Getting Started with EPICS Lecture Series

Introductory Session I

Ned Arnold
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

Introductory Session I

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

What is EPICS?

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

What is EPICS?

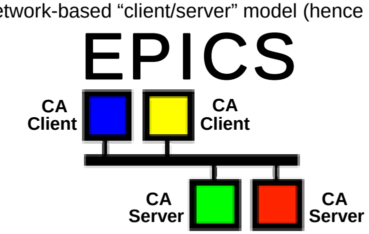
- **A Collaboration**
  - Began in 1989 between LANL/GTA & ANL/APS
    - *(Bob Dalesio & Marty Kraimer)*
  - Over 150 license agreements were signed *before* EPICS became “open source”
  - Recent EPICS collaboration meeting in Santa Fe
    - *100+ Attendees*
    - *34 Institutions*
    - *75+ Presentations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

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)*

What is EPICS?

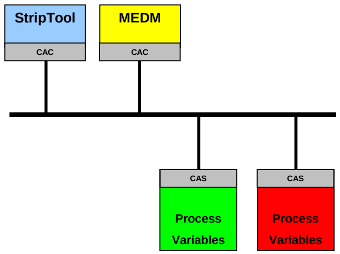
- **A Collaboration**
- **A Control System Architecture**
  - Network-based “client/server” model (hence the EPICS logo)



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

What is EPICS?

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



- **The “service” that a Channel Access *server* provides is access to a <u>*Process Variable*</u>***

*** A <u>*Process Variable*</u> (PV) is a named piece of data.**

What is EPICS?

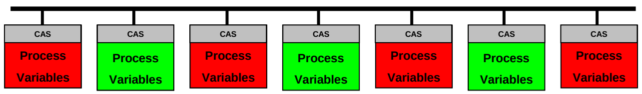
- **Process Variable**
  - A ***Process Variable*** (PV) is a named piece of data associated with the machine (e.g. status, readback, setpoint, parameter)
  - Examples of PV names and values:
    - *S1:VAC:reading* 3.2e-08 torr
    - *LINAC:BPM4:xPosition* -0.323 mm
    - *BOOSTER:gateValvePosition* '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}

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)*

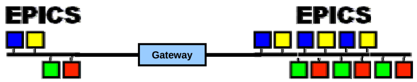
What is EPICS?

- **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



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**

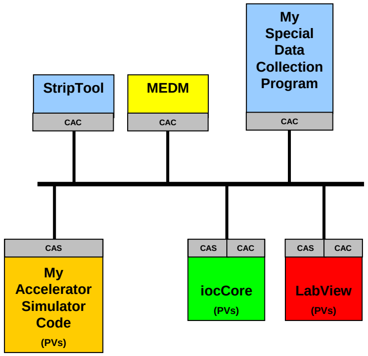


What is EPICS?

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

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.**

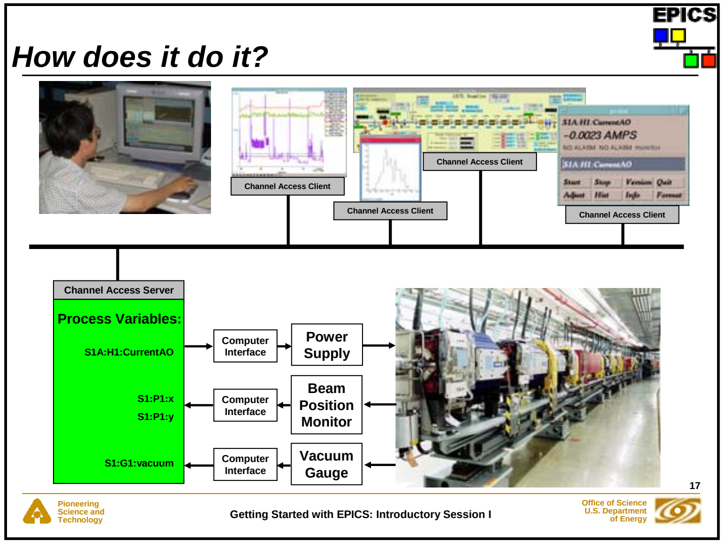


What is EPICS?

