Controls

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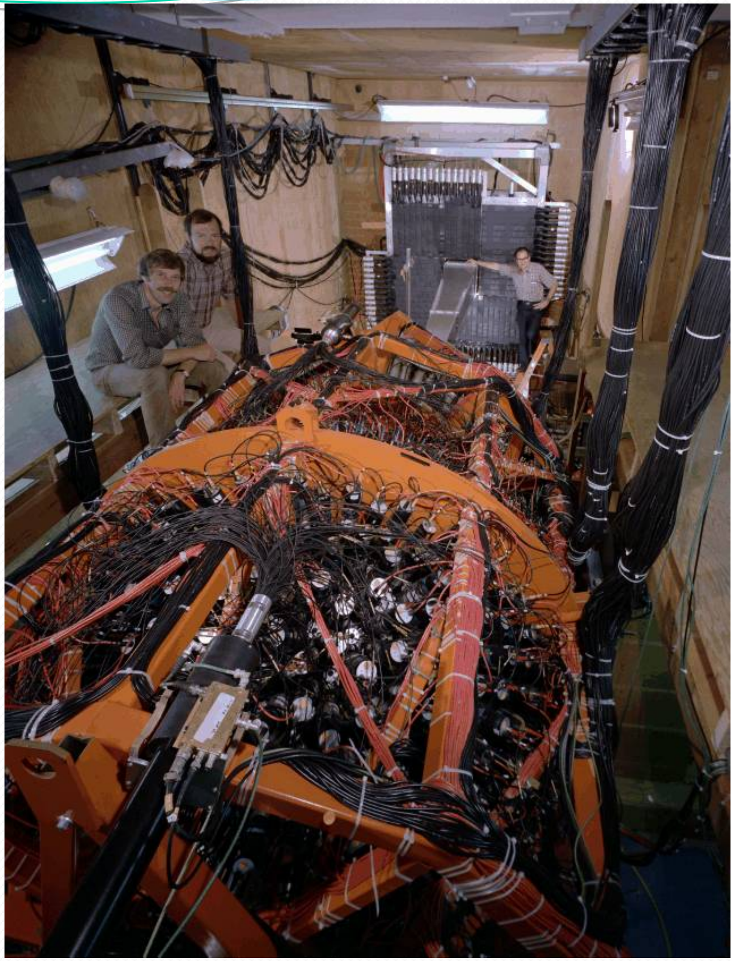
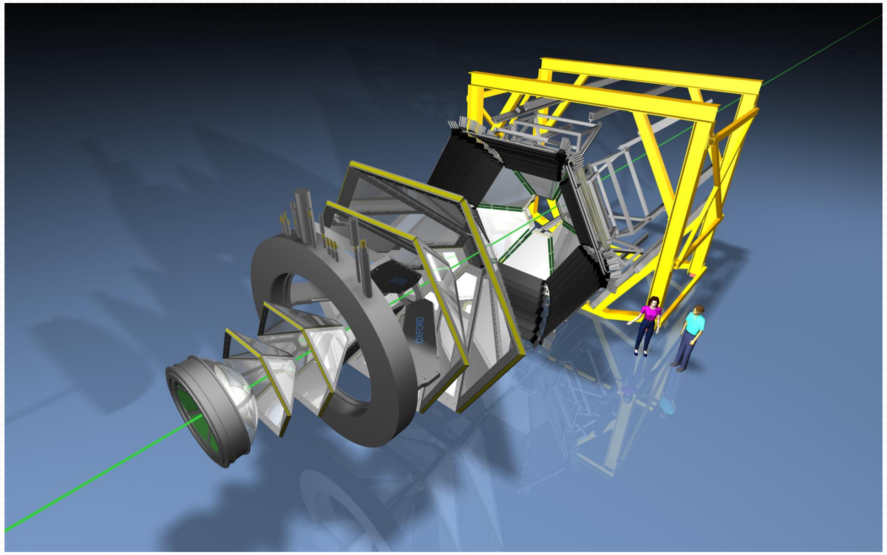
Outline

- Motivation
- What are we dealing with
  - Crates
  - Field busses
  - Devices
  - Control systems
- Example
  - Process Variable
  - IOC
  - Host tools

Curriculum Vitae

- **PhD @ HD 77**
- **Crystal ball @ HD 78**
- **Plastic ball @ LBL 82**
- **WA80/93/98 @ CERN 85**





HADES @GSI 96
CBM @ GSI 08

In the lab

- We use
  - Screwdriver / potentiometer
    - To adjust voltages / thresholds/ flows …

