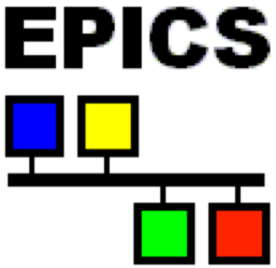
Experimental Physics and Industrial Control System

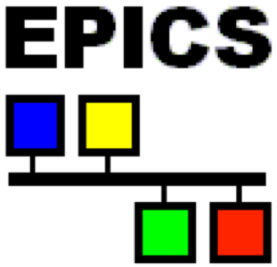


Kay Kasemir

kasemirk@ornl.gov

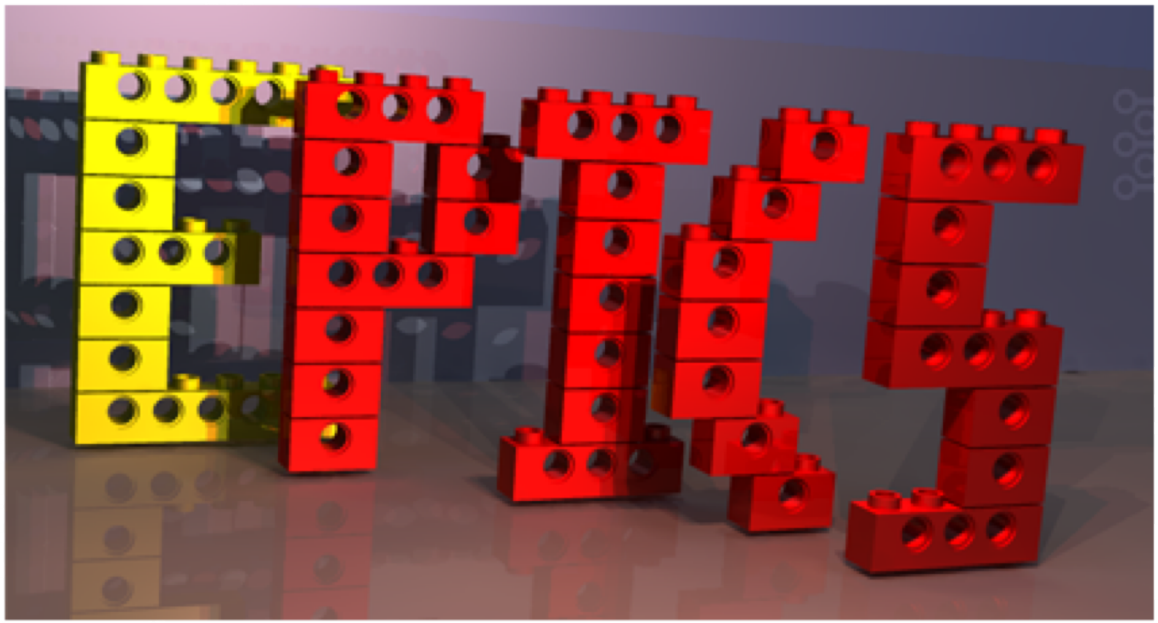
Jan 2019

What EPICS looks like



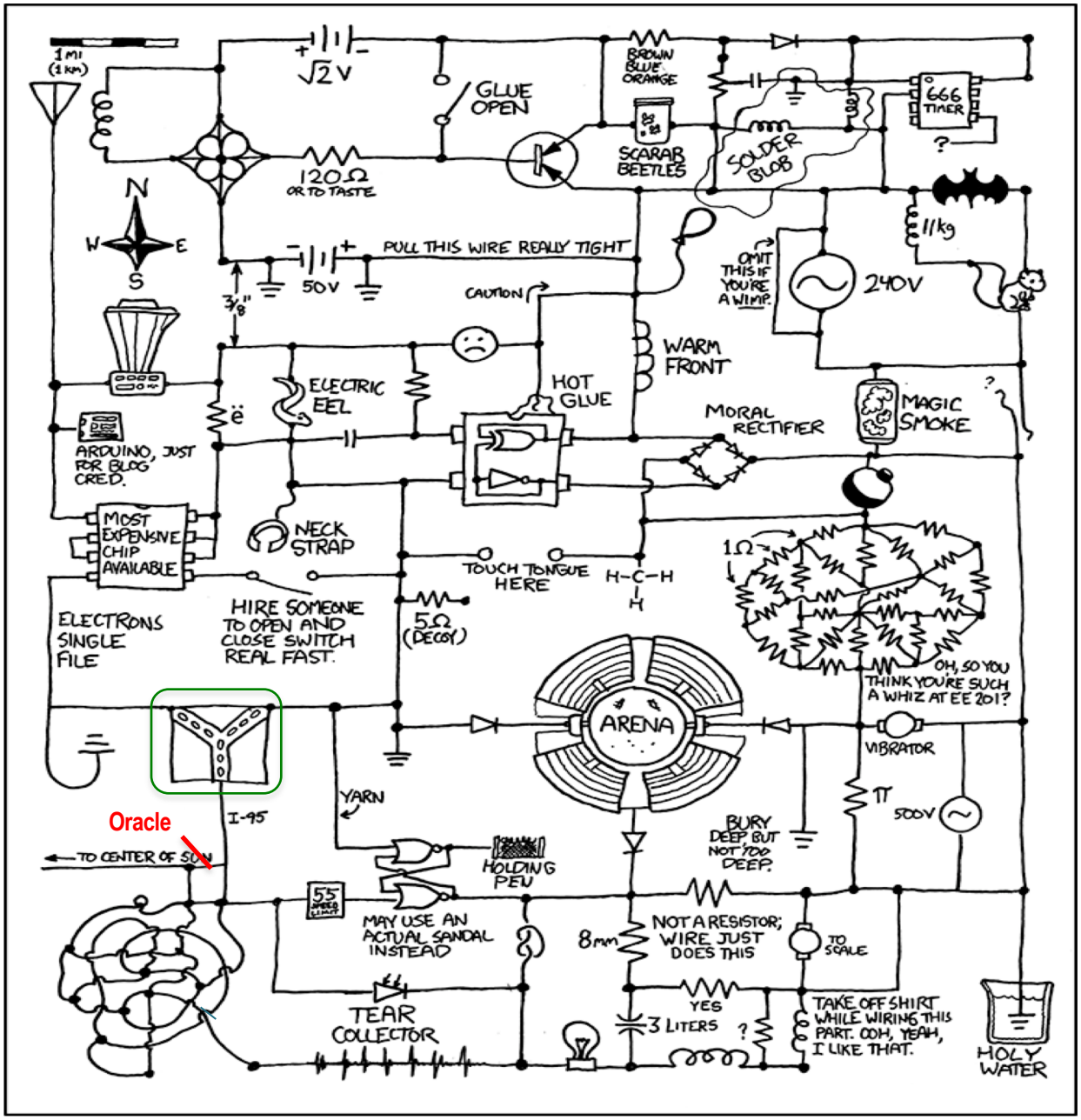
Network Diagram

Network Diagram (new)



