

EPICS Lecture @ KEK

Introduction Part I

Takashi Nakamoto
June 25th, 2013

Based on presentation by Ned Arnold, APS

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**

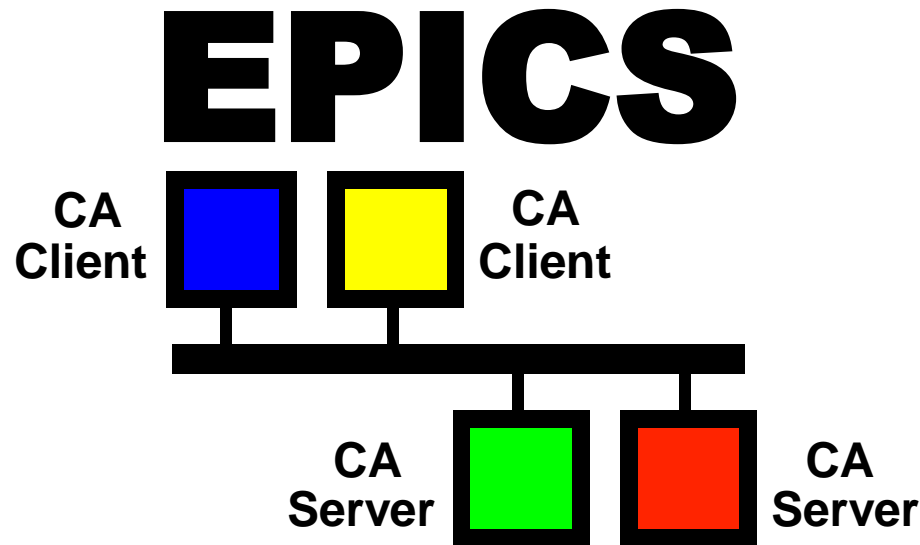
- ANL (APS Accelerator, APS Beamlines, IPNS)
- LANL
- ORNL (SNS)
- SLAC (SSRL, LCLS)
- JLAB (CEBAF)
- DESY
- BESSY
- PSI (SLS)
- KEK

- **Recent Collaborators**

- *DIAMOND Light Source* (Rutherford Appleton Laboratory, Oxfordshire)
- *The Australian Synchrotron (AusSy) (Melbourne)*

What is EPICS?

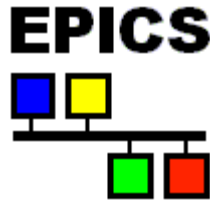
- A Collaboration
- A Control System Architecture
 - Network-based “client/server” model (hence the EPICS logo)



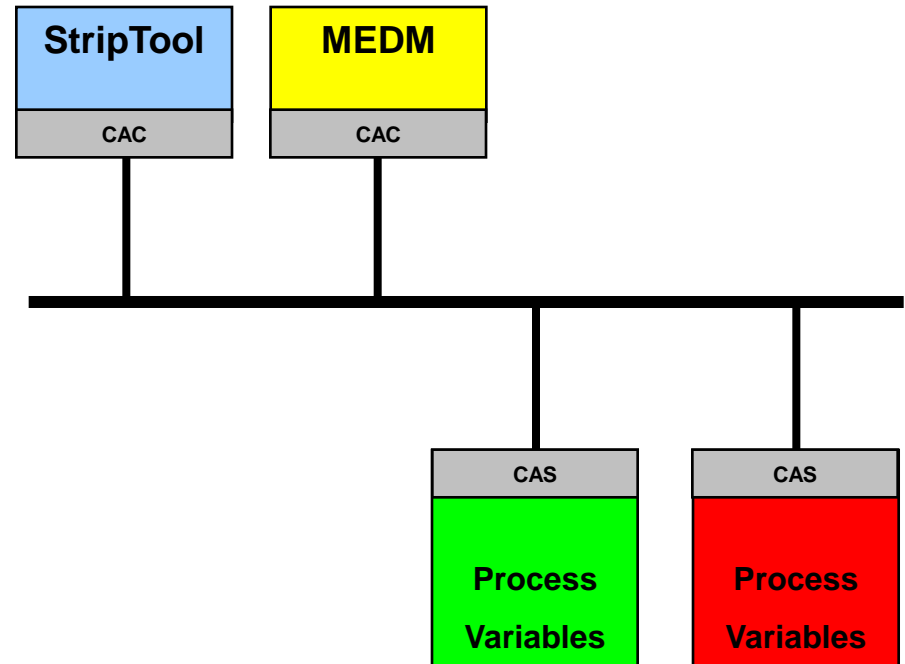
- For EPICS, *client* and *server* speak of their Channel Access role
 - *i.e. Channel Access Client & Channel Access Server*

What is EPICS?

- Channel Access *clients* are programs that require access to 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.

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}**

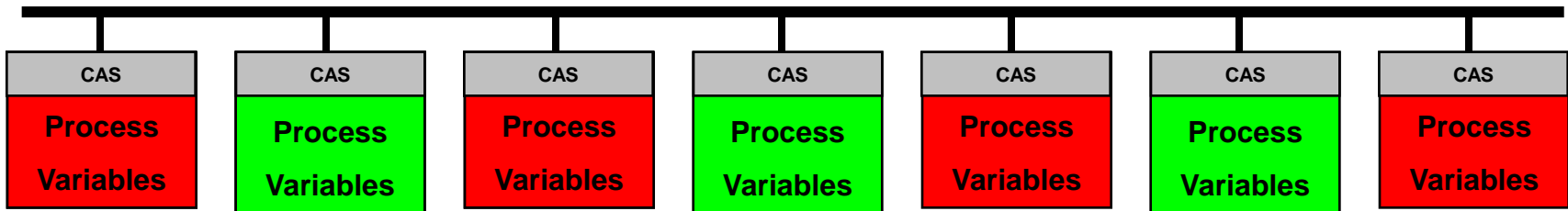
What is EPICS?

- **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)*

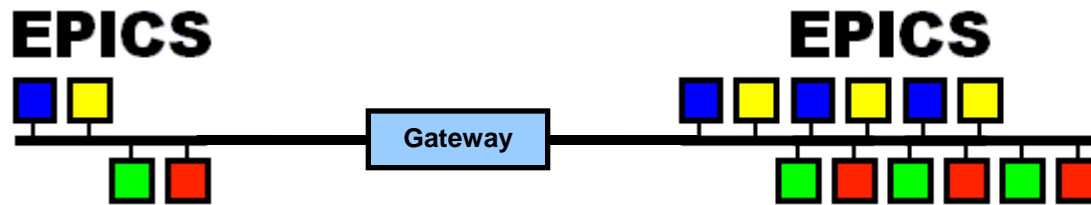
What is EPICS?

