EPICS in SLAC Controls

Ron Chestnut, SLAC

Beijing, 2001

PEP-II Controls

- **SLC for most things**
  Magnets, Digital, Analog

- **EPICS for some things**

  Bunch Injection Control
  NLC Test Accelerator
  Longitudinal Feedback
  RF Control
  BABAR (detector) interface
  Damping Ring RF
  “Alien” PC Communication

Non PEP-II Controls

- **NLC Test Accelerator**

- **Spear 3**
- **LCLS (Free Electron Laser)**

Legacy SLC Controls

- **Dates from 1982**
- **VMS/iRMX based**
- **Central Alpha + ~100 Intel “Micros”**
- **SLCNET (home-built non-Ethernet)**
- **Fortran/”C”/Assembler**
- **Old, stable, and difficult to change**

Moving to EPICS

- **Started in 1995 with RF systems in PEP2**
- **Slowly gained acceptance for six years**
- **Now required for all new projects – NLC Test Accelerator success was big breakthrough**
- **Working hypothesis for basis of Next Linear Collider control system**

EPICS Support at SLAC

- **Three people in the software group**
- **One recently hired employee just now assigned to EPICS**
- **Some help with Archiver, CMLOG, SNL support, and Unix infrastructure**
- **Also BaBar and Spear III (but separate)**

Bunch Injection Controller

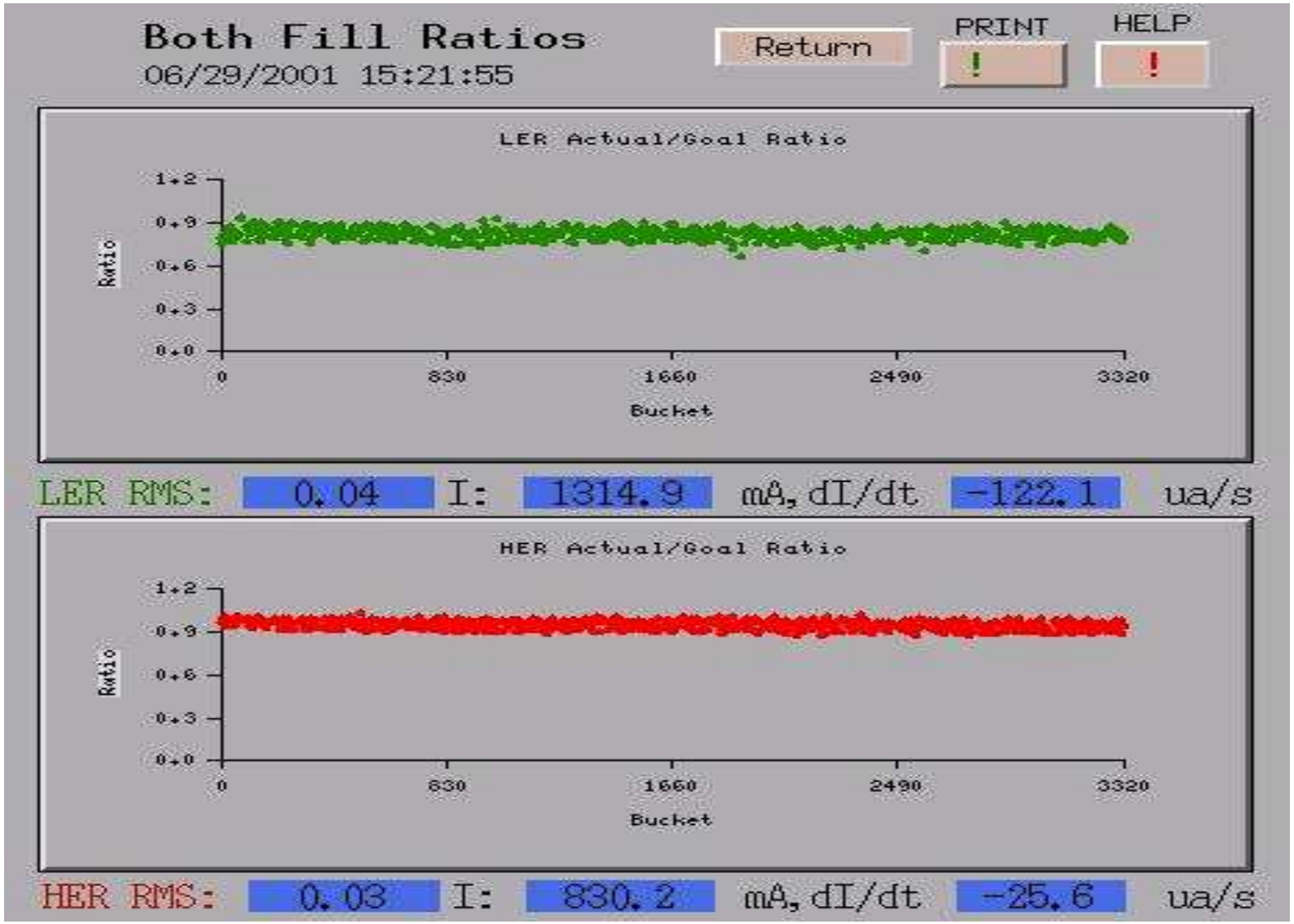
http://www.slac.stanford.edu/grp/cd/soft/pepii/bic/index.html

