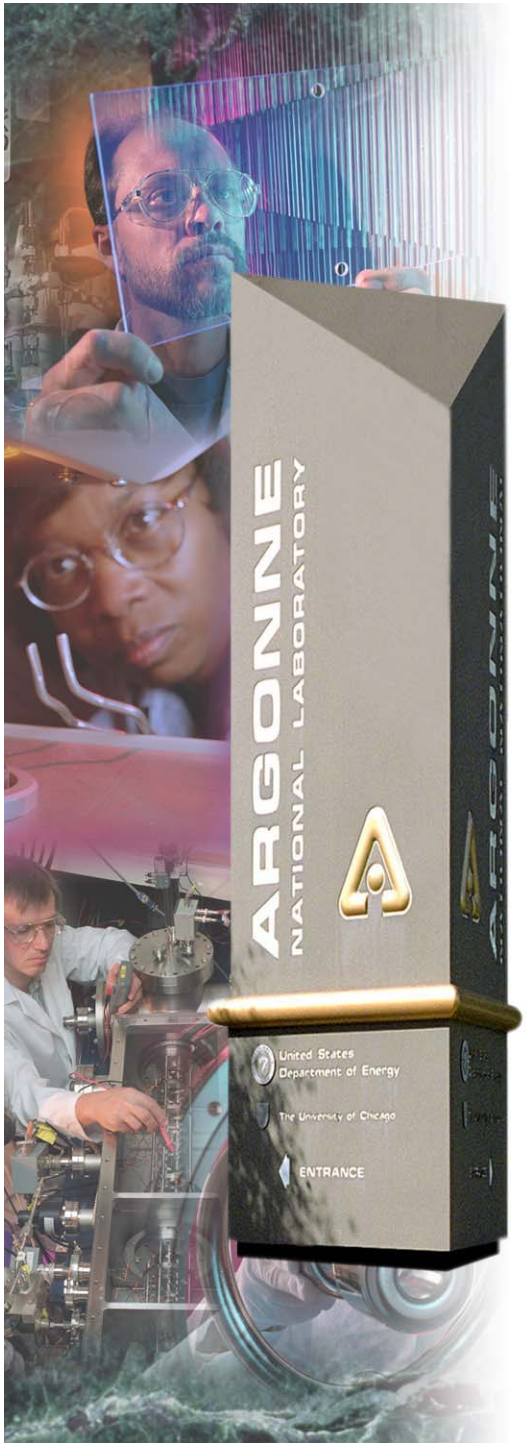

Beamline Automation at the APS

John Maclean
Group Leader,
Beamline Controls and Data Acquisition,
Advanced Photon Source

Argonne National Laboratory

Office of Science
U.S. Department of Energy

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

Introduction

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- **An overview of automation activities at APS beamlines**
- **Outline APS beamline organisation**
- **Control Systems in use at APS**
- **Automation**
  - Beam stabilization
  - Sample changing robots
- **Look at beamlines in different phases of their life**
  - Operational
  - Commissioning
  - Construction

APS Organisation

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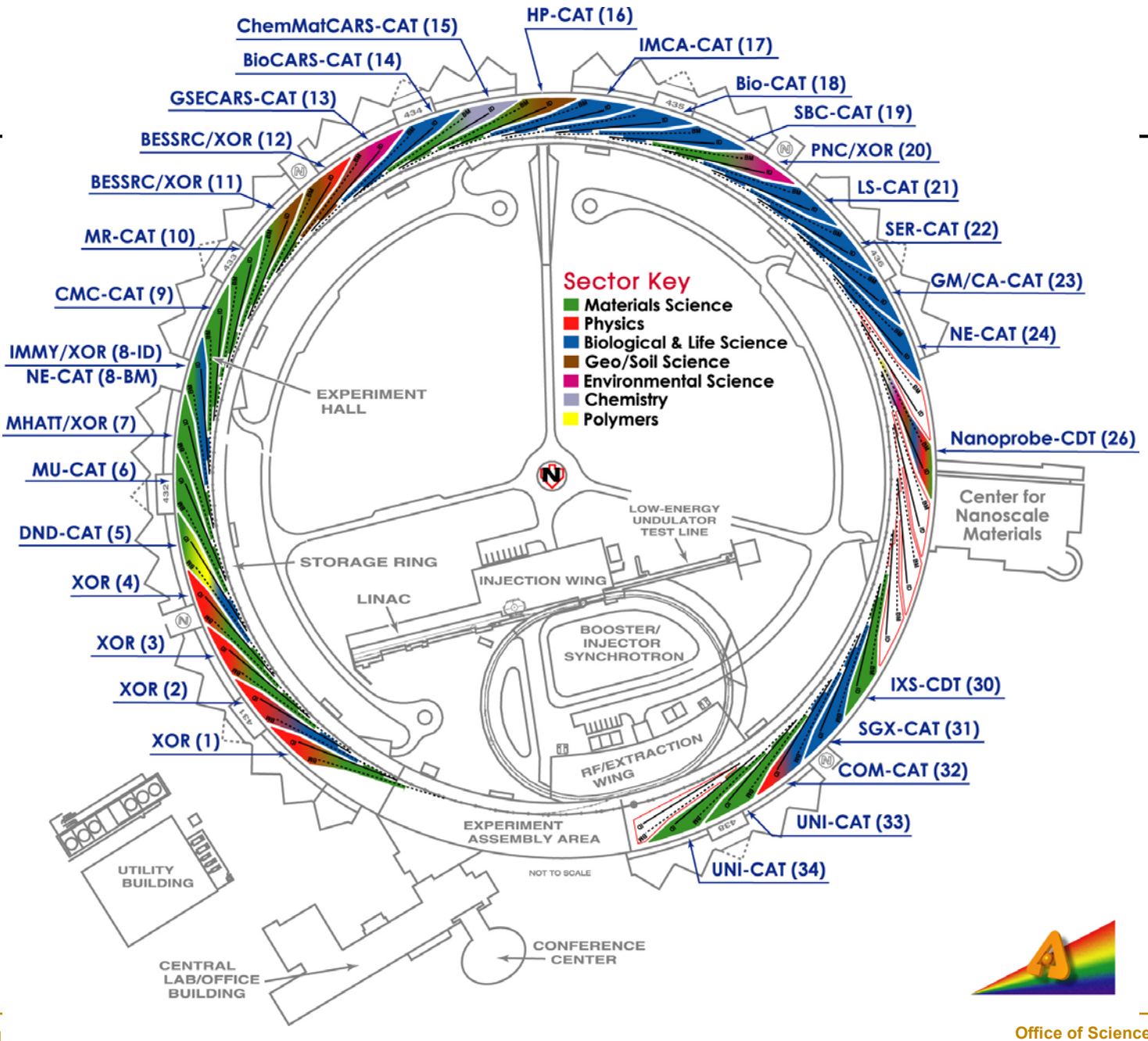
- **Beamlines are run by CATs (Collaborative Access Teams)**
- **9 sectors run by APS**
- **20 sectors run by *independent* CATs**
- **CAT developers responsive primarily to their own users**
- **Collaboration encouraged**
- **Wide variety of requirements for beamline software**
  - "Production" beamlines:
    - *Hardware and experiment rarely change*
    - *Want experiment specific software*
  - "Multi-use" beamlines:
    - *Hardware and experiment frequently change*
    - *Want general-purpose, flexible software*