- **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

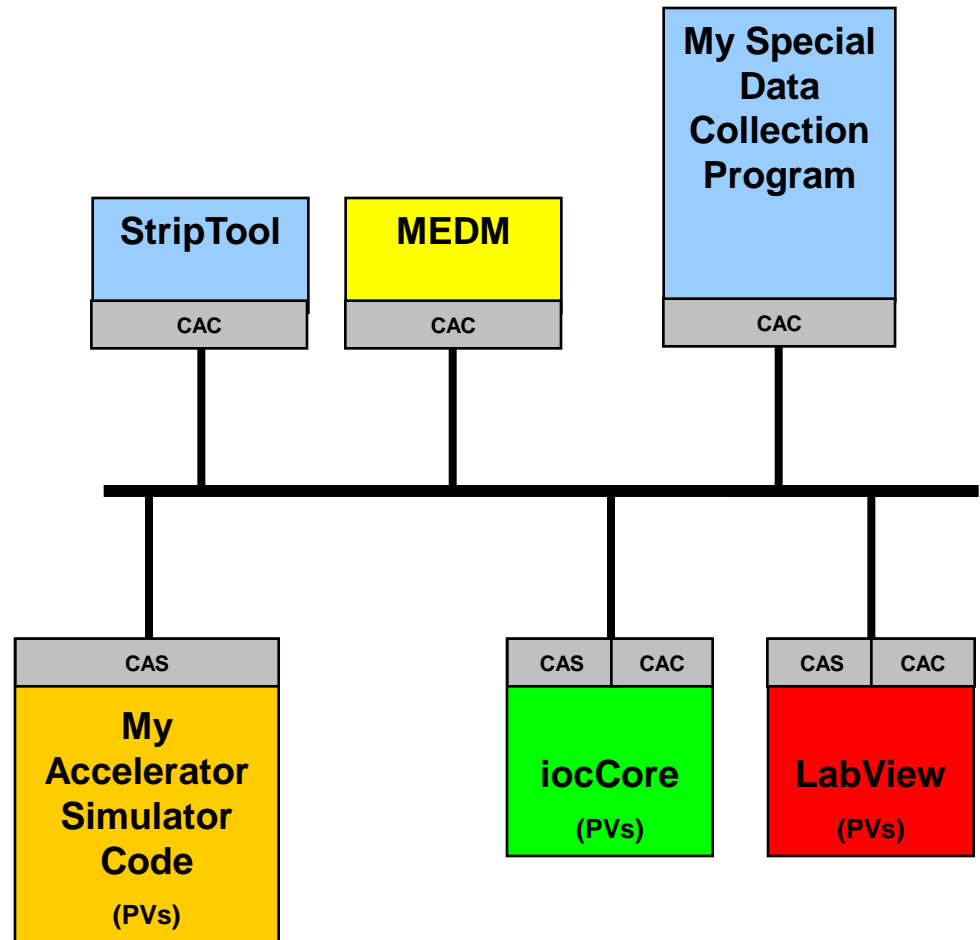


What is EPICS?

- **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

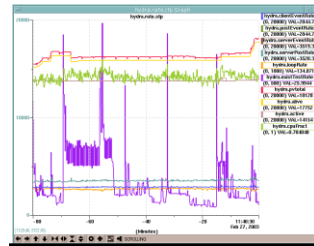
- **A Control System Architecture**
 - A client/server model with an efficient communication protocol (Channel Access) for passing data
 - A distributed real-time database of machine values

- **A Software Toolkit**
 - A collection of software tools collaboratively developed which can be integrated to provide a comprehensive and scalable control system

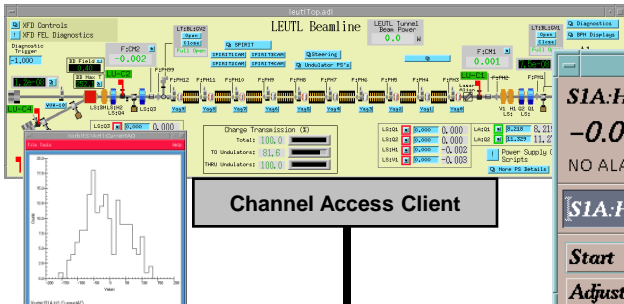
So What Does it Do?

- **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

How does it do it?



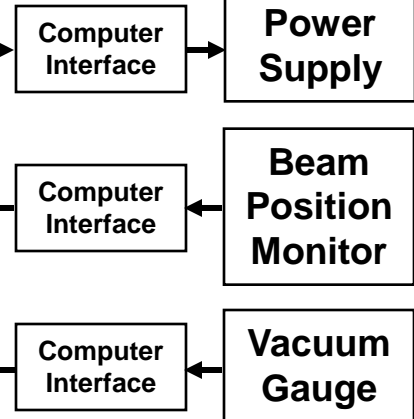
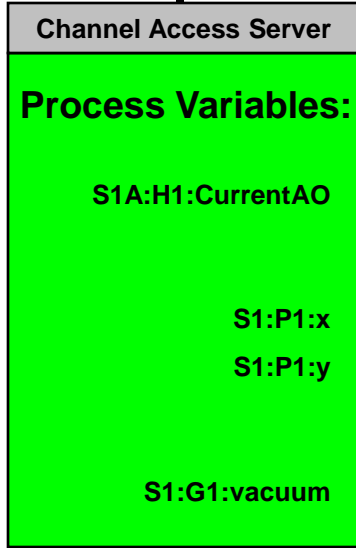
Channel Access Client



Channel Access Client



Channel Access Client

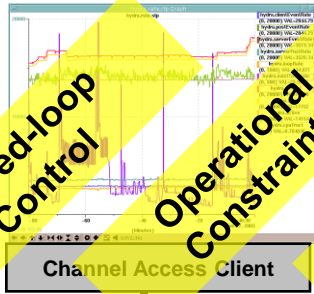


Where does it do it?



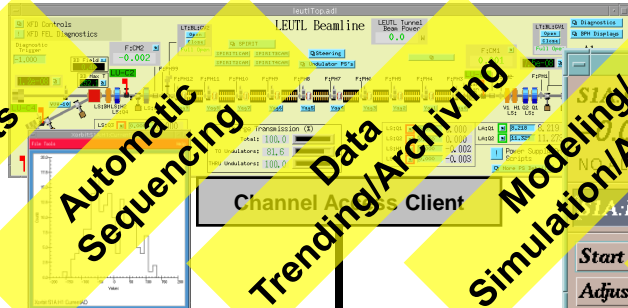
Remote Control & Monitoring

Alarm Logging/Reporting



Closed-loop Control

Operational Constraints



Automatic Sequencing

Data Trending/Archiving



Simulation/Analysis

Configuration Control

Channel Access Server

Process Variables:

S1A:H1:Current AO

S1:P1

S1:T1

S1:G1:vacuum

Data Conversion/Filtering

Alarm Detection

Computer Interface

Computer Interface

Computer Interface

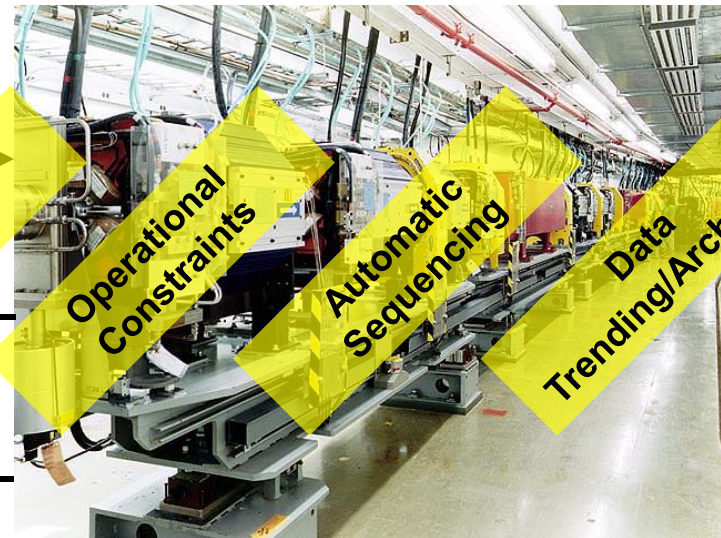
Power Supply

Beam Position Monitor

Vacuum Gauge

Access Security

Closed-loop Control

