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NLCTA Safety Audit

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1 **Background:**

2 The NLCTA was constructed (when in 1994-1995) to demonstrate beam loading
3 compensation schemes for high current long (> fill time) beams with high (>25%) beam
4 loading, and as a development and demonstration x-band linear accelerator. These goals
5 have been largely achieved.

6 ***Contemporary programs:***

7 Recent use of the facility by NLC has been to study the lifetime and performance of X-
8 band accelerator structures running at high gradient. This program requires subjecting
9 the structures to several hundred hours of operation, with brief periods of beam operation
10 to diagnose structure operation. This operation is allowed under the conditions approved
11 by the Radiation Safety Officer as “unattended operation without beam,” and proceeds
12 though the night without a fully manned control room.

13 **Beam Programs**

14 Using the beam, two families of structure tests are interesting. The most common (1/2
15 day every week) consists of accelerating a short (1.5 nS) beam through the structure. The
16 beam loading of the structure leaves energy in the cavity which can be directly measured
17 and transformed into an equivalent in-situ “bead-pull” of the cavity installed on beamline.
18 This is done without applying rf power to the structures under test.

19 Less frequently, the direct energy gain of the structures is measured by accelerating a
20 beam and measuring the energy gain. The relative phasing error of structure pairs is
21 measured using the “bead-pull” technique and the energy gain result are corrected based
22 on this measurement.

23 **Rf processing programs**

24 Recent results from NLCTA indicate that accelerator structures can be produced that,
25 following initial processing, meet or exceed the program goals for the NLC.
26 Unfortunately, continued operation at the NLCTA has shown us that continued operation
27 of the structures can result in continuing damage that detunes the accelerator and destroys
28 its effectiveness as an accelerator.

29 The current program emphasizes the continued operation of a number of differing
30 structure designs to determine the best design, operation, and manufacturing methods to
31 produce long-life structures. Continued rf processing is occasionally interrupted to allow
32 an in-situ bead pull to monitor performance. Run lengths of 500 to 2000 processing
33 hours are desired.

34 ***Future programs***

35 There are several facility development programs proceeding simultaneously.

1 The NLC project needs to develop and demonstrate reliable production of high power rf
2 (goal of around 600 MW by 400 nS delivered to 8 loads sequentially. This 8-pack¹
3 project will proceed in several phases: (1) the installation of a 4-klystron modulator and
4 high power SLED-II rf folded delay line compression, followed by the namesake project
5 of an 8-klystron modulator (the “8-pack”) followed by an overmoded delay-line
6 distribution system which allows the 8 klystron’s power to be summed to 8 output ports
7 sequentially. One or two output ports will eventually be powering accelerator structures
8 in the NLCTA.

9 The ORION² project and the implications to the Operation and Safety of the NLCTA will
10 not be discussed. This project is not an approved experimental program at present, and
11 will require a thorough review prior to proceeding.

12 **Project Organization:**

13 The NLCTA is a project currently being run by the NLC project in the Technical
14 Division. Dave Burke is the NLC Project Leader and NLCTA Facility Head, Marc Ross
15 is the Operations Manager, and Keith Jobe serves as Operations Manager in Ross’
16 absence.

17 **Safety Organization:**

18 NLCTA safety organization has Keith Jobe as Safety Officer for almost all aspects of
19 operational safety and project planning.

- 20 • The NLCTA Safety Officer is involved with the design and specification of the 8-
21 pack development.
- 22 • No NLCTA safety oversight of the ORION project design and development has
23 been established to date.

24 The Accelerator Department Safety Office (ADSO), with Mike Saleski and Paul Miller,
25 is responsible for the operational radiological safety issues such as approval of Radiation
26 Safety Work Control Forms (RSWCF) and control of the ADSO locks on certain
27 radiation devices such as the electron gun pulser and devices requiring control through
28 the RSWCF process. Their help in this area helps avoid the conflict of interest that can
29 occur because the safety officer is heavily involved in the operations program.

30 End Station B is a Research Division building. The Building Manager is Sandy Pierson
31 who has held the position since late September 2001. We are working with Sandy to
32 understand the appropriate division of responsibilities.

¹ <http://www-project.slac.stanford.edu/lc/local/Projects/8Pack/8pack.html>

² <http://www-project.slac.stanford.edu/orion/>

1 **ESH Participation in the program**

2 Radiation Safety issues and authorizations are handled by the Radiation Physics
3 department. Ralph Nelson is the current Radiation Physicist, with Sayed Rokni serving
4 as both the SLAC Radiation Safety Officer and backup Radiation Physicist. Support
5 from the OHP group is excellent.

