AIR WAR COLLEGE

AIR UNIVERSITY

THE THIRD NUCLEAR AGE: HOW I LEARNED TO START WORRYING ABOUT THE CLEAN BOMB

by

James L. Denton, Lt Col, USAF

A Research Report Submitted to the Faculty

In Partial Fulfillment of the Graduation Requirements

Advisor: Dr. Grant T. Hammond

14 February 2013

Disclaimer

Biography

Lieutenant Colonel James L. Denton is a United States Airman. He holds a master's degree in nuclear engineering and is a graduate of the School of Advanced Air and Space Studies (SAASS). Colonel Denton has served as a security forces officer, bomber aviator, on two joint staffs, and commanded the POSSE (2d Operations Support Squadron)--the Best B-52 Squadron in the United States Air Force. He has fought in the air over Iraq as well as in the air and on the ground in Afghanistan. Upon graduation from the Air War College, he will serve as the nation directs.

Abstract

Fourth generation fusion nuclear weapons (FGNW) represent a significant improvement in nuclear weapons technology and suggest the potential for small, clean, low-yield nuclear weapons. These weapons will be difficult to monitor, present significant challenges to treaty verification, begin to approximate conventional explosives with nuclear effects, and are a potential deterrence destabilizer. FGNW threaten to lower the barrier for use by removing the largest impediment one typically encounters in contemplating the use of nuclear weapons, the long-term effects of fallout. The possible end of the non-use nuclear taboo, clean detonation, and blurring of the conventional-nuclear lines threaten to produce a Third Nuclear Age—a dawning of the regular use of nuclear weapons in conflict. FGNW represent a vast increase in what Thomas Schelling referred to as the "threat that leaves something to chance."

This paper is the result of research conducted for the Air Force's Blue Horizons program. Blue Horizons focuses on future challenges that the United States and its Air Force may face twenty-five years from now. This paper does not answer whether the fusion technology is possible and assumes it as an inevitable technological advancement. Instead, this study predicts a world in which low yield, clean fusion weapons exist and considers their implications.

In the interim, FGNW provide an opportunity to consider clean fission warheads as the technological traits correlate with one another. Clean fission weapons release magnitudes less radiation than previous fission-based weapons but still more radiation than FGNW. Further, clean fission weapons are already present and embraced by other nations as operational, warfighting weapons.

Introduction

Fourth Generation Nuclear Weapons (FGNW) threaten to blur the distinct line between the use of conventional and nuclear weapons as well as threaten a Third Nuclear Age in which the world could witness the regular use of nuclear weapons. Advancing technology, miniaturization, and advanced computer simulations create the potential for micro-nuclear weapons with one to one hundred ton yields and little residual radiation.[1] These combined traits make FGNW use attractive. Ultimately, the Third Nuclear Age will be the full realization of a Revolution in Military Affairs (RMA) as precision guidance, coupled with a clean nuclear detonation, overcomes the nuclear taboo and leads to ubiquitous use of nuclear weapons. This significantly lowers the threshold for nuclear weapons use and may fundamentally transform the world's approach to nuclear weapons.

This paper does not investigate the scientific feasibility of fusion-based weapons that are likely within two decades.[2] Instead, it assumes their future presence and contemplates the implications such weapons will have on policy and nuclear strategy.[3] During the First and Second Nuclear Ages, fission nuclear weapons were terrifying, but their presence promoted international and deterrence stability. Policy and strategy decisions reinforced this stability by insuring the US and USSR roughly understood each other's capability. In the Third Nuclear Age, FGNW present severe challenges by incentivizing use, which leads to instability.

Fusion Nuclear Weapons

Two nuclear detonations in August 1945 marked the dawn of the First Nuclear Age and a subsequent race between two key protagonists in developing and building ever-larger arsenals of devastating nuclear weapons. The next six decades saw these weapons' prominence rise and fall in international relations and military conflict. Nuclear weapons advanced in both quality and quantity. Weapons yield increased from atomic kiloton “block busters” to thermonuclear megaton “city destroyers,” while weapons stockpiles grew from tens to tens of thousands.

Although lagging slightly, nuclear weapons strategy and deterrence theory followed trends of weapons technology development. In the 1960s and 1970s, political leaders agreed that mutual suicide was not a credible bargaining positioning and sought less devastating options.[4] Ironically, the introduction of limited strike options in lieu of absolute mutual destruction inspired belief in the probability of use in opponents’ minds. With options short of total annihilation, the credibility of the nuclear threat was renewed.

In 1991, the Soviet Union fell; the First Nuclear Age abruptly ended; and a Second Nuclear Age dawned. Colin Gray states a “transformed political architecture of threat” marked this age.[5] It included a US hegemony and uncertainty “over the future of the US nuclear arsenal and nuclear strategy.”[6] As these dynamics changed, leaders believed the hopeful non-use taboo that developed in the first age would continue in the second, and nuclear weapons fell into relative neglect as political tools.[7]

As an alternative, nations sought parity in the technological advancement of conventional weapons. Some were convinced that the world held no place for nuclear weapons. This US-led information-enabled RMA suggested precise conventional weapons would replace nuclear weapons. This RMA marked a significant inflection point in strategic thought. However, no nation was quick to surrender its nuclear weapons, and governments maintained a distinct line between the use of conventional and nuclear weapons—a line marked by the level of devastation and long-term radiation effects.

