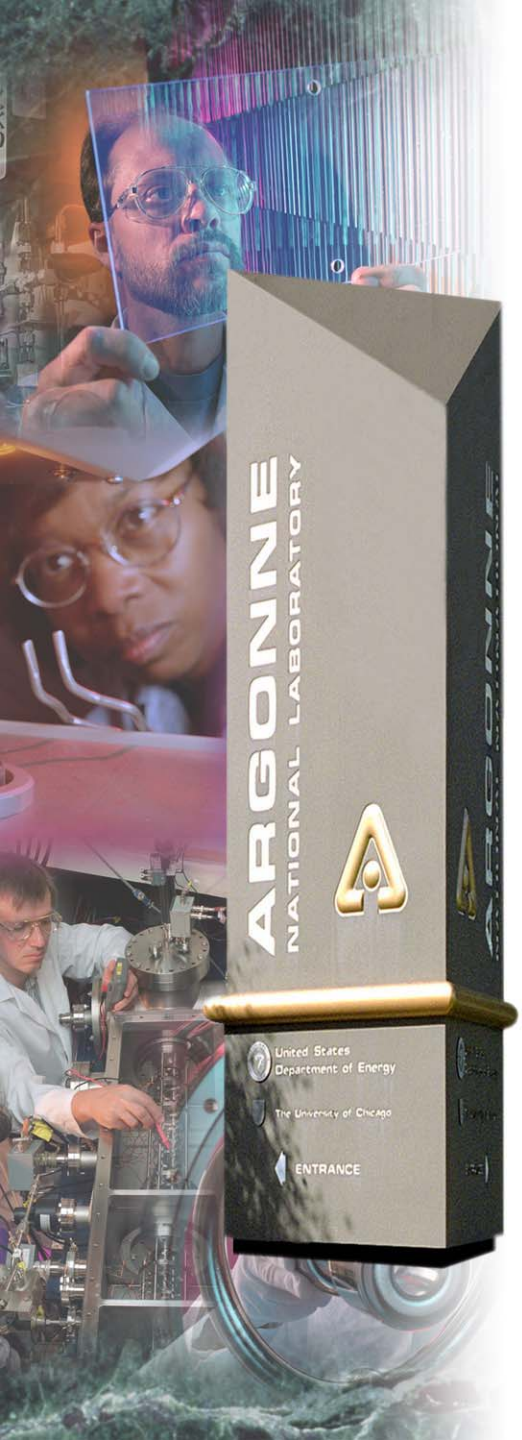


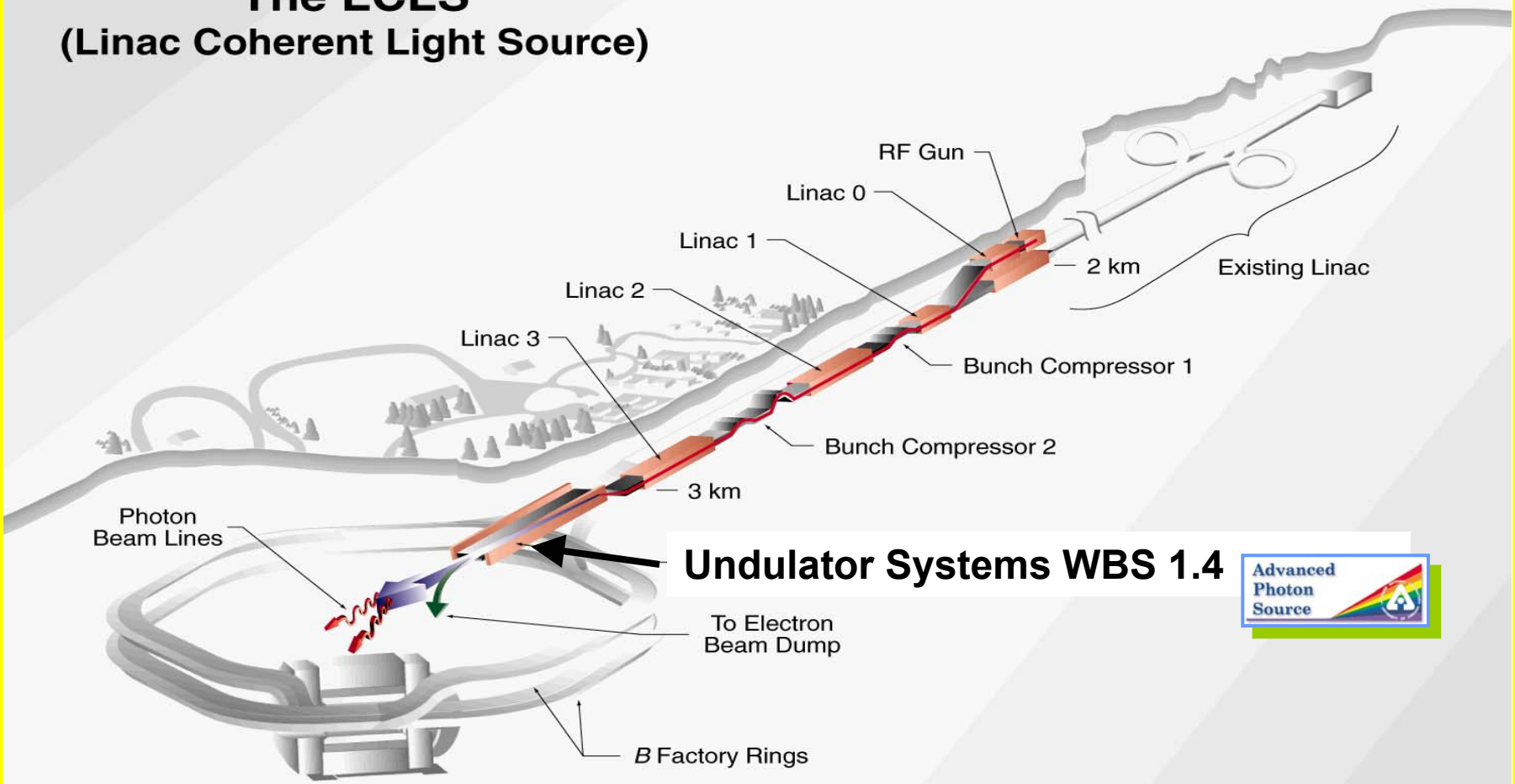
The Linac Coherent Light Source

Stephen Milton

The University of Chicago Review
for the Advanced Photon Source
at Argonne National Laboratory

September 17-19, 2003

The LCLS
(Linac Coherent Light Source)



