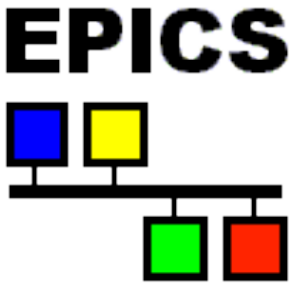
Experimental Physics and Industrial Control System



Kay Kasemir

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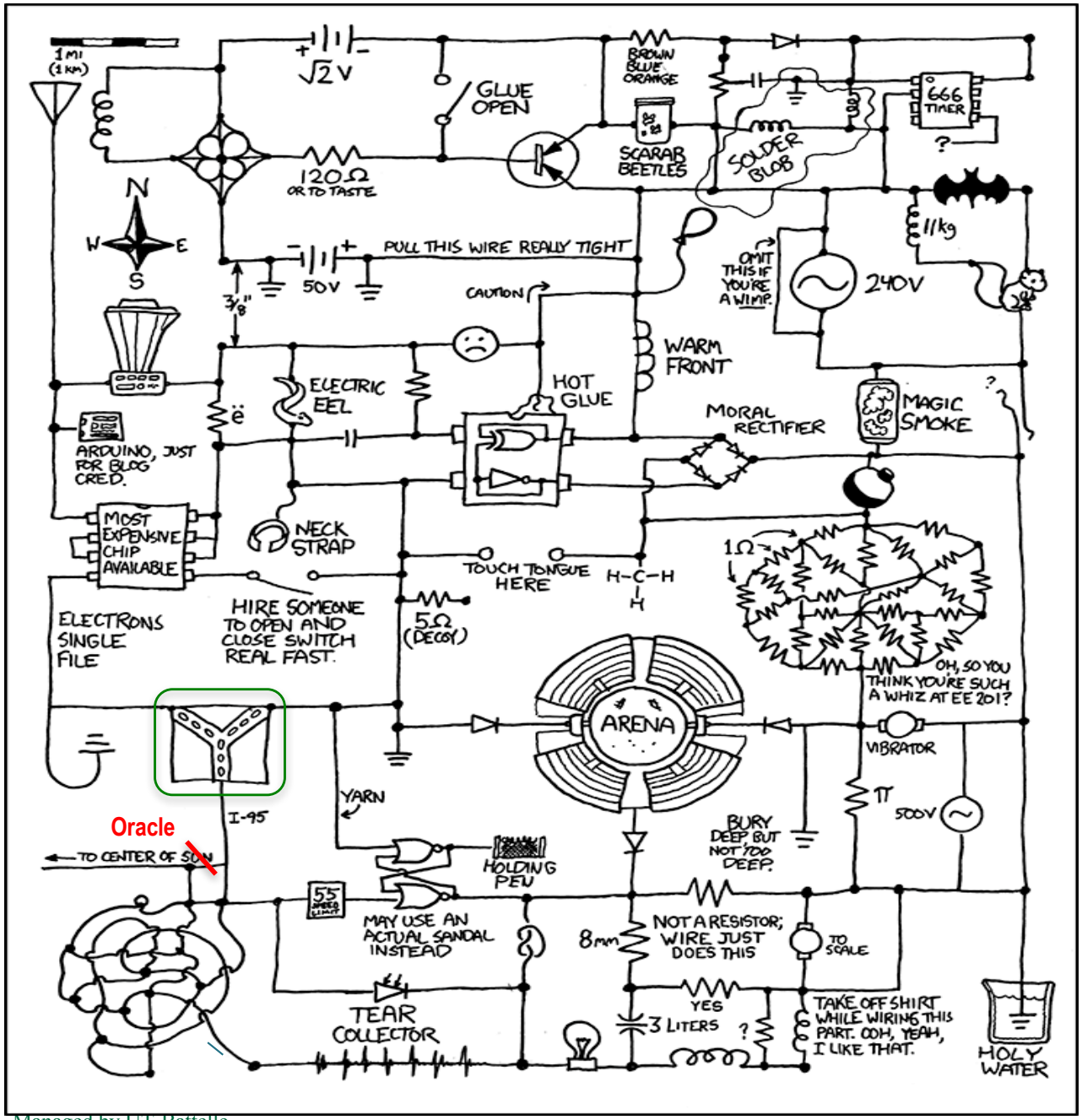
July 2017