Along with nuclear ages, nuclear experts refer to nuclear weapons designs through numbered generations. (There is no correlation between nuclear ages and nuclear generation designations.) First generation nuclear weapons are gun- and implosion-type weapons used at Trinity, Hiroshima, and Nagasaki. These designs are the suspected types used by North Korea.[8] Second generation weapons are thermonuclear weapons that use a fission primary explosion to drive a fusion secondary explosion to produce dramatic yields. Third generation weapons are weapons designed to yield specific effects, such as high rise time of gamma emission for a massive electromagnetic pulse or neutron weapons with antipersonnel effects.[9] Finally, the world is on the cusp of a markedly different fourth generation: fusion-only weapons that produce effects from a deuterium-tritium mix.[10]

Compared to fission reactions, fusion occurs remarkably efficiently and relatively cleanly. Efficiency is a measure of the amount of nuclear material consumed and turned into other forms of energy (shock, radiation, and heat). The first three weapons generations use fission to release energy from nuclear bonds with 25 to 50% efficiency.[11] This low efficiency requires more fissile material and a heavier weapon to obtain desired yields. This results in radiation-laden fallout from the unreacted fissile material and the now radioactive weapons components.

In contrast, FGNW are not only smaller, they also lack the same level of residual radioactive products. Fusion reactions produce a flux of neutrons, and these neutrons radioactively activate materials in the same way as fission neutrons.[12] However, FGNW lack a fission stage; therefore, fusion-only FGNW reactions do not have the same resulting radioactive fragments as fission reactions.[13] This makes the resulting problem orders of magnitude less severe.

Like previous generations of nuclear weapons, FGNW produce shock, thermal, electromagnetic pulse (EMP), and neutron effects that are useful on the modern battlefield.[14]

The first two effects are common with conventional weapons. The third and fourth are unique to nuclear weapons. Shock is advantageous against military and underground targets. Neutron radiation is detrimental to all life forms and to electronics. Both of which require significant shielding to protect against neutron radiation.[15] All four effects in a small package increase the appeal of FGNWs against targets for which one could consider either nuclear or conventional weapons, with the clean nature of fusion weapons tipping the scale in their favor. Andrew Marshall of the Office of the Secretary of Defense's Office of Net Assessment considers the small size and low yield of these weapons to be less important than the fact that the weapons are nearly clean, which lowers their threshold for use.[16]

Fortunately, the technology barrier for achieving these weapons will limit them to technologically advanced states. A number of nations are conducting research to create energy through fusion reactions by researching inertial confinement fusion (ICF) and magnetic confinement fusion (MCF). These fusion-specific research approaches are effectively dual-use civilian and military technologies. The ICF approach focuses on pulsed energy release, like that of nuclear weapons. Twelve countries are conducting ICF experiments ostensibly focused on power generation technology.[17] Seventeen nations are conducting MCF experiments, which are more suited for energy applications.[18] At ICF facilities, there is no distinction between what would be a *peaceful* and a *military* micro-explosion.[19] This is important as FGNW will be developed through fundamental and applied research along with sophisticated computer simulation but with only limited testing.[20] Even then, Dr. John Harvey, Principal Deputy Assistant to the Secretary of Defense, suggests it would be difficult to bring these weapons to fruition in a world that prohibits nuclear weapons testing.[21] The unanswered question is to what degree this testing is discoverable.

Limited testing and low yield are challenges to detection and enforcement. By restricting weapons testing, the goal of the Comprehensive Test Ban Treaty (CTBT) was to constrain the development of nuclear weapons and to eliminate the development of new advanced types of weapons leading to eventual nuclear disarmament.[22] Nevertheless, there is not a perceived limitation in the development of fusion-only weapons, as the CTBT does not appear to prohibit fusion research. Even if prohibited, it would be difficult to detect a small yield FGNW with present sensors. Additionally, a Department of Energy report states that ICF "does not constitute a nuclear explosive device within the meaning of the NPT or undertakings in IAEA safeguard agreements against diversion to any nuclear explosive device."[23]

As fusion research is a dual-use technology, it will likely proliferate. Assuming a similar proliferation of associated FGNW technology, creating FGNW is a step towards nuclear weapons proliferation without the extensive infrastructure associated with today's fission weapons. As a result, the world runs the risk that certain countries will equip themselves directly with FGNW, bypassing the acquisition of previous generations of weapons.[24] This is not unlike the adaptation of cell phone technology by nations that skipped the installation of landlines along with the associated cost of infrastructure. Already, counter proliferation is a demonstrably challenged philosophy with non-nuclear nations seeking their own weapons or threatening to leave the reassuring umbrella of nuclear-armed states. Considering the possible proliferation of FGNW technology, there is a substantial chance of the present dyadic nuclear relationships shifting to multipolar nuclear relationships.