ChemMatCARS-CAT (15)
HP-CAT (16)
IMCA-CAT (17)
BioCARS-CAT (14)
Bio-CAT (18)
GSECARS-CAT (13)
SBC-CAT (19)
BESSRC/XOR (12)
PNC/XOR (20)
BESSRC/XOR (11)
LS-CAT (21)
MR-CAT (10)
SER-CAT (22)
CMC-CAT (9)
GM/CA-CAT (23)
IMMY/XOR (8-ID)
NE-CAT (24)
NE-CAT (8-BM)
MHATT/XOR (7)
Nanoprobe-CDT (26)
MU-CAT (6)
DND-CAT (5)
XOR (4)
XOR (3)
IXS-CDT (30)
XOR (2)
SGX-CAT (31)
XOR (1)
COM-CAT (32)
UNI-CAT (33)
UNI-CAT (34)
Sector Key
Materials Science
Physics
Biological & Life Science
Geo/Soil Science
Environmental Science
Chemistry
Polymers
EXPERIMENT HALL
LOW-ENERGY UNDULATOR TEST LINE
STORAGE RING
INJECTION WING
LINAC
BOOSTER/ INJECTOR SYNCHROTRON
RF/EXTRACTION WING
EXPERIMENT ASSEMBLY AREA
NOT TO SCALE
Center for Nanoscale Materials
UTILITY BUILDING
CENTRAL LAB/OFFICE BUILDING
CONFERENCE CENTER

Software In Use

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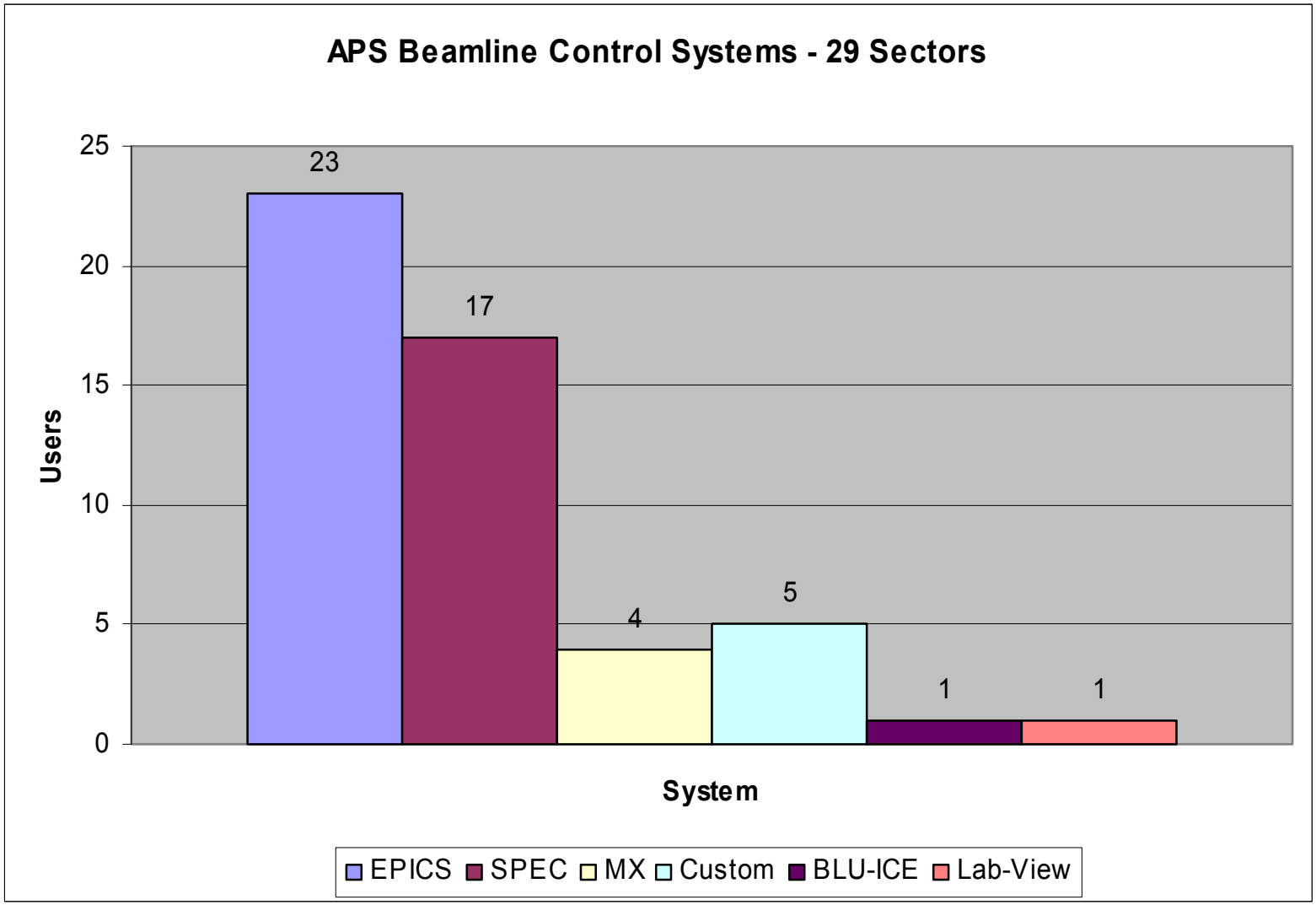
- **Control software in use on APS beamlines**
  - EPICS
  - SPEC
  - MX
  - Lab View
  - BLU-ICE
  - Custom
- **Host software in use on APS beamlines**
  - Linux
  - Windows
  - Solaris