What EPICS looks like

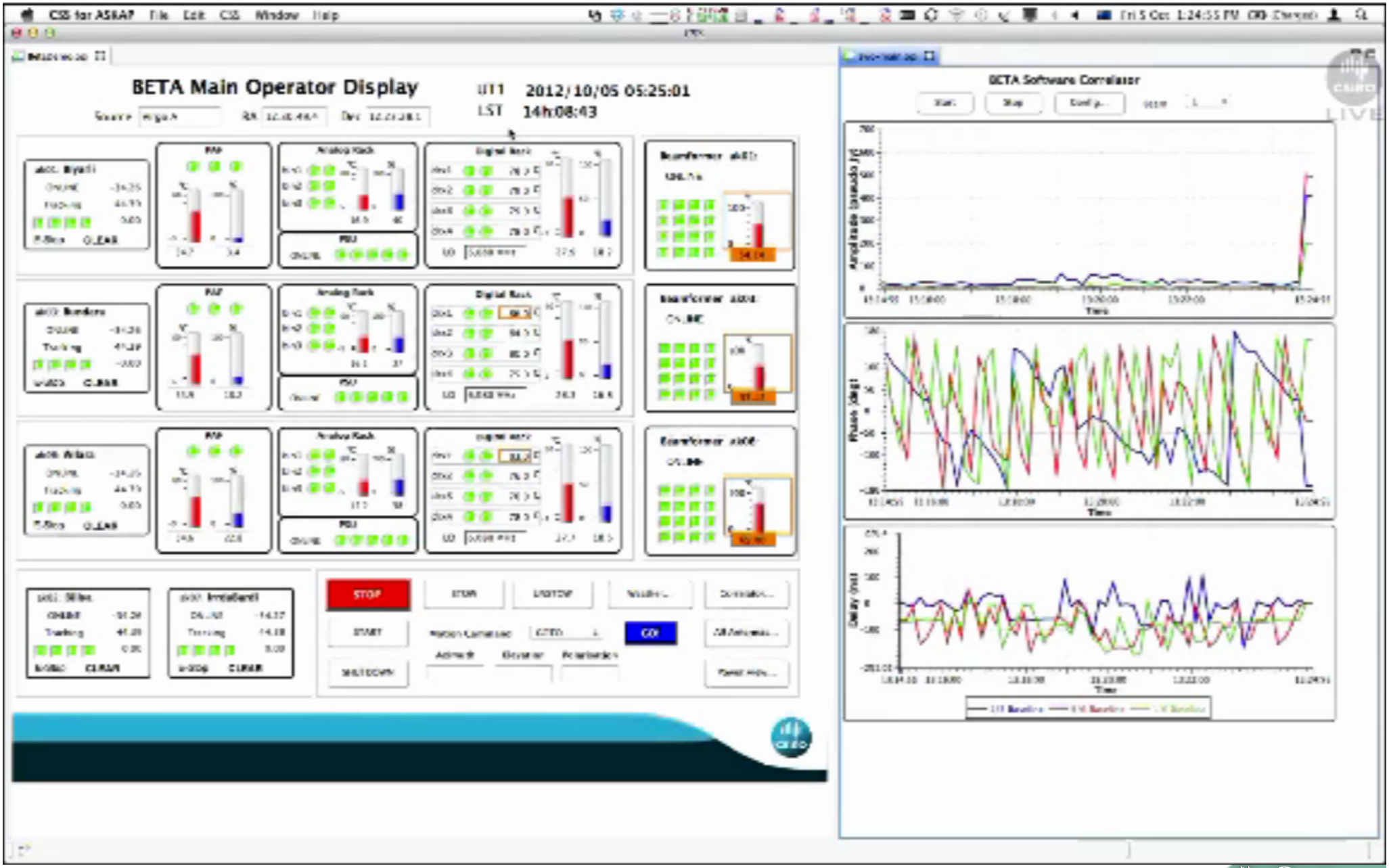


http://xkcd.com/730/

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

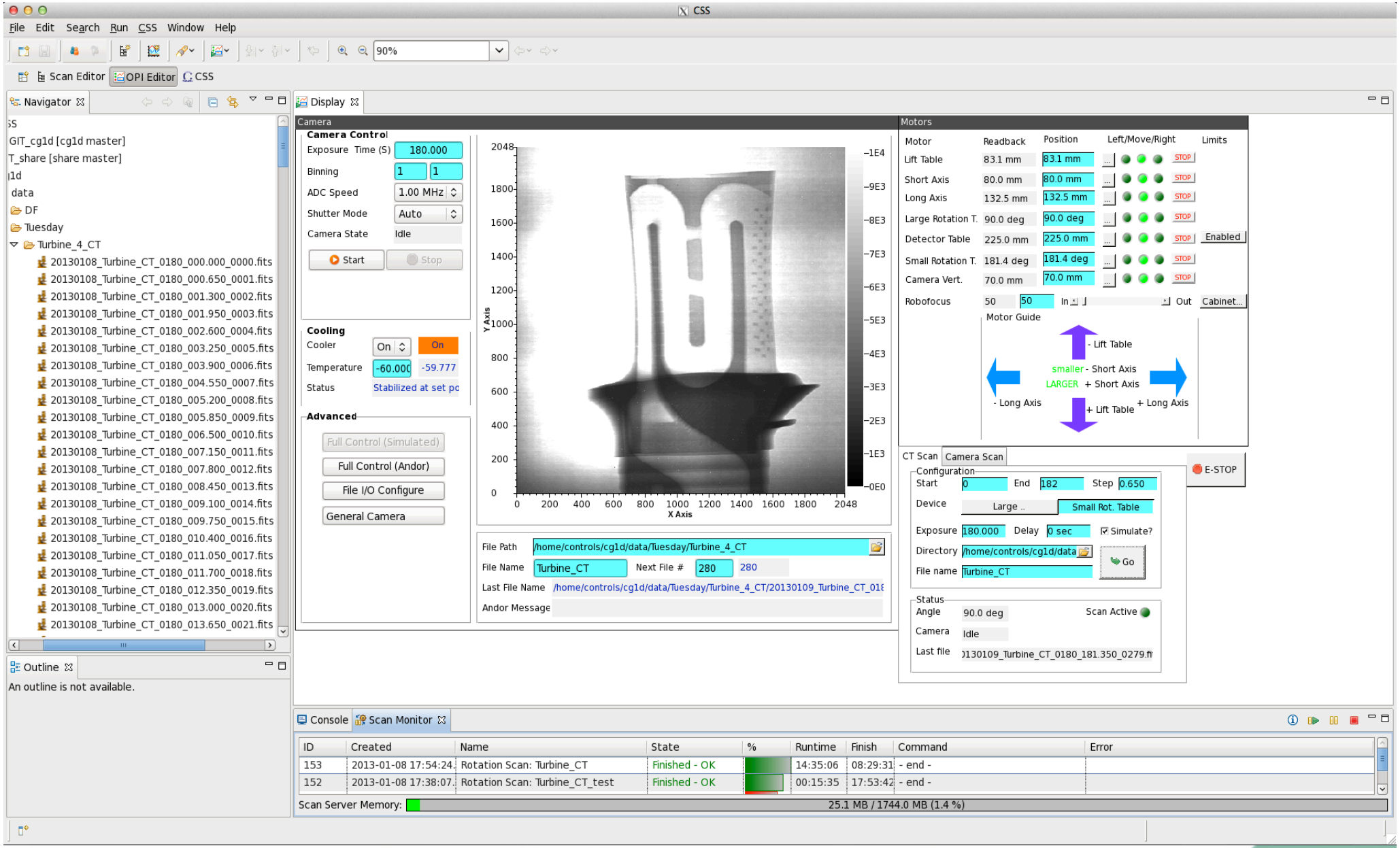
Juan Guzman, http://www.aps.anl.gov/epics/tech-talk/2012/msg02113.php

ASKAP User Interface



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

HFIR CG-1D



First EPICS/CSS operation with beam, Jan. 8, 2013

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, 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 in England; KEK-K, 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 2004, 05, 06.
- 'Tech-Talk' email reflector usually provides responses within a few hours
  - http://www.aps.anl.gov/epics

EPICS Meetings

Pohang, 2013

Santa Fe 2004

Tzukuba, 2000

Berlin, 1998

for the Department of Energy

EPICS is a Toolkit

… for distributed control systems.

