NLC - The Next Linear Collider Project

Global Controls Software

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Control Software Overview

- Control Software Baseline Model (WBS1)
  - General Control System Requirements
  - Software Architecture
  - EPICS Overview
  - Controls Software Requirements
  - Enterprise-Wide Database
  - Software Cost Estimates
- CDR Project (WBS2)
  - Conceptual Design Effort
  - R&D Tasks, Schedule and Budget
- Summary of CD Phase Readiness

General Requirements for the Global Controls System

- Support an accelerator facility spread over a large geographic area.
- Acquire, process and distribute massive amount of data.
- Support pulsed multi-bunch accelerator operation.
- Provide a rich set of applications for commissioning and operation.
- Provide an extensive feedback facility.
- Seamlessly accommodate various data acquisition systems.

Controls System Baseline Model

- Distributed hardware & software control system
- Use of commercially available “open” communications Networks
- Support for industry standard I/O buses
- Server based processing located in a central facility
- A suite of SLC style user applications
- An extensive feedback facility
- Enterprise-wide consolidated database

Experimental Physics & Industrial Control System (EPICS)

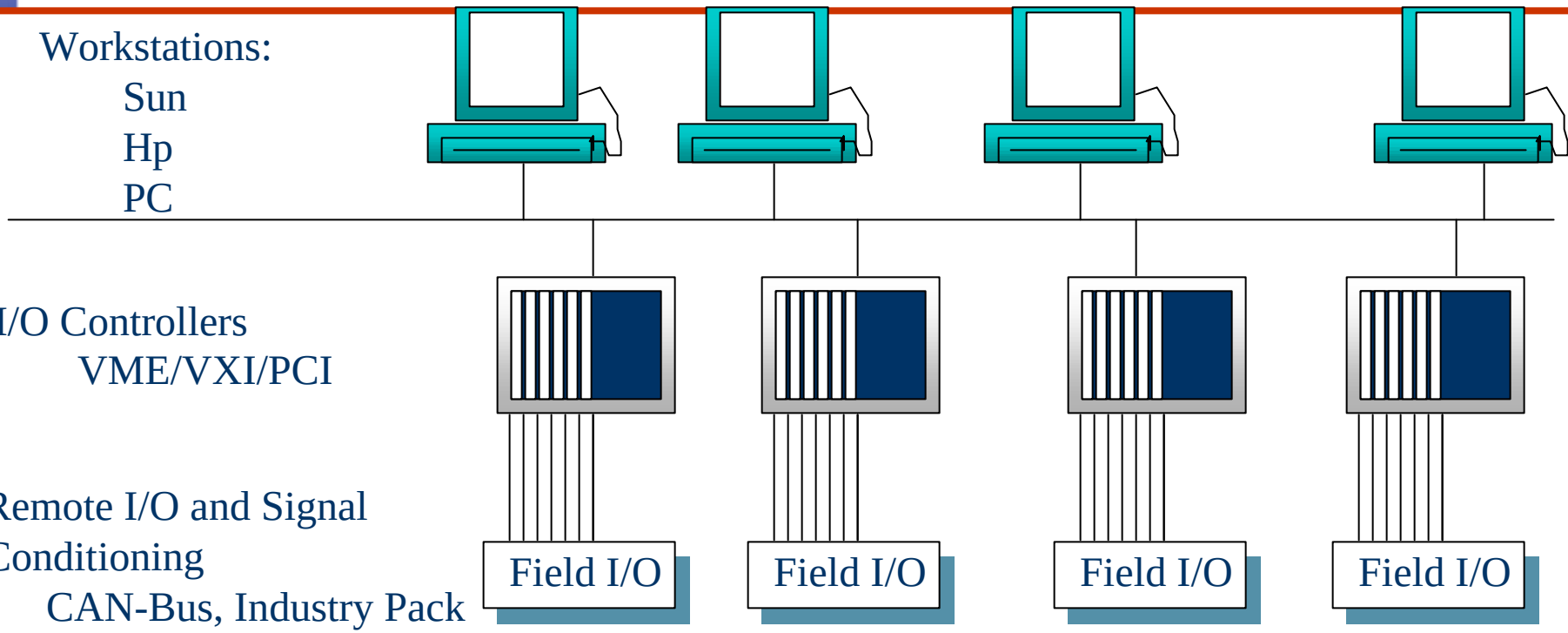
- A control system development facility in use by more than 100 projects in North America, Europe and Asia.
  - **The Advanced Photon Source and Beam-lines @ ANL**
  - **The Thomas Jefferson National Accelerator Facility**
  - **Proton Storage Ring @ LANSCE**
  - **Injection Linac for KEKB Factory @ KEK**
  - **Advanced Free Electron Laser @ LANL**
  - **Duke Free Electron Laser and Mark III Laser @ Duke University**
  - **Heavy Ion Fusion Test Stand @ LBL**
  - **Intense Pulsed Neutron Source @ ANL**
  - **HERA Cryogenic Plant and Tesla Test Facility @ DESY**
  - **RF Control for the B-Factory @ SLAC**
  - **Bates Linear Accelerator @ Bates MIT**
  - **Racetrack Microtron @ University of Athens**
  - **BESSY II @ BESSY**