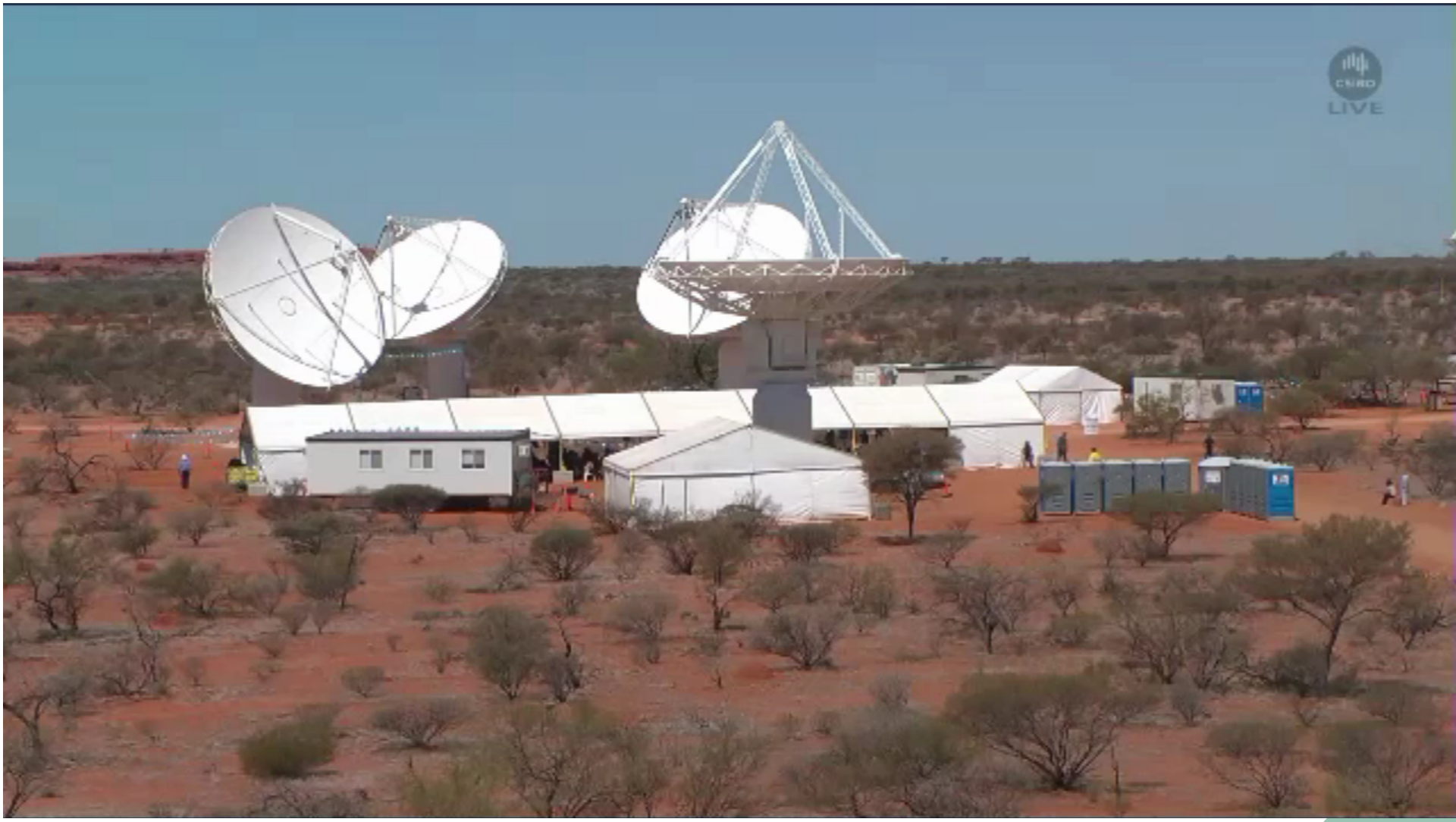
Block Diagram

What EPICS looks like



http://xkcd.com/730/

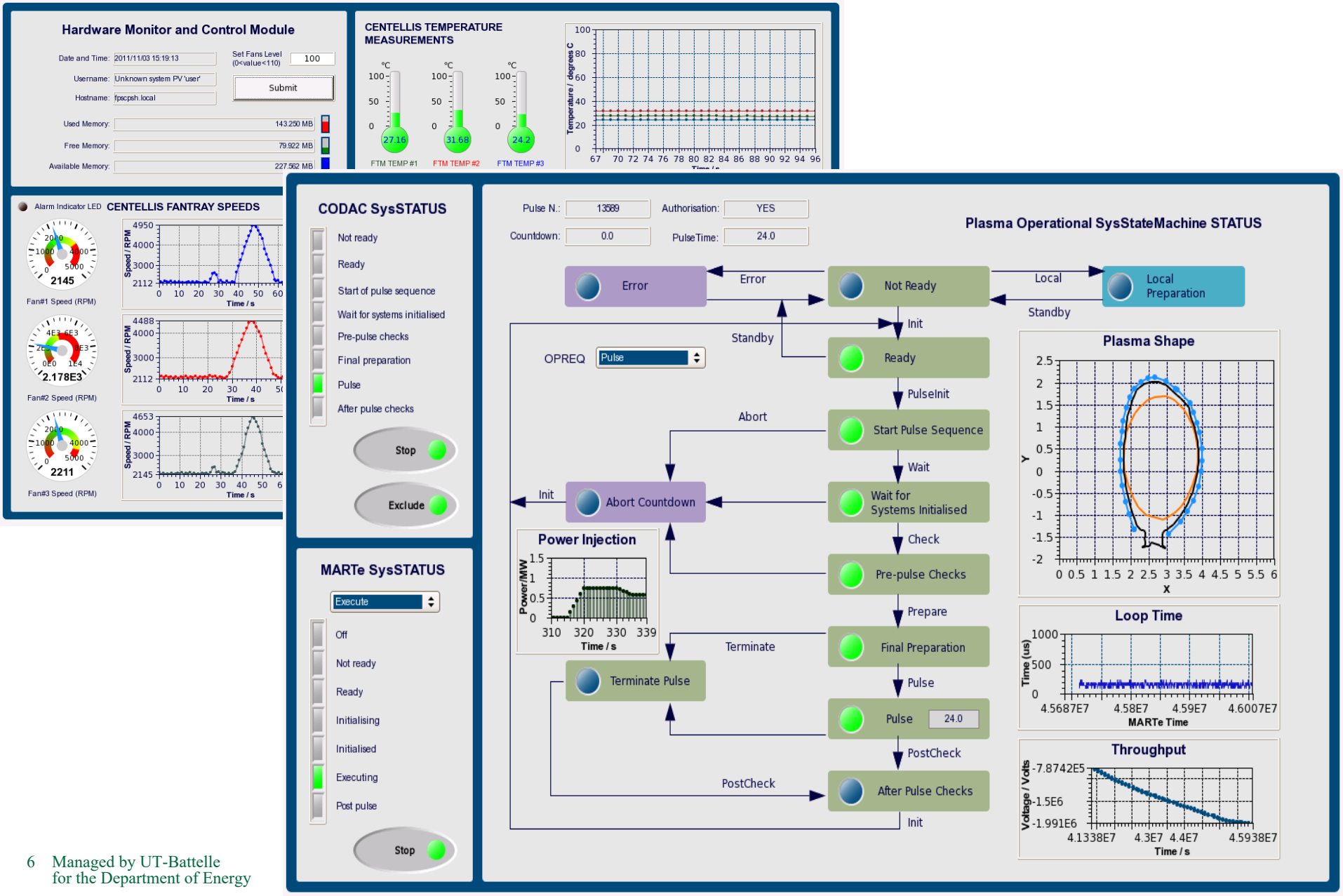