- **Reads out 3492 bunch currents at 60Hz**
- **Calculates bucket injection sequence**
- **Calibrates bucket injection quanta**
- **Data input through shared memory**
- **Extensive use of waveforms**
- **Extensive use of sequences**
- **Few Hundred Process Variables**

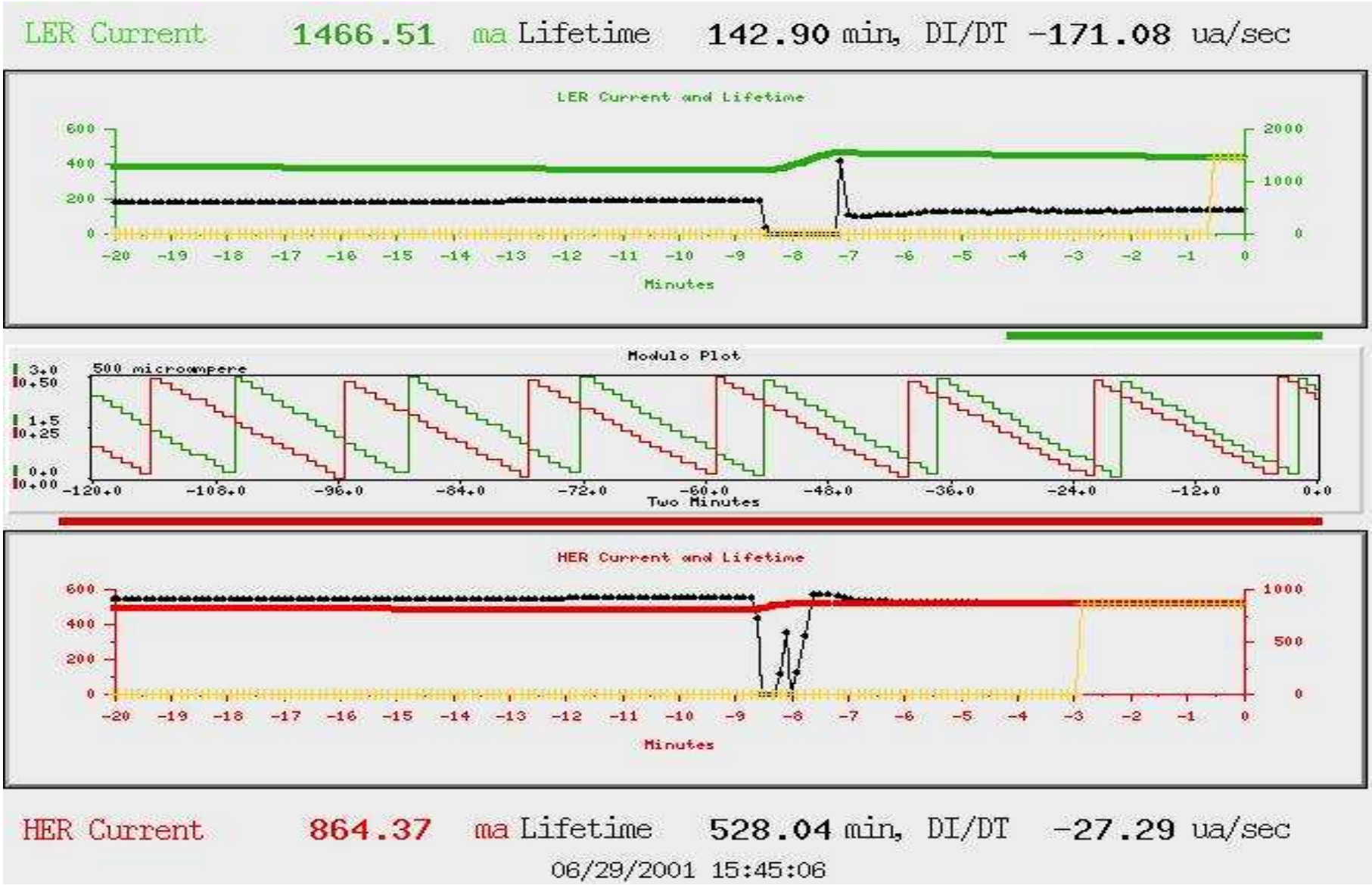
BIC Requirements and Features

- **Make injection requests once a second for 60 Hz injection of two rings**
- **BIT-3 shared memory input from Bunch Current Monitor Hardware**
- **BIT-3 shared memory I/O to Master Pattern Generator**
- **Heavily parameterized for customization**
- **Supports arbitrary fill patterns**

