Argonne NATIONAL LABORATORY

Advanced Photon Source
10 Years of Operation
A Facility / User Perspective

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THE UNIVERSITY OF CHICAGO

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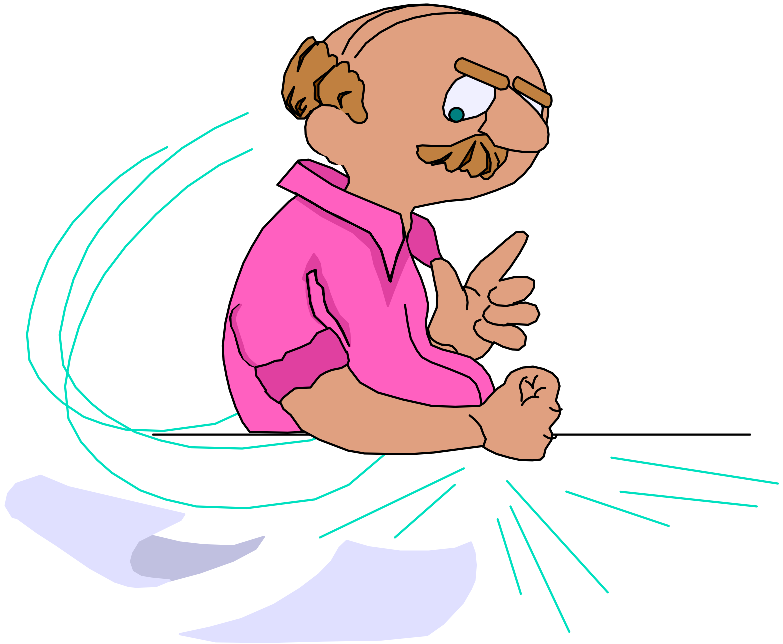
Disclaimer

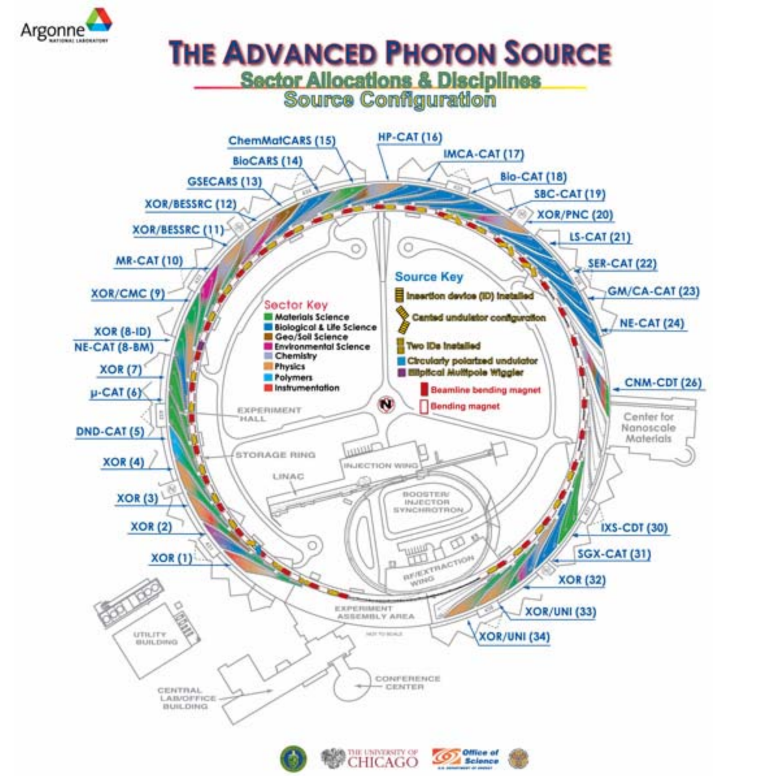
- This talk will not cover any facts or figures of APS operation
- For more information on APS visit the WEB site at http://www.aps.anl.gov
  - After ten years of operation we still haven't got the WEB site right…

- Most of the information provided in this talk is my perspective, having been a user/beamline staff at NSLS for 6 years, then 3 years as a APS user/beamline staff and finally 12 years as a facility person involved with making the Users Happy!!!!



Introduction

- This presentation consists of two parts:
  - A high level management assessment of the APS project just after commissioning of the APS
  - My perspective of the beamlines/ facility after 10 years of operation….



