Manufacturing Nuclear Weapon “Pits”: Paths toward 80 Pits Per Year

Presentation to
Nuclear Deterrence Summit

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February 19, 2015
Pit

- Fissile core of a nuclear weapon
- Uses plutonium
- Detonates the secondary stage
- No pit, no weapon
A Sisyphean History

• Cold War mfg capacity: 1,000-2,000 war reserve (WR) pits per year (ppy)
  – WR: pits accepted for use in the stockpile
  – Rocky Flats Plant halted ops in 1989

• Many facilities proposed since 1989
  – NMSF, Building 371, MPF, CNPC, Complex 2030, CMRR-NF
  – None succeeded
  – Two (NMSF, Bldg. 371) were built and torn down
  – No new plutonium processing facilities brought online since 1978 (PF-4)
Pit Manufacturing Capacity

• Zero since June 2013
  – PF-4 ops paused due to concerns over criticality safety and formality of ops
  – LANL working to restore PF-4 pit mfg to operating status
  – Equipment, processes, people for mfg are available
  – Also, no requirement to manufacture WR pits
  – Therefore, some quality assurance processes to certify pits as WR have been suspended
80 ppy: Now Required by Law

- DoD requirement
- Some argue for higher or lower numbers
  - In 2024, manufacture 10 WR pits
  - In 2025, manufacture 20 WR pits
  - In 2026, manufacture 30 WR pits
  - For 3 months in 2027, manufacture at rate of 80
    - May be delayed 2 years if DoD, DOE report justification
What’s Needed to Manufacture 80?

• Manufacturing tasks
  – Material prep, pit fabrication, material control and accountability, quality control, waste mgmt, etc.
  – All tasks entail Material At Risk (MAR) and space
    • MAR: “The amount of radioactive materials (in grams or curies of activity for each radionuclide) available to be acted on by a given physical stress.” (DOE)
    • Space: laboratory floor space suitable for ops
Margin

- $\text{Margin}_{\text{space}} = \text{Available}_{\text{space}} - \text{Required}_{\text{space}}$
- $\text{Margin}_{\text{MAR}} = \text{Available}_{\text{MAR}} - \text{Required}_{\text{MAR}}$
- These produce static, point-in-time numbers
Calculating Margin: Is There Enough?

• Critical question for Congress, NNSA, DoD
• “Enough” = margin > 0

• Need 4 numbers:
  – 1. MAR available for mfg
  – 2. MAR required for mfg
  – 3. Space available for mfg
  – 4. Space required for mfg
  – These numbers can change over time

• 1 and 3 are available (may need updating)

• 2 and 4 have not been calculated rigorously for 80 ppy, so cannot know how much is enough
Margin and Uncertainties