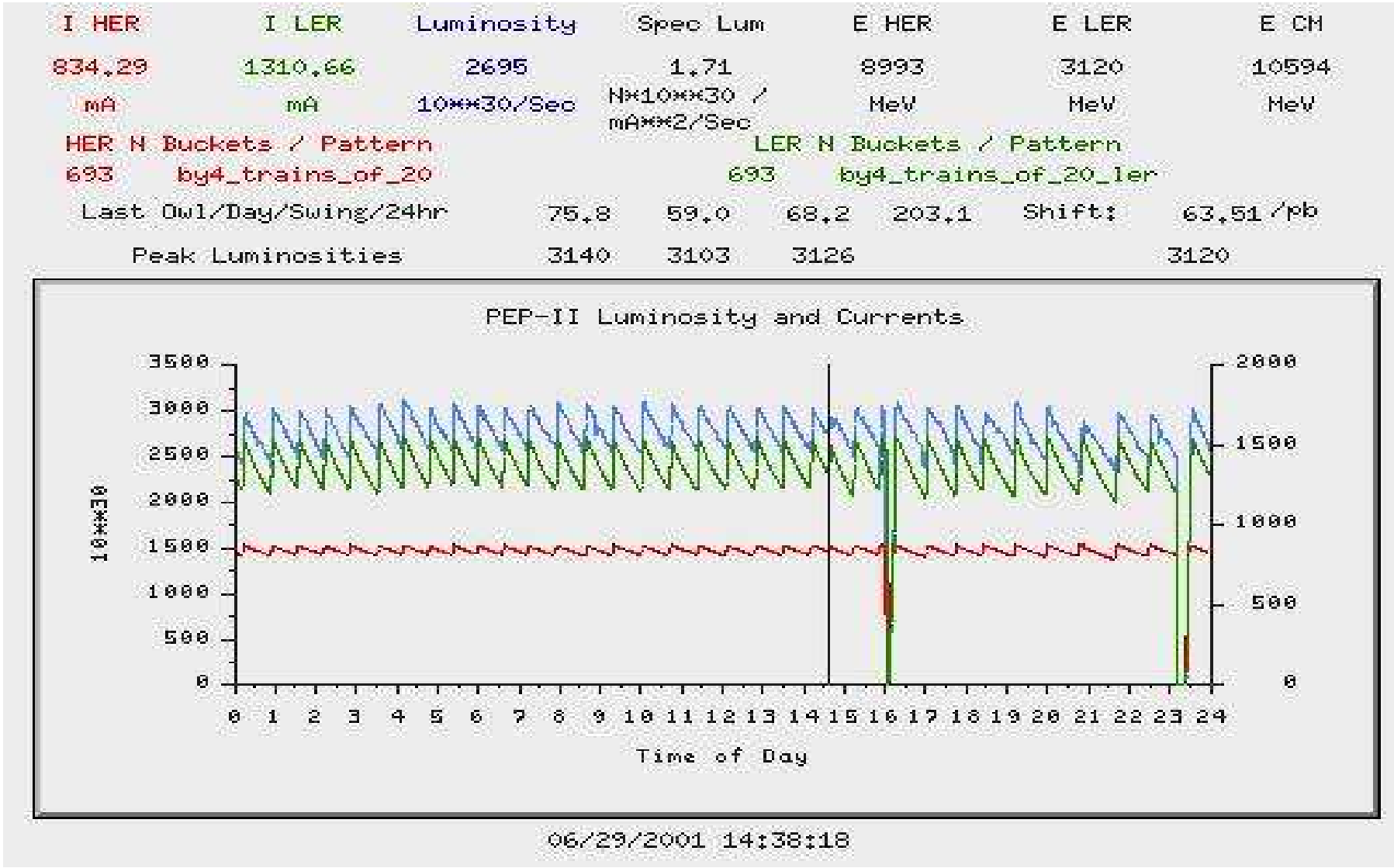
PEP-II Fills


Both Fill Ratios
06/29/2001 15:21:55
Return
PRINT
!
HELP
!
LER Actual/Goal Ratio
Ratio
1.2
0.9
0.6
0.3
0.0
0
830
1660
2490
3320
Bucket
LER RMS: 0.04 I: 1314.9 mA, dI/dt -122.1 ua/s
HER Actual/Goal Ratio
Ratio
1.2
0.9
0.6
0.3
0.0
0
830
1660
2490
3320
Bucket
HER RMS: 0.03 I: 830.2 mA, dI/dt -25.6 ua/s

PEP-II Currents



PEP-II Luminosity



NLC Test Accelerator

http://www.slac.stanford.edu/grp/cd/soft/nlcdev/tarf/index.html

- **Moving from Labview & VeeTest**
- **Runs unattended**
- **High visibility project**
- **Allen Bradley for slow control**