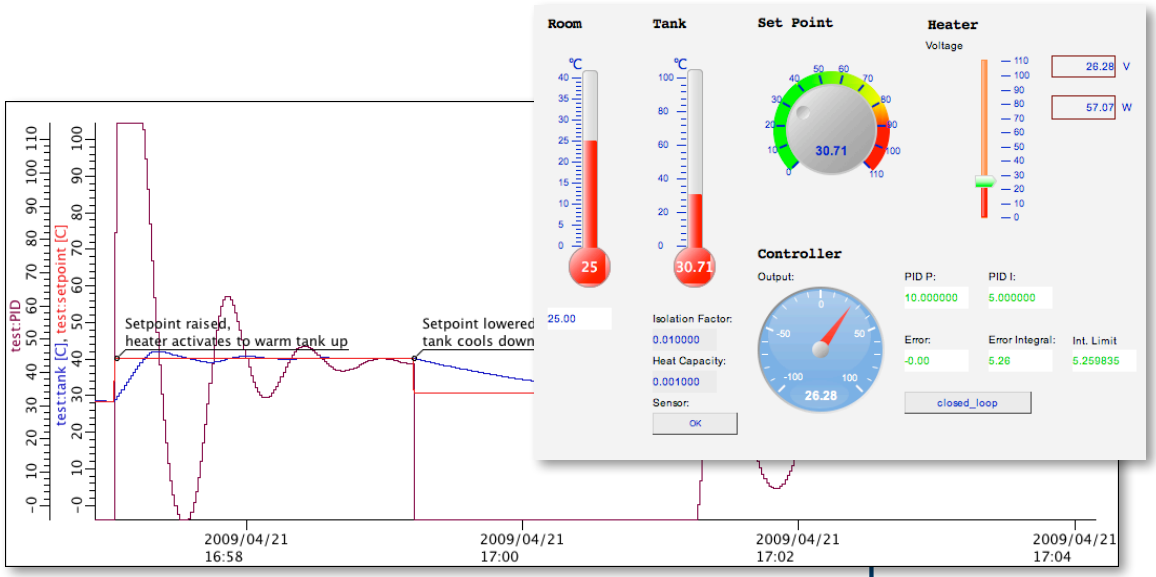
- Front-end: “Input/Output Controller” (IOC)
- Protocol: Channel Access
- Clients: Operator displays, alarm system, …

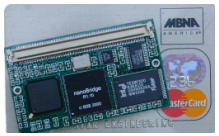
- Mostly Portable: vxWorks, RTEMS, Linux, OS X, Windows

