in the US means that much of the offensive nuclear capability is frozen in time, stuck in the 1970s and 1980s. Strategists and politicians have suggested a complete redesign of the US nuclear warheads over the decades, however the foreseeable dilemma with this

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[125] Robbie Gramer, "America’s Nuclear Weapons Infrastructure Is Crumbling," (Foreign Policy, March 2017). http://foreignpolicy.com/2017/03/17/americas-nuclear-weapons-infrastructure-is-crumbling-national-nuclear-security-administration-deterrence-aging-congressional-oversight/.

[126] Gramer, "America’s Nuclear Weapons Infrastructure Is Crumbling."

[127] "No Going Back: 20 Years Since the Last U.S. Nuclear Test," (Arms Control Association, Sept 2012). https://www.armscontrol.org/issuebriefs/No-Going-Back-20-Years-Since-the-Last-US-Nuclear-Test%20.

proposal is an inability to test these warheads.[128] Under current standards, all nuclear testing the US conducts is on supercomputers, through modeling. The Minuteman III missiles have been updated and maintained, but they still contain components from the 1960s, when they were first built. With such old technology, many have asked whether a nuclear-loaded Minuteman III would truly work as intended if fired on an enemy during war. Complacency and apathy toward a vital component of the nation's safety have placed the state on a path for disastrous consequences.

With the drastic decrease in budget, the government can no longer afford to divvy up its nuclear resources; it must pick them carefully. About 75% of the nuclear budget is for operations and maintenance, rather than development, modernization and enhancement.[129] A report from the Government Accountability Office found that the Pentagon's Strategic Automated Command and Control System, which "coordinates the operational functions of the US' nuclear forces, such as intercontinental ballistic missiles, and nuclear bombers – runs on an IBM Series/1 Computer, first introduced in 1976."[130] Furthermore, the complacency and lack of innovation has led to "low morale, understaffing and equipment shortages" throughout the nuclear enterprise. In 2014, reports brought to light that "three nuclear bases had only one special wrench that's needed to put nuclear warheads on missiles, and they had to share the wrench between bases."

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[128] Sergei Ryabkov and Lassina Zerbo, "The Nuclear Test Ban: Time to Finish What We Started," (The Diplomat, April 2017). https://thediplomat.com/2017/04/the-nuclear-test-ban-time-to-finish-what-we-started/.

[129] *Federal Agencies Need to Address Aging Legacy Systems*, (May 2016).

[130] Merrit Kennedy, "Report: U.S. Nuclear System Relies On Outdated Technology Such As Floppy Disks," (NPR, May 2016). https://www.npr.org/sections/thetwo-way/2016/05/26/479588478/report-u-s-nuclear-system-relies-on-outdated-technology-such-as-floppy-disks.

The degradation of US nuclear technology reached such a critical point that Stephen Wilson, the Vice Chief of Staff of the Air Force, testified in August 2017 before Congress that, "the stark choice the US faces today is not between modernizing these systems or continued life extension programs, the choice is between modernization or losing these foundational capabilities starting in as early as the late-2020s."[131] In summary, General Wilson is saying that the US can either redesign the entire nuclear triad, or lose it, and there is no middle ground. The Cold War silos in rural Wyoming and North Dakota have become a point of shame for US policymakers and strategists that are literally watching US power decay in the form of 1970s IBM computers and floppy disks.

[131] Russ Read, "Top Generals Warn The US Nuclear Arsenal Is Dangerously Outdated," (The Daily Caller News Foundation, March 2017). http://dailycaller.com/2017/03/08/top-generals-warn-the-us-nuclear-arsenal-is-dangerously-outdated/.

## CHAPTER VI:

## ASIAN INNOVATION

At the turn of the 21st century, two Asian powers that historically relied on traditional defense ideas, began their rise to superpower status. China and India both rely on their enormous populations to field massive armies in pursuit of their common defense, but have begun transitioning away from that strategy, realizing the necessity for nuclear innovation as a national interest. While the two have possessed nuclear programs for several decades, both are in the midst of their own nuclear innovation age, accelerating at a rapid rate. “There is a growing belief that China and India’s rising geopolitical rivalry in the Indo-Pacific region combined with their efforts to build diverse and sophisticated deterrent forces could potentially produce security dilemmas and an arms race similar to the one that enveloped the superpower rivalry during the Cold War.”[132] The nuclear competition between India and China has been described as the “epicenter of the second nuclear age,” as both countries work to improve nuclear programs that can guarantee their national security.[133] Historically, the only nuclear rivalry in the Pacific has been the India-Pakistan relationship. However, there is evidence that nuclear innovation within China and India is changing global national security.

The rivalry has been traditionally overlooked due to the presence of “louder” actors in the region drawing more attention to themselves, namely North Korea and Pakistan. The India-China “rivalry is rooted in geopolitical concerns that relate to borders, the security of

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[132] Gaurav Kampani, "China–India Nuclear Rivalry in the “Second Nuclear Age”," (Oslo, Norway Norwegian Institute for Defense Studies, March 2014). https://brage.bibsys.no/xmlui/bitstream/handle/11250/226454/1/Insight2014_3.pdf.

[133] Ashley J Tellis, "Strategic Asia 2013-14: Asia in the Second Nuclear Age," (The National Bureau of Asian Research, October 2, 2013).

the sea-lanes of communications, and military assistance to third parties, as much as in China and India's self-identification as peer competitors and regional hegemonic powers."[134] Since the inception of both the nations' nuclear programs, the consistent theme has been "catch up," with both powers devoting their resources to developing the same technology that the more advanced powers already possess. However, as they have begun devoting more assets and resources to military and civilian nuclear programs, they are on the cusp of taking the high ground in nuclear technology.

**China**

For China, their past nuclear developments and modernizations have always been geared toward the US, its Asian allies, and neighboring USSR/Russia, with India existing only as an afterthought in Chinese national security priorities.[135] While the two nations fought over a border dispute for 32 days in 1962, China remains unconcerned about Indian military power. China has dealt with India primarily by assisting Pakistan in their nuclear development efforts, and not much else. However, as the Indo-Pacific region has become more significant to geopolitics and global economy in the 21st century, China has recently begun viewing India as more of a threat than they have in the past. The three primary sources of Chinese unease and rivalry with India are: "(1) control over the Tibet Autonomous Region (TAR); (2) the security of the Sea-Lanes of Communications straddling the Indian Ocean region through which the bulk of Chinese global trade and energy supplies traverse; and (3) India's participation in US plans to potentially contain or at least check Chinese power in Asia and the western Pacific. These three points of contention have become security concerns

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[134] Tellis, "Strategic Asia 2013-14: Asia in the Second Nuclear Age."

[135] Kampani, "China–India Nuclear Rivalry in the "Second Nuclear Age"."

for China that require their attention, truly putting India in their crosshairs for the first time."[136]

With the dawn of the second nuclear age, both China and India are becoming increasingly aware of the weaknesses in their nuclear programs. India aside, China has realized that its capabilities remain incredibly vulnerable to the US and Russia. With "the growing professionalization of the PLA (People's Liberation Army – China's Department of Defense), the greater availability of funds, and the maturing of technological programs launched in the 1980s and 1990s, China has launched a broad campaign for nuclear innovation."[137] Their intention is to use nuclear innovation to bolster national defense and international security, and in turn, utilize the robust nuclear community created by that innovation to better improve and solidify their energy self-sufficiency.

To provide context, in 2008, China's nuclear arsenal was assessed as consisting of no more than 151 nuclear warheads, obsolete nuclear bombers, and a submarine fleet believed to operate without its complement of ballistic missiles.[138] Until the early 2000s, China still deployed liquid-fuel missiles and stored the warheads separately from the missile systems, making a missile launch a "prolonged and detectable process."[139] Additionally, the Chinese had a very weak early warning system that left the large Chinese mainland highly vulnerable to an attack. The underwhelming capabilities of such a major power have been largely attributed to the first and second generation of leadership in China, with Mao outlining a

[136] Kampani, "China–India Nuclear Rivalry in the "Second Nuclear Age"."

[137] Lewis and Xue 2012, 45–62

[138] Hans Kristensen, "Chinese Nuclear Arsenal Increased by 25 Percent Since 2006, Pentagon Report Indicates," (Federation of American Scientists, Mar 2008). https://fas.org/blogs/security/2008/03/chinese_nuclear_arsenal_increa/.

[139] Kristensen, "Chinese Nuclear Arsenal Increased by 25 Percent Since 2006, Pentagon Report Indicates."

"minimum" deterrence posture that gave China just enough nuclear firepower to deter an attack, while not being a legitimate "nuclear power."

