Introduction

• Present situation:
  – Big effort on US LC Warm/Cold study
  – Growing effort on PEP-ii (Andrei Seryi, Andy Wolski, Peter Tenenbaum, Mark Woodley, Marc Ross, Joe Frisch, Mauro Pivi, Yuri Nosochkov)
  – Some contribution to SPEAR-3 (PT and Nan Phinney)
  – Support for the I-TRP (site visits; information requests)
  
  – R&D program aimed at short term goals for I-TRP timescale
    • Linac diagnostics
    • Electron cloud
    • Stabilization
  
  – Need to be considering longer-term issues of LC design effort whatever technology
Collaboration Mtg Discussion

Topics that are to be discussed will be considered with the following priority:

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 (but too slow for the I-TRC)**
4. **Are important for the realization of a warm LC (but will be too slow for the I-TRC)**

The AP issues include no 1’s, some 2’s, and lots of 3’s and 4’s (but these are still important issues)
TRC Luminosity Concerns

**R2 Items**
- Electron cloud and ion instabilities need study
- *Additional simulations and experiments on ε correction are needed for damping rings*
- Demonstrate DR extraction kicker with better than 0.1% stability
- Complete static DR→IP tuning simulations with dynamic effects
- Develop most critical beam instrumentation, including intra-train diagnostics
- Develop sufficiently detailed prototype of linac girder/cryostat to provide information on vibration

**Cryptic R3 Items**
- Damping ring dynamic aperture
- *Intrabeam scattering*
- LET electron cloud and ion effects
- LET tuning algorithm robustness
- Linac BPMs need demonstration
- Quadrupole center stability
- Linac technical noise sources
- Collimator wakefields
- Final magnet stabilization
- Background modeling
- Develop compact SC quads
- Measure detector solenoid stability

*Italics = essentially done*
Sources

- **Electron source is in good shape**
  - E-158 has demonstrated cathode performance at ~85% polarization
  - Concern over the laser but best to address this with serious engineering not a small R&D effort

- **Positron source is more difficult and needs work**
  - Undulator source is not desirable for initial operation (1st N years)

- More than 2x greater integrated luminosity w/ conventional

- **Need to develop conventional source for warm and cold designs**
  - Target radiation damage needs to be addressed for both Ti and W
Positron Source

- Many unresolved questions regarding target viability of both undulator-based source and conventional source
- Need to invest additional effort on the conventional source
  - Parametric studies suggest enlarging the target spot size to reduce the number of conventional targets from 3 to 2 and possibly down to 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>NC Conv.</th>
<th>SC Conv.</th>
<th>NC Und.</th>
<th>SC Und.</th>
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<td>-</td>
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<td>2 / 1</td>
<td>1 / 1</td>
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<td>0.125</td>
<td>0.8</td>
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<td>1500</td>
<td>46</td>
<td>1200</td>
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<td>ΔT [C]</td>
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<td>256</td>
<td>422</td>
<td>410</td>
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<td>Yield</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
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Damping Rings

• Warm DR is much easier than the cold DR but …. 
  – Warm DR will still be a challenge to build successfully
  – Diagnostics and kickers are difficult
  – Tolerance sensitivities are at cutting edge of 3rd generation SRS
  – Collective effects are more important than seen in 3rd gen. SRS
    • Electron cloud and ion effects
    • Coupled-bunch instabilities
    • Must be maintained with pulsed beam – large dynamic range
  – Nonlinear dynamics enter new regime with long wiggler
  – Pre-PDR could use more work

• Many issues can be addressed at ATF

• Many other issues can be further quantified with simulation/calculation on I-TRP timescale
Experiments at ATF Ring

