The construction of a nuclear weapon requires either weapons-usable plutonium or weapons-usable uranium. To prevent the proliferation of nuclear weapons capabilities, these materials must be carefully controlled and kept out of circulation.

Much confusion can be caused by misconstruing the precise definition of technical terms:

(a) although some materials are called "weapons-grade" it is not true that only weapons-grade materials can be used to make nuclear weapons;

(b) although some nuclear weapons are said to have a "fizzle yield", it is not true to infer that such weapons fail to detonate, nor is it is correct to suggest that a fizzle yield is anything short of an enormously destructive explosion;

(c) although some isotopes of plutonium are said to be "non-fissile", it is not correct to infer that such materials cannot function as nuclear explosives.

Here are some important facts relevant to the question of nuclear weapons proliferation:

1. All nuclear weapons require a primary nuclear explosive material to produce a nuclear fission explosion. The only realistic candidates for a primary nuclear explosive are (i) highly enriched uranium (uranium with more than 20 percent uranium-235), (ii) plutonium extracted from used nuclear fuel, or (iii) human-made uranium-233. These three materials are designated as "sensitive nuclear materials" by the IAEA. See "Safeguarding Sensitive Nuclear Materials: Reinforced Approaches"

2. A nation or subnational group with access to a sufficient quantity of a sensitive nuclear material can use that material to construct one or more nuclear weapons. Even the smallest possible yield of such a weapon, the so-called "fizzle" yield, still corresponds to an enormously destructive explosion. According to Carson Mark, who headed up the Theoretical Division at Los Alamos from 1947 until 1973, the blast radius from such a fizzle yield would be about one-third to one-half of a mile – enough to destroy the core area of any city.

> "Very heavy damage and acute hazard from the blast, thermal, and prompt radiation effects, which extended out to a radius of about a mile in the case of the weapons used in Japan, would, for these 'small' yields, extend out 'only' to a radius of one-third or one-half a mile."
>
> *Carson Mark, Explosive Properties of Reactor-Grade Plutonium, from the section on Effects of Preinitiation on Yield Distribution*

3. Any plutonium extracted from spent nuclear fuel can be used to make enormously destructive nuclear weapons. This is true regardless of the "burnup" of the fuel or the isotopic composition of the extracted plutonium. "Weapons-grade plutonium", with over 93% plutonium-239 and less than 7% of other plutonium isotopes, is preferred by bomb-makers. However, all reactor-produced plutonium is weapons usable even if it is not weapons-grade. It is then called "reactor-grade plutonium".

> "At the lowest level of sophistication, a potential proliferating state or subnational group using designs and technologies no more sophisticated than those used in first-generation nuclear weapons could build a nuclear weapon from reactor-grade

plutonium that would have an assured, reliable yield of one or a few kilotons (and a probable yield significantly higher than that)."

> US Department of Energy, *Non-proliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives, 1997, pp. 37-39*

4. The yield of a plutonium bomb – especially those of the simplest and earliest designs (circa 1945-1950) – cannot be predicted with complete accuracy. The exact yield depends on the timing of the first neutron that initiates the chain reaction. If it happens too early, the "preinitiation" (or "predetonation") results in a suboptimal yield. The most extreme case of this is a "fizzle yield", which can be ten or twenty times less powerful than the optimal yield. Even so, a "fizzle yield" of one or two kilotons (as described above) is still an extremely powerful explosion. Recall that a yield of just one kiloton corresponds to the simultaneous explosion of 1000 tons of TNT.

5. The simplest and earliest design for a plutonium bomb (circa 1945) had no built-in protection against stray neutrons triggering a preinitiation event. The more stray neutrons there were, the greater the uncertainty in the yield of the bomb. The total spectrum of possible yields remained unchanged, but the presence of more stray neutrons increased the odds of suboptimal performance. Since plutonium-240 gives off a lot more stray neutrons than plutonium-239 does, it was easy to see that keeping plutonium-240 to a minimum in comparison with plutonium-239 would help to ensure that fizzles, though still possible, remained exceedingly rare. That was one of the key reasons why weapons-grade plutonium was preferred.

