Program Overview

D. L. Burke

NLC Machine Advisory Committee
SLAC
December 8-10, 2003
The NLCTA with 1.8 m accelerator structures (ca 1997).

Accelerating gradient of 25 MV/m (loaded) with good wakefield control and energy spread.

Demonstrated ability to reach 500 GeV cms.
X-Band SLED-II Systems

NLCTA
SLED-II System
(ZDR 1996)

– Conventional PFN modulator
– 50 MW/1.2μs solenoid-focused klystrons
– SLED-II pulse compression
– DDS structures at 40 MV/m

X-Band TeV
SLED-II System
(Baseline 2002)

– Solid-state modulator
– 75 MW/1.6μs PPM-focused klystrons
– Dual mode SLED-II pulse compression
– DDS structures at 65 MV/m
**Overview**

D. L. Burke

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### GLC/NLC Energy Reach

**High Energy IP Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Stage 1</th>
<th>Stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMS Energy (GeV)</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>Site</td>
<td>US</td>
<td>Japan</td>
</tr>
<tr>
<td>Luminosity (10^{33})</td>
<td>20</td>
<td>25</td>
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<tr>
<td>Repetition Rate (Hz)</td>
<td>120</td>
<td>150</td>
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<tr>
<td>Bunch Charge (10^{10})</td>
<td>0.75</td>
<td>0.75</td>
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<tr>
<td>Bunches/RF Pulse</td>
<td>192</td>
<td>192</td>
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<tr>
<td>Bunch Separation (ns)</td>
<td>1.4</td>
<td>1.4</td>
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<tr>
<td>Loaded Gradient (MV/m)</td>
<td>50</td>
<td>50</td>
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<tr>
<td>Injected (\gamma_x / \gamma_y) (10^{8})</td>
<td>300/2</td>
<td>300/2</td>
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<tr>
<td>(\gamma_x) at IP (10^{-8}) m-rad</td>
<td>360</td>
<td>360</td>
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<tr>
<td>(\gamma_y) at IP (10^{-8}) m-rad</td>
<td>4</td>
<td>4</td>
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<tr>
<td>(\beta_x / \beta_y) at IP (mm)</td>
<td>8/0.11</td>
<td>13/0.11</td>
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<tr>
<td>(\sigma_x / \sigma_y) at IP (nm)</td>
<td>243/3.0</td>
<td>219/2.1</td>
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<tr>
<td>(\theta_x / \theta_y) at IP (nm)</td>
<td>32/28</td>
<td>17/20</td>
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<td>(\sigma_z) at IP (um)</td>
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<td>(\gamma_{ave})</td>
<td>0.14</td>
<td>0.29</td>
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<tr>
<td>Pinch Enhancement</td>
<td>1.51</td>
<td>1.47</td>
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<td>Beamstrahlung (\delta B) (%)</td>
<td>5.4</td>
<td>8.9</td>
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<td>Photons per e+/e-</td>
<td>1.3</td>
<td>1.3</td>
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<tr>
<td>Two Linac Length (km)</td>
<td>13.8</td>
<td>27.6</td>
</tr>
</tbody>
</table>

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**The NLC/GLC Stage 2 design luminosity is**

\[5 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}\] **at 1.3 TeV cms.**
GLC(X)/NLC Level I R&D Requirements (R1)

- “Test of complete accelerator structure at design gradient with detuning and damping, including study of breakdown and dark current.”

- “Demonstration of SLED-II pulse compression system at design power level.”
Is there any reason to change the course of the R&D activities critical to the demonstration of X-Band technologies?

“In November 2002, the collaboration reset the course to demonstrate the X-band capability using SLED-II with the intent of demonstrating its capability by the end of 2003.”

“At this point, the Committee does not identify any reason to change the course that was set in November 2002.”

“Stay on course, and work hard to maintain schedule and scope.”
Are we preparing properly for a technology “shoot out” next summer?

“Yes, the Committee believes that the collaboration is moving in the right direction to prove that the X-band technology is a viable option to the linear collider with efforts to respond to the recommendations of the Technical Review Committee (R’s).”

“Complete as many of the “R’s” given by our colleagues (TRC) as possible. It will be useful to have comprehensible documentation on the X-band linear collider.”
Are our priorities for remaining work well focused? We may still need to make some difficult decisions if resources become tightened further.