- Great progress with ATF studies
  - Vertical emittance has been demonstrated due to improved diagnostics as well as intensive tuning and BBA studies
  - IBS discrepancies have been (mostly) resolved
- Two additional proposed studies that are unique to ATF:
  - CSR instability threshold appears to be at $1 \sim 1.5 \times 10^{10}$
    - Opportunity to measure impact of instability on beam
  - Ion instability
    - Very fast growth rates calculated for all damping rings $\sim 100 \mu s$
    - Observations in a number of SRS facilities but not studied in detail
    - Difficult to simulate saturation – measurements needed
- Plans to focus on multi-bunch issues at ATF are also interesting
Electron Cloud Studies

- Four approaches to electron cloud issue
  1. Simulation of cloud generation and saturation
     - Goal of modeling a damping ring arc cell with fringe fields
  2. Simulation/calculation of cloud effects on beam
     - Need to set limits in LET: BC, Linac, BDS
     - 3-D PIC simulation in DR
  3. Benchmark simulation codes
  4. Measurement of secondary yield for different materials
     - Want to understand performance of TiN and TiVZr coatings
     - Some of these can be done on 6 month timescale but ….
  5. Ultimately demonstrate viable path to e-cloud control

![Cloud density vs. time](image)
Electron Cloud Studies

• Thresholds in DR and BDS are usually much less than equilibrium levels
  – Need to understand electron cloud everywhere
  – A problem in even 0.1% of the length might be too much
  – Trapping in multipoles make effects as important for SC as NC
  – Damping ring wigglers are another example where SEY must be 1.2~1.3 is either SC or NC rings

• Excited by possibility of TiVZr plus conditioning but …
  – Tests being performed at ESRF, CERN, BNL, SLAC, …
  – Would be an excellent choice for BDS is sufficiently inexpensive

• Goal of program is to install a test chamber in PEP-ii in 2yrs
  – Effects are of interest to many groups and possible collaboration
  – Details from Mauro Pivi but missing engineering support to build test chambers and instrumentation
  – No help from PEP
Main Linac Issues

- Working on quantifying structure tolerances with errors NC/SC
  - 3MHz random/random errors seem tolerable in NC
  - Decrease in piecewise alignment requirements
  - Doing same for SC
- The main linac emittance preservation relies on:
  - 0.3 µm resolution Q-BPM’s
  - 3 µm precision S-BPM’s
  - Micron stability of quadrupole magnetic center of weeks
  - Micron stability of BPM center over weeks
- Would be good to demonstrate these diagnostics
  - Lots of experience that is close (factors ~3 larger than spec.)
  - Very nice to demonstrate RF-girder alignment with beam
- Performing NC dark current simulations to quantify dipole kick
  - Is a measurement possible?
Structure LR-Wake Sensitivities

No $\Delta f$ errors

Random/systematic $\Delta f$ of 3 MHz rms

Random/random $\Delta f$ of 5 MHz rms

Random/random $\Delta f$ of 3 MHz rms
Linac Diagnostics

• Three main diagnostics: S-BPMs, Q-BPMs, ε-wires

• S-BPMs
  – Specification of 3 um for an rf girder with 4 structures (6um/structure)
  – Technique demonstrated on RDDS1 at ASSET with 11 um rms limited by SLC beam jitter of 100 um
  – Considered ‘fast’ demonstration using collimator wakefield facility but not really reasonable – may be possible during next ASSET runs

• Q-BPMs
  – Specification is 0.3 um resolution and 1 um/week drift
  – FFTB striplines had 1 um resolution and 30 um/26 month drift
  – ATF rf BPMs have 0.1 um resolution and drift is unknown
  – Possible to measure FFTB stripline triplet to set new limit on drift

• Emittance diagnostics
  – Laser wires are becoming a big industry
  – Rf BPMs can act as tilt monitors to locally detect wakefield dilutions
Linac Dark Current and Breakdown Kicks

- Studying kicks due to dark current using MAGIC
  - Concern that fluctuating dark current sources could cause beam jitter
  - Primary effect localized to emission point – initial results look small but ...
  - Want to try to measure asymmetry in NLCTA using 11.424 GHz dipole cavity