NLCTA Requirements

- **Collect data at 120 Hz from 24 ADC channels and 12 TDC channels**
- **Decide on Go/No go for next RF pulse**
- **Provide average, min, max at 1 Hz for archiving**
- **Provide consistent snapshots on demand or of “bad” events**

NLCTA Implementation

- **CAENV265 charge integrating ADCs**
- **Lecroy 1176 TDCs**
- **VMIC-4100 DAC**
- **VMIC-2534 Digital I/O**
- **Record for ADC processing**
- **Complex subroutine record for GO/NOGO**
- **Allen Bradley and VSAM (SLAC) for slow signals**
- **MATLAB offline processing**

Longitudinal Feedback

- **Two 5-IOC setups (VXI)**
- **A “farm” of DSP chips**
- **Control by EPICS**
- **About 100 monitor points**
- **About 20 control points**
- **Maintained by another group**

PEP-II RF System

http://www.slac.stanford.edu/grp/cd/soft/pepii/rf/index.html

- **Eight stations (VXI)**
- **Each with about 100 Control points**
- **Each with about 1000 Monitor points**
- **Extensive use of Allen Bradley**
- **EPICS provides control and monitoring**

PEP-II RF Features

- **Extensive use of sequences**
- **Heavily parameterized**
- **Well documented**
- **Sophisticated DM displays**
- **Faults saved for MATLAB analysis**
- **Used by operators and RF experts**
- **Controls SLAC-built VXI modules**

Damping Ring Upgrade

http://www.slac.stanford.edu/grp/cd/soft/pepii/drrf/index.html

- South and North Damping Ring RF control and status were upgraded to use EPICS with an Allen Bradley PLC. This is modelled on the PEP-II RF implementation.

- Flat Database, about 100 PVs in each ring.
- Everything mapped to Allen Bradley.
- All real work in the PLC, done by RF group.

“Alien” Connections

- **Kai Kasimir’s Active-X CA Server used in conjunction with Labview to interface foreign devices**
- **Requires some mirroring (general purpose IOC) to implement save/restore**
- **Beam size measurements**
- **Beam abort analysis**
- **Injection laser control**

General Purpose “Soft” IOC

- **Soft records and Ethernet GPIB only**
- **Mirror records for Labview-served Process Variables**

- **Overhead display management**
- **Moving all GPIB to EPICS control**

Luminosity Analysis

- **Replacing PC-based, connectionless system (Pascal, DOS)**
- **CAMAC control being moved from PC to VME IOC (TJNAF CAMAC package)**
- **Complex Pascal program becomes simple sequence plus a score of PVs.**
- **Next version of processor board will be moved from CAMAC to VME**