Australian Square Kilometre Array Pathfinder (ASKAP), Oct. 5, 2012



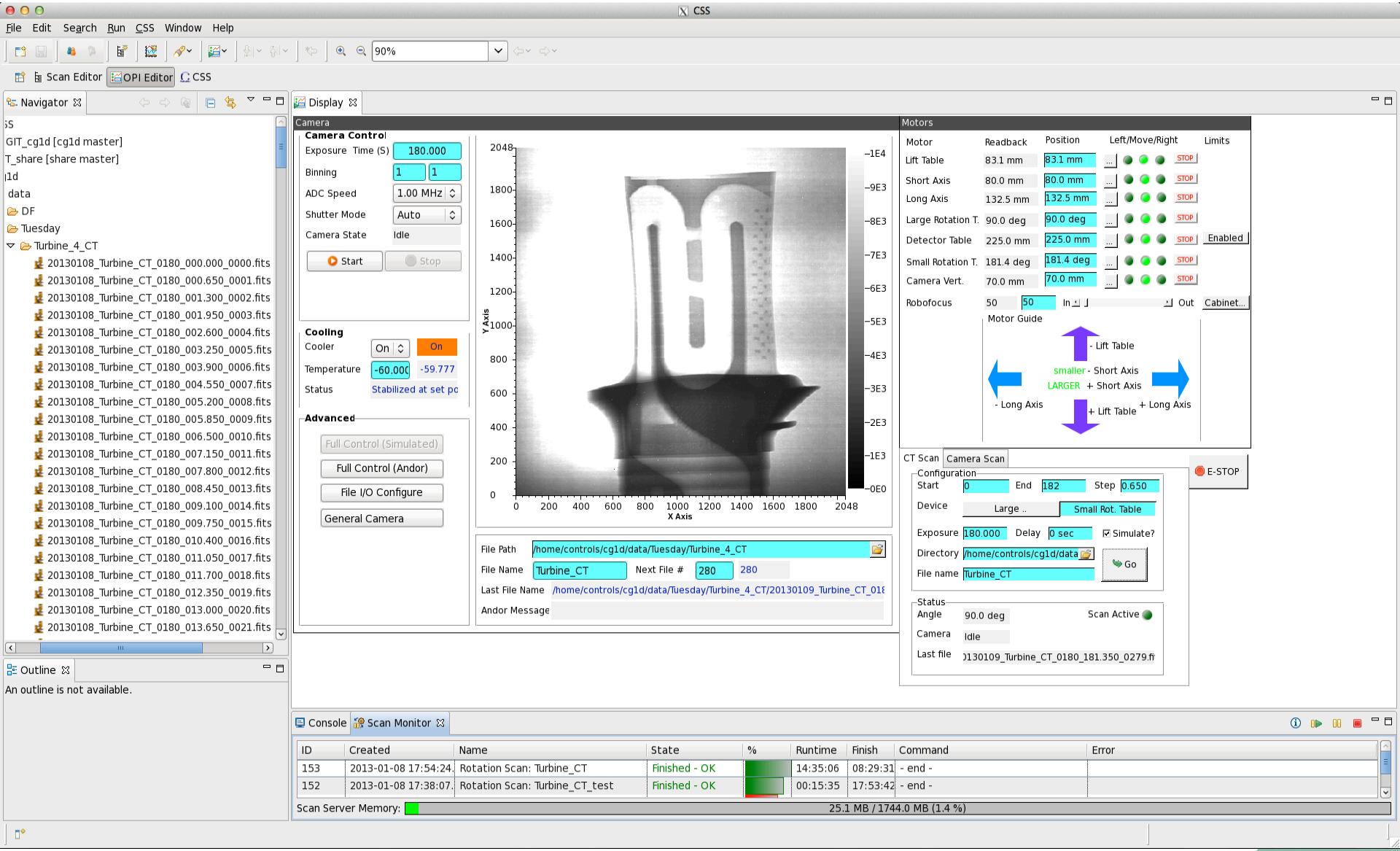
Juan Guzman, http://www.aps.anl.gov/epics/tech-talk/2012/msg02113.php