Undulator Systems WBS 1.4

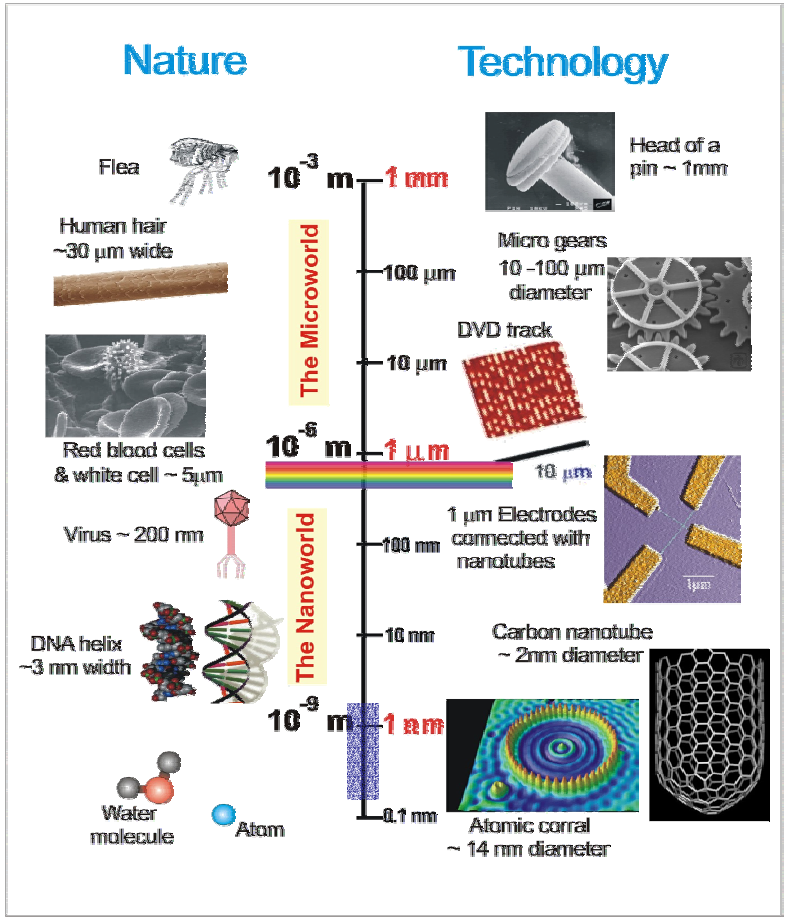
Advanced Photon Source

10-97
8360A1

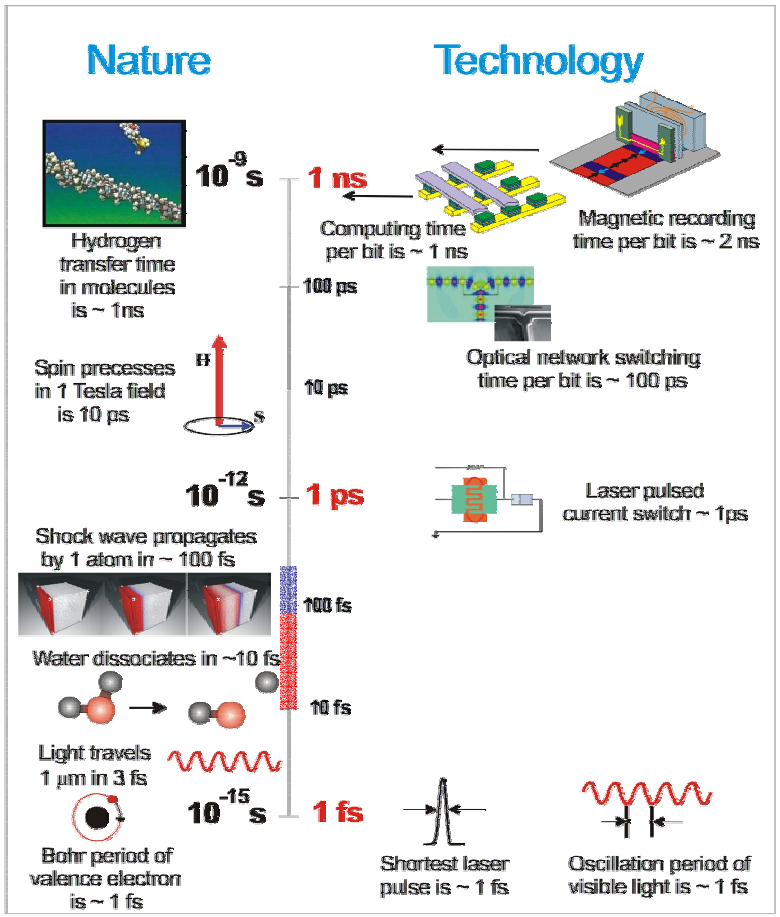
LCLS: The World's First X-ray Laser for Scientific Research

X-Rays have opened the Ultra-Small World
X-FELs open the Ultra-Small and Ultra-Fast Worlds

