

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

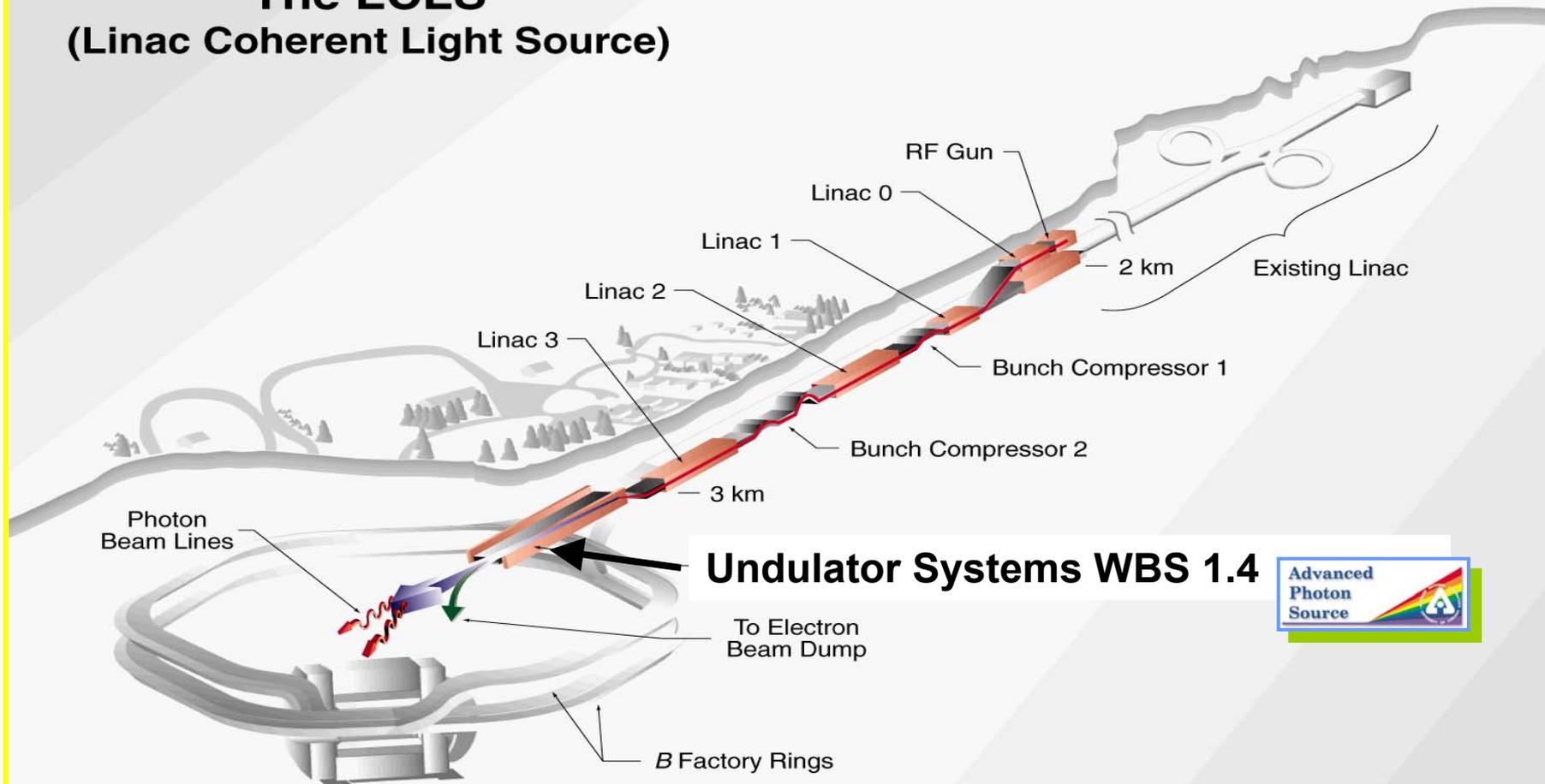


Office of Science
U.S. Department of Energy

A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago



The LCLS (Linac Coherent Light Source)



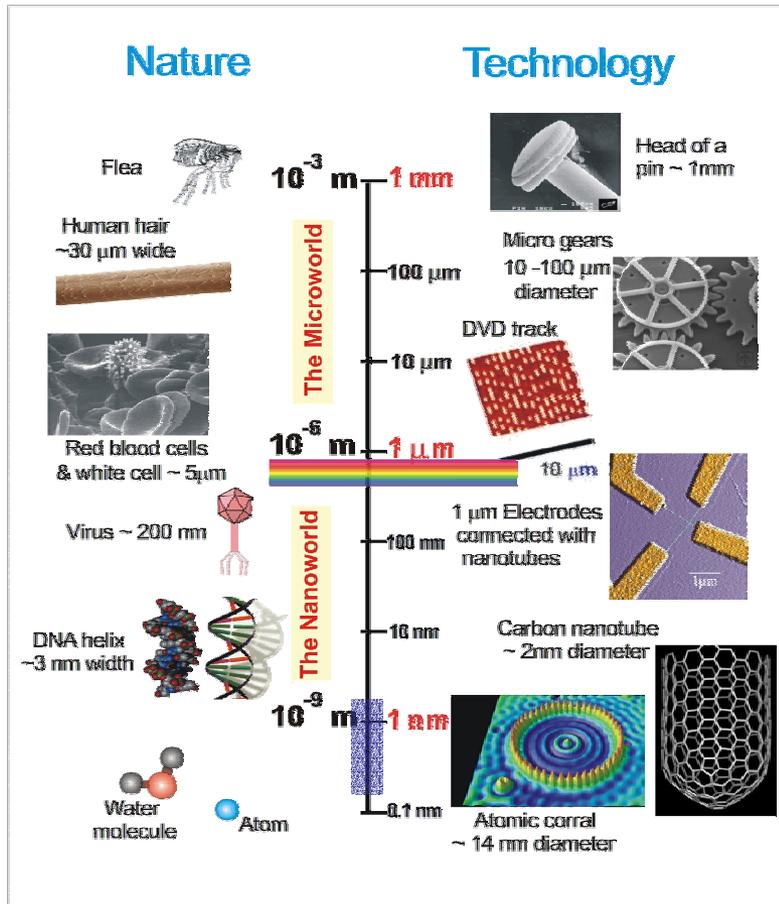
10-97
8360A1



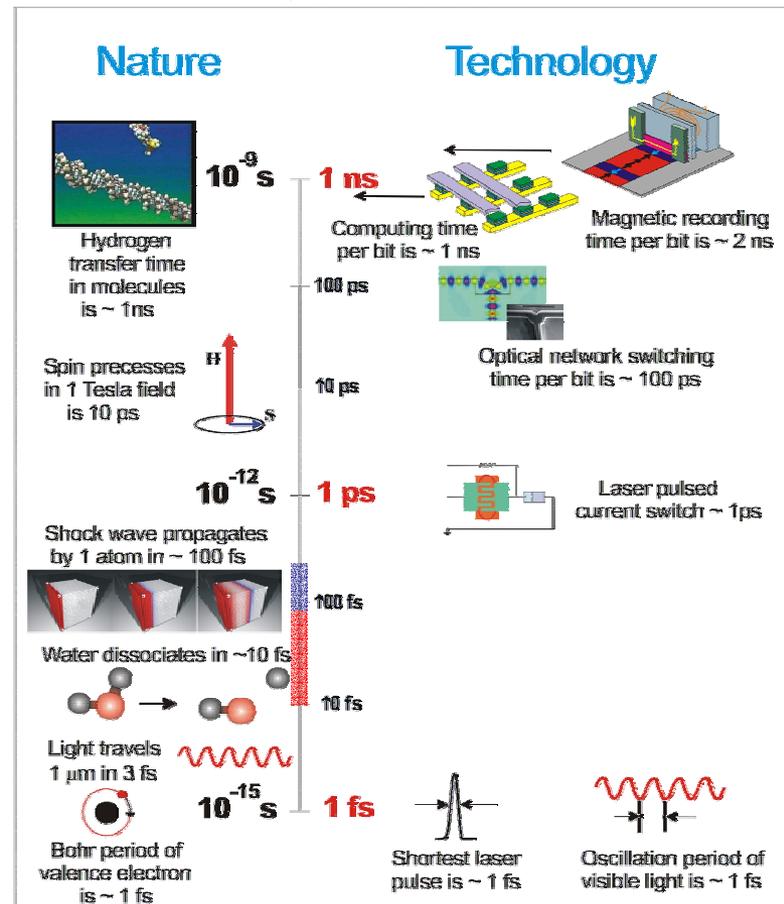
LCLS: The World's First X-ray Laser for Scientific Research

