DOE/EIS-0281-SA-03

SUPPLEMENT ANALYSIS

Site-Wide Environmental Impact Statement for Sandia National Laboratories/New Mexico

Installation of a Petawatt Laser System in TA-IV

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INTRODUCTION – PURPOSE OF SUPPLEMENT ANALYSIS

This Supplement Analysis (SA) has been prepared to determine if the *Site-Wide Environmental Impact Statement for Sandia National Laboratories/New Mexico* (SWEIS), DOE/EIS-0281, and subsequent NEPA documentation, adequately address the environmental effects of a proposal to add High-Energy Petawatt (HEPW) capabilities at the Z-Beamlet Laser Facility and Z Accelerator at Sandia National Laboratories/New Mexico (SNL/NM), or if additional documentation under the National Environmental Policy Act (NEPA) is needed. The need for a SA to an existing environmental impact statement (EIS) is initiated by subsequent changes in the basis upon which the original EIS was prepared and the need to evaluate whether or not the EIS is adequate in light of those changes. It is submitted according to the requirement for determining the need for supplemental environmental impact statements (10 CFR 1021.314) in the Department of Energy's (DOE) regulation for implementing NEPA.

DOE has identified a need to revitalize HEPW lasers in support of its Stockpile Stewardship Program (SSP) mission. The SSP mission is to maintain a safe, secure, and reliable nuclear weapons stockpile. A vital High-Energy Density Physics Program (HEDP) is an essential component of the SSP mission. HEPW lasers can provide a major technological advancement for the HEDP program through advanced radiographic diagnostics, the ability to create unique states of matter, and the exploration of advanced ignition concepts. In addition to the provision of a HEPW capability at SNL/NM, HEPW laser configurations are also proposed for the existing OMEGA laser facility at the University of Rochester's Laboratory for Laser Energetics and the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory. This Supplement Analysis does not address environmental compliance for these two laser facilities.

The SWEIS analyzed the environmental effects of operating the Z Accelerator under three alternative levels of operation – No Action, Expanded Operations, and Reduced Operation Alternative. The No Action Alternative would maintain the status quo – operating at planned levels as reflected in current DOE management plans. Operating levels under the Expanded Operations Alternative would increase to the highest reasonable levels that could be supported by current facilities and their potential expansion, as well as construction of identified facilities for future actions. Operating levels under the Reduced Operating Alternative would be reduced to the minimum levels needed to maintain facilities and equipment in an operational readiness mode. The Record of Decision for the SWEIS, issued in December 1999, documents DOE's preferred alternative as the Expanded Operations Alternative. Under this preferred alternative the Z Accelerator would continue to subject various targets to intense bursts of x-rays. The capability of the Z Accelerator would be increased to a maximum of 350 firings per year, of which approximately 78 percent could involve nuclear materials.

The DOE proposal analyzed in this SA is to add a high-energy petawatt capability to the Z-Beamlet Laser Facility/Z Accelerator combination. The addition of this capability will enable the peak laser powers to transition from the current value of a few terawatts (a few trillion watts) to the anticipated value of a few petawatts (a few quadrillion watts), an increase of roughly 1000 fold. The addition of a petawatt capability would expand the experimental scope of Z-Beamlet and Z-Accelerator combination but will maintain the same operational relationships.

This SA specifically compares key impact assessment parameters evaluated in the SWEIS of operating the Z Accelerator at activity levels and operational modes for the preferred or Expanded Operations Alternative with comparable impact assessment parameters of the proposed action. Included in this comparison are actions associated with the Z-Beamlet Laser Facility and the Z Accelerator that were addressed in Categorical Exclusions subsequent to the SWEIS. Based on this analysis, this SA will be used to make a formal NEPA determination whether (1) the existing SWEIS should be supplemented, (2) a new EIS should be prepared, or (3) no further NEPA documentation is required.