6 For non-radiological issues and support, the NLCTA receives help from the ES&H
7 division only upon request. We do not have an ES&H representative who is familiar with
8 the activities or regular operation of the NLCTA, or anyone who is in regular contact
9 with us regarding ongoing issues.

10 **Proposed facility developments:**

11 **Near term accelerator beamline development:**

- 12 • Development of a intra-beam feedback scheme applicable to linear collider final
13 focus beamlines. (NLC)
- 14 • Powering accelerator structures with power derived from the 8-pack modulator
15 installation (NLC)

16 **Near term accelerator support environment development:**

- 17 • 8-pack installation in north half of end station hall (oil, seismic, electrical,
18 occupational, radiation) (NLC)
- 19 • Installation of new generation SLED-II delay line (NLC)
- 20 • Installation of delay-line distribution system (NLC)

21 **Components of the NLCTA**

22 **The accelerator - beamline**

- 23 • A shielded accelerator area (“tunnel”) that starts inside End Station B and extends
24 substantially east outside the end station.
- 25 • A single PPS controlled area with two entry modules.
- 26 • No beamline entering or exiting the tunnel.
- 27 • A thermal electron gun without any subharmonic (or other types of) buncher,
- 28 • A 60 MeV injector powered by a single X-band klystron,
- 29 • A bunch-length defining collimating chicane (at 60MeV)

- 1 • Six experimental structure test locations (each able to accommodate a single 1.8
2 meter structure). The existing installation uses 3-4 of the test locations for high
3 power structure testing.
- 4 • An energy spectrometer (horizontal), with
- 5 • A vertical kicker which can spread the beam vertically onto the energy screen to
6 establish correlations between microbunch location, energy, and energy spread
7 (plus some perhaps higher order terms such as distribution shapes).

8 ***The accelerator – support equipment***

- 9 • A thermal cathode DC gun. This gun runs at about 150 KV and may be driven
10 with either a 1.5 nS or a 150 nS cathode modulator board. Hardware changes are
11 required to change pulse length. Peak beam current is about 6 amps with a three-
12 fold hardware, administrative, and BAS limit of allowed repetition rate to 10 Hz
13 or less.
- 14 • Three klystron modulators powering differing configurations of pulsed X-band
15 (11.424 GHz, or 4 times SLAC frequency) klystrons. The first modulator (Station
16 0) powers a single klystron (30-40 MW pulsed, 1.5 uS @ 60 Hz) which powers
17 the 60 MeV injector. The second and third modulators (Stations 1 and 2) each
18 have a pair of klystrons which are summed together to generate peak powers of
19 around 100 MW (pulsed, 1.5 uS at 60 Hz).
- 20 • Three SLED-II resonate delay line rf compressors. These compress the incoming
21 rf drive by a factor of 4.5 in rf power, transforming a 1.5 uS pulse to a 250 nS
22 pulse.
- 23 • Control racks, control room, etc.
- 24 • Magnet power supplies for klystron and accelerator beamline magnets (electrical,
25 seismic)
- 26 • Klystron modulator power supplies (electrical, seismic, radiation)

27 **Operation of the NLCTA**

28 ***Procedures and Operations Documents***

29 NLCTA Operations documents are available on the NLCTA website³. These documents
30 fall into four general classes:

- 31 • Administrative – directives, personnel plan, organization chart.

³ <http://www-project.slac.stanford.edu/lc/local/Projects/NLCTA/nlcta.htm>

- 1 • Safety – procedures and processes directly related to the safe operation of the
2 facility.
- 3 • Training – for operators of the facility.
- 4 • Emergency Procedures – the institutional facility emergency plan plus some
5 NLCTA specifics.

6 The goal is to have the latest approved version of every document online. Just noted are
7 some exceptions which may be resolved prior to the review.

8 A few documents require further discussion:

9 Operations Directives

10 This document was modified as part of the change of operation related to unattended
11 operation. Currently signed off, the document requires some minor changes prior to
12 being released. (Revision number, org. chart, minor changes). The most recent version
13 is available in the NLCTA control room.

14 Beam Authorization Sheet (BAS)

15 This master document is provided by Radiation Physics and specifically allows the
16 operation of the accelerator as a radiation source at SLAC. The BAS must be understood
17 by every operator, and initialed on a daily basis to indicate the “safety envelope”
18 conditions are understood and remain valid⁴.

19 Daily Inspection Checklist

20 The conditions for unattended operation (operator not required to be present) with rf (and
21 no beam) require the completion of a checklist every weekday. The project just received
22 authorization to run over weekend days and vacation days without completing this
23 checklist over the weekends. This checklist asks that certain radiation shielding controls
24 and shielding be verified.

