IMPACT OF FUTURE TECHNOLOGY ON WARFARE: ADVANCED NUCLEAR WEAPONS

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Introduction

In the past, science fiction had fired the imagination of potential inventors, which led to the development of new technologies by them. For example, Jules Verne in his classic "Twenty Thousand Leagues Under the Sea" imagined a great underwater ship called the Nautilus, which inspired American inventor, Simon Lake to invent his own submarine. H.G.Wells first broached the idea of atomic power in his 1913 novel, "The World Set Free". His vision inspired scientist Leo Szilard, twenty years later, to create a nuclear reaction, which led to the Atom Bomb. In the past, there used to be a prolonged gap between the imagination, realization of technology and its widespread availability.

However, in today's global information age, globalization and the information revolution, including the Internet and other communication leaps - have led to much greater visibility into the availability and potential for science and technology. Science will continue to enable new technological developments becoming accessible and affordable to a large number of nations and as a consequence - advanced technology is no longer the domain of the few.

As new and unpredicted technologies are emerging at a seemingly unprecedented pace globally, communication of those new discoveries is occurring faster than ever. They are becoming readily available. The emerging fields within cutting-edge science and technology include: robotics and autonomous unmanned systems, artificial intelligence, bio-weapons, precision technology, directed energy weapons, space - based weapons platforms, advanced nuclear weapons and so on.
In contrast to the bulky nuclear devices of 1950s or even during the Cold War, nuclear weapon design is several generations in advance now. A wide variety of nuclear weapons exist and they have been developed in all sizes from the smallest 'micro nukes' with yields measuring in hundreds of tonnes of TNT equivalent up to truly monstrous two and three stages bombs with yields of millions of tonnes of TNT equivalent (mega-tonnes or MT). The small yield and limited destruction capability of these so called mini- and micro-nukes means it is possible to keep their use secret. Now that advanced nuclear weapons have become or soon becoming part of modern conflict, it is imperative that we must understand about their characteristics, effects and employment.

In this paper, it is proposed to study and analyse the impact of 'Advanced Nuclear Weapons' on the future of warfare. The subject is being covered under the following heads:-

2. Third Generation Nuclear Weapons.
5. Prospects and Implications of FGNWs.

Evolution of Nuclear Weapons: First and Second Generations

The first generation nuclear weapons are those based on nuclear fission chain reaction in which atoms of Uranium-235 or Plutonium-239 are split by neutrons, resulting in the release of stupendous quantity of energy - roughly equal to that produced in the detonation of thousands of tons of TNT. The release of so much energy in so small a space results in a temperature at the instant of burst, measured in millions of degrees. The fission products, and the bomb shell as well, are vaporized instantly. The formation of a large mass of gaseous matter in a small space and in microseconds (millionths of a second) gives rise to an enormous pressure - which results in origination of shock wave that produces physical damage. An atomic bomb burst also produces a brilliant flash of light that burns and melts all objects near the point of explosion.²

In the original first generation solid core fission device called the 'Atom Bomb', developed during World War II, a solid core Plutonium pit was
compressed to less than 75 percent of its original size in order to create a critical mass. Approximately 5000 lbs of high yield explosives and 32 shaped charges were used to shock compress about 10 kg of Plutonium. Only about 1 to 2 kg of Plutonium was fissioned off before final disintegration of the nuclear core occurred. The remainder 80 to 90 percent of the unfissioned material resulted into fallout. Solid core fission devices are very inefficient due to the fact that about 90 percent of the fissionable material is used as a neutron multiplier and it is only 10 to 20 percent of the nuclear core that produced the explosive blast effect. This is why solid core nuclear weapons are no longer used. They are very large and bulky in size and require a sophisticated multi-point, electronically controlled, shaped charge implosion system to function properly and create large amounts of fallout.\(^3\)

Due to the problem of aging with Plutonium, after about 16 to 32 years, the Plutonium pit has to be remanufactured, which is a costly and toxic process. So it was considered to be cheaper and easier to keep making new pits and worry about recycling the older junk warheads later. Uranium-235 based weapons do not have an aging problem as they are good for over 100 years. Plutonium route was chosen simply because four times more Plutonium-239 could be produced as compared to enriched Uranium-235, meaning more bombs faster. The Plutonium production rate after January of 1945 with the US was set at one bomb per every 10 days of reactor operation, versus one bomb every 30 to 45 days with enriched uranium production.\(^4\)

Second Generation nuclear weapons were based on nuclear fusion - the combining of two different isotopes of hydrogen into helium - that is 'Hydrogen Bomb' or 'Thermonuclear Weapon'. The energy released in case of fusion reaction is far greater as compared to nuclear fission, somewhere in the range of 11.3 to 19.7 million electron-volts (MeV). Almost all nuclear weapons which are currently in the arsenal of official and de-facto nuclear-weapons states are so called "Second Generation nuclear weapons". In contemporary thermonuclear weapons, most of the yield actually comes from fission rather than fusion as can be seen from Figure 1 and Table 1 at the Annexure.\(^5\) Thus, the earlier talk of Hydrogen Bomb being a "Clean" bomb was only to disorient public opinion. Thermonuclear Weapons are actually more "dirty".