Issues and R&D Critical to the LCLS

Paul Emma
SLAC

UCLA

Stanford Linear Accelerator Center

Advanced Photon Source

SSRL

LLNL

BROOKHAVEN NATIONAL LABORATORY

Los Alamos

15 GeV Electrons **LCLS** 1.5 Å X-Ray

Linac Coherent Light Source

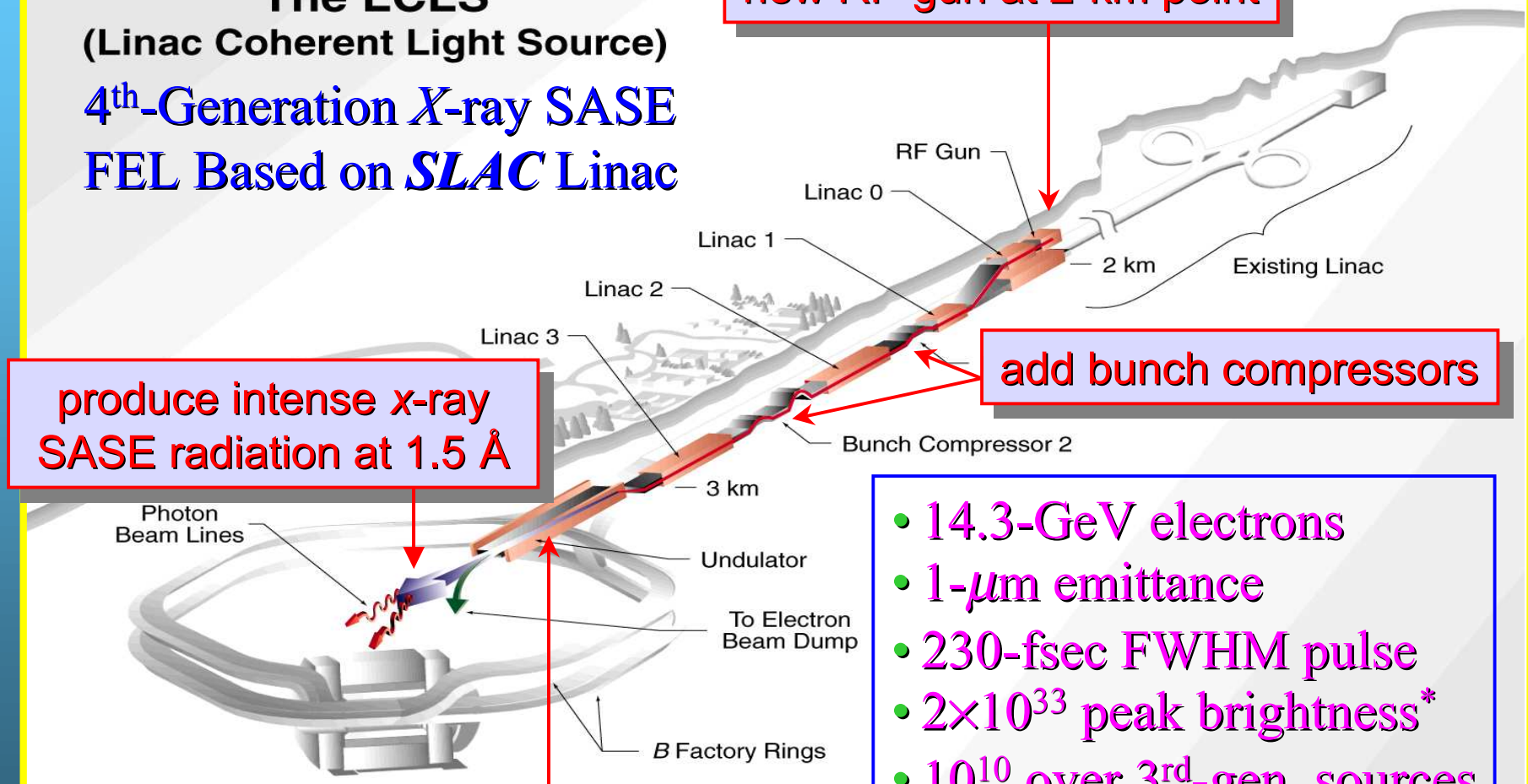
UBS

Linac Coherent Light Source (*LCLS*)

The LCLS
(Linac Coherent Light Source)

4th-Generation *X*-ray SASE FEL Based on *SLAC* Linac

new RF-gun at 2-km point



add bunch compressors

produce intense *x*-ray SASE radiation at 1.5 Å

- 14.3-GeV electrons
- 1-μm emittance
- 230-fsec FWHM pulse
- 2×10^{33} peak brightness*
- 10^{10} over 3rd-gen. sources