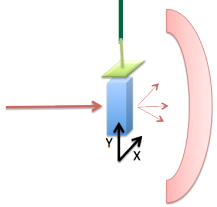
Distributed

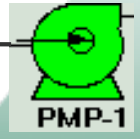
- Operator interface

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









OAK RIDGE National Laboratory

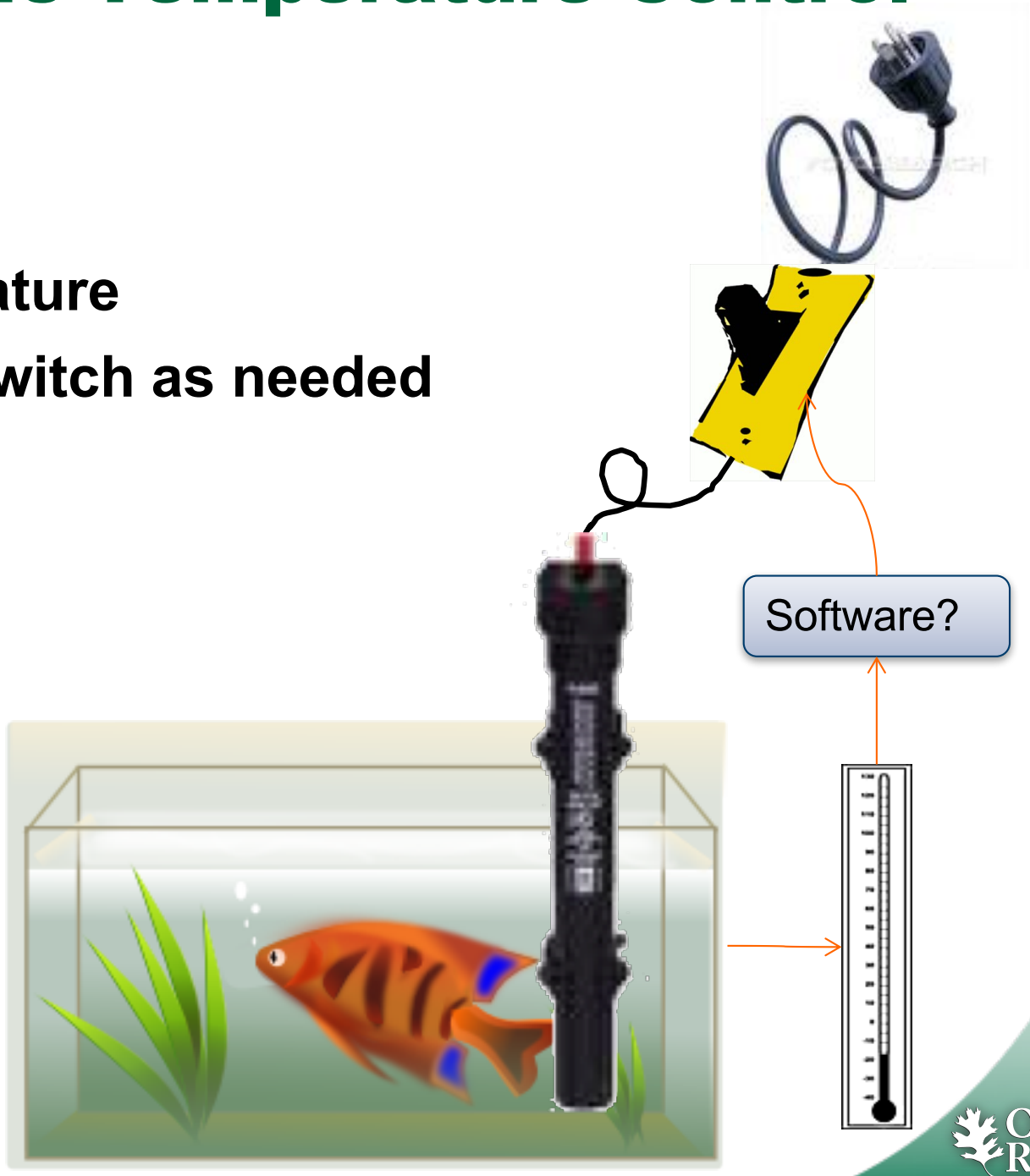
What an IOC does

- 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**



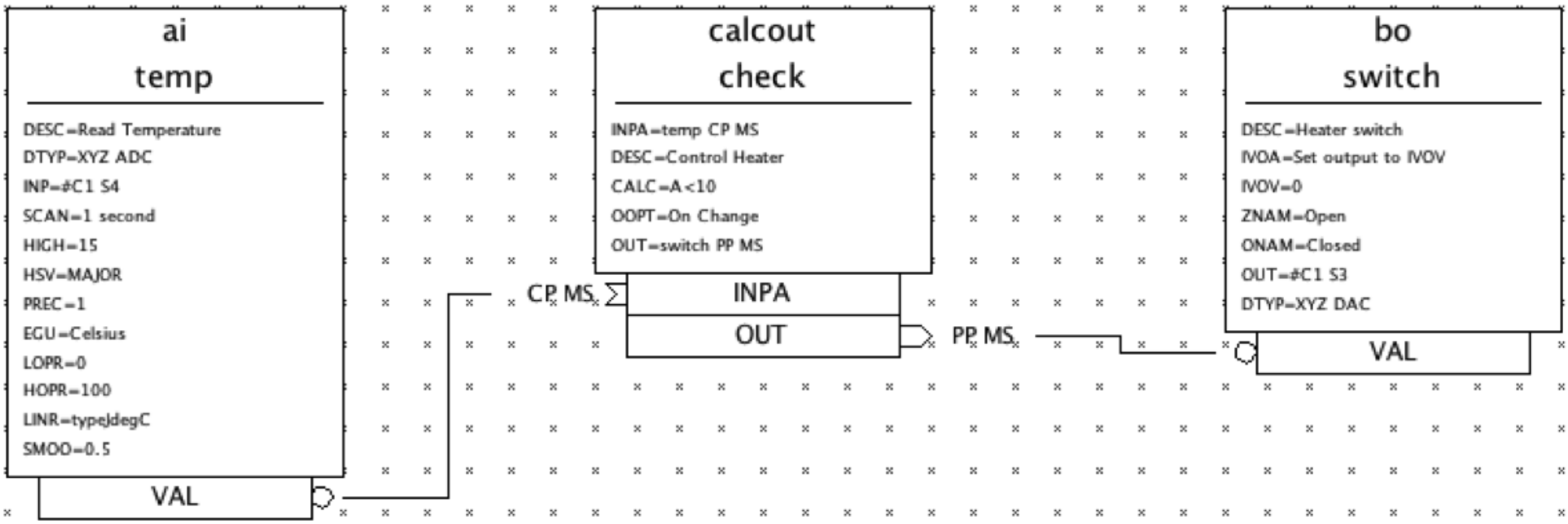
Simplistic Code

```
Sensor temp = connectToSensor(…);

Switch switch = connectToSwtich(…);

Loop:

        if (temp.value() < 25)
            switch.close();
        else
            switch.open();

        sleep(1.0);
```

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?