In the lab

- We use
  - Our eyes and other senses
    - To read voltages, meters …

In the lab

- We use
  - A logbook
    - To write down all parameters

In the lab

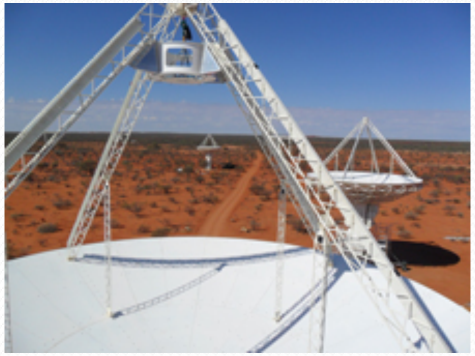
- We use
  - Our ears
    - To hear alarms
  - Our nose
    - To smell burning
  - Our skin
    - To feel heat

If our equipment is

- In a shielding

If our equipment is

- Far away



© W. M. Keck Observatory

We need a Control System

- Screwdriver
- Eye, nose, skin
- Logbook
- Alarm
- Measurement sequence

- remote actuator
- remote sensors
- archiving, database
- alarm handler
- automation, state machines

Why a Control System?

- We want to solve similar problems only once
- We do this by abstraction
- We provide the same “look and feel”
- Through structuring we hide complexity and large numbers of “control parameters”

What are the benefits?

- Remote setting via a graphical user interface (GUI)
- Remote setting via scripts or “backup and restore” tools
- Remote setting via automation tools – state machines, high level physics applications
- Coordinated simultaneous setting

What are the benefits?

- Automatic read back / monitoring
- Automatic archiving of data
- Alarm handling
- Trending

And what about Disadvantages?

- No direct “feeling”
- Time delay
- Some things may be hidden

What have we learned so far?

- Control systems are used for remote equipment
  - They provide
  - Control
  - Monitoring
  - Alarms
  - Archiving and trending

So? Why a Control System?

- I have a student who wants to program this device…
- … months later …
- Device works beautifully
- He gets his degree
- He leaves
  - Program documentation?
  - Reusability?
- Next student comes and throws it all away…

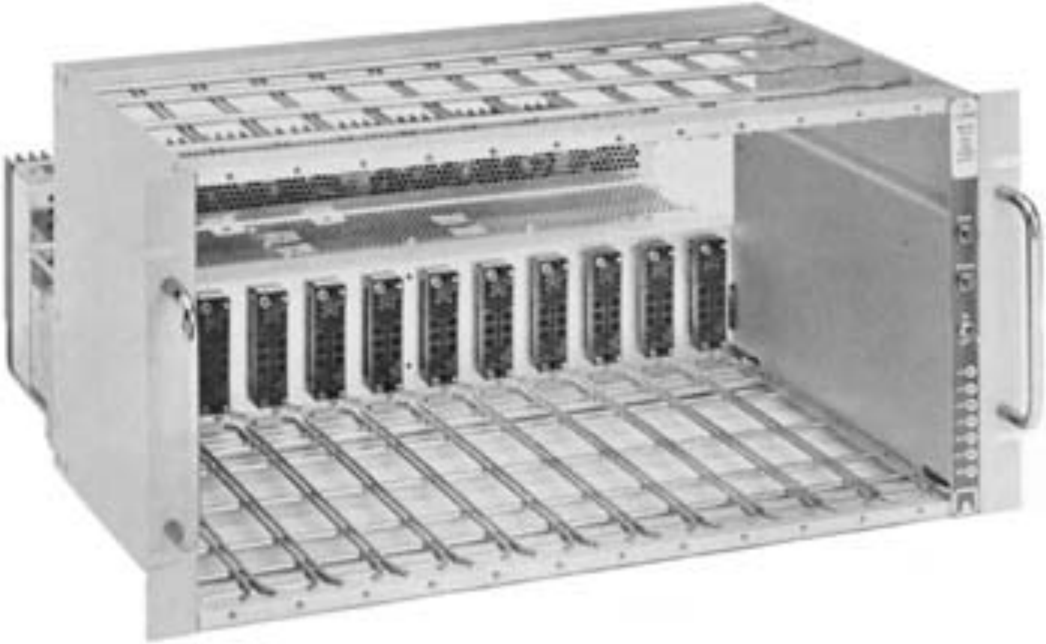
How does the World look like from a Control System?