“In case a choice must be made among the R&D directions, the Committee recommends the following priority order:

1. Work on the RF power source including SLED-II system and Klystrons
2. Accelerator structure (Closely equal to the number 1 in priority)
3. Electron Cloud”
Other Remarks

• “The klystron development still looks critical …”

• “The Committee … strongly encourages Fermilab management to find a way to at least maintain momentum.”

• “The Committee welcomes this [BNL] new collaboration.”

• The Committee supported the major directions of the Collaboration:
  – Steady progress in development of the damping ring design and R&D.
  – Continuing efforts on understanding alignment, ground motion, and stabilization.
  – Cautious support for study of positron production in the FFTB.
  – “Cradle-to-Grave” beam dynamics simulations.
NLC/GLC SLED-II Baseline Test

NLCTA Housing
Dual-Mode SLED-II
Solenoid-Focused Klystrons
Solid-State Modulator

Baseline pulse of 475 MW for 400 nsec to loads.
Dual Mode SLED-II Test
(Low Power “Cold Tests”)

Measurements Through The TE01 Arm of the Directional Coupler

Goal

Power Gain

Time (ns)
Final high-temp bake-out completed early November.

Modulator and klystrons running stably at 30 Hz.

SLED processing rate set exclusively by out-gassing as microwave power is increased (probably $\text{H}_2$).
Running at over 500 MW, and see no sign it will not do better.

TRC R1 Met

Talk by Tantawi.
After improvements to the RF at NLCTA in 2000, we realized the installed structures would not meet specification at gradients needed for TeV operation.

KEK and SLAC (joined by Fermilab) launched an aggressive R&D program:

- New structure designs to improve rf efficiency and power handling.
- Extensive computer modeling of structure properties.
- Improve construction, handling, cleaning, and processing methods.

- Have built and tested over 25 structures.
- Over 15,000 hr of high-power operation at NLCTA.

T-Series Structures – built with high shunt impedance to study high-gradient properties of copper.
T53VG3MC Processing History
(Low-Temperature Couplers)

Overview
D. L. Burke

Structure Gradient (MV/m)

Onset of “Spitfests”

1 Trip per 25 Hrs

1 Trip per 25 Hrs

NLC/JLC Trip Goal:
Less than 1 per 10 Hrs at 65 MV/m

Time with RF On (hr)

400 ns Pulse Width
No Phase Change (< 0.5°)
GLC/NLC designs with wakefield detuning and damping slots.

Meet specification at 60 MV/m, but trip rate is higher than goal at 65 MV/m.

Completed tests of alternate design possibilities:

- Standing-wave structures reached acceptable performance at (loaded) gradient of 55 MV/m. Marginal increase in operating gradient does not make up for loss in packing fraction.
- Structure built by CERN with moly irises tested. Slow processing with no apparent damage, but no gain in operating gradients.
High Gradient Performance

Breakdown Rate (#{/hr} / 0.6 m) at 60 Hz

Gradient (MV/m)

- H90VG3 (1600 Hours Operation)
- H60VG3-FXB3 (700)
- H60VG3-6C (1400)
- H60VG3S18 (460)
- H60VG3R17 (500)

Mean

Goal
Cost of the linac is a balance between cost of the power sources (which increases with gradient), and cost of accelerator length (which decreases with gradient).

Minimum occurs when these are equal, and is rather shallow. The linac is about half the total cost of the collider.

Collider optimized at 60 MV/m would be 10% longer, and cost 3% more than with the present design at 65 MV/m.

→ An acceptable design can be made with what we have achieved.
More Overhead: $a/\lambda = 0.17$ Designs

Peak Surface Field Profile -vs- Structure Type

- **H60VG3** ($a/\lambda = 0.18$, Rounded Irises, Inline Taper, Already Tested)
- **H60VG3S18** (Elliptical Irises - Reduces Peak Fields by 5% but Requires + 5% Power, Currently Under Test)

NLC/JLC Candidates:
- **H60VG3S17** (Elliptical Irises, Lower $a/\lambda$, Different $v_g$ and Thickness Profile, Requires 10% Less Input Power Than H60VG3)
- **H60VG4S17** (Same as Above but Wider, Asymmetric Dipole Spectrum)
### Structure Schedule