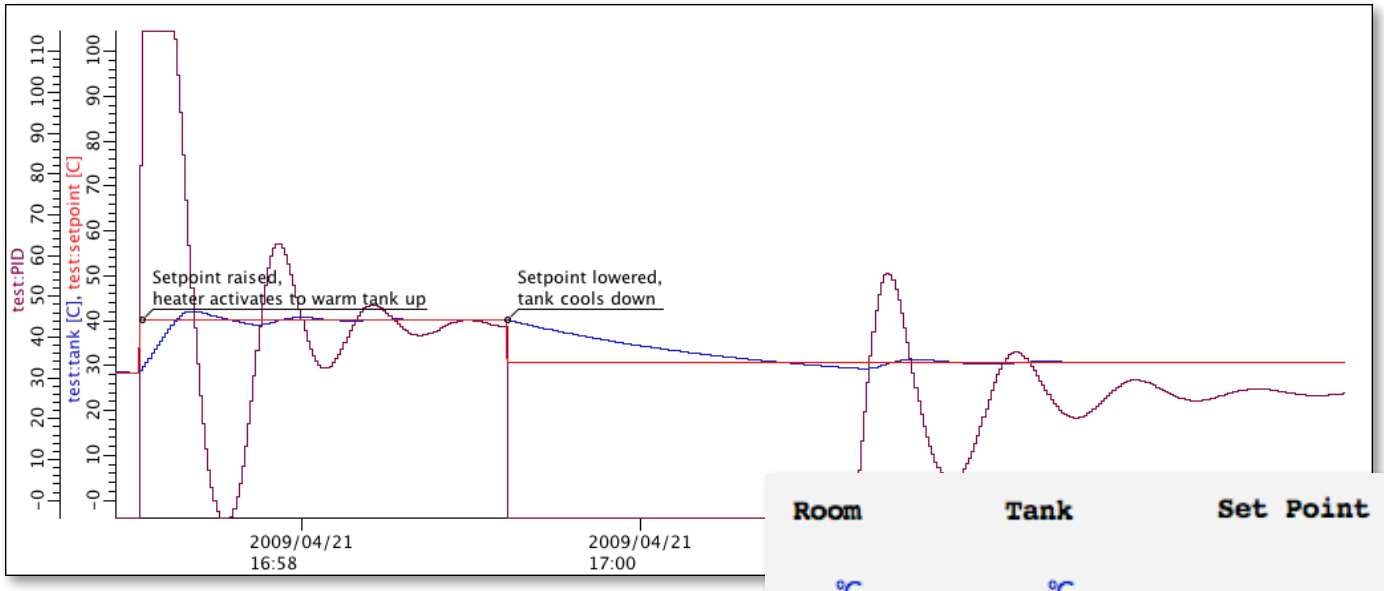
- Can be fast or slow, it depends how you use it!
- Use the correct tool for the job; Database, custom code (IOC) or custom code (client)
- Ultimately speed depends upon hardware
- Some benchmarks*:

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
  - Soft IOC
    IOC software running on Linux, …, 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
  EPICS network protocol. Exposes Channels aka Process Variables

Information

- http://www.aps.anl.gov/epics

  ’Base’

  - ‘Record Reference Manual’

    Everybody Must read!

  - ‘EPICS Application Developer's Guide’

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

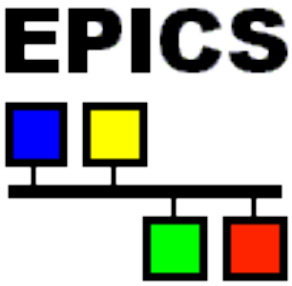
  ’Modules’, ‘H/W by Manufacturer’

  - 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,
    …

Argonne NATIONAL LABORATORY

BROOKHAVEN NATIONAL LABORATORY

DESY

diamond

iter the way to new energy

Los Alamos NATIONAL LABORATORY EST. 1943

SNS SPALLATION NEUTRON SOURCE

OAK RIDGE National Laboratory