6. Long ago, however, more sophisticated designs for plutonium bombs were developed that are effectively immune to the influence of stray neutrons. Those designs, whose details remain highly classified, were spurred by the realization that during a nuclear conflict, stray neutrons emanating from exploding nuclear bombs might cause preinitiation in neighbouring bombs – a kind of "fratricide" effect. To overcome this challenge weapons designers came up with designs that effectively prevent preinitiation caused by stray neutrons. In such designs, the extra neutrons given off by plutonium-240 are of little or no importance.

"… advanced nuclear weapon states such as the United States and Russia, using modern designs, could produce weapons from reactor-grade plutonium having reliable explosive yields, weight, and other characteristics generally comparable to those of weapons made from weapons-grade plutonium. Proliferating states using designs of intermediate sophistication could produce weapons with assured yields substantially higher than the kiloton-range possible with a simple, first-generation nuclear device."

> US Department of Energy, *Non-proliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives, 1997, pp. 37-39*

7. Even-numbered plutonium isotopes, like plutonium-240 and plutonium-242, correctly classified as "non-fissile" materials, are still weapons-usable. A "non-fissile" material is,

by definition, one that cannot support a nuclear chain reaction using slow (moderated) neutrons. That is true of both Pu-240 and Pu-242. However, both can sustain a chain reaction using fast (unmoderated) neutrons, so both can serve as nuclear explosive materials. The term "bare critical mass" refers to the smallest mass of a sensitive nuclear material that is able to sustain a nuclear chain reaction; that is, the smallest mass needed to bring about a nuclear explosion without the use of neutron reflectors. The bare critical masses of Pu-240 & Pu-242 are in both cases smaller than the bare critical mass of weapons-grade uranium, so they are definitely weapons-usable.

> "… all of the plutonium isotopes are fissionable. Indeed, a bare critical assembly could be made with plutonium metal no matter what its isotopic composition might be…. The bare critical mass of Pu-240 in alpha-phase metal is about 40 kilograms. Since the bare critical mass of weapons-grade uranium (94 percent U-235) is 53 kilograms, Pu-240 may be said to be a more effective fissionable material than weapons-grade uranium in a metal system."
>
> Carson Mark, *Explosive Properties of Reactor-Grade Plutonium*

8. Many nuclear power advocates have been misled into believing that plutonium-240 is not weapons-usable in and of itself. Confusion on this point is probably due to an inappropriate analogy with uranium-238, a non-fissile even-numbered isotope of uranium that cannot sustain a nuclear chain reaction with slow or fast neutrons and is therefore unusable as a primary nuclear explosive. Such is not the case with plutonium-240 or plutonium-242, both of which are powerful nuclear explosives.

9. As a corollary, while weapons-grade uranium can be isotopically denatured to make it no longer usable as a nuclear explosive, the same cannot be done for weapons-grade plutonium. Indeed, down-blending weapons-grade uranium with a sufficient quantity of the abundant non-chain-reacting uranium-238, results in a kind of uranium that cannot be used as a nuclear explosive without re-enrichment. On the other hand, weapons-grade plutonium cannot be isotopically denatured in any practical way so as to make it unusable as a nuclear explosive. This fundamental difference between uranium and plutonium underlies the great difficulty the global community faces in securely dealing with excess weapons plutonium, in contrast to excess weapons uranium.

10. A well-equipped subnational group with access to weapons-usable plutonium can fabricate a powerful nuclear explosive device whose blast, thermal, and prompt radiation effects extend out to a radius of at least one-third or one-half a mile, and probably much further. By using modern weapons design information, more powerful yields – ten or twenty times more powerful – can be reasonably assured. The necessary information can be gleaned from ex-nuclear weapons scientists. Alternatively, clever designs can be re-invented anew – knowing that the problem is solvable is already half the battle. It is therefore irresponsible to assume that reactor-grade plutonium is inherently less risky than weapons-grade plutonium. All plutonium is weapons-usable, and with modern weapons designs all plutonium is equally destructive when weaponized.

Hampstead, Quebec, March 31, 2024