Department of Energy
Washington, DC 20585

June 16, 1995

MEMORANDUM FOR ROBERT PANKHURST
ACTING DIRECTOR
STANFORD SITE OFFICE

FROM: MARTHA A. KREBS *Martha Krebs*
DIRECTOR
OFFICE OF ENERGY RESEARCH

SUBJECT: LOW HAZARD RADIOLOGICAL FACILITY CLASSIFICATION FOR THE NEXT LINEAR COLLIDER TEST ACCELERATOR AT THE STANFORD LINEAR ACCELERATOR CENTER (SLAC)

In response to your request of March 29, 1995, and after review of potential hazards, I designate the Next Linear Collider Test Accelerator as a Low Hazard Radiological Facility.

cc:
Burton Richter, SLAC
Kenneth Kase, SLAC

CHRON

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STANFORD LINEAR ACCELERATOR CENTER

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May 31, 1995

Mr. Robert Pankhurst
DOE Stanford Site Office/Bin 08A
Stanford Linear Accelerator Center
P.O. Box 4349
Stanford, CA 94309

Dear Mr. Pankhurst:

Attached is the proposed Hazard Classification for the Next Linear Collider Test Accelerator. Also attached is the NLCTA-Note #46.1, which supports the Hazard Analysis.

Sincerely,

Kenneth R. Kase
Associate Director
Environment, Safety & Health

KRK/ms

Attachment

NEXT LINEAR COLLIDER TEST ACCELERATOR (NLCTA)

PROPOSED HAZARD CLASSIFICATION

Revised: May 30, 1995

1. Introduction

Hazards considered here are those which arise as a consequence of the operation of the NLCTA facility, thus normal industrial hazards, or those which arise in the day to day business of the laboratory site are not included.

The hazard descriptions are for the purpose of assigning a hazard classification to this facility, and the method of analysis is that specified in *Safety of Accelerator Facilities*, DOE 5480.25, section 9.d, and the relevant *Guidance*: Part 1A.

These references require that the hazard impact be assessed for Off-site locations, and for On-site locations outside secured areas.[1]

The accelerator system is contained within the fenced Radiological Control Area, with unescorted access being confined to persons having received radiological training. The terms On-site and Off-site are, for the purposes of this section, considered to be synonymous with Inside the Radiological Control Area, and Outside the Radiological Control Area respectively.

Hazard potential is described in accordance with the *Guidance* Part 1.A:

- Routinely Accepted – the activity has ordinary or customary hazards of the types and magnitudes routinely encountered and accepted by the general public (e.g. cafeteria operations, office space, and machine shops).

- Low Hazard – other than routinely accepted hazards, the activity only has hazards with the potential for no more than minor On-site and negligible Off-site impacts to people or the environment.

- Moderate Hazard – the activity has hazards which have the potential for presenting considerable On-site impacts to people or the environment, but at most only minor Off-site impacts.

- High Hazard – the activity has hazards with the potential for On-site or Off-site impacts to large numbers of people of for major impacts to the environment.

The facility reviewed here does not contain radioactive material in excess of the Category 3 quantity cited in DOE-STD-1027-92. Consequently, the facility is not a nuclear facility, but a radiological facility, as defined in the standard.

Neither hazardous chemicals nor cryogenic liquids are used in conjunction with the operation of this facility in types and quantities greater than those routinely encountered and accepted by the general public.

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[1] *Guidance* 2.e.

The operation of this facility is controlled by *SLAC Guidelines for Operations*, and other documents arising from the *Guidelines*.

2. Summary Description of the Facility

The facility exists for the purpose of evaluating accelerator systems to be incorporated in future colliding beam accelerator facilities. The NLCTA is constructed partly within End Station B, a shielded enclosure formerly used for the generation of secondary beams from the SLAC Linear Accelerator Facility. The shielding constituting the walls of the end station is not utilized for radiation protection of the NLCTA, which has its own shielding enclosure. The down stream part of the NLCTA extends beyond the walls of the End Station, extending some 80 feet across the Research Yard.

2.1. Design Parameters

The beam parameters and expected losses in each region of the NLCTA Facility are described below. The nominal design, upgrade plans, allowed beam power, maximum credible beam power, and safety envelope are considered separately.