Ultra-Small

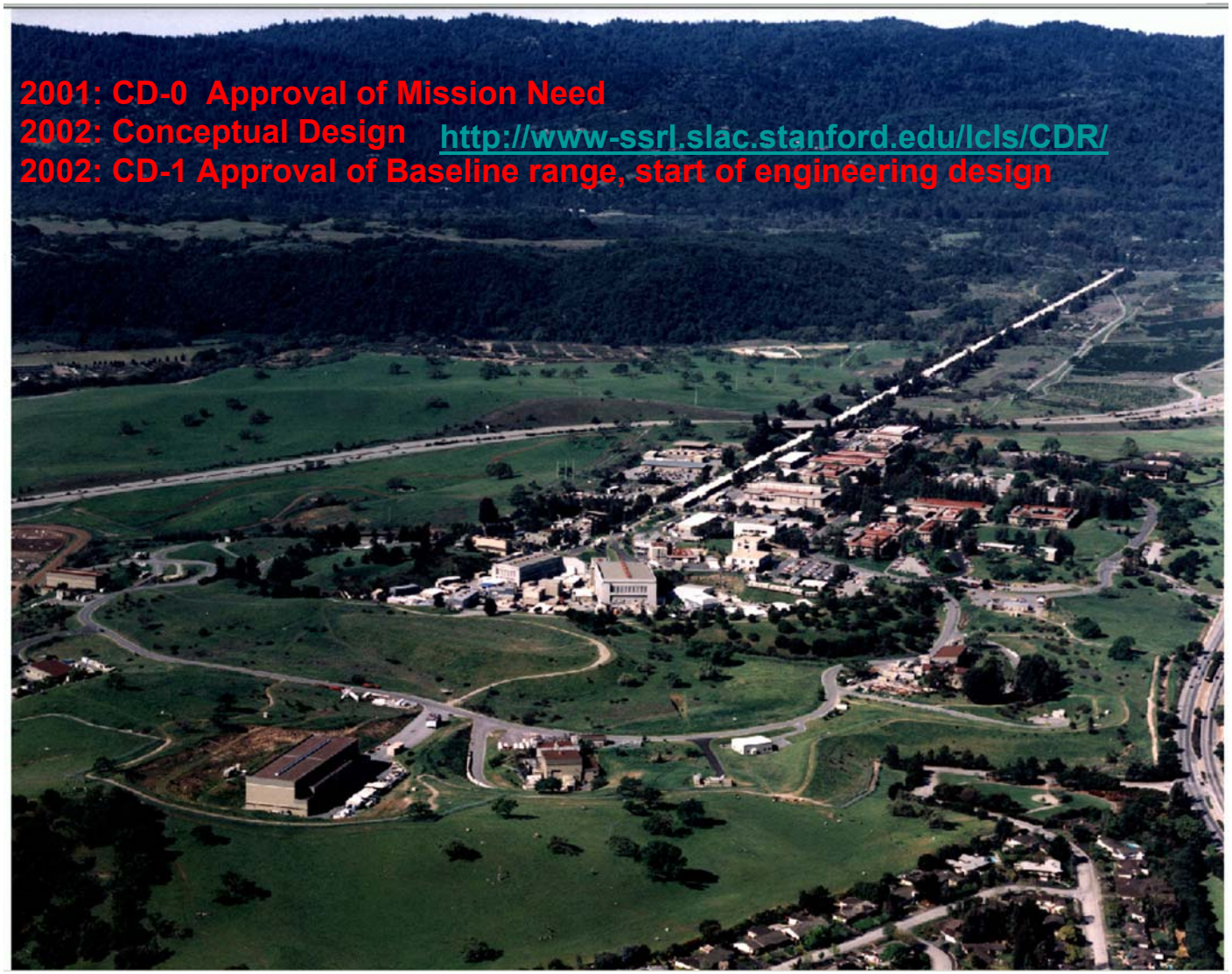


Ultra-Fast

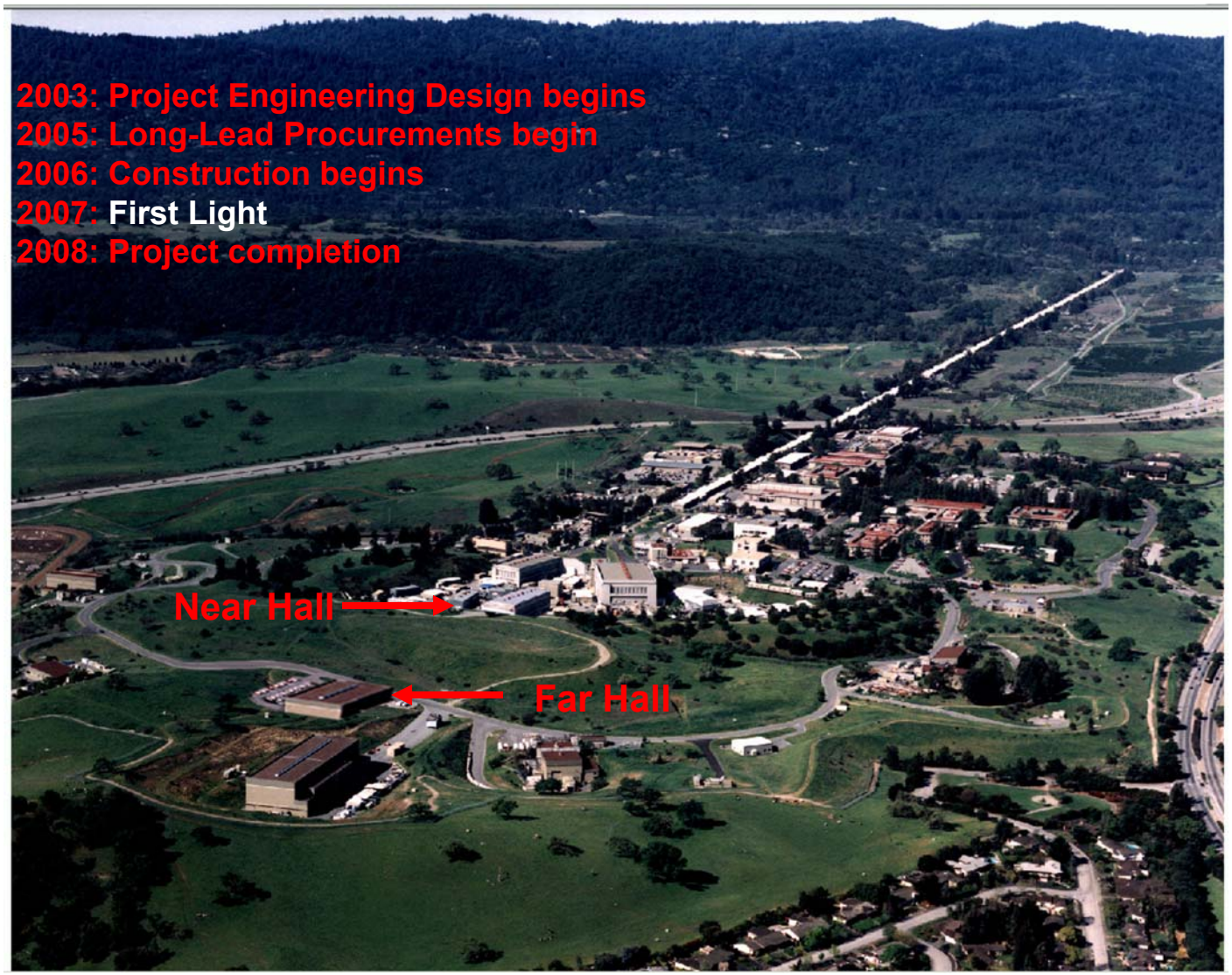


Linac Coherent Light Source

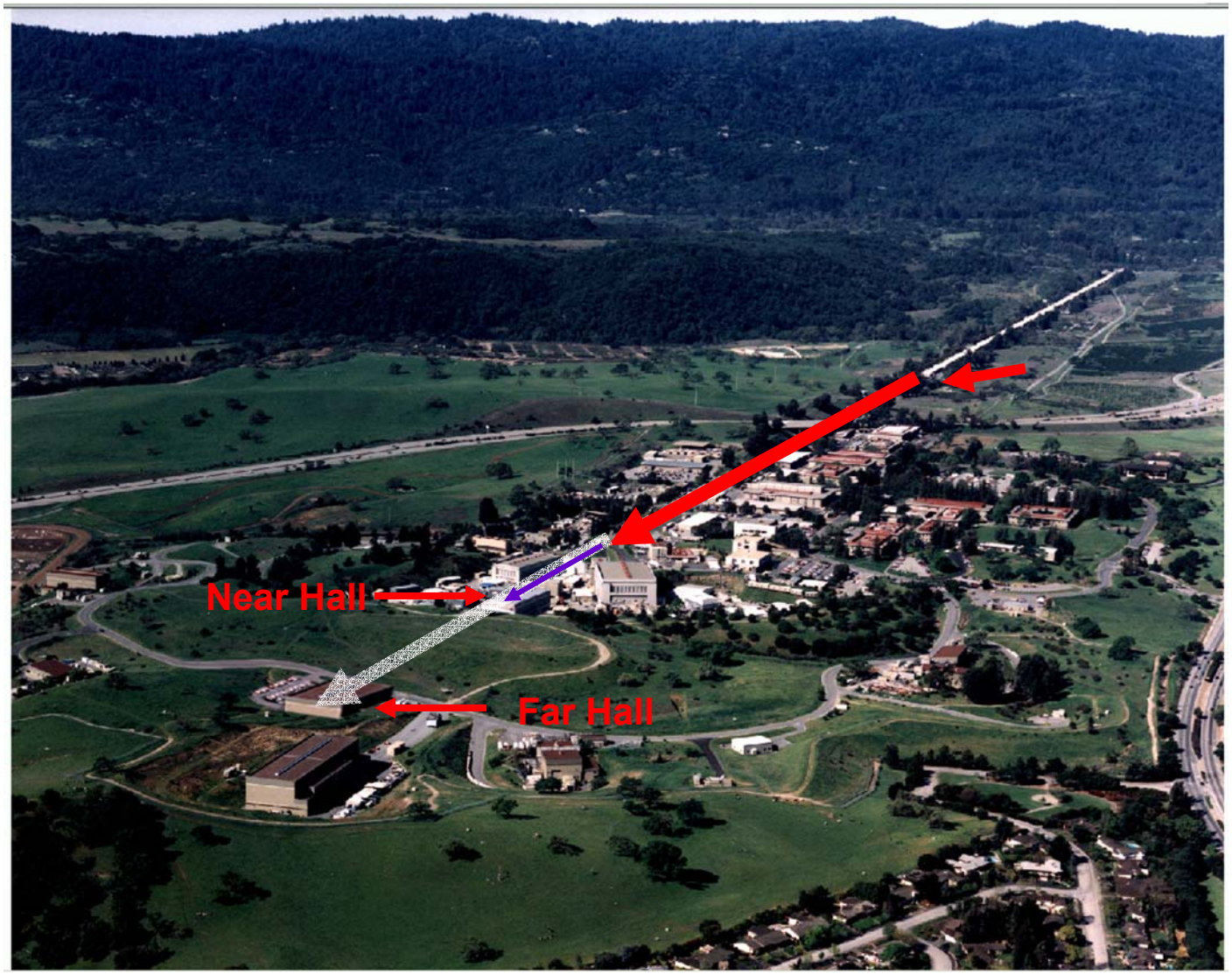
Linac Coherent Light Source



Linac Coherent Light Source



Linac Coherent Light Source – Project Description



Linac Coherent Light Source

Capabilities

Spectral coverage: 0.15-1.5 nm

To 0.5 nm in 3rd harmonic

Peak brightness: 10^{33}

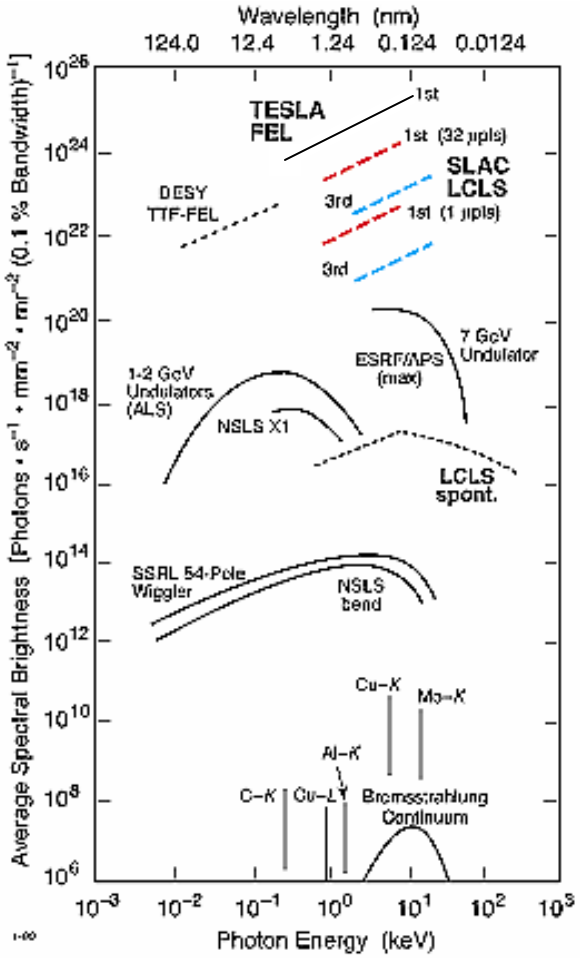
Photons/pulse: 10^{12}

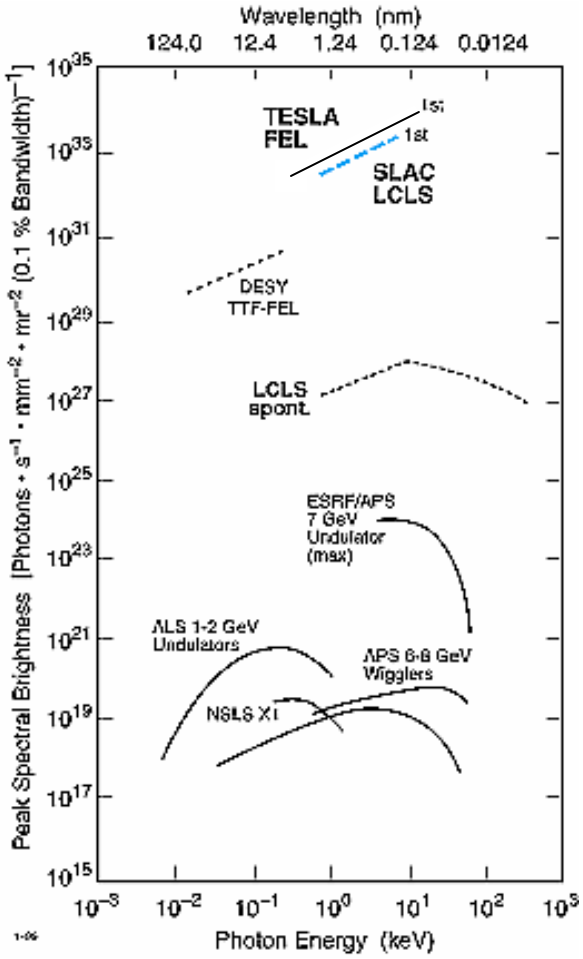
Average brightness: 3 x 10^{22}

Pulse duration: <230 fs

Pulse repetition rate: 120 Hz

Upgrade – more bunches/pulse





Assessment of Scientific Case

- **1997** Birgeneau-Shen BESAC report

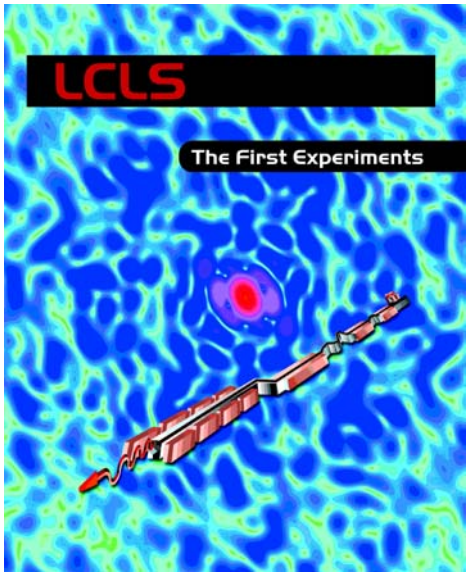
  DOE Synchrotron Radiation Sources and Science
  Among the **highest priority** *recommendations: funding an R&D program in next-generation light sources and convening another BESAC panel to focus on this topic.*

- **1999** Leone BESAC report
  Novel, Coherent Light Sources

  Concluded: "Given currently available knowledge and limited funding resources, the hard X-ray region (8-20 keV or higher) is identified as the most exciting potential area for innovative science. DOE should pursue the development of coherent light source technology in the hard X-ray region as a priority. This technology will most likely take the form of a linac-based free electron laser using self-amplified stimulated emission or some form of seeded stimulated emission…"

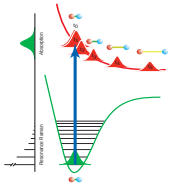
Presentation of the Scientific Case

- Presented to BESAC 10-Oct-2000
- Critical Decision 0 approved 13-June 2001

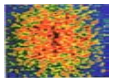


Program developed by international team of scientists working with accelerator and laser physics communities

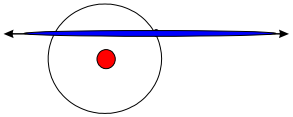
"the beginning.... not the end"



