ILC R & D Plan

Presentation to the HEPAP ‘P5’ Panel,
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ILC R & D Resources: Provided ‘In – Kind’

• Anyone can join, provided they have:
  – Their own funding
  – Sufficient relevance
• Their commitment:
  – Communicate & Participate
• Our commitment:
  – Open decision making process
• Our ‘product’ → an updated baseline, with a plan
• Model for international science
• No central institution
  – No centralized project funding source
• Regional, Professional, Infrastructure Diversity
  – Roughly equal contributions from each region
Goal and Definition:

Goal: The primary goal of GDE activities will be to advance
(i) the technology,
(ii) the design and
(iii) the construction plans for ILC, so that
approval for construction can be sought in ~2012

EDR will
(i) explain the capabilities of the technology at that time,
(ii) will detail the design of the machine and the construction plans, and
(iii) will present an updated value estimate.

The Technical Design Phase (I & II) must produce an engineering design of the project in sufficient technical detail that approval from all involved governments can be sought, and so that the ILC can begin construction soon after that approval is obtained.
Importance of developing consensus

• RDR represents consensus – based accelerator design
  – From the 2004 Technology Recommendation to an agreed-upon design

• The next step is harder, focus on:
  – lab and project based activities and
  – specific designs to mitigate remaining risk and reduce cost

1. Validate performance expectations
   – Superconducting RF
   – Key beam parameters; mitigation of instabilities

2. Engineering-based cost reductions
Primary contributors – projects and labs

- DESY / Europe – XFEL Project
  - 18 GeV, 300 M Euro accelerator
  - Very similar technology, operation starts in 2013
  - Single most important project supporting ILC R & D
    - ~10% scale full system demonstration; including production and operation
  - FLASH UVFEL

- Fermilab
  - NML Linac Test Facility

- KEK
  - STF Linac Test Facility
  - ATF Linear Collider Test Facility
Technical Design Phase (TDP) I – 2010

- Technical risk reduction
  - **Gradient**
    - Based on re-processed cavities, rather complete production cycle
    - 30% reduction in number of available cavities / cavity tests
  - **Electron Cloud (CesrTA)**
- Cost Risk / Cost Reduction – Main Cost Drivers
  - Conventional Facilities (Main Linac infrastructure)
  - Main Linac Technology (RF Power Generation and distribution)
- Technical Advancement
  - Cryomodule Design and Testing process
Technical Design Phase II – 2012

- RF unit test – 3 CM + beam (STF/KEK)
- Complete the technical design and R & D needed for project proposal
- Fully documented
- Updated comprehensive value estimate

- A ‘Project Implementation Plan’
  - developed through consensus
  - CM Global Manufacturing Scenario
  - Siting Plan or Process
SCRF linac – basic building block

Figure 1.2-1: A TESLA nine-cell 1.3 GHz superconducting niobium cavity.

- ~70 parts electron-beam welded at high vacuum
  - mostly stamped 3mm thick sheet metal
- pure niobium and niobium/titanium alloy
  - niobium cost similar to silver
- weight ~70 lbs
- 18% of the ILC value estimate
Cavity in cryogen tank

Eight in a string

Hang string from support tube

Slide into cryostat

Completed Cryomodule in Fermilab ICB, November 2007
Cavity Gradient:

- TDP I - 2010
- R&D priority – very high
  - RDR estimate: 10% improvement in gradient reduce ILC cost by 7%
- Goal: Determine production yield at nominal (35 MV/m) gradient
  - Ansatz (DESY): focus on surface processing
  - Subject a given set of cavities to multiple chemical process / test cycles
  - Use estimated production yield to guide project plan
- Progress since technology choice (08/2004):
  - (Primarily at DESY; also J-Lab and KEK)
  - 50% yield 27.5 MV/m in 2006
  - 50% yield 31.5 MV/m in 2008
  - each based on sample population of 15 nine cell cavities
Superconducting Cavities

- Global Cavity program
  - Cavities available
  - Process and Test cycles anticipated
- From 2006 to 2012 with milestone at end of TDP I

<table>
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<tr>
<th>Americas</th>
<th>FY06 (actual)</th>
<th>FY07 (actual)</th>
<th>FY08</th>
<th>FY09</th>
<th>FY10</th>
<th>TDP I (04 - 10)</th>
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<th>FY12</th>
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<td>Global totals</td>
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<td>Global totals - cavity fabrication</td>
<td>76</td>
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<td>135</td>
<td>175</td>
<td>381</td>
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Development of flexible RF distribution systems will allow higher gradient operation, approaching $E_{\text{max}}$. 
Cryomodule (CM):