2.1.1. Injector

The injector contains a thermionic-cathode gun and two X-band accelerator sections. The gun current is 1.5-A nominal (3-A maximum), accelerated electrostatically to 0.15 MeV. The gun pulse has 0.125-microsecond duration. The pulse-repetition rate is variable up to 10 Hz. A pair of 0.9-m-long X-band accelerator sections, powered by a single 50-MW klystron with a dedicated pulse modulator, boost the beam energy by 70 MeV. (The zero-current accelerating gradient is 50 MV/m.) Detailed modeling of the injector indicates that the net current loss in the injector will be approximately 30%.

2.1.2. Chicane

A magnetic chicane downstream from the injector contains a pair of bends that offset the beam axis by 9 inches, and a second pair of bends that restore the beam to its original axis. Two fixed collimators and one adjustable collimator are positioned between the two pairs of bends. The nominal beam power entering the chicane is 100 W. The dominant sources of radiation in the chicane are expected to be beam losses in the bends or the collimators. A net loss of 30%, either at a bend or at a collimator, is assumed.

2.1.3. Insertable Faraday Cup

An insertable Faraday cup downstream from the chicane, when inserted into the beam line, will absorb the full beam power transmitted through the chicane.

2.1.4. Linac

The linac contains three pairs of 1.8-m-long X-band accelerator sections. Each pair is powered by a single 50-MW klystron with a dedicated pulse modulator. Each pair boosts the energy of the nominal-current beam by 135 MeV, for a total energy gain of 405 MeV. (The zero-current accelerating gradient is 50 MV/m.) The dominant source of radiation in the linac is expected to be small, distributed beam losses. The net loss is expected to be much less than 0.5%, consistent with experience in the SLAC linac and Final Focus Test Beam. However, for the purpose of estimating the radiation doses, a net loss of 0.5% at the highest energy, concentrated at a single point, is assumed.

2.1.5. Spectrometer and Beam Dump

A 12° spectrometer line, and a straight-ahead line, both terminate in an iron and concrete beam dump. The dump will absorb the full beam power. The iron target will be cooled by natural convection and thermal radiation. Water cooling will not be necessary, nor will it be provided.

2.2. Upgrade Plans

A future upgrade of the RF system is planned in which the microwave power will be tripled by replacing each 50-MW klystron with a pair of 75-MW klystrons, which will increase the accelerating gradient in the injector and in the linac by $\sqrt{3}$.

A future upgrade of the injector which would increase the peak current and change the micropulse structure may be desirable to advance NLC accelerator-development studies. The injector upgrade as planned would increase the pulse current to 3-A nominal and 4.5-A maximum.

The radiological safety design has been based on the higher currents and energies which will be possible after the upgrades.

2.3. Maximum Credible Beam Power

The beam power will exceed its nominal value if the gun pulse-repetition rate, pulse duration, or pulse current exceed their nominal values. The pulse-repetition rate will be hardware-limited to the nominal value (10 Hz) by three independent, retriggerable, monostable multivibrator circuits. The duration of the accelerated beam pulse is limited, by the duration of the high-power rf-pulses and by the filling time of the accelerator structure, to 1.6 times nominal.

If the three repetition-rate limiting circuits all fail in such a way that the beam pulse-repetition rate increases to 180 Hz—the maximum possible rate of klystron and modulator pulses—then the power is limited by a simple, fail-safe electronic circuit that limits the average beam current.[2] Failure-mode analysis indicates that the maximum credible average current sustainable for more than one pulse is 11 microamps. It is judged that a simultaneous failure of the rate-limiting circuits and the average-current-limiting circuit is not a credible event.

The maximum credible beam power corresponds to the maximum credible increase in average current. The maximum credible beam power, and the energy at which it is obtained, are summarized below in Table 1.

[2]See *Average Current Limit for the NLCTA Thermionic Gun*, NLCTA-Note #48, May 30, 1995.

Table 1: Maximum credible beam power, and the energy at which it is obtained.

	Before Upgrades		After Upgrades	
	Power (W)	Energy (MeV)	Power (W)	Energy (MeV)
Injector Exit	670	87	1180	153
Linac Exit	3230	600	5750	1070

2.4. Safety Envelope

The Safety Envelope for the NLCTA corresponds to 100% loss of the maximum credible beam power, either in the chicane, in the insertable Faraday cup, at the high-energy end of the linac, or in the beam dump.