• Uncertainties may creep in over time, affecting availability and requirements for MAR and space
• Thus need margin to offset uncertainties
• Examples of uncertainties
  – Requiring more ppy increases demand for space, MAR
  – A new regulation reduces available MAR
  – Removing unneeded Pu from PF-4 increases available MAR
• More examples ...
<table>
<thead>
<tr>
<th>Factors</th>
<th>Example 1</th>
<th>Example 2</th>
<th>Example 3</th>
<th>Example 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Factors increasing supply (availability) of MAR</td>
<td>Develop and install means to increase PF-4 seismic resilience</td>
<td>Clean out PF-4 vault, store more Pu needed for ongoing work in vault</td>
<td>Remove unneeded plutonium</td>
<td>New interpretation of a regulation permits increased MAR (as with RLUOB)</td>
</tr>
<tr>
<td>2 Factors reducing supply (availability) of MAR</td>
<td>A previously unknown seismic fault is discovered at TA-55</td>
<td>New interpretation of a regulation tightens restrictions</td>
<td>Cracks in concrete from earthquake reduce confidence in PF-4</td>
<td>Defense Nuclear Facilities Safety Board raises concern about an existing procedure</td>
</tr>
<tr>
<td>3 Factors increasing supply (availability) of space</td>
<td>More efficient use is made of PF-4 basement; some lab operations are moved there</td>
<td>Build modules</td>
<td>Clean out and repurpose rooms in PF-4</td>
<td>Add shielding around gloveboxes, permitting more in a room</td>
</tr>
<tr>
<td>4 Factors reducing supply (availability) of space</td>
<td>Add non-pit mission in PF-4</td>
<td>Pit manufacture uses more equipment than previously thought</td>
<td>A new regulation requires increasing space between gloveboxes to reduce dose</td>
<td>Contamination from an accident prevents use of a room in PF-4 for some time</td>
</tr>
<tr>
<td>5 Factors increasing demand (requirements) for MAR</td>
<td>Requirement changed to 125 ppy because of geopolitical developments</td>
<td>Faster process exposes more MAR</td>
<td>Partial collapse shuts CMR; its plutonium is moved to PF-4</td>
<td>Problem in a deployed weapon brings more pits to PF-4 for analysis</td>
</tr>
<tr>
<td>6 Factors reducing demand (requirements) for MAR</td>
<td>Requirement changed to 40 ppy because pit reuse proves more applicable than expected</td>
<td>Place more plutonium in highly robust containers</td>
<td>Develop lower-MAR manufacturing processes</td>
<td>Move Pu-238 mission out of PF-4</td>
</tr>
<tr>
<td>7 Factors increasing demand (requirements) for space</td>
<td>Requirement changed to 125 ppy because pit surveillance reveals unexpected pit problems</td>
<td>Workload for processing drums containing plutonium waste abruptly increases</td>
<td>A new manufacturing layout increases throughput but uses more space</td>
<td>Pit Disassembly and Conversion workload increases</td>
</tr>
<tr>
<td>8 Factors reducing demand (requirements) for space</td>
<td>Requirement changed to 40 ppy because plutonium is found to age more slowly than previously thought</td>
<td>Use 2 or 3 shifts per day</td>
<td>A new layout that minimizes space is designed</td>
<td>Some AC equipment is moved from PF-4 to RLUOB</td>
</tr>
</tbody>
</table>

Source: CRS. Green = factors increasing margin; red = factors reducing margin.
Key Decisions on Margin

• If there is not enough margin for space and MAR for 80 ppy, how can it be provided?

• Once there is enough margin, how can it be maintained over decades despite uncertainties?
Space: Providing and Maintaining Sufficient Margin

• Focus: PF-4 (Plutonium Facility 4)
  – Main Pu building at Los Alamos National Laboratory (LANL)
  – Only multi-program, multi-function, plutonium processing facility; only building that can currently make pits

• Various construction/non-construction options
  – Implement some promptly, hold others in reserve
  – Ability to maintain margin provides confidence in capacity
  – May assess margin annually
PF-4 Space Allocation as of Early 2012

Source: Los Alamos National Laboratory. The blocks in this diagram represent space allocations to scale, but do not show the physical location of each activity within PF-4.
Releasing Space in PF-4 with Two Modules

Source: Base graphic, Los Alamos National Laboratory, modifications by CRS. The blocks in this diagram represent space allocations to scale, but do not show the physical location of each activity within PF-4.
Releasing Space in PF-4 by Moving Pu-238 Offsite

Source: Base graphic, Los Alamos National Laboratory, modifications by CRS. The blocks in this diagram represent space allocations to scale, but do not show the physical location of each activity within PF-4.
Increasing Space Margin in PF-4 for Mfg without Major Construction (Examples)

– Use additive mfg. to fabricate segmented crucibles for electrorefining Pu

– Repurpose unused or lower-priority space
  • E.g., remove unused gloveboxes

– Make better use of basement

– Use 2 or 3 shifts per day

– Use CaCl, not NaCl-KCl, in electrorefining Pu
MAR: Providing and Maintaining Sufficient Margin

• Focus: PF-4

• Various construction/non-construction options
PF-4 MAR Usage by Program on 2/27/2013

Units in this graphic are kilograms of plutonium, not area. MAR allowance for this configuration is 1,800 kg of plutonium.

Source: Los Alamos National Laboratory. The blocks in this diagram represent MAR allocations to scale, but do not show the physical location of each activity within PF-4. MAR allowance for this and the next three slides is for the main laboratory floor of PF-4.
PF-4 MAR with Seismic Upgrades

Units in this graphic are kilograms of plutonium, not area. MAR allowance for this configuration is 2,600 kg of plutonium.