- There are
  - Crates with modules
  - Field busses connecting to
    - Crates
    - Modules
  - Individual modules
    - Not really

Crate systems

- NIM
- CAMAC
- FASTBUS
- VME/VXI
- ATCA/μTCA

NIM



Nuclear Instrumentation Module
Defined in 1968-1969
Still used, provides only power

http://en.wikipedia.org/wiki/Nuclear_Instrumentation_Module

CAMAC

Computer Automated Measurement and Control
Defined in 1972
Parallel or serial branch
24 bit data/ 1 µs
Provides power and master/slave control

http://en.wikipedia.org/wiki/Computer_Automated_Measurement_and_Control

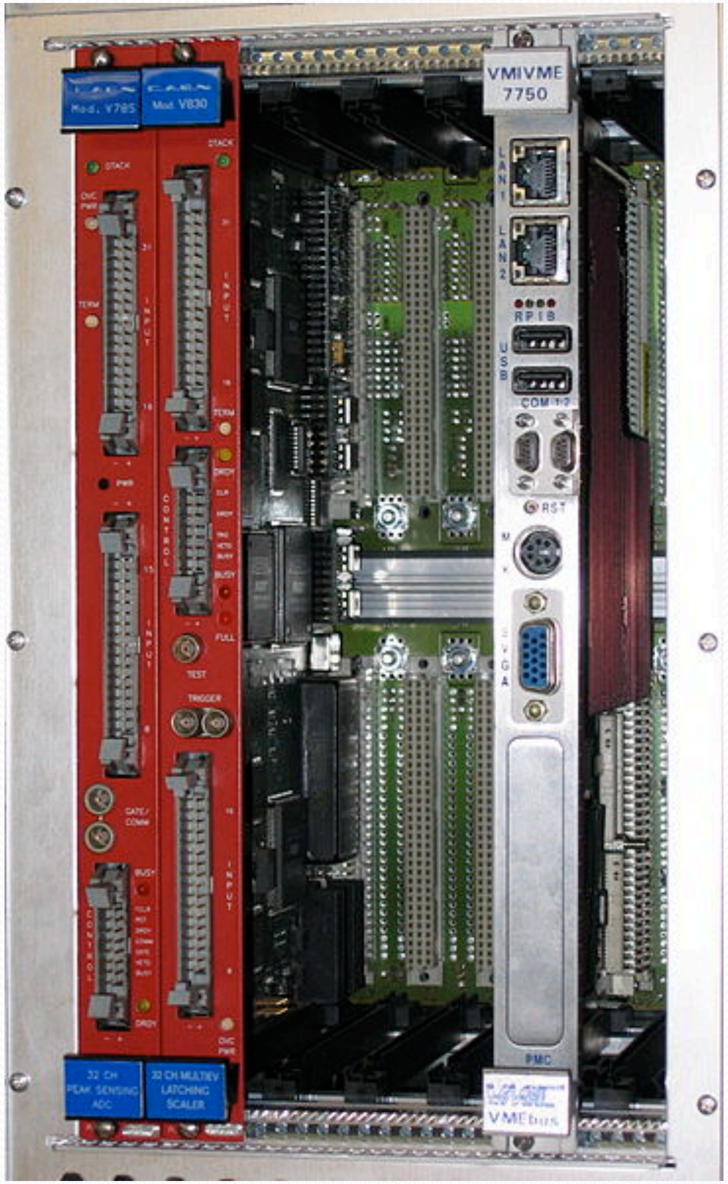
FASTBUS

FASTBUS (IEEE 960)
Defined in 1984
Segment interconnects:
Crate and cable segment
Large cards 14” by 15”
High power
ECL as electrical standard

http://en.wikipedia.org/wiki/FASTBUS

VME

VMEbus (ANSI/IEEE 1014-1987)
Originated from Motorolas 60000 cpus
Uses Eurocard size modules
Many revisions and speed improvements
VME64- VME320
Flat 32 bit memory model
Arbitration, multiple masters
Very widely used today



http://en.wikipedia.org/wiki/VMEbus
http://en.wikipedia.org/wiki/VXIbus

ATCA/μTCA

ATCA is a crate system developed by the telecommunications industry to house high performance processing cards in a high speed interconnect backplane

http://en.wikipedia.org/wiki/Advanced_Telecommunications_Computing_Architecture

Field busses

- RS232/485
- Ethernet
- CANbus
- Modbus
- GPIB
- EtherCAT
- OPC server
- Profibus
- WorldFIP

RS232/485

- The good old terminal line…
- Comes as simple RS232 line to connect one piece of equipment with a computer
- Or as RS485 with multi drop capability
- Protocol is normally ASCII command/response
  - SCPI
- Rarely also as binary transmission of bytes
- Connection also via com-servers on TCP/IP
- http://en.wikipedia.org/wiki/Rs232
- http://en.wikipedia.org/wiki/RS-485

Ethernet

- The network standard
  - Protocols:
    - TCP/IP
    - UDP
    - SNMP
    - telnet/socket
    - …
    - http://en.wikipedia.org/wiki/Ethernet