The possible development of fusion weapons and associated proliferation challenges led Nobel Prize recipient Hans Bethe in 1997 to urge President Clinton to ban investigating "new types of nuclear weapons, such as pure-fusion weapons."[25] In order to realize Dr. Bethe's vision, there would need to be preventive measures such as legally binding restrictions on relevant areas of fusion-only weapon research.[26] Even were such restrictions in place and enforceable, significant research into clean weapons has already occurred, and Russia appears now to be investigating development of a new generation of clean nuclear weapons, to include fusion-only weapons.[27]

The Third Nuclear Age and Policy Implications

FGNW represent a "new arena of nuclear competition" and are a new challenge to the way in which nations consider deterrence.[28] Clean nuclear weapons threaten to usher in a Third Nuclear Age in which the regular use of clean nuclear weapons becomes likely. This age may see the regular use of FGNW as nations use conventional weapons today. Marshall warns that with FGNW and clean fission weapons, "The long period of non-use is likely to end. If so, this will lead to a recalibration of other countries' perspective on nuclear weapons, and increase the desirability and risks in having them. This is a huge psychological difference. The next use is what we are trying to avoid."[29]

The increased probability of clean nuclear weapon use is not new. The debate resembles that focused on neutron bomb development during the '50s and '60s. Samuel Cohen, the father of the neutron bomb, argued that the clean neutron weapon would be invaluable during limited wars.[30] Concerning the next evolution of clean weapons, in a prescient 1960 *Foreign Affairs* article, Freeman Dyson, Professor at Princeton's Institute for Advanced Study, predicted,

> [A fusion weapon] would not be 100-percent clean. It would contaminate the countryside enormously less than existing fission or hydrogen bombs, but this is not its main advantage. The decisive advantage of a fission-free bomb is that it could be built economically in small sizes. … There seems to be no law of nature forbidding the construction of fission-free [fusion] bombs. The question remains whether this theoretical possibility is likely soon to be realized.[31]

As Dyson noted over five decades ago, there is no law prohibiting fusion weapons. These weapons are scientifically feasible but technically challenging. In fact, the absence of a law prohibiting a physical principle is a tacit license for its pursuit, eventual realization, and subsequent maturation.[32]

The most significant burden to the use of nuclear weapons is the long-term fallout associated with fission-based weapons. As Dyson mentioned, though not completely clean, the radiation effects of fusion weapons are limited and far less polluting than fission-based neutron weapons.[33] Harvey concurs by noting that FGNW are point radiation weapons meaning the radiation is highly localized.[34]

Because of the clean yield, FGNWs and clean fission weapons are a sustained area of investigation for Russian scientists and are complementary to Russian military strategy. According to Sergei Rogacheve, Deputy Director of the Arzamas-16 nuclear weapons design laboratory: "Russia views the tactical use of nuclear weapons as a viable alternative to advanced conventional weapons."[35] To that end, Russia has already embraced low yield, low radiation "clean" nuclear weapons as operational warfighting weapons with possible use on their own soil.[36] Even before the end of the Cold War, the USSR engaged in low-yield weapons design. The last Soviet nuclear warhead designed was an enhanced radiation device with a total yield of only 300 tons.[37] This push for low-yield, usable nuclear weapons is a direct counter to a perceived US asymmetric advantage in technologically advanced conventional weapons.

While the US considers nuclear weapons to be instruments of policy, Russia considers them warfighting weapons. For Russia, the limited use of nuclear weapons is acceptable, even prescribed in doctrine.[38] Russian military doctrine prescribes the first use of nuclear weapons beyond that declared by any other nuclear power.[39] Senior Russian military officers advocate for the use of precise, low-yield nuclear weapons in Russian military journals.[40] In addition, they openly discuss nuclear weapons use in local and regional conflicts as a balance to weak Russian conventional forces.[41] This doctrinally enshrined embrace of the operational use of nuclear weapons becomes even more likely should Russia possess a clean nuclear weapon.

Russian military leadership also advocates for nuclear warfighting capability useable across broader conflict spectrum. Former Russian Deputy Commander in Chief of the Strategic Rocket Forces Muravyev advocated for strategic missile systems capable of conducting "surgical strikes" across a spectrum of targets at various ranges and with "minimal ecological consequences."[42] This strategy fits perfectly with low, clean yield FGNW. Considering Russia's embrace of low-yield fission weapons, access to clean fusion weapons is an additional incentive for use—even on Russian soil.

In addition to stark differences between the US and Russia regarding likely use, unlike Russia, the US has failed to embrace new nuclear weapon designs. Those in opposition note that new, cleaner, low-yield weapons are more likely to lead to the US using them. Opponents successfully lobbied against the US's proposed Robust Nuclear Earth Penetrator by stating the low yield of the weapon also increased the likelihood of use.[43] Even upgrading current weapons is a challenge. The National Nuclear Security Administration's Steve Goodrum described a reluctance to add a new, more accurate tail kit to the B61 nuclear bomb that would thereby allow for a lower yield. The principle concern was that a lower yield would increase the likelihood of use.[44]

Deterrence Theory and Nuclear Strategy Revisited

Colin Gray notes that strategic history is cumulative and not serial.[45] This thought highlights the impact of history and technology on deterrence thinking and strategy. With the advent of FGNW, the fundamental underpinnings of deterrence remain the same, and the nature of war is unchanged. What is different is the likelihood of increased use of nuclear weapons to punish or compel. Given the possible introduction of FGNW within two decades, this leads to several questions regarding the likelihood of use, incentive for first use, nature of nuclear strategy, present verification challenges, and attribution difficulty.[46] The marked changes in these five categories distinguish the Third Nuclear Age. Table 1 summarizes the characteristics of the three nuclear ages.