The newer generations of leadership in China have seen the weaknesses of past policies and current technologies and introduced radical change. The late 1980s and 1990s saw an overhaul of nuclear doctrine and the establishment of a legitimate Chinese nuclear community that could begin the process of innovation.[140] The first step was modernizing their delivery systems, replacing the liquid-fueled missiles with solid fuel, improving missile ranges by several-fold, developing sea-based missiles, and implementing MIRV technology in their missiles. Nuclear innovation, that has taken place in the Second Artillery Corps of the Chinese military, was legitimized by transforming into People's Liberation Army Rocket Force (PLARF), solidifying China's resolve toward nuclear weapons, and placing them on the same strategic level as the Chinese Army, Navy and Air Force.[141] China's nuclear weapon innovation has gone so far as to lead the global development of hypersonic glide vehicles (HGVs), small, highly maneuverable nuclear vehicles designed to penetrate any nation's missile defense system. While missile delivery systems are not strictly a facet of "nuclear innovation," HGVs are a game-changing element in the future of nuclear deterrence.

China's official nuclear weapons policy is one of defensive "no first use" (NFU). China will "not use atomic weapons against any non-nuclear states and would only use atomic weapons to retaliate after a nuclear first strike against China."[142] NFU was originally put in place in response to what China perceived as American nuclear blackmail.

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[140] Hans Kristensen, "Chinese Nuclear Weapon," (Federation of American Scientists, November 29, 2006). https://fas.org/nuke/guide/china/nuke/index.html.

[141] Alexander Koty, "China Announces Sweeping Overhaul of Government Institutions," (China Briefing, March 14, 2018).

[142] Paul J. Bolt and Albert S. Willner, *China's nuclear future*, (Boulder, Colo.: Lynne Rienner Publishers, 2006). 147.

Additionally, by adopting a NFU, China was seen as the more rational or stable nuclear power, viewed as a "leader" to the non-aligned world, which was its' intentions when it developed the policy in 1960s. Also, due to the nation's economic and technological limitations at the time, in conjunction with a smaller arsenal, NFU just made a lot of sense.

Having a NFU policy makes China seem less much less aggressive to other countries when compared to the US and Russia. On numerous occasions, they have publicly declared that their nuclear force is simply a deterrent retaliatory force, and they would never be the first to use nuclear weapons "at any time and in any circumstance."[143] However, Chinese analysts have been calling for China to abandon the unconditional NFU in favor of conditional first strike. "Some believe that NFU reduces the credibility of China's already small nuclear forces, and that abandoning NFU may enhance China's nuclear deterrent. Abandoning NFU, they argue, is the most cost-effective way to free up scarce resources from defending China's vital strategic targets for offensive capabilities to realize China's primary strategic objectives."[144] The Chinese development of the HGV, essentially a stealth warhead designed to penetrate radars and ABM systems, hint at the possibility of an abandonment of the NFU policy, once they possess more advanced technology ideal for a first strike.

The two biggest concerns that NFU brings up regarding US interests in the Trans-Pacific region is Taiwan and the Terminal High Altitude Area Defense (THAAD) system in Korea. Some scholars have questioned the applicability of Chinese nuclear weapons against Taiwan, "as it may be interpreted strictly as a domestic issue unconstrained by NFU."[145] As

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[143] Bolt and Willner, *China's nuclear future*. 35.

[144] Nan Li, "China's Evolving Nuclear Strategy: Will China Drop "No First Use?"," (The Jamestown Foundation, 2018). https://jamestown.org/program/chinas-evolving-nuclear-strategy-will-china-drop-no-first-use/.

[145] Bolt and Willner, *China's nuclear future*. 151.

an important US partner in the region, it is critical to note that China may be willing to conduct a nuclear first strike on Taiwan without officially departing from their NFU policy. Secondly, the US development of anti-ballistic missile THAAD systems will eventually drive Chinese efforts to end NFU.[146] When the US and South Korea began working on an arrangement to install the system on the Korea peninsula to deter North Korea, Chinese President Xi Jinping said that, “the U.S. deployment of an advanced anti-missile system in South Korea gravely harms the strategic security interests of China, Russia and other countries in the region.” With the THAAD deployment in South Korea, from China's perspective, it becomes harder and harder to guarantee their ability to maintain a credible second-strike capability, making preemptive strike a more valid option, and undercutting the stability that NFU brings.

Finally, the innovation of nuclear weapons inevitably focused innovation on civilian power generation. The majority of China's electricity is produced through fossil fuels, predominantly from coal – 73% in 2015.[147] Rapid growth in energy demands due to a continuously growing population, general urbanization, and industrialization, gave rise to power shortages, and near-exclusive reliance on fossil fuels that has led to some of the worst air pollution in the world.[148] The World Bank estimates the economic loss due to pollution from fossil fuels at almost 6% of GDP, and the current leadership, under President Xi Jinping, has prioritized alternative energy sources. Wind and solar have been a point of emphasis for the new government, however, due to a poor power grid, many new projects

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[146] THAAD is a medium range ABM system designed to shoot down a warhead after it has re-entered the atmosphere.

[147] "Nuclear Power in China."

[148] Official measurements of fine particles in the air rose to a record 993 micrograms per cubic meter in Beijing in 2013, compared with World Health Organization guidelines of no higher than 25

have been put on hold or altogether cancelled. The necessity of having wind and solar in mostly unpopulated areas requires a robust power grid to transfer the power over massive areas of mainland China. However, in the coastal areas of China, where most of the population centers lie, nuclear power has been developing rapidly. China initially used mostly French nuclear technology to build its first generations of reactors, but in its push for nuclear innovation, began developing its own reactor designs, with the goal of nuclear export capabilities.[149]

Prior to 2008, the government had initially planned to increase nuclear capacity to 40 GWe by 2020, with a further 18 GWe under construction.[150] However, projections for nuclear power then increased to 70-80 GWe by 2020, 200 GWe by 2030, and 400-500 GWe by 2050. In April 2015 the Chinese Nuclear Energy Administration (CNEA) declared that by 2030, actual installed nuclear capacity would be 160 GWe, providing 10% of all Chinese electricity, and by 2050, an installed nuclear capacity 240 GWe would provide 15% of electricity, decreasing coal to 50.5%.[151]

In December 2011, CNEA said that China would make nuclear energy the foundation of its power-generation system in the next "10 to 20 years," focusing on capacity and emerging technologies. The CNEA confirmed that China could manufacture eight full sets of reactor equipment per year, and in 2014 it confidently announced that China was aiming for world leadership in nuclear technology. To put things into perspective, in 1995, the US nuclear power industry produced approximately 100 GWe from 109 reactors, and China produced 2.1 GWe from 3 reactors. In 2017, the US produced 99 GWe from 99 reactors with

[149] "Nuclear Power in China."

[150] "Nuclear Power in China."

[151] Sources suggest that the post-Fukushima slowdown may mean that the 2030 figure is only about 120 GWe.

two additional reactors stalled under construction, while China produced approximately 40 GWe from 38 reactors, with 20 more under construction.[152] In China, almost 70% (865 GWe) of its power plants were built within the last decade, whereas in the US, approximately half of the infrastructure (580 GWe) is over 30 years old.

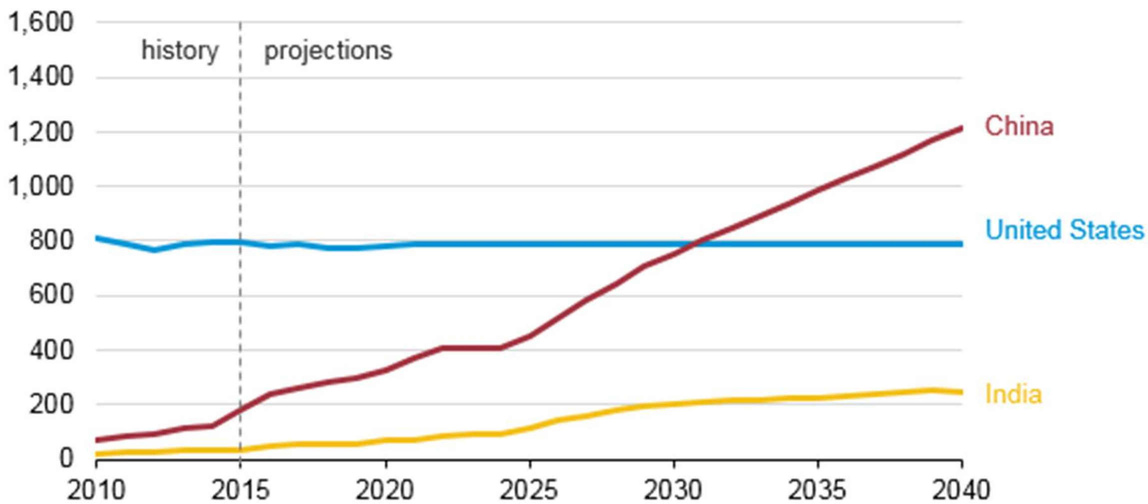


*Figure 12 Projected Nuclear Electricity Generation (2010-2040)*[153]

The massive shift in China toward nuclear innovation demonstrates just how much of a factor nuclear power is playing in 21st century national security. While Russia has been the primary rival of the US since the end of WWII, China's nuclear capabilities are on a trend that already appears dangerous for US national security. While China's nuclear innovation age is still in its very early stages, once the government perfects their strategies, it will be nearly impossible for the US or any nuclear power to compete with China's first-rate industrial capabilities and economy.

