

# Getting Started with EPICS Lecture Series

## Introductory Session I

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8/16/2004

**Argonne National Laboratory**

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





# Getting Started with EPICS

- ASD Controls and AOD BCDA are coordinating a series of lectures entitled "Getting Started with EPICS". Starting in mid-August, the lectures will be held once or twice per week with one or two topics covered each time. The topics will be grouped into five general categories representative of how one might be involved with an EPICS control system:
  - Introduction to EPICS
  - Getting Started with Using EPICS Tools
  - Getting Started with Developing EPICS Tools
  - Getting Started with Input/Output Controllers
  - Applications/Special Topics

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# Introductory Session I

- **Content**
  - Introduction to EPICS
  - Introduction to the "Getting Started" Lecture Series
  - EPICS Vocabulary
  - Introduction to the "Virtual LINAC" Application

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# What is EPICS?

- A Collaboration
- A Control System Architecture
- A Software Toolkit

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## What is EPICS?

- **A Collaboration**
  - Began in 1989 between LANL/GTA & ANL/APS
    - (*Bob Dalesio & Marty Kraimer*)
  - Over 150 license agreements were signed *before* EPICS became “open source”
  - Recent EPICS collaboration meeting in Santa Fe
    - *100+ Attendees*
    - *34 Institutions*
    - *75+ Presentations over 3 days*
  - List server; *tech-talk*: the collaboration in action
  - Collaborative efforts vary
    - *Assist in finding bugs*
    - *Share tools, schemes, and advice*

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## What is EPICS?

- **Major Collaborators**
  - ANL (APS Accelerator, APS Beamlines, IPNS)
  - LANL
  - ORNL (SNS)
  - SLAC (SSRL, LCLS)
  - JLAB (CEBAF)
  - DESY
  - BESSY
  - PSI (SLS)
  - KEK
- **Recent Collaborators**
  - *DIAMOND Light Source* (Rutherford Appleton Laboratory, Oxfordshire)
  - *The Australian Synchrotron (AusSy)* (Melbourne)

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## What is EPICS?

- **A Collaboration**
- **A Control System Architecture**
  - Network-based “client/server” model (hence the EPICS logo)

- For EPICS, *client* and *server* speak of their Channel Access role
  - *i.e. Channel Access Client & Channel Access Server*

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## What is EPICS?

- **Channel Access *clients* are programs that require access to Process Variables to carry out their purpose**

- **The “service” that a Channel Access server provides is access to a Process Variable\***

\* A Process Variable (PV) is a named piece of data.

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## EPICS

# What is EPICS?

- **Process Variable**
  - A **Process Variable** (PV) is a named piece of data associated with the machine (e.g. status, readback, setpoint, parameter)
  - Examples of PV names and values:
    - S1:VAC:reading 3.2e-08 torr
    - LINAC:BPM4:xPosition -0.323 mm
    - BOOSTER:gateValvePosition 'OPEN'
    - S3:DIPOLE:PS:setPoint 123.4 Amps
    - APS:Mode 'Stored Beam'
    - BL3:HISTOGRAM {3, 8, 1, 2, 56, 44, 32, 43, 3, 5, 1}



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## EPICS

# What is EPICS?

- **Process Variable**
  - A **Process Variable** is a named piece of data with a set of attributes
  - Examples of Attributes:
    - Alarm Severity (e.g. NO\_ALARM, MINOR, MAJOR, INVALID)
    - Alarm Status (e.g. LOW, HI, LOLO, HIHI, READ\_error)
    - Timestamp
    - Number of elements (array)
    - Normal Operating Range
    - Control Limits
    - Engineering Unit Designation (e.g. degrees, mm, MW)



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## EPICS

# What is EPICS?

- **A Control System Architecture**
  - Network-based “client/server” model where the basic data element is a Process Variable
  - The Channel Access Protocol defines how Process Variable data is transferred between a server and client
  - The entire set of Process Variables establish a *Distributed Real-time Database* of machine status, information and control parameters

CAS						
Process Variables						



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## EPICS

# What is EPICS?

- **By default, Channel Access traffic is constrained to a single subnet, but configuration options can direct traffic elsewhere**
- **Physical hierarchies can be implemented using switches, routers, and gateways**





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## What is EPICS?

- A Collaboration
- A Control System Architecture
- A Software Toolkit

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## What is EPICS?