- **TDP 2: RF Unit** equivalent to 3 each cryomodules
- **R&D Priority – High**
  - Primary ILC ‘High-Tech’ component;
  - GDE development and construction plan must account for regional & institutional ambitions
- **6 basic components:**
  - Cryostat, internal supports and cryogen plumbing:
  - and 4 interchangeable internal sub-assemblies
    - Cavity + cryogen tank + tuner 64% CM cost
    - Power input coupler 12%
    - Quad 4%
    - BPM 2%
  - (Cryostat & plumbing/supports 19%)
Cryomodule R&D Strategy:

Twofold:

1. Devise a cost model and construction plan based on a globally-unified design
   - Develop and test the model
     • Industrialization realized and demonstrated by XFEL

2. Aggressively promote cost savings / performance improvements
   - Specify interface between 6 basic components
   - Provide test facilities
Cryomodule testing plan

• Development of CM unified design;
  – fabrication in at least two labs – provides a test facility
  – Project X plans to adopt this design

• R&D goal:
  – A cryomodule (of any type) with operational MV/m gradient 31.5MV/m

• Testing to be completed: TDP2:
  – KEK /STF – full beam test RF unit in 2012; CM testing from 2009
  – Fermilab – NML – CM testing from 2009
CM Program: Development of Industrial capacity

• ILC production model → ~300 cryomodules/year (worldwide) –
  – 1850 total
  – Based on the European XFEL (Saclay, DESY, INFN…) demonstration of ~ 50 / year
    • Total 101 to be built from 06.2010 to 06.2012
    • Cavities from EU vendors (2+)
    • ILC participation in production process through contracting labs
    • Assembly at Saclay – also open to direct ILC participation

• Global participation / project implementation model –
  – For GDE to develop and deliver TDP 2
  – Based on XFEL technical and project experience

• Ready to submit for approval - 2012
Beam Tests

Demonstrate stable beam operation:

- **Damping Ring**
  - Cornell (also KEK)

- **Main Linac**
  - DESY (also KEK and Fermilab)

- **Beam Delivery**
  - KEK

- **Technical Demonstrations and beam dynamics tests**
Electron Cloud Mitigation - CesrTA

- TDP I
- R & D Priority: Very High
- Mitigate interaction between secondary electrons and positron beam
  - Also important in proton storage rings (Project X R & D priority)
- Simulations: LBL, SLAC, KEK, CERN, etc…
- Experimental work done at B-factories
- 2008 – 2010 NSF – funded R&D program at CesrTA
  - Test Vacuum chambers with diagnostics
  - ILC wiggler-dominated optics
  - Beam size diagnostics and emittance minimization process
## CesrTA Milestones

<table>
<thead>
<tr>
<th>Period</th>
<th>Tasks &amp; Milestones</th>
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<tbody>
<tr>
<td>May-June 2008</td>
<td>1) Install first dedicated electron cloud instrumentation section in CESR arc (dipole and drifts) followed by beam tests</td>
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</table>
| July-Sept 2008| 1) Reconfigure CESR for low emittance  
               2) Install wigglers with instrumented vacuum chambers  
               3) Optics line for X-ray beam size monitor (positrons)  
               4) Deploy upgraded BPM system around majority of ring  
               5) Upgraded leveling and adjustment system for quadrupoles |
| Fall 2008     | 1) Tests of EC growth in vacuum chambers at 2-2.5 GeV. Characterize growth as a function of bunch spacing, intensity, train configuration, emittance. |
| Mid-2009      | 1) Complete key CESR upgrades to attain and measure ultra low emittance beams      |
| Fall 2009     | 1) Complete evaluation of electron cloud growth in wigglers, dipole and quad chambers. Compare with simulation and prepare evaluations for ILC EDR  
               2) Continue program to achieve ultra low emittance  
               3) Detailed experiments at the lowest achieved emittance to characterize EC instability thresholds and emittance dilution  
               4) Commission electron X-ray beam size monitor  
               5) Measure electron cloud growth and mitigation in wigglers at 5GeV |
| Feb-Mar 2010  | 1) Complete program to achieve ultra low emittance  
               2) Characterize electron and positron instability thresholds and emittance-diluting effects at the lowest achievable vertical emittance for both electrons and positrons |
Overview of the 2 Year CesrTA Schedule