Distributed Hardware Configuration

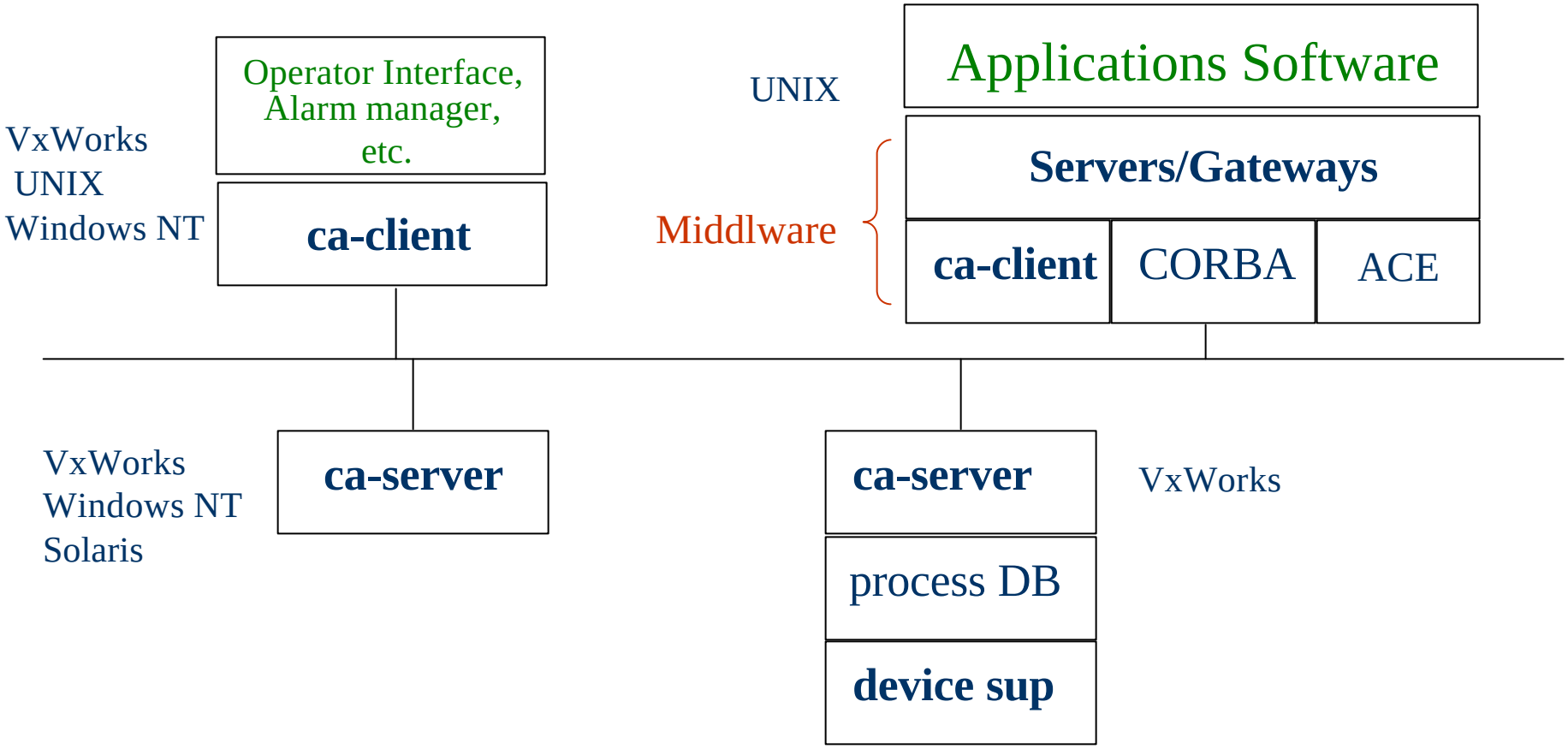
Workstations:
- Sun
- Hp
- PC

I/O Controllers
- VME/VXI/PCI

Remote I/O and Signal Conditioning
- CAN-Bus, Industry Pack
- VME, VXI, PCI, ISA
- CAMAC, GPIB
- Profibus, Bitbus, Serial, Allen-Bradley, Modbus, IEEE 1394 (Firewire)



Distributed Software Architecture



EPICS Overview

- A Strong Collaboration to Share Development Effort
- EPICS provides the Following Components:
  - Network Protocol (Channel Access) for a distributed client/server control system
  - Distributed run-time database with tools for database generation and maintenance providing data acquisition, control & monitoring
  - A suite of utilities such as display generation, configuration control, alarms, archiving, etc.
  - Fast real time processing Interfaces for large applications
  - IOC - input output controller
  - Operator Interface and Display Management

Controls Software Requirements

- Low-Level Applications
  - **Timing control, pattern broadcast, 120 Hz operation**
  - **Data acquisition, e.g. BPMs, laser-wires**
  - **Device control and monitoring, e.g. Magnets**
  - **Low-level RF control**
- High-Level Applications
  - **Accelerator modeling**
  - **Beam steering**
  - **Beam properties correction and optimization**
  - **Beam-based alignment and other diagnostics**
  - **IP collision optimization**

Controls Software Requirements Continued

- Feedback Systems
  - **Beam-based feedback for linacs and transfer lines**
  - **Damping rings local and global orbit feedback (APS)**
  - **Slow feedback for large time-scale correction and watchdog functions**
- User-Level Tools and Utilities
  - **Configuration control (save and restore)**
  - **Data archiving**
  - **Data acquisition and correlation analysis**
  - **Status and alarm management**
  - **Multi-device knobs**

Controls Software Requirements Continued

- Protection Facilities
  - **Machine protection system**
  - **Personnel protection system interface**
  - **Beam containment system**
- Detector Interface
  - **Pulse related data**
  - **Slow data**
- Automation
  - **Beam Startup sequencing**
  - **Diagnostics**