APS Beamline Control systems



Monochronometer feedback

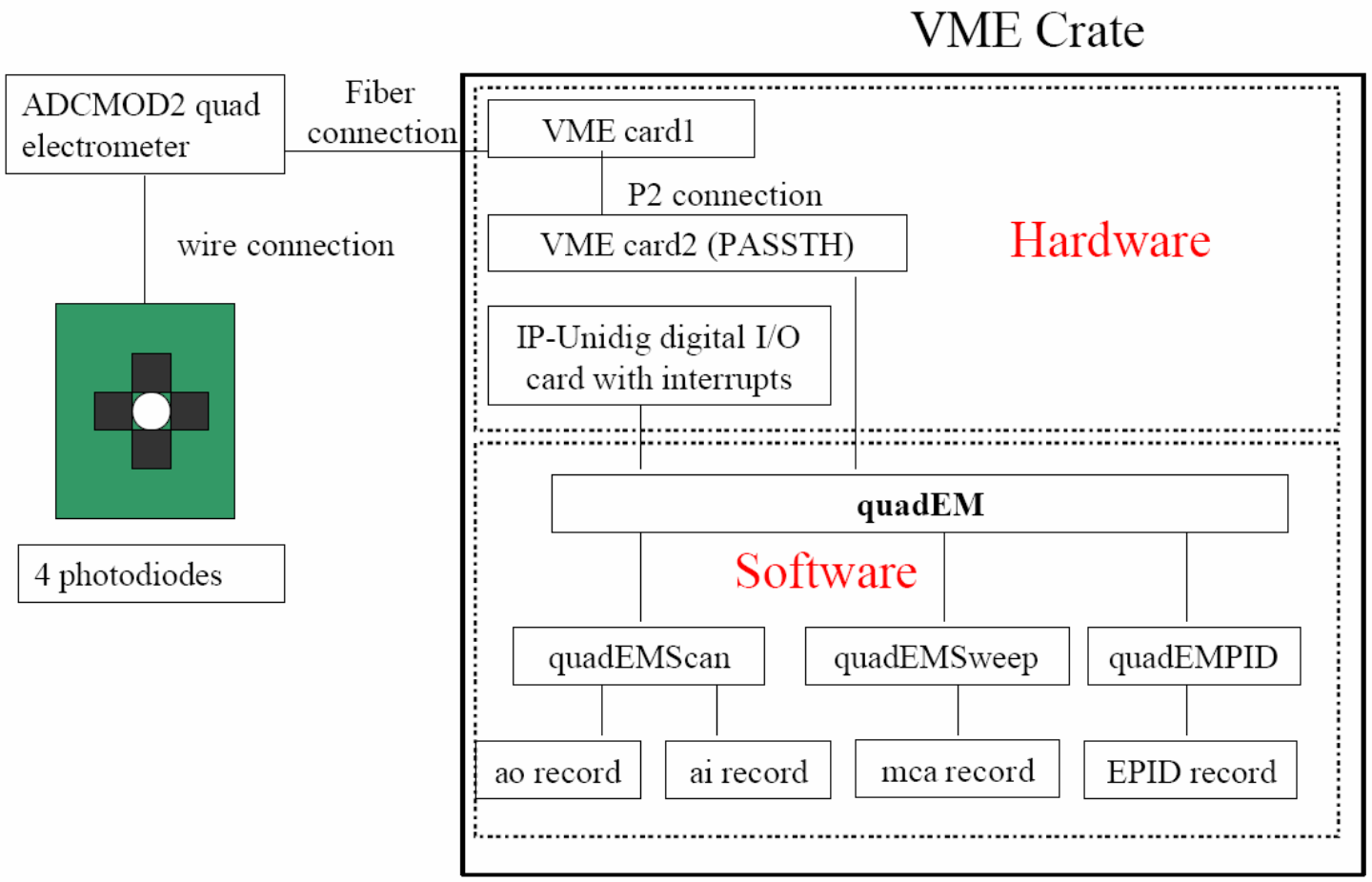
- **Position feedback to control 2nd crystal position**
- **Done at numerous beamlines**
- **Several solutions**
- **E.G. GSCE-CAT**

GeoSoilEnviroCARS
The University of Chicago
Argonne National Laboratory • Advanced Photon Source

- **Control system: EPICS, Linux & Windows hosts**
- **Work by Mark Rivers, James Cistron, Steve Ross(APS)**
- **Performance:**
  - ±0.2μm RMS deviation in horizontal and vertical planes over 30+ minutes.

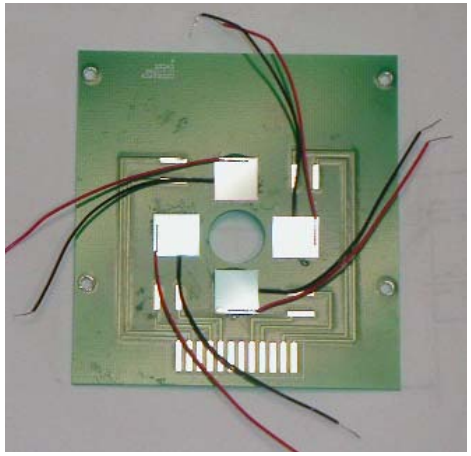
Feedback system

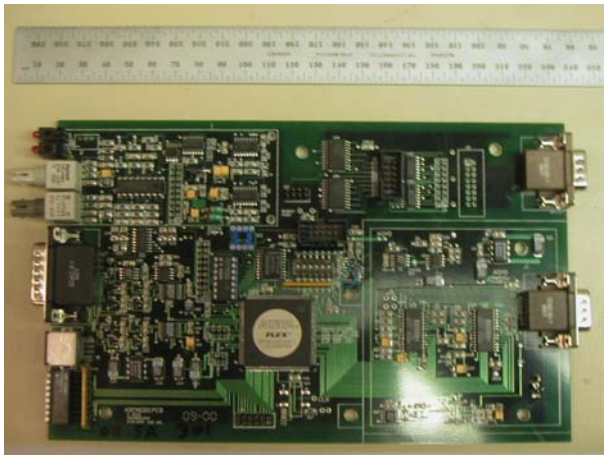
System Architecture



Low noise electrometer

- Low noise charge amplifier, and data acquisition system.
- Detector typically 4 photodiodes.
- Started out being used for fast EXAFS, now mainly applied to x-ray beam position monitoring along a beamline. Currently at 8 sectors, more coming.
- Dynamic Range: 20 bit ADC, LSB = 10 pA, full = 50 uA
- Noise of system, including UDT S100-VL 1 cm^2 diode, 70 pA RMS





APS Automated Sample Mounting

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- **Cartesian robot system for sample mounting study 1998**
  - **Cartesian robot system for x-ray tomography at XOR 2-BM 2001**
- **XOR 2-BM, APS Beamline, EPICS control**
- **APS R&D on Automation for Cryogenic Crystal Sample Mounting for Structural Biology CAT**
  - **6-axis robot with Kappa configuration and 48-Yale pins, 2001**
  - **6-axis robot with Kappa configuration and 96-Hampton pins, 2002**
    - ***Integration with SBC 19-BM experimental station, 2003***
    - ***Integration with SBC 19-ID experimental station, 2004***
- **SBC – DoE & NIH funded,**
  - National macromolecular crystallography user facility
  - EPICS Control System