PROPOSAL DESCRIPTION

<u>Background</u>

Facility Characterization and Current Uses

- *The Z Accelerator*. The Z Accelerator facility, formerly known as the Particle Beam Fusion Accelerator II, is located in Building 983 in Technical Area IV. This multiple use facility provides weapons systems survivability testing for the Inertial Confinement Fusion Program and weapon science research by simulating the X-rays produced by nuclear weapon detonations. Operating on the principle of pulsed power, the Z Accelerator stores electrical energy over a period of minutes then releases that energy in a concentrated burst. The accelerator produces a single, extremely short, extremely powerful pulse of energy that can be focused on a target. The Z Accelerator consists of 36 modules arranged radially around a central experiment vacuum chamber. It is located in an open-air tank that is 108 feet (ft) in diameter and 20 ft high and is divided into three annular regions containing 540,000 gallons of transformer oil, 600,000 gallons of deionized water, and a vacuum chamber. The primary operating mode of the Z Accelerator produces a 60- nanosecond pulse with about 3.0 megajoules of electrical energy and 50 terawatts of peak power. Experiments are conducted in a central vacuum chamber. The Z Accelerator has not lost vacuum in the experimental vacuum chamber during its experimental life, which essentially eliminates any release to the environment during the sequence of events that involve firing the accelerator.

Radiological hazards currently exist at the Z Accelerator. Both prompt and residual ionizing radiation hazards are produced. Operational activities produce a prompt photon (and sometimes neutron) pulse and objects inside the center section are routinely activated and contaminated. In addition, radioactive targets are sometimes used in experiments. The large amounts of water and oil that surround the center section provide a substantial amount of shielding. The high bay (including the –10 and –25 foot levels) and the roof are evacuated during shots. Quarterly radiation doses in occupied areas of the building are less than 10 millirem, and operating personnel do not receive a measurable dose from the prompt radiation pulse.

- *Z-Beamlet Laser Facility*. The Z-Beamlet Laser Facility is located adjacent to the Z Accelerator Facility in Building 986. An overhead laser transport structure connects the two facilities. Z-Beamlet is the former Beamlet laser at Lawrence Livermore National Laboratory (LLNL) that was put into operation at SNL/NM on Z Accelerator experiments in 2001. Its original mission while at LLNL was as a research laser to develop, test, and refine technology options for the National Ignition Facility. Z-Beamlet is a multi-kilojoule, nanosecond (billionth of a second) laser that is now used as an x-ray radiographic diagnostic for Z experiments. Currently, the Z-Beamlet Laser Facility and the Z Accelerator can operate independently or in tandem, with the Z-Beamlet Laser Facility being required for its primary mission of x-ray backlighting on the accelerator. It is used to create a bright x-ray source for taking x-ray pictures of material under extreme conditions of temperature and density during Z Accelerator experiments.

National Environmental Policy Act Documentation – Site-Wide Environmental Impact Statement for Sandia National Laboratories/New Mexico and Categorical Exclusion B3.6

- Preferred Alternative – Expanded Operations.

  Z Accelerator. Under the expanded operations alternative the Z Accelerator would continue to be used to produce extremely short, extremely powerful energy pulses at various targets. The Z Accelerator's capability would be maximized to 350 firings per year. Approximately 78 percent of accelerator operations would involve tritium, deuterium, plutonium, and depleted uranium. A recent proposal (documented in NEPA review SNA 01–0700**)** to modernize the Z Accelerator with a resultant increase in shot capacity from the 350 firings analyzed in the SWEIS to 400 firings per year was categorically excluded from the need to prepare an environmental assessment or an environmental impact statement (2/6/02).

- Lawrence Livermore Backlighter Laser System

  Z-Beamlet Laser Facility. As stated, the Record of Decision for the SWEIS that documents DOE's preferred alternative as the Expanded Operations Alternative was issued in December 1999. Creation of the Z-Beamlet Laser Facility (initially called the Lawrence Livermore Backlighter Laser System because most of the components for the laser were obtained from LLNL) was not included in the SWEIS assessment because it was proposed near the completion of the SWEIS and could not be included. Installation of instrumentation in Building 986 to create the Z-Beamlet Laser Facility and modifications to Buildings 986 and 983 were categorically excluded from the need to prepare an environmental assessment or environmental impact statement by Categorical Exclusion B3.6 – siting/construction/operation/decommissioning of facilities for bench-scale research, conventional laboratory operations, small-scale research and development and pilot projects (SNA 98-051 and a subsequent update SNA 98-080).