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[152] "Nuclear Power in China."

[153] "China Expected to Account for More than Half of World Growth in Nuclear Power Through 2040," (Energy Information Administration, Sept 2016). https://www.eia.gov/todayinenergy/detail.php?id=28132.

**India**

For India, China has long been a major focus of national security concern. "India's nuclear quest was triggered by the humiliating defeat of its military during the 1962 war with China along the Himalayan border, not by a rivalry with Pakistan."[154] While India believes an immediate nuclear threat comes from Pakistan, India's national security apparatus maintains that the real long-term threat comes from China. A major concern for India is that, in the China–India rivalry, nuclear innovation clearly favors China. China has already developed three generations of nuclear warheads – fission, thermonuclear and enhanced radiation. China has tested and "may" possess tactical nuclear weapons, has a four-decade lead over India in the development, deployment, and operations of ballistic missiles, and has procedures and training protocols for deployment and use of nuclear weapons.[155] While China has historically remained behind the curve in nuclear innovation, they still possess a nuclear infrastructure and community.

With India's formal declaration as a nuclear state in 1998, its leaders have realized that India must dramatically improve its nuclear capabilities to prevent becoming a victim of nuclear blackmail by its neighbors. "The growing institutionalization of the professional military's role in policy planning has also led to the realization that symbolic capabilities are likely to produce deterrence failures."[156] India has relied heavily on nuclear demonstrations to guarantee their national security, calculating that nations will be deterred from attacking

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[154] Samit Ganguly, *Fearful Symmetry: India-Pakistan Crises in the Shadow of Nuclear Weapons*, (2005).

[155] Enhanced radiation refers to a neutron bomb.

[156] Bharat Karnad, "India's Nuclear Policy," (October 2008). https://www.abc-clio.com/ABC-CLIOCorporate/product.aspx?pc=C9664C.

them simply due to their possession of nuclear weapons. However, their nuclear capability is so outdated that a demonstration is essentially the extent of their capabilities. Like China, past political leaders pushed ideology that favored minimal operational capabilities, with a primarily political role for nuclear weapons over a warfighting one.[157]

India's 15-year role as a "nuclear fence sitter" existed because its' nuclear weapons program was run by civilian scientists, instead of military leaders. Concerned about public perception, Indian political leadership heavily limited nuclear technology that the civilian nuclear community was permitted to pursue, instead choosing to rely on demonstrations to display their possession of nuclear weapons. Furthermore, since India is not a signatory of the Non-Proliferation Treaty (NPT), there was significant international pressure, mainly from the US, to prevent India from acquiring any dual-use technology.[158] International pressure forced the Indian government to bury many elements of their program in order to maintain relations with the international community. Due to the complete lack of assistance from external actors, severe design flaws made their way into the Indian program, and because of the moratorium on testing, the scientists had difficulty properly addressing the problems.

Like the Chinese's Second Artillery Corps, India finally placed their nuclear program under military control in 2002, four years after officially declaring itself a nuclear state. This transfer from civilian to military control released its nuclear program from the difficulties brought on by secrecy and isolation. The introduction of the military into the nuclear program also shifted the focus from an unsubstantial gunboat diplomacy strategy to a focus on technical numbers and statistical damage.

[157] Kampani, "China–India Nuclear Rivalry in the "Second Nuclear Age"."

[158] Components that can be used in both civilian and military nuclear programs.

Since 1998, light, rugged fission bombs have been the backbone of India's nuclear arsenal. On several occasions, Indian scientists have claimed to possess thermonuclear weapons, however, their claims have been proven inaccurate. Since officially outlining their nuclear triad in 1999, India's military has relied most heavily on the air component, although they lack the actual range to conduct effective attacks against Chinese targets without modern airframes and tankers. Since establishing their triad, the Indian military has invested heavily in developing more advanced missile systems and sea-based capabilities, in order to maintain relevancy in the 21st century. As their focus on innovation continues to intensify, they have devoted significant resources to a land-based ICBM, moving away from reliance on Cold War aircraft. Focus on ICBMs, of which they have developed three, "afford advantages of longer ranges, easier storage, maintenance and mobility."[159]

Much of the early nuclear innovation that began in India, however, was only at a strategic and doctrinal level, not at an actual scientific level. Due to a number of complicated laws and agreements, any forward movement for the Indian nuclear program was severely impaired. In response to the first Indian nuclear test in 1974, an organization called the Nuclear Suppliers Group (NSG) was founded by Canada, West Germany, France, Japan, the USSR, the UK and the US to further limit the sale of dual-use nuclear technology to specific nations. For India, this agreement made any future development and innovation extremely difficult, as well as isolating them from the nuclear powers.

In late 2008, this all changed for India when the US, under President Bush's direction, organized an international effort to release India from their ban from nuclear technology. In order to allow India the ability to purchase much-needed technologies, while maintaining the integrity of the international laws, the IAEA granted an unprecedented

[159] Tellis, "Strategic Asia 2013-14: Asia in the Second Nuclear Age."

safeguards agreement to India. The IAEA would conduct routine inspections of Indian nuclear sites, and in exchange, would allow international civilian nuclear cooperation. Additionally, the US approached the NSG to grant India a waiver to resume civilian nuclear trading. The group agreed to the waiver, making India the only non-NPT signatory with permission to conduct legitimate nuclear commerce. Due to the nature and size of such an agreement, the details are still being actively negotiated, with unsurprising push-back from China on India's waiver. However, while all the regulations have not yet been lifted, with most of the import/export bans gone, India could officially and legally begin their nuclear innovation age.

China has focused on nuclear innovation to further national defense and international relations, while India is far more interested in using nuclear innovation to guarantee their self-sufficiency, evidenced by the fact that the majority of their modern nuclear innovation has come in the form of nuclear reactors. In 2017, British Petroleum projected India's energy consumption rising by 129% between 2015 and 2035, with a very heavy reliance on fossil fuels (86%).[160] This 129% increase does not take into account that, in 2014, 20% or 260 million Indians still did not have access to electricity, putting the nation at the same energy availability level as Yemen and Ghana.[161] The power crisis in India hit its peak in July 2012 when India's Northern power grid failed while carrying a full load in the early morning. The following day, the Northern grid plus parts of two other grids failed, causing over 600 million people, or 11% of the entire world's population, to be without power.

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[160] "Nuclear Power in India," (World Nuclear Association, October 2017). http://www.world-nuclear.org/information-library/country-profiles/countries-g-n/india.aspx.

[161] *Access To Electricity*, (2014). Up from 55%

The government began taking action and penned the nation's 12th five-year plan for 2012-17, which included the addition of 94 GWe of power, costing $247 billion. The International Atomic Energy Agency predicts that India will need $1.6 trillion of investment in power generation, transmission and distribution to meet 2035 estimates.[162] In addition to the aging power infrastructure, the nation's shortage of fossil fuels is driving the need for nuclear innovation, as the government has set a 25% nuclear power goal for 2050, when 1094 GWe of total base-load capacity is expected to be required.[163] In May 2017, the government approved the construction of ten 700 MWe reactors in addition to the 6 already under construction.

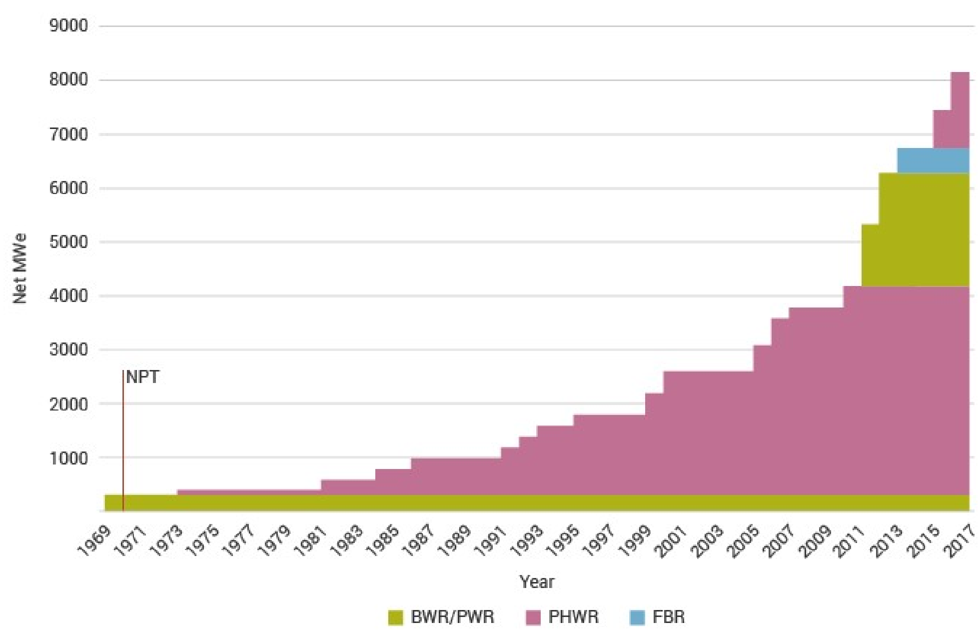


*Figure 13 Indian Nuclear Power Capacity*[164]

[162] "Nuclear Power in India."