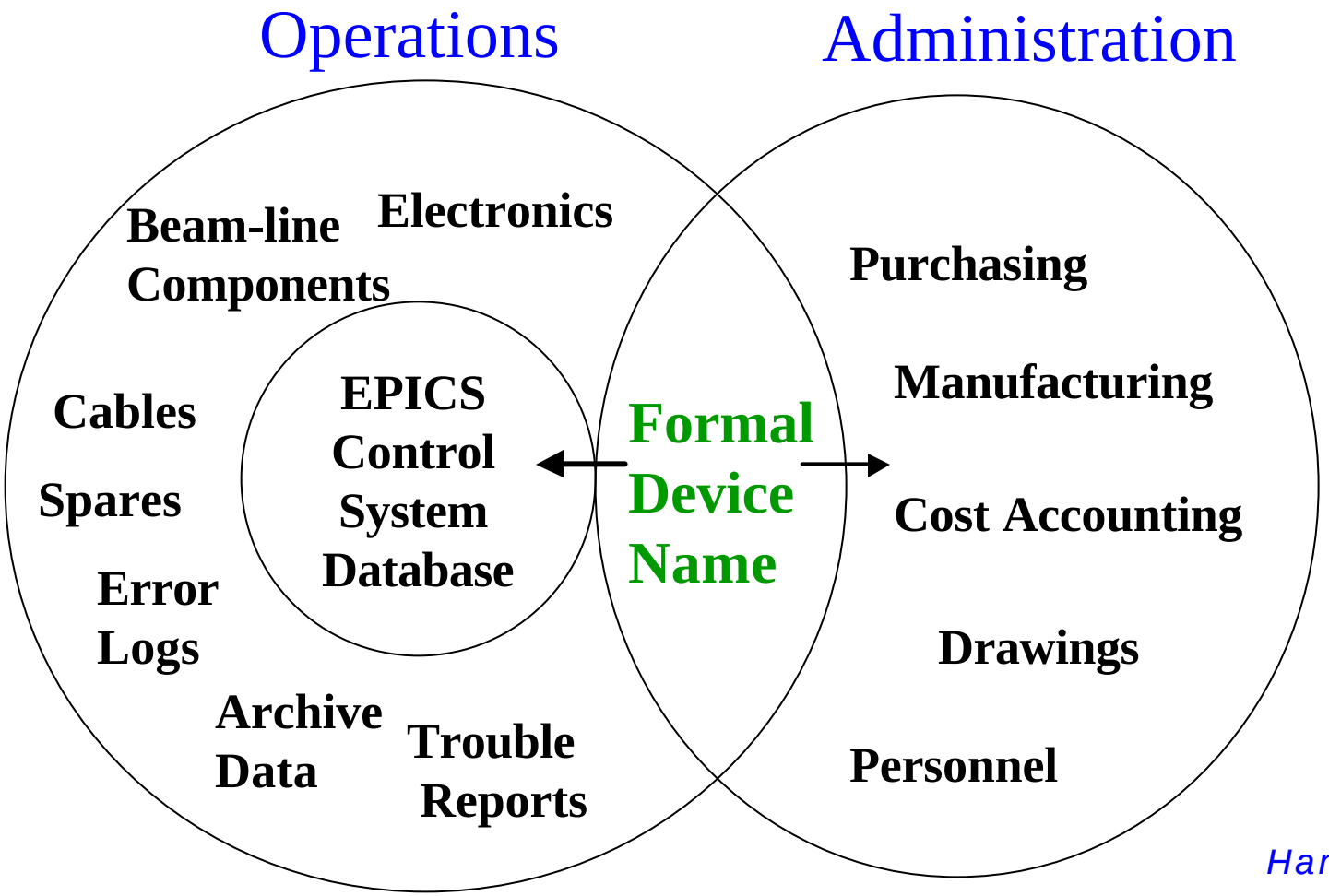
EPICS Enhancements

- 120 Hz pulsed operation
  - Data acquisition, processing and distribution
- Real time data sharing between CPUs over Kilometer distances
- High level applications
- Tools and utilities upgrade
- Midleware servers
  - Name servers (broadcast issues)
  - Data concentrator (scaling issues)
  - Coordinators and controllers
  - Application servers
  - Software bus