- **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

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


EPICS
How does it do it?
Channel Access Client
Channel Access Client
Channel Access Client
Channel Access Client
Channel Access Server
Process Variables:
S1A:H1:CurrentAO
S1:P1:x
S1:P1:y
S1:G1:vacuum
Computer Interface
Power Supply
Computer Interface
Beam Position Monitor
Computer Interface
Vacuum Gauge
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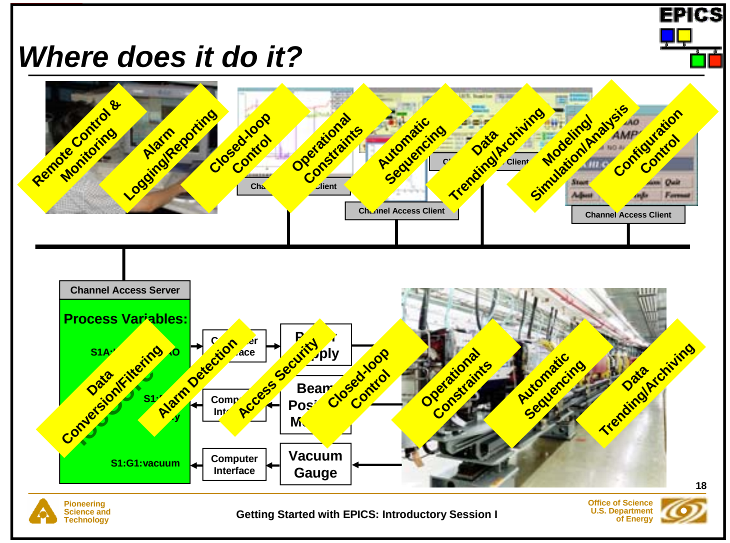
EPICS
Where does it do it?
Remote Control & Monitoring
Alarm Logging/Reporting
Closed-loop Control
Operational Constraints
Automatic Sequencing
Data Trending/Archiving
Modeling/ Simulation/Analysis
Configuration Control
Channel Access Client
Channel Access Client
Channel Access Server
Process Variables:
S1:G1:vacuum
Data Conversion/Filtering
Alarm Detection
Access Security
Closed-loop Control
Operational Constraints
Automatic Sequencing
Data Trending/Archiving
Computer Interface
Vacuum Gauge
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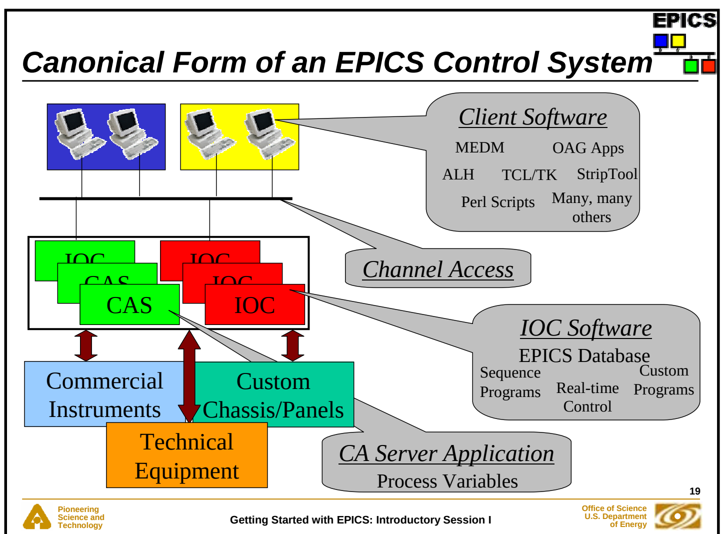
