Reliable Replace Warhead
Executive Summary

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1 SUMMARY

1.1 Abstract

NNSA tasked JASON to conduct a technical review of the Reliable Replacement Warhead (RRW), with a focus on the LLNL/Sandia design, now called WR1. This report summarizes our findings and recommendations. The design of a new warhead, without new nuclear explosive tests, relies on the scientific connections and traceability of that design to (1) the legacy nuclear explosive test data, (2) established physics, and (3) new and ongoing experiments. The WR1 design is pursued with these principles in mind, but certification is not yet assured. The certification plan presented needs further development. For example, additional experiments and analyses are needed that explore failure modes, and assess the impact on performance of new manufacturing processes. Substantial work remains on the physical understanding of the surety mechanisms that are of high priority to the RRW program. Establishing that the case for confidence in any RRW has been satisfactorily made will require a new peer review process. In addition to certification issues, it is too early to assess how the WR1 will impact the modernization and streamlining of NNSA's production complex.

1.2 Study Charge

NNSA tasked JASON to conduct a technical review of the Reliable Replacement Warhead (RRW) program from January to September 2007. The updated charge of May 4, 2007 is as follows:

1. Review the competing RRW weapons system designs currently being done by LANL and LLNL. This review should include an analysis of the competing designs from each of the laboratories and should consider the inter-lab peer review process that was employed.

2. Evaluate the NNSA/Navy recommended design as of May 1,2007 to understand and affirm that this particular design

   - will meet the military characteristics (MCs) as defined by the Department of Defense and Congress,
   - that the device design encompasses the essential safety and use control features,
   - that there are design features built in to ensure that the warhead will age gracefully and not require refurbishment for several decades,
   - that the planned peer review process is credible.

3. Other key issues for inclusion in the review document include the relationship between the manufacturing processes, the new materials to be used in the device, the capabilities and capacity of the transformed Nuclear Weapons Complex. Given the progress to date, is it possible to establish whether the latest design plans are consistent with modernization and streamlining of the NNSA's production complex?

4. The RRW review document will comment on the JASON's level of confidence that the existing and planned science base is sufficient to certify the RRW weapons system without nuclear testing. In this context, certification is defined as the process in which predictions of RRW performance and other required attributes are traceable to established physics, to results of experiments, existing or planned, and to the legacy underground test database. If this science base is currently insufficient, the report will identify steps that JASON recommends will be required

to achieve a threshold for certification. Finally, the report must include a discussion of the fundamental premise of the RRW initiative, that a replacement nuclear warhead can be designed, produced and certified for use without the need for a nuclear weapons test, and that it can be deployed in the intended delivery systems.

JASON was not asked to assess the merits of the RRW program relative to other options, such as life-extension programs.

The study began with presentations on the competing RRW designs in July 2006. These were followed in January 2007 by in-depth presentations on both designs, including the proposed surety features as well as a summary of the interlab peer reviews. An interim report was submitted to NNSA in February 2007 describing the JASON assessment of the two RRW designs (Task 1 in the charge) and posing questions for the Summer 2007 JASON study. In March 2007, NNSA chose the LLNL/Sandia design as the basis for the RRW design (subsequently called WRl) and directed that further design iterations target Navy delivery platforms. In June 2007 the LLNL/Sandia RRW project team briefed JASON and provided detailed design information. Presentations were also delivered on the inter-lab peer review process.

The WRl design derives from tested systems. The nuclear-explosive package and the ancillary non-nuclear supporting systems have been sized so as to fit into the three missile systems (with some minor modifications) of the Navy and the Air Force. The design includes features intended to enhance the safety of the weapon in abnormal environments such as fires. In addition, new features are incorporated to preclude unauthorized use.

This report summarizes the JASON response to the NNSA charge. In Section 1.3, we address Task 4 in the Charge by summarizing our understanding of nuclear weapons performance and the challenge of fielding any new device without a new nuclear explosive test. The particular challenges to certification for WR1 (Task 2) are addressed in Section 1.4, where we make specific recommendations. We were not shown material on cost or schedule sufficient to establish the impact of WR1 on the nuclear weapons complex (Task 3).

1.3 Confidence and Certification for RRW Designs

The basis for assessing the confidence required for certification of any RRW design is that used for the current stockpile: quantification of margins and uncertainties (QMU). Each stage of nuclear weapon function is assessed, and performance margins (M) and uncertainties (U) are estimated from analysis of nuclear and non-nuclear tests and simulations. In order to establish this confidence in any RRW design, the objective is to achieve high values of the ratio M/U.

The process of certification can be divided into two parts. For non-nuclear components, such as the electrical or gas-transfer systems, it is possible to qualify the components and ultimately certify the system through a process of engineering tests and analyses. In contrast, the performance of the nuclear explosive package must be assessed through the use of simulation tools informed by experimental results, including previous nuclear explosive tests. The JASON study largely focused on this second aspect of certification.