25 Weekly Inspection Checklist

26 The weekly inspection checklist asks that environmental safety, radiation safety, and
27 certain operations conditions be verified. Since the end station has secondary
28 containment and hazardous waste storage areas, some of the requested checks are
29 required on a periodic basis.

30 ***Training and Operator Control***

31 The procedures include sections detailing training for operators of the facility. All
32 current NLCTA operators have come from MCC either as operators or as accelerator
33 physicists / support personnel, allowing for an easy training experience. The training

⁴ The concept of “daily” signatures on the BAS is currently being redefined to allow over-weekend unattended operation without beam.

1 program will be revisited as we train the first post-doc operator candidate this coming
2 year.

3 Operators are issued a key to the NLCTA key safe. The keys to the PPS panel are kept in
4 the key safe, and are only available to NCLTA operators.

5 **NLCTA Safety Systems**

6 The instrumented safety systems for the NLCTA are largely limited to the control of
7 radiological and electrical hazards, fire, and a small system designed to help control a
8 possible environmental spill.

- 9 • PPS and Tunnel electrical safety systems follow the best practices of the PPS
10 systems at SLAC.
- 11 • A small number of rack mounted power supplies are protected using interlocked
12 doors to limit potential exposure to the rear power supply connections.
- 13 • The klystron modulators and 500 kW power supplies have door interlocks and
14 shorting contactors to deactivate and discharge the 20 and 40 kV power sources.
- 15 • The fire alarms are signaled to the SLAC fire system. Additionally, alarms from
16 the high sensitivity smoke detector for the modulators and rf racks turns off the
17 power to the modulators and high voltage power supply. This interlock was
18 added to reduce the possibility of an arc-driven capacitor fire.
- 19 • A level indicator in the secondary containment tanks of the oil tanks of the
20 modulators alerts surveillance of excessive fluid in the tank. The hazard is not oil
21 spills (for which the containment meets code) but water leaks which have the
22 potential of washing out the entire oil supply with site LCW.

23 **Radiation Safety Systems**

24 The test accelerator is equipped with a relatively simple Personnel Protection System
25 (PPS) and Beam Containment System (BCS) combined with an (electrical) hazard
26 control system.

27 The PPS and BCS systems are certified every six months. The most recently filled out
28 certification procedure is available in the control room. Additionally, limited PPS checks
29 are performed following every significant access period, and BCS checks are required
30 every shift when the electron gun is operated.

31 **PPS**

32 Since the NLCTA consists of a single radiological enclosure without any beamlines
33 entering or exiting the enclosure, the PPS system consists of a relatively simple perimeter
34 control system with two fully instrumented PPS gates (“entry modules”). This is a stand-

1 alone system with no conventional beam stoppers or integration with any other
2 accelerator protection system.

3 There are four access states:

- 4 • Permitted Access – all electrical hazards (magnets) off, gun off, high voltage
5 power supplies for modulators off. Doors are unlatched, and search secure status
6 is lost.
- 7 • Controlled Access – all above listed hazards are off, and must be off to enter this
8 state. Door is latched and under operator and keybank control. Area may be
9 searched, setting search secure status.
- 10 • Restricted Access – can only be entered from Controlled Access if search secure
11 is set, and can only be entered from No Access if hazards (electrical and
12 radiation) are off. In this mode, there are provisions to energize electrical hazards
13 (magnets) with people in the tunnel under special administrative and key controls.
- 14 • No Access – accessible from Restricted Access if keybanks are complete (i.e.:
15 tunnel is empty). Electrical hazards may be turned on. Radiation hazards require
16 an additional key enable, and may be turned on / remain on only if the Beam
17 Shutoff Ion Chambers (BSOIC) are clear.

18 The BSOICs, required to permit the generation of radiation, are set by Radiation Physics
19 to levels described in the Beam Authorization Sheet (BAS). Operations may monitor and
20 reset the BSOICs, but cannot adjust the detector's sensitivities.

21 ***BCS Safety System***

22 The BCS is designed to disable the high voltage power supplies for the klystron
23 modulators when the beam loss inside the tunnel exceeds the design average beam loss
24 power levels. The BCS consists of ten ion chambers with approximately ½ liter gas
25 volume installed inside the radiation enclosure. Trip thresholds are set to 10 nA.

26 Operations documents describe the daily checks required for beam running.

27 ***Fire Safety System***

28 The NLCTA is located inside End Station B. This building is equipped with rated
29 ceiling-mounted ionization smoke detectors which may be able to provide early detection
30 of an equipment fire.

