

NLCTA Accelerator Safety Envelope

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Record of Revisions

Version	Changes	Date
R000	First version as stand-alone document. Prior versions were included in NLCTA Safety Assessment Document, versions 1996 and 2007	02/19/2009
R001	References to Lasers (power, administrative and engineering controls) deleted. Section 6. "Limitations on Laser Power" deleted.	09/24 2009

1. Introduction

The Next Linear Collider Test Accelerator (NLCTA) at the SLAC National Accelerator Laboratory (SLAC) consists of a 630 MeV electron accelerator and associated equipment which is used for accelerator R&D primarily related to future linear colliders. The test beam R&D program entails advanced accelerator research. NLCTA is housed inside End Station B (ESB) in SLAC's research yard. NLCTA is not connected to the SLAC Main Linac, SSRL or LCLS. NLCTA's operation schedule is independent of that of the other accelerator facilities at SLAC.

1.1 Facility Purpose

NLCTA is an experimental facility designed to test and integrate new technologies of accelerator structures, RF systems and instrumentation being developed at SLAC and elsewhere in the world for the International Linear Collider (ILC) and other advanced accelerator systems. There is a short test beam line to the shielded experimental hall for advanced accelerator R&D.

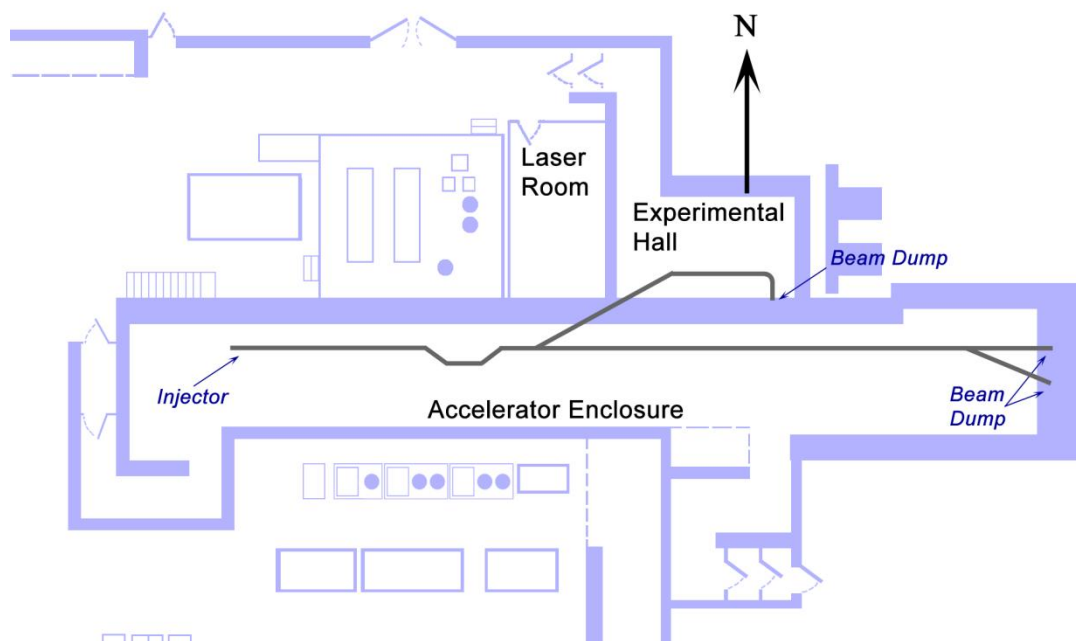
1.2 Upgrade of Facility Beam Energy

NLCTA is designed to allow an upgrade in beam energy to a maximum energy of 1,066 MeV unloaded energy gain. The presently installed power sources cannot generate a beam with this higher energy anticipated in the facility design. The shielding of the facility, and thus the Accelerator Safety Envelope, is based on the energy upgrade option of 1,066 MeV¹.

1.3 Facility Operations

Beam is typically only available during the day and early evening shifts. The shielding analysis is based upon the expectation that the facility will be operated in beam operations mode for not more than 1,000 hours per year at maximum power and energy. RF power is supplied around the clock to accelerator structures under test with interruptions as required to install new devices.