ASKAP User Interface

Juan Guzman, http://www.aps.anl.gov/epics/tech-talk/2012/msg02113.php


Hardware Monitor and Control Module
Date and Time: 2011/11/03 15:19:13
Username: Unknown system PV 'user'
Hostname: fpscpsh.local
Set Fans Level (0<value<110)
100
Submit
Used Memory: 143.250 MB
Free Memory: 79.922 MB
Available Memory: 227.562 MB
CENTELLIS TEMPERATURE MEASUREMENTS
°C
27.16
31.68
24.2
FTM TEMP #1
FTM TEMP #2
FTM TEMP #3
Temperature / degrees C
Time / s
Alarm Indicator LED
CENTELLIS FANTRAY SPEEDS
2145
Fan#1 Speed (RPM)
2.178E3
Fan#2 Speed (RPM)
2211
Fan#3 Speed (RPM)
Speed / RPM
Time / s
CODAC SysSTATUS
Not ready
Ready
Start of pulse sequence
Wait for systems initialised
Pre-pulse checks
Final preparation
Pulse
After pulse checks
Stop
Exclude
MARTe SysSTATUS
Execute
Off
Not ready
Ready
Initialising
Initialised
Executing
Post pulse
Stop
Pulse N.: 13589
Authorisation: YES
Countdown: 0.0
PulseTime: 24.0
Plasma Operational SysStateMachine STATUS
Error
Not Ready
Local
Local Preparation
Standby
Init
Ready
OPREQ
Pulse
PulseInit
Abort
Start Pulse Sequence
Wait
Wait for Systems Initialised
Check
Abort Countdown
Pre-pulse Checks
Prepare
Final Preparation
Terminate
Terminate Pulse
Pulse
24.0
PostCheck
After Pulse Checks
Power Injection
Power/MW
Time / s
Plasma Shape
Y
X
Loop Time
Time (us)
MARTe Time
Throughput
Voltage / Volts
Time / s

HFIR CG-1D



First EPICS/CSS operation with beam, Jan. 8, 201

EPICS is not...

One product that you

- Install
- Run
- Done!

EPICS is a Collaboration

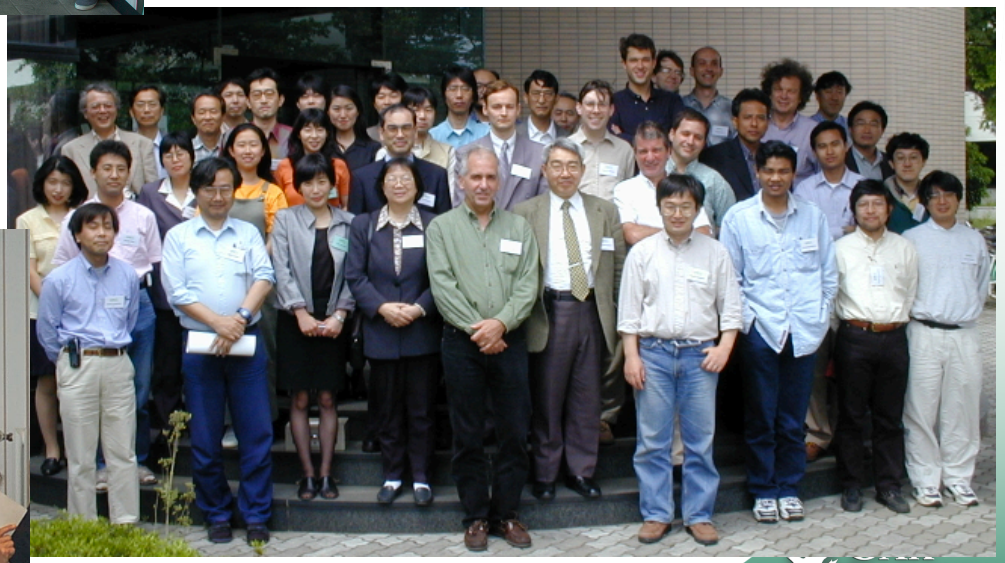
- ~1989: Started between
  - LANL Ground Test Accelerator
  - ANL Advanced Photon Source
- Until 2004: License agreement required
  - LANL registered >150
- Now:
  - SNS, ANL/APS, BNL, FRIB, SLAC, LANL, JLAB/CEBAF, LBNL, Fermilab D0, Keck & Gemini Telescopes … in the USA
  - Canadian Light Source; DESY, BESSY, .. in Germany; PSI/SLS in Switzerland; Ganil, SACLAY in France; Diamond Light Source and ISIS in England; KEK, J-Parc in Japan; IHEP in China; NSRRC in Taiwan; PLS in South Korea; Australian Synchroton, …
- Yearly collaboration meetings
  - One each in US and elsewhere
  - ~100 people attended in 2016, 2018
- 'Tech-Talk' email reflector usually provides responses within a few hours
  - https://epics-controls.org

https://epics-controls.org Meetings

Chicago, 2018

Oak Ridge, 2016

Tzukuba, 2000



Berlin, 1998

EPICS is a Toolkit

… for distributed control systems.