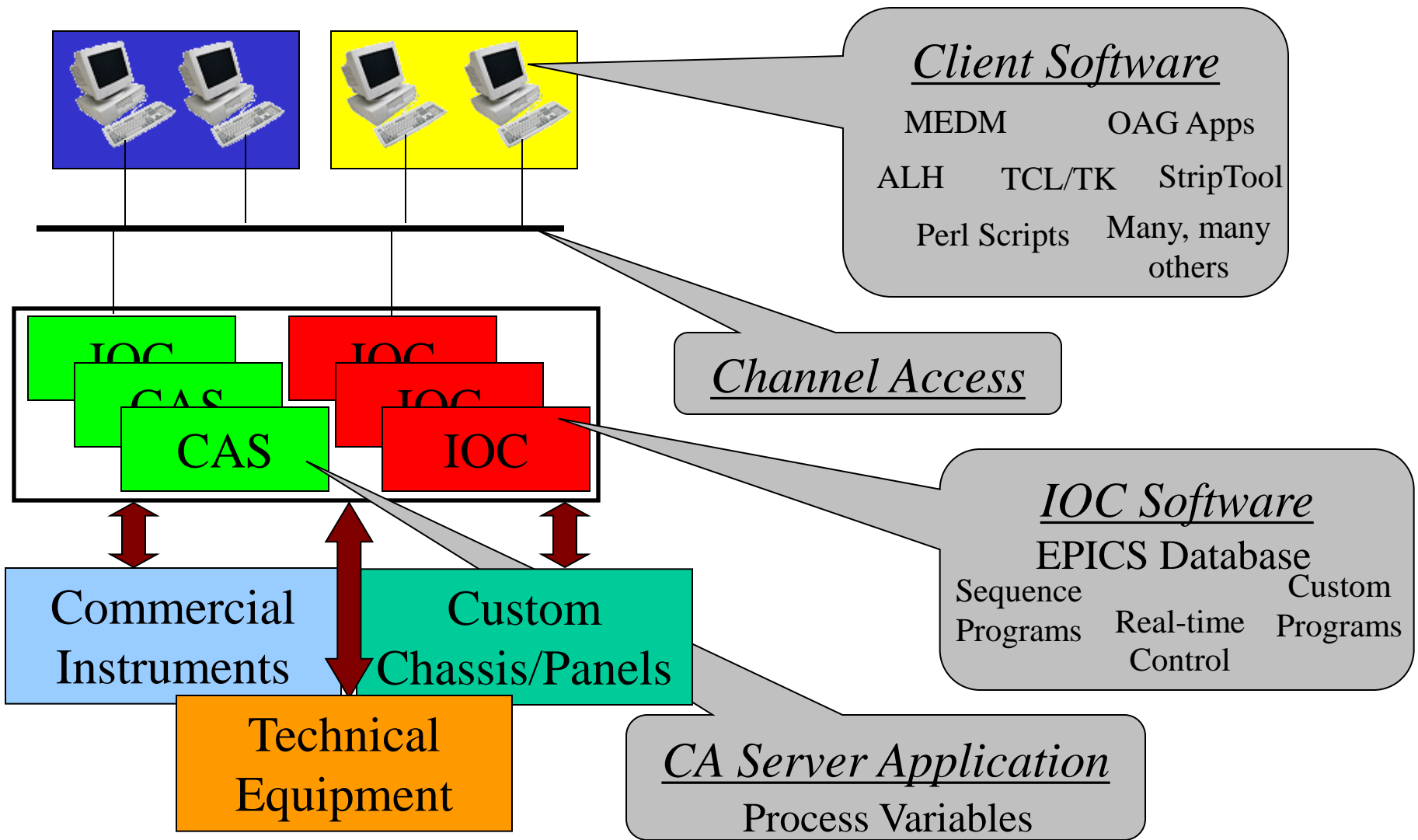


Operational Constraints

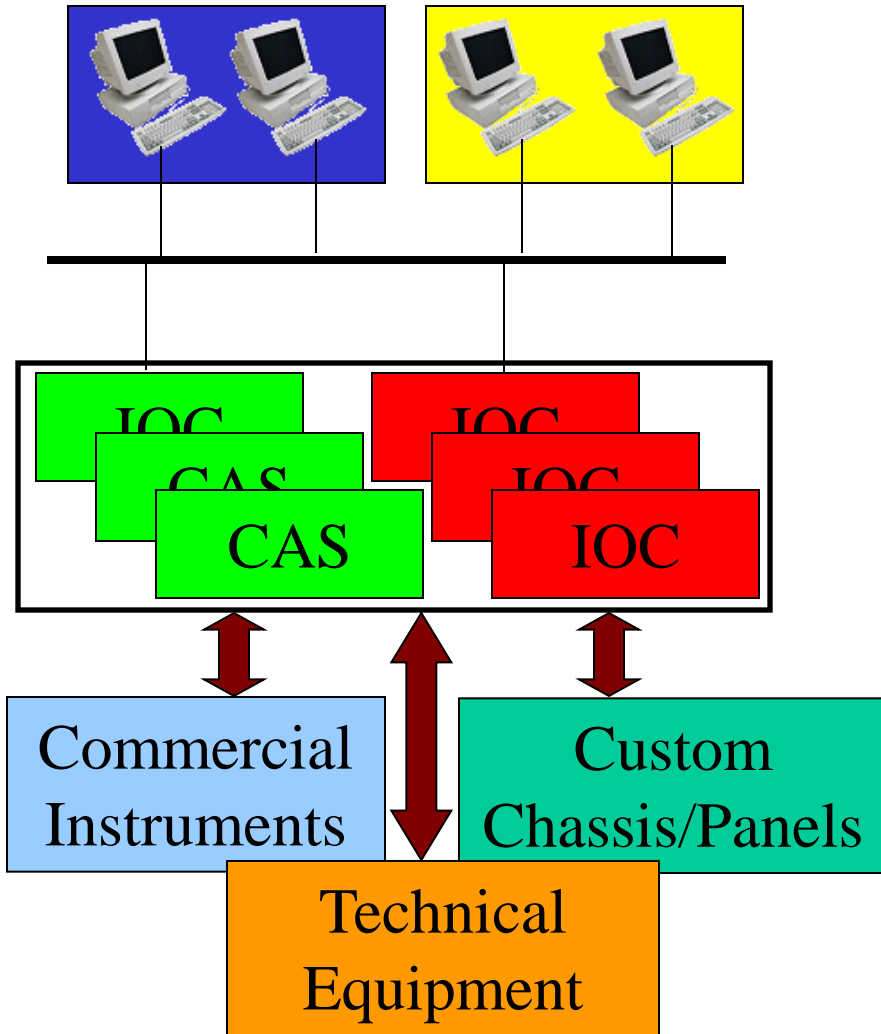
Automatic Sequencing

Data Trending/Archiving

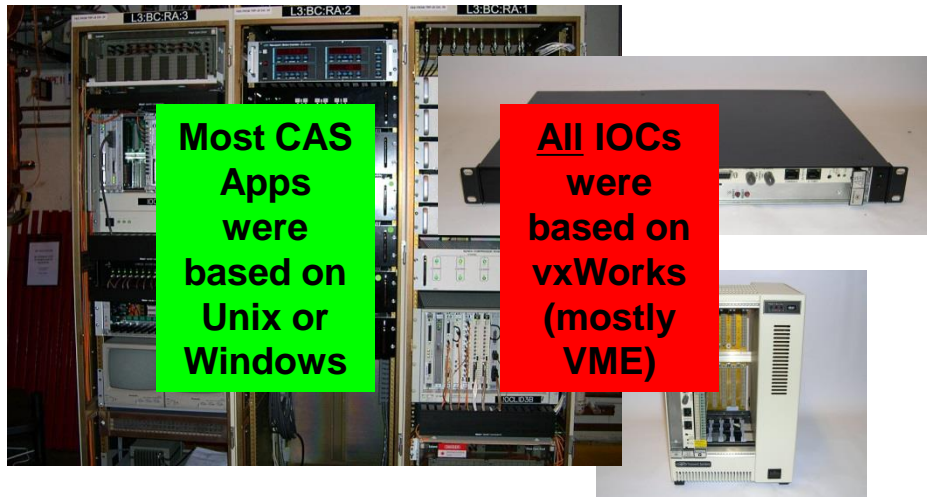
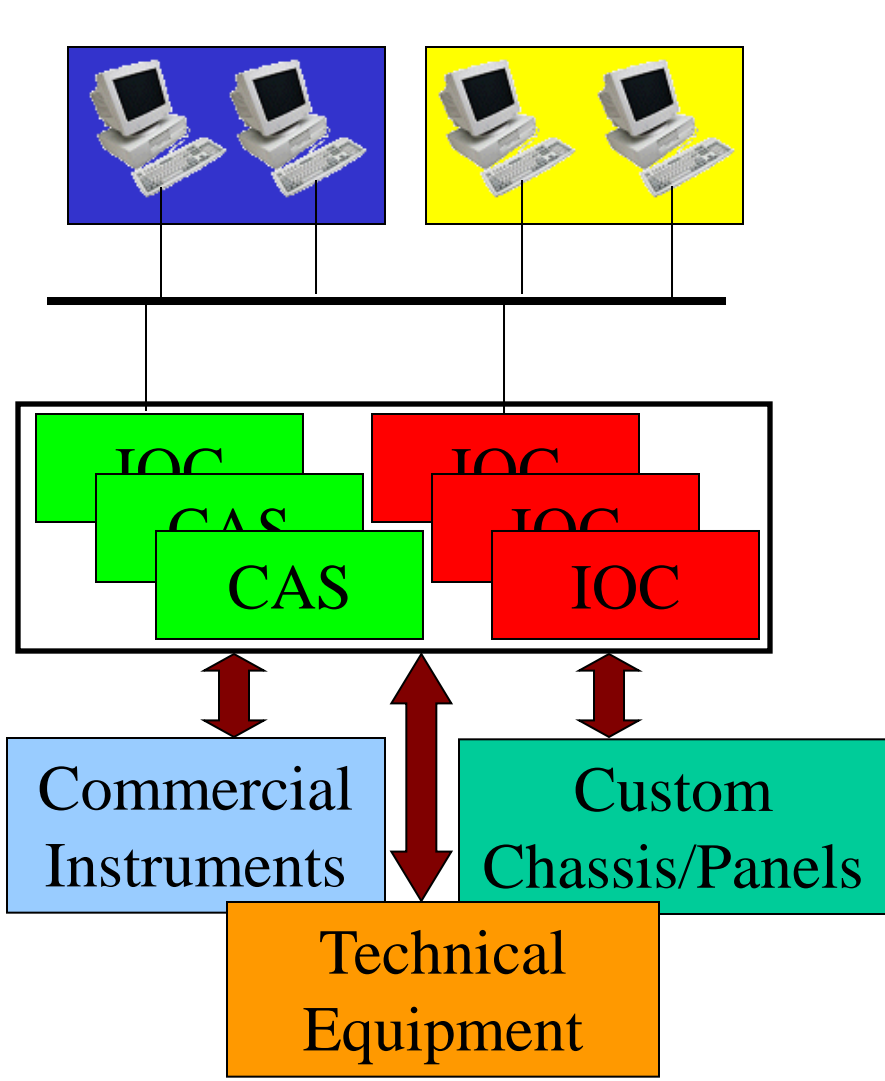
Canonical Form of an EPICS Control System