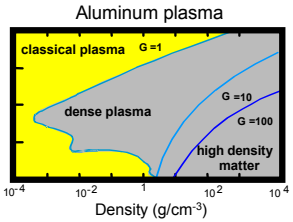
Femtochemistry



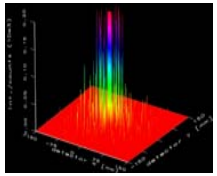
Nanoscale Dynamics in Condensed matter



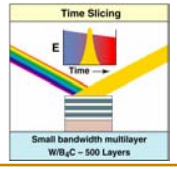
Atomic Physics



Plasma and Warm Dense Matter

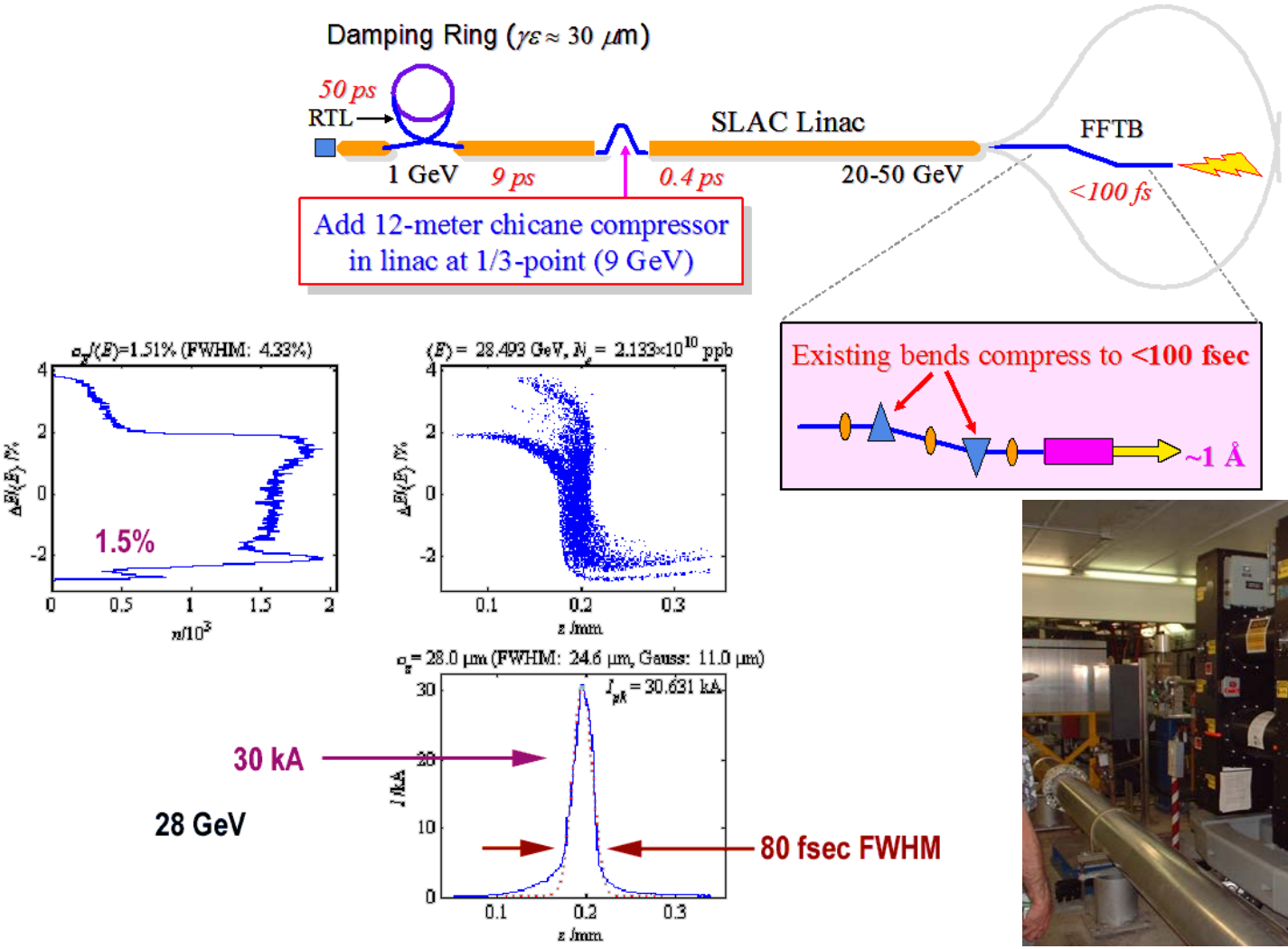


Structural Studies on Single Particles and Biomolecules



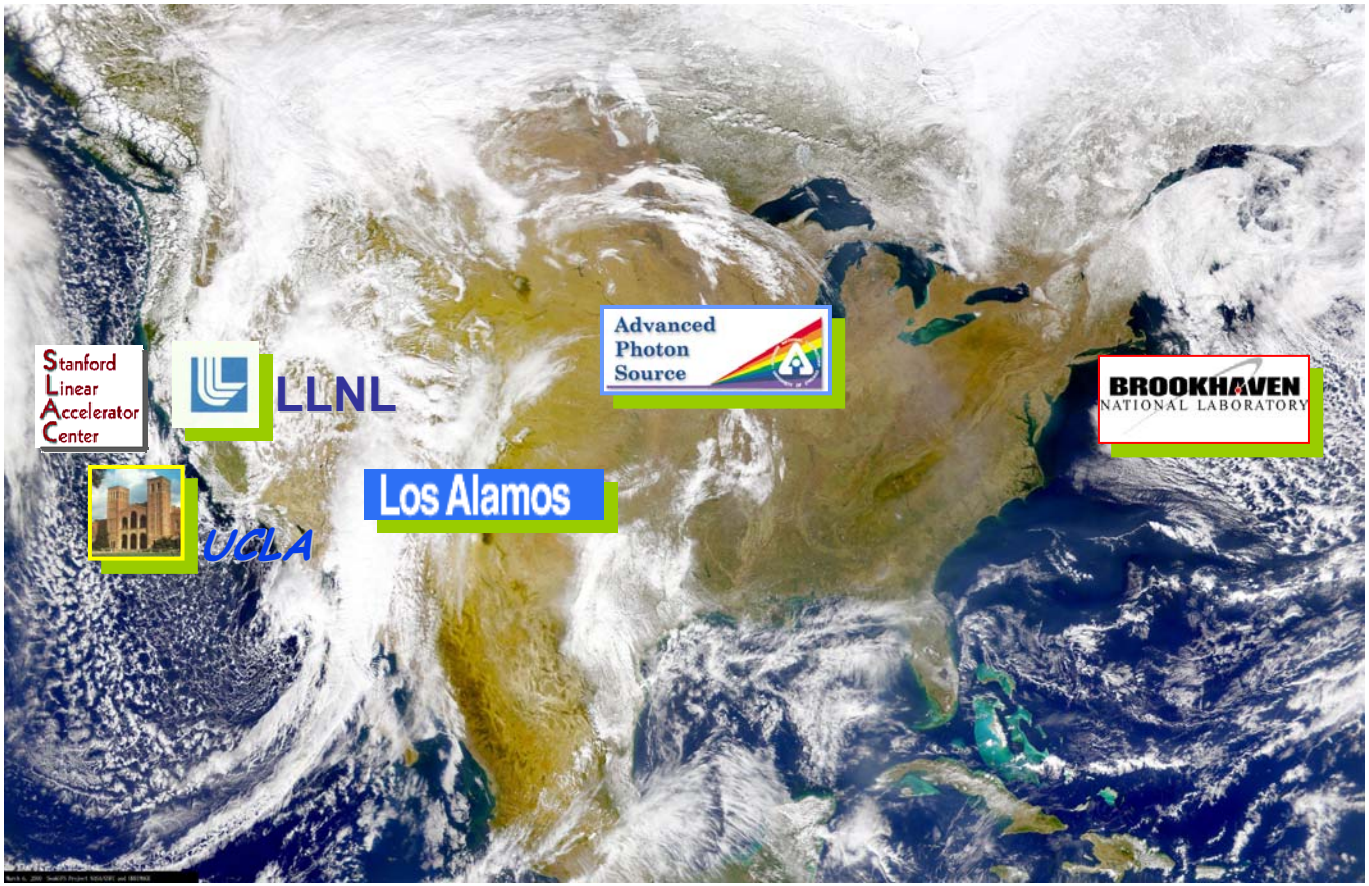
FEL Science/Technology

Sub-Picosecond Pulse Source: SPPS

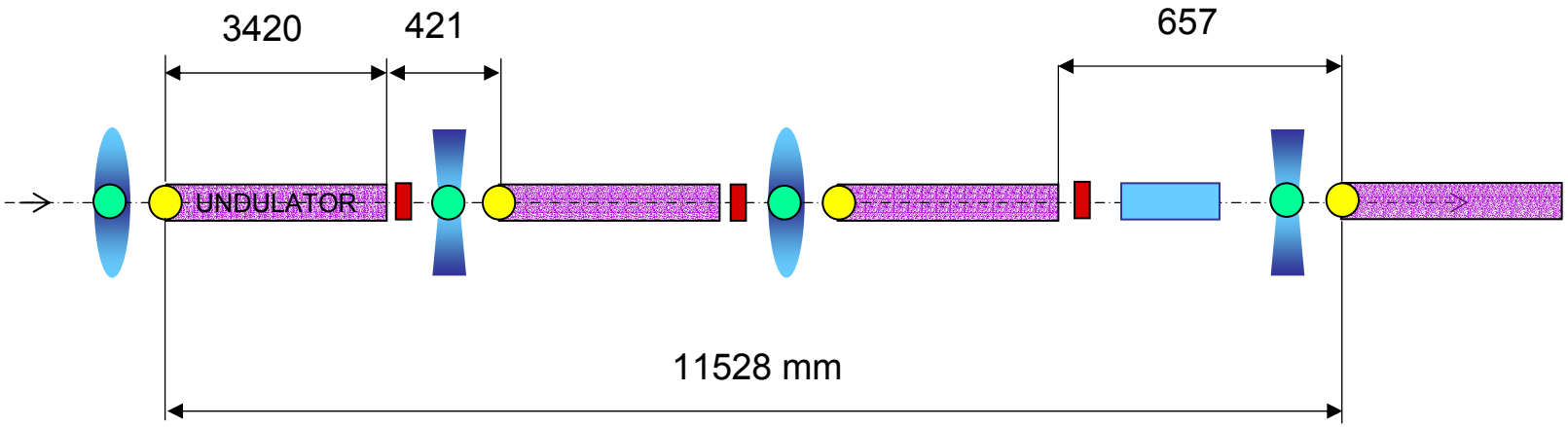


LCLS R&D Collaboration

FEL Theory, FEL Experiments, Accelerator R&D,
Gun Development, Undulator R&D



Cell Structure of the LCLS Undulator Line



Horizontal Steering Coil

Vertical Steering Coil

Beam Position Monitor

X-Ray Diagnostics

Quadrupoles

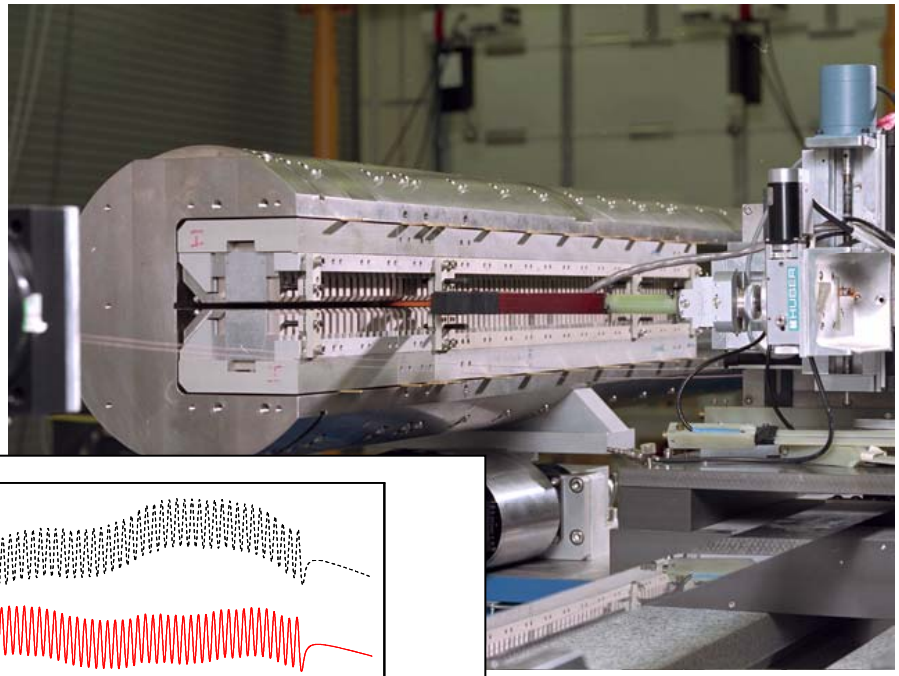
33 Undulators
~ 130-m