**Third Generation Nuclear Weapons**

Third Generation Nuclear Weapons are basically "tailored and special
effects" warheads and systems developed between the 1960s and 1980s, mainly for tactical uses or ballistic missile defence. The enhanced radiation warhead or neutron bomb had been cited by the U.S. officials as a "crude forerunner" of a third generation weapon. Dr. Edward Teller, known as the "father of the hydrogen bomb" had been the most vocal proponent of the third generation concept. Various developments or concepts in the field of Third Generation Nuclear Weapons are:-

- **Enhanced Radiation Warhead (ERW) or the Neutron Bomb** is a low yield thermonuclear explosive specifically designed for an increased output of high-energy neutrons per kiloton of total yield. It is intended to be a nuclear anti-personnel weapon that produces minimal concomitant blast damage and radioactive fallout. ERW or neutron bomb could be designed and developed with a yield of around 1 Kt such as 1 Kt W 79, 8-inch artillery shell.

- **Reduced Residual Radiation (RRR) Bomb.** In contrast to the ERW, RRR Bomb minimises radiation and fallout. The RRR explosives were originally developed for the excavation activities of Project Plowshare, the now discontinued US programme to use nuclear explosives for peaceful purposes. In the RRR bombs, the mechanical and blast effects of the nuclear weapon were enhanced. The RRR Bomb is believed to be advantageous in destroying sensitive targets and maintain the advance in military offensive.

- **Electromagnetic Pulse Bomb.** The Electromagnetic Pulse (EMP) effect was first observed during the early testing of high altitude air burst nuclear weapons. The effect is characterised by the production of a very short (hundreds of nanoseconds) but intense electromagnetic pulse. This pulse of energy produces a powerful electromagnetic field, which can be sufficiently strong to produce short lived transient voltages of thousands of volts (i.e. Kilovolts) on exposed conductors such as wires, or conductive tracks on printed circuit boards (PCBs). It is this aspect of the EMP effect, which is of military significance, as it can cause irreversible damage to a wide range of electrical and electronic equipment, particularly computers and radio or radar receivers. Both the United States and Russia are known to have these weapons in their inventory. Rather, North Korea has also reportedly developed EMP attack capabilities with the help of hired Russian nuclear scientists. The U.S. Defence Department has been using surge arrestors, faraday cages and other devices that prevent EMP from damaging electronics as also micro-grids that are...
inherently less susceptible to EMP, for more than 50 years to protect crucial military installations and strategic forces.\textsuperscript{10} • Nuclear Explosive-Powered Directed Energy Weapons (NDEWs). The U.S. Department of Energy (DOE) and the Strategic Defense Initiative Organization (SDIO) had examined five NDEWs: X-ray Lasers (XRLs) - code named ‘Éxcalibur’, Nuclear-powered Kinetic Energy Weapons (NKEWs) - code named ‘Prometheus’, Microwave weapons, Optical-wavelength lasers, and particle beams. Of these, there have been nuclear tests of at least three - XRLs, NKEWs, and other probably a microwave device.\textsuperscript{11}

Third generation weapons progress seemed to be limited to enhancement of radiation already present in nuclear detonations (as was done for the neutron bomb) or a few nuclear tests demonstrating the potential of NDEWs. Most third generation concepts were found to be encumbered by technical uncertainties and operational risks and were probably never deployed on a large scale.\textsuperscript{12} Research was already being scaled back by the end of Reagan Administration, and appears to have been finally terminated after the end of nuclear testing in 1992.\textsuperscript{13}

Fourth Generation Nuclear Weapons (FGNW): A Quantum Leap

There is no standard definition of Fourth Generation Nuclear Weapons. However, the following two definitions, possibly cover the processes being followed under this category of weapons :-

- "Nuclear explosive devices based on atomic and nuclear processes that are not restricted by the Comprehensive Test Ban Treaty (CTBT)"\textsuperscript{14} or
- "Nuclear explosive devices based on low-yield thermonuclear pellets triggered by compact non-fission primaries."