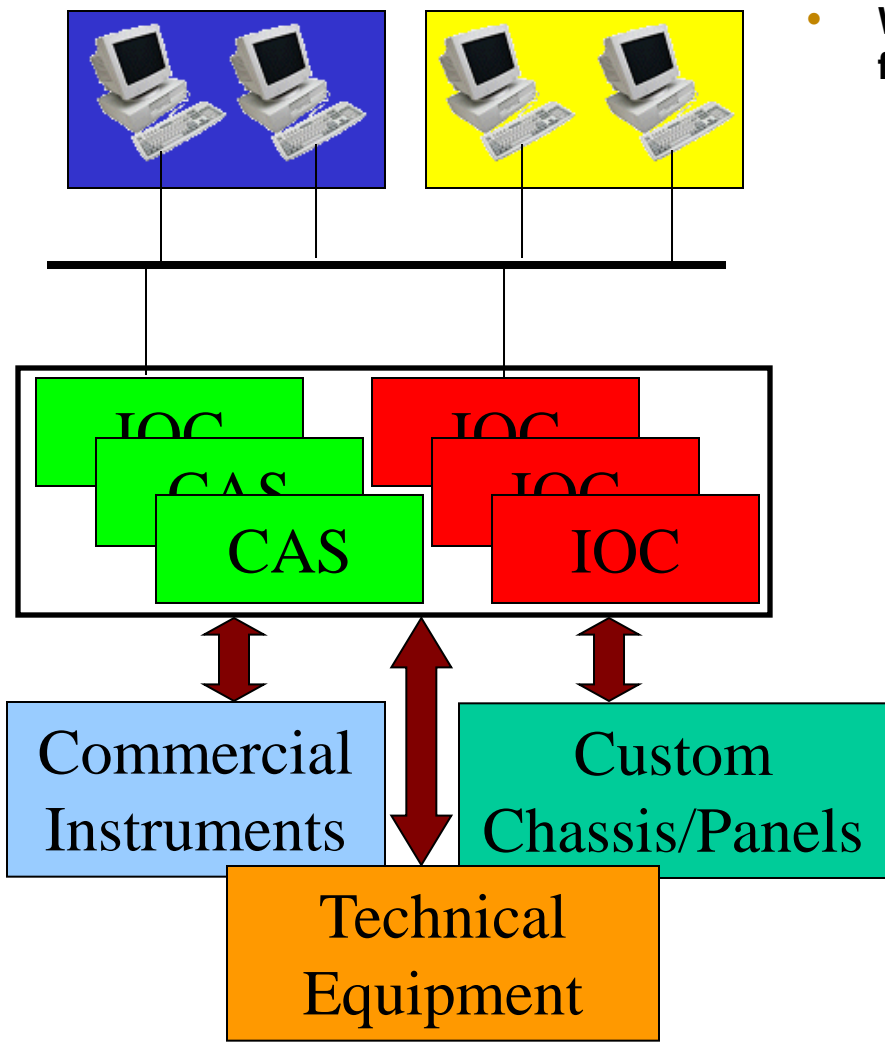
Typical Realizations of an EPICS System



Typical Realizations of an EPICS System



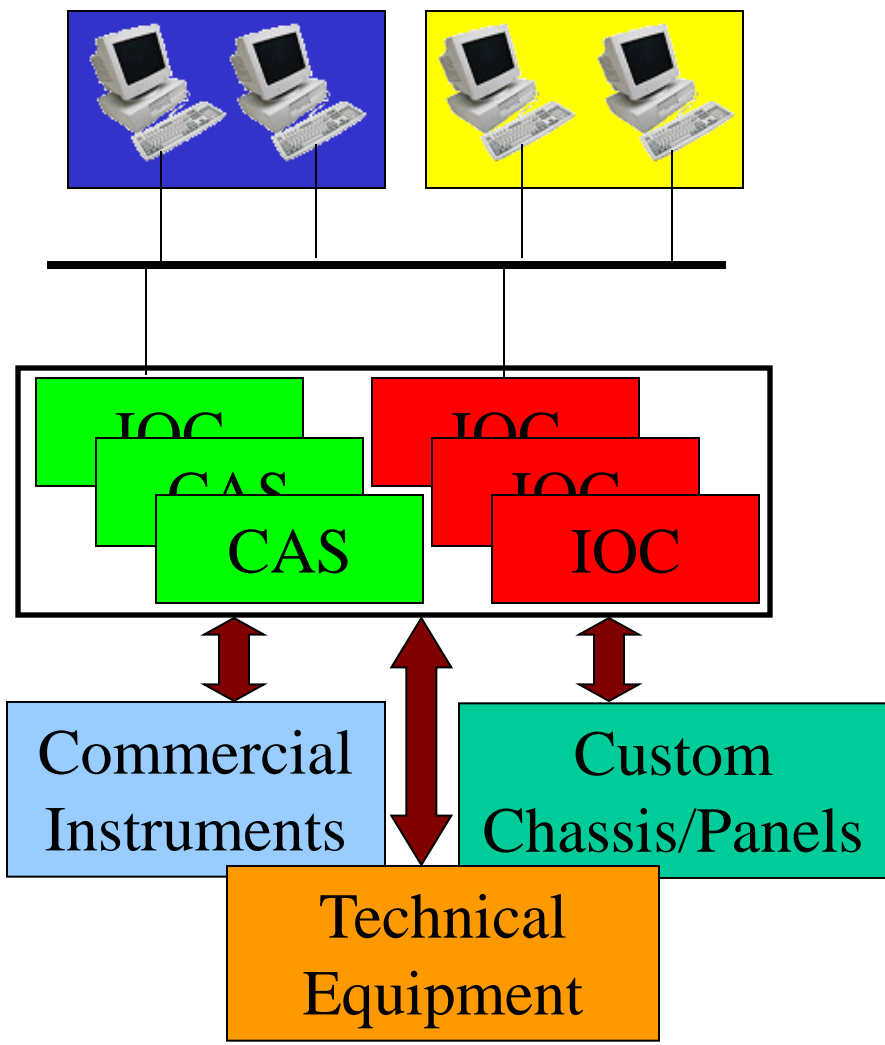
Typical Realizations of an EPICS System



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



Typical Realizations of an EPICS System