Traits	First Nuclear Age	Second Nuclear Age	Third Nuclear Age
Number Nuclear Nations	Two Major/Six Minor	Nine with a possible tenth (Iran) joining soon	A score or more
Likelihood of Use	Only one nation used	Nuclear taboo and embrace of advanced conventional capability	Highly likely to use
Quantity	Tens of Thousands	Thousands	Tens of thousands
Deterrence Stability	Stable	Stable	Likely unstable
Treaty Verifiable	Yes…	Yes	Unlikely
Nuclear Relationships	Dyadic	Unipolar shifting to multipolar	Multipolar
Strategy Focus	Counterforce/ Counter value	Counterforce	Both…massive disruption
Yields	Tens of kilotons transitioning to megatons	Megatons or less (several hundred kilotons)	One to one hundred tons
Effects	Shock, heat, & massive, persistent radiation	Shock, heat, & massive, persistent radiation	Coupled shock, heat, & minimized radiation

Table 1. Characteristics of the Three Nuclear Ages

In the Third Nuclear Age, deterrence with FGNW still applies as these weapons can punish transgressions and deny the advantage of an attack. As FGNW are closely equivalent to conventional weapons, there is a dramatic increase in the probability of their use as first strike or retaliatory weapons. This has implications to deterrence and deterrence stability.

Deterrence stability hinges upon the ability to retaliate. Deterrence is stable when one is confident in the ability to *respond* to an attack—that is the survivability of a retaliatory force.

Thomas Schelling noted it is not "the efficient *application* of force but on the *exploitation of potential force*" that convinces an enemy to not strike.[47] Latent force is key, and one bargains with latent power in order to convince an opponent that some other possible outcomes are undesirable. It is the threat that leaves something to chance.[48]

Kenneth Waltz elaborated on deterrence stability by noting that war is less likely if adversaries understand their relative strengths.[49] The calculus of nuclear war is unlike that of conventional conflicts. The errors in calculus cause war, especially when one nation believes it can achieve an affordable victory and the other side believes it can escape defeat.[50] The ability to act if attacked causes uncertainty in an opponent's mind.[51] That incalculable uncertainty is what makes deterrence stable. Opponents will engage in war if the likelihood of defeat is low and then only if success results in minimal negative consequences.[52] Removing uncertainty in an opponent's mind as to his assured fate should he initiate a nuclear war is a sure method to prevent one.

Is this, however, the same with FGNW? What is certain is that these weapons have significant deterrence stability implications as the clean nature of FGNW increases the likelihood of their use. In addition to the Russian doctrine of low-yield weapon use to counter superior conventional forces, Russia formally adopted a nuclear escalation doctrine that characterizes the introduction of nuclear weapons into a conventional conflict as "de-escalation" of the conflict.[53] A declassified CIA report states: "Recent statements on Russia's evolving nuclear weapons doctrine lower the threshold for first use of nuclear weapons and blur the boundary between nuclear and conventional warfare. Very low-yield nuclear weapons reportedly could be used to head off a major conflict and avoid a full-scale nuclear war."[54] In Russia's case, weapons are operational warfighting weapons. Former Russian Atomic Energy Minister Mikhaylov wrote that a new generation of ultra low-yield nuclear weapons would implement the Russian strategy, and Russia should be clear that these weapons would be used in future limited conflicts.[55]

In addition to their likelihood of use, the increased capability and large numbers of FGNW leads to incentive for first use against an opponent, which affects deterrence stability. Unlike with conventional weapons, a precisely delivered FGNW can both destroy a hardened nuclear silo and deliver localized, short-term high-energy neutron radiation that overcomes radiation hardening and damages electronic components.[56] The near total destruction of one nation's nuclear arsenal may lead to retaliation with the remaining fourth generation or thermonuclear weapons. Even more disconcerting is the concern of possible outright destruction of a nation's retaliatory ability. This concern triggers a circular logic of unacceptable consequences that drives both sides to consider preemptive strikes.

With precise FGNW, one could achieve greater effect on a small target or greater area effects with massive numbers of weapons by using a combination of shock and high-energy neutron radiation. This ability holds at risk large or hard and deeply buried targets in ways different from before. FGNW can deposit a massive amount of radiation into a target that produces a shockwave *directly in* the target.[57] This is more effective than creation of a shockwave external to a target that then moves through another medium (air or ground) to the target. Present nuclear weapons transmit less than 10% of total shock energy to a target. In contrast, a FGNW can directly transmit as much as 50% of its shock energy.[58] Specialized third generation fission nuclear weapons can produce similar effects but are not as clean as FGNW.

The resulting vulnerability of a hardened response force may force a reconsideration of the present makeup of nuclear forces. This may lead to a focus on a well-dispersed deterrence force consisting of frequently moving mobile missiles and submarine launched ballistic missiles.

Fixed airfields would be especially vulnerable during a no-notice strike, and this may lead to a frequent repositioning of dispersed bombers or a revisit of the nuclear bomber alert posture. Ultimately, FGNW capability is likely to lead nations to move away from fixed, hardened nuclear forces and toward dispersed, mobile nuclear forces that are more difficult to detect and destroy.