The second definition recognizes the technical fact that radically new, but 'realistic', types of nuclear weapons will most probably use highly compressed Deuterium-Tritium (DT) pellets as the main source of their explosive energy. This means that while fission was the main source of yield in the first three generations, the main source of yield in the Fourth Generation will be the fusion reaction:

\[
D + T \rightarrow He4 (3 \text{ MeV}) + n (14 \text{ MeV})
\]

The physics of the ignition and burn of such DT pellets is being studied
vigorously in all nuclear weapons states, as well as in a few other technologically advanced countries, most prominently in Japan and in Germany.\textsuperscript{15} Primarily, two components are required to study and examine the effects of above fusion reaction - Laboratory facility to conduct the experiments and a non-fission primary to compress and ignite the DT pellets:

- **Inertial Confinement Fusion (ICF).** ICF basically consists of exploding very small amounts of thermonuclear fuel highly compressed by lasers or other means, and it enables to study the physics of thermonuclear secondaries in the laboratory. This technique has primarily been developed as an alternative to the underground testing of nuclear weapons, and as a tool for designing new types of nuclear weapons. Reportedly, world's largest ICF facilities are in: the United States at Livermore (NIF), France at Bordeaux (LMJ), Japan at Osaka (ILE) and Germany at Darmstadt (GSI). The latter puts Germany in the same "Club" as the other most advanced countries in this field, i.e., the United States, France, Japan and the UK. ICF reproduces in the laboratory the same arrangement as the one on which two-stage H-Bomb was based: the "Teller-Ulam Principle".

- **Compact Trigger or 'Non-Fission Primary'.** Designing a compact trigger i.e., a non-fission primary, to compress and ignite the DT pellet in a weaponizable configuration is a formidable technical challenge. Some of the most attractive technologies to achieve the above are super lasers, magnetic compression, nuclear isomers and antimatter.\textsuperscript{16}

According to a Reuter Press release of June 1994, it was an arms race between Russia and the US as to who would develop fourth generation of nuclear weapons first.\textsuperscript{17}

An important and fascinating aspect of antimatter technology is that it leads to the prospect of "nuclear bullets", i.e., the thermonuclear explosive devices that would have the size of an egg and an explosive yield of a few tons high-explosive equivalent.\textsuperscript{18}

**Characteristics of FGNWs versus Previous Generation Nuclear Weapons**

- **Mechanical and Thermal Effects.** A first significant difference between DT-based FGNWs and all other types of explosives is that up to 80 percent of the yield is in form of high-energy neutrons, so that
only about 20 percent of the total yield contribute directly to heat and blast effects. Thus for a given total yield, FGNWs will have somewhat reduced collateral effects in terms of heat and blast.

The second significant difference between DT-based FGNWs and all other types of explosives is the high direct-coupling with intended targets made possible by the flux of high-energy neutrons. Direct-coupling to a finite-size target is related to the distance between the point of explosion and the surface of the target; and this distance should be of the order of a few metres at most for about 1 ton FGNW to be effective. This requires truly high accuracy in delivery, and a corresponding accuracy in the knowledge of the target coordinates.

- **Prompt Radiation Effects.** The lethal effect of high fluxes of high-energy neutrons was much debated during the "neutron bomb" controversy of the 1970s to the mid-1980s. From those publications, radiation dose produced by a pure DT-fusion explosion in air has been derived fairly accurately. Distance below which the "instant permanent incapacitation" is close or equal to 100 percent:

  - 1 ton FGNW: more than 10,000 rad below 100m
    - > 240 C body temperature rise.
    - > 99 % lethal within 1 hour.

  and the distance beyond which the probability of survival is higher than 50 percent:

  - 1 ton FGNW: less than 300 rad beyond 300m
    - 10 C body temperature rise.
    - < 50 % lethal within one month.

  It can be seen from the above that an instantaneous full-body temperature rise from normal temperature of 370 C to 610 C will have a very big impact on physiology leading to immediate loss of consciousness and nearly instantaneous death. On the other hand, 10 C temperature rise will not have such a strong physiological effect, and death will be due to radiation sickness, which can be medically treated to some extent.