Figure 1. NLCTA Subsystems



This Accelerator Safety Envelope (ASE) describes the engineered and administrative bounding conditions that ensure the safe beam operation of the NLCTA. The NLCTA is comprised of the following subsystems as shown in Figure 1:

- Accelerator Enclosure
- Experimental Hall

A general discussion of the hazard analysis and summary of safety issues associated with this facility is found in the *NLCTA Safety Assessment Document*² (SLAC-I-010-30100-001). The machine parameters discussed in the safety assessment document that must be bounded for the safe operation of the accelerator are discussed in this accelerator safety envelope (ASE).

Engineered safety systems are employed to ensure:

- That the accelerator components operate within predetermined ranges.
- That no primary electron beam can be introduced into an area occupied by people.
- That radiation levels in occupied areas do not exceed predetermined limits.

Written procedures specify activities critical to ensuring that the accelerator can be operated safely.

Operational limits on the allowed running conditions for radiological hazards for each mode of operation are listed explicitly in the *Beam Authorization Sheet*³ (BAS), which is issued for each running period and is subject to a formal approval process. The BAS typically specifies allowed beam parameter limits, settings of radiation sensors, special shielding configurations, and lists of safety certifications, interlock checks, initial beam tests, and other requirements that may depend on particular experimental configurations.

Compliance with the requirements of the BAS ensures that operational parameters remain within the bounds set by the ASE and that the level of risk to all persons is maintained at an acceptably low level.

Unplanned events, such as power outages, may interrupt operations but do not compromise the safety of the facility. As required by DOE Order 420.2b, no operation is allowed which violates the ASE. If such a violation occurs, the offending activity must be terminated immediately and not restarted before the Department of Energy has been notified and has given permission to restart.

Safety issues that are not covered in this document, and for which a safety analysis has not been performed, could arise. Such an issue would constitute an Unreviewed Safety Issue under DOE Order 420.2B Section 4c. Activities that involve unreviewed safety issues must not be performed if significant safety consequences could result from either an accident or a malfunction of equipment. Activities involving identified unreviewed safety issues must not commence before DOE has provided written approval.

1.4 Document Information

1.4.1 Document Ownership

This document is owned by the AD/ARD/Test Facilities Department.

1.4.2 Review and Update Schedule

The ASE will be reviewed and updated as needed, but no less frequently than every two years. This ASE will also be revised whenever major modifications are made to the facility (see *SLAC Guidelines for Operations*⁴ (SLAC-I-010-00100-000), *Guideline 25: Safety Assessment Documents*). All major modifications to the facility will be done with the concurrence of the Department of Energy (DOE).

2. Sources of Beam

2.1 Thermionic-gun Injector

The original injector for the NLCTA used a thermionic electron gun capable of high-current long pulse-length operation. The accelerator enclosure shielding has been designed to operate with the beam available from the thermionic electron gun, however the experimental hall shielding has not. This gun has been removed from the injector and stored for future use. The injector is currently equipped with a laser-driven RF photocathode gun (see below). There are no plans at present to reinstall the thermionic electron gun. The ASE for the Accelerator Enclosure is based on the capabilities of the thermionic injector.

The thermionic-gun injector parameters are listed in the Table 2.

Table 2. Thermionic-gun Injector Electron Beam Power

	Power within the Accelerator Enclosure	Power within the Experimental Hall
Nominal Operation	1,450 W	<i>Thermionic beam not allowed</i>
Missteering Case	1,450 W	<i>Thermionic beam not allowed</i>
Max. Accident Case	5,745 W	<i>Thermionic beam not allowed</i>

2.2 Laser-Driven RF Photocathode Injector

The currently installed injector uses a laser-driven RF photocathode electron gun capable of delivering particle beams which may vary from a few electrons per pulse to an equivalent power of 76.2 Watts at 30 pulses per second. Given the modest capabilities of the RF photocathode (compared to the thermionic injector), an RF photocathode-based gun cannot exceed the beam power limits of the ASE within the Accelerator Enclosure.

Beam power from the Accelerator Enclosure into the Experimental Hall is limited by beam loading effects. The maximum credible beam power within the Experimental Hall from RF photocathode is 15.7 Watts. The ASE for the Experimental Hall is based on the capabilities of the laser-driven RF photocathode electron gun injector.