Additionally, the possible use against space-based assets becomes much greater. Present attacks against space-based assets are precise kinetic strikes with resulting extensive debris fields. Nations avoid the use of fission-based nuclear weapons as these weapons result in the pumping of electron radiation into the Van Allen belts, which destroys all nations' low earth orbit and some medium earth orbit satellites.[59] FGNW, unless specifically designed to do so, do not have the equivalent challenges. The resulting short-term neutron radiation is somewhat localized and effective against individual satellites, and the deposit of electron radiation into the Van Allen belts is limited. The result is an anti-satellite weapon capable of destroying individual satellites without creating a hazardous debris field for other satellites. This discriminate capability makes space-based warfare more likely.

The Third Nuclear Age's potentially increased use of nuclear weapons also has nuclear strategy implications. To date nuclear strategy dealt with two broad categories: type of target (counter value or counter force) and mass of response.[60] In one regard, an FGNW is an optimal counter value weapon in that along with the low explosive yield, it delivers massive high-energy neutron radiation that is particularly effective against people. This is a revisit of the neutron weapon. FGNW are also effective against hardened or deeply buried forces, which lends to a counterforce strategy. What is likely is a combination of the two, with a focus on massive salvos of low-yield weapons overwhelming a target country with multiple warheads dedicated to each target. While invoking images of multiple independently targetable reentry vehicles (MIRVs), the approach with FGNW would be slightly different. After reentry, the MIRV could dispense several FGNW in a fashion similar to a cluster bomb. Several small FGNW weapons striking a target may be more effective than a single megaton-class nuclear weapon and with magnitudes less radiation.

This marks a new approach to nuclear strategy. Before FGNW, nuclear weapons were not precision weapons. They were weapons with limited precision and long-term radiation effects resulting in huge numbers of deaths that included people downwind from the blast. Even the second-order genetic effects lasted for generations. FGNW may become the common artillery shells and bombs of the future and allow low-yield nuclear strikes on targets en mass. As Freeman Dyson noted, one of the attractive characteristics of fusion weapons is the ability to produce them economically in large numbers.[61] This also leads to their likely use as warfighting weapons. The Gulf War and following conflicts demonstrated the efficacy of precision conventional weapons. Precise delivery combined with FGNW may be the true realization of the suggested RMA in the 1990's. The small size, coupling effects, localized radiation, and multiple weapons per target may be better than one large nuclear weapon.

The utility of FGNW goes beyond nuclear targets and broadens to non-nuclear targets with a focus on *strategic effect* and not *strategic (nuclear) weapons.* The ability to destroy effectively large portions of a nation's economic structure, its political leadership, and/or warfighting capability would lead to a massive systemic disruption without the first-order massive casualties of a fission weapon-based exchange.[62] The resulting warfighting theme may move beyond *mass destruction* and concentrate on *mass disruption* with a focus on attacks against political leadership, economic targets, and military command and control. Combined with a high-altitude nuclear detonation and resulting electromagnetic pulse, the combination punch would have long-term, disruptive impact on a nation.[63]

When combined with rapid, global strike delivery platforms, FGNW make decapitation strikes more likely and effective. Leadership groups are especially vulnerable. Striking political or military leadership is lucrative and can have effects at the tactical, operational, or strategic levels of war.

Verifying the numbers of FGNW is especially challenging. The small size of FGNW make them easy to conceal. Further, the weapons do not require the extensive infrastructure associated with special nuclear materials like refined uranium or reactor-breed plutonium.[64] A nation producing FGNW will have the ability to separate deuterium and tritium and will likely have an advanced physics program.[65] However, these characteristics do not necessarily lead to having FGNW and are not indications of the number of weapons a nation may possess. Despite this, one must entertain that these nations have a latent ability to be a fourth generation nuclear powers.

Additionally, while historically a good measure of nuclear warfighting ability, counting traditional nuclear delivery vehicles will not indicate a nation's FGNW capability. Some present methods of verification rely upon counting bombers, missiles, and submarines. These systems are the modern equivalent of dreadnaught battleships—easy to count and with known capabilities. The ubiquitous and less complex nature of FGNW will lead to their mating on numbers of common weapon systems. This weapons system agnostic approach to delivery opens a vast number of possibilities previously unconsidered and exponentially increases potential targets. The inability to verify numbers of weapons and the absence of an associated nuclear infrastructure is problematic for counter proliferation efforts.

In addition to verification challenges, there will be a difficulty in attributing attacks. The inability to attribute creates serious implications for the US. The ionizing radiation in present fission-based nuclear weapons facilitates detection. Additionally, certain traits of nuclear components leave “fingerprints” that can assist in the attribution of nuclear weapons.[66] In contrast, FGNW are not likely to have either the ionizing radiation or the distinct fingerprints characteristic of fission weapons. This also makes FGNW attractive for unfriendly nations and an overall challenge to mutual trust.

Additionally, the inability to verify weapon numbers or attribute detonations pose significant challenges in the hands of non-state actors. One present method to ensure weapons remain out of the hands of terrorists is the ability to attribute a weapon to the nation providing it.[67] FGNW will be difficult to detect and attribute, making them a terrorist’s dream weapon. FGNW could be strategically pre-placed and await command detonation; the result is massive numbers of difficult to detect, pre-planted, command detonated, un-attributable, long-term latent nuclear devices.