[163] Current installed baseload capacity as of June 2017 is 330GWe

[164] "Nuclear Power in India."

Unfortunately, India is a country almost entirely void of the Uranium required to produce nuclear power, making massive fuel imports a necessary evil for the nation. While the Indian engineers work to provide a viable, reliable power grid for the nation, scientists are working on their nation's resource problem. India's nuclear innovation has come in the form of alternative fuel sources. Due to the lack of Uranium, scientists have been forced to look at different nuclear fuel sources to power their reactors and achieve self-sufficiency. The fast breeder reactor (FBR) at Kalpakkam is part their nuclear innovation toward self-sufficiency.

After 15 years of conceptualizing, experimenting, and testing, India is on the verge of accomplishing what no nation has ever done, they will begin generating nuclear power for widespread civilian use without Uranium. In 1899, approximately 60 years after the discovery of a black rock named Thorium, Ernest Rutherford discovered that this rock had unique radioactive properties. Physicists discovered that Thorium and Uranium had almost identical properties, and that, when Thorium-232 absorbed a neutron, after transitioning to Thorium-233 and Protactinium-233, it decayed to Uranium-233 (U-233) after 27 days.[165] During the Manhattan project, physicist Glenn Seaborg, famous for his discovery of Plutonium, discovered that U-233 fell into the exclusive category of fissile isotopes, alongside U-235 and Plutonium-239. However, the weapons designers quickly ruled out U-233 as a possibility for a bomb due to its instability in an uncontained environment and the possibility for intense gamma radiation.

After the conclusion of the WWII, the new US Air Force was envious of the Navy's pressurized water reactor and called upon the nuclear community to build an unpressurized,

[165] "Thorium Fuel Cycle — Potential Benefits and Challenges," (May 2005). https://www-pub.iaea.org/mtcd/publications/pdf/te_1450_web.pdf.

safer nuclear reactor that could power its long-range strategic bombers. Oak Ridge National Laboratory undertook the project and created a 7.4MW test reactor that used Thorium as its primary fuel.[166] Instead of water, the reactor used air that was blown over radiators, in conjunction with a system that cooled and recirculated the liquid nuclear fuel as its cooling systems. This eliminated the need for unsafe high pressures. Additionally, due to new designs combined with the unpressurized nature of the reactor, the reactor could regulate its own temperature, meaning that it could not melt down. If the reaction gets too hot, the expanding liquid fuel will be forced out of the reaction chamber into the circulating system, decreasing the amount of fuel and cooling down the reaction. If too much fuel is pushed out and the power begins dropping, the lack of liquid in the chamber causes more space in the core, which means less moderation and more reactivity, causing the power to rise again. The cycle constantly repeats itself, always regulating itself for the optimal temperature.[167]

There are a variety of theories as to why the US did not pursue this technology after the nuclear aircraft project was cancelled. These theories boil down to the fact that this technology wasn't an effective method for producing nuclear weapons. In the 1960s, when the US was trying to produce as many weapons as possible, Thorium simply wasn't a viable option, and so the technology was pushed aside for the more dangerous and complicated pressurized water reactors, which were good at producing the materials for nuclear weapons.

India, which has the largest supply of Thorium in the world, has embraced the research conducted at Oak Ridge and invested heavily in Thorium-powered reactors. The

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[166] Richard Martin, *Superfuel : thorium, the green energy source for the future*, First edition. ed., (New York: Palgrave Macmillan, 2012).

[167] Badawy Elsheikh, "Safety Assessment of Molten Salt Reactors in Comparison with Light Water Reactors," *Journal of Radiation Research and Applied Sciences* (October 2013), https://www.sciencedirect.com/science/article/pii/S1687850713000101.

Oak Ridge reactor type, called a Molten Salt Reactor (MSR), after the liquid fuel used in it, has played heavily into the future of the Indian nuclear program. They have begun developing different variants of the MSR-type reactors, some that rely on Thorium, and some that rely on Uranium-238. With current reactor technology, the amount of Thorium in India could theoretically power the country for 10,000 years, and if the technology was made more efficient, it could last 60,000 years.[168]

If India is successful in their implementation of this new generation of nuclear reactor, it could change power and energy throughout the world. A nation crippled by a lack of power could begin exporting both power and technology. Nations without access to large bodies of water could begin building safe, proliferation-resistant nuclear power plants to provide access to their people. An additional benefit of MSRs is that, instead of Thorium, nations can also use depleted Uranium or Uranium from disassembled weapons as fuel, eliminating the need for nuclear waste repositories like the one at Yucca Mountain in Nevada.

India is an important strategic partner of the US and while their growing power is not a direct threat to the US, it is a growing threat to regional and global stability.[169] While the India-China rivalry is a fairly conventional, historical rivalry, the Indian military was soundly defeated in the Sino-Chinese war, which demonstrated the weaknesses in their military structure and technology, leaving unresolved conflict between the two. Border friction between the two nations exists to this day, and if India improves their infrastructure and technology, innovation could mean a new confidence for India, which could drive a renewed

[168] Andrew Follett, "India Has Almost Finished The World's First Advanced Thorium Nuclear Reactor " (The Daily Caller). http://dailycaller.com/2017/07/10/india-has-almost-finished-the-worlds-first-advanced-thorium-nuclear-reactor/.

[169]Kampani, "China–India Nuclear Rivalry in the "Second Nuclear Age"."

conflict between the two nations. As a close ally, the US would be placed in a destabilizing situation as it would be forced to choose to either join in what could realistically become a world war or abandon its ally to face the Chinese alone.

**US Consequences**

Because of US inattention to its nuclear arsenal and failure to innovate, the nation is facing several major geopolitical dangers that may lead to a fundamental shift in international relations. This section will briefly address some geopolitical issues and international actors not covered in the previous sections. First is a rapidly rising China that is breeding trouble in the Trans-Pacific region for the US and its interests there. While the US is committed to maintaining its Pacific influence through partnerships with Taiwan, Japan, and South Korea, it is beginning to feel more pressure from China. China continues its unimpeded push into the East and South China Seas, its continued support of North Korea, and its attempts to undermine regional US alliances, demonstrating China's view of the US as a weakening power. Weakening that is, in part, due to outdated technology and overextension in other regions of the world.

Next, US national security is still being endangered by the remnants of the rogue innovation age and nations like Pakistan, Iran, and North Korea who have upset the nuclear power balance and trained their sights on important US partners (i.e., India, Israel, Japan/South Korea). Not beholden to any treaties, these nations are focused on highly mobile missile forces that avoid many of the security problems that come with having permanent silos. The often-unpredictable nations can rapidly deploy their difficult to track forces and attack the US or its allies with little to no warning. Without modern nuclear technologies, this capability presents a major point of weakness to the US.

The final geopolitical threat that the US is currently facing, as a result of stagnant US nuclear innovation, is conventional threats from Russia and Iran. For the last 15 years, the US has had a large presence in the Middle East – deposing dictators, intervening in civil wars, and attempting to right past wrongs. However, due to indecision and strategic failures throughout the wars, the protracted conflict has no end in sight. Combined with a deteriorating nuclear deterrent capability from the US, Russia and Iran have begun intervening in the Middle East, directly undermining the influence and position of the US there.[170] Russia's public support for Syrian dictator Assad is the most overt example of the Russian government and military opposing US strategy and efforts in the region. Additionally, the Russians have been working to take military support from the Turks, recently reaching an agreement to sell the Turks SA-21 surface-to-air missile (SAM) systems.[171] Iran, while not a close political partner of Russia, also has an interest in preventing US interventions in the Middle East and expanding their territory. They have used the constantly changing power of the US in the Middle East to their advantages on multiple occasions, wrestling control of territory from the Islamic State (IS) for their own purposes. While, at times, they have been a valuable asset in the fight against IS, many are concerned that with IS fading, they with capitalize on the future power vacuum that will inevitably arise in IS's wake.[172]

Nations around the world are beginning to recognize the waning influence of the US as a result of its inability to provide the nuclear deterrence capability it once was. This is not

[170] Robin Wright, "Russia and Iran Deepen Ties," (The New Yorker, March 2, 2018). https://www.newyorker.com/news/news-desk/russia-and-iran-deepen-ties-to-challenge-trump-and-the-united-states.