Cartesian robot system

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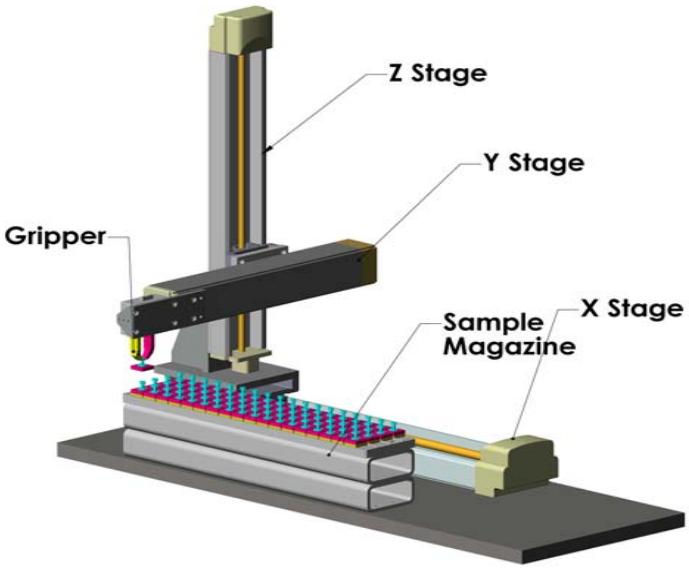
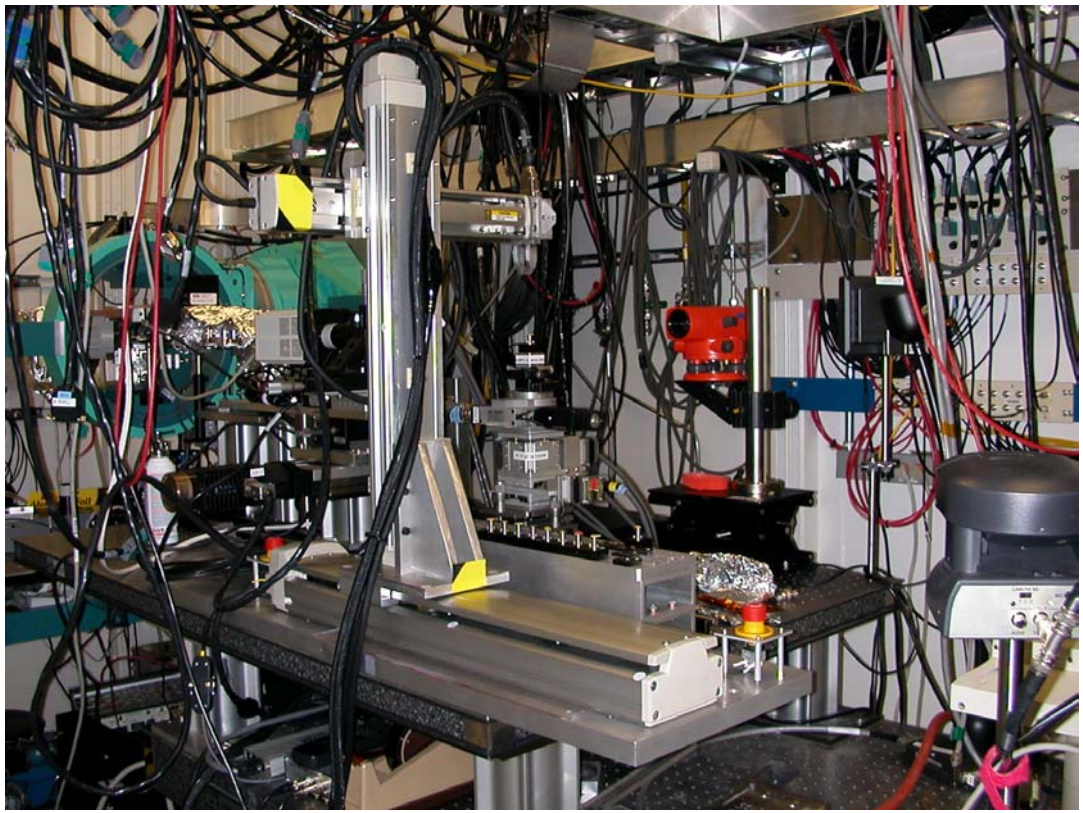
Cartesian robot system for x-ray tomography at XOR 2-BM





Six Axis Robot

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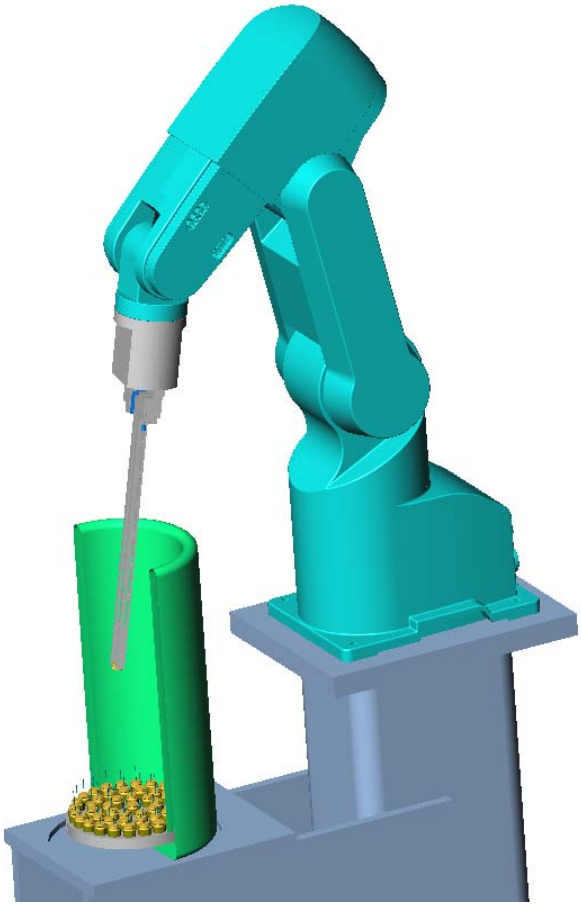
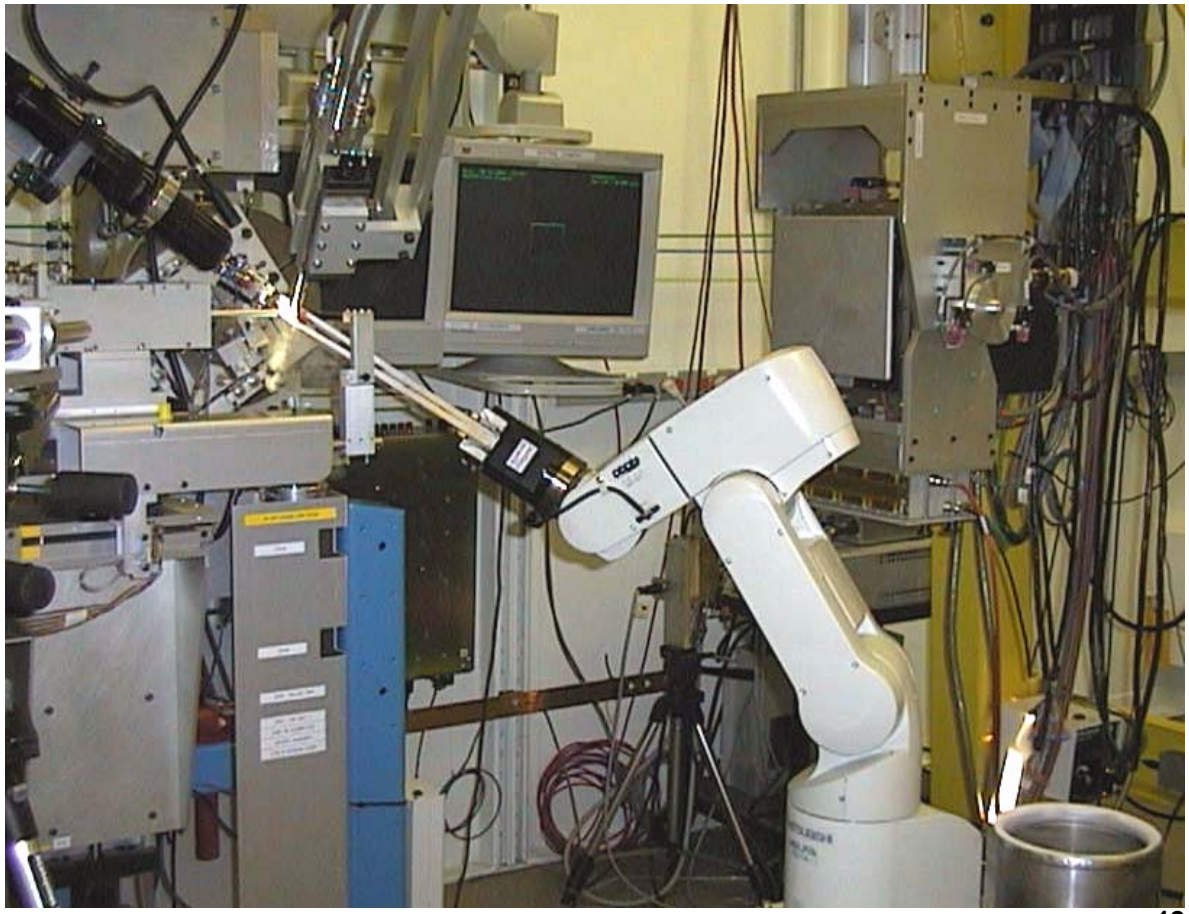
6-axis Mitsubishi robot with Kappa configuration and 48-Yale Pins