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

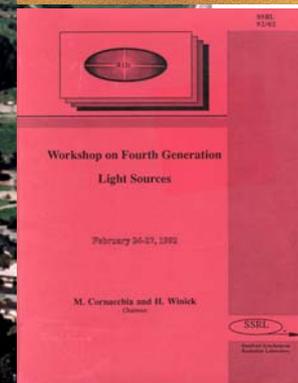
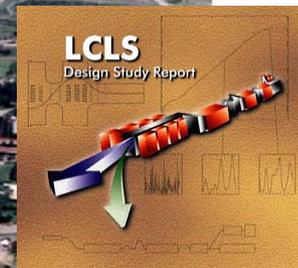
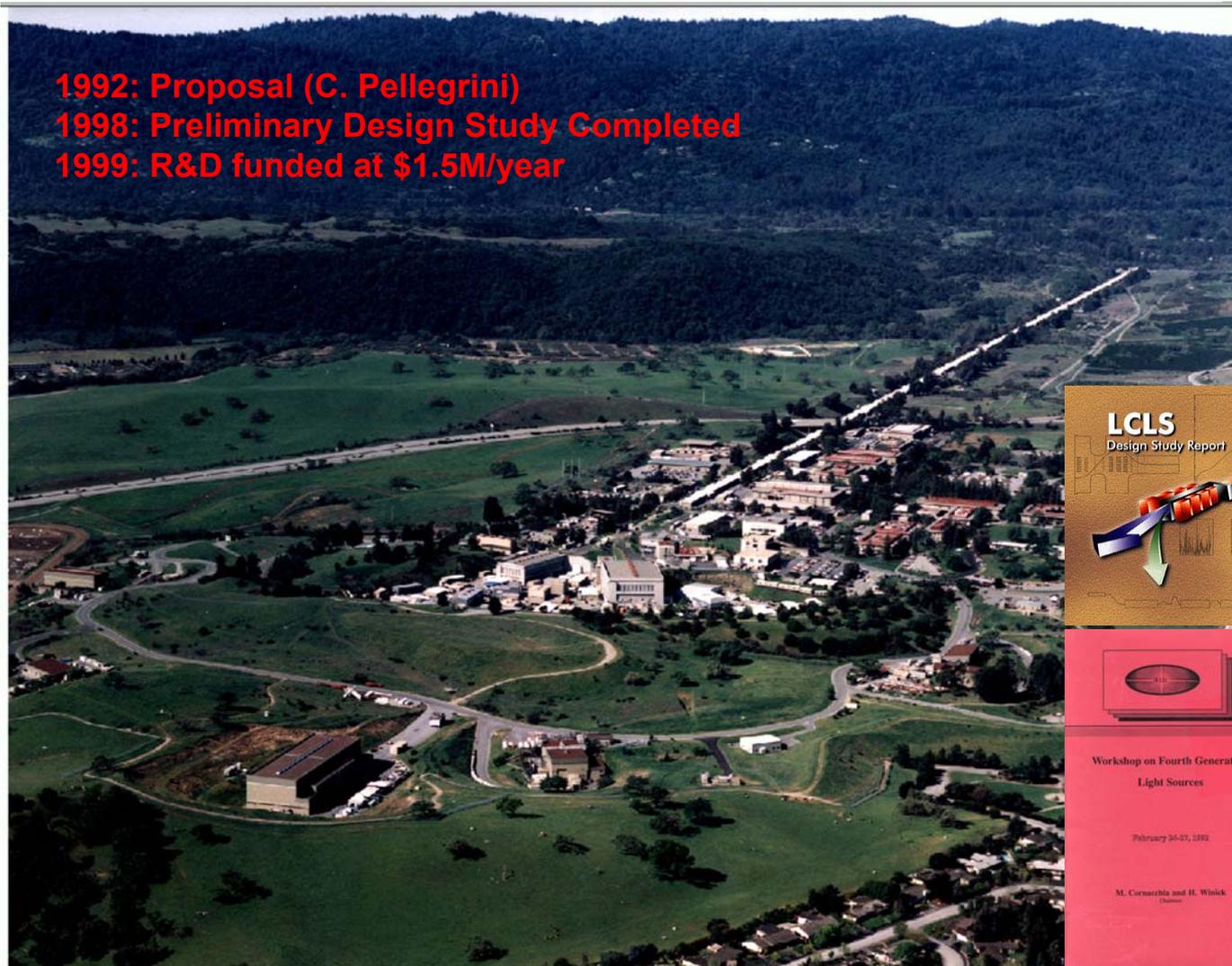
Ultra-Small



Ultra-Fast



Linac Coherent Light Source



Linac Coherent Light Source

2001: CD-0 Approval of Mission Need

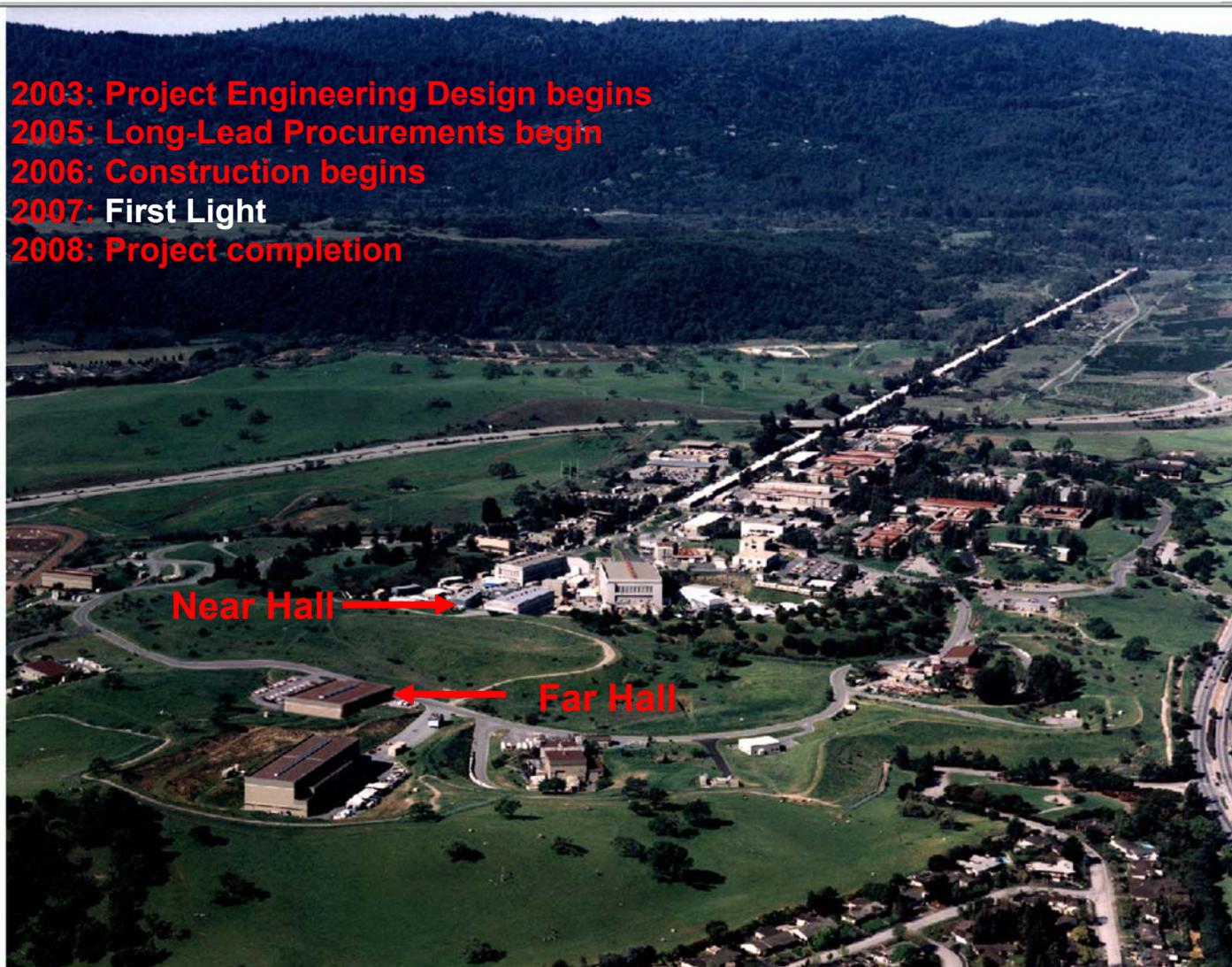
2002: Conceptual Design <http://www-ssrl.slac.stanford.edu/lcls/CDR/>