Overall Length

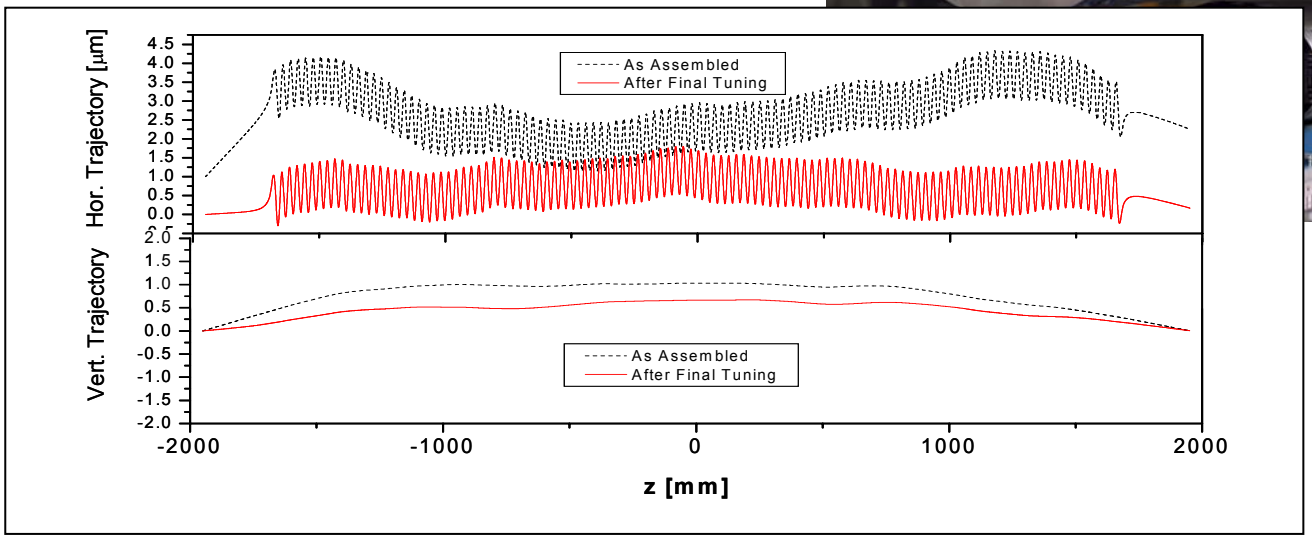
List of the Undulator Line Systems

- Undulator module
  - Magnets
  - Poles
  - Strongback
  - Other
- Mechanical support - movers
- Quadrupole lens
- Coils - correctors
- E-beam position monitors
- X-ray diagnostics
- Undulator vacuum chamber and diagnostics station
- Controls and data acquisition
- Support laboratory - magnet measurement facility
  - Technical definition and oversight only

Full-Length Prototype

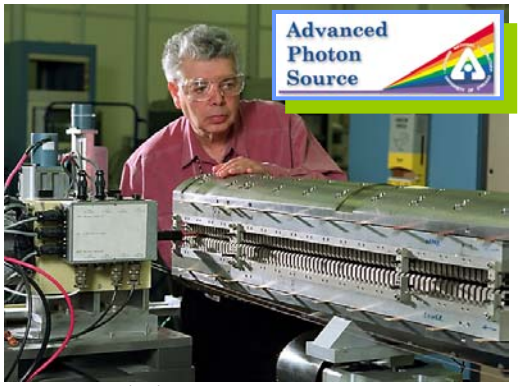
Performance measured to be within the design specification



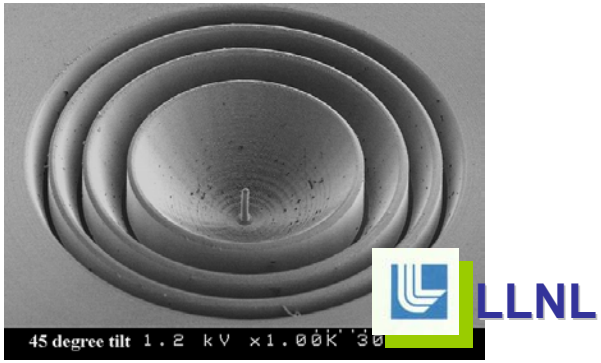


Firm Basis for Design and Cost Estimate

Gun design
R&D at SSRL gun test facility



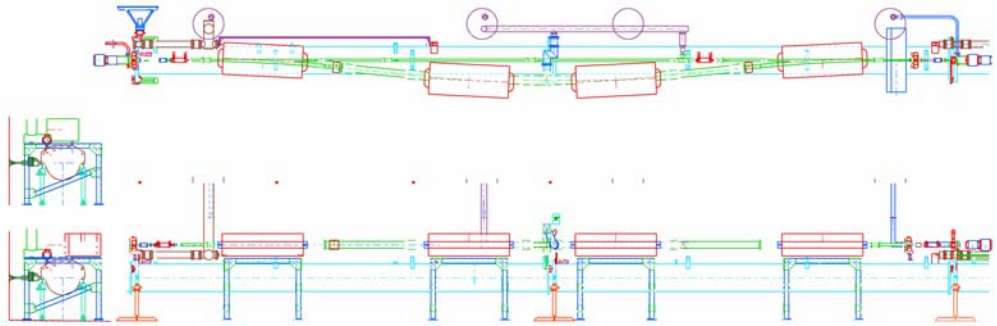
Undulator prototype
has met specifications