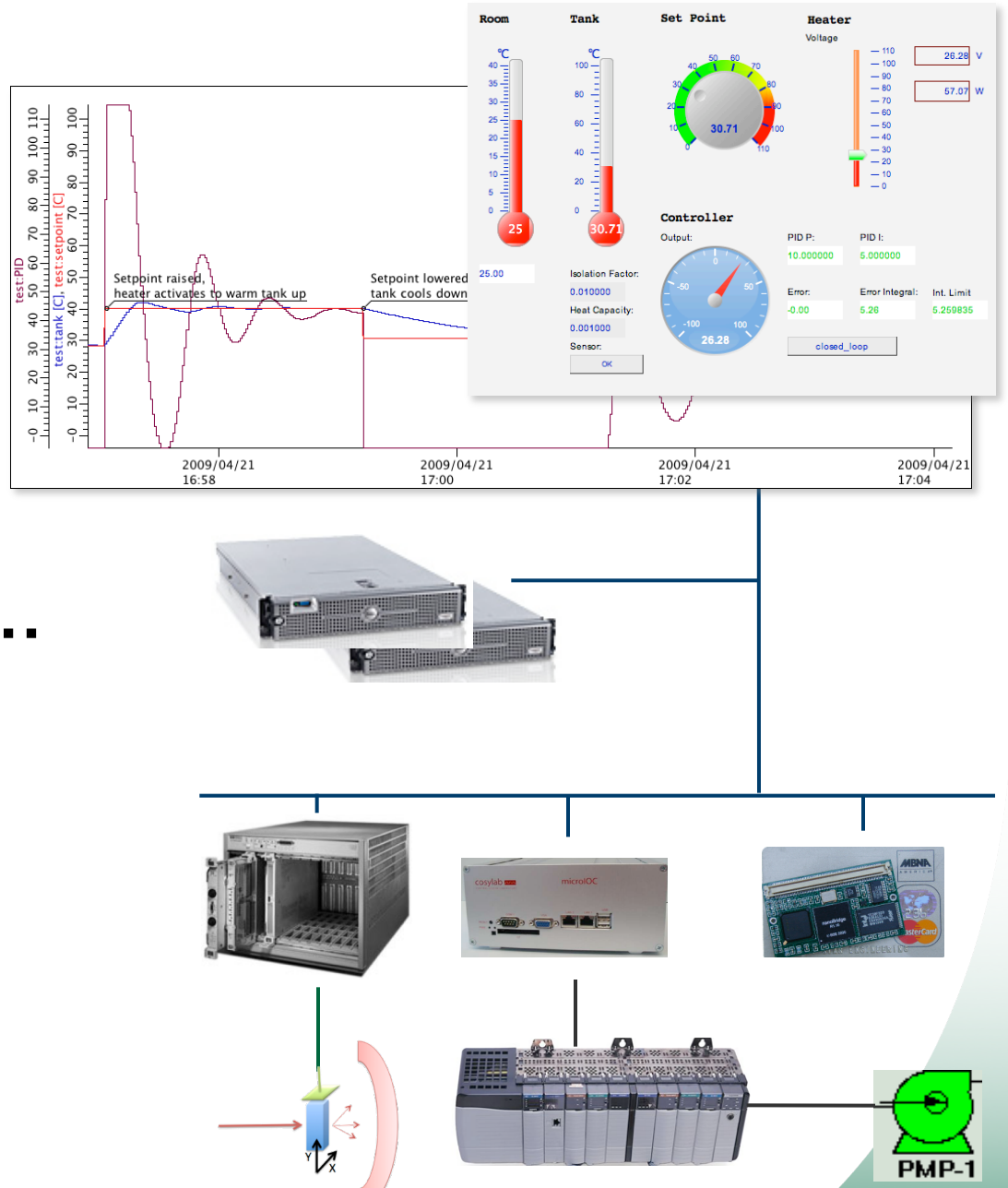
- Front-end: “Input/Output Controller” (IOC)
- Protocol: Channel Access (PV Access)
- Clients: Operator displays, alarm system, …

- Mostly Portable:
  vxWorks, RTEMS, Linux, OS X, Windows

Distributed

- Operator interface

- Services: Archive, …
- Front-end IOCs
- I/O, PLCs, ..