31 Parts of the NLCTA are sprinklered. These parts include the radiation enclosure, the
32 power supply and rf racks, and the control room. The sprinklers are not expected to
33 respond in time to significantly limit equipment damage in the event of a fire. Because
34 the entire end station is not sprinklered, the building is not considered as a sprinklered
35 building per code.

36 The project is equipped with a high sensitivity smoke detection (HSSD) system which is
37 installed on most of the racks supporting the klystrons and low level rf electronics.

1 Coverage also includes the high voltage power supplies for the klystron modulators,
2 klystron modulators, and the radiation enclosure.

3 In addition to the SLAC Fire Alarm System, one HSSD channel (1) removes interlock
4 permissive for the modulator power supply and (2) trips the 208 volt circuit breakers
5 supplying modulator power.

6 **General Safety Concerns and Areas of Interest**

7 ***Environmental Safety & Hazardous Materials***

8 The project uses 2000 gallons of mineral oil as a dielectric insulator in the pulse tanks for
9 the three modulators. The development of the 8-pack will double the oil use. Mineral oil
10 is a NFPA Hazard Identification: Health 0, Fire 1, Reactivity 0 and is rated as a CA
11 Hazardous Material.

12 Procedural measures:

13 Spill response includes a 55 gallon wet-dry vacuum cleaner designated for
14 emergency use and several hundred pounds of absorbent.

15 Engineering controls:

16 Tunnel access has been modified to prevent spilt oil from running down
17 into the subterranean tunnels.

18 Active protection equipment:

19 Level sensors in the secondary containment for the modulators signal in
20 the Sector 30 gate. Procedures indicate responses necessary to secure the
21 water supply to prevent a water leak from washing oil from the primary
22 containment, over the secondary containment, and into the environment.

23 Other than oil, there are no NLCTA-specific environmental issues that are different than
24 commonly encountered throughout the institution.

25 ***Pressure and Vacuum Vessel***

26 Not applicable.

27 NLCTA does not have any pressure or vacuum vessels that require review by the
28 Pressure and Vacuum Vessel Safety citizen's committee⁵. The SLED delay lines and the
29 vacuum transport lines are classified as distributed systems and are thus exempt.

⁵ Richard Boyce, private conversation. 10/29/2001

1 **Laser Safety**

2 There are no high power lasers in the NLCTA at present.

3 Small He-Ne and diode laboratory lasers are sometimes used for alignment and
4 calibration of diagnostic equipment.

5 **Seismic Safety**

6 The following presentations have been made to the Seismic Safety Committee with
7 approvals granted:

8	8/27/92	NLCTA Shielding Enclosure
9	5/27/93	End Station B South Wall Reinforcement
10	8/11/93	B501 Power Substation
11	9/13/93	NLCTA Overhead Utilities Cable Tray System
12	5/11/94	NLCTA Control Building

13 There is no evidence that the support equipment, power supplies, racks, or experimental
14 equipment have ever been reviewed or inspected by the committee.

15 The NLCTA items of seismic interest are:

- 16 • Racks are reasonably secured. Connection to the concrete deck appears to have
17 been properly made using Hilti Quickset fasteners.
- 18 • Power supplies (both LGPS type and 500 KW type) are restrained in a “SLAC-
19 Standard” manner with “dogs” (plates with a bolt at the fulcrum). While these
20 provide some measure of seismic restraint, they do not meeting the committee’s
21 current standard. Since this is an institutional problem and our power supplies are
22 interchangeable with others on site, we have chosen to have this to be addressed
23 in a site-wide and not a project-specific manner. At this point, there is no site-
24 wide solution for securing the this class of power supplies.
- 25 • Accelerator equipment and rf transport systems are believed to be reasonably
26 restrained.
- 27 • Klystrons are not restrained (they are well supported against gravity).
- 28 • There is no information on the seismic competency of the bridge crane.
- 29 • The rolling door has not been seismically evaluated. There is a small chance that
30 the top-side clearance is small enough to ensure that the wheels will not jump the
31 rails. (See next item).
- 32 • The East “Plug Wall,” North, South, and parts of the East walls of the End Station
33 probably fail seismic standards in a significant manner. Additionally, the North
34 Emergency Exit (the secondary life safety exit for the building) will certainly
35 collapse given a significant tremor. A “Phase II Seismic Assessment” of End
36 Station B is being considered by Brad Youngman.