- Next step study kick due to breakdown events

4 cell structure with emission from iris between cell 1 and 2
Beam Delivery System

- Many recent improvements
  - Large bandwidth dump line (20% ΔE/E)
  - New layout with larger energy coverage
  - Update documentation (beyond USLCSG study)
- Recent e-cloud simulations indicate BDS thresholds are reasonable
  - Need to update other collective effects calculations
- Need integrated background/collimation/feedback simulations
  - Personally worried about IP feedback given performance requirements and large background fluxes around diagnostics
- SC quadrupole being developed at BNL look reasonable
  - Need vibration demonstration

![Figure 54.2](n_0, 1e11 m^3 at 250 GeV)
BDS Layout and Optics

- Further optimization for US LC Mtg at Cornell in July
- Recent focus has been backgrounds and MPS issues
SC Final Quadrupole

• Superconducting final quadrupole is the baseline model for NLC based on BNL compact SC magnets
  – Significant effort to develop prototype magnet and understand vibration characteristics
  – New technique of laying wire that allows much more compact coils
  – Vibration measurements in SC system are focused on sensor development
  – Develop models for cryostat and cold mass to analyze vibration response
Collimation System and Backgrounds

- Collimator wakefields are still a significant limitation
  - Tail-folding octupole to yield similar performance as linear system with 3x larger gaps
    - **Needed** to reduce wakefield amplification due to collimators
    - Not enough at low energy
    - Need to work through a consistent set of parameters for low energy operation

- Still need detailed measurement/simulations of wakefields
  - A third collimator set with $T_i$ (for resistive terms) is in progress
  - Need a set with NLC-like geometry and need to push simulations

- Need to study performance with non-ideal beams
  - Integrate into detector background simulations?
Stabilization and Vibration Suppression

• Three different avenues being pursued:
  – Inertial stabilization
  – Optical anchor (primarily at UBC although commercial products exist)
  – Fast intra-train feedback (FONT at NLCTA and FEATHER at ATF)

• FONT at NLCTA
  – Last run is happening now
  – Need to document performance – significant effect on 67% of train

• Inertial stabilization
  – Success stabilizing a rigid block (discussed last few MAC meetings)
  – Developing compact non-magnetic sensors
  – Working to stabilize an extended object that models a PM final quadrupole and cantilevered support tube
  – ATF NanoBPM project will also develop nm-level diagnostics
Inertial Sensors

• Rigid block experiment used cheap commercial sensors
  – Two problems: noise too large and don’t work in magnetic fields

• Started program to develop compact non-magnetic sensor
  – Been quite successful although slower than expected
  – Present prototypes are ~100 times noisier than design but much better
    than other compact sensors and probably sufficient for NLC
  – Two new prototypes will be developed with results expected next fall
Stabilization Demonstrations

- Final magnet stabilization large concern for warm technology
  - Tolerance is ~0.5 nm for 5% $\Delta L/L$
  - An extended object that models a PM final quadrupole and support tube has been fabricated and installed in ESB
  - Proceeding with MARK-4 sensors which have a noise spectrum similar to that of present non-mag. sensor
  - Expect results in few months
  - Will need to verify internal noise in SC quadrupole (started at BNL)
  - Should analyze simplest model (no external connections, possible?)
  - Need to measure solenoid stability

Same mechanical properties as final design
ATF: NanoBPM Project

- Nano-BPM studies to demonstrate nm-level BPM resolution and stability
  - High resolution rf BPMs installed in ATF extraction line
  - Could be used to demonstrate stabilization at nm-level
  - Progress is has been too slow to impact I-TRP but will form an excellent test bed longer term
  - Large effort to develop the system and fully stabilize the relative motion