[171] Selcan Hacaoglu, "Turkey Chooses Russia Over NATO for Missile Defense," (Bloomberg, July 2017 ). https://www.bloomberg.com/news/articles/2017-07-13/turkey-is-said-to-agree-to-pay-2-5b-for-4-russian-s-400-sams.

[172] Henry Meyer, "Putin Is Filling the Middle East Power Vacuum," (Bloomberg, October 3, 2017).

to say that the US no longer possesses a deadly nuclear force, just that the US's competitors are beginning to smell the death throes of that force. If US leadership is unwilling to recognize the dangers that are facing it, it will be faced with far more dangerous geopolitical issues than China building islands and Russia backing Assad.

## CHAPTER VII:

## THE US IN THE SECOND NUCLEAR AGE

In the last decade, America has seen two Presidential administrations pursuing contrasting national and energy security visions. President Barak Obama's strategy was diplomacy-focused while emphasizing "green" power and a disdain for nuclear weapons. After eight years of the Obama Administration's strategy, President Donald Trump was elected in November 2016 on promises of bringing back coal power, increasing military spending, and a willingness to use nuclear weapons offensively.

The 21st century began with the US shift to counterinsurgency as a result of the 9/11 attack. After the decline of nuclear reactors in the 1980s, nuclear weapons reached a low point of relevancy for military planners in the early 2000s. Fighting the "War on Terror" meant the military's focus was shifted from mutually assured destruction through nuclear weapons to traditional fighting tactics with conventional forces relying on personnel. As a result of this change, nuclear infrastructure, weapons and reactors were largely ignored. Under President Obama, nuclear power was publicly denounced, resulting in the closure of nuclear power plants in California, Florida, Wisconsin, Vermont, and Nebraska during his tenure.[173] Additionally, before a crowd in Prague, Czech Republic, the President told the world that the US, "as the sole country ever to fire a nuclear weapon in anger, bears the moral responsibility for launching a new era of nuclear disarmament aimed at eliminating nuclear stockpiles."[174] His Presidency would see "America's commitment to seek the peace and security of a world without nuclear weapons."

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[173] "List of All Decommissioned Power Plants in USA."

[174] "Obama Prague Speech On Nuclear Weapons," (Huffington Post, May 9, 2009). https://www.huffingtonpost.com/2009/04/05/obama-prague-speech-on-nu_n_183219.html.

While President Obama was not able to fully achieve this goal during his time in office, he made advancements toward it. “As of September 2016, the US active stockpile of nuclear warheads consisted of 4,018 warheads. This number represents an 82 percent reduction from its level (22,217) when the Berlin Wall fell in late 1989.”[175] From fiscal years 1994 through 2016, the United States dismantled 10,681 nuclear warheads, although a disproportionately large percentage occurred between 2009 and 2016. “From fiscal year 2009 through the end of fiscal year 2016, the US dismantled 2,226 warheads and retired 1,255 weapons.”[176] A decreasing quantity of outdated weapons combined with crumbling, dangerous nuclear power plants have put the US’s state of national security in a perilous position.

The Trump administration, under President Trump, has acknowledged the important role of nuclear power and the sad state of its condition, but done very little to correct any problems thus far. In the administration’s first nuclear posture review, released in Q1 2018, President Trump indicated that he will continue many of President Obama’s policies and views on nuclear power, however, he did specify that he foresees nuclear weapons playing a larger role in the defense of the nations, specifically with a focus on Russian aggression.[177] The nuclear strategy released in the posture review was much tamer than the policies proposed by the President during his campaign, which has left many concerned that he is apathetic toward the US’s dying nuclear weapons industry.

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[175] "The Prague Nuclear Agenda," (The White House, January 11, 2017). https://obamawhitehouse.archives.gov/the-press-office/2017/01/11/fact-sheet-prague-nuclear-agenda.

[176] "The Prague Nuclear Agenda."

[177] Department of Defense, "2018 Nuclear Posture Review," (Office of the Secretary of Defense, 2018). https://media.defense.gov/2018/Feb/02/2001872886/-1/-1/1/2018-NUCLEAR-POSTURE-REVIEW-FINAL-REPORT.PDF.

The situation for nuclear reactors in 2018 remains bleak from a political perspective. Due to a politically bloated regulation and certification process, coupled with general apathy toward new industry as a whole, there is only one nuclear plant under construction in the entire country, with an undetermined future. The Vogtle Nuclear Plant in Georgia is currently five years behind schedule and $9 billion over budget.[178] By the time of completion, the new reactor could have a price tag of up to $25 billion, an absurd figure when considering that China is building similar reactors for $4 billion.[179] President Trump, a pro-coal advocate, and his Secretary of Energy, Rick Perry, a pro-oil former Texas governor, have not given the nuclear community any confidence in future nuclear plant production.

The nuclear state of affairs may be dismal, but there is still a path forward if the government is focused on national security. Looking to the future, there are several different courses of action that the US government should consider. First and foremost, the government must begin innovating nuclear technology again. It has the resources and the infrastructure in place to guarantee the nation's security without beginning an arms race. By relying on modern, emerging technologies instead of sheer numbers, the US government can provide for the common defense, improve international relations at a time when the US is decidedly unpopular internationally, and achieve self-sufficiency through safe, green methods.

To begin the process of innovating nuclear reactors, the US must invest and encourage participation by private industries, pursue India's Thorium strategy, and loosen the crippling regulations imposed by the NRC. For innovation in nuclear weapons, the

[178] Gold, "Tab Swells to $25 Billion for Nuclear-Power Plant in Georgia."

[179] Francois de Beaupuy, "China Builds Nuclear Reactor for 40% Less Than Cost in France," (Sortir du Nucléaire, November 2010). http://www.sortirdunucleaire.org/China-Builds-Nuclear-Reactor-for.

government must let the nuclear weapons labs build nuclear weapons instead of continuing repair of the same antiquated platforms that are 50 years old. It also must stop investing in the money-pit that has become strategic anti-ballistic missiles, or ground-based midcourse defense (GMD).[180] Nuclear innovation is not a Cold War-era concept; India and China are pursuing it with fervor, and so to must the US.

**The Path for Reactors**

The biggest resource of future innovation for nuclear reactors lies in encouraging and funding private industry. In September, Idaho Senator Jim Risch stated that, "to maintain our competitiveness over countries like China that are pouring ever more resources into advanced nuclear technologies, the U.S. must have policies in place and provide the resources to support U.S. R&D, and the partnerships between industry and the national labs that will enable the rapid development, commercialization and deployment of new reactors, including SMRs and advanced non-water cooled reactors."[181] Senator Risch is, in part, referring to the growing private nuclear industry in the US that is fueling the path to US participation in the second nuclear innovation age. There is a burgeoning sector of US private industry that has recognized and begun pursuing smaller, privately owned nuclear reactors.

SpaceX's revival of the space exploration industry demonstrates the effect that private industry can have. Nuclear power companies like Flibe, Terrestrial Energy, Transatomic Power Corporation, and Bill Gates' TerraPower are fueling a renewed interest and focus on peaceful power generation. They have easily identified the enormous concerns

[180] GMD is designed to intercept ICBMs outside the earth's atmosphere.

[181] "How Public-Private Partnerships Drive Innovation at National Labs," (Nuclear Energy Initiative Sept 2017). https://www.nei.org/News-Media/News/News-Archives/2017/How-Public-Private-Partnerships-Drive-Innovation-at-national-labs.

presented by pressurized water reactors and are actively pursuing safer, more efficient reactors. Many of the companies have identified superpowers like Westinghouse Electric as major roadblocks of nuclear innovation, and like SpaceX, are working to break the stranglehold of companies that are largely funded by the US government.[182] The US government is not an entity known for its ability to deviate from the status quo, but to stay relevant in the 21st century, it must begin considering options other than unconditional support for the recently bankrupt Westinghouse.[183] The focus on MSRs as well as small, more decentralized reactors known as small modular reactors (SMRs) are the only feasible way forward for the US. China and India will surpass the US in their capabilities due to their head start in nuclear innovation, but it is up to the US to decide whether it wants to stay relevant.