2002: CD-1 Approval of Baseline range, start of engineering design

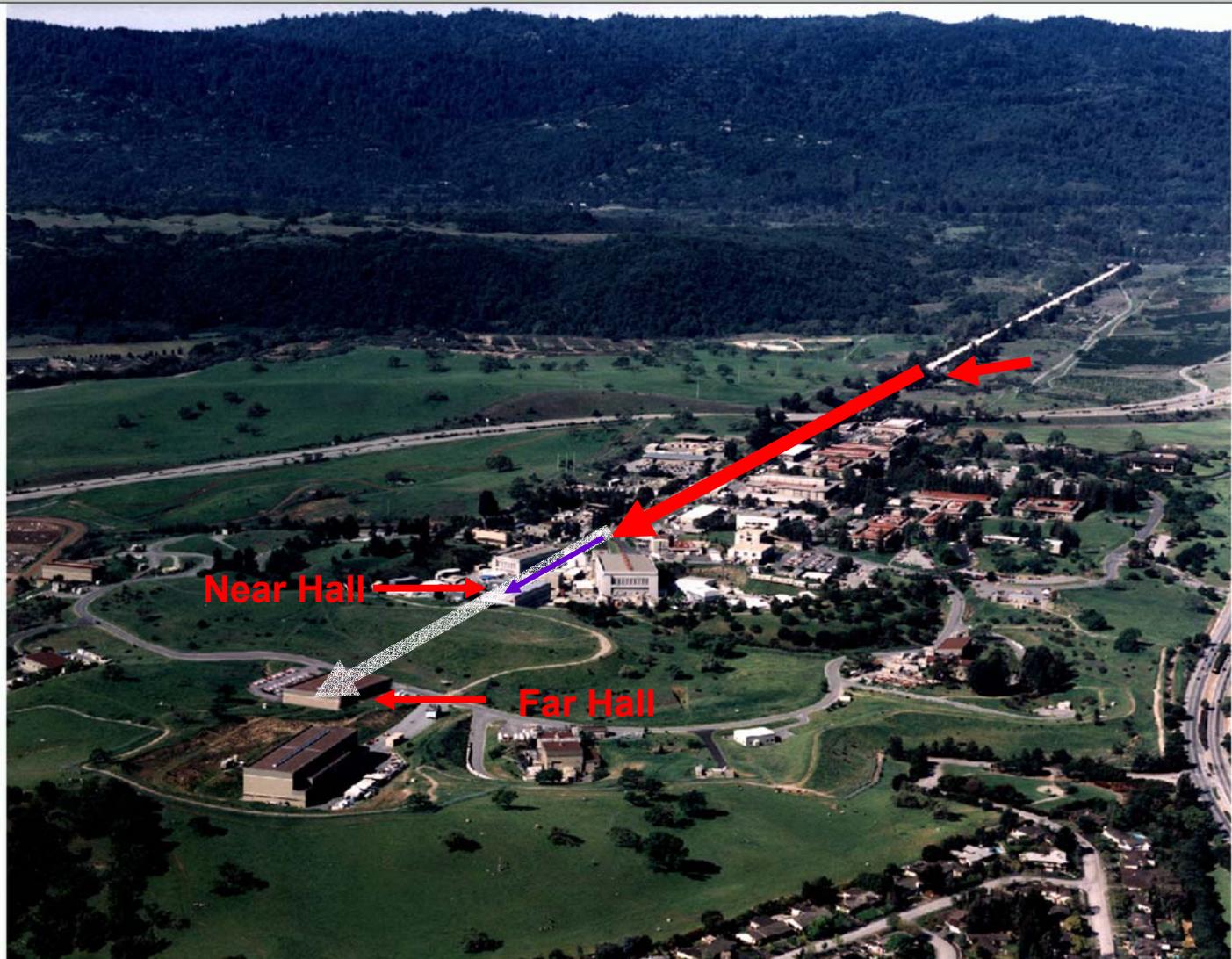


Linac Coherent Light Source

2003: Project Engineering Design begins
2005: Long-Lead Procurements begin
2006: Construction begins
2007: First Light
2008: Project completion