- Any tool/program/application that abides by the Channel Access protocol could be described as "EPICS Compliant".
- EPICS can be viewed as a "toolkit" of EPICS compliant programs. One can select the appropriate tool for their need or develop their own.

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## What is EPICS?

- A Collaboration
  - A world wide collaboration that shares designs, software tools, and expertise for implementing large-scale control systems
- A Control System Architecture
  - A client/server model with an efficient communication protocol (Channel Access) for passing data
  - A distributed real-time database of machine values
- A Software Toolkit
  - A collection of software tools collaboratively developed which can be integrated to provide a comprehensive and scalable control system

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## So What Does it Do?

- EPICS tools are available to accomplish almost any typical Distributed Control System (DCS) functionality, such as:
  - Remote Control & Monitoring of Technical Equipment
  - Data Conversion/Filtering
  - Closed Loop Control
  - Access Security
  - Equipment Operation Constraints
  - Alarm Detection/Reporting/Logging
  - Data Trending/Archiving/Retrieval/Plotting
  - Automatic Sequencing
  - Mode & Facility Configuration Control (save/restore)
  - Modeling/Simulation
  - Data Acquisition
  - Data Analysis

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### How does it do it?

The diagram illustrates the data flow from a Channel Access Server to various hardware components. The server's process variables (S1A:H1:CurrentAD, S1:P1:x, S1:P1:y, S1:G1:vacuum) are accessed via computer interfaces. These interfaces connect to hardware such as Power Supply, Beam Position Monitor, and Vacuum Gauge, which are part of a larger experimental facility.

**Channel Access Server**  
**Process Variables:**  
 S1A:H1:CurrentAD  
 S1:P1:x  
 S1:P1:y  
 S1:G1:vacuum

**Hardware Components:**  
 Power Supply  
 Beam Position Monitor  
 Vacuum Gauge

**Client Software:**  
 Channel Access Client

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### Where does it do it?

This diagram shows the same hardware components as slide 17, but with yellow callouts indicating specific EPICS capabilities. The callouts include: Remote Control & Monitoring, Alarm Logging/Reporting, Closed-loop Control, Operational Constraints, Automatic Sequencing, Data Trending/Archiving, Modeling/Simulation/Analysis, and Configuration Control.

**Channel Access Server**  
**Process Variables:**  
 S1A:H1:CurrentAD  
 S1:P1:x  
 S1:P1:y  
 S1:G1:vacuum

**Hardware Components:**  
 Power Supply  
 Beam Position Monitor  
 Vacuum Gauge

**Client Software:**  
 Channel Access Client

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### Canonical Form of an EPICS Control System

This diagram shows the canonical form of an EPICS control system. It is a hierarchical structure starting with Client Software (MEDM, OAG Apps, ALH, TCLTK, StripTool, Perl Scripts, etc.) at the top, which connects to Channel Access. Channel Access connects to IOC Software (EPICS Database, Custom Programs, Sequence Programs, Real-time Control). IOC Software connects to Commercial Instruments and Custom Chassis/Panels, which in turn connect to Technical Equipment. A CA Server Application (Process Variables) also connects to the IOC Software.

**Client Software**  
 MEDM OAG Apps  
 ALH TCLTK StripTool  
 Perl Scripts Many, many others

**Channel Access**

**IOC Software**  
 EPICS Database Custom Programs  
 Sequence Programs Real-time Control

**Commercial Instruments** **Custom Chassis/Panels**

**Technical Equipment**

**CA Server Application**  
 Process Variables

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### Typical Realizations of an EPICS System

This diagram shows typical realizations of an EPICS system. It includes a control room with multiple computer workstations and a server rack containing various hardware components. The structure is similar to the canonical form, showing the connection between client software, channel access, IOC software, and hardware.

**Client Software**

**Channel Access**

**IOC Software**

**Commercial Instruments** **Custom Chassis/Panels**

**Technical Equipment**

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**EPICS**

### Typical Realizations of an EPICS System

The diagram shows a hierarchy of components. At the top are client computers. Below them are IOC (green), CAS (red), and IOC (red) components. These connect to Commercial Instruments (blue) and Custom Chassis/Panels (teal), which in turn connect to Technical Equipment (orange). Arrows indicate bidirectional communication between the IOC/CAS/IOC layer and the instruments/chassis, and between the instruments/chassis and the technical equipment.