Optics fabrication techniques
Ongoing tests at SSRL

Stanford
Linear
Accelerator
Center

Cost-effective magnet fabrication
techniques developed for NLC

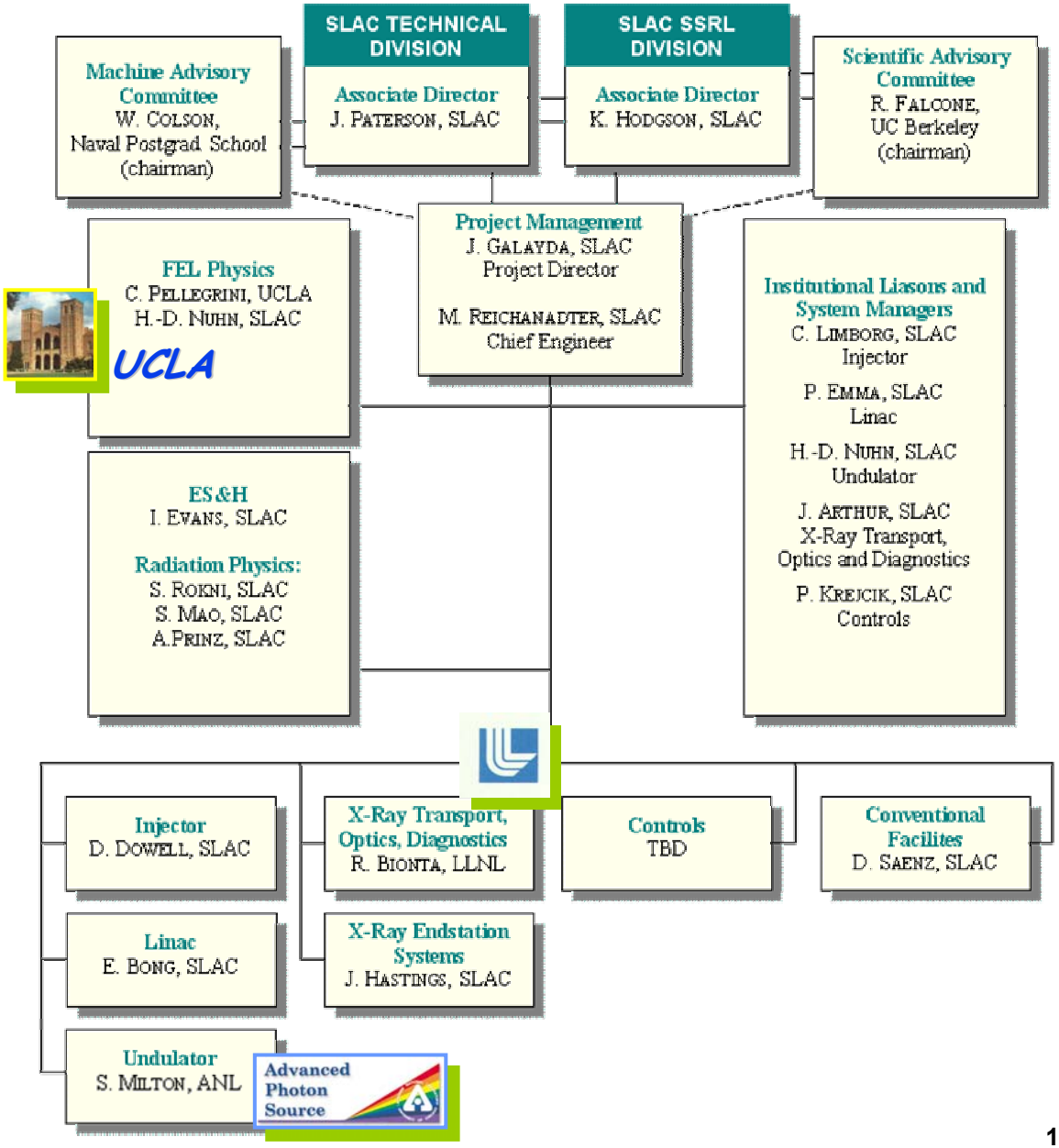


Chicane for advanced accelerator R&D
with ultrashort electron bunches

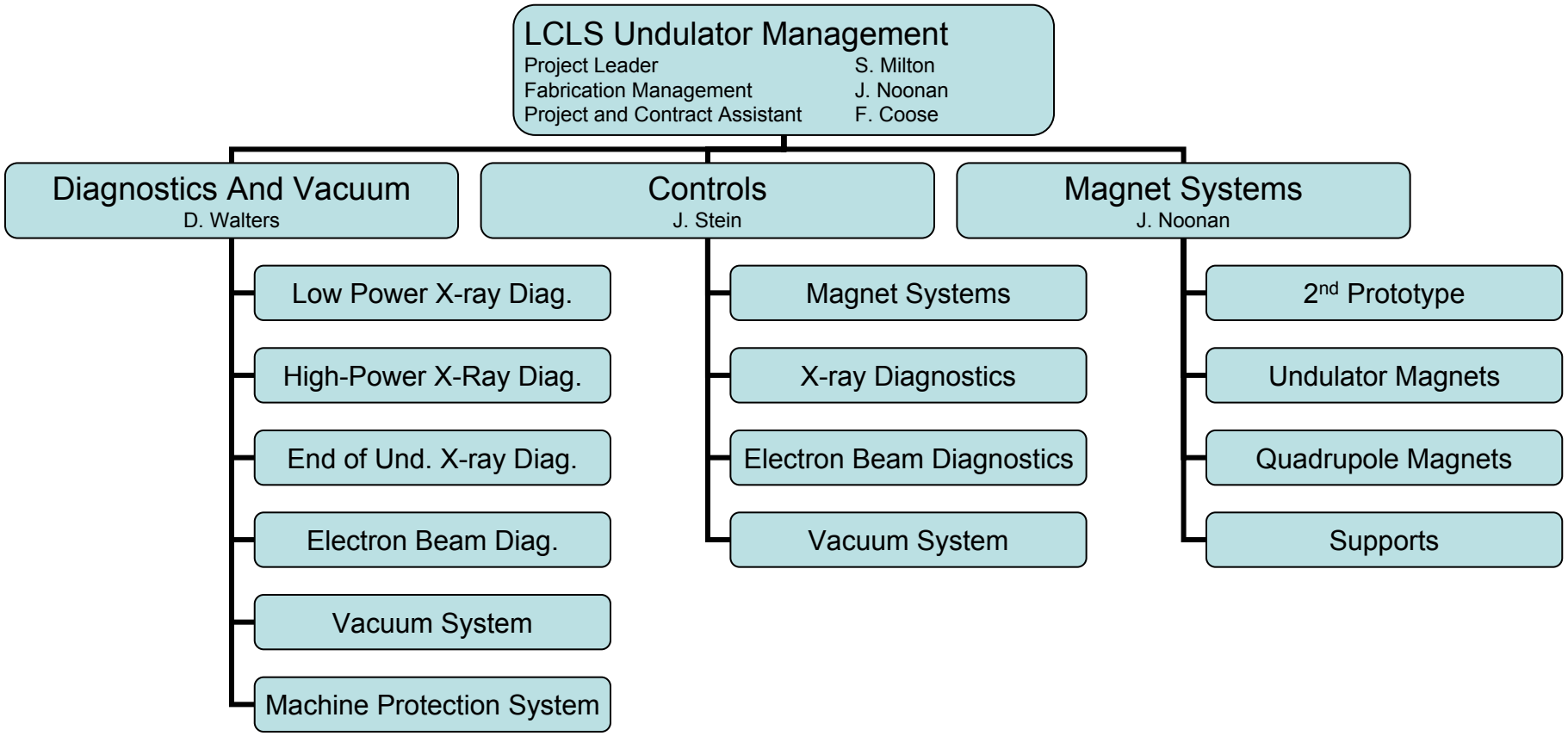
Estimated Cost, Schedule

- $200M-$240M Total Estimated Cost range
- $245M-$295M Total Project Cost range
  - ANL $50M-$55M for the undulator system
- Schedule:
  - **FY2003** Authorization to begin engineering design
    - Emphasis on injector and undulator
  - **FY2005** Long-lead purchases for injector, undulator
  - **FY2006** Construction begins
  - **January 2007** Injector tests begin
  - **October 2007** FEL tests begin
  - **September 2008** Construction complete