EPICS
Canonical Form of an EPICS Control System
Client Software
MEDM
OAG Apps
ALH
TCL/TK
StripTool
Perl Scripts
Many, many others
Channel Access
CAS
IOC
IOC Software
EPICS Database
Sequence Programs
Real-time Control
Custom Programs
Commercial Instruments
Custom Chassis/Panels
Technical Equipment
CA Server Application
Process Variables
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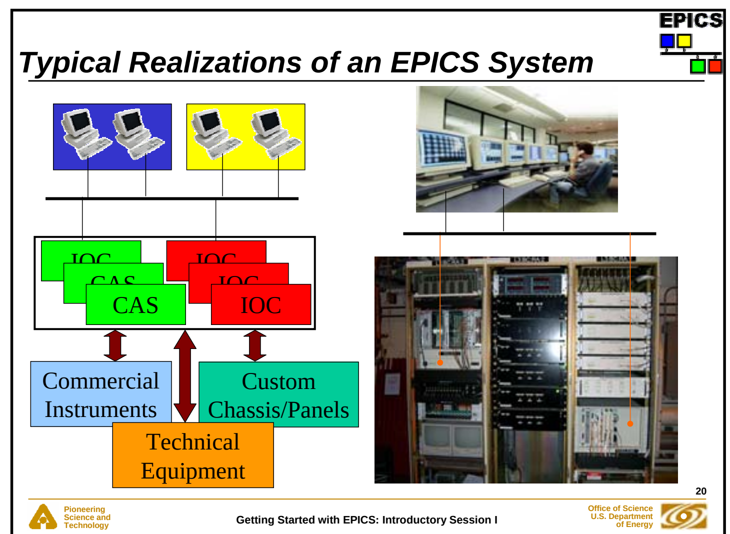
EPICS
Typical Realizations of an EPICS System
CAS
IOC
Commercial Instruments
Custom Chassis/Panels
Technical Equipment
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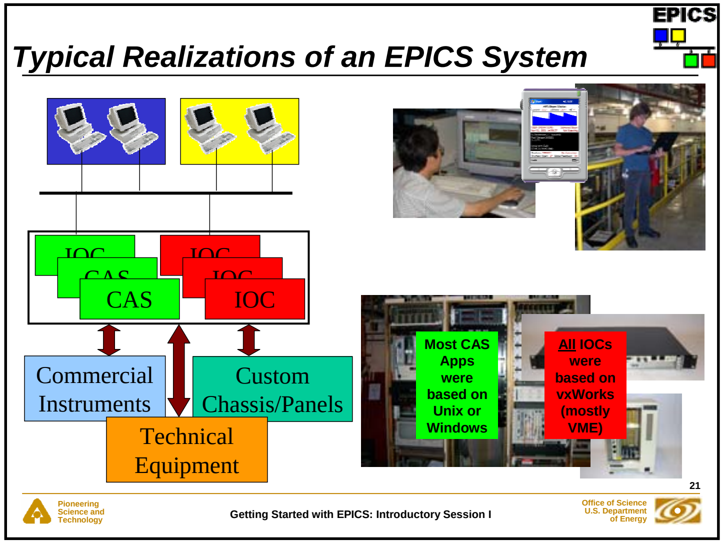
Typical Realizations of an EPICS System
EPICS
IOC
CAS
IOC
CAS
IOC
Commercial Instruments
Custom Chassis/Panels
Technical Equipment
Most CAS Apps were based on Unix or Windows
All IOCs were based on vxWorks (mostly VME)
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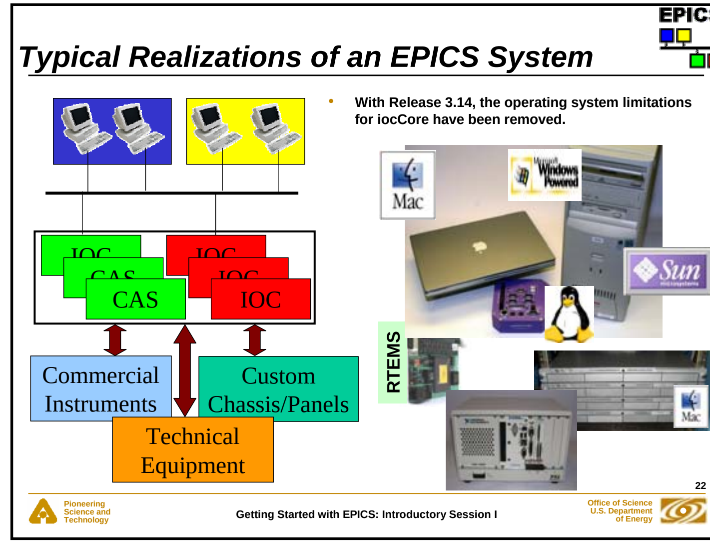
Typical Realizations of an EPICS System
EPICS