Estimated resolution of 91 nm
Vibration Measurements

• Extensive measurements of natural ground motion
• Many measurements of ‘cultural’ sources and transmission
  – Isolated measurements of modulators, accelerator structures with cooling, quadrupole magnets with cooling all look acceptable
  – Transmission between tunnels is large so must be careful in utility tunnel as well as the main tunnel

• Need to develop prototype main linac girder to measure vibration of full system
  – Program at FNAL has made good progress despite Run-II conflicts

• Need to develop prototype of utilities cluster to measure noise from pumps, pipes, etc.
Simulation Programs

• Self-consistent 3-D PIC electron cloud simulations are being run at UCLA/USC
  – Mauro is discussing improvements on cloud generation with them
  – Need measurements to benchmark ion and electron cloud instability codes

• Working with Accelerator Computer Department on next generation LET codes
  – What is needed beyond MatLIAR / GuineaPig?
  – High speed tracking engine with easy user interface
  – Making this part of SCaLeS proposal
  – Need to broaden collaboration
    • Nick Walker (DESY) is interested
    • Daniel Schulte (CERN) is interested
    • Glen White (QMUL) is interested

• Must complete NC/SC dark current/breakdown simulations?
LET Simulations

• Many simulations supporting USLCSG study
• Goal is integrated luminosity estimation
  – Two aspects:
    • LET simulations for “peak” luminosity
    • Operations simulations to understand availability/recovery
• Studying the LET system in pieces before going back to full integrated simulations
  – Need to understand ‘static’ tuning with ‘dynamic’ errors
  – Need to understand performance reduction as a function of hardware failures
  – Need to integrate feedback and beam steering systems
  – Need to understand limits of GLC model for fast-steering
Main Linac $\epsilon$ Correction Timescales

- Description developed for US LC discussions
- Described many other elements of $\epsilon$ control
  - SBPMs
  - Structure alignment
  - QBPMs
  - Etc
- Need next iteration for I-TRP
LET Simulations – $\epsilon$ Bumps

- Working on effectiveness of emittance bumps in NC / SC
  - Studied dispersion and wakefield effects separately
  - Bumps are quite effective in both cases in both machines
    - Single pair is sufficient for cold
    - Two pairs is needed in warm for similar performance

**Warm dispersion bumps**

**Cold wake bumps**

**Locations of 2 bump pairs**

**Location of single bump pair**
LET Simulations

• Must understand ‘dynamic’ errors in tuning simulations
  – Reduce effectiveness of main linac BBA and DFS
  – Reduce effectiveness of BC and BDS global tuning techniques

Simulation of TESLA design intra-train feedback

Linac simulations after DFS and bumps with jitter equal to 1x and 2x the budgets

• Must understand performance limitations of feedback systems
  – Especially true at IP where both warm and cold must have fast or slow deflection feedback
US LC Study – LET Studies

• Extensive simulations made on parallel basis
  – BBA followed by DFS – some errors uncertain in cold case
  – Cold results are similar to 30% found in Schulte & Walker (PAC2003) if rf structure tilts and quad rotations are ignored
  – Bumps are not included in either study – hold in reserve!

<table>
<thead>
<tr>
<th>Random Error Term</th>
<th>Warm LC</th>
<th>Cold LC</th>
<th></th>
<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Value</td>
<td>$\Delta y / \sigma_y$</td>
<td>$\Delta \varepsilon / \varepsilon_y$</td>
<td>Value</td>
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<td>85 nm</td>
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<td>Total</td>
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<td>41%</td>
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US LC Study – LET Studies

• Beam Delivery System
  – Cold BDS has 4 times larger vertical IP beta function → 2x looser tolerances for same IP beam effect
  – Cold collisions have 2x stronger disruption → 4x greater sensitivity to IP changes
  – Some effects are worse, some are better in cold versus warm design