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</thead>
<tbody>
<tr>
<td>H60VG3S18 (0.18, 150°, slots, no HOM loads)</td>
<td>69 MW</td>
<td>Station II - 1</td>
<td>KEK/SLAC</td>
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<td>CERN Structure (Mo irises)</td>
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<td>CERN</td>
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<td>H60VG4R17 (0.17, 150°, no slots)</td>
<td>57 MW</td>
<td>Assembly On Hold</td>
<td>SLAC</td>
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<td>H75VG4S18 (0.18, 150°, slots)</td>
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<tr>
<td>H60VG3R17 (0.17, 150°, no slots)</td>
<td>57 MW</td>
<td>Station II - 1</td>
<td>SLAC</td>
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<td>FXB6 – H60VG3 (0.18, 150°, no slots)</td>
<td>63 MW</td>
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<td>FNAL</td>
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<td>FXB7 – H60VG3 (0.18, 150°, no slots)</td>
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<td>FNAL</td>
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<td>KEK/SLAC</td>
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<td>H60VG4S17-2 (0.17, 150°, slots)</td>
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<td>Station 1 Modulator Rebuild Complete</td>
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<td>4 X FXC H60VG3S17 (0.17, 150°, slots)</td>
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<td>FNAL</td>
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<td>H60VG4SL17-A (0.17, 150°, slots, HOM coupling)</td>
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<td>KEK/SLAC</td>
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<td><strong>Cup Fabrication</strong></td>
<td><strong>Special parts fab.</strong></td>
<td><strong>Assembly</strong></td>
<td><strong>ASSET Test High Power Tests</strong></td>
<td><strong>4X FXD (H60VG4S17, 0.17, 150°, slots, HOM coupling)</strong></td>
<td>59 MW</td>
<td></td>
<td>FNAL</td>
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</table>

**Overview**

D. L. Burke

**NLC MAC**

December 2003
RF pulse distribution inside NLCTA to power eight structures and accelerate beam.

First four structures in presently used slots, and initially will continue to be powered by existing NLCTA stations.

- Fabrication of hardware underway.
- Goal to run 1000 hrs of high-gradient operation by summer.
Delay Line Options

Remove SLED Iris

Dual-mode SLED lines become low-loss 400 nsec delay line.

- Cross Potent

- Recover SLED-II inefficiency (4/3.1). M-K efficiency will go down, but run higher power. → Full utilization of rf power.
- Lower average power. → Run at 120 Hz.
- Independent control of groups of four structures instead of eight. → Increase break-down rate spec factor of two.
- Eliminate SLED-II “front porch” rf pulse on structures. → Ease high-gradient breakdown.
There will be a recommendation made before the end of 2004 by a panel of the International Linear Collider Steering Committee for a preferred accelerator technology for a TeV linear collider. The NLC Collaboration priorities for 2004 are things that:

(1) Are necessary for this technology recommendation;

(2) Are important for this technology recommendation and can yield information in time for the panel’s deliberations;

(3) Are important for the realization of a collider irregardless of the accelerator technology.

References:
• ILC-TRC Report.
• USLCSG Task Force Report.
• NLC MAC.
NLC Activities for the Next Year

• Technology R&D will stay focused on the main linac components.
  – SLED-II Phase-2a power source with full section (eight 60 cm) high-gradient structures.

• Remainder will still be squeezed by the FY04 budget which is once again held at 19.2M$. The priorities are:
  – Prototype modulator “2-Pack” and PPM klystrons.
  – Damping Ring and ATF
    • Multi-bunch emittance.
    • Electron Cloud
  – Vibration and Stabilization
    • Beam Instrumentation and Control
    • Thermo-mechanical Instrumentation and Control

• Accelerator Design centered around the USLCSG Task Force analysis now shifting to preparations for ICFA ITRP technology review.
Second-Generation IGBT Modulator

**Features**

- 6.5 kV IGBTs
- Cast casings.
- Improved cooling.
- Improved connections.

**“DFM” 2-Pack**

Bechtel-LLNL-SLAC 20 kV test stack.

Prototype 500 kV modulator ready by New Year, with installation at NLCTA in March to drive two PPM tubes at 120 Hz.

Talk by Cassel.
High Rep-Rate
Permanent-Magnet Klystrons

KEK/Toshiba

PPM2: Tested at 75 MW with pulses of 1.6 μsec duration at 60 Hz.

PPM4: Tested at 75 MW with pulses of 1.6 μsec duration at 50 Hz.

SLAC XP3-3

Tested at 75 MW with pulses of 1.6 μsec duration at 120 Hz.

Talk by Cornuelle.
SLAC and KEK physicists survey the ring.