The Stockpile Stewardship Program has led to continuing progress in the understanding of basic weapons physics. Simulation combined with theoretical advances and experiments is providing important insights. Even though simulation capability has substantially improved, the domain of validity of simulations remains an issue.

For the purpose of weapons simulations, codes are largely calibrated to data from experiments and legacy nuclear explosive tests. A concern remains, however, that even though codes can reproduce the performance of previously tested weapons, it is not yet possible to quantify how well excursions from a tested design can be modeled and predicted. For this reason, the reliability of the stockpile is assessed by requiring that any proposed changes (such as those made in a life-extension program) are validated using non-nuclear or zero-yield (sub-critical) nuclear experiments, that the simulations are consistent with archival nuclear explosive tests, and, ideally, that changes do not decrease M/U. This approach has been successfully applied to assess the consequences of specific departures from the legacy stockpile. A notable example is the recent work that improved understanding of plutonium aging on the performance of primaries. Another significant example is the certification of pits manufactured by a new process.

Successful certification, both for the legacy stockpile and RRW designs, is a process in which predictions of performance and other required attributes are traceable to established physics, to results of existing or newly designed experiments, and to the legacy nuclear explosive test data. The uncertainties associated with these predictions must be acceptably smaller than the corresponding required margins, and must be similarly traceable.

The absence of new nuclear explosive testing increases the need for experiments, computational tools, and improved scientific understanding of the connection of the results from such experiments and simulations to the existing nuclear explosive test data. Even when suitably validated simulations can predict device failure, and provide reliable estimates of margins and uncertainties, a continued non-nuclear experimental basis will be required for certification of any new design. This is especially true at the present time for the RRW surety features.

1.4 Findings and Recommendations for the WRl

The WR1 design is pursued with the above principles in mind, but certification is not yet assured. The certification plan presented needs further development. For example, additional experiments and analyses are needed that explore failure modes, and assess the impact on performance of new manufacturing processes. Substantial work remains on the physical understanding of the surety mechanisms that are of high priority to the RRW program.

Our findings and recommendations are as follows:

1. Certification for WR1 will require new experiments, enhanced computational tools, and improved scientific understanding of the connection of the results from such experiments and simulations to the existing nuclear explosive test data. We recommend

    - continued investigation and development of quantitative measures that assess the connection of WR1 with the legacy nuclear test data,
    - additional hydrodynamic and other (non-nuclear explosive) experiments beyond those indicated in the certification plan presented. Such experiments are intended to extend modeling and simulation capabilities so that future computational tools are predictive not only of device performance, but also of device failure and the limits of validity of the computer simulations. This effort will require the continued availability of hydrodynamic test facilities;
    - that an improved understanding of materials aging and interactions over the proposed multi-decade lifetime of RRW systems be developed.

2. The physical understanding of the enhanced surety features, which address a top requirement for WRl, is still under development. We recommend

    - that substantial effort be placed into surety science, including modeling, materials properties and experimentation (beyond that proposed in the reviewed certification plan),
    - once an improved physical understanding is in hand, a QMU-based assessment of the surety features must be performed.

3. New fabrication processes are proposed for WRl with the intent of simplifying manufacturing and achieving cost savings. To ensure that the new manufacturing processes do not have a deleterious effect on WRl performance we recommend that

    - their impact on performance be understood. This will require additional experiments and computer simulations beyond those presented in the certification plan;
    - proven manufacturing processes be maintained as contingency.

4. In the absence of new nuclear-explosive testing, the challenges to certification must be met in a peer review regime that establishes confidence in the WRl design. Peer review is essential to establishing the technical credibility of new designs. Peer review for RRW certification must play a larger role than provided for by current NNSA guidelines or envisaged in the LLNL plans presented to us. We recommend that NNSA establish a RRW peer review mechanism with the following elements:

    - the process must be visible, funded, and administered to assure the nation that all expertise available has been applied to a rigorous evaluation of the new design;
    - it is imperative that its effectiveness be examined periodically by an independent organization;

- the peer review team should be broadly constituted and have authority to pose formal tests of a computational or experimental nature to the design team;
- issues identified through peer review must be documented, tracked and follow a formal process of closure with participation by the peer review team;
- responsibility for conducting peer review should be assigned to the weapons design laboratory not leading the design effort.

1.5 Transformation of the Complex

The WR1 design is intended to meet the transformational objectives for the nuclear weapons complex. The early engagement and cooperative working relationship between the design laboratories and production plants during the feasibility phase has led to fewer hazardous materials in the design and a likely reduction of steps in the manufacturing processes. However, JASON was not presented with any cost or schedule information for WR1, so we cannot assess the impact of WR1 or the RRW concept on transforming the production complex at this stage.