Most CAS Apps were based on Unix or Windows

All IOCs were based on vxWorks (mostly VME)

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### Typical Realizations of an EPICS System

This diagram is similar to slide 21 but includes logos for various operating systems: Mac, Windows, Sun, and Linux. It also shows images of RTEMs (Real Time Embedded Modules) hardware. A bullet point states: "With Release 3.14, the operating system limitations for iocCore have been removed."

With Release 3.14, the operating system limitations for iocCore have been removed.

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**EPICS**

### Typical Realizations of an EPICS System

The diagram is titled "Driving a motor with EPICS" and shows the evolution of the system. On the left is the standard architecture. On the right, a blue arrow points to a computer labeled "circa 1995". A second blue arrow points to a rack of hardware labeled "circa 2002".

Driving a motor with EPICS

circa 1995

circa 2002

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**EPICS**

### Canonical Form of an EPICS Control System

This diagram defines the canonical form of an EPICS control system. It includes callouts for different software layers:
 

- Client Software:** MEDM, OAG Apps, ALH, TCL/TK, StripTool, Perl Scripts, Many, many others.
- Channel Access:** A layer between the client and the IOC.
- IOC Software:** EPICS Database, Sequence Programs, Custom Real-time Programs, Control.
- CA Server Application:** Process Variables.

Client Software  
MEDM OAG Apps  
ALH TCL/TK StripTool  
Perl Scripts Many, many others

Channel Access

IOC Software  
EPICS Database  
Sequence Programs Custom Real-time Programs Control

CA Server Application  
Process Variables

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**Standalone CA Clients** (from EPICS Website)

- ADT: Array Display Tool
- ALH: Alarm Handler
- AR: Data Archiver (the original, deprecated)
- BURT: Backup and Restore Tool
- CAEX: Channel Access Examples
- CASR: Host-based Save/Restore
- CAU: Channel Access Utility
- Channel Archiver (SNS)
- Channel Watcher (SLAC)
- DM2K: Display Manager 2000 (BESSY)
- EDD/DM: Editor and Display Manager (LANL)
- EDM: Extensible Display Manager (ORNL)
- HistTool: Data Histogramming Tool
- JoiMint: Java Operator Interface and Management Integration Toolkit (DESY)
- Jprobe: Java Version of Probe, a Channel Monitoring Program
- Knobs: Knob Manager and KnobConfig, an Interface to SunDials
- MEDM: Motif Editor and Display Manager
- Probe: Motif Channel Monitoring Program
- StripTool: Strip-chart Plotting Tool
- Yviewer: Data Visualization Tool

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**Canonical Form of an EPICS Control System**

Client Software  
MEDM OAG Apps  
ALH TCL/TK StripTool  
Perl Scripts Many, many others

Channel Access

IOC Software  
EPICS Database Custom Programs  
Sequence Programs Real-time Control

Commercial Instruments Custom Chassis/Panels  
Technical Equipment

CA Server Application  
Process Variables

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**Channel Access in One Slide**

CA Client

CA Server

Channel Access Server

Process Variables:  
S1A:H1:CurrentAO  
S1:P1-x  
S1:P1-y  
S1:G1:vacuum

"connection request" or "search request"

"get" or "caGet"

"put" or "caPut"

"set a monitor"

Who has a PV named "S1A:H1:CurrentAO"?

Change its value to 30.5

Notify me when the value changes

I do.

25.5 AMPS

OK, it is now 30.5

It is now 20.5 AMPS

It is now 10.5 AMPS

It is now -0.0023 AMPS

"put complete"

30.5 is too high. It is now set to the maximum value of 27.5.

"post an event" or "post a monitor"