“Laser Wire”

Overview
D. L. Burke
Beam Instrumentation and Control
(ATF and NLCTA – KEK, SLAC, LLNL, Queen Mary)

Nano-BPM at ATF
(40 nm resolution, so far).

LLNL Space Frame
Mounts for 3 BPMS

FONT at NLCTA (Queen Mary)
(factor 10 jitter reduction, so far).

Overview
D. L. Burke

NLC MAC
December 2003
Inertial I&C

Rigid Block tests met target goals.
IP SC Magnet Development
(BNL)

- Finish implementation of the new “Nested Serpentine” winding pattern that promises superior performance along with simplified coil design and production.

- Study vibrations introduced by cryogenic fluids.
NLC - The Next Linear Collider Project

Geo-Technical R&D

Site Studies in CA and IL

Los Angeles MTA

Universal City

Overview
D. L. Burke

NLC MAC
December 2003
Equipment Isolation

Measurements at the 8-Pack

A possible place to study isolation and transfer of mechanical vibrations.

SLAC North SLC Arc

LCW Unit
The Accelerator Subcommittee of the US Linear Collider Steering Group (USLCSG) has been charged by the USLCSG Executive Committee with the preparation of options for siting an international linear collider in the US.

Membership of the USLCSG Accelerator Subcommittee:

- David Burke* (SLAC)
- Gerry Dugan* (Cornell) (Chairman)
- Dave Finley (Fermilab)
- Mike Harrison (BNL)
- Steve Holmes* (Fermilab)
- Jay Marx (LBNL)
- Hasan Padamsee (Cornell)
- Tor Raubenheimer (SLAC)

* Also member of US LC Steering Group.
Two technologies: warm LC, based on the X-Band design of the NLC/GLC Collaboration, and a cold LC, similar to the TESLA design at DESY. Both to meet the physics design requirements specified by the USLCSG Scope document.

Both developed in concert, using as much as possible, similar approaches in technical design for similar accelerator systems, and a common approach to cost and schedule estimation methodology, and to reliability and risk assessments.

Accelerator Subcommittee formed four task forces:
- Accelerator physics and technology design (G. Dugan, chair).
- Cost and schedule (D. Burke, chair).
- Civil construction and siting (V. Kuchler, chair).
- Availability design (T. Himel, chair).

Risk assessment carried out by a team formed from members of the other task forces.
• Establish top level availability requirements including
  – Annual scheduled operating time
  – Hardware availability
  – Beam efficiency

• Consider 3 machines:
  – Warm
  – Cold in 1 tunnel
  – Cold in 2 tunnels

• Allocate top-level availability requirements down to major collider systems.

• As time allows attempt to balance availability specs to minimize risk and cost.

• Compare to data from existing accelerators.
Risk and Risk Assessment

• Risk is not Failure and it is not Reliability.
  – Failures are going to occur. The Project Plan should account for this with overhead, contingency, and mitigation strategies. Reliability is an engineering and design parameter.

• Risk is threat to the Project Mission.
  – Performance Goals
  – Cost and Schedule

• Risk Assessment differs from Reliability Engineering or Failure Analysis

• Standard Practice proscribed by DOE. Examples: US LHC, NIF, ...

• Standard Practice in industry where they have to make money.
USLCSG Pre-Conceptual
Lap Around the Project Cycle

UCLCSG
“Mother Group”

Release or Cancel

UCLCSG
Accelerator Subgroup

Management Review

Failure Modes & Effects Analysis
Risk Assessment

Task Forces
Accelerator Design
Availability Design
Conventional Construction/Site

Performance Evaluations
Cost and Schedule ReBaseline

C&S Task Force

Engineering and Design
R&D

ALCPG
Mission Definition
Performance Metrics
Cost and Schedule Targets

Overview
D. L. Burke

NLC MAC
December 2003
1. Define the Project Mission (ALCPG Scope Document)
   – Construct a collider with initial cms energy 500 GeV that can be upgraded later to 1 TeV (or higher).
   – Deliver 500 fb⁻¹ integrated luminosity within the first 4 years of physics running.
   – Run concurrently with the LHC. We took as a mission goal to begin operations for physics research by the middle of the next decade (2015).