Management Perspective

- In 1996 APS management performed an assessment of the APS project
- Based on this assessment a lessons learned document was prepared
- Some of the topics covered are
  - Procurement, Human Relations, Fiscal Oversight
  - Cost Schedule Control System
  - Cost Control
  - Schedule Control
  - Technical Change Control
  - Design/Construction and Contract Management
  - Quality Assurance / Quality Control
  - Environment, Safety, and Health
  - DOE Relationship

- Will highlight a few of the items mentioned above
- More details are available in the document

Management Perspective

Procurement

- Need dedicated procurement group as part of the project
- Integrate the procurement staff with the rest of the project staff
- Educate project technical staff on the procurement process
- Develop database to track the procurements

Human Relations

- Need dedicated HR group as part of the project
- HR head should be well versed in Employment, Compensation and Labor Relations
- Advertise in national and international journals
- Attention to spouse and family needs is crucial in recruitment

Management Perspective

Cost Control

- Cost control was managed through a rigid and formal system
- Each budgeted item was allocated funds with no contingency
- Any commitment below the budget returns the difference into contingency
- Any commitment above the budget requires a change order and draws from contingency
- Advantage is all contingency stays under management control
- Disadvantage is potential delays in processing a change order

Schedule Control

- Overall schedule was consider sacred
- Overall schedule was maintained by Project Management
- Detailed schedule was formally rebaselined annually
- Group leaders were responsible for establishing milestones
- Monthly meetings between group leaders and APS management was held to discuss the milestones

Management Perspective

Design/Construction and Contract Management

- Architect/Engineering firms are, in general, not strong in designing buildings and providing facilities to house equipment and apparatus which are highly technical
- In-house technical expertise is essential to provide input to the design and construction phase
- Establishing a uniform and strict standards for all design and drafting including the type of CADD system is essential for long term success of the project

Quality Assurance/ Quality Control

- QA/QC was considered crucial for the success of the project from the start
- Appropriate procedures were part of the design/ manufacturing specifications
- QA/QC was a technical and line responsibility throughout the APS
- APS QA/QC representatives had technical background
- QA/QC representatives were involved in all cost, schedule, design reviews to procurement follow up to final inspection upon delivery

Conventional Facilities

- Experiment hall is ~30 feet high with the maximum height of stations of 20 feet
- Ceiling of experiment hall has special acoustic design to absorb sound
- All the main water lines, air handling system are suspended from the ceiling
- Lighting on the experiment hall is special type which is pleasing to the eye
- No overhead crane on the experiment floor
- Aisle way between the sectors are 44 inches wide and are sacred

Conventional Facilities

- APS allocated the beamlines as a sector with each sector consisting of one bending magnet and one insertion device beamline
- APS was designed with the capability to provide for each sector:
  - Four 30 KVA 3 phase power (one for clean and one for utility)
  - Compressed air at 120 PSI with a maximum capacity of 20 CFM for operating valves, shutters, etc…
  - Deionized water at ~71º F with supply at 110 PSI and return of 40 PSI (minimum) with a capacity of 20 GPM for cooling beamline components
  - Chilled water at ~ 40º F with a capacity of 10 GPM for cooling, air conditioning, etc …
- Air handling from the facility for temperature control of stations
- APS obtained waiver from the fire protection sprinkler system requirements for beamlines experiment enclosures

Conventional Facilities

Based on other large facility experience the APS management decided:

- Beamlines were not allowed to use the facility DI water
- Beamlines were not allowed to have large air handling ducts in the middle of the experiment hall
- Beamlines were not allowed to have work area enclosures

- Beamlines had to design their own DI water plant for closed loop operation
- Chilled water provided was very dirty and too cold for any practical usage
- Compressed air provided was oil free and as such pneumatic cylinders were getting dry
- No emergency power was provided for beamlines
  - APS has generators around the facility for facility use
- Beamlines had to use the chilled water with a mixture to temperature control the station

Conventional Facilities

After numerous years of experience ……

- Beamline are being switched over to use facility DI water
- Beamlines are allowed to have work area enclosure
- Beamlines are allowed to hookup to facility air handling systems
- Beamline are provided emergency power at 7.5 KVA
- APS has installed liquid nitrogen distribution system with 4 large tanks around the ring and a tap for each sector.

User Procurement

- APS management in the early days of the project had an agreement with the ANL management for waiver of all ANL overheads for capital procurement for the CATs
- All experiment stations were procured through ANL
- Major beamline components for some beamlines were also procured by ANL
- APS had dedicated procurement staff
- A committee was charged to coordinate and track all user procurements

- Even now we have one ANL procurement staff at APS working solely on large scale procurements and user procurements

Close cooperation between the APS staff and procurement staff resulted in smooth sailing on a rough sea.

Survey and Alignment

APS uses a global survey system. We can position any component within 300 microns

- Have a central monument in center of the storage ring
- Have sighting towers around the building to sight the monument
- Have fixed monuments all around the experiment floor
- All data in a database
- Periodic measurements of the floor settlement
- All front end components have fiducials between the internal apertures and standard reference tooling balls on the tables
- All beamline components are for most parts fiducialized and aligned by APS Survey and Alignment group

We have had extremely good track record on alignment of components. This has resulted in very fast commissioning of beamlines.