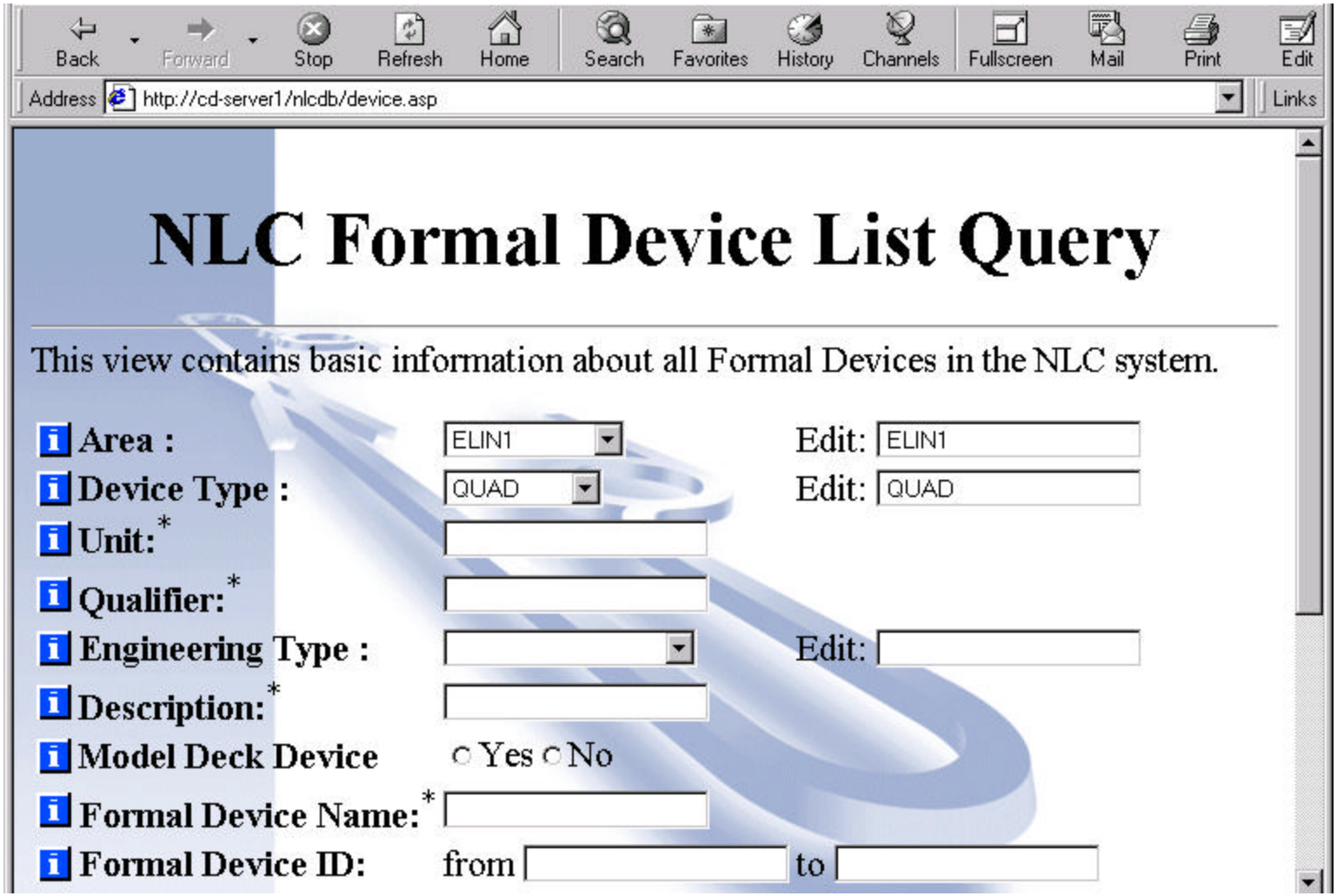
Controls Software Infrastructure

- Global Controls Architecture & Systems Software
  - Network and communication protocols
  - High-level software architecture
  - Real-time infrastructure
  - Software development environment
- Enterprise-Wide Database
  - A central repository for accelerator information
  - Easy Web-based access and update
  - To be used throughout project life cycle: R&D, design, construction & manufacturing and operations

Enterprise-Wide Database Many Types of Information are Connected via a Formal Device Name



NLC Database Browser



Software WBS Example

WBS									Person-Year
13	GLOBAL CONTROL SYSTEM								
136	GLOBAL CONTROL SYSTEM SOFTWARE								
1361	Control Software								474
13611	Systems Architecture							30	
						Overall System Design	6		
						High Level Networks and Communication	5		
						Low Level Networks	5		
						Computer & Networks Security	2		
						High-Level Software Architecture (Device Abstraction)	6		
						Digital Audio and Video Infrastructure	2		
						Supervision	4		