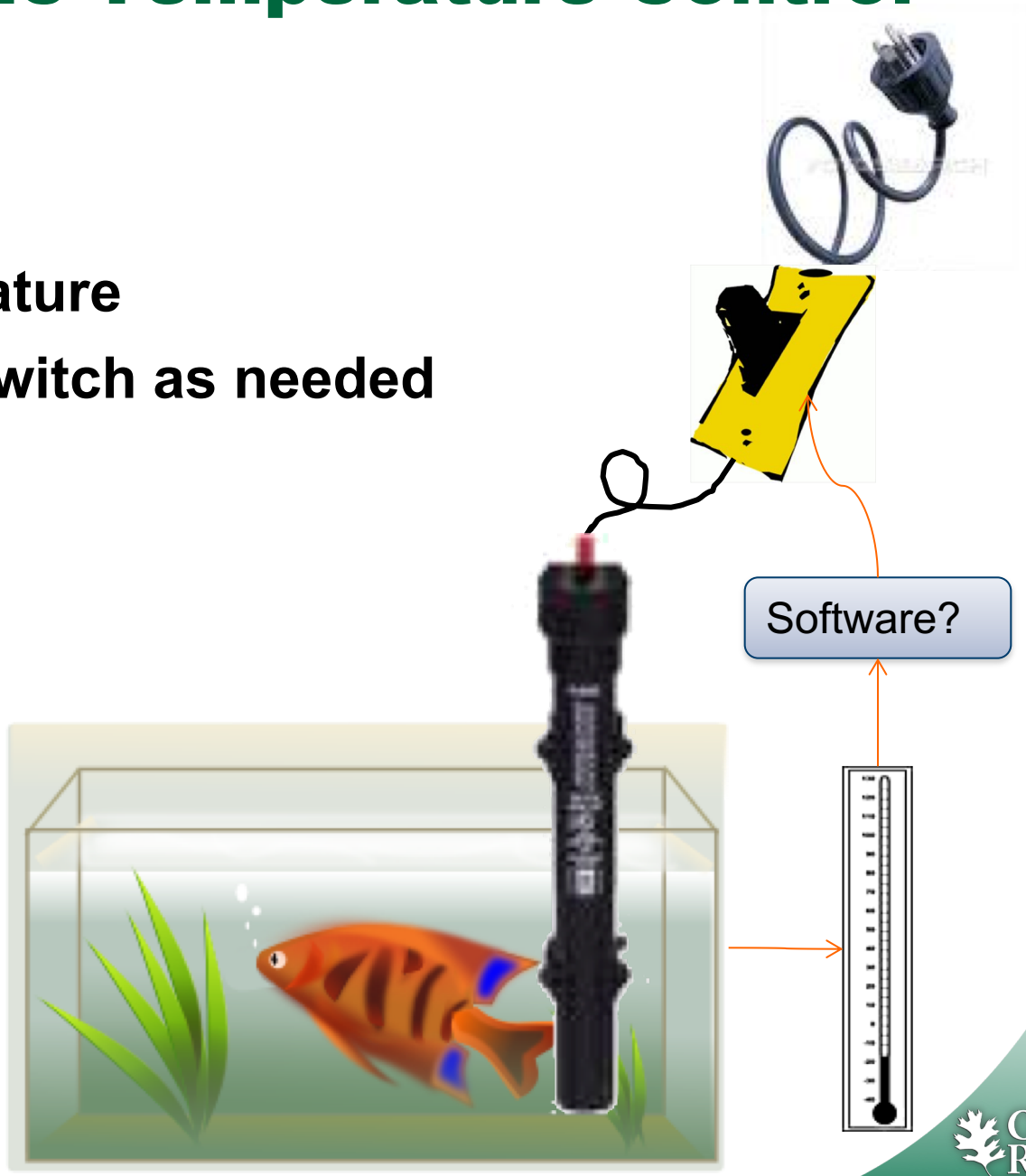
What an IOC does

- Runtime ‘Database’
  - Executes records
- Known set of ‘Records’
  - Read analog value
  - Write analog value
  - Perform computation
  - Control motor
- Configuration
  - SCAN=1 second
  - INP=..what to read..
- Serve all via Channel Access

Example: Basic Temperature Control

Task:

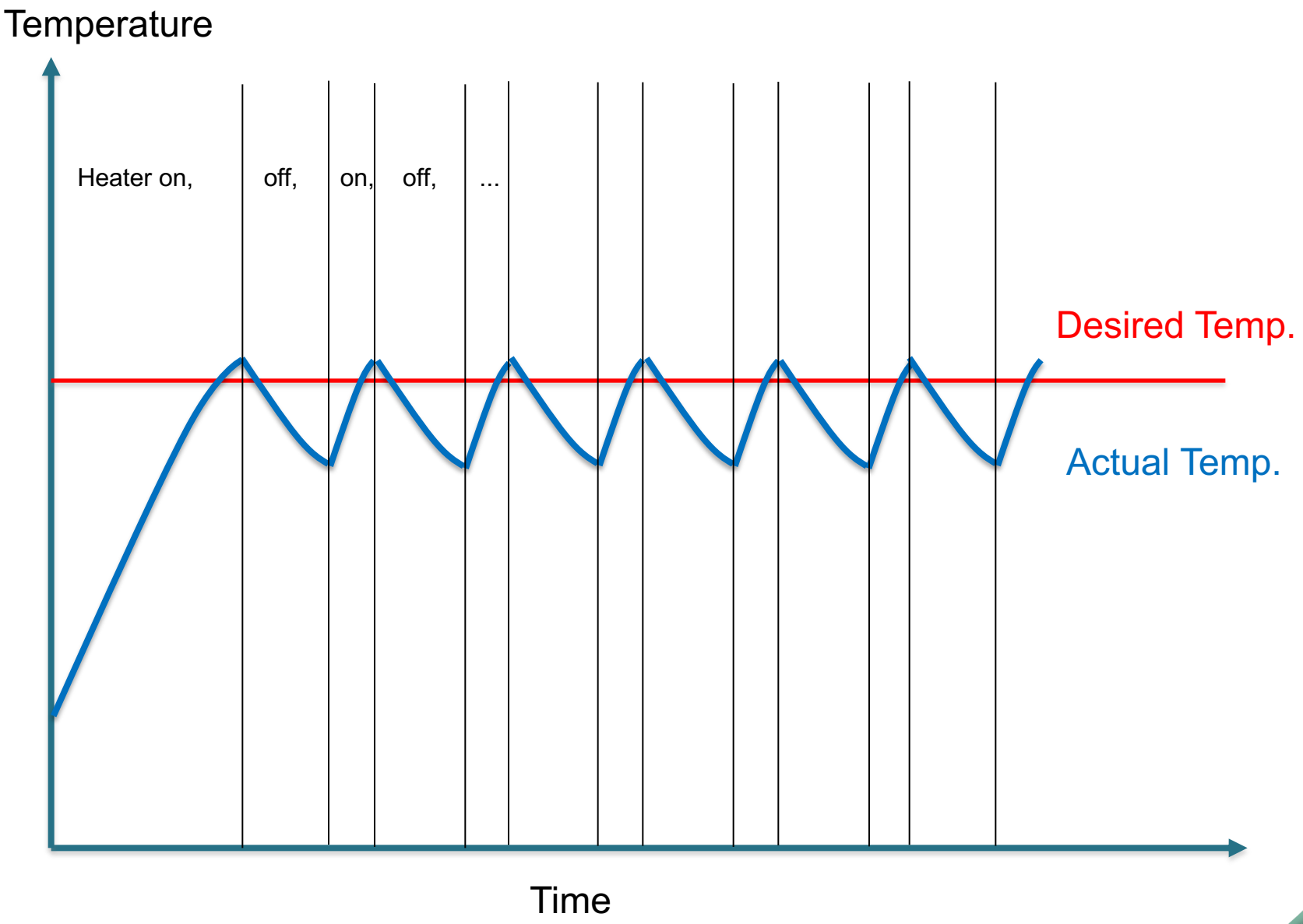
1. **Read temperature**
2. **Open/close switch as needed**
3. **Repeat**