Front Ends

- All Bending Magnet Front Ends were designed for 300 ma and are identical
  - Exit configuration of dual Be windows of 250 μm thick each
  - Exit configuration of Differential Pump with an aperture in between
- First Phase Insertion Device Front Ends were designed for 100 ma for either Undulator A (2.4m long 3.3 cm period) or Wiggler A (8.5 cm period)
  - Dual Be window (250 μm each) protected by Graphite with an exit aperture of 4.5x 4.5 mm
  - Single 500 μm Be window with an 3x2 mm aperture
  - Differential Pump with a 4.5 x 4.5 mm aperture

- More Undulator only front ends for higher current capacity and canted geometry were recently designed and installed
- All components were manufactured by outside companies
  - Need good quality control for a successful venture

Standardization is very important for cost saving and maintenance. Easy for record keeping and spares inventory.

Vacuum System

APS developed a vacuum policy and has enforced it (almost!) from start

- No oil based pumps were not allowed on the experiment floor
- Vacuum policy took into consideration the problem of high heat loads and window issues
  - Requires two Be windows to air for white beam
  - No coolant to vacuum joints (exception is Liquid Nitrogen) on windowless beamlines

Myth: Differential Pumps are a danger for Storage Rings!

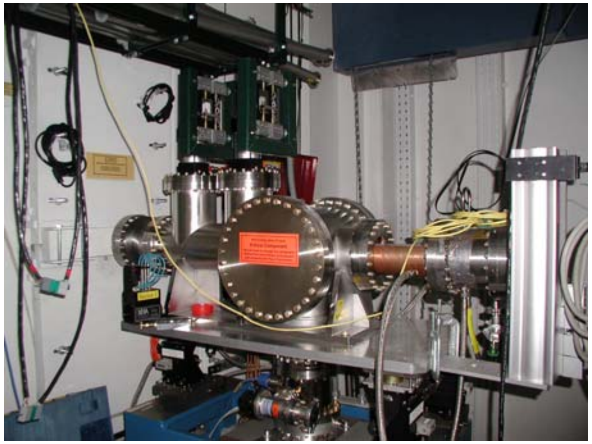
We started our first differential pump on a brand new beamline in 1996

Most ID beamlines operate under Differential Pump and have their exit window as post monochromator

As of 10 years we have had three instances of beamline vacuum ruptures with no perturbation to the front end!!

Standard Components

- APS had a dedicated engineering group responsible for design of all front ends and beamline components
- A standardization committee was set up for designs
- Beamline components to handle high heat load was a major issue
- APS designed numerous shutters, masks and slits for handling different types
- Designs were made available to all users

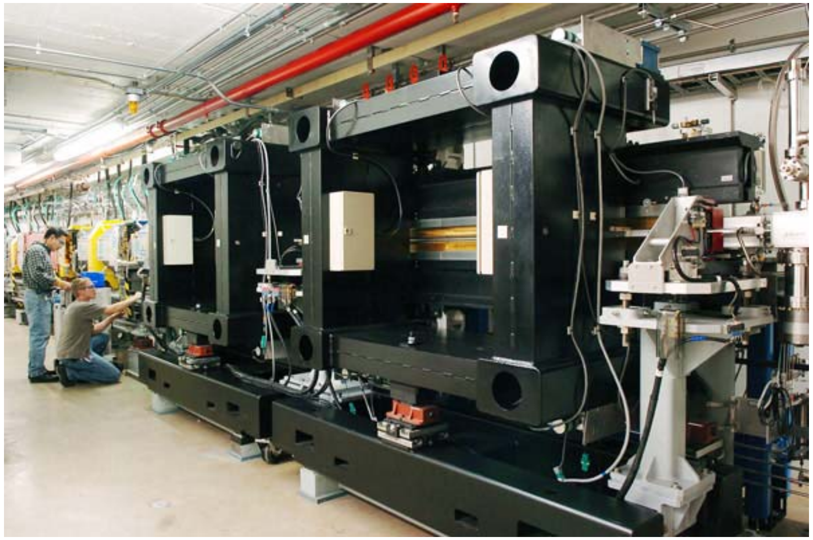


Numerous vendors have used the designs for beamlines

Standardization provides an easy path for maintenance and spares inventory.