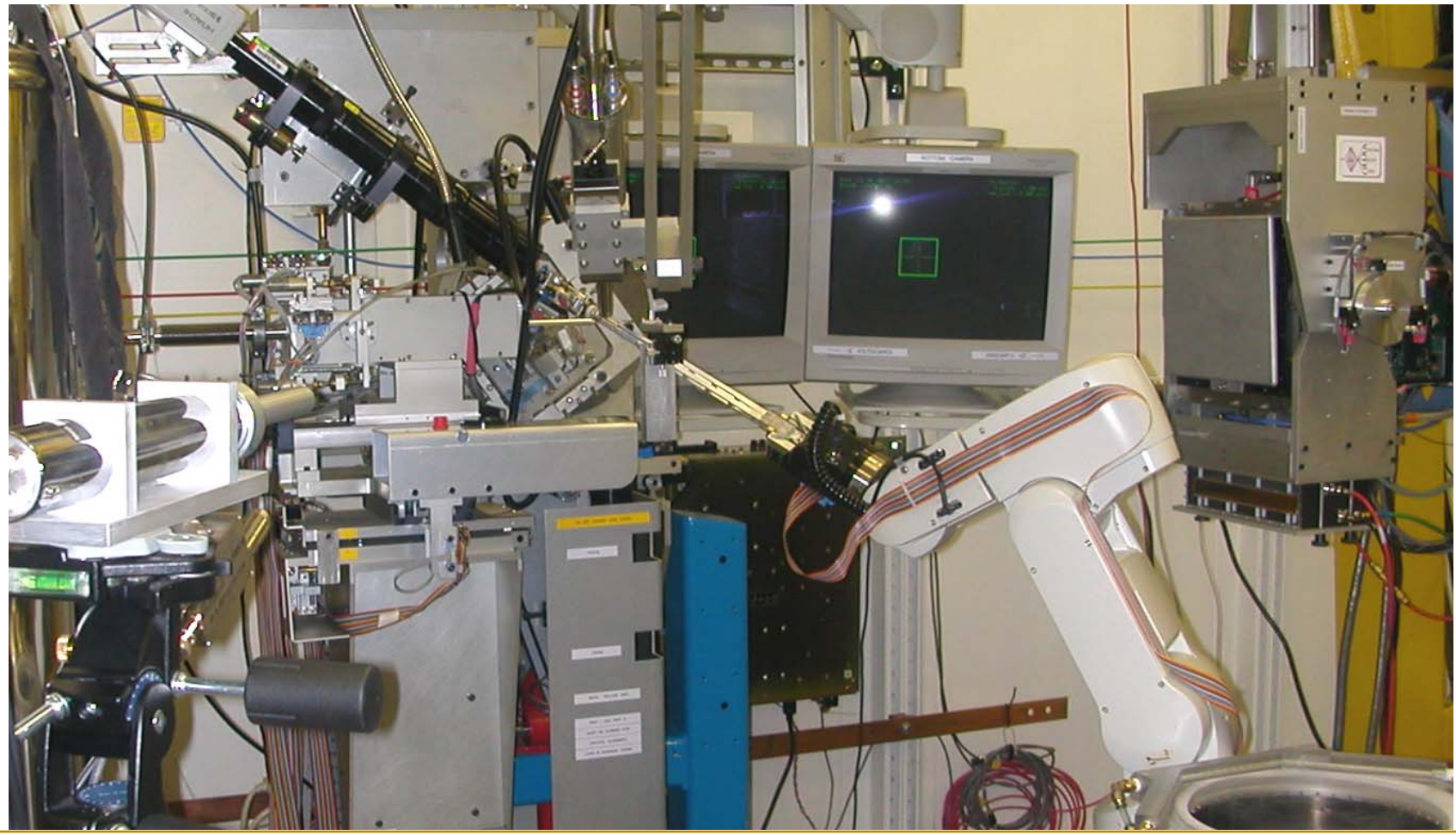




Six Axis Robot

Advanced Photon Source
Argonne National Laboratory

6-axis Mitsubishi robot with Kappa configuration and 96-Hampton Pins



APS Automated Sample Mounting

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- **Mitsubushi RV-1A Robot Arm. 6 degrees of freedom.**
- **Custom "handset" (grippers). Uses strain gauges to:**
  - Detect the contact force intensity and direction
  - Provide a precise gripping action
  - Feel the results of gripping
- **Fingers thermal design ensures sample temperature remains lower than 105K during the mounting process**
- **System compatible with a miniature kinematic mounting sample holder, provides near-micron positioning repeatability for pre-aligned special small samples**
- **Triangular sample magazine maximizes use of Dewar space**
  - 120 samples can be arranged in Dewar
  - System is compatible with commercial round shape sample magazines (e.g. ACTOR™ type magazines), which allow a maximum of 96 samples in Dewar.