LCLS Project Engineering Design (PED) Organization



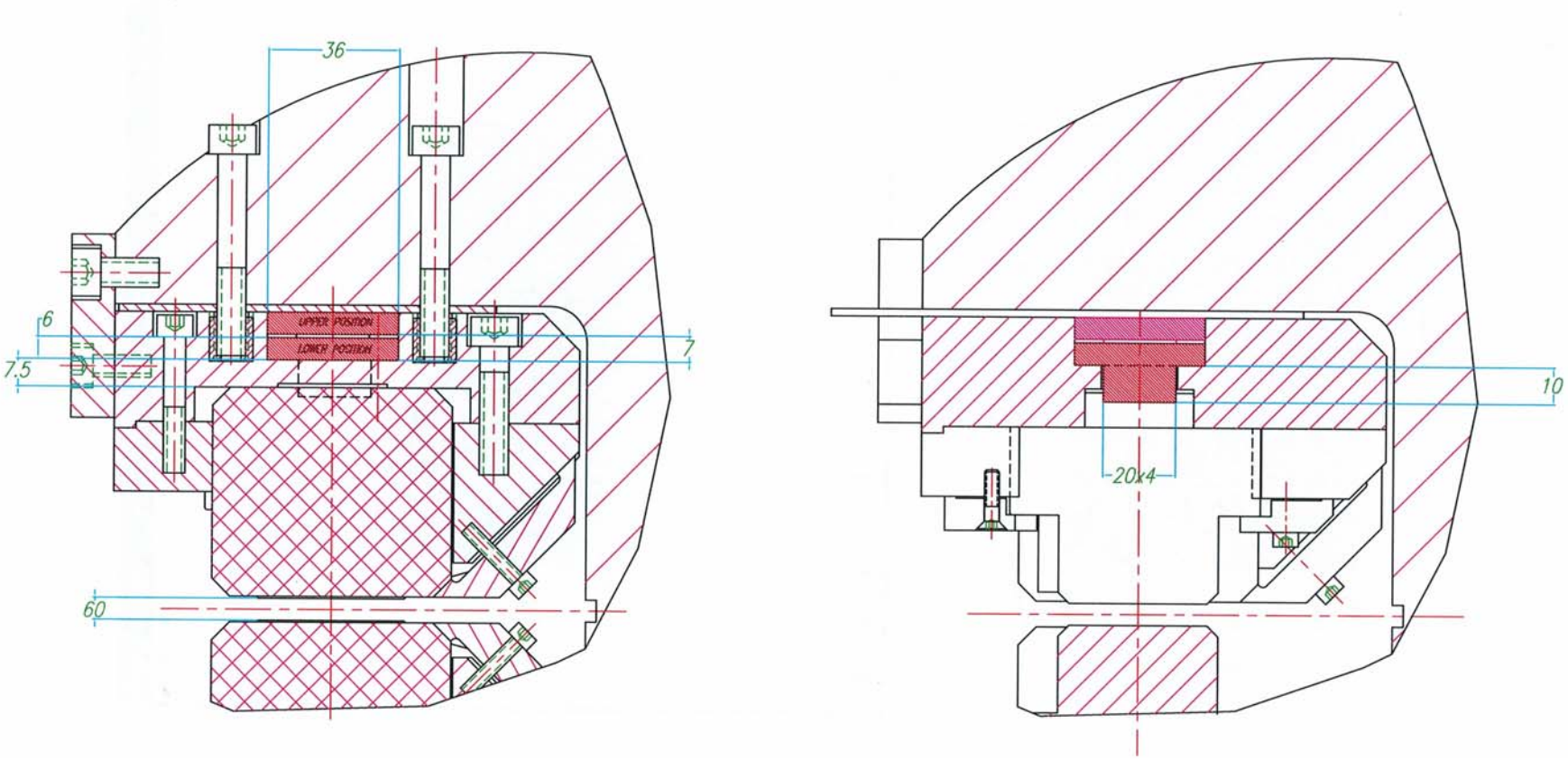
PED Organization



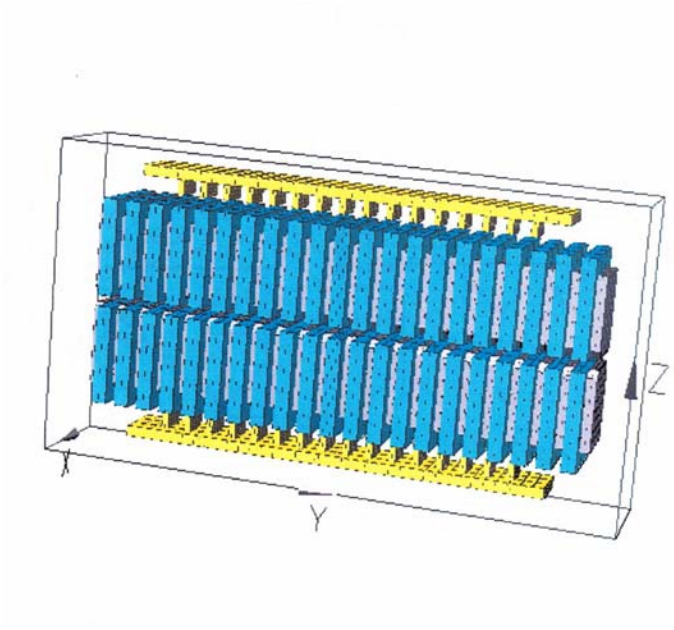
Undulator Design Issue

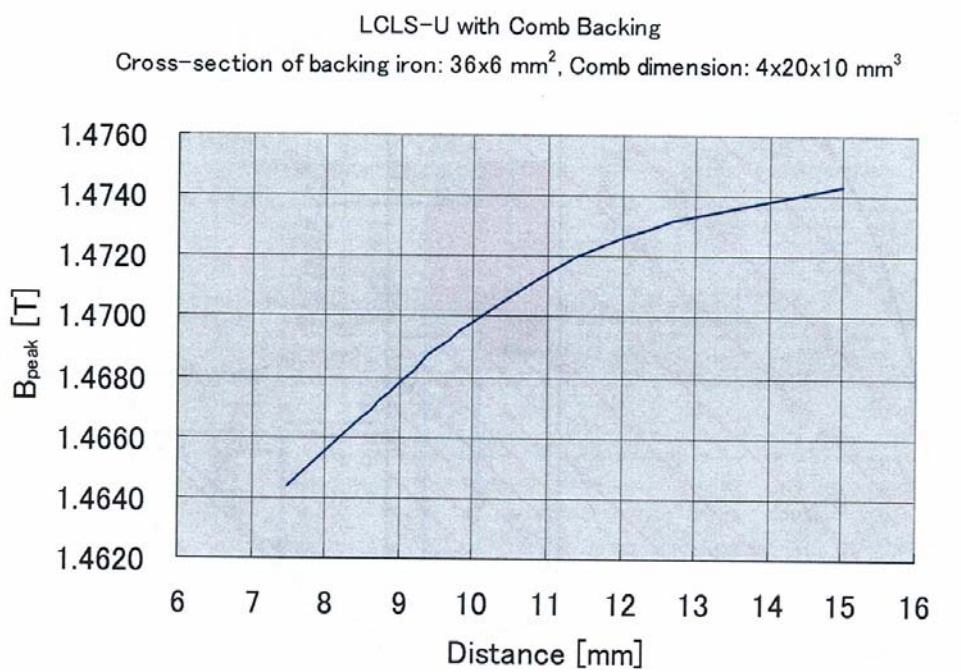
- Field variations
  - Must maintain $\Delta B/B < 1 \times 10^{-4}$
    - Implies gap changes of < 1 μm
    - And to maintain temperature to within 0.4 C°
    - Partial compensation
      - Accomplished by differential expansion of the titanium strong back and the aluminum magnet array comb
      - This helped, but did not fully compensate the device
  - Temperature control of device complicated

Field Control Concept



Field Control Concept





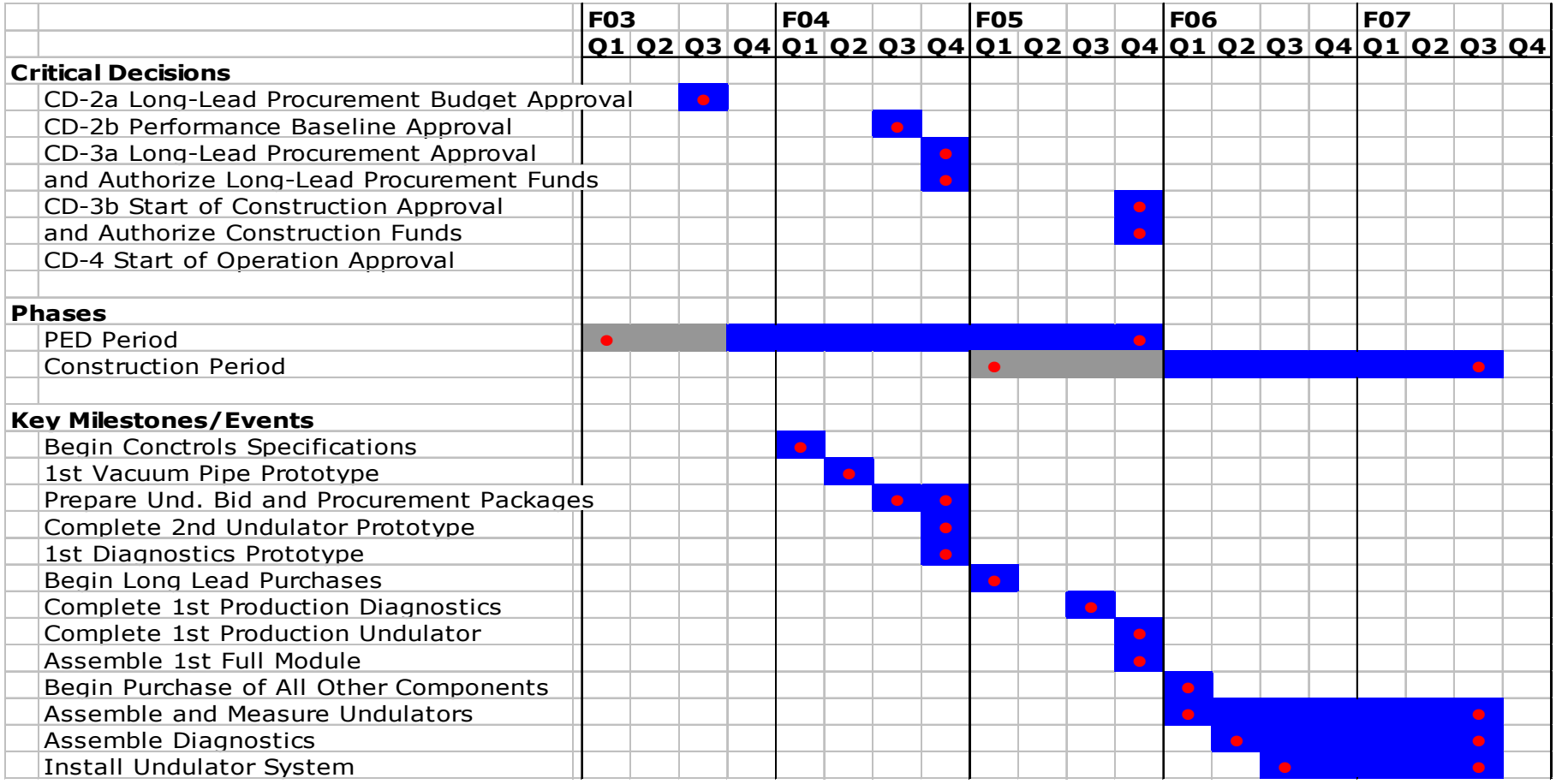
Other Complex Issues

- X-ray diagnostics
  - Wide range of photon energies
    - 8 KeV to 800 eV
  - Wide range of surface power densities
    - >10 orders of magnitude along the device
- Beam position monitors
  - Must have better than 1-mm single-pass resolution
  - Must be stable over long periods of time
- Long-term stability
  - Many components need to be held stable relative to one another to better than 50 μm and some significantly better

Project Management

- Current Status
  - Work Breakdown Structure
    - 80% complete
  - Resource-loaded first draft schedule with logic
    - Due to SLAC by end of September
  - Final draft of schedule
    - Due by end of November
  - Next Lehman Review
    - End of March 2004
    - Critical Decision 2b
      - Project cost and schedule baselining

Undulator System Schedule



Milestone Summary of Schedule

Milestone	Date
Design of second undulator prototype	9/30/03
Diagnostics specifications completed	1/1/04
Preliminary design of diagnostics completed	4/1/04
Prototype vacuum chamber assembled	7/1/04
Final design of undulator complete	9/1/04
Assembly and testing of second prototype undulator complete	9/15/04
Prototype diagnostics system assembled	4/1/05
Final design of vacuum system complete	5/1/05
Bid package for undulator assembly complete	7/1/05
Diagnostics, vacuum chamber, electromagnet bid package complete	7/1/05
First production undulator complete	7/1/05
Thirty-third production undulator complete	6/1/07
Installation of undulator system complete	7/1/07

Where We Stand

- In the Project Engineering Design phase
- Need to ramp up in staffing…quickly!
  - 10 to 15 people working full time within 6 months to 1 year
  - People will be drawn from APS and ANL when possible
  - Contract work out as necessary
- Project will be baselined in April 2004
- Long-lead procurements begin in FY05
- “Real” construction begins in FY06
- Undulator installed and ready to go in summer 2007
- First operations in winter 2008