The second step that the US must take in innovating nuclear reactors is to focus on the use of Thorium. As of 2015, the US has the 9th largest reserves of Uranium, with 138,000 tons, mining about 1,125 tons per year, and only using about 9% of its own locally mined uranium in its reactors, importing much of it from Kazakhstan, Canada, and Australia[184] However, the US has the 3rd highest Thorium reserves in the world, about 400,000 tons, or 13% of the entire world reserves. With such abundant reserves of Thorium at the nation's disposal, the US could power itself for thousands of years. The private industry has seen the limitless possibilities that result from the use of Thorium, but the government must be willing to pursue them as well.

[182] Just recently, the US government announced a partial bailout of Westinghouse, giving them an $800 million loan.

[183] Tom Hals, "Westinghouse reaches deal for $800 million U.S. bankruptcy loan," (Reuters, May 2017). https://www.reuters.com/article/us-toshiba-accounting-westinghouse/westinghouse-reaches-deal-for-800-million-u-s-bankruptcy-loan-idUSKBN18J2M2.

[184] "How Public-Private Partnerships Drive Innovation at National Labs."

The final piece of the nuclear reactor innovation plan must come from the Nuclear Regulatory Commission (NRC). The NRC is the government agency tasked with overseeing the safety of nuclear reactors as well as the licensing of new and existing reactors. The intent behind having an organization like the NRC is necessary for safeguarding the public, but they have become a poorly run entity. Their primary role in the nuclear community has been promoting big businesses such as Westinghouse. When a company like Westinghouse comes forward with a proposal for a new reactor, the NRC will "rubber stamp" the proposal, automatically approving the plans. However, when a non-industry company, such as one of the various newer startup reactors companies, submits a proposal, the NRC has blocked it a majority of the time, blocking 32 out of 36 plans submitted at the beginning of the decade.[185] Any plans that are not blocked outright will be drown in red tape and bureaucratic delays. The current, short-term obstacle for any innovation in nuclear reactors comes from blatant corruption and over-politicization of the NRC. Additionally, the NRC has become historically famous for intentionally overlooking security flaws in big-business reactor designs in order to continue construction. Until the government focuses on revamping or simply eradicating the political and safety nightmare that is the Nuclear Regulatory Commission, innovation and power production cannot proceed.

Roadblocks aside, reactor innovation will prove to be much easier for the US than nuclear weapon innovation. The innovation of nuclear weapons is not a difficult process in itself but innovating without starting an arms race or all-out war is a much more difficult task. Just as the Chinese have created their hypersonic glide vehicle, the US must focus on developing newer, more modern technologies – technology that doesn't rely on floppy disks

[185] David Lochbaum, "NRC's Project Aim: Off-target?," (February 2018). https://allthingsnuclear.org/dlochbaum/nrcs-project-aim-off-target.

and 1970s computers. It must accept that bigger is not better. Low-yield, highly accurate nuclear weapons are far less destabilizing than megaton-size city killers. The US must still continue to maintain its deterrence capabilities, but nuclear innovation of smaller and more accurate nuclear weapons can lead both the US and the other nuclear powers to a more stable geopolitical state.

Anti-ballistic missile (ABM) systems are another nuclear weapons technology that acts as a global destabilizing factor. In 1972, the US and USSR signed a treaty that tightly controlled the use of anti-ballistic missile systems designed to shoot down incoming ICBMs. The treaty was proposed by the US, the global leader at the time in ABM systems, out of fear that the rapidly advancing ABM system would spark another arms race. In 2001, President Bush announced that the US would withdraw from the ABM treaty in order to protect itself from nuclear blackmail by rogue states such as North Korea and Libya. The US then began investing billions of dollars towards solving the problem of shooting down a rocket flying in space while moving 15,000mph, or as engineer Montgomery Scott once quipped, “trying to hit a bullet with a smaller bullet, whilst wearing a blindfold, riding a horse.”[186]

Aside from the technical complexity, and the enormous cost – $40 billion to develop the midcourse defense system, and approximately $200 million per test – ABMs are an inherently provocative and destabilizing system.[187] The Russians and the Chinese have both publicly voiced outrage at the advancement and placement of US ABM systems. In 2008, “the Russian military, furious at American plans to install a missile defense shield in Eastern Europe, talked of the prospect of turning Cuba into a base for its long-range nuclear

[186] Jeffrey Abrams et al., "Star trek," (United States: Paramount Pictures, 2009).

[187] David Mosher, "Understanding the Extraordinary Cost of Missile Defense." https://www.rand.org/natsec_area/products/missiledefense.html.

bombers."[188] As discussed previously, the THAADs being installed in South Korea has also been a major point of contention throughout the Trans-Pacific region. The more effective that US ABM systems become, the more unsafe the geopolitical climate will become. Due to the largely unsuccessful history of ABM tests and the staggering costs, the US should instead direct the ABM funds toward nuclear reactor and weapons development.

[188] Sean-Paul Kelley, "Withdrawing From ABM Was Destabilizing," (Huffington Post, 2008). https://www.huffingtonpost.com/seanpaul-kelley/withdrawing-from-abm-was_b_115161.html.

# CHAPTER VIII:

# CONCLUSION

Nuclear power is the foundation of modern, 21st century nations. Without nuclear weapons and a willingness to improve its atomic technological capabilities, a nation is irrelevant. After the nuclear bombings of Hiroshima and Nagasaki, the first nuclear innovation age produced unprecedented economic growth and enhanced national security. The US and the USSR poured money into technological renewal at a staggering rate, investing in fusion bombs, submarine-based reactors, ICBMs, ABM systems and MIRVs. In pursuit of national security in a new geopolitical world, the two created a balance of terror that reduced the prospect of war between major powers.

The first nuclear innovation age came to a jolting end when the Chernobyl reactor exploded, and the USSR collapsed, further complicating global geopolitics. Without a rival superpower to defend against, the US government began shifting their national security focus to other areas, preferring to distance itself from the politically charged topic of nuclear power. While it had pioneered nuclear innovation, the US began falling dangerously far behind its competitors. Once nuclear power's biggest champion, the US has turned its back on nuclear innovation in favor of unreliable ABM systems, delusional expectations of global cooperation between major powers and environmentally destructive fossil fuels. The government's disdain for nuclear power has permeated the public perception, leading to vilification of nuclear power and a unwillingness to improve a energy source vital for national and economic security.

Global, 21st century national security has transitioned away from large conventional forces to a national defense guaranteed by nuclear power and atomic weapons. Due to military modernization and weaponization of their nuclear programs, India and China have taken the lead on atomic innovation, beginning a second nuclear innovation age. India and China see nuclear innovation as a major factor in guaranteeing national security again. Both nations realize their nuclear technologies were antiquated and too reliant upon external powers. China has begun developing new nuclear weapons and large-scale nuclear reactors hoping to enhance their national security position vis-à-vis major competitors. India, due to a lack of uranium, has invested heavily in emerging technologies that would provide safer, more efficient power for the nation's rapidly expanding population.

Although China could surpass US nuclear capabilities, time has not yet run out for saving US national security. If the US is willing to break some of the norms that it has established over the last 60 years and begin innovating again, it could correct its course. Investing in private nuclear industries, Thorium research, and new nuclear weapons, while limiting the NRC and ABM investments would substantially bolster US national security to a point where it is no longer in peril. The nation needs innovative minds like Ernest Rutherford and Robert Oppenheimer to lead the country out of their nuclear apathy and back to a place where the government and public alike can see the value in securing the nation from external threats.

## BIBLIOGRAPHY


Abdulla, Ahmed. "A Retrospective Analysis of Funding and Focus in Us Advanced Fission Innovation." Environmental Research Letters, August 2017. http://static1.1.sqspcdn.com/static/f/356082/27654623/1502645550377/Abdulla_2017_Environ._Res._Lett._12_084016.pdf?token=hY99KQqU96mHKGzeZOixY%2FvviLo%3D.

Abrams, Jeffrey, Damon Lindelof, Roberto Orci, Alex Kurtzman, Chris Pine, Zachary Quinto, Leonard Nimoy*, et al.* "Star Trek." 14 film reels of 14 on 7 (ca. 126 min., ca. 11,340 ft.). United States: Paramount Pictures, 2009.*Access to Electricity*. 2014.

Afgan, Naim Hamdia. *Resilience of Sustainable Power Plant Systems in Catastrophe Events.* Hauppauge, New York: Nova Science Publishers, Inc., 2014.

Beaupuy, Francois de. "China Builds Nuclear Reactor for 40% Less Than Cost in France." Sortir du Nucléaire, November 2010. http://www.sortirdunucleaire.org/China-Builds-Nuclear-Reactor-for.

Biello, David. "Nuclear Mishap or Meltdown?: It's All a Matter of Degree." Scientific American July 2007. https://www.scientificamerican.com/article/nuclear-mishap-or-meltdown-a-matter-of-degree/.

Blain, Loz. "A Modern Engineering Masterpiece ", New Atlas, May 2007. https://newatlas.com/go/7292/.