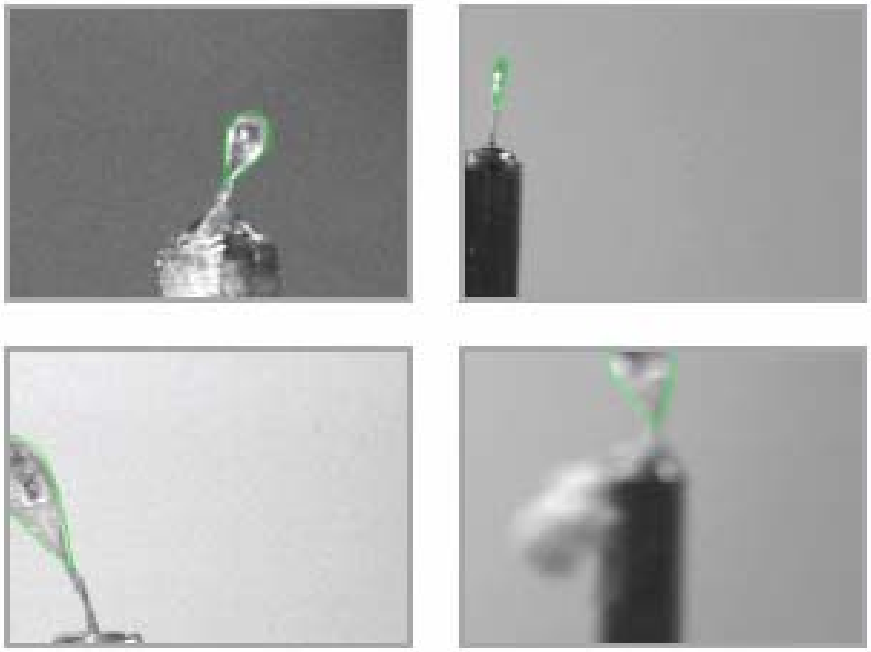
IMCA CAT

- **Industrial Macromolecular Crystallography Association**
- ***"An association of pharmaceutical companies committed to the use of macromolecular crystallography as a tool in drug discovery and product development"***
- **ID and BM beamlines**
- **Control system: MX, Tcl/TK**
- **Want high throughput, ease of use**
- **Installed Rigaku ACTOR™ robot**
  - 12 Sample Hampton magazine
  - Custom Java based GUI

- **Use ADSC Detector – Rigaku & ADSC collaborated to integrate their products**

IMCA - Performance

- **Auto centering**
  - Center on loop
  - Manual adjustment required ~ 5% of time
  - Dual camera centering
  - 30 – 40 seconds typical



RIGAKU video

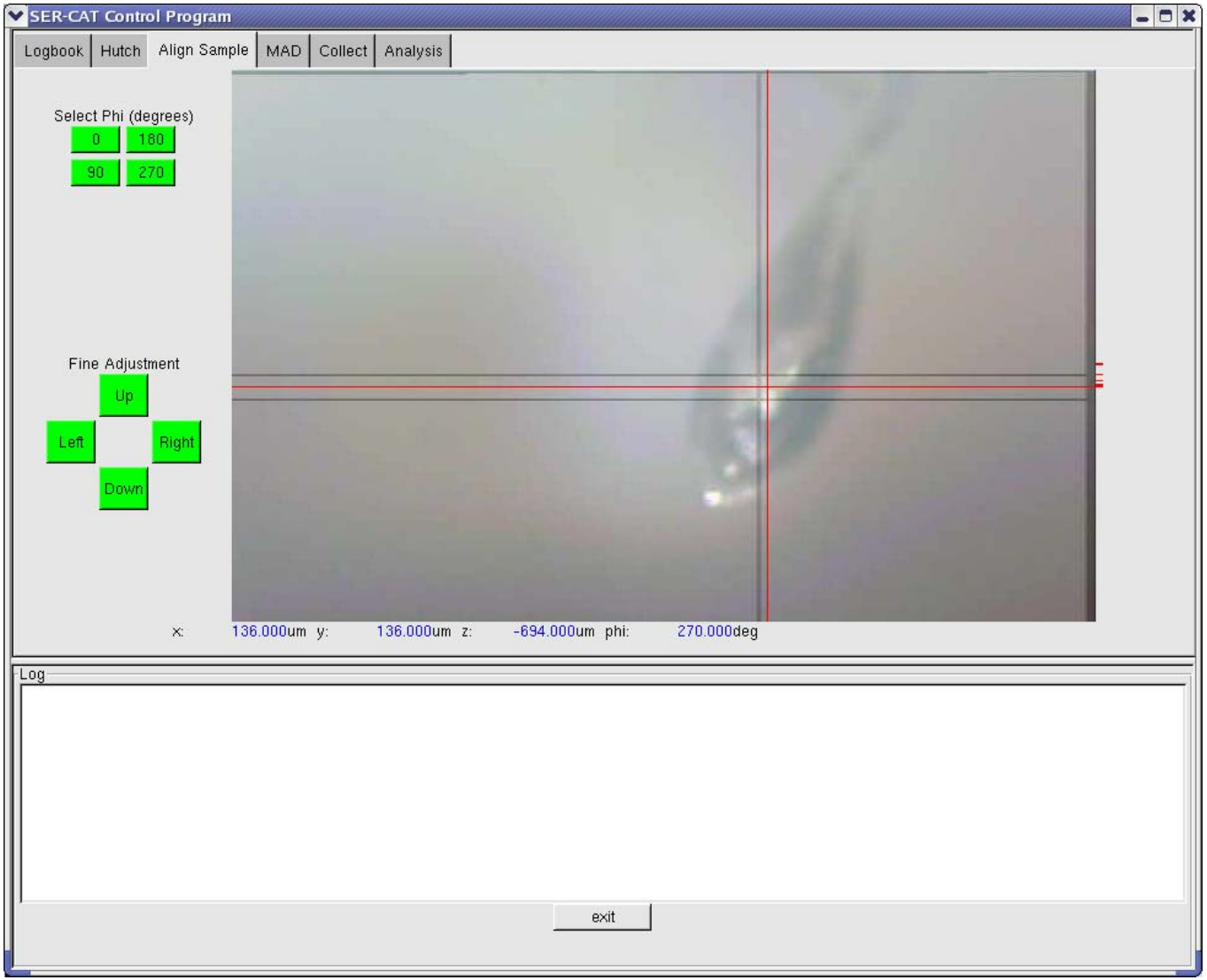
IMCA - Performance

- **Recent user gathered data on 123 samples in one 24 hour run**
  - User was able to leave beamline and sleep
  - Automatic notification of problems by pager
- **Difficult to design intuitive GUI**
  - An iterative process with vendor
- **Now it takes ~15 minutes to train user**
- **Contact Lisa Keefe <keefe@anl.gov> IMCA-CAT Director**