2. Identify and analyze important ways the Project could fail to achieve its Mission.
   – Risk Assessment Task Force with people from each of the other Task Forces.
   – Selection and discussion of important high-level failure modes.
     • Meetings at Cornell and Fermilab.
     • Identified 42 failures that pose significant threat to the Project Mission.
   – Follow up written descriptions and analysis of identified failure modes as they are manifest in each technology option.
3. Risk Ranking

Four factors make up our definition of the risk posed by a potential failure:

- The source or reason for a potential failure.
- The severity of the failure as characterized by its impact on the project mission goals.
- When in the course of the linear collider project the failure will occur or become apparent.
- The consequence of the failure characterized by what would have to be done to overcome it.

For each of these factors we established a description and numerical ranking.

During the ranking process each risk was assigned according to the best description option.
### Risk “Reason” or “Source” Table

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<tr>
<th>Reason</th>
<th>Ranking</th>
<th>Description</th>
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<tbody>
<tr>
<td>Beam Physics</td>
<td>5</td>
<td>No Theoretical Model and No Data</td>
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<tr>
<td></td>
<td>4</td>
<td>Theoretically Understood Data Indicates Problem</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Poor or Ambiguous Data Indicates Problem</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Best Theory Indicates Problem, No Data to the Contrary</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Understood Theory and Data Indicate No Problem</td>
</tr>
<tr>
<td>Engineering/Design</td>
<td>5</td>
<td>Beyond Current Engineering Solutions</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Feasibility of Engineering Solution is Uncertain</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Engineering Feasible, but Untested Design</td>
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<tr>
<td></td>
<td>2</td>
<td>Tested R&amp;D Design</td>
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<td>1</td>
<td>Tested Industrial Design or Similar Design in Hand</td>
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<tr>
<td>Technology</td>
<td>5</td>
<td>Beyond State of the Art</td>
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<td></td>
<td>4</td>
<td>State of the Art - Should be Able to Do It but No Proof</td>
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<tr>
<td></td>
<td>3</td>
<td>R&amp;D Prototypes, but Extrapolation Remains</td>
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<td></td>
<td>2</td>
<td>Available, but a Specialty Item</td>
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<td>1</td>
<td>Commercially Available Off The Shelf</td>
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# Severity, Detection, and Consequences Tables

## Table 8.1.2: Severity Table

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<th>Severity</th>
<th>Ranking</th>
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<td>Limiting</td>
<td>5</td>
<td>Effect on Parameter is a limit less than design.</td>
</tr>
<tr>
<td>Steep</td>
<td>4</td>
<td>Effect on Parameter is quadratic or steeper.</td>
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<tr>
<td>Linear</td>
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<td>Effect on Parameter is linear.</td>
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<tr>
<td>Marginal</td>
<td>2</td>
<td>Effect on Parameter is less than linear.</td>
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<td>Contributing</td>
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<td>Parameter dominated by other effects.</td>
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## Table 8.1.3: Detection Table

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<td>PreOps</td>
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<td>Not detected until facility preoperations.</td>
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<td>PE&amp;D</td>
<td>2</td>
<td>Not detected until project engineering and design.</td>
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<tr>
<td>R&amp;D</td>
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<td>Detected by R&amp;D.</td>
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## Table 8.1.4: Table of Consequences

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<thead>
<tr>
<th>Consequence</th>
<th>Ranking</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impossible</td>
<td>5</td>
<td>Would be impossible or too expensive to fix.</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>4</td>
<td>More R&amp;D would be needed.</td>
</tr>
<tr>
<td>Major</td>
<td>3</td>
<td>Possible, but would require major redesign or rework.</td>
</tr>
<tr>
<td>Minor</td>
<td>2</td>
<td>Alternate design available, would need new plan or minor rework.</td>
</tr>
<tr>
<td>Ops</td>
<td>1</td>
<td>Alternate operating point will meet mission goals.</td>
</tr>
</tbody>
</table>
USLCSG Task Force Analysis

- A major effort for NLC Collaboration members.

- It has been a good-spirited and strenuous exercise with a lot of good discussion between U.S. accelerator physicists with experience in both warm and cold technologies.

- Report is ready for presentation to USLCSG.

- The USLCSG will release the report (in some manner) to become part of the international considerations leading to a recommendation by ICFA for the technology for the main accelerator.
Questions for the MAC

We have “stayed the course”, so the questions remain largely the same as last time:

• Comment on the R&D activities critical to the demonstration of X-Band technologies.
  • Any reason to change the course?
  • Advice and concerns.

• Are we preparing properly for a technology “shoot out” next summer?

• Are our priorities for remaining work correctly chosen and well focused?