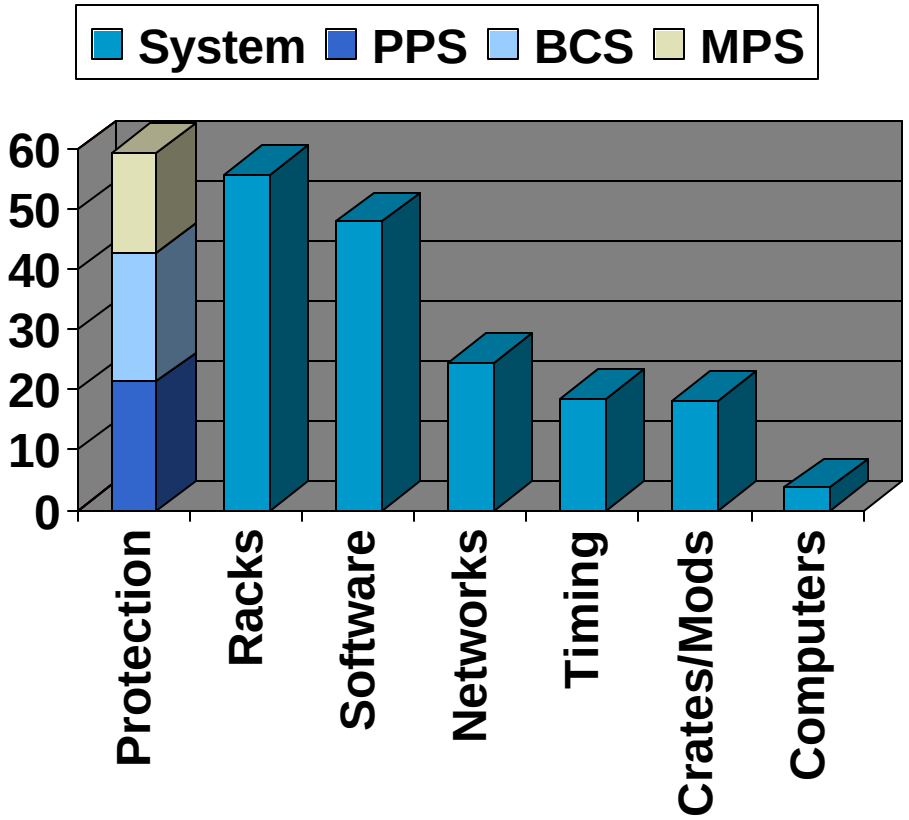
Software WBS Cost Roll Up

1	PROJECT	Person-Year
13	GLOBAL CONTROL SYSTEM	
136	GLOBAL CONTROL SYSTEM SOFTWARE	
1361	Control Software	474
13611	Systems Architecture	30
13612	Software Infrastructure	104
13613	Low-Level Applications	137
13614	Tools and Utilities	25
13615	High-Level Applications	23
13616	Feedback Systems	24
13617	Protection Systems	48
13618	Systems Integration	20
13619	Automation	4
1361A	Detector Interface	3
1361B	Supervision	56

Global Control Hardware Cost Roll Up Example

WBS	Item	Count	Unit Cost ($K)	M&S ($K)	ED&I ($K)	Labor ($K)	TOTAL ($K)
131	GLOBAL CONTROL SYSTEM COMPUTERS						
1311	Software Development Computing and Networks			$300	$50	$100	$450
1312	Distributed Consoles			$165	$100	$100	$365
1313	Maintenance Consoles			$156	$100	$100	$356
1314	Displays			$160	$100	$100	$360
1315	Servers			$1,200	$200	$100	$1,500
1316	Instrumentation & User Interface			$220	$100	$140	$460
1317	Licensing			$275			$275
134	GLOBAL CONTROL CRATES & MODULES						
1341	IOCs, Crates & Modules			$14,760	$2,950	$500	$18,210
136	GLOBAL CONTROL SYSTEM SOFTWARE						
1361	Control Software	0			$47,400		$47,400
1362	Software Test Facility			$412	$118	$100	$630
1363	Engineering Test Stands				$750		$750
1364	Mobile Control Room			$95	$300	$50	$445
1365	Mobile Diagnostic Facilities (2)			$50	$100	$30	$180
137	CONTROL ROOMS						
1371	Networking Infrastructure			$222	$210	$85	$517
1372	Consoles			$300	$100	$70	$470
1373	Utilities and Services			$180	$30	$50	$260
1374	Design and Layout			$200	$100	$100	$400