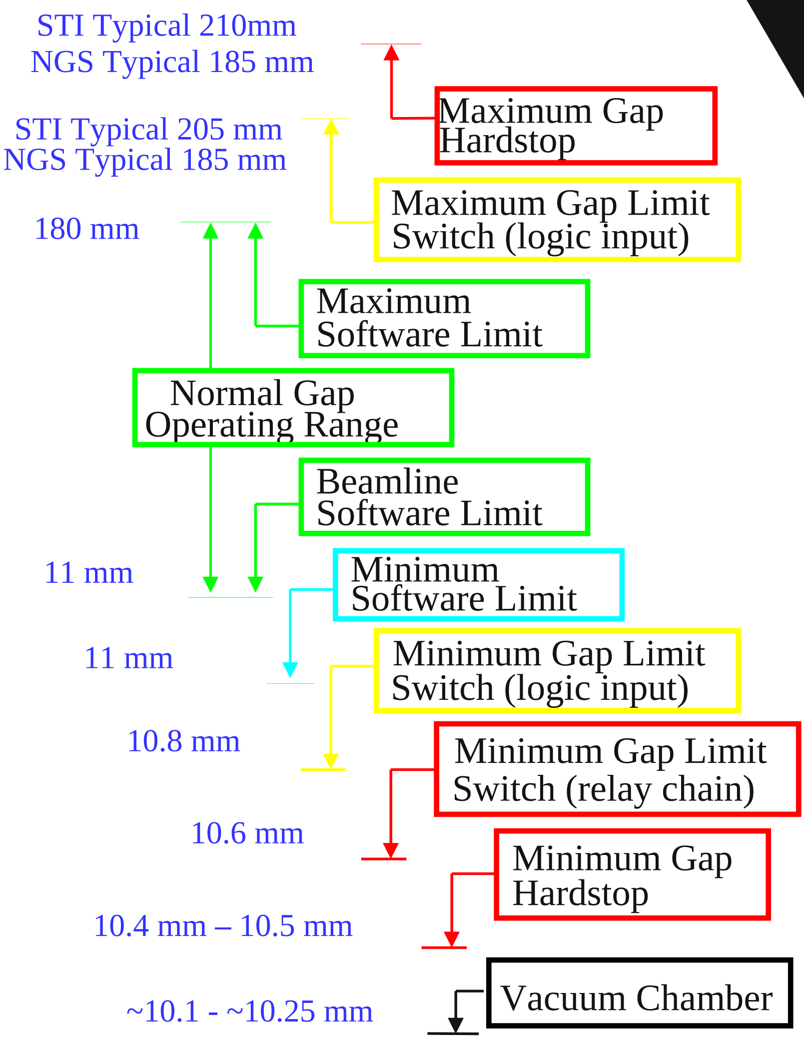
Insertion Device

- Most of the Insertion Devices at APS are permanent magnet hybrid undulators
- Typical devices are 2.4 m long and 3.3 cm period
- APS straight sections can hold 5 m long undulators or two 2.4 m devices
- Initial procurement of undulators were from STI Optronics
- All IDs were magnetically tuned by shimming techniques prior to installation
- APS designed and built its own gap separation mechanisms
- APS now designs and builds the strong back and the magnetic array
- We have two special devices:
  - Elliptical Multipole Wiggler
  - Circularly Polarizing Undulator



Insertion Device

- ID control system is EPICS based
- User has control of ID during operations
- Typical ID vacuum chamber is 8 mm internal aperture and 10.5 mm outside
- One vacuum chamber is 5 mm internal aperture and 7.5 mm external vertical
- Numerous safeguards to protect the device and the vacuum chamber
- STI devices are 2 motors devices while NGS devices are 4 motor devices
- All devices can be tapered to a maximum of 5 mm between the two ends
- Typical operation of the device is untapered and scanned with user optics
- Control system provides controls in energies up to 7th harmonics



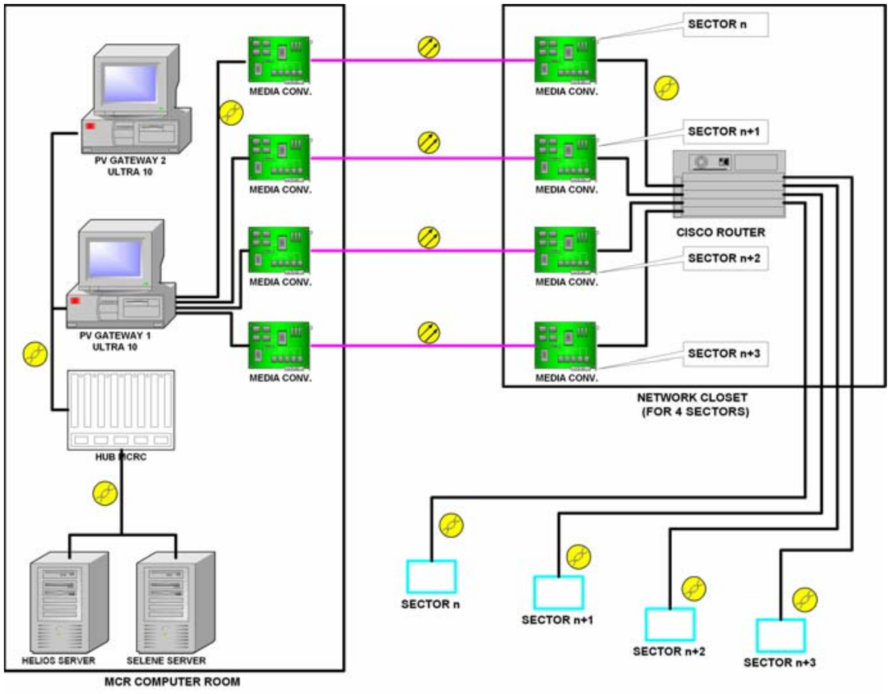
Insertion Devices and their Controls have been very effective in providing a reliable operation over the course of 10 years.