Bodman, Samuel W. *National Security and Nuclear Weapons in the 21st Century*, 2008.

Boese, Wade. "U.S. Withdraws from Abm Treaty; Global Response Muted." Arms Control Association, 2002. https://www.armscontrol.org/act/2002_07-08/abmjul_aug02.

Bolt, Paul J., and Albert S. Willner. *China's Nuclear Future.* Boulder, Colo.: Lynne Rienner Publishers, 2006.

Britannica, Editors of Encyclopedia. "Big Stick Policy." December 2017. https://www.britannica.com/event/Big-Stick-policy.

Buchonnet, David. "Mirv: A Brief History of Minuteman and Multiple Reentry Vehicles." Lawrence Livermore Laboratory, February 1976. https://nsarchive2.gwu.edu/nsa/NC/mirv/mirv.html.

Chalecki, Elizabeth. "Environmental Security: A Case Study of Climate Change." Pacific Institute for Studies in Development, Environment, and Security, 2001. https://www.pacinst.org/reports/environment_and_security/env_security_and_climate_change.pdf.

"China Expected to Account for More Than Half of World Growth in Nuclear Power through 2040." Energy Information Administration, Sept 2016. https://www.eia.gov/todayinenergy/detail.php?id=28132.

Collie, Craig. "How a Last-Minute Decision Led to the Nuking of Nagasaki." Business Insider, Aug 2012. http://www.businessinsider.com/how-a-last-minute-decision-led-to-the-nuking-of-nagasaki-2012-8.

Collins, Catherine, and Douglas Frantz. *Fallout : The True Story of the Cia's Secret War on Nuclear Trafficking.* 1st Free Press hardcover ed. New York: Free Press, 2011.

Coster-Mullen, John. "Atom Bombs: The Top Secret inside Story of Little Boy and Fat Man." 112-13, 2002.

Council, National Intelligence. *Global Trends 2025: A Transformed World*, 2008.

De Geer, Lars-Erik, Christer Persson, and Henning Rodhe. "A Nuclear Jet at Chernobyl around 21:23:45 Utc on April 25, 1986." *Nuclear Technology* (2017). http://dx.doi.org/10.1080/00295450.2017.1384269.

Defense, Department of. "2018 Nuclear Posture Review." Office of the Secretary of Defense, 2018. https://media.defense.gov/2018/Feb/02/2001872886/-1/-1/1/2018-NUCLEAR-POSTURE-REVIEW-FINAL-REPORT.PDF.

Diesendorf, Mark. "Do We Need Base-Load Power Stations?", EnergyScience Coalition, December 2015. http://energyscience.org.au/BP16%20BaseLoad.pdf.

Dinesh, A. "Impact of Nuclear Weapons on International Relations." http://www.yourarticlelibrary.com/international-politics/impact-of-nuclear-weapons-on-international-relations/48526.

Doménech, Francisco. "The True Alchemists." The Open Mind, September 2015. https://www.bbvaopenmind.com/en/the-true-alchemists/.

Dowling, Stephen. "The Monster Atomic Bomb That Was Too Big to Use." BBC, August 2017. http://www.bbc.com/future/story/20170816-the-monster-atomic-bomb-that-was-too-big-to-use.

Dunn, Dianne. "Monthly Energy Review April 2018." U.S. Energy Information Administration Office of Energy Statistics, Ap ril 2018. https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf.

"Economic Security Overview." Department of Homeland Security, July 2015. https://www.dhs.gov/topic/economic-security-overview.

Elsheikh, Badawy. "Safety Assessment of Molten Salt Reactors In Comparison with Light Water Reactors." *Journal of Radiation Research and Applied Sciences* (October 2013): 63-70. https://www.sciencedirect.com/science/article/pii/S1687850713000101.

"Energy Security." International Energy Agency, Feb 2018. https://www.iea.org/topics/energysecurity/.

"Energy Security." World Nuclear Association, April 2014. http://www.world-nuclear.org/information-library/economic-aspects/energy-security.aspx.

*Federal Agencies Need to Address Aging Legacy Systems*. May 2016.

Follett, Andrew. "India Has Almost Finished the World’s First Advanced Thorium Nuclear Reactor ", The Daily Caller. http://dailycaller.com/2017/07/10/india-has-almost-finished-the-worlds-first-advanced-thorium-nuclear-reactor/.

Frantz, Douglas, and Catherine Collins. *The Nuclear Jihadist.* 1st ed. New York: Twelve, 2007.

———. *The Nuclear Jihadist : The True Story of the Man Who Sold the World's Most Dangerous Secrets-- and How We Could Have Stopped Him.* 1st ed. New York: Twelve, 2007.

Ganguly, Samit. *Fearful Symmetry: India-Pakistan Crises in the Shadow of Nuclear Weapons.* 2005.

Gold, Russell. "Tab Swells to $25 Billion for Nuclear-Power Plant in Georgia." Wall Street Journal, 2017. https://www.wsj.com/articles/tab-swells-to-25-billion-for-nuclear-power-plant-in-georgia-1501691212.

Gramer, Robbie. "America's Nuclear Weapons Infrastructure Is Crumbling." Foreign Policy, March 2017. http://foreignpolicy.com/2017/03/17/americas-nuclear-weapons-infrastructure-is-crumbling-national-nuclear-security-administration-deterrence-aging-congressional-oversight/.

Hacaoglu, Selcan. "Turkey Chooses Russia over Nato for Missile Defense." Bloomberg, July 2017 https://www.bloomberg.com/news/articles/2017-07-13/turkey-is-said-to-agree-to-pay-2-5b-for-4-russian-s-400-sams.

Hals, Tom. "Westinghouse Reaches Deal for $800 Million U.S. Bankruptcy Loan." Reuters, May 2017. https://www.reuters.com/article/us-toshiba-accounting-westinghouse/westinghouse-reaches-deal-for-800-million-u-s-bankruptcy-loan-idUSKBN18J2M2.

Holgate, Laura S. H. "Linking Energy Security and Nuclear Security." International Conference "G8 Global Security Agenda: Challenges and Interests Towards the St. Petersburg Summit" Nuclear Threat Initiative, April 2006. http://www.nti.org/analysis/speeches/linking-energy-security-and-nuclear-security-laura-holgate/.

"How Public-Private Partnerships Drive Innovation at National Labs." Nuclear Energy Initiative Sept 2017. https://www.nei.org/News-Media/News/News-Archives/2017/How-Public-Private-Partnerships-Drive-Innovation-at-national-labs.

Ischinger, Wolfgang, and Ulrich Weisser. "Nato and the Nuclear Umbrella." New York Times, Feb. 15, 2010. http://www.nytimes.com/2010/02/16/opinion/16iht-edischinger.html.

Jones, Vincent C. *Manhattan, the Army and the Atomic B Omb.* United States Army in World War Ii Special Studies. Washington, D.C.: Center of Military History For sale by the Supt. of Docs., U.S. G.P.O., 1985.

Kampani, Gaurav. "China–India Nuclear Rivalry in the “Second Nuclear Age”." Oslo, Norway Norwegian Institute for Defense Studies, March 2014. https://brage.bibsys.no/xmlui/bitstream/handle/11250/226454/1/Insight2014_3.pdf.

Karnad, Bharat. "India's Nuclear Policy." October 2008. https://www.abc-clio.com/ABC-CLIOCorporate/product.aspx?pc=C9664C.

Kelley, Sean-Paul. "Withdrawing from Abm Was Destabilizing." Huffington Post, 2008. https://www.huffingtonpost.com/seanpaul-kelley/withdrawing-from-abm-was_b_115161.html.

Kennedy, Merrit. "Report: U.S. Nuclear System Relies on Outdated Technology Such as Floppy Disks." NPR, May 2016. https://www.npr.org/sections/thetwo-way/2016/05/26/479588478/report-u-s-nuclear-system-relies-on-outdated-technology-such-as-floppy-disks.

Koty, Alexander. "China Announces Sweeping Overhaul of Government Institutions." China Briefing, March 14, 2018.

Kristensen, Hans. "Chinese Nuclear Arsenal Increased by 25 Percent since 2006, Pentagon Report Indicates." Federation of American Scientists, Mar 2008. https://fas.org/blogs/security/2008/03/chinese_nuclear_arsenal_increa/.

———. "Chinese Nuclear Weapon." Federation of American Scientists, November 29, 2006. https://fas.org/nuke/guide/china/nuke/index.html.

———. "United States Discloses Size of Nuclear Weapons Stockpile." Federation of American Scientists, 2010. https://fas.org/blogs/security/2010/05/stockpilenumber/.

Langewiesche, William. *The Atomic Bazaar : The Rise of the Nuclear Poor.* 1st ed. New York: Farrar, Straus and Giroux, 2007.