Unfortunately, one cannot just consider the threat of clean nuclear weapons to be a pair-match between the US and Russia; the relationship will instead be multipolar. FGNW could be more common as nations pursue fusion power research. It is challenging to limit fusion research and development as it is a distinctly dual-use technology. Attempts to limit fusion technology to civilian-only use may be pointless. Futurist Peter Scott-Morgan notes that in an era characterized by increased globalization, digitization, miniaturization, networking and simulation, the spread of the science, technology and weaponry is virtually guaranteed.[68]

The sharing of fusion technology will likely result in increased access to FGNW. Fusion weapons will be easier and cheaper to produce as the technology for doing so proliferates. If the technology is not shared, the result will still be a world of *haves* and *have not's*. In the Third Nuclear Age, nations with FGNW may no longer see a need for fission-based nuclear weapons and dismantle their inventories. However, fusion weapons will not lose their attractiveness to those who cannot produce them. Nations not possessing FGNW may perceive an asymmetric weakness and look for a counter in the same way they presently search for a balance against the US's superior conventional capabilities. The result may be a new arms race of *fission* weapons by *have not* nations.

Conclusion

As the world inches toward fusion technology, fusion weapons are a natural step along the way. Fusion weapons are likely to predate fusion power as one only needs to obtain a yield from a fusion reaction rather than to sustain it. Once achieved, FGNW will forever end the notion that *nuclear* equals *strategic* as these weapons become common warfighting tools. This frequent use of FGNW marks the Third Nuclear Age with characteristics different from the previous two.

In this new age, the number of nuclear nations threatens to increase as dual-use fusion technology leads to multiple FGNW-capable nations. Those nations deprived of fusion technology and FGNW will likely spawn a new fission arms race as they look for a counter capability with fission nuclear weapons as the likely candidate.

The nature of deterrence remains unchanged in the Third Nuclear Age, and the likelihood of deterrence by punishment is increased. A fission-based strike and counterstrike would lead to massive destruction and radiation-wasted land for both combatants. This ultimately denied any advantage to using nuclear weapons. FGNW do not have the same radiation burden, and deterrence in the Third Nuclear Age will be by punishment. The increased likelihood of use, the low radiation burden, and the conventional-like results naturally lead to the use of FGNW without the long-term effects.

In the anticipated two-decade lead up to the Third Nuclear Age, the US has an opportunity to shape this age. First, the US must recognize that the world is on the cusp of FGNW and investigate policy and treaty protocols in anticipation of their development. That investigation must include the present generation of clean fission weapons already deployed and considered tactical warfighting weapons. As mentioned, the discussion of FGNW is a useful surrogate for considering the present generation of Russian clean fission weapons.

Next, the US must lead the world in reducing the number of tactical nuclear weapons. The opportunity to do this is in the next round of nuclear arms reduction discussions. New START limited strategic nuclear weapons and left tactical weapons untouched. As reflected in Russian warfighting doctrine, the world is in greater danger of a nuclear conflict initiated with tactical nuclear weapons than with strategic nuclear arsenals. It is under the umbrella of tactical nuclear weapons that FGNW will likely reside.

Ultimately, the best way for the US to contend with the arrival of FGNW is to lead in their development. The failure to investigate the consequences of these weapons in the hope that they will not be realized is wishful thinking. As was the case with fission weapons, once the first nation develops FGNW, others will soon follow. By aggressively investigating fusion technology and FGNW now, the US has a greater freedom of action in future military and diplomatic efforts. Otherwise, the US will find itself in a position of intolerable weakness in negotiations and conflicts. The US relies heavily on its advanced conventional capability and may find itself at a distinct disadvantage against a similarly capable opponent, armed with FGNW, and backed by thermonuclear weapons.

The development of FGNW is simply a matter of time—it is not a question of if, but when. When FGNW become a reality, they will cause significant instability in and fundamentally transform the nature of the international system. Thinking about the consequences of such a world and the policy options to deal with it are prerequisites to developing an appropriate national security strategy.

Notes

All notes appear in shortened form. For full details, see the appropriate entry in the bibliography.

[1] A way to conceptualize the yield of FGNW and present conventional weapons is to consider that the standard Joint Direct Attack Munition (JDAM) is a two thousand pound weapon of which half is explosive weight. Thus, at the lowest end a FGNW would have the explosive equivalent to two, 2,000-pound JDAMs. At the high end of 100 tons yield, it would be roughly equivalent to eight fully loaded B-1 bombers.

[2] Gsponer states that the ignition of thermonuclear pellets in inertial confinement facilities (ICF) is possible within a decade. He admits that weaponizing this reaction is a "formidable technical challenge." Gsponer et. al., *The Physics of Thermonuclear Explosives*, 12.

[3] There are other possible avenues of producing FGNW. Some sources include transplutonic and super heavy element weapons in the category of FGNW. This paper omits these from consideration as they are still fission-based reactions and yield substantial fallout.

[4] This era also marked significant negotiation on arms control resulting in several treaties: Partial Test Ban Treaty (1963), Outer Space Treaty (1967), Strategic Arms Limitation Treaty (SALT I, 1972), Ant-Ballistic Missile Treaty (1972), Threshold Test Ban Treaty (1974), and the Strategic Arms Limitation Treaty (SALT II, not entered into force).