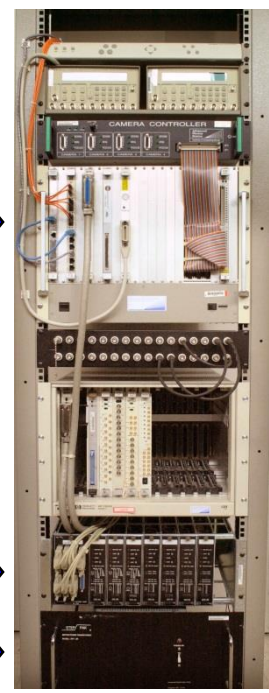


Driving a motor with EPICS

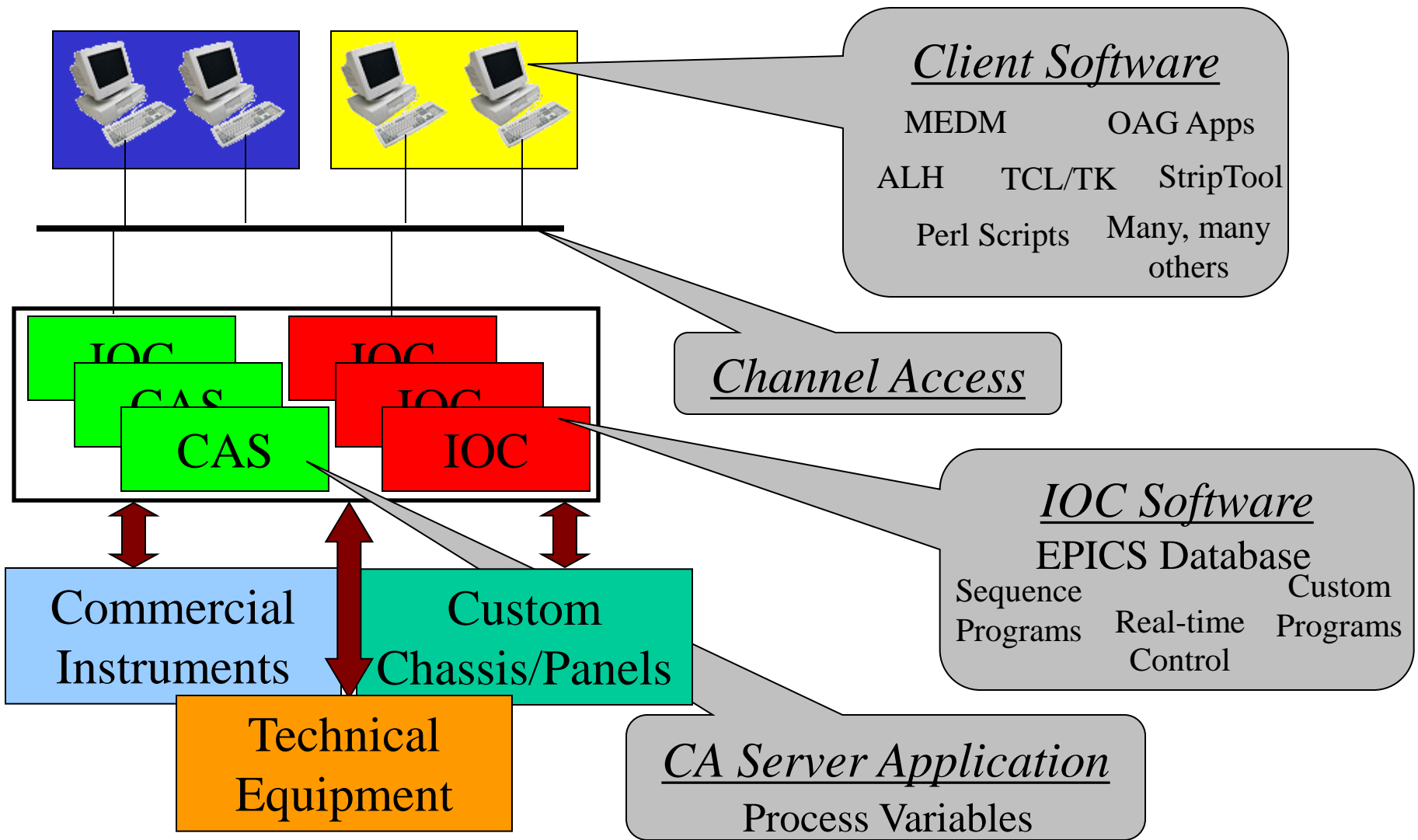
circa 1995



circa 2002



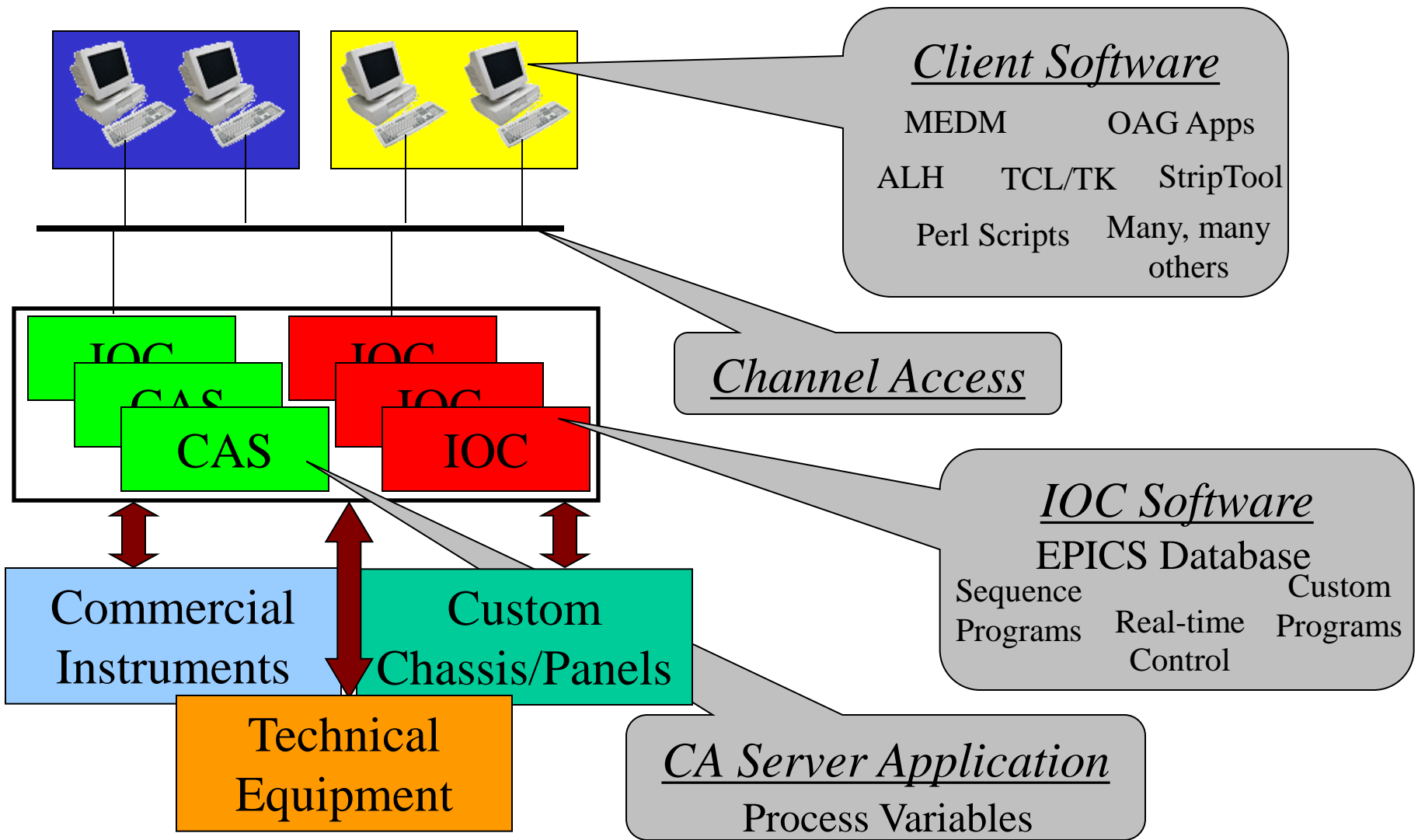
Canonical Form of an EPICS Control System



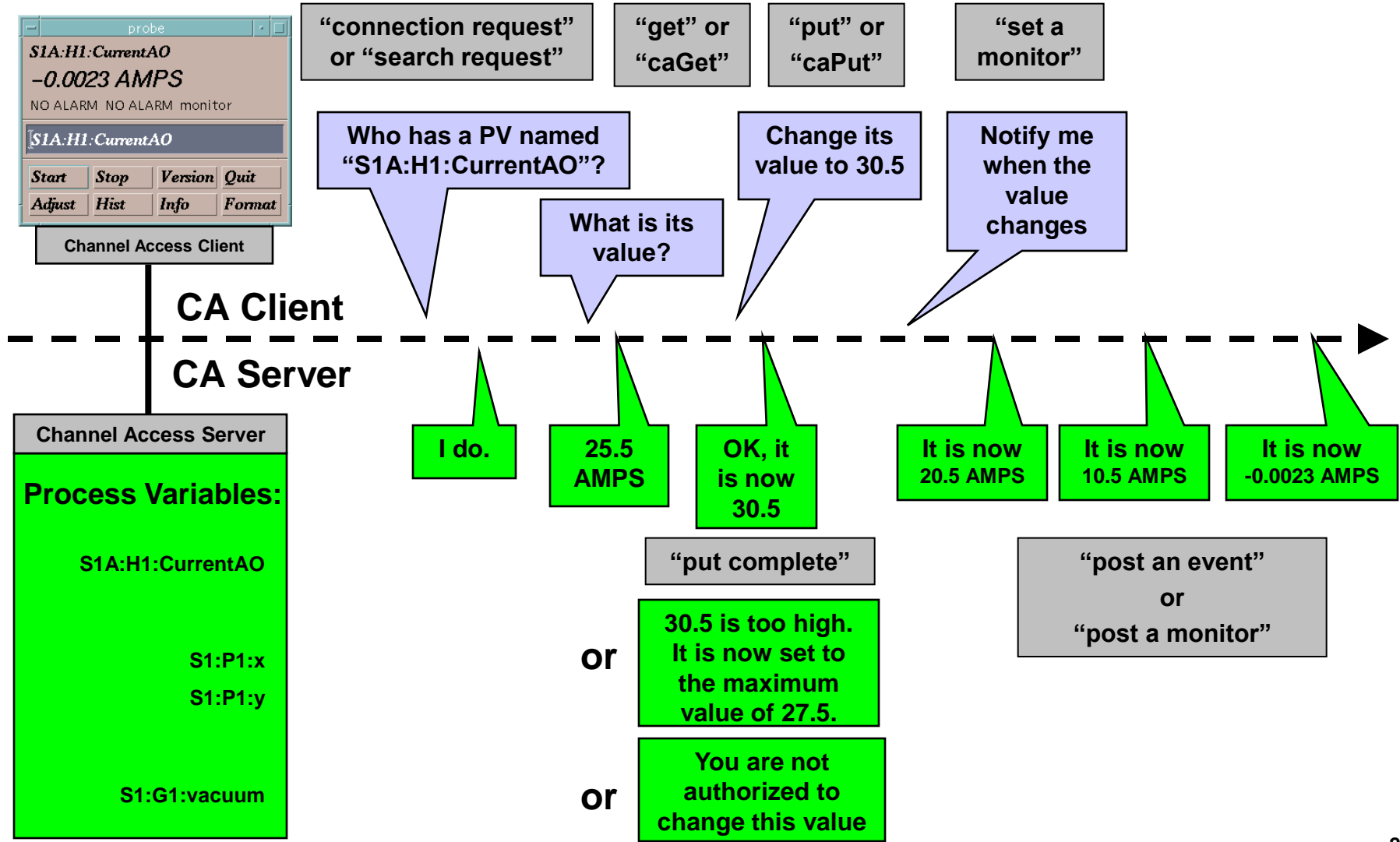
Standalone CA Clients *(from EPICS Website)*