WBS1 Summary
Global Systems (230 $M)



Summary and Status of Baseline Model

- Identified global requirements for the control software.
- Developed conceptual design based on EPICS.
- Developed WBS and loaded in planning tools.
- Documented detailed component list & cost catalog.

The first iteration of baseline model (WBS1) is done.

CDR Project (WBS2)
Conceptual Design Goals

- Collect detailed software functional requirements.
- Specify and refine specifications for the global system.
- Perform risk analysis.
- Develop software subsystem architecture.
- Perform reliability analysis.
- Optimize design for performance, cost, and reliability.
- Document CDR
- Develop EPICS extensions specifications
- Define application program Interface (API)
- Develop enterprise-wide database

CDR Project (WBS2) R&D Objectives

- Reduce/eliminate risks
  - Technical risks
    - Architecture uses new and untested technology
    - Extending EPICS to larger scales and higher speeds
  - Schedule risks
    - Inadequate or uncertain requirements
    - Software estimate uncertainty
    - With 470 person-years of software, there is a substantial ramp up problem and delay risk
- Support the overall NLC R&D effort

CDR Project (WBS2) R&D Tasks

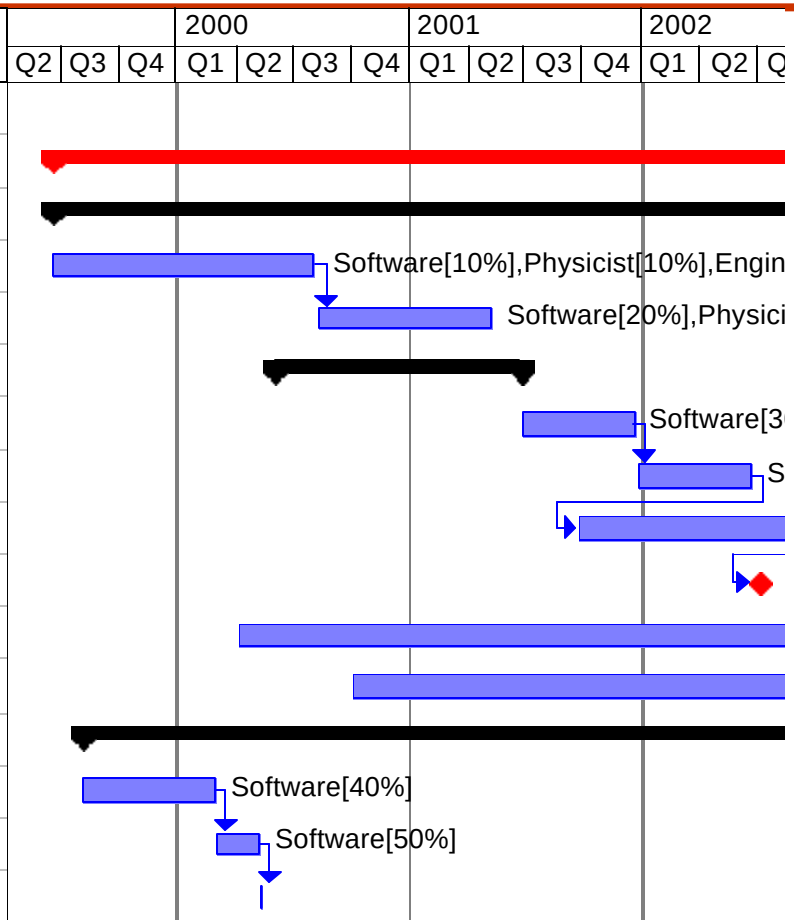
- Prototype & evaluate commercial networks
- Verify 120 Hz pulsed operation
- SBIR project to develop a ruggedized, triggered remote I/O device connected to a reliable long line communication system.
- Evaluate fieldbus commercial options
- Develop database in support of NLC R&D
- Identify required EPICS enhancements
- Investigate/reduce schedule risks

Database and EPICS R&D Tasks

- Database - support NLC R&D effort by developing needed database components
  - Beam-line device and area lists, cabling database, documents and drawings
  - Easy access including use of spreadsheets
- EPICS enhancements
  - Identify requirements and options for non-IOC application development environment including middleware interfaces
  - Evaluate emerging technologies: CORBA, Java, etc.