Control System

- The control system of choice at APS is EPICS
- APS had a large staff in the Accelerator Systems Division developing EPICS
- Beamline EPICS development effort was very small
- All APS operated beamlines control system are EPICS based
- Numerous other beamlines also use EPICS
- Insertion device control had to be integrated into the beamline controls
- All ID beamlines require some basic level EPICS interface for ID controls
- Data from the APS control system is needed by the beamline controls
- There was a delayed start on the EPICS buy in from the user community
- Numerous problems existed in interaction between the APS control system and beamline controls in the early days
- EPICS was designed around accelerators. Extending to beamlines were part of growing pains
- Due to computer security, the APS control system was isolated from beamlines
- Development of a gateway interface was dictated due to user control of IDs

Control System

- After various false starts a unique scheme was designed for control systems interface
- Each beamline was provided with an individual Process Variable gateway
- EPICS PV gateway resided in their own beamline subnet
- The PV gateway machine was also their nameserver and timeserver
- EPICS software releases were also distributed through these machines
- Data from the beamline to APS control system are also provided when needed through a reverse gateway



Beamline controls and Accelerator controls have to go hand in hand. There has to be two way communication between the two systems from the beginning.

Beam Stability

- The storage ring has 40 sectors
- Each sector has 9 RF Beam Position Monitors for a total of 360
- Each ID straight section has an additional 2 mini RF BPM
- Each front end has 2 X-ray Beam Position Monitors
  - Bending magnet XBPM is available only for vertical plane
  - Insertion device XBPM is for both horizontal and vertical planes
  - Position and angle are available from the XBPM
- Beam stability is very important for beamlines
- Both short term and long term stability is important

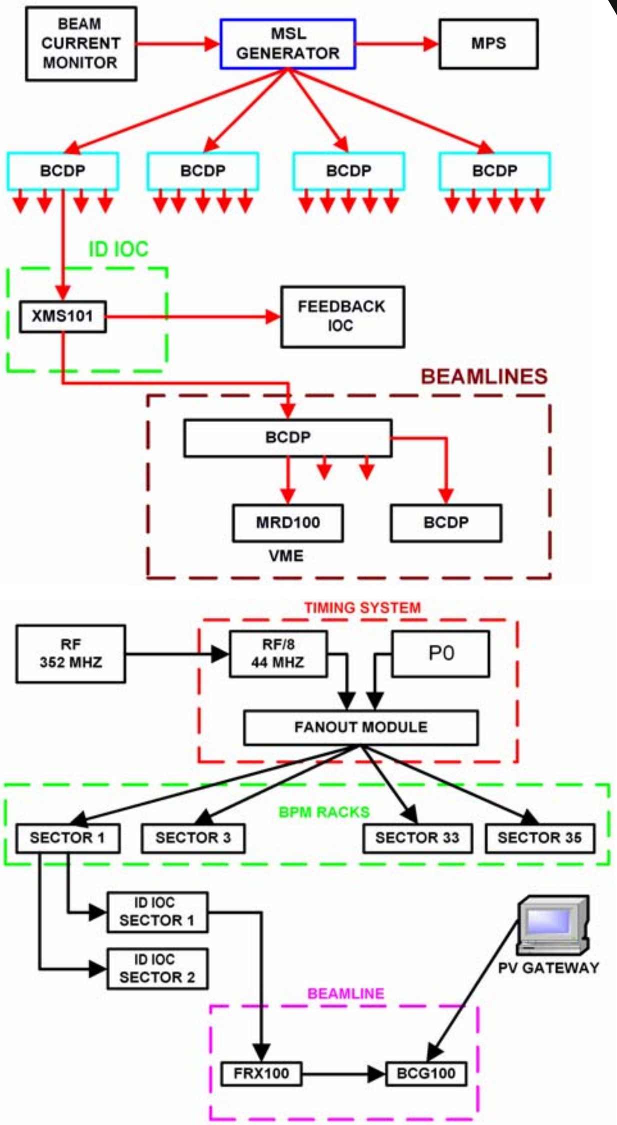
- We have a real time feedback system for fast feedback and a slow feedback system for long term stability and repeatability
- Front End XBPM are now integrated into the feedback system

X-ray BPM located on beamlines is an important tool for beam stability. These can be integrated into the feedback system for improved orbit corrections in real time.

Timing

APS provides two types of timing signals to the beamlines

- A revolution clock signal synced to the first bunch (P0) is provided (~ 3.6 μsec)
- Additional data from the APS control system is also provided in this Machine Status Link
- A faster timing of a signal for each bunch loaded is provided on a separate link
- A dedicated VME module is used to recreate the 352 MHz signal and phase locked with the P0 signal and using the fill pattern the signal is generated



New experiments and detector technology require timing of the system with the time structure of the particle beam.

Provision for providing timing signals between the beamlines and facility should be an integral part of the design of the facility.