- **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



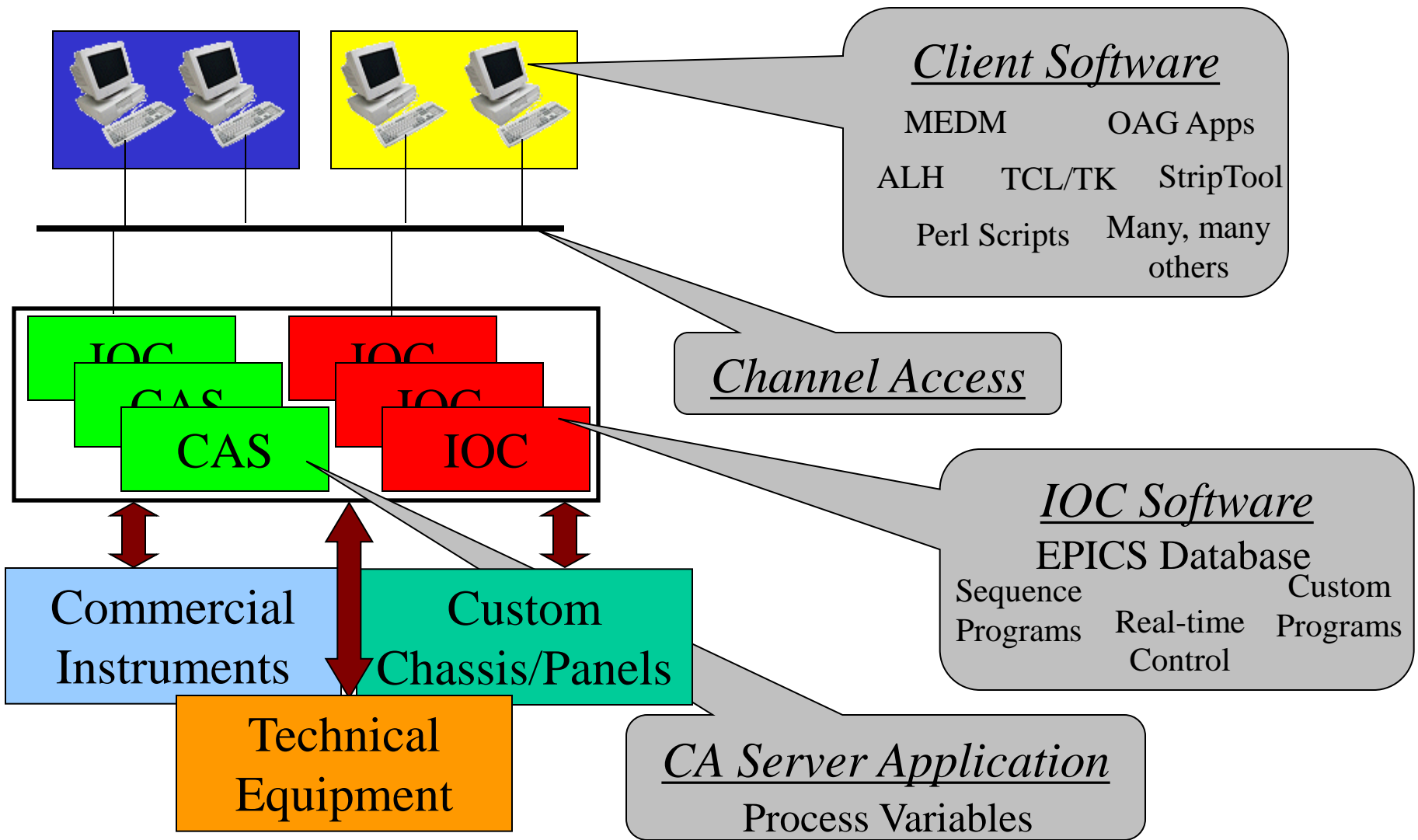
Channel Access in One Slide



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

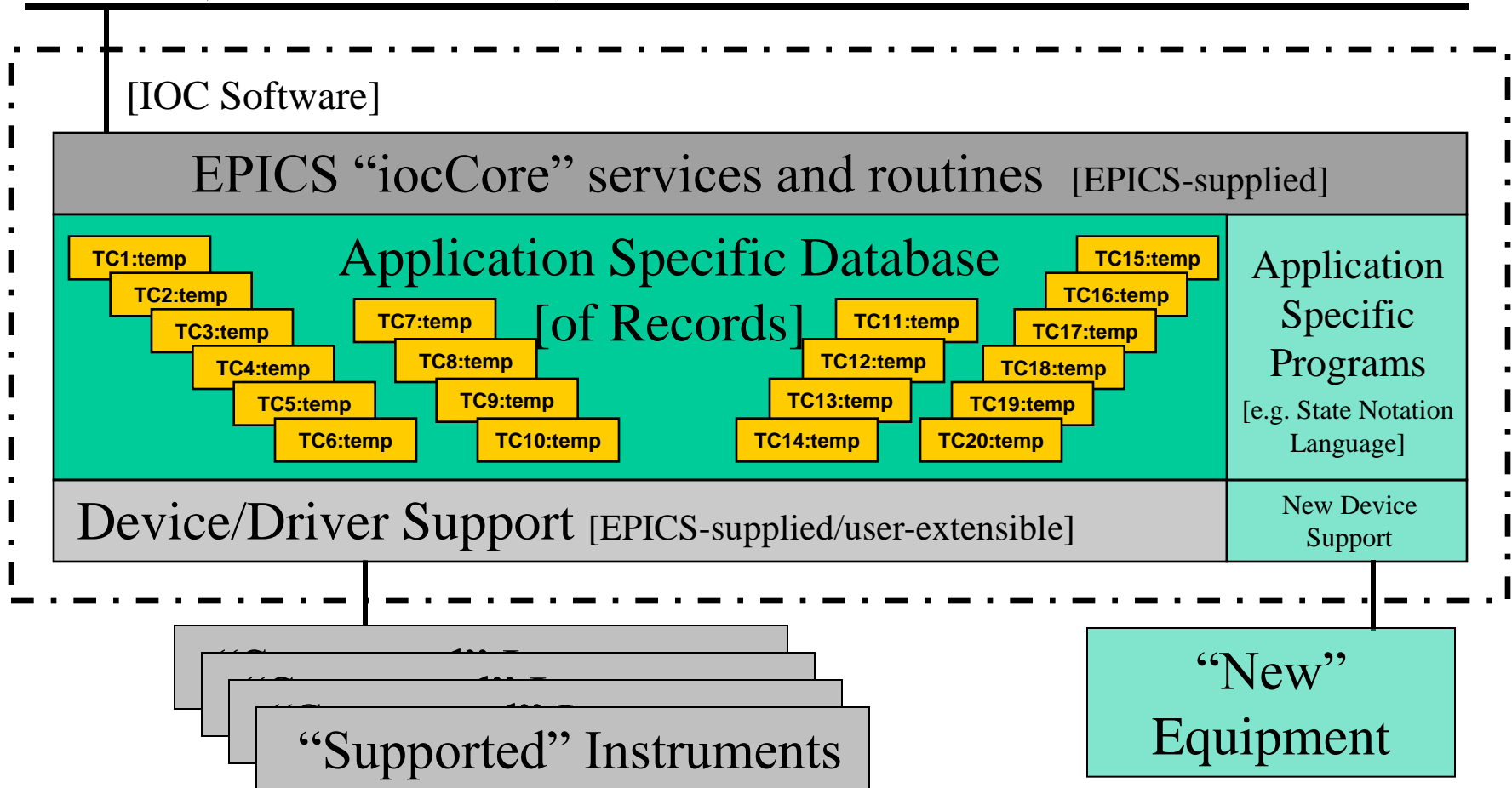


Key Features of IOC software ...