With Release 3.14, the operating system limitations for iocCore have been removed.
IOC
CAS
IOC
CAS
IOC
Commercial Instruments
Custom Chassis/Panels
Technical Equipment
Mac
Windows Powered
Sun
RTEMS
Mac
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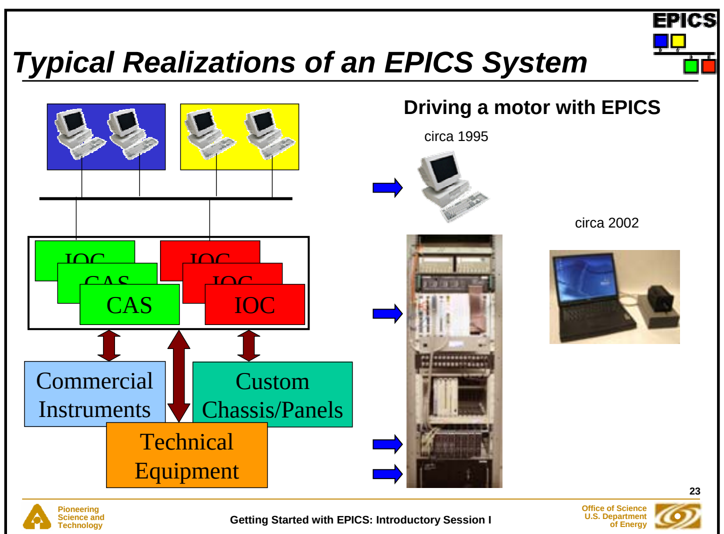
Typical Realizations of an EPICS System
EPICS
Driving a motor with EPICS
circa 1995
circa 2002
IOC
CAS
IOC
CAS
IOC
Commercial Instruments
Custom Chassis/Panels
Technical Equipment
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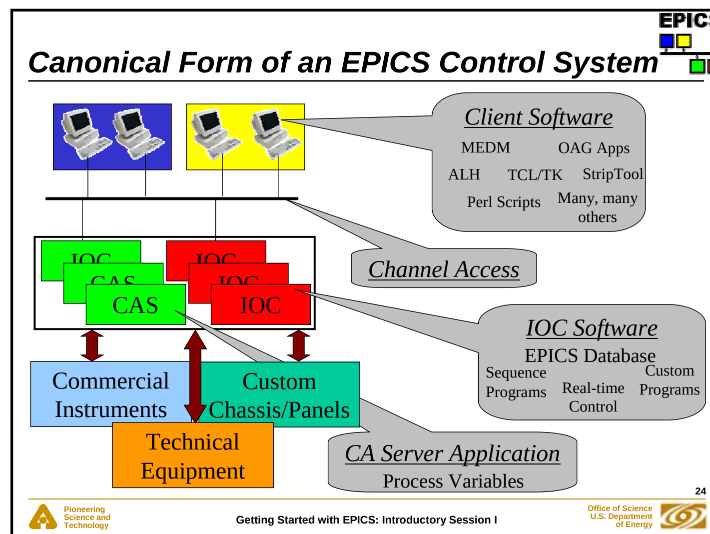
Canonical Form of an EPICS Control System
EPICS
Client Software
MEDM
OAG Apps
ALH
TCL/TK
StripTool
Perl Scripts
Many, many others
Channel Access
IOC Software
EPICS Database
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CA Server Application
Process Variables
IOC
CAS
IOC
CAS
IOC
Commercial Instruments
Custom Chassis/Panels
Technical Equipment
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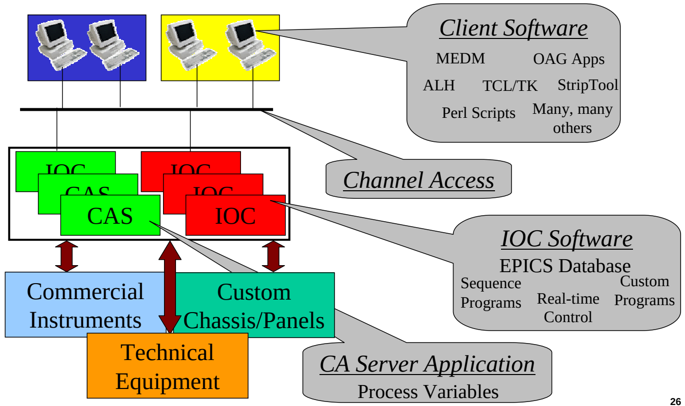
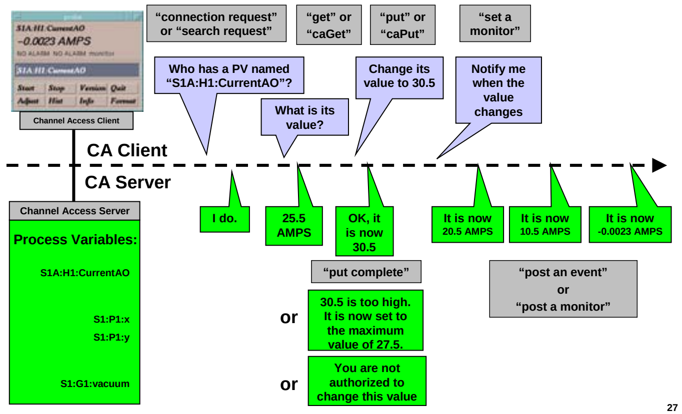
Standalone CA Clients (from EPICS Website)