- **Operations Schedule**
  - 2 experimental runs in 2008
  - 3 experimental runs in 2009
  - 1 experimental run in 2010
  - Avg ~40 days/run

- **Down Periods**
  - Major Reconfiguration down Jul-Sep 2008
  - Hardware installation downs
    
    - 2 in 2008

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<th>2008</th>
<th>2009</th>
<th>2010</th>
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<tr>
<td></td>
<td>Apr</td>
<td>May</td>
<td>Jun</td>
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<tr>
<td>Preparation for Ring Reconfiguration</td>
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<td>Downs with Upgrades/Modifications</td>
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<td>CesrTA Runs</td>
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<td><strong>Low Emittance Program</strong></td>
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<td>BPM System Upgrade</td>
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<td>Positron Beam Size Monitor</td>
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<td>Electron Beam Size Monitor</td>
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<td>Survey and Alignment Upgrade</td>
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<td>Beam Studies</td>
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<tr>
<td><strong>Electron Cloud Studies</strong></td>
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<td>Instrumented Vacuum Chambers w/EC Mitigation</td>
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<td>Feedback System Upgrade</td>
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<td>Photon Stop for 5 GeV Wiggler Operation</td>
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<td>EC Growth Studies</td>
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<tr>
<td>Beam Dynamics Studies at Low Emittance</td>
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**Legend:**
- Design/Fabrication
- Down Period
- Installation
- Commissioning
- Operations and Experiments

Now – April 1: Design, fabrication and prototyping efforts
High Gradient SCRF Linac
TTF/FLASH, STF, ILCTA-NML

• TDP 1
• R & D Priority: High
• Combine operation near gradient-limit with high current - full beam loading
  – Demonstrated 2003; somewhat lower current and gradient
  – Also required for XFEL
• Testing plan under development at DESY
  – Using DESY fully functioning 1 GeV SCRF linac
  – Full ILC RF unit test at STF (KEK) in 2012
  – ILC CM tests at ILCTA-NML
Beam Delivery – ATF2

- TDP 2
- R & D Priority: High
  - Scaled Beam Delivery System
- Demonstration of precision beam tuning
  - Small beam tuning – 35 nm; beam size stabilization
  - Beam stabilization – few nm
- Schedule
  - start of commissioning with beam to dump in min configuration of ATF2 beamline: Autumn 2008
  - finish hardware commissioning for ATF2 beamline: 2009
  - ATF2 optics & beam size studies: 2010
  - assessment of beam size studies: 2011-2012
Conventional Facilities

- TDP I
- Development Priority - Very High
- Cost reduction - from basic systems / value engineering
- Two components selected:
  - **Underground construction (48% of total CFS)**
    - RDR Design and cost based on CERN LHC
    - Underground space ‘usage basis’ guidelines not yet developed
  - **Power and Water for main linac (8%)**
    - Heat removal from power source and feed system
      - Pumping and Piping costs ~70%
    - Substantial cost reduction with increased delta T
Main Linac Technology

- TDP I
- Priority - High
- Power generation and delivery technology
  - 27% linac value estimate
  - Production activity at DESY –
    - Proven design, cost optimizations still possible
  - Development activity at SLAC
  - Modular high voltage system - ‘Marx generator’
    - ‘Flexible’ RF distribution system using variable tap-off’s
- Motivation – cost reduction, gradient optimization:
ILC and CERN / CLIC R&D

• CERN R & D support strong for ‘CLIC’
  – 53 M CHF for 2008-2010
  – (Comparable to one of the three ILC regions)
  – Collaborator’s efforts additional
• Strongly overlapping design efforts:
  – past, present, future
• Many Common elements:
  – Beam Delivery
  – Beam Dynamics
  – Conventional Facilities / Civil Construction
  – Detector / IR Hall
  – Sources, Damping Rings
• Formal GDE ↔ CLIC planning meeting Feb 8, 2008, CERN
ILC R & D Summary:

• Two Phases
  – 2010 and 2012
• Prioritized using RDR Value Estimate and Technical Risk Assessment
  – Superconducting RF Technology
  – Conventional Facilities
  – Beam Tests
• Broad basis; strong multi-lateral collaboration
  – Test facilities in each region covering key issues