Linac Coherent Light Source – Project Description



Linac Coherent Light Source

Photon Beam Handling Systems

■ X-ray Transport, Optics and Diagnostics

- *Front end systems – attenuators, shutters, primary diagnostics*

- *Optics – the prerequisites for LCLS experiments*

■ X-ray endstation systems Hutches, Personnel Protection

- *Computer facilities for experiments*

- *Laser for pump/probe experiments*

- *Detectors matched to LCLS requirements*

*Essential Infrastructure for the LCLS
Experimental Program*

Capabilities

Spectral coverage: 0.15-1.5 nm

To 0.5 nm in 3rd harmonic

Peak brightness: 10^{33}

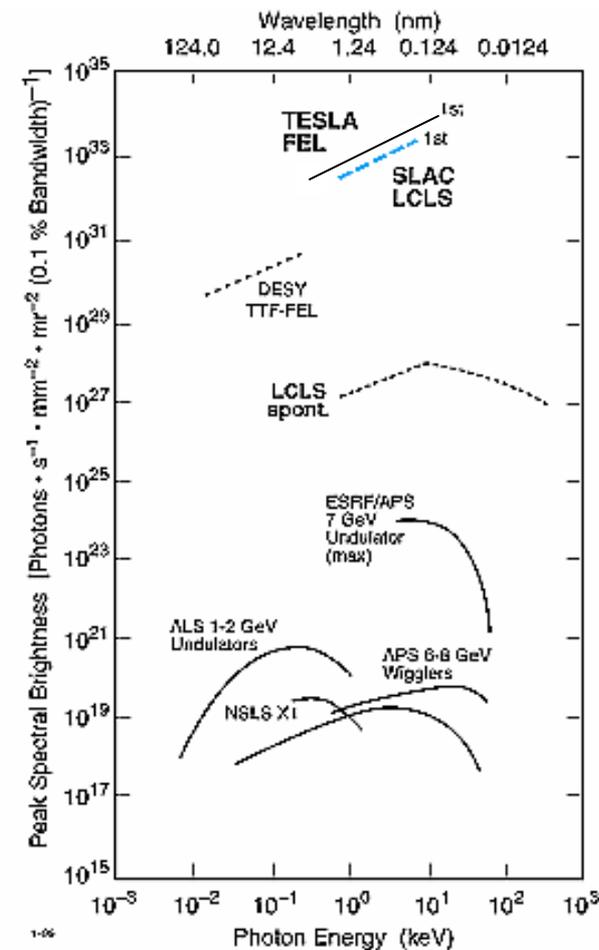
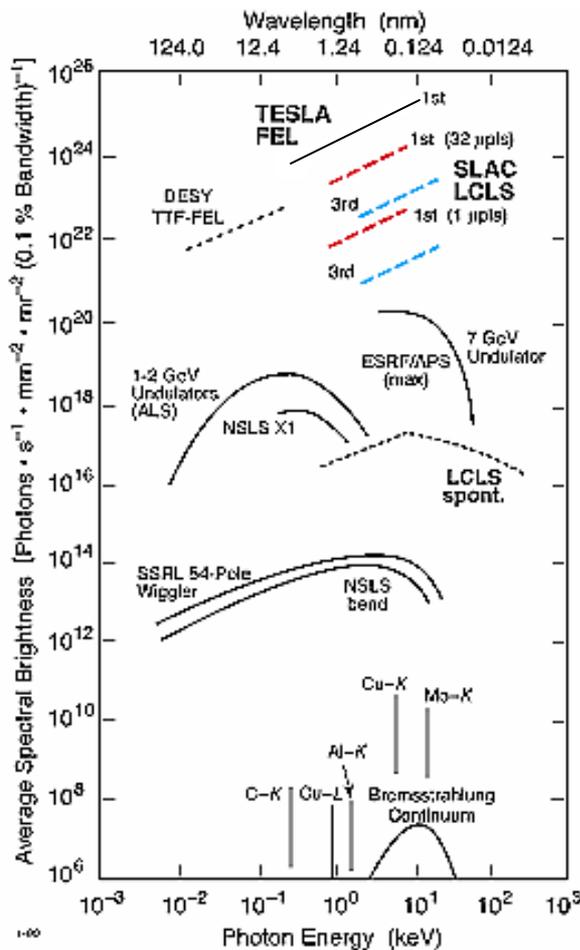
Photons/pulse: 10^{12}

Average brightness: 3×10^{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.*

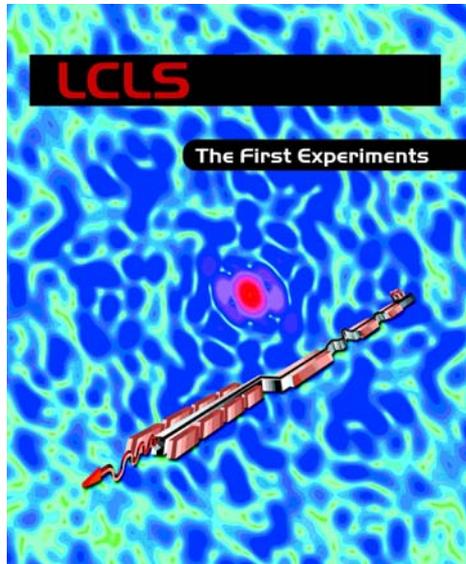
- **1999** Leone BESAC report
Novel, Coherent Light Sources

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...”



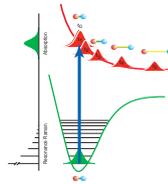
Presentation of the Scientific Case

- 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

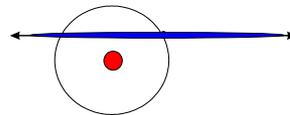
“the beginning.... not the end”



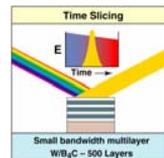
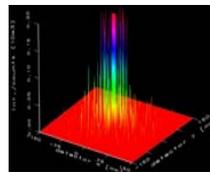
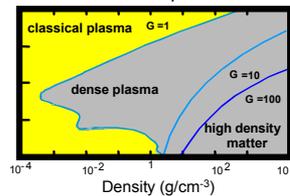
t=τ



t=0



Aluminum plasma



Femtochemistry

Nanoscale Dynamics in Condensed matter

Atomic Physics

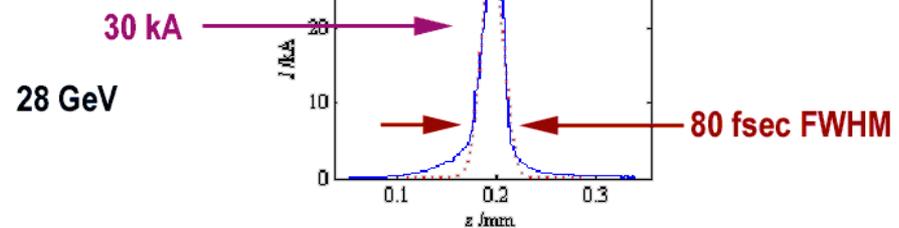
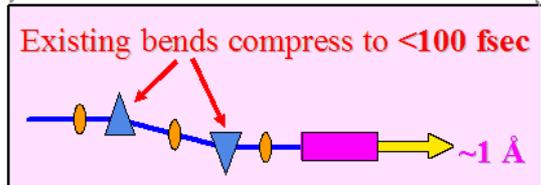
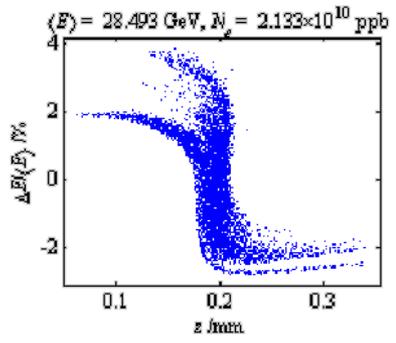
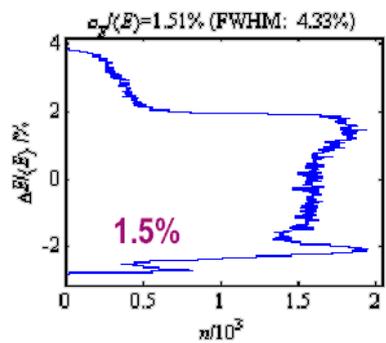
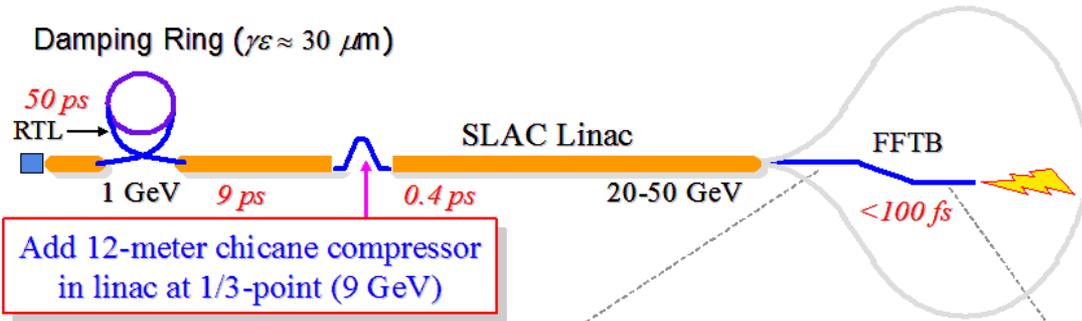
Plasma and Warm Dense Matter

