Manufacturing Nuclear Weapon "Pits": Paths toward 80 Pits Per Year

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(slide 1) I want to thank the organizers of this Summit for inviting me, and would like to remember Ed Helminski, who cared passionately about the nuclear weapons enterprise.

(slide 2) I'll talk about a part of that enterprise, the production of nuclear weapon pits. As you know, the primary stage of a thermonuclear weapon has at its core a pit, a hollow shell whose fissile material is plutonium.

(slide 3) The history of US pit manufacturing is Sisyphean. During the Cold War, Rocky Flats Plant made 1,000 to 2,000 pits per year (ppy). These were "war reserve," or pits accepted for use in the stockpile. Production at Rocky Flats halted in 1989. In the quarter-century since, the US has made at most 11 war reserve ppy, and that in one year only, 2007. Since 1989, two plutonium facilities were debated, funded for a while, and rejected, two were proposed but not implemented, and two were built and torn down because of problems with design and construction. The last plutonium processing building, PF-4 at Los Alamos, was brought online in 1978. It is the only building in the nuclear weapons complex currently set up to manufacture pits.

(slide 4) Current capacity is zero, as most pit manufacturing operations at PF-4 have been suspended since June 2013, though Los Alamos is working to restore these operations.

(slide 5) DoD has wanted NNSA to have the capacity to make 80 ppy. These would be used in some life extension programs and, it is argued, to provide hedge capacity in the event of geopolitical surprise or if a pit type developed problems unexpectedly. Some argue the capacity should be higher; some say lower. However, the FY2015 NDAA requires NNSA to ramp up and demonstrate a capacity of 80 ppy for 90 days in 2027, and that capacity is the focus of my talk.

(slide 6) Manufacturing involves many tasks, such as material preparation, casting plutonium into hemishells or "half-pits," welding them together to form pits, and material control and accountability. Most of these tasks could be conducted in PF-4.

I'll use three terms in my talk. First is Material At Risk, or MAR, radioactive material that could be acted upon by an event. All pit tasks place plutonium at risk of being dispersed into the atmosphere by a catastrophic event, such as an earthquake that collapsed PF-4 followed by a fire. Each building that handles radioactive material has a MAR ceiling calculated for it, measured in grams or kilograms of material. A second term, space, is the amount of laboratory floor space.

(slide 7) The third term is margin. Space margin is space available for pit production minus space required, and MAR margin is MAR available for pit production minus MAR required. Solving these equations produces static numbers.

(slide 8) How much margin is enough? Both margins must be >0. To calculate margin, you need four numbers: MAR available, MAR required, space available, and space required. While figures for space and MAR available have been calculated, space and MAR requirements have never been calculated rigorously for 80 ppy, so we don't know how much is enough.

(slide 9) Beyond that, many uncertainties that affect margin can creep in over time. Requiring more ppy would increase the MAR and space required for pit production. Removing unneeded plutonium from PF-4 would increase available MAR.

(slide 10) This slide shows 32 uncertainties that might affect margin. Examples in green increase margin, whether by increasing the availability of MAR or space or by reducing the requirements for MAR or space; examples in red reduce margin. No need to read them all! The briefing slides will be posted on the Summit's website.

(slide 11) The analysis leads to two decisions on margin: If there is not enough margin for space and MAR for 80 ppy, how can it be provided? And once there is enough margin, how can it be maintained over decades despite uncertainties? Let's look at space margin, then at MAR margin.

(slide 12) I'll focus on PF-4, the main Pu building at Los Alamos. Various options could increase space margin. Some could be implemented soon; others could be held in reserve to provide confidence in the ability to maintain capacity despite uncertainties. Given the importance of maintaining margin, it may be wise to assess it annually.

(slide 13) So, here's the space allocation for PF-4 from a few years ago. As you see, PF-4 housed ten tasks. Some were related to pit production, such as pit fabrication and plutonium recycle and purification. Some, such as materials characterization, support multiple programs in PF-4. And some, such as plutonium-238 work, are not related to pits.

(slide 14) One way to make more space available for pit production is to build modules, reinforced-concrete structures of perhaps 5,000 square feet buried near PF-4 and connected to it by a tunnel. They would be considered an extension of PF-4. The FY2013 NDAA, as amended, authorizes NNSA to build at least two modules.

(slide 15) Another possibility would be to move the plutonium-238 line, perhaps to Idaho National Laboratory or Savannah River Site. This would require substantial new construction, whether at existing facilities or building one or more modules. This would free up in PF-4 a few hundred square feet less than the previous one, but would greatly reduce MAR in PF-4, as I'll discuss in a moment.