Simplistic Code

```
Sensor temp = connectToSensor(…);

Switch switch = connectToSwitch(…);

Loop:

        if (temp.value() < 10)
            switch.close();
        else
            switch.open();

        sleep(1.0);
```

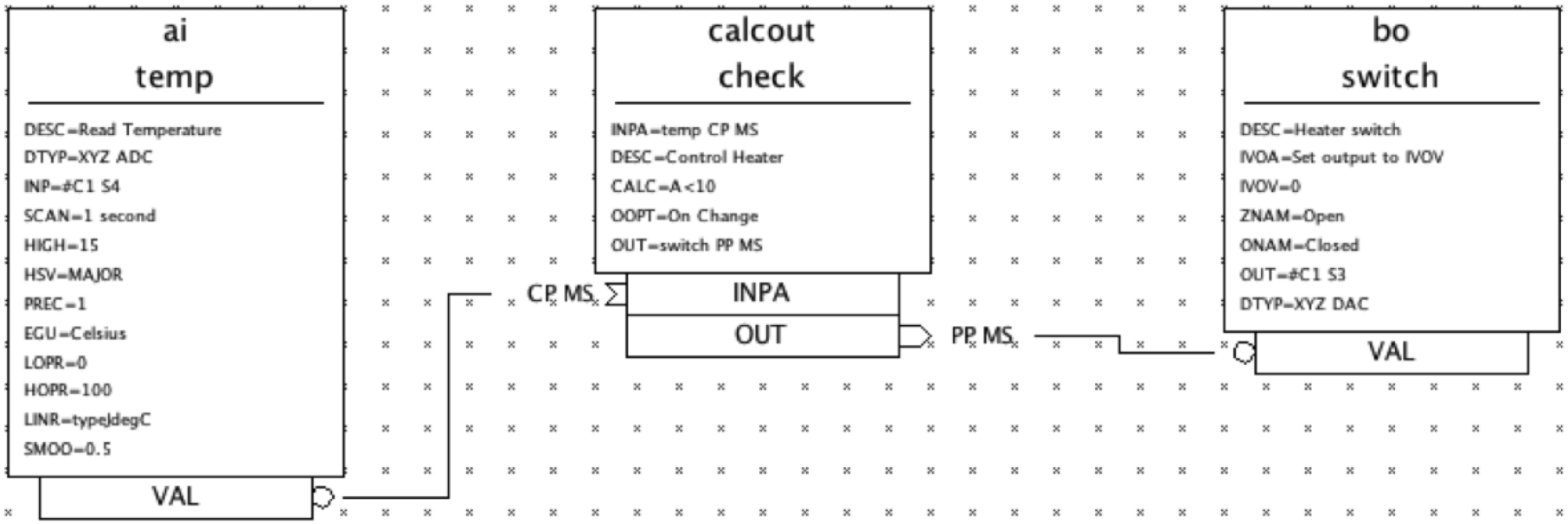
That basically works…



What we omitted

- Error checking
- Code comments
- Apply some smoothing to the temperature reading to filter noise.
- Send current temperature and switch state to network clients (operator display). With units.
- Attach a time stamp to the data, so that network clients can see for example when the switch was last opened.
- Send alarm when the temperature is too low or high.
- Allow runtime changes of the threshold from the remote operator interface.
- Allow runtime changes to the scan rate.
- Maybe allow runtime changes to the device address?
- What if we have more than one fishtank?

EPICS 'Database' for Fishtank



Takes getting used to, but handles what we omitted.

Some Detail on EPICS 'Records'

```
record(ai, temp) {
  field(DESC, "Read Temperature")
  field(SCAN, "1 second")
  field(DTYP, "XYZ ADC")
  field(INP, "#C1 S4")
  field(PREC, "1")
  field(LINR, "typeJdegC")
  field(EGU, "Celsius")
  field(HOPR, "100")
  field(LOPR, "0")
  field(SMOO, "0.5")
  field(HIGH, "15")
  field(HSV, "MAJOR")
}


record(calcout, check) {
  field(DESC, "Control Heater")
  field(CALC, "A<10")
  field(INPA, "temp CP MS")
  field(OUT, "switch")
  field(OOPT, "On Change")
}


record(bo, switch) {
  field(DESC, "Heater switch")
  field(DTYP, "XYZ DAC")
  field(OUT, "#C1 S3")
  field(ZNAM, "Open")
  field(ONAM, "Closed")
  field(IVOA, "Set output to IVOV")
  field(IVOV, "0")
}
```

~~Programming~~ Configuration

- "SCAN=1 second" instead of start thread, delay until next multiple of 1 second, lock required resources, …
- "SMOO=0.5" configures the smoothing algorithm.
- Almost any field in any record is accessible via network at runtime
  - Change scan rate, smoothing, …

IOC Database

- A single record can handle the scanning, signal conditioning, alarming of a temperature, pressure, or similar analog reading.
- Combined with binary and computational records, it can express the data flow logic for a front-end computer
  - Avoiding the pitfalls of real-time, multithreaded and networked programming.
- Can have thousands of records in one IOC.
- kHz-rate processing with record chains is doable
  - Of course limited by CPU. Not 1000nds of kHz rate-records…

How fast?