  If instead of unprotected soldiers or people, one considers heavy battle-tanks, which provided some shielding against radiations, the kill radius will be smaller. Assuming a protection factor of 20, the tank crew will
be instantly killed by a 1 ton FGNW exploding at a distance of less than 20 metres. In tank warfare terms, this corresponds to a "radiation kill" while a direct hit would have produced a "hard-kill". Thus similar to neutron bomb, FGNWs have a strong potential to be used as anti-personnel weapons. Again it is going to be as controversial as neutron bomb except the fact that absence of a fission-trigger in FGNW may make it more acceptable to some.\textsuperscript{20}

- **Delayed Radiation Effects.** Two main delayed radiological effects of FGNWs are due to the unburnt tritium and the activation of the ground and other materials by high-energy neutron irradiation. FGNWs induce a considerably smaller radioactive burden relative to the previous generations of nuclear weapons: Tritium dispersal and induced ground-radioactivity will to a large extent not impair further military activity; Just as it was the case with the use of depleted-uranium weapons, it may be arguable that the radiological burden due to use of FGNWs could in some way be tolerable. It may be worth to note that almost 400 tons of depleted Uranium penetrators [U-238 munition] had been expended during the 1991 war in Iraq. Corresponding long-term radiological burden is equivalent to the hypothetical use of hundreds of thousands of FGNWs, each with a yield of 1 ton.\textsuperscript{21}

- **Electromagnetic Effects.** In earlier generation nuclear weapons, fission is the dominant source of electromagnetic effects. Thus the pure fusion FGNWs will have significantly reduced electromagnetic effects - unless they are specially designed to use the fusion neutrons to drive an EMP generator, or to interact with a special material to produce a tailored effect.\textsuperscript{22}

### Prospects and Implications of FGNWs

The FGNWs are still in a scientific stage and its actual employment may still be very far in the future. The development of FGNWs related technologies does not require any "political decision" or "conspiracy". Apart from inertial confinement fusion (ICF), the main areas of science and technology leading to the development of FGNWs are micro-electromechanical engineering and nanotechnology. The most promising technology for providing the high energy-density necessary to trigger very compact FGNWs is anti-matter. As the main source of yield in FGNWs is the DT fusion reaction, large-scale tritium technology is required to develop a full-scale arsenal of FGNWs. This implies that the development and
deployment of FGNWs is linked to that of thermonuclear fusion reactors. The main alternative source of tritium is its production by means of high-energy particle accelerators, which is at the same time the most matured technology for the large scale production of antimatter.

Irrespective of how far in future, it will be technologically feasible to deploy FGNWs, knowing its technical characteristics, its future military employment and the related aspects must be studied in advance. Its military aspects are:

• FGNWs can have yields in the range of 1 to 100 tons equivalent of TNT i.e., in the gap, which today separates conventional weapons from nuclear weapons.
• Compared to previous generations, FGNWs have enhanced direct coupling to dense targets and reduced collateral effects, as well as the capability to drive powerful "jets" and "forged fragments".
• FGNWs are in line with the "increased precision" and "reduced collateral damage" trends of modern warfare.

Conclusion

Over 72 years ago, when the first generation nuclear weapon was developed, only 10 percent of the fissile material was consumed in the original explosion with 90 percent being left over as fallout. Tremendous advancement has taken place in nuclear weapons technology since then. A nuclear blast can be shaped or modified in the type of energy it releases; either as Heat, Blast effect, X-rays, Gamma rays, EMP or just pure neutrons etc. A nuclear blast can be directed in any direction acting as a nuclear shaped charge, just like Atk TNT based shaped charge. A 1 Kt B 61-11 nuclear bunker-buster can blast (melt) a hole 10 feet wide and over 1,000 feet long into solid granite.

Further, FGNWs are relatively low-yield nuclear explosives, which will not qualify as weapons of mass destruction. Construction of large ICF micro explosion facilities in both nuclear-weapon and non-nuclear weapon states is giving the nuclear arms race a fresh boost.

There is a great possibility that certain technologically advanced countries will equip themselves directly with "Fourth Generation Nuclear Weapons", without having to go through the process of acquisition of...
previous generation of nuclear weapons.²⁷

Annexure

Figure 1: Schematic Depiction of A Three-Stage Fission-Fusion-Fission Bomb with Natural Uranium U-238

Table 1: Estimated Fission and Fusion Fractions in the first (Mike) and latest (W-88) United States’ Thermonuclear weapons

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<th>Yield (kt)</th>
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<th>Fusion[%]</th>
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References
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12. Ibid., p.220.
15. Andre Gsponer, op.cit., p.11.
16. Ibid., pp. 11-12; and Enigma Hood, “4th Generation Nuclear Weapons” available at https://m.youtube.com/watch?v=M5VNnmAoY1Y (accessed on 28 January 2017) [ Video clip covers in extreme detail with beautiful illustrations about the concept of Fourth Generation Nuclear Weapons].
17. Andre Gsponer, op.cit., p.43.
18. Ibid., p.22.
19. Ibid., pp. 41-42.
20. Ibid., pp. 42-43.
23. Ibid., pp. 46-47.
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25. Ian Greenhalgh and Jeff Smith, op.cit., p.16.
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