CANbus

- The automotive standard
  - Multi master
  - Multi slave
  - Deterministic
  - In cars for motor control, ABS, traction control
  - In physics for crate control, HV
  - Bit synchronous bus
  - Length limitation
  - http://en.wikipedia.org/wiki/CANbus

Modbus

- Connects to PLC (programmable logic controller)
- Simple protocol
  - read/write
  - Boolean/ 16bit
- Used for „DIN rail“ devices
- Practical use via ModTCP
- **http://en.wikipedia.org/wiki/Modbus**

GPIB

- Older fieldbus invented by HP (HP-IB) (late 1960s)
- Standard IEEE-488 (1975)
- Parallel bus for many measuring instruments
- Now used via Ethernet/GPIB adapters

http://en.wikipedia.org/wiki/GPIB

EtherCAT

- Ethernet based protocol with real time functionality for controls
- Proprietary protocol by BECKHOFF

http://en.wikipedia.org/wiki/EtherCAT

OPC server

- Ethernet based protocol with control functionality
- Started as proprietary protocol by Microsoft (DCOM, OLE for process automation
- Now standardized

http://en.wikipedia.org/wiki/Opc_server

Profibus and WorldFIP

- Attempts by the german and french authorities to establish fieldbus standards
- Still used in some labs

http://en.wikipedia.org/wiki/Profibus
http://en.wikipedia.org/wiki/WorldFIP

What have we learned so far?

- Crates and field bus systems exist in a great variety
- They act as housing or transport medium to connect the devices with a control system

Some devices

- High voltage supply
- Low voltage supply
- Temperature control/ monitor
- Gas handling systems
- Discriminators and FEE
- Scalers

- And many more

Control Systems

- Commercial systems:
  - PVSS/WinCC
  - Labview
- Open source systems:
  - Tango
  - EPICS

- http://en.wikipedia.org/wiki/WinCC
- http://en.wikipedia.org/wiki/EPICS
- http://en.wikipedia.org/wiki/TANGO
- http://en.wikipedia.org/wiki/Labview

How to decide

- Commercial versus open source
  - Philosophical question
  - License fees
  - Support
  - Dependence on operating system

Let’s assume we have chosen EPICS

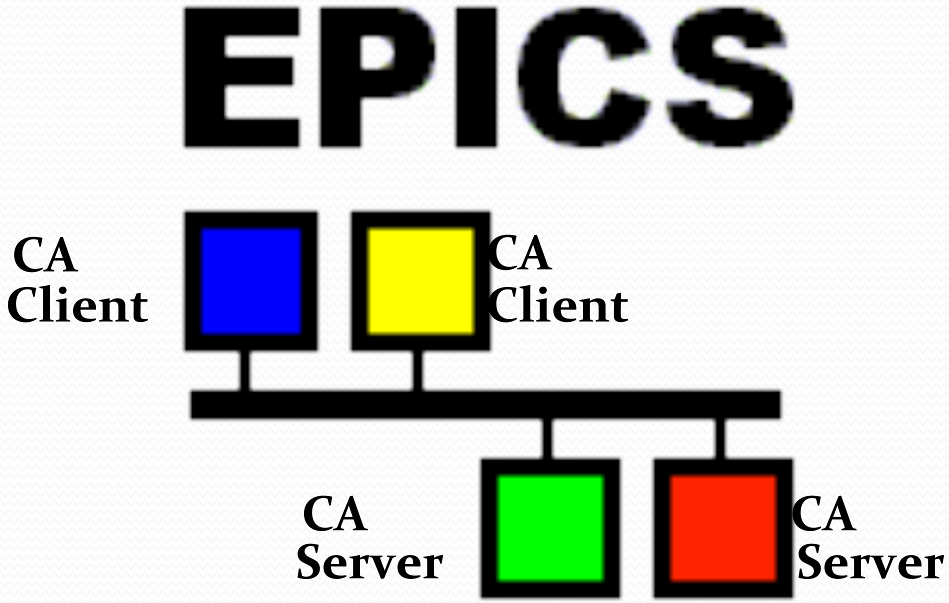
- So – what can we do with it?
- What is EPICS?
  - A Collaboration
  - A Control System Architecture
  - A Software Toolkit

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"
- Over 100 installations
- Many hundred collaborators
- List server; *tech-talk*: the collaboration in action
- Collaborative efforts vary
  - Assist in finding bugs
  - Share tools, schemes, and advice

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*

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

Example EPICS

Ten Really Neat Things About EPICS

1. It is free. No license fees, no new payment for every upgrade. You can download EPICS free of charge from the web.
2. It is Open Source (i.e. the source code is accessible). Adaptions and changes due to a special environment are therefore possible.
3. There are lots of users. It is tested and most bugs are already found.
4. All a client needs to know to access data is a PV name. No single point of failure due to a nameserver and no messing around with fixed addresses.
5. You can pick the best tools out there ...
6. ... or build your own.
7. The boring stuff is already done. For example the communication with Channel Access is stable and well tested.
8. There is a lot of expertise available close by.
9. A good contribution becomes internationally known.
10. It doesn't matter whether you need 10 PVs or 10 Million PVs. You can scale EPICS almost freely.