Interlocks

- APS chose Programmable Logic Controller based system over hardwired relay logic system for all its interlocks
- All accelerators are interlocked by ACIS
  - Both Chain A and Chain B are Allen-Bradley PLC and provide the redundancy
- Beamline personnel protection is provided by the PSS
  - Chain A is Allen-Bradley and chain B is GE
  - Chain A has in addition to safety oversight, command and control of shutters, doors, etc.
  - Beamlines have hardwired control panels and kirk keys
- Front End equipment protection is provided by the FE-EPS
  - Has one Allen-Bradley PLC
  - Monitors vacuum system and water flow on components
  - Operates all valves in front end and one shutter
  - Interfaces to PSS, BL-EPS and Machine Protection System
- Beamline equipment protection is provided by the BL-EPS
  - Most are PLC based
  - Interfaces to PSS and FE-EPS

Interlocks

- New beamlines are provided the next generation of PSS
  - Has three PLCs
  - Two chains provide the safety oversight
  - Third chain provides the command and control functionality
  - User interface is through touch panel
  - EPICS integration as part of design
- New Front End EPS and beamline EPS are also based on touch screen interface and EPICS controls
- Beamline EPS does not have any formal verification process
  - Based on trust
  - Controlled by the beamline staff

New systems should integrate the chain C with the Front End EPS and the Beamline EPS.

Provides a formal validation and good control over the system.

Chain C does not require the same rigor as the other two safety system.

Provision to monitor and control through the control system of choice should be integrated from the design stage.

Beamline Review

- APS had designed a complete process for CATs for beamline design, construction, commissioning and operation
- All beamlines were required to submit in the following order
  - Conceptual Design Report
  - Management Plan
  - Preliminary Design Report (30 % design level)
  - Final Design Report (90% level)
- Beamline Review Committee consisting of members from accelerator and users reviewed both the PDR and FDR

The BRC had a heavy case load for most of the time in the early days. All members were busy with their normal activities and their membership in this committee was voluntary. While there were some complaints from users about the delays for approval, overall the reviews were comprehensive.

Due to different designs the work load for the committee was high.

Have some dedicated & knowledgeable staff to review. Use as much as possible standardized components.

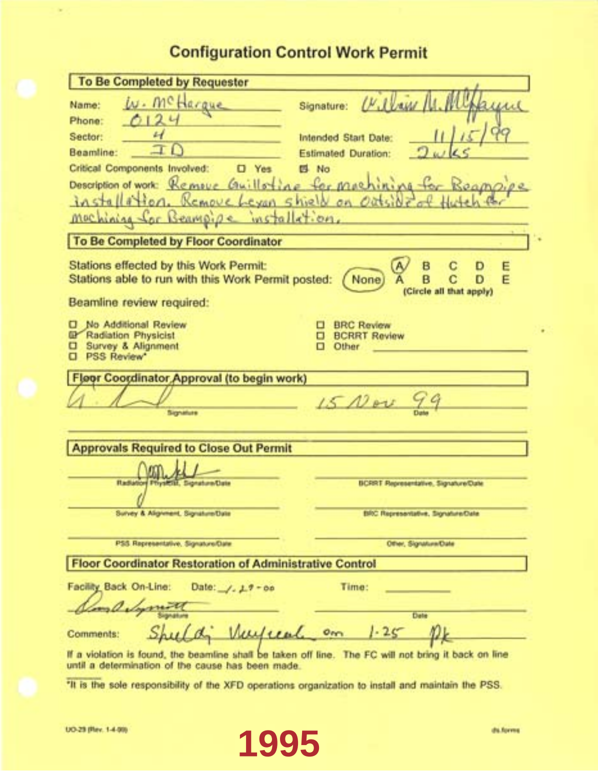
Commissioning and Verification

- Prior to start of commissioning APS developed a complete Beamline Readiness Process
  - Appointed APS staff (myself) as Chair of the team to perform the readiness checks and commission the beamlines
  - To this day I have commissioned every beamline (P. K. Job has also been with me on this till now)
  - The Beamline Commission Readiness Review Team consisted of members from different groups and had a specific role in this team. A beamline staff, Health Physics staff, QA/QC representative were members of this team
  - All outstanding issues from the Beamline Review Committee was handled by this review team for closure
- APS was responsible for initial commissioning of all new beamlines. This included shielding verification of new stations, verification of shutters, collimators and stops. (Contractual responsibility for stations)

This readiness process has been very effective. Worst case shielding scenarios were used to verify the shielding integrity.

Process and Controls

- APS developed numerous processes for beamlines from the start
- Specifically for shielding on beamlines a Configuration Control Work Permit (CCWP) has been in place since 1995
- A configuration Control Work Permit (CCWP yellow form) has to be filled out and approved prior to start of work on any component identified as part of the Radiation Safety System



Configuration Control Work Permit

To Be Completed by Requester

Name: W. McHargue — Signature: William M. McHargue
Phone: 0124
Sector: 4 — Intended Start Date: 11/15/99
Beamline: ID — Estimated Duration: 2 wks
Critical Components Involved: ☐ Yes ☒ No
Description of work: Remove Guillotine for machining for Beampipe installation. Remove Lexan shield on outside of Hutch for machining for Beampipe installation.

