
Plutonium Aging: Executive Summary (Unclassified)

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JSR-25-03ESU

March 25, 2026

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1 Executive Summary

This study was performed in response to a Congressional mandate that JASON evaluate and report on the status and future outcomes of research concerning the lifetime of the plutonium (Pu) pits in the US nuclear weapons stockpile. For background and context, the term “Pit lifetime” refers to the point at which Pu aging causes unacceptable loss of Margin in the performance of a given weapon - the value differs for different weapons systems. Understanding Pu aging and its effect on Margins and Uncertainties is essential for informing i) annual certification, ii) stockpile and military planning and iii) the schedule for pit production and re-use.

The performance of a pit can degrade over time due to effects of the radioactive decay of the Pu-239 nuclei. Before 2010, tests of Pu at the age in the stockpile did not show evidence of degradation of properties relevant to weapons performance. This is in part because annealing processes in materials like Pu partially counteract the damage caused by radiation. After 2010, some aging effects began to be observed in stockpile-age and artificially aged Pu. In response, in 2021 the National Nuclear Security Administration (NNSA) created a 10-year Research Plan for Pu and Pit Aging (the “Plan”) that was implemented at its Laboratories. Many significant achievements were made in the first five years of the Plan including: property measurements that directly compare new with aged Pu, advances in materials characterization using newly developed tools at NNSA facilities, and simulation tools with enhanced calibration based on new experimental results. Overall, the results from the first five years of the Plan show that there are gradual changes in Pu material properties as a function of age, at a level that do not call into question present weapons performance.

Reliable prediction of future consequences of aging requires carefully designed follow-on experiments, computation, and theory, and these are the basis for continuing work under Proposed Updates to the Plan for the next five years. The Proposed Updates incorporate new information learned in the first five years of the Plan, as well as changes to address delayed availability of the Enhanced Capability for Subcritical Experiments (ECSE). The Updated Plan includes a number of different experiments to directly explore weapons-relevant trajectories to improve assessments. The updated Plan also includes preparation for experiments with ECSE when it comes online. If appropriately funded, focused, prioritized, and scheduled, the Updated Plan should further reduce uncertainties in weapons performance due to Pu aging.

Updated assessment of Margins and Uncertainties as a function of pit age in each weapon system by FY30 is thus on track. In parallel, the uncertainties in the predicted pit lifetimes need to be interpreted and communicated to inform military planning. To do so, the experiments must continue to be designed with relevance to stockpile performance in mind and evaluated based on scientific understanding. Some statistical evaluations, especially when using historical data that were not designed for identifying specific effects, are multivariate, difficult, and risky. Such analyses must be thoroughly documented and be evaluated with rigorous external peer review.

The following high-level Findings and Recommendations for this study are informed by information provided by the NNSA Laboratories, the NWC Requirements and Planning Document (RPD), and the NNSA Advisory Committee on Nuclear Security (ACNS) reports on the Research Plan.

1.1 High-Level Findings

- F1** Despite delays in construction of the Enhanced Capability for Subcritical Experiments (ECSE), the proposed modified research Plan for the second five years (FY26-30) – if appropriately supported, focused, prioritized, and scheduled – should further reduce uncertainties in performance degradation due to Pu aging, and deliver updated performance assessments by FY30.
- F2** The Pu in the stockpile appears to be aging slowly. The degradation issues that have been observed do not call into question present weapons performance.

1.2 High-Level Recommendations

- R1** Further advance assessments of Pu aging effects on primary performance using experimental measurements of materials properties under weapons-relevant conditions, supported by theory and modeling tools. Use the Modified Plan to develop, support, and prepare to execute the work needed in FY31-40.
- R2** In the next five years:
- As feasible, accelerate completion of the Scorpius component of ECSE, which will provide key information about pit performance;
 - Use the new and emerging capabilities to conduct integral and focused experiments;
 - Increase throughput of experiments via expanded facility access, management of materials controls, and streamlined shipping.
- R3** Continue to develop and deploy predictive, validated models of the effects of Pu aging on weapons performance. Base those models on scientific understanding of the aging processes in the context of weapons performance. Apply new statistical analyses with appropriate caution, requiring clear documentation and rigorous review before they are used to inform high-impact National Security assessments and decisions.

1.3 Overarching Recommendation

NNSA and its Laboratories must prioritize execution of subcritical experiments at ECSE if possible before FY30 and no later than FY35, along with establishing pit production capabilities that may be needed to provide options to mitigate any future aging-related issues. As information from the next five years is assimilated, NNSA and its Laboratories should develop a focused FY31-40 Research Plan to inform timely weapons maintenance and delivery decisions by maturing understanding of Pu aging effects on performance. The NSE should continue to develop thoroughly documented and rigorously reviewed measures of performance to inform certification, stockpile and military planning, and schedules for pit re-use and production.