October 7, 2016

Dr. Ralph Schneider NNSA
NA-113 Forrestal Building
1000 Independence Avenue, SW
Washington, DC 20585

Dear Dr. Schneider:

This letter (JSR-16-Task-011) provides JASON's response to the tasking from NNSA to review technical aspects of the Enhanced Capabilities for Subcritical Experiments program. A study group consisting of 12 JASON members participated.

Background

As a result of a Congressional mandate, NNSA commissioned JASON to investigate aspects of the Enhanced Capabilities for Subcritical Experiments program, which is intended to provide a new x-ray radiographic source to diagnose subcritical experiments at U1a at the Nevada National Security Site. The statement of work requested that JASON assess

- The need for new radiographic facilities
- Any gaps between experimental needs to certify the nuclear weapons stockpile and present experimental capabilities

and review planning for the project. The JASON review focused on the needs for x-ray diagnostics in subcritical experiments to support the stockpile, and any current gaps in meeting those needs, but not on the technical implementation of the x-ray machine itself. Due to the short time available, JASON submits this letter report in response to this tasking, but will not submit a full-length technical report.

ECSE is currently managed at LANL with cooperation from LLNL and support from SNL. The program plans to design, manufacture, install in U1a, and operate an x-ray source based on a linear induction accelerator (LIA) for electrons, similar but not identical to the 2 LIAs at LANL's DARHT. Technical information on the radiographic needs, goals and planned capabilities of ECSE was presented to JASON in one day of briefings at La Jolla on July 8, 2016 accompanied by discussions and technical documents. Representatives from LANL, LLNL and SNL were present, as well as personnel from NNSA. In particular, representatives of the primary design divisions at LANL and LLNL presented information about stockpile needs.

JASON has not reviewed in this study the need for, or possible capabilities of, neutron diagnostics for subcritical experiments (NDSE) at U1a, which may ultimately provide complementary information to that from ECSE radiography.

Summary Conclusions by JASON

- Scaled experiments in Pu, appropriately diagnosed, would reduce uncertainties in stockpile assessment and certification.
- A gap exists in the current US capability to carry out and diagnose such experiments.
- Closing this gap would reduce uncertainties in assessments of aging in the stockpile and in certification decisions for possible future stockpile options.
- The current radiographic requirements for ECSE have been derived from detailed analyses of the most important uncertainties. (But in this narrow-scope study, JASON did not attempt to validate these requirements quantitatively.)

Stockpile Needs

Subcritical experiments obtain information about the performance and safety of the US nuclear weapons stockpile in the absence of nuclear testing. They are one variety of hydrodynamic experiment in which chemical explosives produce high pressures that are applied to plutonium (Pu) or other materials. A subcritical experiment includes Pu but no critical mass is formed so that no self-sustaining nuclear chain reaction occurs. At present such experiments are carried out only at U1a. (Though certain limited hydrodynamic experiments on Pu are also authorized at DARHT, they have never been executed.) X-ray radiography and neutronics are the most feasible technologies for diagnosing the dynamics throughout the required duration of these experiments. This report assesses needs and requirements for such radiography.

Hydrodynamic experiments are also carried out with surrogate materials (other heavy metals) instead of Pu. Because these materials never support a neutron chain reaction, surrogate experiments can be mounted at DARHT and other facilities. However, the material properties of surrogates differ from those of Pu so that surrogate experiments require extrapolation and interpretation; they complement rather than replace subcritical experiments in Pu.

Only x-rays of sufficiently high energy can penetrate the Pu and produce a radiographic image. JASON has reviewed the required penetration (in report JSR-11-340, in subsequent technical interchanges with the physics labs, as well as in the present study) and concurs that an electron energy above 10MeV is required for useful radiography at late times. In particular, the two existing CYGNUS sources (2.2 MeV) at U1a, while performing as designed and useful for other experiments, are inadequate for late-time subcritical experiments in Pu.

JASON finds that x-ray radiography is needed to diagnose subcritical experiments in Pu, that such experiments must be carried out at U1a, and that the US currently lacks adequate radiography at U1a for this purpose.

Basis of Requirements

Primary designers from LANL and LLNL provided input to JASON on important issues in the assessment of primary function, and needs for radiography of scaled experiments in Pu to assess weapon performance. JASON finds that the main use is to decrease uncertainties in primary performance. For all weapons in the current stockpile, at the present time margins are adequate and uncertainties are within margins, both for normal operation and for nuclear safety should accidents occur. However, future aging of these weapons and their remanufacture may increase uncertainties, and JASON finds that scaled experiments in Pu may significantly reduce uncertainties that may arise in the future due to aging, or in certification of weapons through future life extension programs (LEPs) or alterations (ALTs), or through remanufacture or reuse of weapon components. Analyses supporting global security, non-proliferation, and defense against nuclear terrorism may also benefit from scaled experiments in Pu through reduction of uncertainties.

Though detailed assessment of stockpile primaries is the pre-eminent need for subcritical experiments, another issue contributes: Subcritical experiments are integrated experiments, which are valuable because they test all the processes together and provide a check on the overall design and construction of the primary.

Requirements

LANL and LLNL have recommended requirements for ECSE, driven by key uncertainties identified by the primary designers. The principal recommendations are that 1) x-ray energy must be high enough to penetrate the experiment throughout its course; 2) the x-ray spot size must be small enough to resolve spatial features as necessary; 3) multiple short pulses are needed to diagnose time-dependent phenomena; 4) quantitative values of the aforementioned parameters must allow comparison with archived data from nuclear tests and current simulations; and 5) dual or multiple axes, while useful, are less important than multiple pulses on the same axis. JASON concurs with the basis of these recommendations but has not independently validated the quantitative values of the recommended parameters.

The labs have recommended a linear induction accelerator (LIA) on a single axis as the x-ray source technology that best meets these requirements.

Programmatic and Schedule Considerations

Although JASON did not review the site or LIA aspects of ECSE in detail, a number of issues deserve careful attention. It appears feasible to install a LIA underground within U1a, though new mining of additional drifts is necessary. JASON observes that important design options of the LIA remain to be chosen, which will impact its overall size, cost and serviceability; the down-selection should be made soon to facilitate further project planning. Servicing and troubleshooting the LIA will be more difficult in U1a than at existing above-ground facilities such as DARHT. The project plans first to assemble the LIA above-ground at U1a for testing and commissioning, and then to move its components underground for final assembly; this is prudent. Pu test articles for subcritical experiments must be manufactured in TA-55 at LANL, and adequate capacity there must be planned. Containment vessels for completed experiments must be entombed underground, and it is important to provide ample space in a dedicated drift for all experiments to be completed in the life of the facility.

ECSE is a large NNSA project and must be managed at the bi-lab level; JASON heard support for it from expert primary designers and senior managers at LANL and LLNL, but did not directly hear from the laboratory directors about priority of ECSE at the bi-lab or complex levels compared to possible competing projects. Such prioritization will be necessary for ECSE to go forward.

Please let us know of any further help we can provide.

Sincerely,

Douglas Eardley
Study leader

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JSR-16-Task-011