To Be Completed by Floor Coordinator

Stations effected by this Work Permit: (A) B C D E
Stations able to run with this Work Permit posted: (None) A B C D E
(Circle all that apply)

Beamline review required:

- ☐ No Additional Review
- ☒ Radiation Physicist
- ☐ Survey & Alignment
- ☐ PSS Review*
- ☐ BRC Review
- ☐ BCRRT Review
- ☐ Other ________

Floor Coordinator Approval (to begin work)

[signature] — Signature; 15 Nov 99 — Date

Approvals Required to Close Out Permit

Radiation Physicist, Signature/Date: [signature]
BCRRT Representative, Signature/Date
Survey & Alignment, Signature/Date
BRC Representative, Signature/Date
PSS Representative, Signature/Date
Other, Signature/Date

Floor Coordinator Restoration of Administrative Control

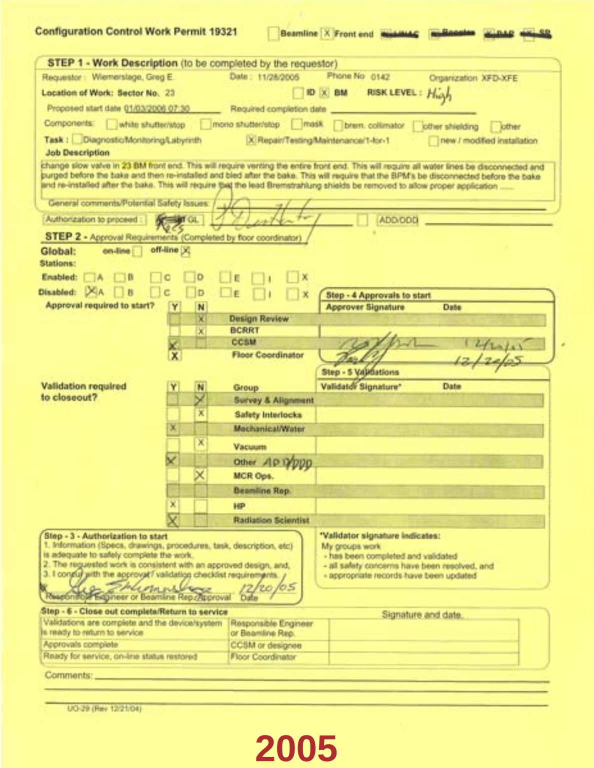
Facility Back On-Line: Date: 1-27-00 Time: ________
[signature] — Signature; Date
Comments: Shielding Verified on 1-25 pk

If a violation is found, the beamline shall be taken off line. The FC will not bring it back on line until a determination of the cause has been made.

*It is the sole responsibility of the XFD operations organization to install and maintain the PSS.

UO-29 (Rev. 1-4-99) ds.forms

1995



Configuration Control Work Permit 19321 ☐ Beamline ☒ Front end [redacted]

STEP 1 - Work Description (to be completed by the requestor)

Requestor: Wiemerslage, Greg E. Date: 11/28/2005 Phone No 0142 Organization XFD-XFE
Location of Work: Sector No. 23 ☐ ID ☒ BM RISK LEVEL: High
Proposed start date 01/03/2006 07:30 Required completion date ________
Components: ☐ white shutter/stop ☐ mono shutter/stop ☐ mask ☐ brem. collimator ☐ other shielding ☐ other
Task: ☐ Diagnostic/Monitoring/Labyrinth ☒ Repair/Testing/Maintenance/1-for-1 ☐ new / modified installation
Job Description
change slow valve in 23 BM front end. This will require venting the entire front end. This will require all water lines be disconnected and purged before the bake and then re-installed and bled after the bake. This will require that the BPM's be disconnected before the bake and re-installed after the bake. This will require that the lead Bremstrahlung shields be removed to allow proper application ......
General comments/Potential Safety Issues:
Authorization to proceed: ☒ GL [signature] ☐ ADD/DDD

STEP 2 - Approval Requirements (Completed by floor coordinator)
Global: on-line ☐ off-line ☒
Stations:
Enabled: ☐ A ☐ B ☐ C ☐ D ☐ E ☐ I ☐ X
Disabled: ☒ A ☐ B ☐ C ☐ D ☐ E ☐ I ☐ X

Approval required to start? Y	N		Step - 4 Approvals to start: Approver Signature	Date
	X	Design Review		
	X	BCRRT		
X		CCSM	[signature]	12/20/05
X		Floor Coordinator	[signature]	12/20/05

Validation required to closeout? Y	N	Group	Step - 5 Validations: Validator Signature*	Date
	X	Survey & Alignment		
	X	Safety Interlocks		
X		Mechanical/Water		
	X	Vacuum		
X		Other AD/DDD		
	X	MCR Ops.		
		Beamline Rep.		
X		HP		
X		Radiation Scientist		

Step - 3 - Authorization to start
1. Information (Specs, drawings, procedures, task, description, etc) is adequate to safely complete the work.
2. The requested work is consistent with an approved design, and,
3. I concur with the approval/ validation checklist requirements.