You are not authorized to change this value

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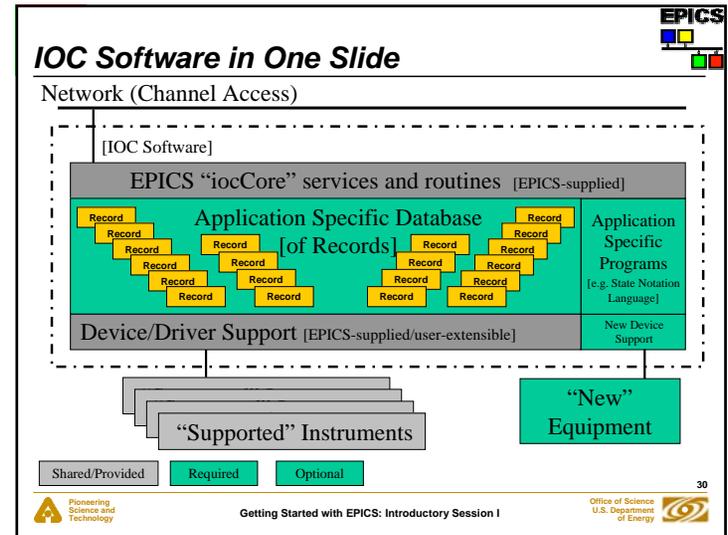
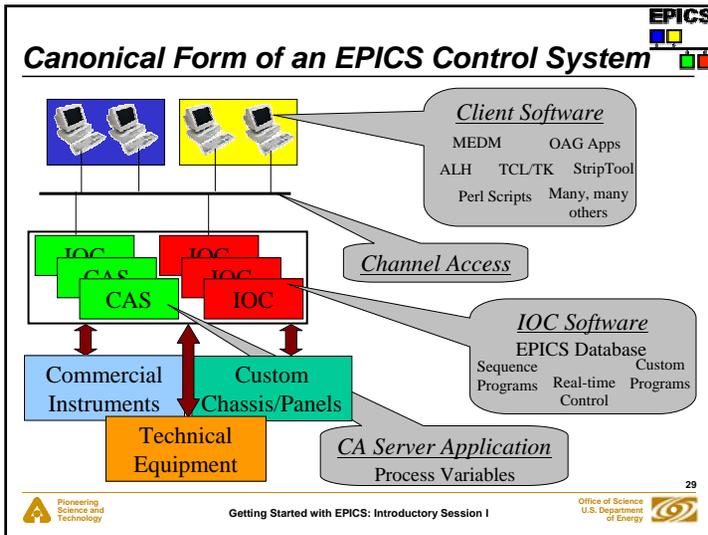
**Key Features of Channel Access ...**

- Clients broadcast PV names to find the server in which they exist
- Channel Access Security can be applied to limit access to Process Variables
- Clients can wait until a 'put request' is completed before proceeding
- Clients can 'set monitors' on PVs and will then be notified when the value changes