Structural Studies on Single Particles and Biomolecules

FEL Science/Technology

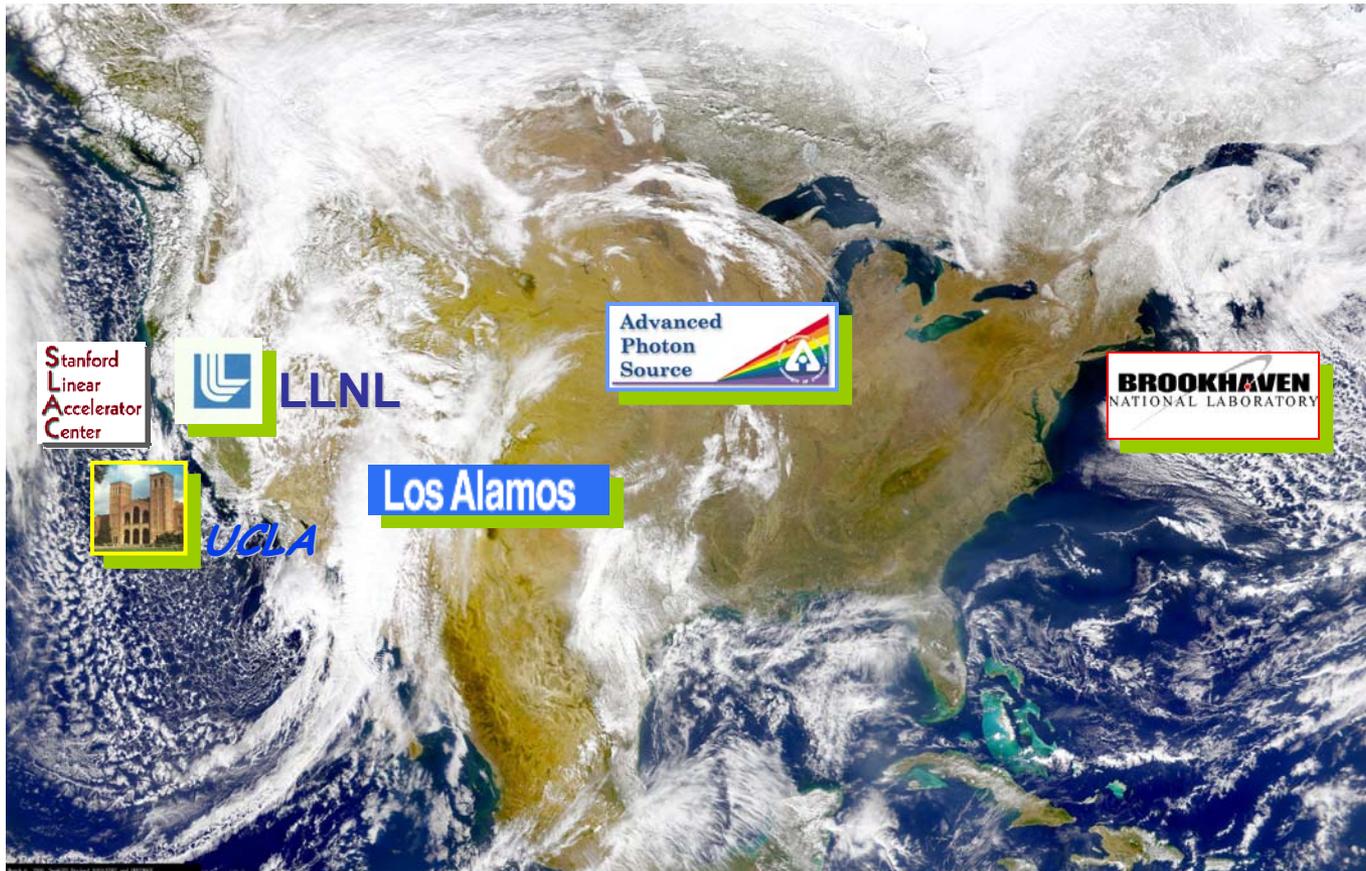


Sub-Picosecond Pulse Source: SPSS

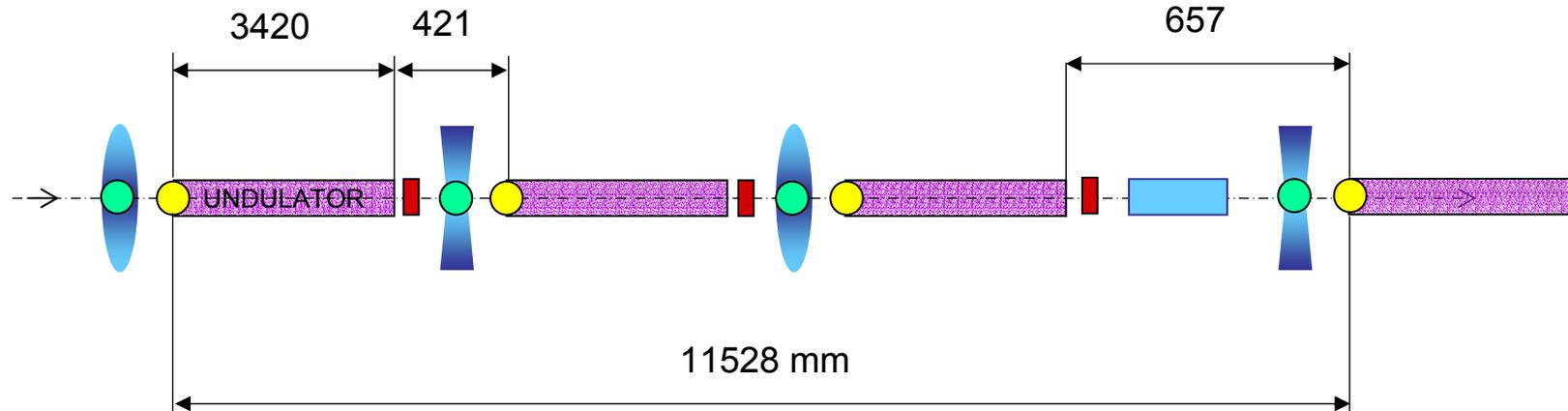


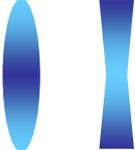
LCLS R&D Collaboration

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



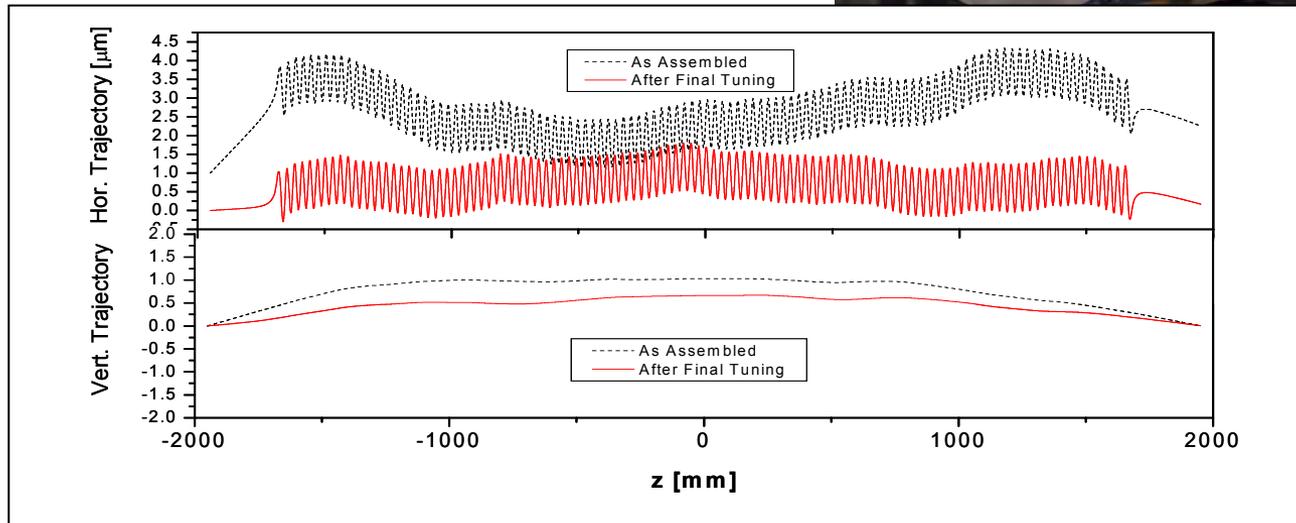
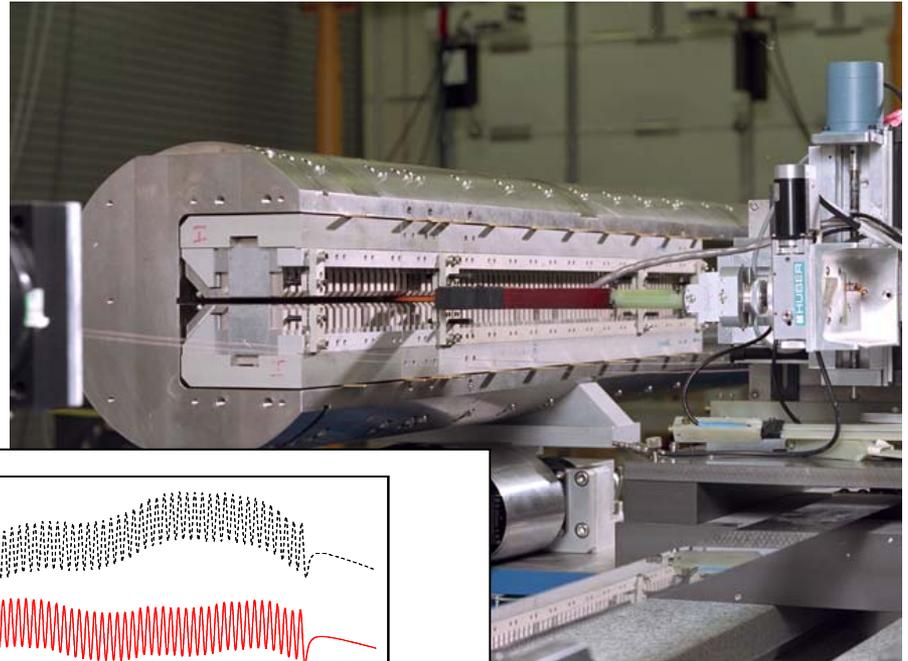
List of the Undulator Line Systems