install 120-m undulator in 'FFTB' hall

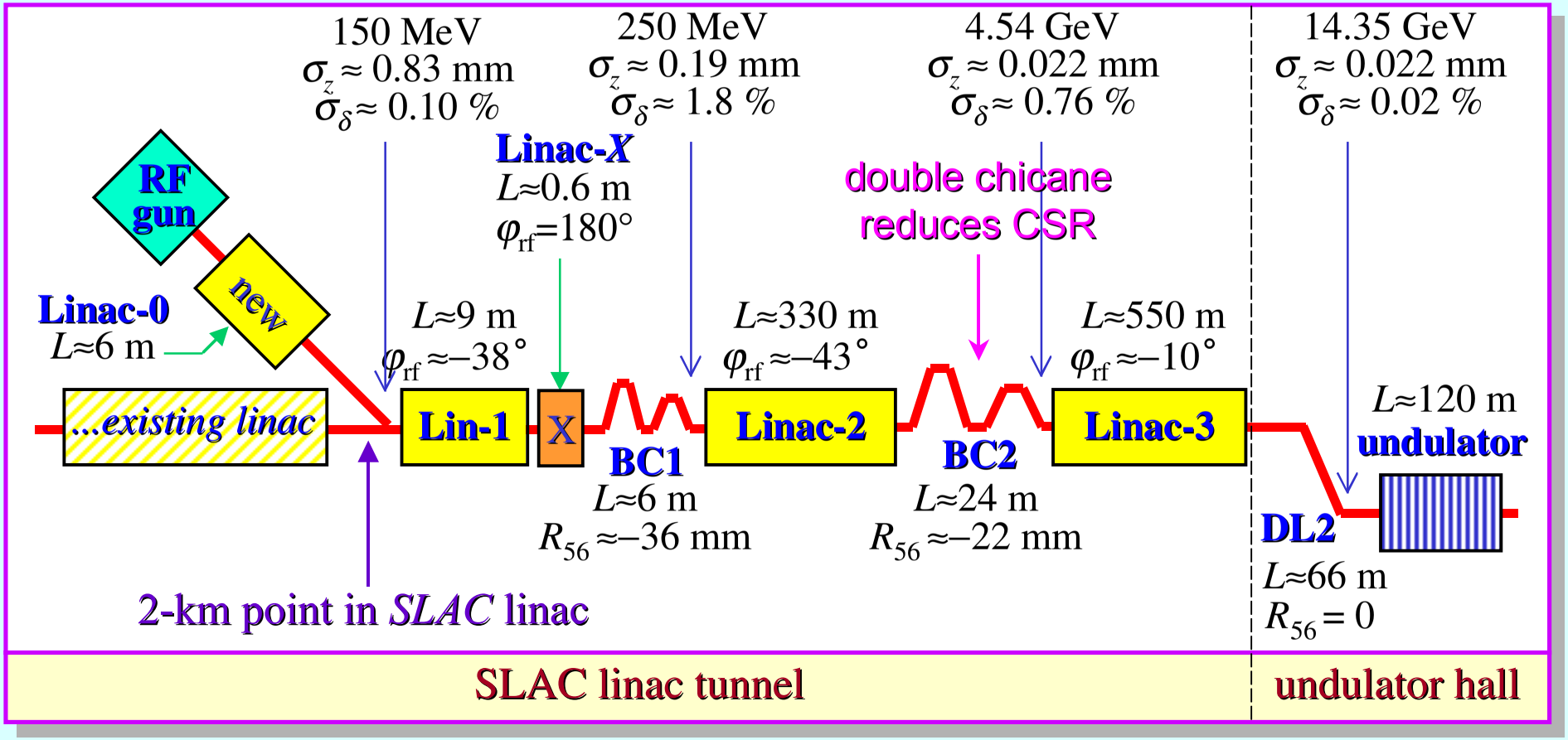
10-97
8360A1

* photons/sec/mm^2/mrad^2/0.1%-BW

LCLS Issues and R&D

- Injector Requirements
  - $\gamma\varepsilon \leq 1$ μm at 1 nC and 100 A
  - Stability <1 psec timing & <2% charge
- Acceleration and Compression
  - ε-preservation → 'CSR' and wakefields
  - RF stability of 0.1°, 0.1% rms
- Undulator
  - Design, precise fabrication, and thermal stability
  - Trajectory alignment to <5 μm
  - Undulator wakefields
- X-ray optics