(slide 16) Other options to free up space do not require major construction. The Defense Nuclear Facilities Safety Board stated that PF-4 has "an entire wall of legacy gloveboxes," and removing them would "free up … considerable space for new programmatic work." Another option involves electrorefining, which purifies Pu for use in pits. This process uses sodium chloride and potassium chloride as the electrolyte. These salts retain some Pu. Pu is recovered by dissolving this mixture in acid, a process that requires several gloveboxes. In contrast, the UK uses calcium chloride as the electrolyte. Recovering Pu from calcium chloride uses only one glovebox. Using calcium chloride would free capacity in the acid recovery gloveboxes, so a given number of those gloveboxes would support a higher rate of Pu purification. That, in turn, would reduce the space required to support a higher pit production rate, increasing margin.

(slide 17) Now let's look at ways to increase MAR margin. Again, we'll focus on PF-4.

(slide 18) This diagram shows MAR used by programs in PF-4 as of February 27, 2013, a few months before the Los Alamos director paused operations in PF-4. The MAR allowance for the main lab floor was 1,800 kg of Pu-239 equivalent (PE). Pu-239 is the fissile isotope in weapons-grade Pu. Note that Pu-238 accounts for nearly a quarter of the MAR ceiling. Even though the amount of Pu-238 is about 1.6 kg, it is as radioactive as 441 kg of Pu-239 because Pu-238 is 277 times more radioactive. This configuration has 386 kg of unallocated MAR allowance.

(slide 19) PF-4's MAR allowance was reduced from 2,600 kg to 1,800 kg in June 2013. New seismic studies increased the risk that PF-4 could collapse in an earthquake; to offset the risk, NNSA reduced PF-4's MAR allowance. This slide shows seismic upgrades restoring the MAR allowance, which results in 1,186 kg of unallocated MAR allowance. In practice, the allowance might be higher or lower depending on the upgrades.

(slide 20) This slide shows the effect on PF-4 MAR of building two modules, one for casting molten Pu and the other for acid processes to recover Pu. Compared to the previous slide, this configuration increases the unallocated MAR allowance from 1,186 kg to 1,385 kg.

(slide 21) And this slide shows the effect on PF-4 MAR of building one module for Pu-238. MAR is not spread across the Pu-238 space like peanut butter. Instead, a 5,000-sf module could accommodate about nine-tenths of the Pu-238 MAR and would make 1,588 kg available in PF-4.

(slide 22) But there are other ways to make more MAR available in PF-4. Structural upgrades could reduce the risk that PF-4 would collapse. The photo, from Google Earth, shows a drag strut on the roof of PF-4. It transmits lateral forces generated by an earthquake to a shear wall, which is designed to resist these forces. To reduce the amount of plutonium that would be released if PF-4 collapsed, Los Alamos is anchoring gloveboxes more strongly to the floor. As another example, Los Alamos removed 22 tons of combustible material from PF-4 to reduce the risk of a fire that could create plutonium oxide particles and loft them into the air.

(slide 23) Yet another way to make more MAR available in PF-4 is to increase the MAR permitted there. MAR is set with reference to a dose of radiation that a nearby worker and a member of the public would receive from a worst-case accident.

(slide 24) This ten-factor equation, multiplying the terms downward, converts MAR to dose. Factors include damage to the building, the fraction of plutonium released into the air, the fraction of that plutonium in particles of a size that could be trapped in the lungs, and so forth. DOE sets the values to use in the equation. However, when multiple worst-case values are used, the result goes far beyond plausibility.

(slide 25) According to Kamiar Jamali, Associate Administrator for Safety and Health in NNSA, "When complex analyses are employed to derive distributions for output variables for calibration of the degree of uncertainties in analysis results, the 95th percentile is generally associated with the upper-bound. … [However,] when several input parameters are taken at their bounding values, the obtained result dwarfs the derived 95th percentile of the output by orders of magnitude." He proposes using "[t]he mean value … as the metric that is consistent with the concept of reasonable conservatism in nuclear safety analysis, as its value increases towards higher percentiles of the underlying distribution with increasing levels of uncertainty." Mean and median values are quite similar in this analysis. In this case, when median assumptions are used instead of worst-case assumptions, the dose drops by a factor of 35,000. Put differently, for the same accident, 1 gram of plutonium using worst-case assumptions would produce the same dose as 35,000 grams using median assumptions. Yet an increase of PF-4 MAR by a factor of ten, or perhaps less than two, would probably be enough to allow production of 80 ppy.

(slide 26) So to conclude, there are many potential paths toward 80. But without knowing MAR and space needs for that level of production, we can't know which combination of options would be necessary or sufficient. It may be that what is in place now is enough, or that non-construction options would suffice, or that minor construction like drag struts would suffice, or that modules would be needed. And without knowing MAR and space requirements, we can't know if zero, 1, 2, or 3 modules would be necessary or even sufficient. Thank you.