- 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

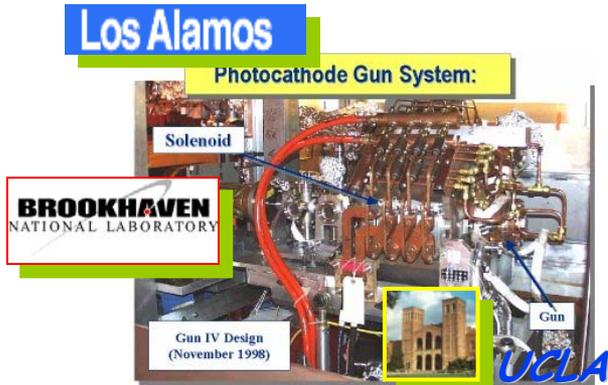


Full-Length Prototype

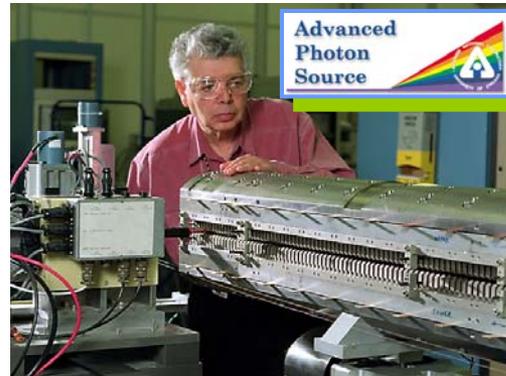
Performance measured to be within the design specification



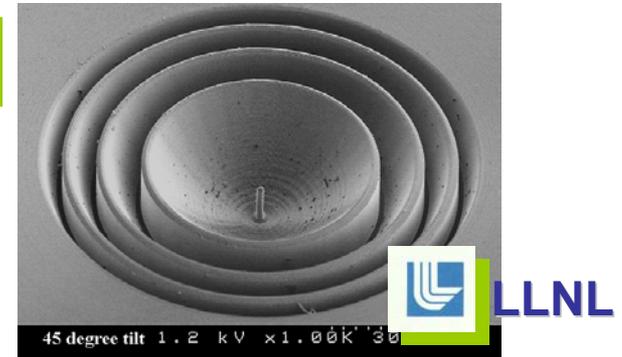
Firm Basis for Design and Cost Estimate



Gun design
R&D at SSRL gun test facility



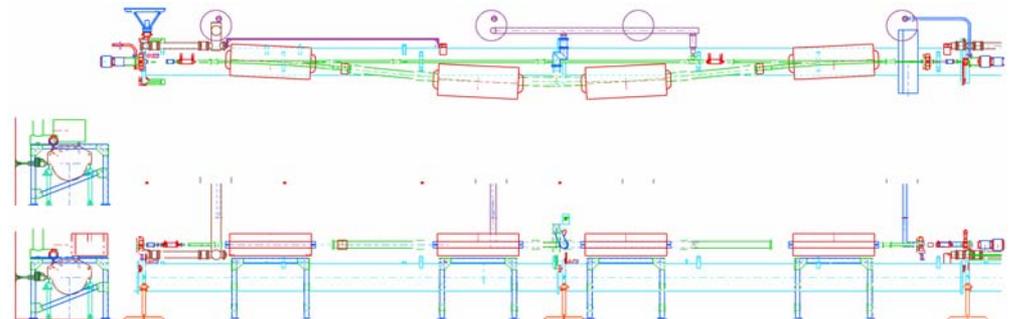
Undulator prototype
has met specifications