Proposed Action

Sandia National Laboratories, New Mexico (SNL/NM), is proposing to add a high-energy petawatt capability to the Z-Beamlet Laser Facility/Z Accelerator combination. The addition of this capability would increase the peak laser power from the current value of a few terawatts (a few trillion watts) to an anticipated value of a few petawatts (a few quadrillion watts). The petawatt capability would allow new radiography capabilities in conjunction with the Z Accelerator in the form of harder x-rays and potentially proton radiography. This ability can provide images of denser materials and possibly electric field mapping. The addition of the petawatt capability would also enable fast ignition fusion research where the Z Accelerator compresses fusion fuels and the petawatt laser pulse provides an additional heat source for fusion.

The incorporation of a petawatt capability at the Z-Beamlet Laser Facility/Z Accelerator combination would involve the development of an integrated test bed at Z-Beamlet to enable prototyping of the petawatt technology prior to full petawatt activation and the installation of a passive power amplifier (short-pulse compression system) at the Z Accelerator to achieve the full operational capability at the petawatt power level. These developments and necessary facility modifications are more fully characterized as follows:

- *Z-Beamlet Laser Facility (Bldg. 986).* Modifications to the Z-Beamlet Laser Facility would require the incorporation of a new short-pulse front-end laser, a new vacuum grating compressor, and an experimental target area. As described, these additions would create a system known as an integrated test bed. These additional facilities would require the construction of an approximately 2500 square foot (sq. ft.) building addition at the northwest corner of the building – at the existing air lock. Two small sheds and some water and communications utilities would require relocating.

The 2500 sq. ft. building addition would include an approximately 260 sq. ft. space to house the target area. The existing airlock would be remodeled to form the target area. A target area is necessary to validate the laser capabilities. Radiation shielding would be incorporated into the design of the target area because of the elevated levels of penetrating radiation and high-energy particles produced by the higher power levels and intensities. Personnel access to the test facility would be restricted during test operations. The production of ionizing radiation and the associated use of shielding have not been part of the experimental life of Z-Beamlet.

- *Z Accelerator (Bldg. 983).* Modifications to Building 983 would consist of renovating the Phase C area and adding a two-story building and two small air locks. Approximately 4900 sq. ft. of existing space in the Phase C area (primarily the high bay and old Mechanical Room) would be renovated to house equipment used in the petawatt laser system. An approximately 3800 sq. ft. addition to the Phase C area would be constructed to house the laser components, test equipment, and utility infrastructure necessary to support this new feature.

For use as an x-ray radiography diagnostic, the petawatt laser beam would be focused on a thin-foil target material to produce a plasma with energetic electrons that will, in turn, generate x-rays (and potentially subsequent photoneutrons). In addition, there are plans to use the petawatt laser beam as an additional heat source for fusion in experiments studying the Fast Ignitor target concept.

Measures currently used to control radiological hazards in the center section of the Z Accelerator would continue to be used during pre- and initial operational use of the petawatt laser. These measures would be the minimum level of control and operational radiological data could result in more stringent measures. These measures consist of the following:

- Develop a Technical Work Document. Additional hazards introduced by use of the petawatt laser in the center section could be incorporated into existing Radiological Work Permits.
- Ensure controlled radiological areas are properly delineated, controlled, and posted to prevent personnel access during operations. Area posting and controls could be subsequently modified based on operational radiological data.
- Utilize existing entry control devices for High Radiation Areas. More stringent controls would be utilized should operational data demonstrate a need.

- Coordinate radiological monitoring with Radiation Protection to validate modeling predictions and to verify adequacy of existing radiological controls.