The RF photocathode injector parameters are listed in Table 3.

Table 3. Laser-Driven RF Photocathode Injector Electron Beam Power

	Power within the Accelerator Enclosure	Power within the Experimental Hall
Nominal Operation	6.3 W	0.7 W
Missteering Case	6.3 W	0.7 W
Max. Accident Case	76.2 W	15.7 W

3. Modes of Operation

The NLCTA has three operational modes:

- “RF Only Mode”, where accelerator structures are powered around the clock with interruptions as required to install new devices under test.
- “NLCTA Beam Mode” with electron beam generation and transport solely in the Accelerator Enclosure.
- “Experimental Beam Mode” with electron beam generation and transport in the Accelerator Enclosure and into the Experimental Hall.

3.1 *RF-Only Unattended Operation*

In this mode of operation, the injector is locked off. Beam is not injected into the accelerating cavities. Radiation inside the Accelerator Enclosure is produced from microwave processes such as breakdown, multipactoring, and dark current in the accelerator cavities.

In this mode, Qualified Operators are required to perform checks of the machine each workday. Access into the Accelerator Enclosure or operation of the Experimental Hall Stoppers is controlled by the Personnel Protection System to which only Qualified Operators have keys. The accelerator is allowed to run 24 hours a day without requiring an operator in attendance.

3.2 *NLCTA Beam Mode*

In this mode of operation, the electron beam is generated and remains within the NLCTA Accelerator Enclosure. The PPS beam stoppers for the Experimental Hall are inserted and prohibit the transport of the electron beam into the Experimental Hall.

Qualified Operators are required to be present in the NLCTA facility for this mode of accelerator operation.

3.3 *Experimental Beam Mode*

In this mode of operation, the electron beam is generated within the NLCTA Accelerator Enclosure and is transported to the Experimental Hall.

Only beam generated from the laser injector is permitted in the Experimental Hall.

Qualified Operators are required to be present in the NLCTA facility for this mode of accelerator operation.

4. Limitations on Beam Energy

This section specifies the nominal unloaded energy gain⁵ and the operations envelope for each mode of operation of the NLCTA. The operations envelope is the maximum unloaded energy gain allowed by the BAS for that mode of operation.

The shielding for the NLCTA Accelerator Enclosure was designed to support an upgrade with a maximum unloaded energy gain of 1066 MeV. The unloaded energy gain of the installed accelerator structures varies with the research program.

The shielding for the Experimental Hall has been designed for a maximum credible accident at beam energy of 130 MeV.

The ASE for beam energy is listed in the final row of Table 4.

Table 4. Electron Beam Energy

	RF Only Operation	Accelerator Enclosure	Experimental Hall
Operations Envelope	<i>No beam permitted</i>	<i>On approved BAS</i>	<i>On approved BAS</i>
Nominal Operation⁶	<i>No beam permitted</i>	50-350 MeV	50-70 MeV
Not-to-Exceed unloaded energy gain (ASE limit)	<i>No beam permitted</i>	1,066 MeV	130 MeV

5. Limitations on Beam Power

This section specifies the nominal operating power, the operations envelope, and the maximum credible beam power for each mode of operation of the NLCTA. The nominal operating power is the beam power typically used during that mode of operation. The operations envelope is the maximum beam power allowed by the BAS for that mode of operation.

The shielding for the NLCTA was designed assuming a maximum credible average beam power of 5.75 kW, the nominal beam-loss fractions, beam operation for 1,000 hours per year, and an occupancy factor of one half. The occupancy factor is extremely conservative, since there is no office or other full-time work space immediately adjacent to the NLCTA shielding.

The ASE for beam power is listed in the final row of Table 5.