Optics fabrication techniques
Ongoing tests at SSRL



Cost-effective magnet fabrication techniques developed for NLC



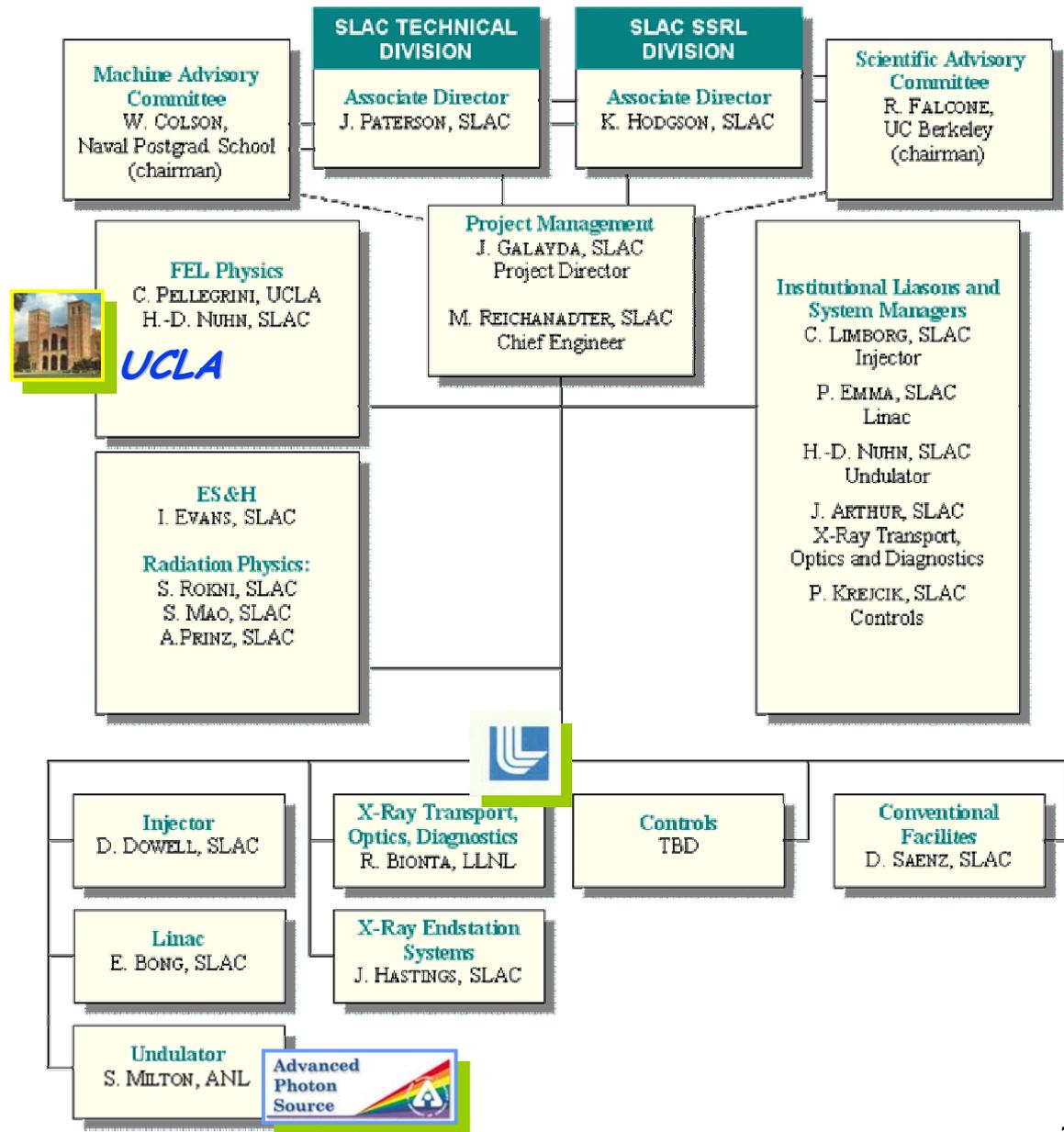
Chicane for advanced accelerator R&D with ultrashort electron bunches

Estimated Cost, Schedule

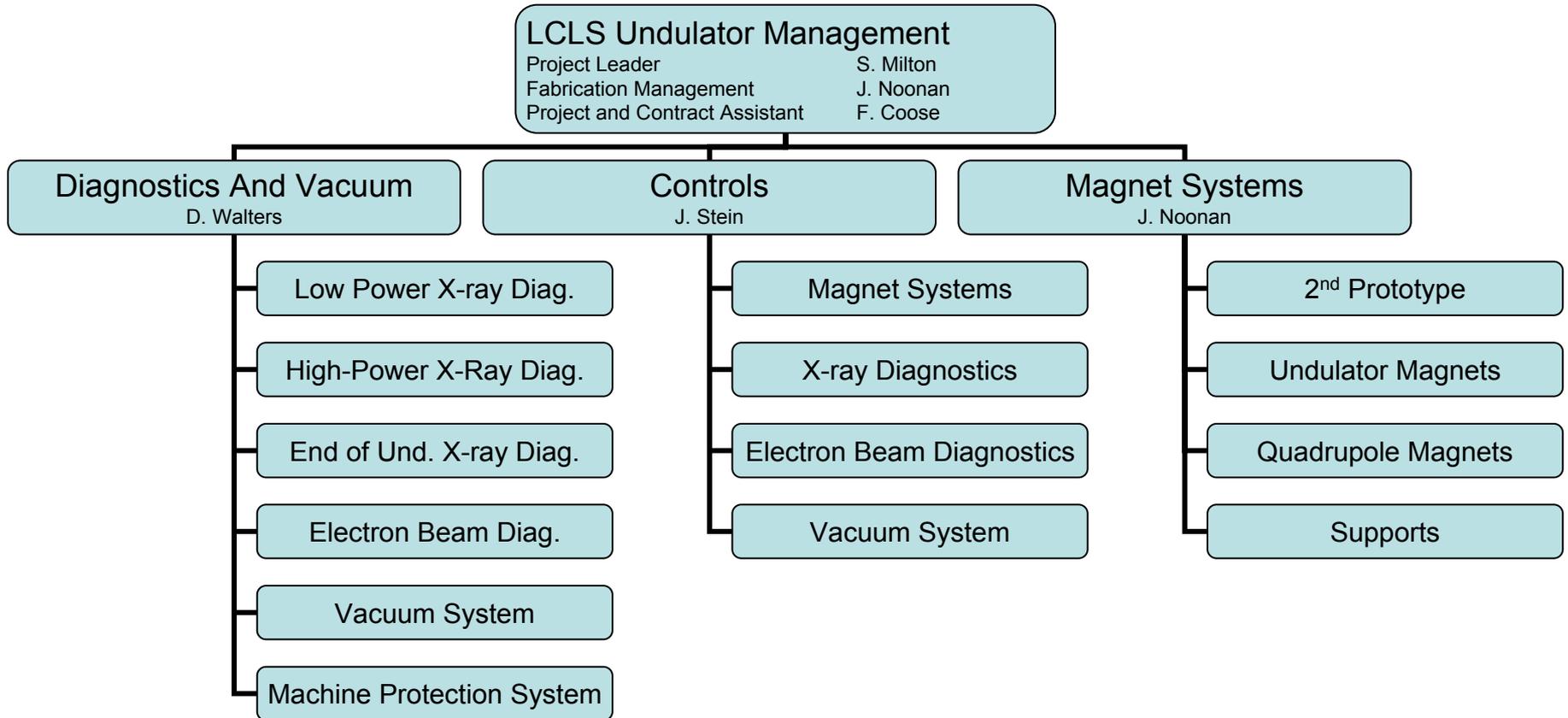
- \$200M-\$240M Total Estimated Cost range
- \$245M-\$295M Total Project Cost range
 - ANL \$50M-\$55M for the undulator system
- Schedule:
 - **FY2003** Authorization to begin engineering design
 - Emphasis on injector and undulator
 - **FY2005** Long-lead purchases for injector, undulator
 - **FY2006**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