[5] Gray, *The Second Nuclear Age*, 22.

[6] Ibid., 22, 39, and 41.

[7] For a discussion see Nina Tannenwald's *The Nuclear Taboo*, 8-11.

[8] Nuclear Weapons Archive, "North Korea's Nuclear Weapons Program."

[9] Gsponer et. al., *The Physics of Thermonuclear Explosives*, 105.

[10] Deuterium, commonly known as heavy water, is an abundant, stable isotope of hydrogen. Tritium is a radioactive isotope of hydrogen. Deuterium and Tritium are the fuel sources for fusion reactions, and the resulting reaction produces a large number of high-energy neutrons.

[11] Nuclear Weapons Archive, "Section 2.0."

[12] There is also a radiation released in the form of x-rays.

[13] Bridgman, *Introduction to the Physics of Nuclear Weapons Effects*, 171-172.

[14] Gsponer et. al., *The Physics of Thermonuclear Explosives*, 45.

[15] Glasstone, *The Effects of Nuclear Weapons, Third Edition*, 325.

[16] Marshall, interview with the author.

[17] Nations conducting ICF experiments include China, Czech Republic, France, Germany, India, Israel, Japan, Russia, South Korea, United Kingdom, and the United States. Taken from Wood, "Fourth Generation Nuclear Weapons," 5.

[18] Nations conducting MCF experiments include Australia, Brazil, Canada, China, Czech Republic, France, Germany, India, Italy, Japan, Portugal, South Korea, Spain, Sweden, Switzerland, United Kingdom, and the United States. Taken from Wood, "Fourth Generation Nuclear Weapons," 5.

[19] Gsponer et. al., *The Physics of Thermonuclear Explosives*, 137.

[20] Ibid., *The Physics of Thermonuclear Explosives*, 105.

[21] Harvey, interview with the author.

[22] Comprehensive Test Ban Treaty Organization, "Comprehensive Nuclear Test Ban Treaty,"1-2.
[23] Office of Arms Control and Nonproliferation, *The National Ignition Facility (NIF) and the Issue of Nonproliferation—Draft Study,* Section E.
[24] Gsponer et. al., *The Physics of Thermonuclear Explosives*, vi.
[25] Bethe"Letter to President William J. Clinton."
[26] Gsponer et. al., *The Physics of Thermonuclear Explosives*, vi.
[27] Marshall, interview with the author.
[28] Wood, "Fourth Generation Nuclear Weapons," 9.
[29] Marshall, interview with the author.
[30] Macgraw, "Teller and the the 'Clean Bomb' Episode," 32-37.
[31] Dyson, "The Future Development of Nuclear Weapons."
[32] Kaku, Michio, *Physics of the Future,* 9-11.
[33] Dyson, "The Future Development of Nuclear Weapons."
[34] Harvey, interview with the author.
[35] Central Intelligence Agency, "Evidence of Russian Development of New Subkiloton Nuclear Warheads," 3.
[36] Ibid., 4. The Peaceful Nuclear Explosions (PNE) initiative investigated the use of clean nuclear weapons for civilian projects such as building harbors.
[37] Central Intelligence Agency, "Evidence of Russian Development of New Subkiloton Nuclear Warheads," 1.
[38] Defense Science Board, *The Nuclear Weapons Effects National Enterprise,* 3.
[39] Schneider, *The Nuclear Forces and Doctrine of the Russian Federation,* 1.
[40] Central Intelligence Agency, "Evidence of Russian Development of New Subkiloton Nuclear Warheads," 3.
[41] Schneider, *The Nuclear Forces and Doctrine of the Russian Federation,* 1.
[42] Central Intelligence Agency, "Evidence of Russian Development of New Subkiloton Nuclear Warheads," 3.
[43] Goodrum, interview with the author.
[44] Ibid., interview with the author.
[45] Gray, *The Second Nuclear Age,* 9.
[46] This paper is an effort to deal with the most salient questions. The author understands there are additional unasked questions.
[47] Schelling, *The Strategy of Conflict*, 5; emphasis in the original.
[48] Schelling, *The Strategy of Conflict*, 187.
[49] Sagan, *The Spread of Nuclear Weapons: A Debate*, 6.
[50] Ibid., 6.
[51] Ibid., 22-25.
[52] Ibid., 7.
[53] Schneider, *The Nuclear Forces and Doctrine of the Russian Federation,* 1.
[54] Central Intelligence Agency, "Evidence of Russian Development of New Subkiloton Nuclear Warheads,"1.
[55] Schneider, *The Nuclear Forces and Doctrine of the Russian Federation,* 20-21.
[56] Glasstone, *The Effects of Nuclear Weapons, Third Edition,* 346-350.

[57] Gsponer, *Fourth Generation Nuclear Weapons: Military Effectiveness and Collateral Effects*, 31.

[58] Ibid., 31-34; specifically designed third generation fission nuclear weapons can have similar effects.

[59] Foster, *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack*, 162.

[60] Freedman, *The Evolution of Nuclear Strategy*, 120-128. Counter value refers to targeting those things on which a nation places substantial value, most often this is the population. Counterforce describes targeting the warfighting forces, most often nuclear forces.