Source: Data provided by Los Alamos National Laboratory, graphic by CRS. MAR available for pit manufacturing in this and the next two slides has increased because seismic upgrades are assumed to permit a substantial increase (here, 44%) in PF-4 MAR. The blocks in this diagram represent MAR allocations to scale, but do not show the physical location of each activity within PF-4.
PF-4 MAR with Two Modules

Units in this graphic are kilograms of plutonium, not area
MAR allowance for PF-4 for this configuration is 2,600 kg of plutonium

Source: Data provided by Los Alamos National Laboratory, graphic by CRS. Module 1, molten Pu operations; Module 2, aqueous (acid) processing of Pu. The blocks in this diagram represent MAR allocations to scale, but do not show the physical location of each activity within PF-4.
PF-4 MAR with One Module

Units in this graphic are kilograms of plutonium, not area. MAR allowance for PF-4 for this configuration is 2,600 kg of plutonium.

Additional MAR Available for Pit Manufacturing
1588 kg, 61.1%

Pit Fabrication
295 kg, 11.4%

Pu Recycle & Purification
143 kg, 5.5%

Material Characterization
143 kg, 5.5%

Pit Disassembly & Conversion
161 kg, 6.2%

Module 1: 402 kg, 15.4%

Source: Data provided by Los Alamos National Laboratory, by CRS. The blocks in this diagram represent MAR allocations to scale, but do not show the physical location of each activity within PF-4.
Increasing MAR Margin in PF-4 without Major Construction (Examples)

• Strengthen PF-4 seismically
  – Wrap columns; shear walls; reinforce ceiling; drag strut
  – These reduce risk of PF-4 collapse in design basis earthquake

• Reduce risk that PF-4 collapse releases Pu
  – Install rugged containers in production areas
  – Anchor gloveboxes more strongly to floor
  – Remove tons of combustible material from PF-4

Photo: Google Maps. Photo shows PF-4 roof with drag strut circled.
Increase MAR by Avoiding Hyper-conservative Calculations of Dose

• MAR permitted for each building depends on calculation of dose
• Ten-factor equation links MAR to dose
## Dose as Function of MAR for PF-4 Using Conservative and Hyperconservative Assumptions

<table>
<thead>
<tr>
<th>Factor</th>
<th>Conservative</th>
<th>Hyperconservative</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAR, g Pu-239 equiv (Pu-239E)</td>
<td>2.60E+06</td>
<td>2.60E+06</td>
</tr>
<tr>
<td>Damage Ratio, DR</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>Airborne Release Fraction, ARF</td>
<td>0.0003</td>
<td>0.002</td>
</tr>
<tr>
<td>Respirable Fraction, RF</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Leak-Path Factor</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>&quot;Chi over Q,&quot; X/Q (s/m$^3$)</td>
<td>1.00E-06</td>
<td>8.77E-05</td>
</tr>
<tr>
<td>Breathing Rate, BR (m$^3$/s)</td>
<td>0.00033</td>
<td>0.00033</td>
</tr>
<tr>
<td>Specific Activity, SA (Ci/g) for Pu-239E</td>
<td>0.0622</td>
<td>0.0622</td>
</tr>
<tr>
<td>Dose Conversion Factor, DCF (rem/Ci)</td>
<td>5.92E+07</td>
<td>5.92E+07</td>
</tr>
<tr>
<td>Dose (rem)</td>
<td>.00474</td>
<td>166</td>
</tr>
<tr>
<td>Dose guideline (rem) per DOE regs</td>
<td>5-25</td>
<td>5-25</td>
</tr>
</tbody>
</table>

Factors are based on DOE rules except Chi over Q, which is specific to TA-55 (main plutonium area at LANL). Chi over Q includes such factors as distance, wind speed, wind direction, and deposition rate. ARF is specific to material form and accident scenario.
Increase MAR by Avoiding Hyper-conservative Calculations of Dose

- “When several input parameters are taken at their bounding values, the obtained result dwarfs the derived 95\textsuperscript{th} percentile of the output by orders of magnitude.” (K. Jamali)
- Using conservative instead of hyperconservative assumptions reduces dose by 35,000x
Wrapup

• Many paths toward 80 ppy
• Can’t know which ones provide enough margin without data on MAR and space requirements
  – No changes may be needed, or
  – Non-construction options may suffice, or
  – Minor construction may suffice, or
  – Major construction may be required
    • Can’t tell if 0, 1, 2, or 3 modules would be necessary
    • Can’t tell if 0, 1, 2, or 3 modules would be sufficient