DISCUSSION

The purpose of this section is to determine if the impacts resulting from the proposed action are within the scope of impacts discussed and evaluated for the Expanded Operations Alternative as presented in the SWEIS and subsequent NEPA determinations. This section (1) identifies key assessment parameters that would be affected by the proposed action, (2) identifies the extent to which these parameters would be affected as a consequence of implementing the proposed action, (3) identifies effects to those parameters that would result from implementation of the Expanded Operations Alternative as presented in the SWEIS and subsequent NEPA documentation, (4) compares differences in the extent of effects to identified key assessment parameters that would result from implementation of the proposed action and the Expanded Operations Alternative, and (5) states whether the magnitude of impacts from the proposed action are encompassed by the analysis presented in the SWEIS and subsequent NEPA documentation.

The key assessment parameters that would or could be affected by the proposed action were identified from the impact assessment parameters evaluated in the SWEIS and subsequent NEPA determinations. Of the key assessment parameters addressed in the SWEIS, including accelerator operations, material consumption, nuclear material inventory/accidents, explosives inventory, waste generation, radiation dose, and air emissions, those that would be affected by the proposed action are accelerator operations and radiation dose (including air emissions). Solid waste that would be generated from demolition, site preparation, and construction was not addressed because of the relatively small amounts that would be produced and inconsequential effects. The experimental use of the petawatt laser beam as an additional heat source would not change key assessment parameters and, consequently, is not addressed further in this SA.

The key assessment parameters evaluated and compared are the following:

- Accelerator Operations
- Radiation Dose (Including Air Emissions)

<u>Accelerator Operations</u>

The potential capacity of annual shots analyzed under the Expanded Operations Alternative for the Z Accelerator, as increased by facility refurbishment, is 400. The petawatt capability would be used in conjunction with operational activities at the Z Accelerator and would not result in an increase in the number of shots at the Z Accelerator. Consequently, the consequences of the proposed action are within those described and analyzed in the SWEIS and subsequent NEPA analysis.

Radiation Dose (Including Air Emissions)

- Z-Beamlet Test Cell Target Area. The x-ray dosage, calculated @ 30 centimeters from the test sphere utilizing 60 and 200 joules of laser energy, would be 19.3 and 351 Rems/shot, respectively. At one meter from the test sphere, and 60 and 200 joules of laser energy, the calculated x-ray dose would be 1.1 and 23.4 Rems/shot, respectively. As stated, the production of ionizing radiation at this facility is new.

  The inclusion of shielding into the design of the target area would reduce the calculated exterior x-ray dose (60 joules of laser energy) to 0.02 mrem/shot with a west beam orientation, 0.21 mrem/shot with a north beam orientation, and 0.09 mrem/shot with a south beam orientation. Utilizing 200 joules of laser energy the calculated exterior x-ray dose would be reduced to 0.63 mrem/shot with a west beam orientation, 2.0 mrem/shot with a north beam orientation, and 61 mrem/shot with a south beam orientation. The number of shots would be limited to prevent the exceedence of 100 mrem/year in any occupied area of the facility. Consequently, radiation doses would be within administrative limits and are within the scope of the SWEIS.

- Z Accelerator. Diagnostic use of the petawatt laser may present multiple radiation hazards at the Z Accelerator. There may be prompt radiation hazards and residual radiation hazards.

  - Prompt Radiation Hazards. Prompt radiation hazards would consist of electrons that are produced in the target by the laser, x-rays produced by the interaction of electrons with the target material or other materials in the center section of the Z Accelerator, and neutrons produced by the interaction of high-energy x-ray with the target material (or other materials) or interaction of protons with the target material.

    Radiation from the prompt x-ray pulse would be the main radiation hazard to personnel in occupied areas, i.e., the control room. The maximum calculated dose exterior to the high bay (evacuated during operation) for normal operations is 6.1 microrem/shot and for “worst case” scenario 0.65 millirem/shot.

    The production of photoneutrons is possible because the petawatt laser can generate electrons (and, therefore, x-rays) with energies up to 100 MeV. However, the probability for photoneutron production is very small. Production of photoneutrons would be further limited since the majority of x-rays produced in the center section would be interacting with the surrounding water and oil, degrading energy levels necessary for photoneutron production. Since photoneutron production could potentially occur anywhere in the high bay volume, it is nearly impossible to calculate the potential resulting dose; however, given the distributed nature of photoneutron production, dose would be expected to be minimal to personnel in occupied areas.