What is a PV

- PV stands for process variable
- It is identified by a name:
  - Myexample
  - HAD:TOF:HV:S1:M8:C5:VMON
- Good practice:
  - Use a facility wide naming convention
- Names must be unique on the network

Attributes of a PV

- NAME
- INPut or OUTput (address specification)
- VALue
- TIMEstamp
- SCANning type
- SEVR severity
- STATus
- RTYP record type
- DTYP device type
- EGU engineering unit
- PRECision
- Alarm/display/driving limits
- … many more

PV

- A PV is the smallest piece of information about a device
  - It holds for example a set voltage
  - The corresponding read back voltage is a different PV
  - A physical device has usually many PVs
  - You could freely name all those PVs
    - But if you choose a naming convention it is much easier to build GUIs for many similar devices

Record type of a PV

- The record type (RTYP) defines the abstract function of the record, i.e.:
  - ai : analog input record
    - Reads a value from a device
    - Converts to engineering units
    - Processes alarm limits
    - Sends monitor values to client
  - bo : binary output record
    - Converts ON/OFF to `1/0`
    - Sends `1` or `0` to device
    - Processes alarm limits
    - Sends monitor values to client

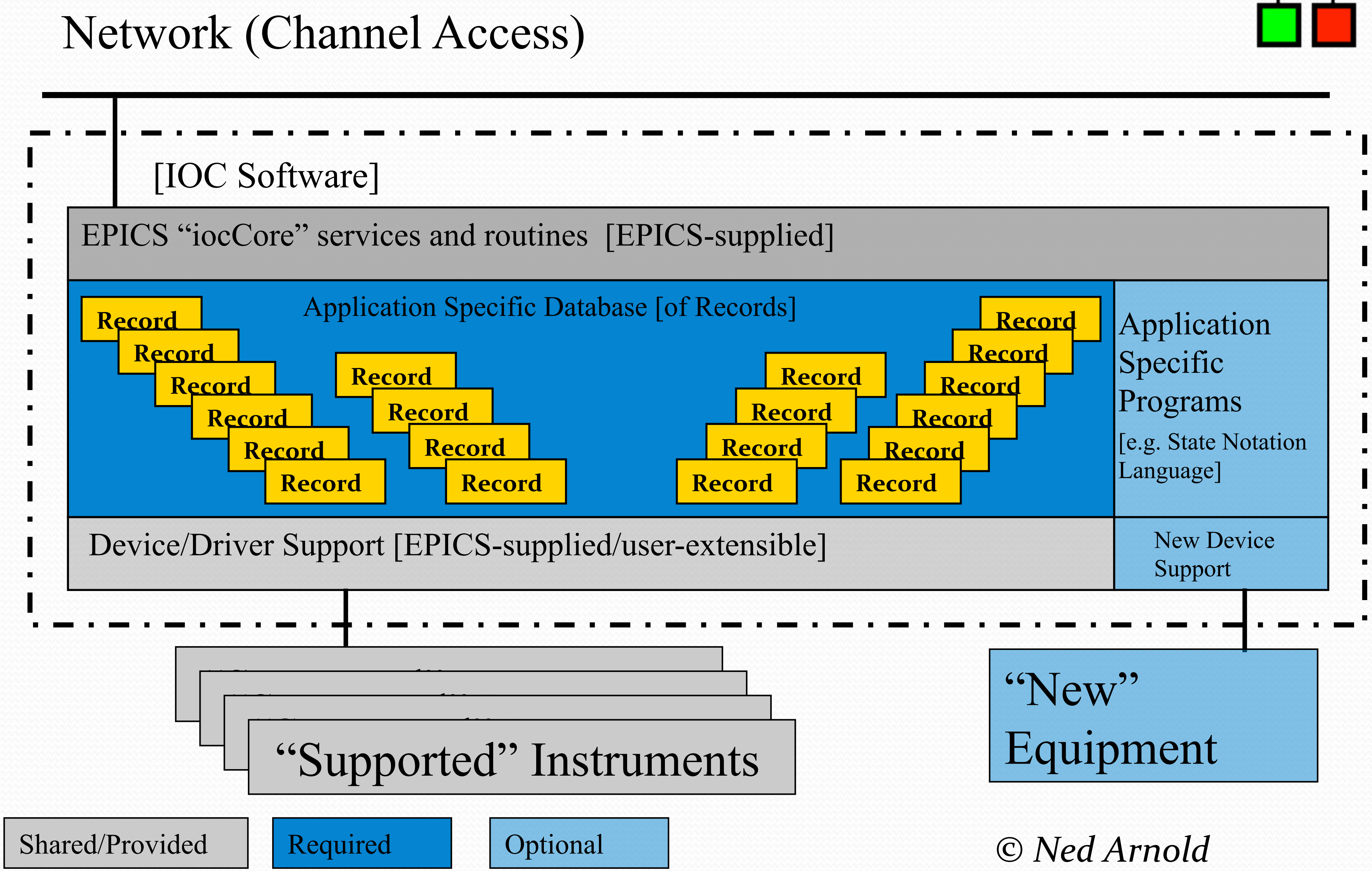
Abstraction layers

- Process Variable (PV)
  - Has a record type (RTYP) and record support
  - Uses device support (DTYP) to connect and format communication
  - May use driver support for low level communication/ interrupt handling
- Channel access (CA)
  - Links records to other records and to clients

PV database and IOC

- The PV database is a runtime collection of all PV records in one instance of an IOC (input output controller)
- The IOC is the program which runs the PV database
  - Schedules execution of PVs (scanning)
  - Takes care of communication with clients (CA)
  - Runs state machines (sequencer)
  - Binds together
    - Records
    - Device
    - Driver layers

IOC Software in One Slide



Network (Channel Access)

[IOC Software]

EPICS “iocCore” services and routines [EPICS-supplied]

Application Specific Database [of Records]

Record Record Record Record Record Record

Record Record Record Record

Record Record Record Record

Record Record Record Record Record Record

Application Specific Programs

[e.g. State Notation Language]

Device/Driver Support [EPICS-supplied/user-extensible]

New Device Support

“Supported” Instruments

“New” Equipment

Shared/Provided

Required

Optional

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IOC

- Originally running on VME cpus under VxWorks operating system
- Now also on RTEMS
- And as Soft IOC on Linux, MacOSX, Windows, ...
- VxWorks and RTEMS are real time OS
  - Needed for fast feedback