• Bunch Compressors
  – Cold linac bunch length is 300 um versus 110 um in warm linac
  – Warm BC has two-stage compressor with greater complexity and greater length and compresses length by ~50x
  – Cold BC has single stage design with ~2x greater energy spread and $\Delta \varepsilon$ scales with $\sigma_E^2$
  – Emittance dilution estimates for TESLA BC are ~3x larger than for warm BC but not clear how much is due to limitations of TESLA design
US LC Study – Emittance Budgets

- Emittance budgets estimated using:
  - 50% $\Delta \varepsilon / \varepsilon$ for main linacs (without beam bumps)
  - 20% $\Delta \varepsilon / \varepsilon$ for bunch compressors (probably insufficient but depends on stability)
  - 30% $\Delta \varepsilon / \varepsilon$ for BDS which is due to aberrations, collective effects, and tuning limitations
  - Luminosity is relative insensitive to emittance dilutions (doubling main linac budget changes luminosity by 5~10%)

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<th>Warm LC</th>
<th>Cold LC</th>
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Operations/Availability Simulations

- Simulations started to model the collider availability
  - Monte-carlo model for hardware faults
  - Including models for tuning and recovery from trips
  - Including models for scheduling repairs and downtime

- Specify hardware requirements to meet up-time goals
  - Quantify overheads and needed redundancy

- Quantify trade-offs in design configurations
  - One tunnel versus two or three for the superconducting linac
  - Undulator-based e+ source versus conventional
  - Damping ring location

- Has been very useful
  - Can we use it for further optimization?
A Virtual Linear Collider
(courtesy of Andrei Seryi)

1 bunch, 500 pulses takes 10 hours on 2GHz PC
(and this is with the limited physics of the codes)

Real time calculations (120Hz, 192 bunch/train) will require:
300000 of 11.4GHz ideally parallel processors

If each of them is 5cm long, they will span 15km

Easier to build real NLC
Risk Issues from TRC/USLCSG…
(that might be addressed quickly)

- Need documentation for results to count for I-TRP
- Sources:
  - Conventional source; target damage; beam loading questions
- Damping rings:
  - E-cloud, ion, and collective effects; dynamic aperture calculations
  - Kickers and diagnostics at ATF
- Main Linac
  - Main linac BPM’s and quadrupole field stability; dark current
  - Structure BPM and structure alignment; measure technical noise
- Beam Delivery / Interaction Region
  - FD stabilization and FONT demonstration
  - Collimator wakefields simulation and measurement
  - Collimation, backgrounds and IP feedback simulations
  - SC quadrupole vibration analysis and solenoid stability measurement
Risk Issues from TRC/USLCSG…
(longer term issues)

- Demonstration of linac instrumentation
  - Rf BPMs in multi-bunch mode and SBPMs
- New attack on start-to-end LET modeling
- New integrated background/feedback simulations
- NC breakdown and SC dark current cascade simulations
- Benchmark electron cloud and ion instability simulations
- Model of minimal SC quadrupole vibration solution

- Demonstration of electron cloud ‘solution’
- Development of compact SC quadrupole and vibration measurements
- Development of linac girder for vibration measurements
- Measurement of technical noise sources in linac
Luminosity Issues Agenda

9:00   Acc Physics Overview               T. Raubenheimer
10:00  Damping Ring Physics            M. Venturini
10:30  Coffee
11:00  Electron Cloud Issues           M. Pivi
11:30  Availability Modeling           T. Himel
12:00  Lunch
1:30   Stabilization R&D, Priorities, and Plans  A. Seryi
2:00   Ground motion and Cultural Noise  F. Asiri
2:30   Executive session
Summary

• Lots to do
  – Too many other time commitments
  – I-TRP will make significant demands on top of those at present

• Some things are resource limited but many are not
  – Need engineering support in a number of cases
  – Need to be clear about priorities

• We have demonstrated rf system
  – Structures at 60 MV/m that meet breakdown performance
  – PPM klystrons that have met performance requirements
  – SLED-II with 3x pulse compression

• Lets move on to the important luminosity issues!