Since the laser will produce a plasma in the target material, protons may also interact with the target material to produce neutrons through (p,n) reactions. The dose in the control room is conservatively calculated to be 1.38 millirem. This figure neglects attenuation by the surrounding water and oil, walls, and increasing distance from the source.

- Residual Radiation Hazards. Residual radiation hazards would consist of activation of air in the high bay, activation of materials and components in the high Bay, and activation and contamination in the center section.

  Air activation is a possibility with x-rays of energies up to 100 MeV. The products of these reactions, ^{13}N and ^{15}O, have relatively short half-lives of 10 and 2 minutes respectively. Because of the short half-lives involved, even if produced in significant amounts, dilution and radioactive decay would quickly reduce the concentration to moderate levels. The estimated maximum concentrations of ^{13}N and ^{15}O in the high bay after a shot are 2.3E-8 μCi/ml of ^{13}N and 1.2E-8 μCi/ml of ^{15}O. Although those concentrations could deliver a potential dose of approximately 44 millirem/year, such a dose would only be possible under continuous occupation exposure (2000 hours/year) at the calculated concentrations. Given the intermittent nature of production, air exchanges within the high bay, the short half-lives of the radionuclides, and other factors, the realistic potential dose would be significantly less than that calculated. Additionally, the calculated values assume that all x-rays produced interact with the air, ignoring more probable interactions with the water and oil surrounding the center section, and that all x-rays also exceed the threshold energy levels required for photoactivation. The calculated dose to the maximally exposed individual from release to the environment is 3.6E-5 millirem (0.000036 millirem) for the radionuclide concentrations stated above and presuming 100 shots/year.

  Neutron activation of materials and components in the High Bay is not expected to be significant at the level of neutron production anticipated. Neutron producing activities that result in neutron fluxes higher than that expected for the petawatt laser are currently conducted at numerous locations at SNL/NM without significant neutron activation of surrounding materials and components. Currently, a Radiological Control Technician must initially enter the High Bay to assess radiation doses from potentially activated items or equipment following neutron-producing shots. This practice would be extended to the initial operations of the petawatt laser in the Z Accelerator Center Section. Additionally, the High Bay is on a periodic survey schedule that would identify activated materials and components.

Consistent with current procedures for Z Accelerator shots potentially resulting in activation or contamination in the Center Section, air from the chamber would be sampled prior to its opening. When the chamber is opened, dose rates and contamination levels would be determined prior to personnel access.

The calculated additional dose potential in occupied areas resulting from petawatt diagnostic applications within the Z Accelerator center section is small. The calculated x-ray dose exterior to the high bay of 2.4 millirem assuming maximum potential operations of 400 shots/year is well within the 100 millirem/year dose limit for members of the public and the calculated air emissions are well within the National Emission Standards for Hazardous Air Pollutants. Coupled with current requirements for radiological hazard control, e.g., monitoring and entry control, already in place, the potential occupational exposure resulting from the use of the petawatt laser would pose little additional radiological safety issues. Based on the above analysis, radiation doses would be well within administrative limits and are within the scope of the SWEIS.

CONCLUSION

DOE has not identified any other differences in parameters relevant to the analysis of environmental impacts between the proposed experiments at the Z-Beamlet Laser Facility and the Z-Accelerator and the actions analyzed in the SWEIS and subsequent Categorical Exclusions for the Expanded Operations Alternative. The scope of the proposed federal action has not changed (in ways that would significantly affect human health or the environment) from the scope of proposed actions described in previously cited NEPA documentation.

Impacts of the proposed activity have been bounded by the impacts analyzed in the SWEIS and subsequent NEPA documentation, and no further NEPA review is considered necessary for proposed addition of petawatt capabilities at the Z-Beamlet Laser Facility/Z Accelerator combination as described. Reliance on the information presented for operation of the Z Accelerator described in the SWEIS is reasonable, and this information was publicly disclosed. Reliance on the rationale presented in the subsequent Categorical Exclusions is also reasonable and up to date. Any changes in approaches in the proposed action have been identified in this SA.