LCLS Project Engineering Design (PED) Organization



PED Organization

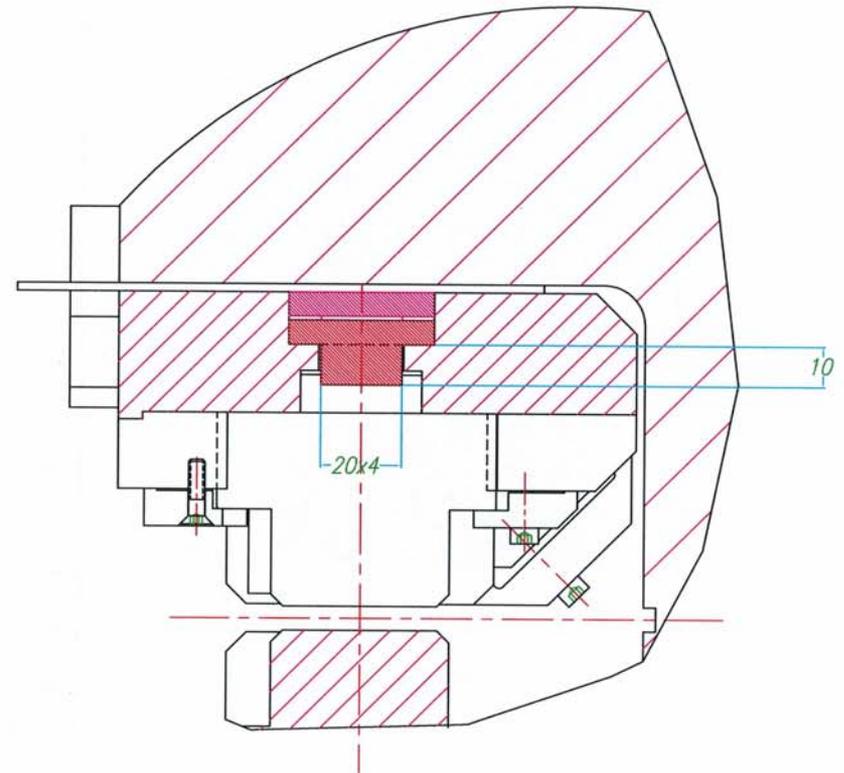
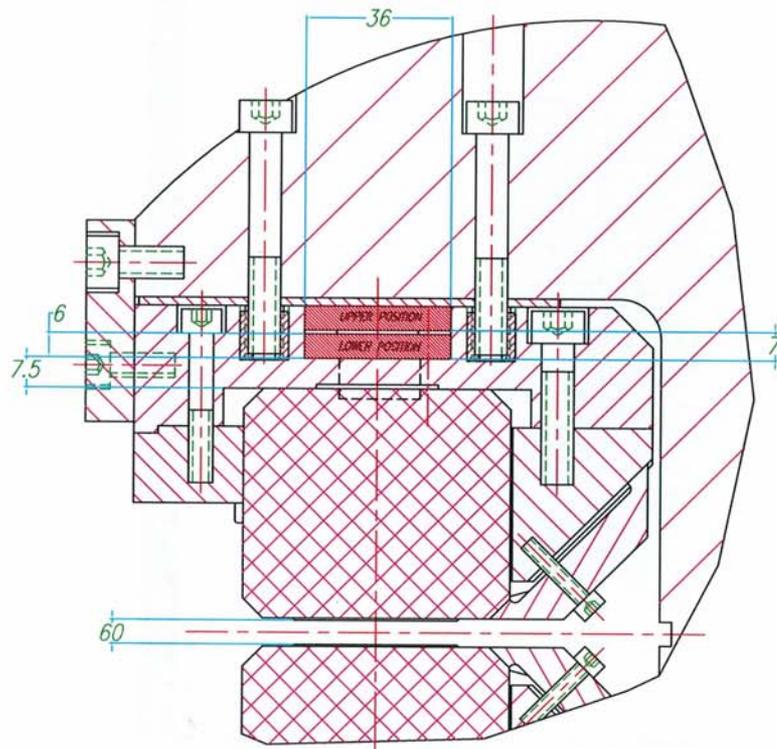


Undulator Design Issue

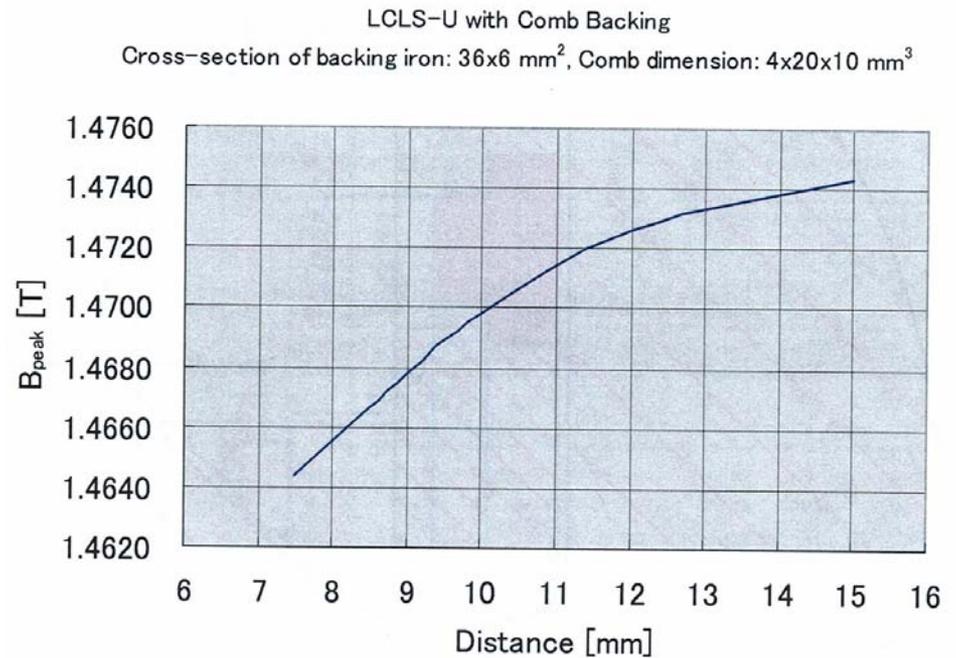
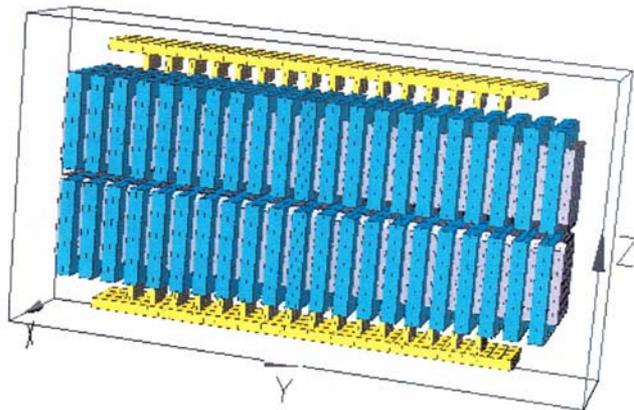
- Field variations
 - Must maintain $\Delta B/B < 1 \times 10^{-4}$
 - Implies gap changes of $< 1 \mu\text{m}$
 - And to maintain temperature to within 0.4 C°
 - Partial compensation
 - Accomplished by differential expansion of the titanium strong back and the aluminum magnet array comb
 - This helped, 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

	F03				F04				F05				F06				F07			
	Q1	Q2	Q3	Q4																
Critical Decisions																				
CD-2a Long-Lead Procurement Budget Approval			•																	
CD-2b Performance Baseline Approval							•													
CD-3a Long-Lead Procurement Approval and Authorize Long-Lead Procurement Funds								•												
CD-3b Start of Construction Approval and Authorize Construction Funds																•				
CD-4 Start of Operation Approval																				
Phases																				
PED Period	•																			
Construction Period									•											•
Key Milestones/Events																				
Begin Controls Specifications					•															
1st Vacuum Pipe Prototype						•														
Prepare Und. Bid and Procurement Packages							•	•												
Complete 2nd Undulator Prototype								•												
1st Diagnostics Prototype								•												
Begin Long Lead Purchases									•											
Complete 1st Production Diagnostics											•									
Complete 1st Production Undulator												•								
Assemble 1st Full Module															•					
Begin Purchase of All Other Components													•							
Assemble and Measure Undulators													•							•
Assemble Diagnostics														•						•
Install Undulator System															•					•

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