- **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

Canonical Form of an EPICS Control System



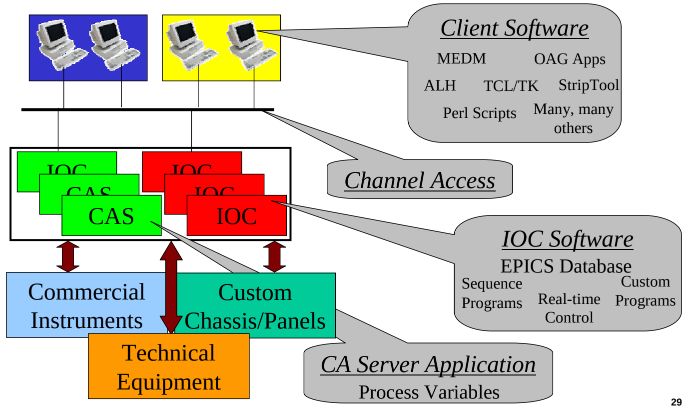
Channel Access in One Slide



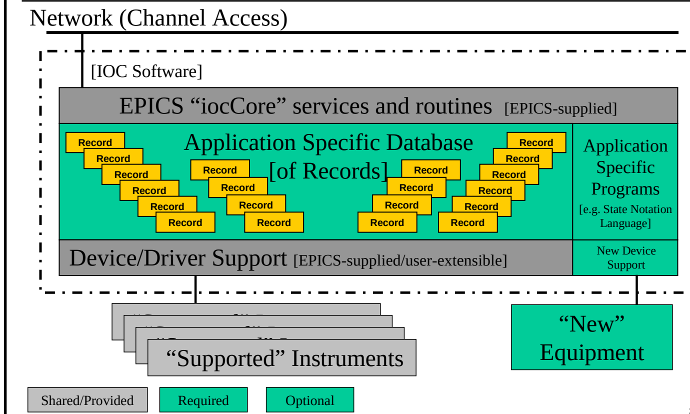
Key Features of Channel Access …

- **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**

Canonical Form of an EPICS Control System



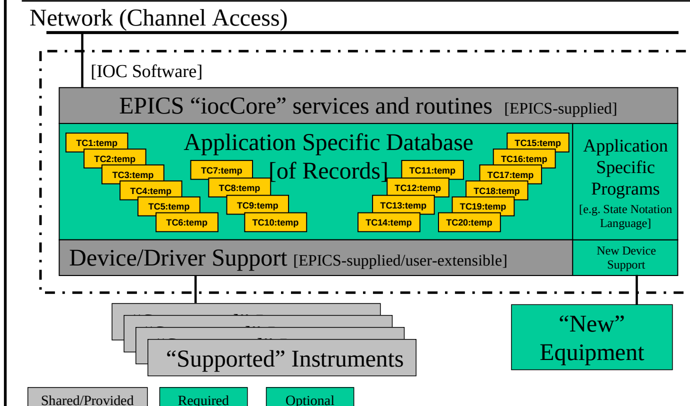
IOC Software in One Slide



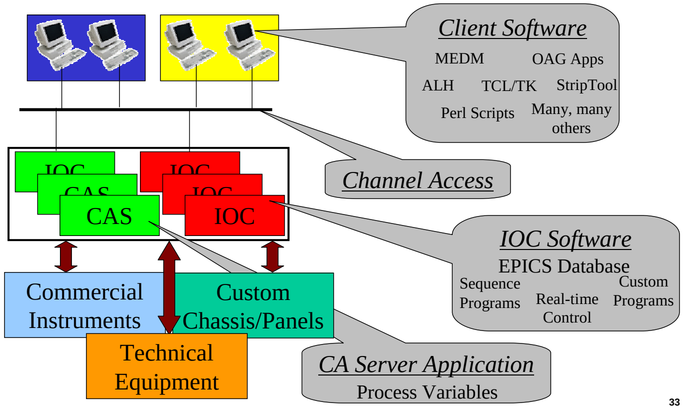
Key Features of IOC software …

- **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.**

IOC Software in One Slide

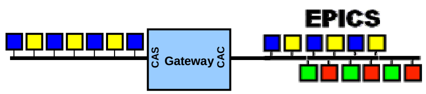


Canonical Form of an EPICS Control System

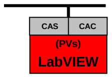


Popular CA Server Applications

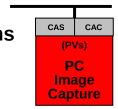
- IOC Core
- PV Gateway



- CA Server Interface to LabVIEW



- CA Server Interface to PC Image Acquisition Systems



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**

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

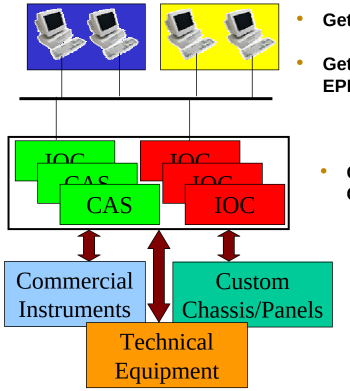
Vocabulary

- **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

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?**

Categories of EPICS Training



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

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, VisualDCT, State Notation Language, record and device support, etc.
- **Applications/Special Topics**
  - synApps, motors, scans, data visualization, etc.

Current Plans: *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**

A Sample of Topics …

August

- **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.

Sept

- **Getting Started with Developing EPICS Tools**
  - Tcl/Tk, Perl, IDL, JAVA, Python, CA Server Applications

Oct/Nov

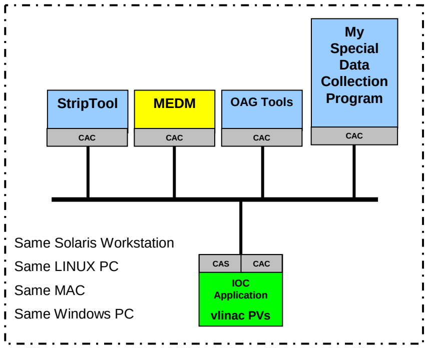
- **Getting Started with Input/Output Controllers (IOCs)**
  - EPICS Databases, VisualDCT, State Notation Language, record and device support, etc.

Nov …

- **Applications/Special Topics**
  - synApps, motors, scans, data visualization, etc.

Virtual LINAC Application

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



Virtual LINAC Application

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.