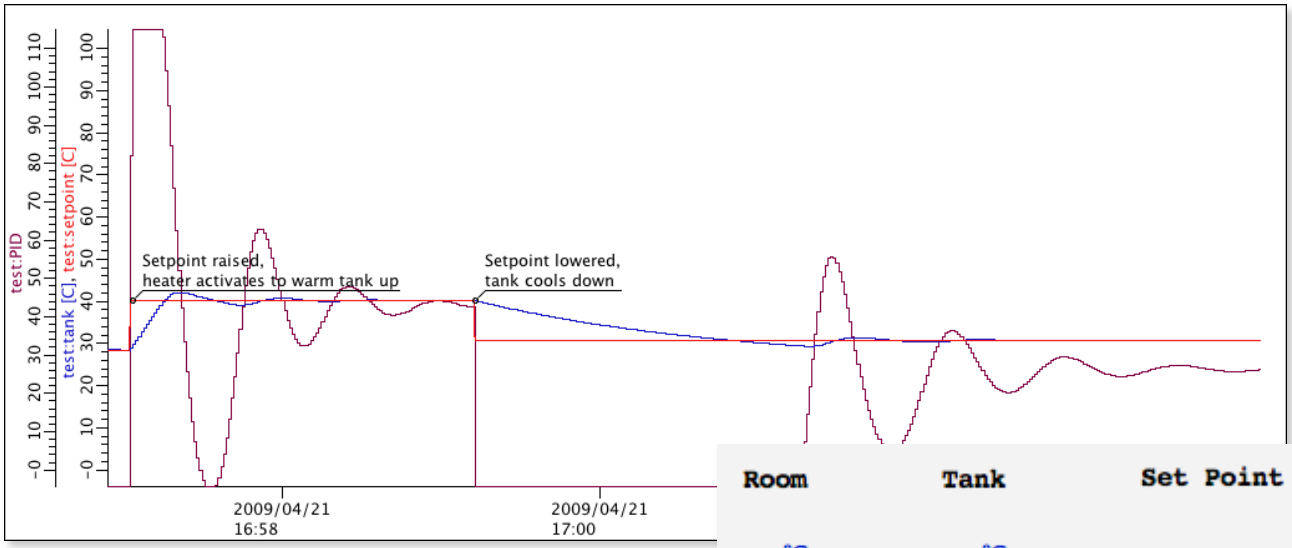
- Can be fast or slow, it depends how you use it!
- Use the correct tool for the job; Database, custom code (IOC) or custom code (client)
- Ultimately speed depends upon hardware
- Some benchmarks*:

Machine	OS	CPU	Speed	Rec/sec	%CPU
MVME167	**vxWorks**	**68040**	**33MHz**	**3,000**	**25**
MVME2306	**vxWorks**	**PPC604**	**300MHz**	**20,000**	**20**
MVME5100	**vxWorks**	**PPC750**	**450MHz**	**100,000**	**25**
PC	**Linux**	**PII**	**233MHz**	**10,000**	**27**
PC	**Linux**	**P4**	**2.4GHz**	**100,000**	**18**

* Extrapolated from benchmark figures courtesy of Steve Hunt (PSI) and L.Hoff, (BNL)

From Andrew Johnson (APS) EPICS Intro slide

Example Client: Operator Displays



Created in Editor

- No coding nor compilation

Networked

- Open/close
- Multiple OPIs

EPICS Vocabulary

- EPICS **Base**
  Code for IOC, database support, basic records, channel access
- **IOC**
  Input Output Controller, the front-end software
  - **Hard IOC**
    Using real-time OS in VME crate running nothing but IOC code
  - **Soft IOC**
    IOC software just another process on host,
    typically communicating with networked I/O
- **Database**
  Executes the EPICS **Records**
- **Record**
  EPICS processing block
- **Device** support
  Code that connects records to hardware Driver
- **Driver**
  Code that talks to hardware. May be unaware of EPICS
- **Channel Access, PV Access**
  EPICS network protocols. Expose **Channels** aka **Process Variables**

Information

- ~~http://www.aps.anl.gov/epics~~
  ~~https://epics.anl.gov~~
  https://epics-controls.org

  ’Base’

  - ‘Record Reference Manual’

    Everybody Must read!

  - ‘EPICS Application Developer's Guide’

    Technical detail about ‘makeBaseApp’, build system, device support, C/C++ API

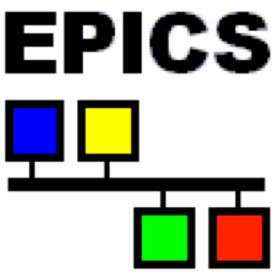
  ’Modules’, ‘H/W by Manufacturer’

  - Look there for device support

  ‘Talk’, ‘tech-talk’

  - Primary mailing list

EPICS Summary



- **Control System Toolkit**
  - Distributed, multi-platform, open source, extensible, …
- **Not fancy, but "works"**
  - Accelerators,
    Beam lines,
    Telescopes,
    Fusion experiments,
    …