Table 5. Electron Beam Power

	RF Only Operation	Thermionic Injector		RF Photocathode	
		Accelerator Enclosure	Experimental Hall	Accelerator Enclosure	Experimental Hall
Operations Envelope	No beam permitted	On approved BAS	Thermionic not allowed	On approved BAS	On approved BAS
Nominal Operation	No beam permitted	1,450 W	Thermionic not allowed	6.3 W	0.7 W
Missteering Case	No beam permitted	1,450 W	Thermionic not allowed	6.3 W	0.7 W
Max. Accident Case	No beam permitted	5,745 W	Thermionic not allowed	76.2 W	15.7 W
Not-to-Exceed beam power (ASE limit)	No beam permitted	1,450 W	Thermionic not allowed	1,450 W	16 W

6. Shielding Criteria

Shielding is designed to limit integrated radiation doses to acceptable levels, as defined in the *Radiation Safety Systems Technical Basis Document*⁷ (SLAC-I-720-0A05Z-002). The maximum acceptable radiation levels are summarized in Table 8.

Table 8. Ionizing Radiation Shielding Design Limits

Condition	Limit	Beam Loss
Outside the shielded enclosure	1 rem/year	Normal operations
At site boundary	0.1 rem/year	Normal operations
Outside the shielded enclosure for safety system failure	25 rem/hour or 3 rem/event	Maximum beam power with BCS failure

Calculations have been done to estimate the integrated radiation doses under a variety of beam loss scenarios, including normal beam losses, missteering situations, and maximum credible beam incidents. The shielding is designed to limit integrated radiation doses to acceptable levels under the worst of these conditions.

The *Beam Authorization Sheet* specifies the shielding needed for each mode of operation for each running period and the testing needed to demonstrate the efficacy of the shielding.

The location of shielding is checked by radiation physicists as part of the pre-running checks for each *Beam Authorization Sheet*. Shielding cannot be moved or modified without adhering to the requirements in *SLAC Guidelines for Operations, Guideline 14 "Configuration Control of Radiation Safety Systems"*.

7. Personnel Protection System Criteria

The Personnel Protection System (PPS) and the Beam Containment System (BCS) are engineered controls for radiological hazards which ensure that personnel remain safe during beam operations and during accelerator housing accesses. The PPS ensures that interlocked hazards cannot be active during accesses, and the BCS ensures that beam power and losses do not exceed the limits established in the hazard analyses. Requirements for the configuration and periodic testing of the BCS are specified in the BAS. Requirements for configuration control and periodic system testing of the Personnel Protection System (PPS) are described in *SLAC Guidelines for Operations*, Guideline 27 “Testing of Personnel Protection Systems”.

8. Administrative Control of Safety Systems’ Configuration

SLAC Guidelines for Operations and *NLCTA Operations Directives*⁸ (02-02-02) are the controlling documents for facility operations. The guidelines and directives, together with the more detailed procedures that implement them, are intended to ensure that operations are carried out in a safe and effective manner. The implementing procedures and associated checklists ensure that all required safety devices (toroid charge monitors, beam stoppers, beam loss monitors, supplemental shielding, etc.) are in place and functioning properly. These include inspection checklists for required safety devices, initial beam tests requirements to calibrate sensors and demonstrate the efficacy of shielding, and work control procedures for maintenance, replacement, or modification of safety devices. Specific devices required for each mode of operation are listed in the *Beam Authorization Sheet*.

9. Minimum Staffing for Operations

Requirements for beam operations, including control room staffing requirements, are specified in the NLCTA Operations Directives. At least one qualified operator is required to be on duty when a beam is being delivered.

¹ V. Vylet and T. Lavine, “Radiation Protection in the NLCTA,” NLCTA Note #46.2, December 5, 1995, revised January 8, 1996

² <https://www-internal.slac.stanford.edu/ad/addo/SAD/sadindex.html>

³ <http://www-group.slac.stanford.edu/tf/library/020339.pdf>

⁴ <https://www-internal.slac.stanford.edu/ad/addo/gfo/gfoindex.html>

⁵ The “Unloaded Energy Gain” is the sum of the energy gradient available multiplied by the active length for each powered accelerating structure in the beam path. The maximum energy for a low current beam is the unloaded energy gain of the accelerator. The energy of a well-tuned high-current beam is significantly less than the no-load energy gain due to phase-offsets and beam energy-loading of the accelerator structures.

⁶ “Nominal Operation” refers to the typical operation parameters of the facility.

⁷ <http://www-group.slac.stanford.edu/esh/documents/techbas/rss.pdf>

⁸ <http://www-group.slac.stanford.edu/tf/library/020202.pdf>