R&D Schedule Example

ID	Task Name	Total Cost
11	**CD-2**	$0
12	Global Control Architecture	$1,376,604
13	Controls Architecture Conceptual Design	$471,280
14	**Functional Requirements & Project Desc**	$39,360
15	**System Technical Specifications**	$35,040
16	**Conceptual Design**	$70,840
21	**Perform Risk Analysis**	$28,600
22	**Optimize Design for Performance/Cost/R**	$40,040
23	**Documentation & CDR Prep**	$26,400
24	**CDR Complete**	$0
25	**Develop EPICS extensions specification**	$99,000
26	**Develop Enterprise-Wide Database**	$132,000
27	Prototype & Evaluate Commercial Network & Sof	$323,440
28	**Specify Project Goals, Collect Product D**	$26,400
29	**Specify Required Software, Network Dev**	$11,000
30	**Buy VxWorks license**	$20,000



Global Controls & Software CDR Project Budget

- A budget plan for the controls architecture and software CD/R&D program has been developed and integrated into the MS project for
  - Conceptual design
  - R&D
  - Labor and M&S categories
- Budget has been profiled by FY quarters (99-02) and is presented in the following excel sheet.

CD Phase Budget
Controls Architecture
$1.5M, 13.8 FTE

	FY99		FY00				FY01				FY02			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Global Systems Engineering & Design														
Controls Architecture Conceptual Design	0.70	0.70	0.70	0.70	0.70	0.70	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5
Controls Architecture R&D	1.20	1.20	1.20	1.20	1.20	1.20	2.2	2.2	2.2	2.2	3.2	3.2	3.2	3.2
FTE/M&S	1.90	25	1.90	25			4.0	100			6.0	100		

The Need for Collaboration Development

- The project could benefit from increased staffing to further minimize schedule risks by
  1. Investigate schedule risk issues.
  2. Explore phased implementation plans for control software.
  3. Refine architecture details to expedite development startup.
  4. Document control system "Principles of Operation" and produce "Application Developer's Guide".
- We need to develop collaborative relationship with other national and international laboratories similar to developing ties to industry and vendors.

Collaboration Development

- Define areas of collaboration
  - System architecture design
  - Networks planning
  - EPICS enhancements
  - Safety: PPS, etc.
- Develop infrastructure for distributed controls effort
  - Detailed requirements and technical specifications
  - Interface definitions
  - Remote project management & communication tools

Summary
CD Phase Readiness

1. *Are Technical Status, Planning and Management Tools ready?*

   Baseline models are defined, R&D plans and management tools are in place to proceed with the conceptual design.

2. *Are R&D Phase cost, schedule and resources adequate?*

   R&D plans are adequately defined through resource loaded schedules. R&D Effort Could Benefit from Additional Resources from Collaborators.

Summary
CD Phase Readiness -2

3. *Is the Management Structure adequate?*

   Management model is based on PEPII model of software management in concert with the successful EPICS collaboration.

4. *Is the NLC CD-1 description complete? Are preliminary (WBS1) costs and schedules adequate starting points?*

   The description is complete with cost models and tasks defined in detail. Preliminary schedule indicates an aggressive timeline for controls software development.

Summary and Conclusion

- Developed conceptual design for global controls architecture and software
- Developed detailed component list & cost catalog
- Identified areas requiring R&D
- Planned R&D project including task & resource lists
- Continuing database work to support NLC R&D

We are Ready to Proceed with the CDR Phase of the Control System