[signature] 12/20/05
Responsible Engineer or Beamline Rep. Approval — Date

***Validator signature indicates:**
My groups work
- has been completed and validated
- all safety concerns have been resolved, and
- appropriate records have been updated

Step - 6 - Close out complete/Return to service — Signature and date.

Validations are complete and the device/system is ready to return to service	Responsible Engineer or Beamline Rep.	
Approvals complete	CCSM or designee	
Ready for service, on-line status restored	Floor Coordinator	

Comments: ________

UO-29 (Rev 12/21/04)

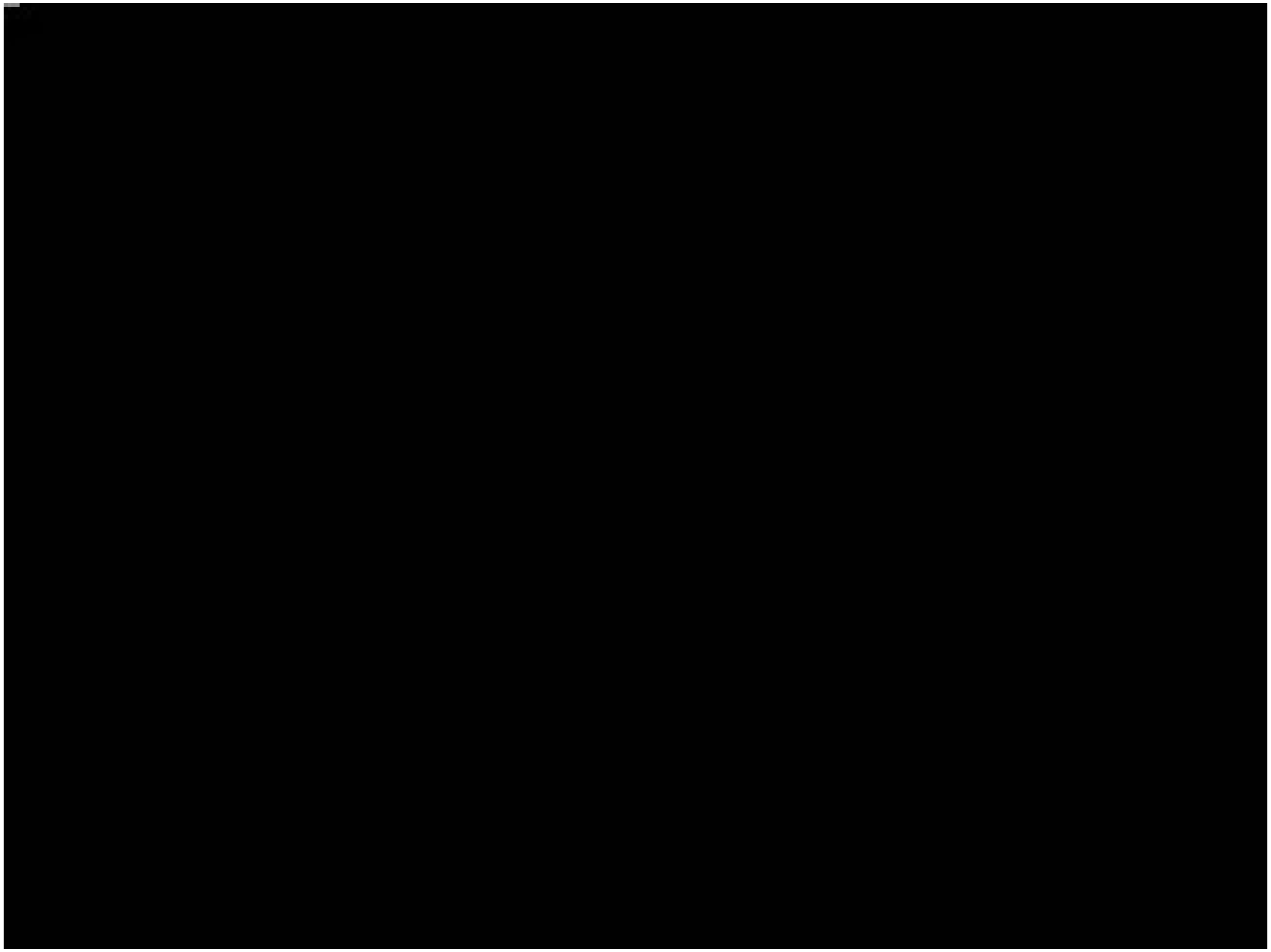
2005

Radiation Safety Systems

- At APS we have had an excellent record on Radiation Safety
- APS developed a culture with the user community based on trust
- All beamline components which are part of the radiation safety are just tagged – no locks
- Access to any of these devices under Configuration Control requires Floor coordinator intervention

- Over the past few years we have had few incidents which had the potential for jeopardizing the operation of this facility
- Most common problems were:
  - Lack of adequate knowledge
  - Unauthorized work on a beamline shutter
  - Work scope creep - working on beamline optics extended to moving a component under configuration control

Final note …..



Thank You