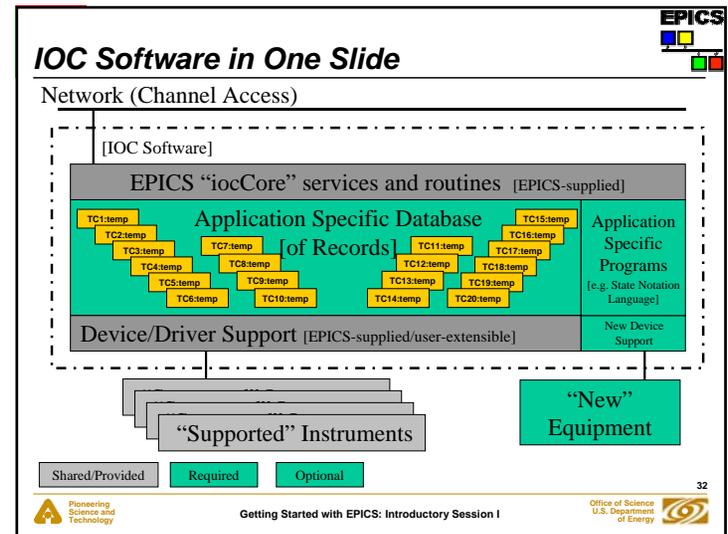
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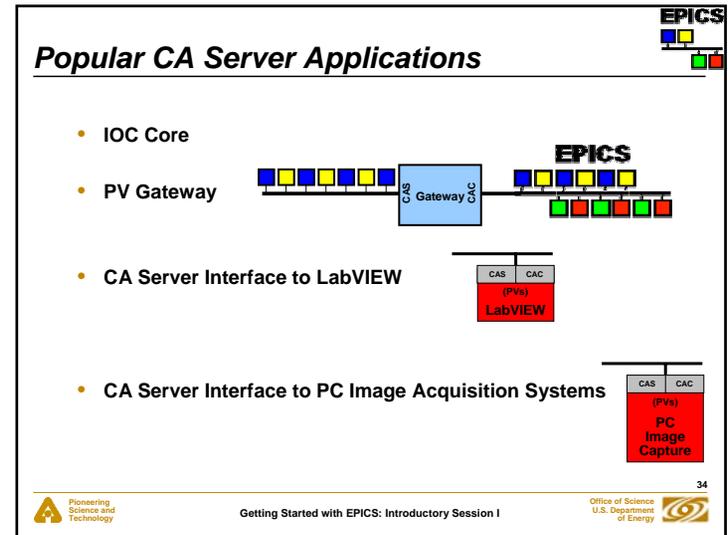
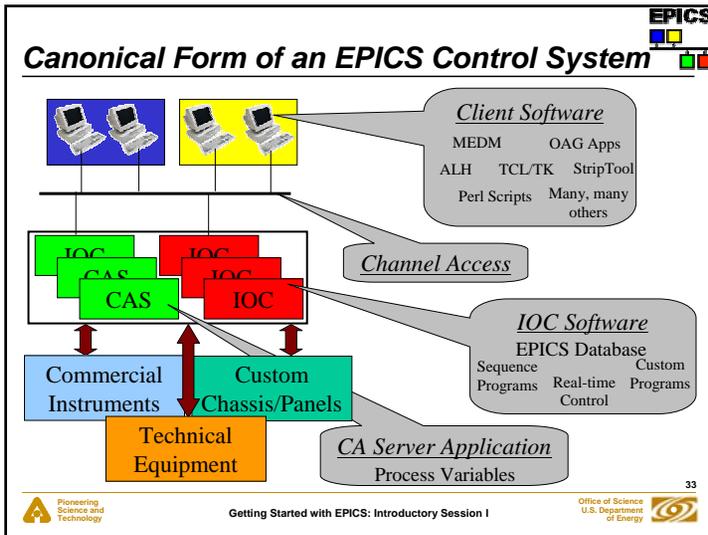
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- ### Key Features of IOC software ...
- **Two primary application specific components:**
    - The real-time database of records (required)
    - State Notation Language programs used to implement state oriented programs (finite-state machine)
  - **Machine status, information and control parameters are defined as "records" in the application specific database.**
  - **The data within a record is accessible via Process Variables.**
  - **Records have some functionality associated with them (scaling, filtering, alarm detection, calculations, etc). Different record types have different functions and uses.**
  - **Records are frequently associated with I/O equipment that requires unique "device support" for that instrument.**
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- ## Ten really neat things about EPICS
- It's free
  - It's Open Source
  - There are lots of users
  - All a client needs to know to access data is a PV name
  - You can pick the best tools out there ...
  - ... or build your own
  - The boring stuff is already done
  - There is a lot of expertise available close by
  - A good contribution becomes internationally known
  - By following a few simple rules, you get a lot for free
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- ## Vocabulary
- **EPICS**
    - Experimental Physics and Industrial Control System
  - **Channel Access**
    - The communication protocol used by EPICS
  - **Process Variable**
    - A piece of named data referred to by its PV name
    - The primary object of the Channel Access Protocol
  - **Channel**
    - A synonym for Process Variable
  - **Channel Access Server**
    - Software that provides access to a Process Variable using the Channel Access Protocol
  - **Channel Access Client**
    - Software that requests access to a Process Variable using the Channel Access Protocol
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**EPICS**

## Vocabulary

- **IOC – Input Output Controller**
  - A computer running *iocCore*, a set of EPICS routines used to define process variables and implement real-time control algorithms
  - *iocCore* uses database records to define process variables and their behavior
- **Soft IOC**
  - An instance of *iocCore* running as a process on a “non-dedicated” computer (i.e. a computer that is performing other functions as well)
- **Record**
  - The mechanism by which a Process Variable is defined in an IOC (using *iocCore*)
  - Dozens of record types exist, each with it’s own attributes and processing routine that describe its functionality

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**EPICS**

## Good Questions to Ask ...

- Does it talk [EPICS, Channel Access]?
- Is there an EPICS tool to do [*whatever*]?
- What is the PV name of the [sector 29 vacuum gauge reading]?
- Is there EPICS device support for [*the instrument I want to use*]?
- What computer platform is being used?
- Where is that function being performed?
  - In a Client? In an IOC? In a custom CAS Application?
- Why can't my CA client find the PV in the CA server on another subnet?