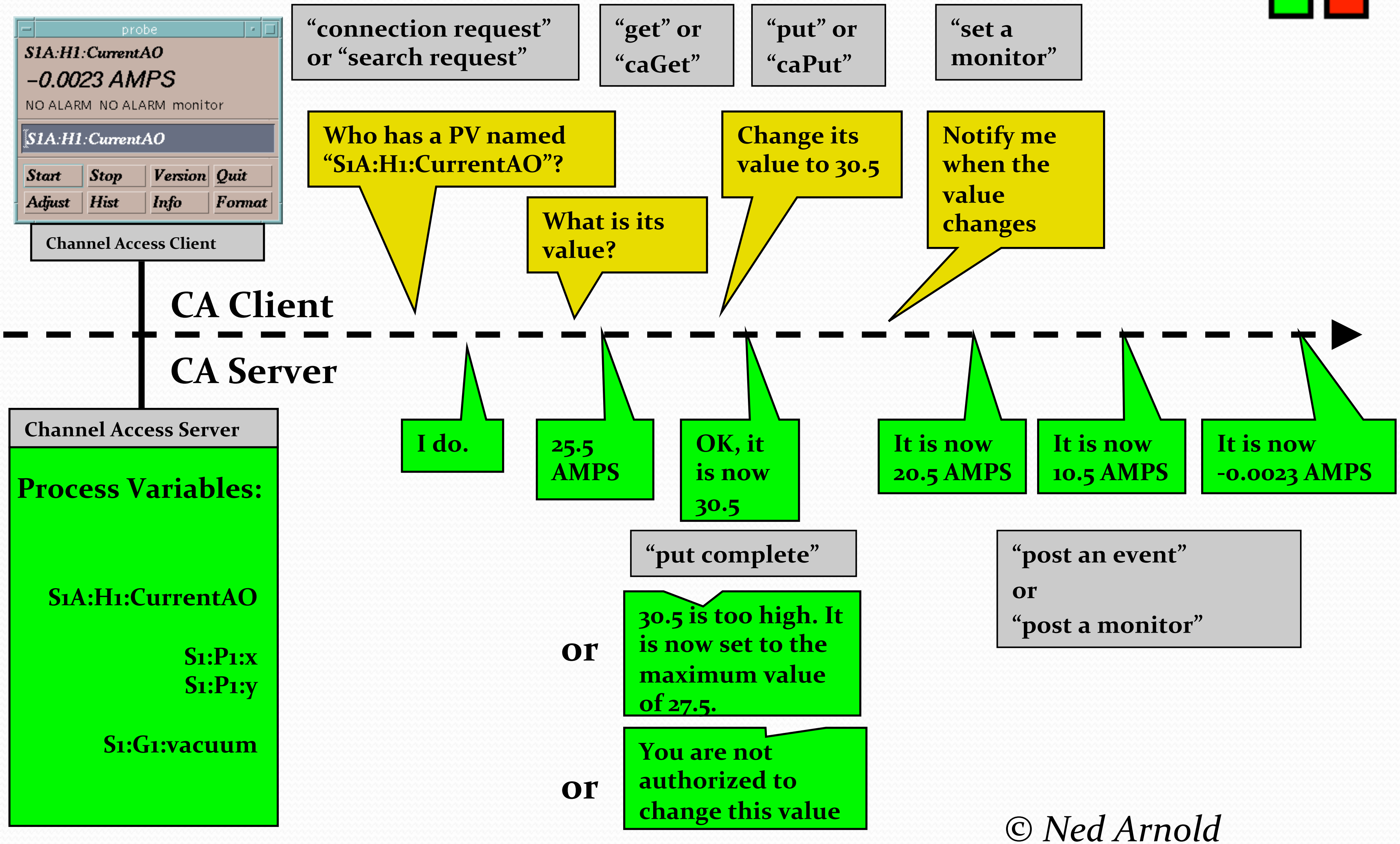
Channel Access

- Is the protocol that links PVs to clients:
  - GUI
  - Alarm handler
  - Archiver
  - Other tools
- A client may also be another PV on the network
- Protocol usually transmits only value, time stamp, and status
- Control info is sent only once at connection time

Channel Access (2)

- 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

Channel Access in One Slide



probe

S1A:H1:CurrentAO

-0.0023 AMPS

NO ALARM NO ALARM monitor

S1A:H1:CurrentAO

Start Stop Version Quit

Adjust Hist Info Format

Channel Access Client