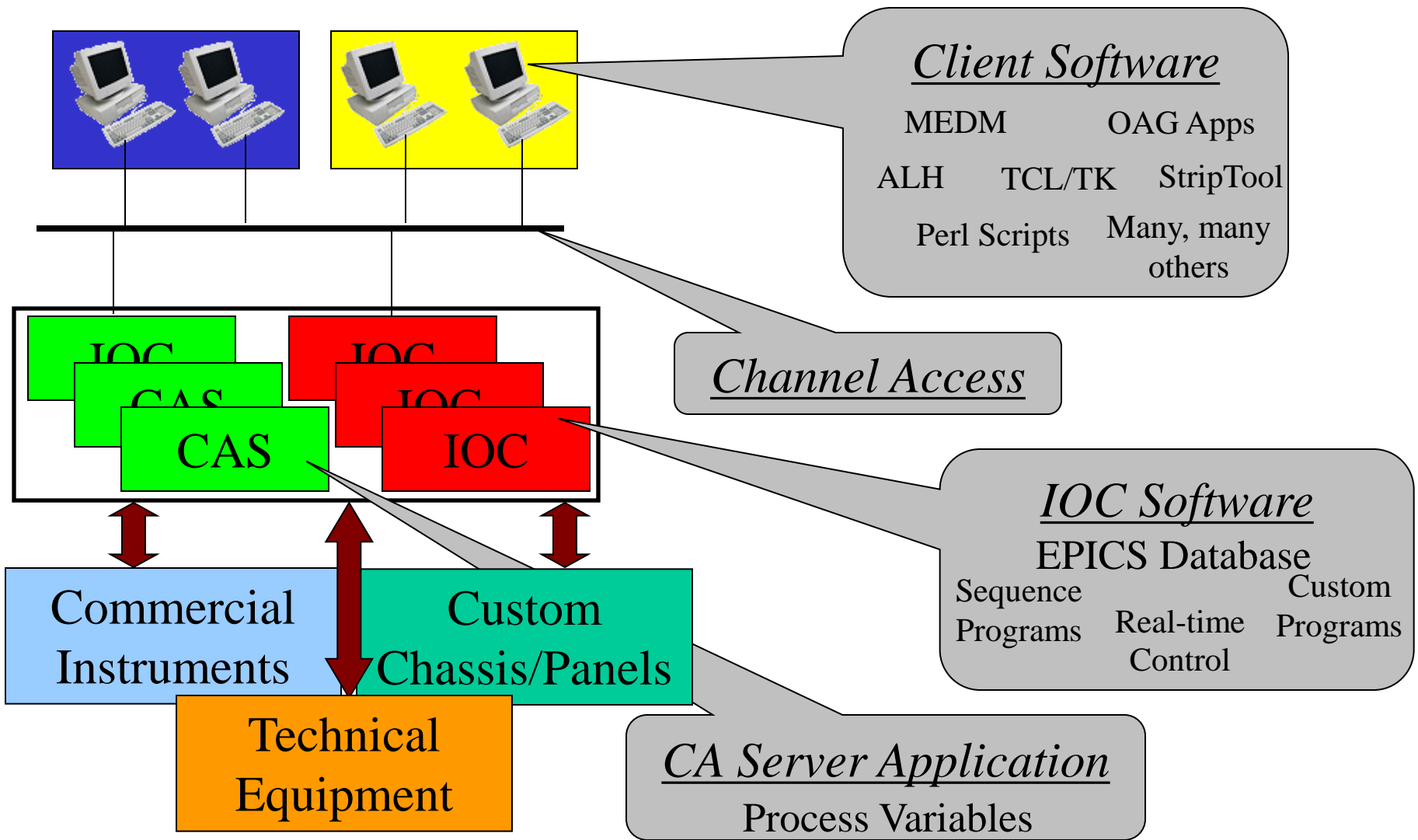
- **Two primary application specific components:**
 - The real-time database of records (required)
 - State Notation Language programs used to implement state oriented programs (finite-state machine)
- **Machine status, information and control parameters are defined as “records” in the application specific 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

Network (Channel Access)



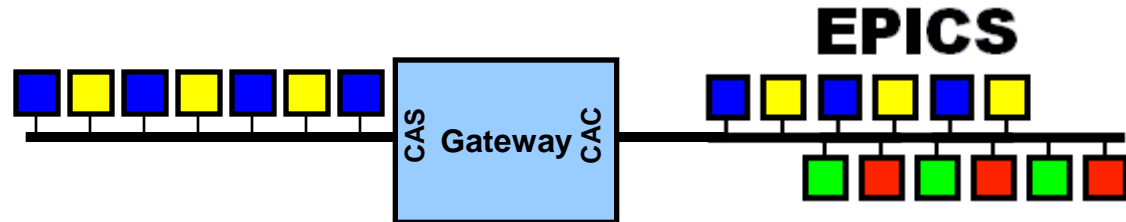
Canonical Form of an EPICS Control System



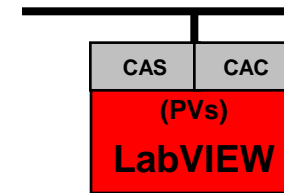
Popular CA Server Applications

- IOC Core

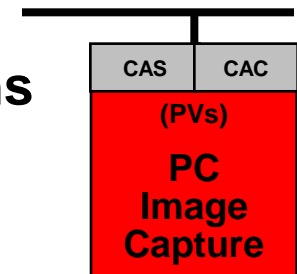
- PV Gateway



- 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?**

Command-Line Tools

- These are client-side tools
- The tools we will cover are:
 - caget – *gets the value of one or more process variables*
 - caput – *sets the value of one process variables*
 - camonitor – *monitors the value changes of one or more process variables*
 - cainfo – *gets information about one or more process variables*
- All accept `-h` to display usage and options

Caget Example

- Get the values of two process variables

```
caget S35DCCT:currentCC S:SRlifeTimeHrsCC
```

Returns

```
S35DCCT:currentCC      102.037
S:SRlifeTimeHrsCC      7.46514
```

Caput Example

- Set the value of a process variable

```
caput Xorbit:S1A:H1:CurrentAO 1.2
```

Returns

```
Old : Xorbit:S1A:H1:CurrentAO      0
New : Xorbit:S1A:H1:CurrentAO      1.2
```


Camonitor Example

- Monitor two process variables

```
camonitor evans:calc evans:bo01
```

Returns

```
evans:calc      2004-08-05 17:23:04.623245 1
evans:bo01     2004-08-05 17:23:04.623245 On
evans:calc      2004-08-05 17:23:05.123245 2
evans:bo01     2004-08-05 17:23:05.123245 Off
evans:calc      2004-08-05 17:23:05.623245 3
evans:calc      2004-08-05 17:23:06.123245 4
evans:calc      2004-08-05 17:23:06.623233 5
evans:calc      2004-08-05 17:23:07.123183 6
```

Use Ctrl-C to stop monitoring

Cainfo Example

- Get information about a process variable

```
cainfo S35DCCT:currentCC
```

Returns

```
State:      connected
Host:      ctlapps41188:5064
Access:    read, no write
Data type: DBR_DOUBLE (native: DBF_DOUBLE)
Element count: 1
```

Currently there is not as much information as with Probe or PvInfo in MEDM