3. Hazards

3.1. Prompt Radiation Hazard from Accelerated Particle Beams

The radiation shielding of the NLCTA consists of concrete block shield walls, typically 6 feet thick, with roof blocks typically 4 feet thick. Re-entrant mazes are constructed to provide shielding at the two access doors. The shielding blocks are of a size that requires heavy rigging equipment to remove the blocks, they are bolted or chained in place, and there is an administrative procedure prohibiting their removal without prior written approval from both operations and radiological control staff.[3]

This shielding is augmented by a $10 \times 15 \times 6$ ft^3 block of iron which serves as the beam dump.

A Beam Authorization Sheet (BAS), which lists necessary radiation safety conditions and requires inspection of moveable items, is required to be signed by representatives of both the Radiological Control Organization and the operations staff before first operation of the facility and before the accelerator is restarted after a shutdown.

Personnel access to the shielding enclosure is through one of two sets of access doors which are interlocked to the accelerator beam through the Personnel Protection System (PPS). Each set of doors is locked, interlocked with the beam, and has active warning signs.

Maximal Credible Accident Scenario

The maximal credible accident scenario is one in which the full available beam power targets on some object within the shielding barrier. Calculations of dose rates outside the shielding indicate a maximum value of 9.8 rem/hour with the maximum beam power shown above for the upgraded facility.[4]

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[3] *SLAC Guidelines for Operations*, Section 14, Configuration Control of Radiation Safety Systems.

[4] See *Radiation Protection in the NLCTA*, NLCTA-Note #46.1, Revised May 30, 1995.

Mitigation Credit.

1. Shielding in place in the manner specified in SLAC shielding policy documents, verified by radiation measurements as required by the Beam Authorization Sheet, assured by configuration control methods. Shielding design policy is such that the effective dose equivalent to an individual On-site, but outside a secured area will be less than 25 rem in one hour; effective dose to an individual Off-site: less than 1 rem in one hour.

2. Access control system (PPS) in place to prevent personnel being in unshielded locations (i.e. inside the secured areas) while beams are on to that area. Such systems are engineered and maintained to the standards described in Part I.F of *Guidance for an Accelerator Safety Program*, September 1 1993. Configuration control is applied to these systems. The access doors are locked, interlocked with the beam, and have active warning signs.

Consequence.

On-site: Effective dose equivalent to an individual outside a secured area less than 25 rem in any one hour; Minor.

Off-site: Effective dose equivalent to an individual less than 1 rem in any one hour; Negligible.

3.2. Prompt Radiation Hazard from Klystrons

The four X-band klystrons used to generate the microwave power which is fed to the accelerator structure can be sources of ionizing radiation, since they operate at 440 kV. The dose rate from these sources varies among individual klystrons, but is in the range of 0–25 mrem/h at 30 cm from the envelope of the tube. Local lead shielding may be applied to mitigate the hazard, and areas which have dose rates in excess of 5 mrem/hr will be roped off and signed as Radiation Areas.

The hazard from this source is negligible, both On-site and Off-site.

3.3. Residual Activity from Materials Exposed to the Particle Beams

Parts of the accelerator systems which may be exposed to the direct particle beams may become radioactive. The maximum dose rate encountered by a worker in the vicinity of the dump is calculated to be 1.2 rad/h.[5] The exposure of workers to this radiation is controlled by procedures which require review of planned radiological work and the consideration of measures to minimize the doses experienced.[6] Dose to the public from material which has been made radioactive by exposure to particle beams is controlled by procedures which prevent items which may be radioactive from being removed except in cases where they are being transferred to Radioactive Material Areas, or entering a controlled waste disposal stream.[7]

The hazard from this source is negligible, both On-site and Off-site.

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[5] See *Radiation Protection in the NLCTA*, NLCTA-Note #46.1, Revised May 30, 1995.

[6] *SLAC Guidelines for Operations,* Section 16, Minimization of Radiation Dose to Workers.

[7] *SLAC Guidelines for Operations,* Section 15, Control over Activated Material, and *SLAC Radioactive Materials Management Program.*

4. Summary of Hazards

The hazards are summarized in Table 2.

Table 2. Summary of Hazards

Hazard	Consequence On-site	Consequence Off-site	Classification
Prompt radiation from accelerated particle beams	Minor	Negligible	Low
Prompt radiation from klystrons	Negligible	Negligible	Low
Residual activity from irradiated materials	Negligible	Negligible	Low

5. Hazard Classification

Based on the above hazard summary it is proposed that the NLCTA should be classified as a low hazard facility.

Approved:

________________ Project Manager

________________ Associate Director, Technical Division

________________ Associate Director, ES&H Division