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"

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

I do.

"get" or "caGet"

What is its value?

25.5 AMPS

"put" or "caPut"

Change its value to 30.5

OK, it is now 30.5

"put complete"

or

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

or

You are not authorized to change this value

"set a monitor"

Notify me when the value changes

It is now 20.5 AMPS

It is now 10.5 AMPS

It is now -0.0023 AMPS

"post an event"
or
"post a monitor"

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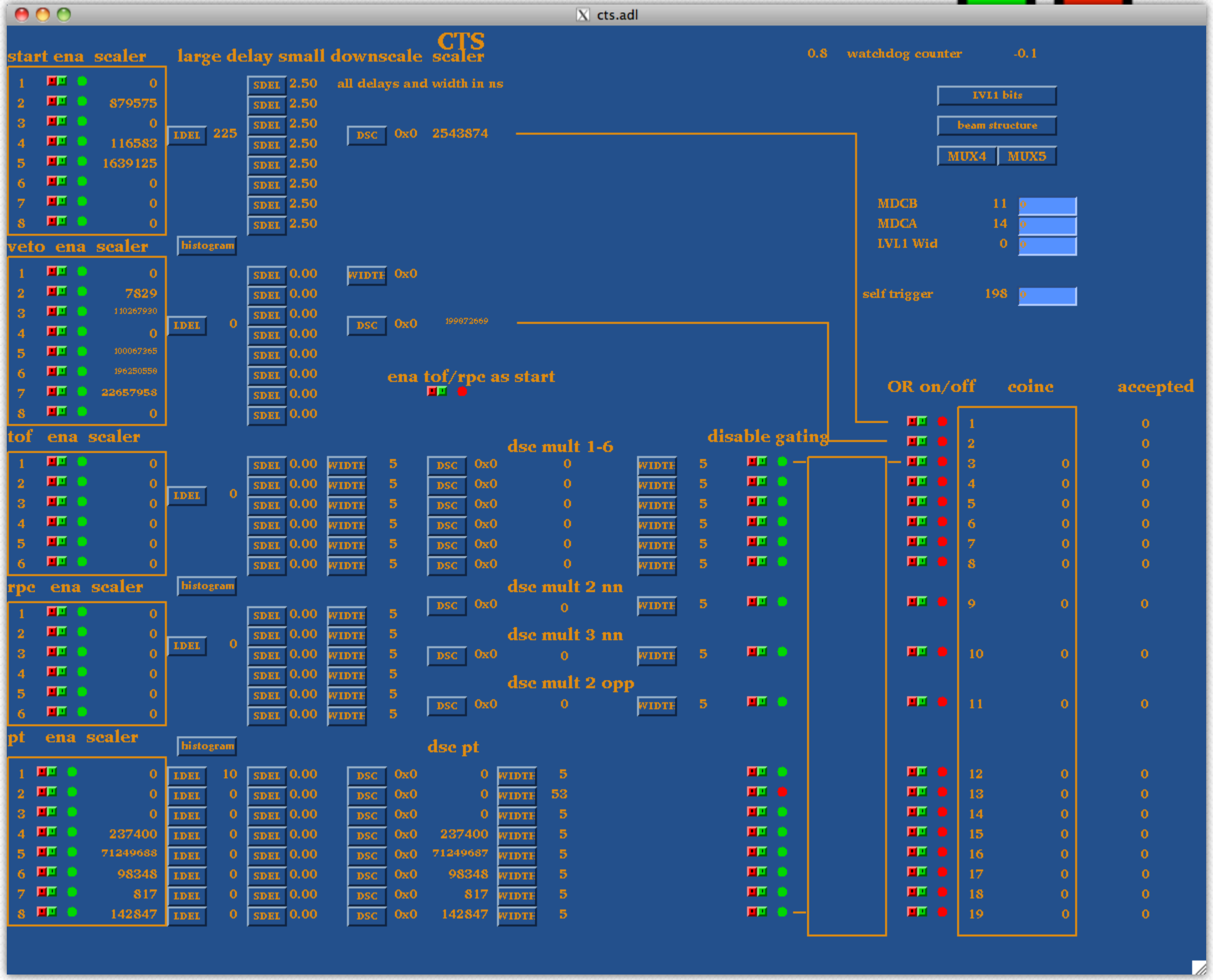
Host tools