Li, Nan. "China's Evolving Nuclear Strategy: Will China Drop "No First Use?"." The Jamestown Foundation, 2018. https://jamestown.org/program/chinas-evolving-nuclear-strategy-will-china-drop-no-first-use/.

"List of All Decommissioned Power Plants in Usa." Public Watchdogs, Sept 2016. https://publicwatchdogs.org/list-decommissioned-nuclear-power-plants-usa/.

Lochbaum, David. "Nrc's Project Aim: Off-Target?", February 2018. https://allthingsnuclear.org/dlochbaum/nrcs-project-aim-off-target.

Longair, Malcolm. "When Rutherford Split the Atom." By Ricky Nathvani. 2017. https://www.thenakedscientists.com/articles/interviews/when-rutherford-split-atom.

Mahaffey, James A. *Atomic Accidents : A History of Nuclear Meltdowns and Disasters : From the Ozark Mountains to Fukushima.* First Pegasus Books edition. ed. New York: Pegasus Books, 2014.

Martin, Richard. *Superfuel : Thorium, the Green Energy Source for the Future.* First edition. ed. New York: Palgrave Macmillan, 2012.

Mershon, Sherie. "A Century of Innovation." Department of Energy. https://www.netl.doe.gov/File%20Library/NewsRoom/NETL-A_Century_of_Innovation.pdf.

Meyer, Henry. "Putin Is Filling the Middle East Power Vacuum." Bloomberg, October 3, 2017.

Mosher, David. "Understanding the Extraordinary Cost of Missile Defense." https://www.rand.org/natsec_area/products/missiledefense.html.

Moynihan, Daniel P. *Secrecy : The American Experience.* New Haven: Yale University Press, 1999.

"National Security Council Report." Executive Secretary to the National Security Council, March 1956. https://history.state.gov/historicaldocuments/frus1955-57v19/d66.

"No Going Back: 20 Years since the Last U.S. Nuclear Test." Arms Control Association, Sept 2012. https://www.armscontrol.org/issuebriefs/No-Going-Back-20-Years-Since-the-Last-US-Nuclear-Test%20.

"Nuclear Chain Reaction." In *Encyclopedia Britannica*, 2015. https://www.britannica.com/science/nuclear-chain-reaction.

"Nuclear Power in China." World Nuclear Association, January 2018. http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx.

"Nuclear Power in India." World Nuclear Association, October 2017. http://www.world-nuclear.org/information-library/country-profiles/countries-g-n/india.aspx.

"Nuclear Regulatory Commission Approves Construction of First Nuclear Units in 30 Years." Energy Information Administration, March 5, 2012. https://www.eia.gov/todayinenergy/detail.php?id=5250.

Nystuen, Gro. "Nuclear Umbrellas and Umbrella States." International Law and Policy Institute, April 2016. http://nwp.ilpi.org/?p=1221.

Nystuen, Gro, and Kjolv Egeland. "A 'Legal Gap'? Nuclear Weapons under International Law." Arms Control Association, March 2016. https://www.armscontrol.org/ACT/2016_03/Features/A-Legal-Gap-Nuclear-Weapons-Under-International-Law.

*O'Connor, JJ*. "John Von Neumann ", University of St Andrews, Scotland, October 2003. http://www-history.mcs.st-andrews.ac.uk/Biographies/Von_Neumann.html.

"Obama Prague Speech on Nuclear Weapons." Huffington Post, May 9, 2009. https://www.huffingtonpost.com/2009/04/05/obama-prague-speech-on-nu_n_183219.html.

Oi, Mariko. "The Man Who Saved Kyoto from the Atomic Bomb." BBC, August 2015. http://www.bbc.com/news/world-asia-33755182.

Oppenheimer, J Robert. "1965 Tv Broadcast." 1965. https://www.shmoop.com/quotes/become-death-destroyer-of-worlds.html.

Petrovsky, Vladimir. "Diplomacy as an Instrument of Good Governance." DiploFoundation, 1998. https://www.diplomacy.edu/resources/general/diplomacy-instrument-good-governance.

"Plans for New Reactors Worldwide." World Nuclear Association, January 2018. http://www.world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx.

"Protocol Additional to the Geneva Conventions of 12 August 1949." edited by International Red Cross, 8 June 1977. https://ihl-databases.icrc.org/ihl/INTRO/470.

Read, Russ. "Top Generals Warn the Us Nuclear Arsenal Is Dangerously Outdated." The Daily Caller News Foundation, March 2017. http://dailycaller.com/2017/03/08/top-generals-warn-the-us-nuclear-arsenal-is-dangerously-outdated/.

Reeves, Richard. *A Force of Nature: The Frontier Genius of Ernest Rutherford.* Great Discoveries. 1st ed. New York: W. W. Norton & Co., 2008.

"Rethinking Security: A Discussion Paper." The Ammerdown Group, May 2016. https://rethinkingsecurityorguk.files.wordpress.com/2016/10/rethinking-security-a-discussion-paper.pdf.

Rhodes, Richard. *Dark Sun : The Making of the Hydrogen Bomb.* Sloan Technology Series. New York: Simon & Schuster, 1995.

———. *Energy : A Human History.* First Simon & Schuster hardcover edition. ed. New York: Simon & Schuster, 2018.

———. *The Making of the Atomic Bomb.* New York: Simon & Schuster, 1986.

Richelson, Jeffrey. "Nuclear Terrorism: How Big a Threat? ." National Security Archive Electronic Briefing Book No. 388, Sept 2012. https://nsarchive2.gwu.edu/nukevault/ebb388/.

Rothman, Noah. "The Age of Nuclear Multipolarity." Commentary Magazine, Aug 2017. https://www.commentarymagazine.com/foreign-policy/nuclear-multipolarity-japan-north-korea/.

Ryabkov, Sergei, and Lassina Zerbo. "The Nuclear Test Ban: Time to Finish What We Started." The Diplomat, April 2017. https://thediplomat.com/2017/04/the-nuclear-test-ban-time-to-finish-what-we-started/.

Schneider, Mycle. "The World Nuclear Industry Status Report 2013." https://www.worldnuclearreport.org/World-Nuclear-Report-2013.html.

Schwartz, Stephen I. "The U.S. Nuclear Weapons Cost Study Project." The Brookings Institution, August 1, 1998. https://www.brookings.edu/research/u-s-nuclear-weapons-cost-study-project/.

Stern, Mark Joseph. "The Nuclear Theory of the Fall of the Ussr.", Slate, January 2013. http://www.slate.com/articles/health_and_science/nuclear_power/2013/01/chernobyl_and_the_fall_of_the_soviet_union_gorbachev_s_glasnost_allowed.html.

Tellis, Ashley J. "Strategic Asia 2013-14: Asia in the Second Nuclear Age." The National Bureau of Asian Research, October 2, 2013.

"The 2015 Long-Term budget Outlook." Congressional Budget Office, June 2015. https://www.cbo.gov/sites/default/files/114th-congress-2015-2016/reports/50250-longtermbudgetoutlook-4.pdf.

"The Economic Benefits of Nuclear Technologies." Management Information Services, March 1980. https://www.nrc.gov/docs/ML0037/ML003719644.pdf.

"The Prague Nuclear Agenda." The White House, January 11, 2017. https://obamawhitehouse.archives.gov/the-press-office/2017/01/11/fact-sheet-prague-nuclear-agenda.

"Thorium Fuel Cycle — Potential Benefits and Challenges." International Atomic Energy Agency, May 2005. https://www-pub.iaea.org/mtcd/publications/pdf/te_1450_web.pdf.

Truman, Harry S. *1945: Year of Decision.*

"Uranium Enrichment ". Nuclear Regulatory Commission, August 2017. https://www.nrc.gov/materials/fuel-cycle-fac/ur-enrichment.html#diffusion.

Wellerstein, Alex. "How to Die at Los Alamos." RESTRICTED DATA: The Nuclear Secrecy Blog, February 2015. http://blog.nuclearsecrecy.com/2015/02/13/how-to-die-at-los-alamos/.

———. "Inside K-25." RESTRICTED DATA: The Nuclear Secrecy Blog. http://blog.nuclearsecrecy.com/2013/05/24/inside-k-25/.

———. "The Price of the Manhattan Project." RESTRICTED DATA: The Nuclear Secrecy Blog, May 2013. http://blog.nuclearsecrecy.com/2013/05/17/the-price-of-the-manhattan-project/.

Wohlstetter, Albert. "The Delicate Balance of Terror." Foreign Affairs, January 1959. https://www.foreignaffairs.com/articles/1959-01-01/delicate-balance-terror.

Wright, Robin. "Russia and Iran Deepen Ties." The New Yorker, March 2, 2018. https://www.newyorker.com/news/news-desk/russia-and-iran-deepen-ties-to-challenge-trump-and-the-united-states.

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