[61] Dyson, "The Future Development of Nuclear Weapons."

[62] Massive second order casualties from the disruption of services is highly likely.

[63] For a discussion of the systemic effects of an electromagnetic pulse (EMP) strike, see the *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack*. For a fictionalized account of the consequences of an EMP strike, see William Forstchen's *One Second After*.

[64] The process of creating these materials as well as methods of nuclear weapon construction lends identifiable characteristics to nuclear weapons.

[65] It requires a nuclear reactor to produce tritium. Or, one can purchase tritium as it is not a material regulated by treaty.

[66] Greene, "Fingerprinting Nukes."

[67] House, *Nuclear Forensics and Attribution Act*.

[68] See Scott-Morgan, *The Reality of Our Global Future*.

Bibliography

Bethe, Hans A. "Letter to President William J. Clinton," 25 April 1997. *Federation of American Scientists.* http://www.fas.org/bethecr.htm (accessed December 21, 2012).

Bridgman, Charles J. *Introduction to the Physics of Nuclear Weapons Effects.* Ft Belvoir, VA: Defense Threat Reduction Agency, 2001.

Central Intellience Agency. "Evidence of Russian Development of New Subkiloton Nuclear Warheads." *Central Intelligence Agency, FOIA*, 30 August 2000. http://www.foia.cia.gov/docs/DOC_0001260463/DOC_0001260463.pdf (accessed 23 December 2012.).

Comprehensive Test Ban Treaty Organization. "Comprehensive Nuclear Test Ban Treaty." http://www.ctbto.org/fileadmin/content/treaty/treaty_text.pdf (accessed 12 November 2012).

Defense Science Board. *The Nuclear Weapons Effects National Enterprise.* Washington D.C.: Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, 2010.

Dyson, Freeman J. "The Future Development of Nuclear Weapons." *Foreign Affairs*, 1960.

Foster, Jr. John S., et. al. *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack.* Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack, 2008.

Freedman, Lawrence. *The Evolution of Nuclear Strategy.* New York, NY: Palgrave MacMillan, 2003.

Glasstone, Samuel and Philip J. Dolan. *The Effects of Nuclear Weapons, Third Edition.* Washington D.C.: United States Department of Defense and Department of Energy, 1977.

Goodrum, William S. (Assistant Deputy Administrator for Stockpile Management, National Nuclear Security Administration), interview with the author, 27 November 2012.

Gray, Colin S. *The Second Nuclear Age.* London: Lynne Rienner Publishers, 1999.

Greene, Robert L. “Fingerprinting Nukes,” 16 February 2010. http://www.economist.com/blogs/democracyinamerica/2010/02/nuclear_attribution (accessed 03 February 2013).

Gsponer, Andre and Jean-Pierre Hurni. *The Physics of Thermonuclear Explosives, Inertial Confinement Fusion, and the Quest for Fourth Generation Nuclear Weapons.* Geneva, Switzerland: Independent Scientific Research Institute, 2009.

Gsponer, Andre. *Fourth Generation Nuclear Weapons: Military Effectiveness and Collateral Effects.* Geneva, Switzerland: Independent Scientific Research Institute, 2008.

Harvey, John (Principal Deputy Assistant to the Secretary of Defense for Nuclear and Chemical and Biological Defense Programs, Office of the Secretary of Defense), interview with the author, 20 December 2012.

House, *Nuclear Forensics and Attribution Act*. 111th Cong., 2nd sess., 2010, HR 730, Government Printing Office. http://www.govtrack.us/congress/bills/111/hr730/text (accessed 13 February 2013).

Kaku, Michio. *Physics of the Future.* New York: Random House, 2011.

Macgraw, Katherine. "Teller and the the ‘Clean Bomb’ Episode." *Bulletin of Atomic Scientists* (1988): 32-37.

Marshall, Andrew (Director, Office of Net Assessment, , Office of the Secretary of Defense) interview with author, 26 November 2012.

Nuclear Weapons Archive. *Introduction to Nuclear Weapon Physics and Design.* 20 February 1999. http://nuclearweaponarchive.org (accessed 03 February 2013).

Office of Arms Control and Nonproliferation. *The National Ignition Facility (NIF) and the Issue of Nonproliferation—Draft Study*. Washington D.C.: Department of Energy, 1995. http://www.osti.gov/news/docs/nif/front.htm (accessed 24 December 2012).

Sagan, Scott D. and Kenneth N. Waltz. *The Spread of Nuclear Weapons: A Debate.* New York, NY: W.W. Norton and Company, 1995.

Schelling, Thomas C. *The Strategy of Conflict.* Cambridge, MA: Havard University Press, 1980.

Schneider, Marc. *The Nuclear Forces and Doctrine of the Russian Federation.* Fairfax, VA: National Institute Press, 2006.

Scott-Morgan, Peter B. *The Reality of Our Global Future.* Charleston, SC: CreateSpace Independent Publishing Platform, 2013.

Wood, Jason D. "Fourth Generation Nuclear Weapons: Moving the Nuclear Debate Beyond Fission." Presented at the Spring 2009 Conference United States Naval Academy. Annapolis, MD, 27 March 2009.