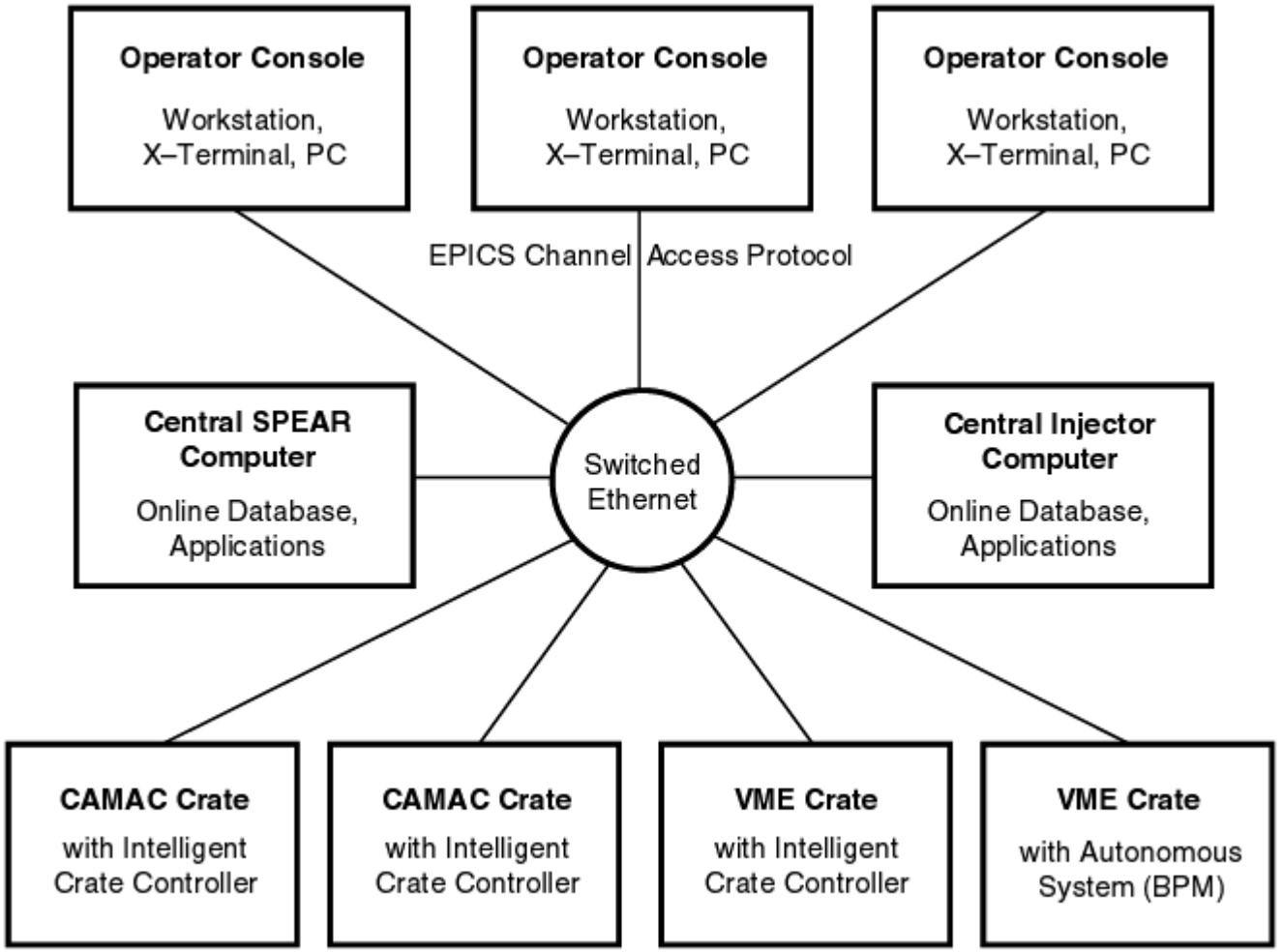
LCLS Acceleration and Compression



- Emittance control given coherent synchrotron radiation in bends
- Adequate machine stability (RF, charge, bunch-timing, …)

SPEAR 3 Instrumentation and Control Systems

- Computer Control System
- Beam Monitoring and Feedback Systems
- Timing System
- Machine Protection Systems
- Personnel Protection Systems
- Cable Plant



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Computer Control System

Expand present control system:

- DEC Alpha (VMS) + switched Ethernet
- CAMAC and VME crates + μVAX controllers
- X-terminal and PC consoles
- EPICS applications and GUI tools
- EPICS Channel Access to existing control system
- Database (Oracle RDB)

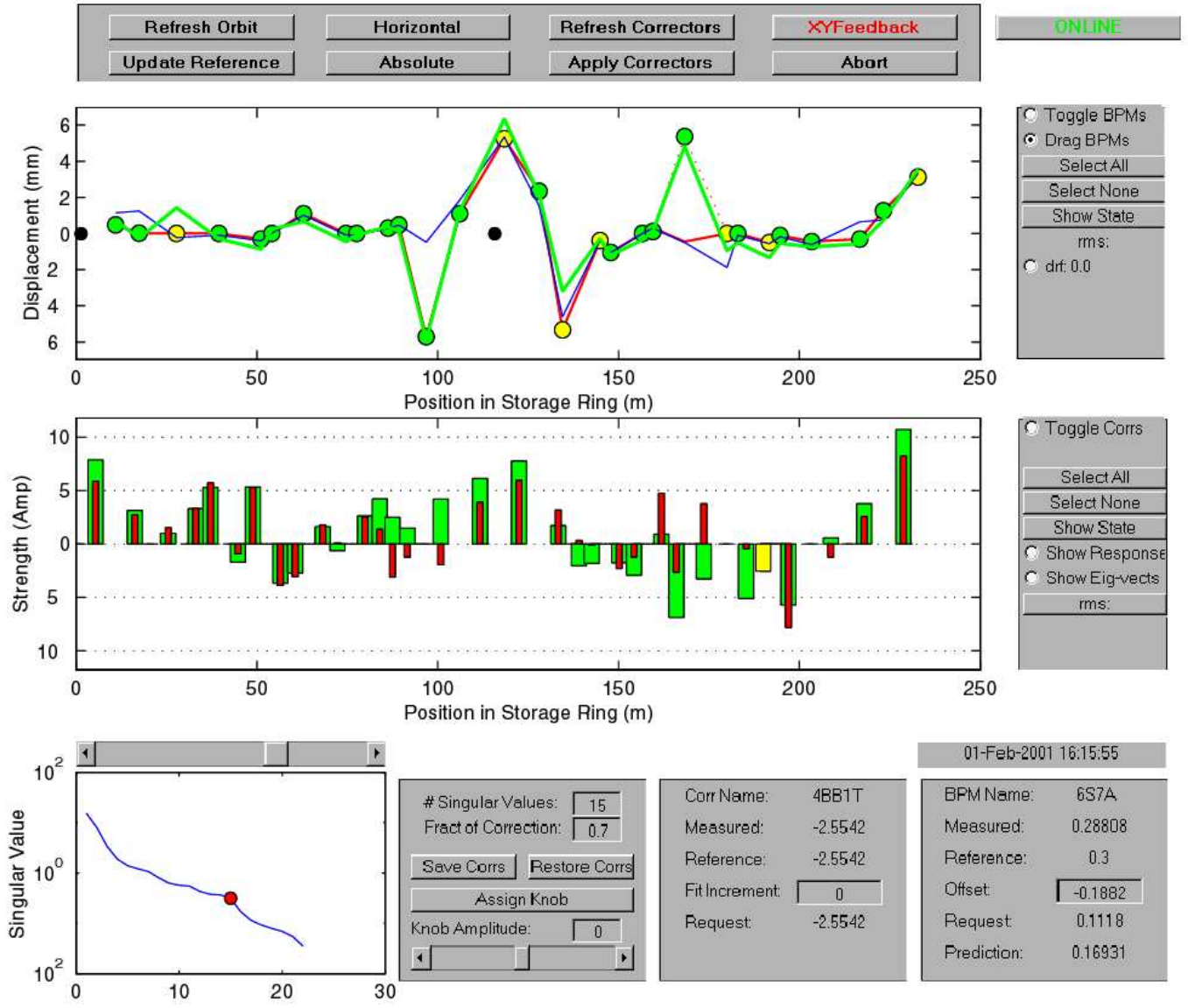
New interface hardware and development:

- Main power supply controllers (slow)
  Bitbus control, obsolete microcontrollers
- Fast power supply digital controller - develop
  Fast Ethernet (100 Mb/s) + switch
- BPM Processor, Orbit Feedback interface
  Power PCs
- RF Control System
  EPICS IOC (NI 68030 or replacement PPC), VXI crates

Software development:

- Intelligent crate controllers
  local process and control, data logging
- Power Supply controllers , BPM Processor, Orbit Feedback
  drivers, control programs, DSP code
- RF Control System
  EPICS,unix development system
  VxWorks, Matlab
- Application software
  VMS, EPICS, Matlab

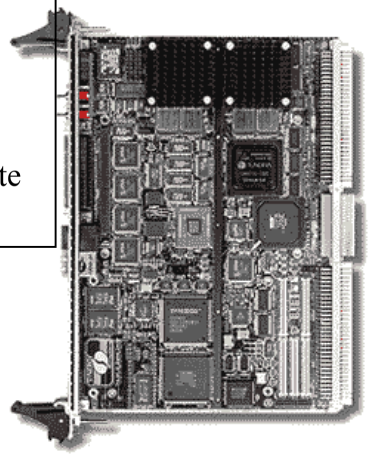
Orbit Control with Matlab and EPICS Channel Access



VME Crates and CPUs

VGM5 VME Dual PPCG4/G3 CPU Board (Synergy)

Dual or single CPUs in a single slot solution
Advanced PowerPC G4/G3 architecture
300-466 MHz CPU speed
Backside L2 cache 1 or 2 MB per CPU
PØ-PCI(TM) secondary data bus, ~264 MB/s
16-512 MB high-speed SDRAM
Up to 9 MB Flash
Supports industry-standard PMC I/O
Autosensing 10/100Base-TX Ethernet
Two serial ports standard; SCSI option
4-digit clock/calendar chip is Y2K compliant
Supports VxWorks, Linux
Supports RACEway with PXB2 PMC module
VME64x support
VME Speedway doubles non-block transfer rate
Conformal coating option



VME Crates (Wiener)

21 slots, 6U VME cards
3U space for fan tray and plenum chamber
Card guides and ejector rails IEEE 1101.10
Monolithic backplane VME64x or VIPA
Microprocessor controlled fan-tray unit UEL 6020 with high efficient DC-fans (3 ea.), alphanumeric display, variable speed fan
Temperature control, front or bottom air inlet
Up to 8 temperature sensors in bin area with network option for remote monitoring and control (CAN-bus)
Remote CPU reset capability
Used at SLAC, BNL, CERN, BESSY, etc.

Beam Monitoring and Feedback Systems

New for SPEAR 3:

- BPM Processing System
- Orbit Feedback System
- DCCT
- Scraper Controls
- Tune Monitor
- Synchrotron Light Monitor
- Quadrupole Modulation System

From SPEAR 2:

- Upgraded injection monitors
- Longitudinal Bunch Phase Monitor
- Transverse Bunch Phase Monitor

General Software Concerns at SLAC

- **Now supporting iRMX, PSOS, VxWorks, VMS, HPUX, Solaris, and NT. Looking at RTEMS and Linux.**
- **Still upgrading old system “micros”**
- **Must move away from VMS**
- **Negotiating for better computer center support**

Challenges for EPICS at SLAC

- **Management support is now there; need more assigned to real work (Hardware AND Software people)**
- **VXI slot-0 controller replacement for NIC-030 is a problem**
- **Supporting PPC, Motorola and National Instruments is interesting**
- **Coordination with BaBar for upgrades**
- **Must move to Tornado (but NIC cannot)**
- **Move from VxWorks (to RTEMS, RT-Linux)?**
- **What about Linux instead of Solaris?**