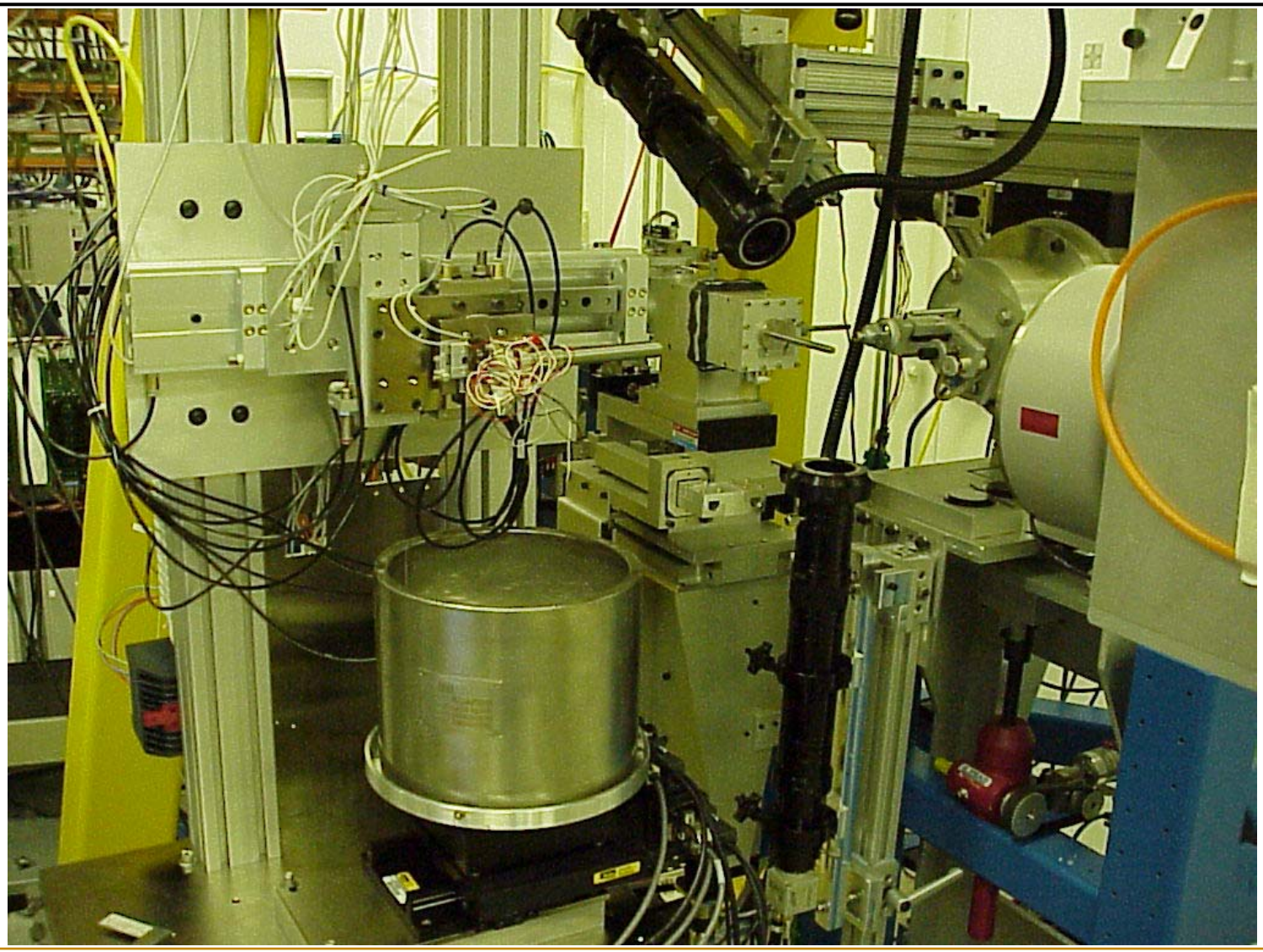
SER-CAT

- **Southeast Regional Collaborative Access Team**
- **"*Provide third generation x-ray capabilities to macro-molecular crystallographers and structural biologists in the southeastern region of USA*"**
- **ID and BM beamlines**
- **Control system: MX, Python, TCI/TK - Linux hosts**
- **Want high throughput, ease of use, remote access**
- **Selected ALS robot design**
  - Simple
  - Low cost
  - X, Y, Head rotation
  - Redesigning dewar
- **Contact John Chrzas <chrzas@anl.gov>**

SER-CAT GUI


SER-CAT Control Program
Logbook
Hutch
Align Sample
MAD
Collect
Analysis
Select Phi (degrees)
0
180
90
270
Fine Adjustment
Up
Left
Right
Down
x:
136.000um y:
136.000um z:
-694.000um phi:
270.000deg
Log
exit

