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Plutonium vs. Uranium: The Road Less Traveled

In a world where nuclear proliferation may no longer be held back by the guise of anti-proliferation treaties, where the news, everyday, warns us of the impending shadow of nuclear terror we live under, it is frightening that so many people don't know how such a threat is made. It will be the attempt of this paper to help clarify some point of confusion, specifically delineating the differences between the Uranium, the Plutonium, and briefly the Hydrogen bomb.

Perhaps it is best to start with a few definitions and explanations. The nuclear bomb works on the principal of starting an uncontrolled fission or fusion reaction. The types of which are varied, but generally involve using a chemical explosive of some sort to force a uranium or plutonium core to implode to critical mass (the state where the atoms of the radioactive material are so tightly compressed that a neutron ejected from one atom, has virtually a 100% probability of triggering another neutron loss upon collision with another atom). Once at critical mass, the loss of any single neutron in an already radioactive element ensures a chain fission reaction in which all the radioactive material emits the energy lost due to the removal of the neutron from the nucleus in the form of radiation. The energy not lost in radiation is dissipated through kinetic energy via the collision of atoms generating the blast. Here, is where the uranium and plutonium bombs stop.

The Hydrogen Bomb

The hydrogen bomb was first developed by the United States in the early 1950s. At the time it was popularly theorized that a fusion reaction could produce more power than a fission reaction. The principal of the bomb relies on using the enormous power of the uranium or plutonium fission reaction to further compress a hydrogen core to critical mass. When the atoms of hydrogen fuse to make helium, they release even more energy than a simple fission reaction thus creating a larger blast radius. The advantage of this "thermonuclear" device versus the "nuclear" uranium and plutonium bombs is that it produces less radiation, although it is more effective in spreading what little radioactive material there is, around.

At this stage in global politics, only the 5 superpowers are known to have the capability of producing a thermonuclear device. The focus on proliferation then lies solely on nuclear devices: Iraq and Korea are known only to attempt nuclear weapons production.

Getting Uranium

The destructive power of the Uranium bomb in war was first demonstrated on Hiroshima. The bomb consisted of 60 kg of U-235 at its core. But what does it mean and how does it work?

99% of all mined Uranium has an atomic weight of 238, only 1% of this Uranium is 235, the form of Uranium that requires the least initial mass (52 kg) prior to detonation to go ‘critical.’ There are many separation processes available to “enrich” Uranium, or extract 235 from its depleted 238 counterpart. This includes gas diffusion, centrifugal diffusion, and mass separation via magnetic field. Unlike its Plutonium counterpart Uranium 235 and 238 react similarly, thus making this enrichment process much more energy intensive.

Both gas diffusion processes involve superheating UF6 until it vaporizes. Since U-235 is slightly smaller and lighter than its counterpart, it can diffuse faster through membranes. Thus, forcing this gas via either back pressure or a centrifuge through multiple layers of semi-permeable membranes slowly filters out the UF6 formed with U-235. This is then condensed and reacted to extract the U-235.

The mass separation method relies on ejecting a stream of Uranium atoms through a very strong magnetic field. The mass differences causes the U-235, the lighter atoms to deflect into a collecting tray. Though slow and also more energy intensive than gas diffusion, this process produces the least nuclear waste.

Depending on how thoroughly these processes are carried out, the product carries different names. Highly enriched Uranium is a product containing over 20% Uranium 235. This is sufficient for a weapon, but efficiency and portability typically require bombs to have weapons grade plutonium with 90% enriched Uranium. Anything lower, can be considered reactor grade.

Because reactor grade Uranium has such a low concentration of U-235 and the final spent rod has even less U-235, extracting enriched Uranium from spent fuel rods is not considered a feasible method of creating weapons grade Uranium.

Getting Plutonium

The destructive power of the Plutonium bomb in war was first demonstrated on Nagasaki. The bomb consisted of 10 kg of Pu-239 at its core. Unlike Uranium, virtually any combination of Plutonium isotopes can be used to make a new clear weapon. However, 238 and 239 are the most effective.

Plutonium is typically harvested from a reactor running off of Uranium fuel rods. When U-235 decays and releases neutrons in a reactor, stray neutrons that fuse with U-238 making the final U-239 product decay to produce Pu-239. The maximum Pu-239 production occurs before the fuel rod is entirely spent, meaning Plutonium enrichment does not also have the by product of creating usable energy. Weapons Grade Plutonium is said to contain greater than 93% Pu-239. 80-93% Pu-239 is considered fuel-grade and below is considered reactor grade.

However, since any Plutonium can be used to create a bomb, no matter how unstable, Plutonium is considered the material most used in the proliferation of nuclear weapons. Its production as a by product of Uranium reactors means that harvesting it requires much less energy than creating enriched Uranium. The downside is extracting Pu-239 from a

Uranium rod, which requires the rod be dissolved in acid, creating a liquid nuclear waste considered highly toxic and difficult to manage.

The Bomb Itself

Comparing not only the nuclear material enrichment process, but the construction of the bomb itself, picking which material to use becomes trickier. 52 kg of Uranium is needed to reach critical mass, whereas only 8 kg of Plutonium is necessary. With a Uranium neutron reflecting shield, that critical mass can be cut in half. But, whereas the Uranium enrichment process requires more energy than Plutonium, Plutonium enrichment also creates a difficult to store acid byproduct. Furthermore, because Plutonium is easier to false detonate than Uranium, typically the critical mass is divided into two halves by a neutron shield, preventing false detonations. Neutron shields imply a Plutonium bomb needs an even greater neutron source to trigger the reaction, this means another radioactive core is needed of Beryllium/Polonium. So even though Plutonium is 'easier' to come by than Uranium, its bomb structure requires a lot more engineering and more time to assemble.

Iraqi and Korean Proliferation.

So what direction did Korea and Iraq choose?

During the last UN inspection, Iraq was found to be enriching Uranium through mass spectroscopy. This suggests Iraq plans on creating a bomb using a Uranium core. Korea, on the other hand, as predicted, chose Plutonium because it could be extracted from spent fuel rods. Since Korea has energy shortages as it is, the high energy Uranium extracting process would be unwise. Sources suggest that Korea's Uranium program is not far behind.

The methodology behind producing such weapons of mass destruction has not advanced very much since its conception, but its production certainly has. If know-how is half the battle, then perhaps this explanation will make you feel safer. . .