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**EPICS**

## Categories of EPICS Training

- Getting Started with Using EPICS Tools
- Getting Started with Developing EPICS Tools
- Getting Started with Input/Output Controllers

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**EPICS**

## A Sample of Topics ...

- **Introduction to EPICS**
  - What is EPICS? What are the lectures about?
- **Getting Started with Using EPICS Tools**
  - MEDM, Alarm Handler, OAG Toolkit, Channel Archiver, etc.
- **Getting Started with Developing EPICS Tools**
  - Tcl/Tk, Perl, IDL, JAVA, Python, CA Server Applications
- **Getting Started with Input/Output Controllers (IOCs)**
  - EPICS Databases, VisualIDCT, State Notation Language, record and device support, etc.
- **Applications/Special Topics**
  - synApps, motors, scans, data visualization, etc.

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**Current Plans:** [www.aps.anl.gov/aod/bcda/epicsgettingstarted/index.htm](http://www.aps.anl.gov/aod/bcda/epicsgettingstarted/index.htm)

- **8/16/04; 2:00 – 4:30 PM; APS Auditorium**
  - An Introduction to EPICS
- **8/17/04; 2:00 – 4:30 PM; APS Auditorium**
  - Overview of Client Tools
  - MEDM
- **8/23/04; 2:00 – 4:30 PM; APS Auditorium**
  - Alarm Handler
  - OAG Tools
- **8/24/04; 2:00 – 4:30 PM; APS Auditorium**
  - Channel Archiver & Viewer
  - Remote Access
- **8/27/04 - APS Shutdown**

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**A Sample of Topics ...**

- **Introduction to EPICS**
  - What is EPICS? What are the lectures about?
- **Getting Started with Using EPICS Tools**
  - MEDM, Alarm Handler, OAG Toolkit, Channel Archiver, etc.
- **Getting Started with Developing EPICS Tools**
  - Tcl/Tk, Perl, IDL, JAVA, Python, CA Server Applications
- **Getting Started with Input/Output Controllers (IOCs)**
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  - synApps, motors, scans, data visualization, etc.

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**Virtual LINAC Application**

- A pre-packaged EPICS application for you to install, operate, enhance, manipulate, etc.

Same Solaris Workstation  
Same LINUX PC  
Same MAC  
Same Windows PC

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**Virtual LINAC Application**

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# Virtual LINAC Application

**The LINAC:** The electrons that circulate in the APS Storage Ring originate in a machine called a Linear Accelerator (LINAC). The electrons are generated by heating a cathode in an "electron gun" and are accelerated as they travel through "accelerating cavities" along the LINAC. Because electrons are charged particles, they can be steered through the narrow vacuum chamber using electro-magnets (magnets that vary in strength as the current is changed through their coils). Obviously, if the electrons are mis-steered and hit the side of the vacuum chamber, they immediately lose their energy and are lost.

**The Operator:** Using the APS Remote Control System, the operator can monitor and control all of the equipment in the facility using the workstations in the Main Control Room. For this demonstration, the operator must control and monitor the temperature of the electron gun cathode, monitor the position of the beam within the vacuum chamber, adjust the steering magnet currents to properly steer the electrons, and control a gate valve (a device that blocks any air and particles from different sections of the LINAC).

**The Challenge:** Follow the steps below to successfully generate and transport electrons to the end of the LINAC.

**STEP 1:** Adjust the blue slider to change the current used to heat the cathode until the cathode temperature is within the desired range (the bar will turn green).

**STEP 2:** Press "Beam On" to send the electrons down the LINAC.

**STEP 3:** Adjust the current through the steering magnets (H1 & V1) until both the horizontal position (X) and the vertical position (Y) are less than 1mm. The positions are plotted on the chart above in BLUE (X) and BROWN (Y). The RED line in the plot represents the number of electrons, which decreases as the beam travels down the line.

**STEP 4:** More steering required ...

**STEP 5:** You will need to open the Gate Valve to let the electrons continue....

**STEP 6:** Adjust the remaining steering magnet currents to transport beam to the end. The final current is measured by a Faraday Cup (FC). Fine tune all the steering magnets to transport the maximum amount of beam current to the end of the LINAC (15 mA is excellent!).

**STEP 7:** RESET will prepare the virtual LINAC for the next operator.

**HELP for the frustrated:** Give up? Push the "Auto-Start" and let the computer take over!



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