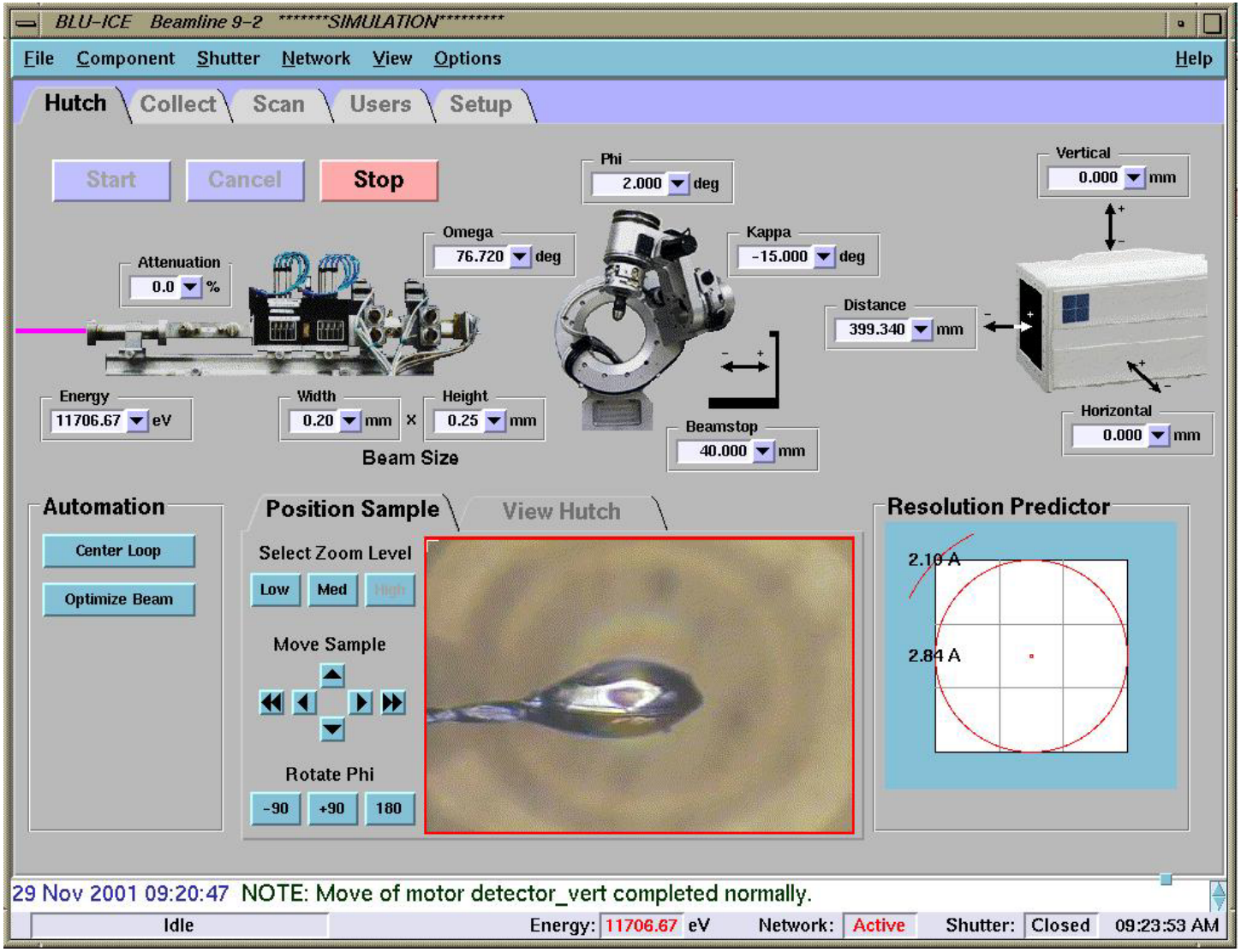
SER-CAT ALS Robot



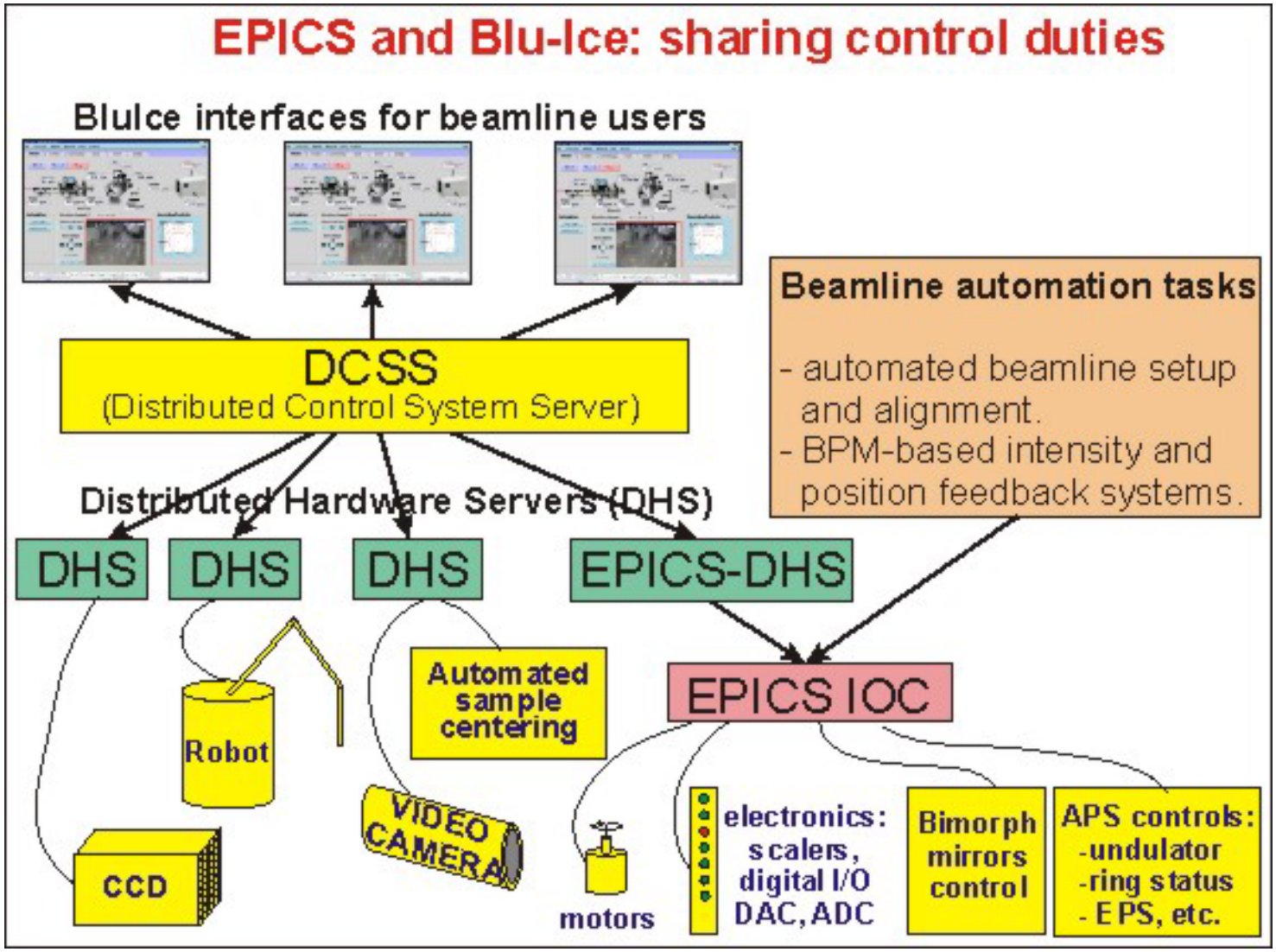
GM/CA-CAT

- General Medicine and Cancer Institutes Collaborative Access Team
- *"National user facility for crystallographic structure determination of biological macromolecules"*
- Under construction – operational 2005
- Control system: EPICS/Blu-Ice, Linux hosts
- Will use ALS robot with SER-CAT modifications
- Automated focusing of bi-morph mirrors
- Contact Sergey Stepanov <sstepanov @anl.gov>

GM/CA-CAT GUI


BLU-ICE Beamline 9-2 *******SIMULATION*********
File Component Shutter Network View Options Help
Hutch Collect Scan Users Setup
Start Cancel Stop
Phi 2.000 deg
Vertical 0.000 mm
Omega 76.720 deg
Kappa -15.000 deg
Attenuation 0.0 %
Distance 399.340 mm
Energy 11706.67 eV
Width 0.20 mm x Height 0.25 mm
Beam Size
Beamstop 40.000 mm
Horizontal 0.000 mm
Automation
Center Loop
Optimize Beam
Position Sample View Hutch
Select Zoom Level
Low Med High
Move Sample
Rotate Phi
-90 +90 180
Resolution Predictor
2.10 A
2.84 A
29 Nov 2001 09:20:47 NOTE: Move of motor detector_vert completed normally.
Idle Energy: 11706.67 eV Network: Active Shutter: Closed 09:23:53 AM

GM/CA-CAT EPICS/Blu-Ice



Conclusion

- **APS has many *Independent* beamlines**
- **A variety of control systems**
- **Different solutions to similar problems**
- **Collaborations across beamlines do exist**
- **Mono feedback now common**
- **PX beamlines pushing automation efforts**
- **Remote access is a coming issue**

Acknowledgements

- None of the work in this presentation was mine!
- Thanks for their time and materials to…
- Mark Rivers, James Cistron, Peter Eng – GSCE-CAT
- Steve Ross, Deming Shu – APS
- Lisa Keefe – IMCA-CAT
- John Chrzas, James Fait – SER-CAT
- Sergey Stepanov – GM/CA-CAT