1 **Crane Safety:**

2 The End Station has the original two-hook 15 / 50 ton bridge crane equipped with a
3 relatively modern remote radio controller. The vast majority of the crane use is for
4 devices which are a very small fraction of the hook's rated capacity. The situation is as
5 follows:

- 6 • There is no institutional record of a certification ever having been done on the
7 crane⁶. The installation company almost certainly certified the crane at the start
8 of operation in the mid 1960's, but there are no records to support this statement.
9 The DOE recertification period for this type of crane is believed to be three years.
- 10 • The bridles in use have been recently certified and dated by an outside contractor.
- 11 • The maintenance of the crane has not been reviewed or carefully organized. The
12 SEM maintenance personnel respond quickly and thoroughly to specific reports of
13 problems and regularly "service" the crane, but do not have a strong maintenance
14 program or one supported by a licensed inspector. Frank Brenkus has just posted
15 a inspector position on site, and we hope the situation will improve.

16 **Radiation Safety**

17 The NLCTA was designed and approved based on a higher beam energy, current, and
18 power than is currently deliverable. Radiation Physics reviews the operation of the
19 accelerator every 6 months as part of the renewal of the Beam Authorization Sheet.
20 Ralph Nelson of Radiation Physics will address the committee on the status of the
21 radiation safety program.

22 **Electrical Safety, AC**

23 The AC distribution system has not undergone any significant changes since the facility
24 was initially commissioned. The power backbone was initially installed with plans for
25 future changes in program scope and size, and has served the facility well.

26 **Grounding**

27 The NLCTA is a well bonded system with verifiable bonding on all accelerator
28 instrumentation, components, power supply, and support systems.

29 **Multiple power sources**

30 The klystron modulator high voltage power supplies and more specifically the modulator
31 itself are examples of devices with multiple power sources requiring the use of a ELP.
32 The latter is powered separately by (1) a single conductor 25 amp 20 kV circuit with
33 stored energy in excess of 10 kJ and (2) a 50 amp 3 phase 208 volt power source.

⁶ Liam Robinson, SEM. Private conversation, 10/2001.

1 **Bakeout**

2 The NLCTA is the only facility at SLAC which regularly uses equipment ground fault
3 detectors and interlocks on 110 and 208 volt powered bakeout systems. Experience has
4 shown that this both protects equipment from uneven heating or burn-through, but also
5 provides a significant reduction in electrical shock potential.

6 ***Electrical Safety, DC***

7 Three classes of DC electrical safety issues exist in the NLCTA.

- 8 • Behind the rack distribution. All power supply connectors are either covered,
9 behind interlocked doors, or at legal voltage / current.
- 10 • Tunnel hazards. All exposed tunnel electrical hazards (there are 100 uncovered
11 magnets and 1 gun) are interlocked to the PPS Hazard Control program which is
12 regularly certified. Additionally, the NLCTA Procedure 02-03-10 details the
13 locking out of all hazards with a dedicated lock set with a single securable key.
14 This key is locked in the NLCTA control room by all affected personnel with
15 their personal locks and tags during installation periods.
- 16 • Modulator power. The modulator and it's power supply is interlocked with a
17 number of door interlocks which turn off the hazardous energy source and short
18 the stored energy. An ELP exists for these devices.

19 Lock and Tag remains a continuing challenge. Due to the PPS interlocking, the
20 determination of source to load control is difficult to verify, and thus the procedure takes
21 a broad approach and locks out the entirety of the tunnel hazards.

22 ***Occupational Safety***

23 SLAC safety guidelines cover all work in the NLCTA area. Special hazards in the
24 project which require special attention include fall protection for lighting and crane
25 maintenance. Groups doing high risk work are expected to be knowledgeable and supply
26 the appropriate personal protection equipment (PPE).

27 ***NLCTA Shop***

28 Trailer 485 (a converted shipping container) houses the NLCTA workshop. Included in
29 the shop are a variety of hand and portable power tools. Additionally, the shop contains a
30 drill press, sander, and an oxygen - acetylene torch. Outside the shop are a variety of
31 cutoff tools which, while used by NLCTA, are part of the Research Division's tool
32 assortment.

33 Users of the shop are primarily physics and engineering support people associated with
34 the project. On the job training covers all equipment use.

1 **NLCTA Storage Buildings**

2 Trailers 483, 484, and 486 are shipping containers used to store cable, power supply
3 components, and vacuum components respectively. There are no identified safety issues
4 in the storage buildings.

5 **ADA Accessibility**

6 The control room is minimally accessible per the current standards for persons with
7 mobility disabilities. The experimental area, beamline, racks, and support environment
8 are not accessible per the ADA criteria.