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This Letter Report to the NNSA is in response to the 2019 Pit Aging JASON summer study charge (Statement of Work attached). A 2006 JASON report (JSR-06-335), entitled Pit Lifetime, examined effects of plutonium aging on primary performance to provide system lifetime estimates for a majority of pit designs in the stockpile. A Defense Programs Advisory Committee (DPAC) report completed in 2018 also revisited Pu-aging issues.

Over the past decade, independently validated experiments have identified examples of age-induced changes in naturally and artificially aged δ-phase Pu. Today's modeling and simulation codes are used with measured rates of change to predict pit and primary performance for warheads over the planned decades of their deployment. The conclusions are based on quantification of margins and uncertainties (QMU), the current approach used to assess the health of the stockpile. While the present assessments of aging do not indicate any impending issues for the stockpile, the possibility that the codes could be out of their domain of validity when they are used to assess aged pits indicate that continued research and ongoing surveillance are required to anticipate any unexpected developments.

The Statement of Work asks JASON to consider the body of work plutonium aging since 2006, and asks if the scientific program responded to the 2006 JASON Pit Lifetime study recommendations. For the present study, JASON is also asked to identify critical areas that may need further attention.

We list below the questions posed to JASON and our response.

1. Is the body of work to date, as well as the proposed future work, sufficient to reduce or bound uncertainties in order to provide a sound scientific basis for lifetime assessments? What are the critical areas of study that need further consideration (if any)?

LLNL and LANL have made important progress on some of the recommendations of the 2006 JASON Pit Lifetime report. An important example is accelerated aging of Pu to the point where changes in various properties become clearly measureable. But in general, studies on Pu aging and its impacts on the performance of nuclear-weapon primaries have not been sufficiently prioritized over the past decade. A focused program of experiments, theory, and simulations is

required to determine the timescales over which Pu aging may lead to an unacceptable degradation of primary performance.

For future work, JASON recommends that LLNL and LANL continue to pursue a sustained program to improve their understanding of Pu aging on pits. The goal should be to identify specific mechanisms for changes in Pu properties that would degrade primary performance, and to determine the timescales over which the performance margin of stockpile weapons would be sufficiently degraded to elicit concern. The experiments and their analysis should be designed to yield clear results that guide simulations of pit aging in the future, minimizing the probability of false positives or false negatives.

The program should assess and, if necessary, mitigate threats to primary performance caused by Pu aging. The labs briefly presented their program to address Pu aging to JASON. The plan seemed sensible, but a detailed JASON assessment would require additional information about the program as well as technical details.

Continued study of Pu-aging should address the following:

- Investigation of the properties of naturally and artificially aged Pu that are relevant to primary yield. These include compressibility, strength, and entropy at weapons-relevant pressures and densities.
- Completion of aging studies for the full set of Pu materials used in the stockpile.
- Extending the range of accelerated aging to identify the types, modes, timescales, and uncertainties in changes of Pu behavior that would affect primary performance.
- The utility of integrated sub-critical experiments with new and aged Pu pits should be explored. They could cover the temperature and pressure conditions encountered during primary implosion to provide information about consequences of Pu aging.

2. In addition to re-establishing a pit manufacturing capability, are there prudent actions that could be taken to increase margins against uncertainty associated with plutonium aging?

A variety of measures might compensate for potential Pu-aging-related effects on primaries:

- Changes in boost-gas composition and concentration can increase performance margins; this mitigation approach is underway, or already completed, for primaries in the stockpile.
- Performance margins could be increased by modifying the high explosive, or by other means. Such measures should be undertaken with care, because they may take the stockpile away from the underground test base used to certify the weapons.
- Maintaining a diversity of weapon types and ages can hedge against the risk of age-related common-mode failures.

Finally, we urge that pit manufacturing be re-established as expeditiously as possible in parallel with the focused program to understand Pu aging, to mitigate against potential risks posed by

Pu aging on the stockpile. The reuse of aged pits in rebuilt primaries can address certain issues, but cannot change the aged pits themselves. A significant period of time will be required to recreate the facilities and expertise needed to manufacture Pu pits. Given the number and age distribution of weapons in the stockpile, it will then include some eighty-year-old pits, even under most favorable circumstances.

The Appendix (S//RD) contains JASON's Findings and Recommendation for this letter report.

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