- GUIs
  - Motif based: MEDM, edm
  - Java based: CSS
- Archiver:
  - ChannelArchiver and
  - dataserver
- Alarm Handler: alh
- Backup and restore tool: burt

GUI

- MEDM



cts.adl

CTS

0.8 watchdog counter -0.1

all delays and width in ns

start	ena	scaler	large delay	small	downscale	scaler
1	🟢	0	LDEL 225	SDEL 2.50		
2	🟢	879575		SDEL 2.50		
3	🟢	0		SDEL 2.50	DSC 0x0	2543874
4	🟢	116583		SDEL 2.50		
5	🟢	1639125		SDEL 2.50		
6	🟢	0		SDEL 2.50		
7	🟢	0		SDEL 2.50		
8	🟢	0		SDEL 2.50		

veto	ena	scaler	large delay	small	downscale	scaler
1	🟢	0		SDEL 0.00	WIDTH 0x0	
2	🟢	7829		SDEL 0.00		
3	🟢	110267930	LDEL 0	SDEL 0.00	DSC 0x0	199872669
4	🟢	0		SDEL 0.00		
5	🟢	100067365		SDEL 0.00		
6	🟢	196250558		SDEL 0.00		
7	🟢	22657958		SDEL 0.00		
8	🟢	0		SDEL 0.00		

ena tof/rpc as start 🔴

tof	ena	scaler	large delay	small	width	dsc mult 1-6		width	disable gating
1	🟢	0		SDEL 0.00	WIDTH 5	DSC 0x0	0	WIDTH 5	🟢
2	🟢	0	LDEL 0	SDEL 0.00	WIDTH 5	DSC 0x0	0	WIDTH 5	🟢
3	🟢	0		SDEL 0.00	WIDTH 5	DSC 0x0	0	WIDTH 5	🟢
4	🟢	0		SDEL 0.00	WIDTH 5	DSC 0x0	0	WIDTH 5	🟢
5	🟢	0		SDEL 0.00	WIDTH 5	DSC 0x0	0	WIDTH 5	🟢
6	🟢	0		SDEL 0.00	WIDTH 5	DSC 0x0	0	WIDTH 5	🟢

rpc	ena	scaler	large delay	small	width
1	🟢	0		SDEL 0.00	WIDTH 5
2	🟢	0	LDEL 0	SDEL 0.00	WIDTH 5
3	🟢	0		SDEL 0.00	WIDTH 5
4	🟢	0		SDEL 0.00	WIDTH 5
5	🟢	0		SDEL 0.00	WIDTH 5
6	🟢	0		SDEL 0.00	WIDTH 5

	downscale	scaler	width	disable gating
dsc mult 2 nn	DSC 0x0	0	WIDTH 5	🟢
dsc mult 3 nn	DSC 0x0	0	WIDTH 5	🟢
dsc mult 2 opp	DSC 0x0	0	WIDTH 5	🟢

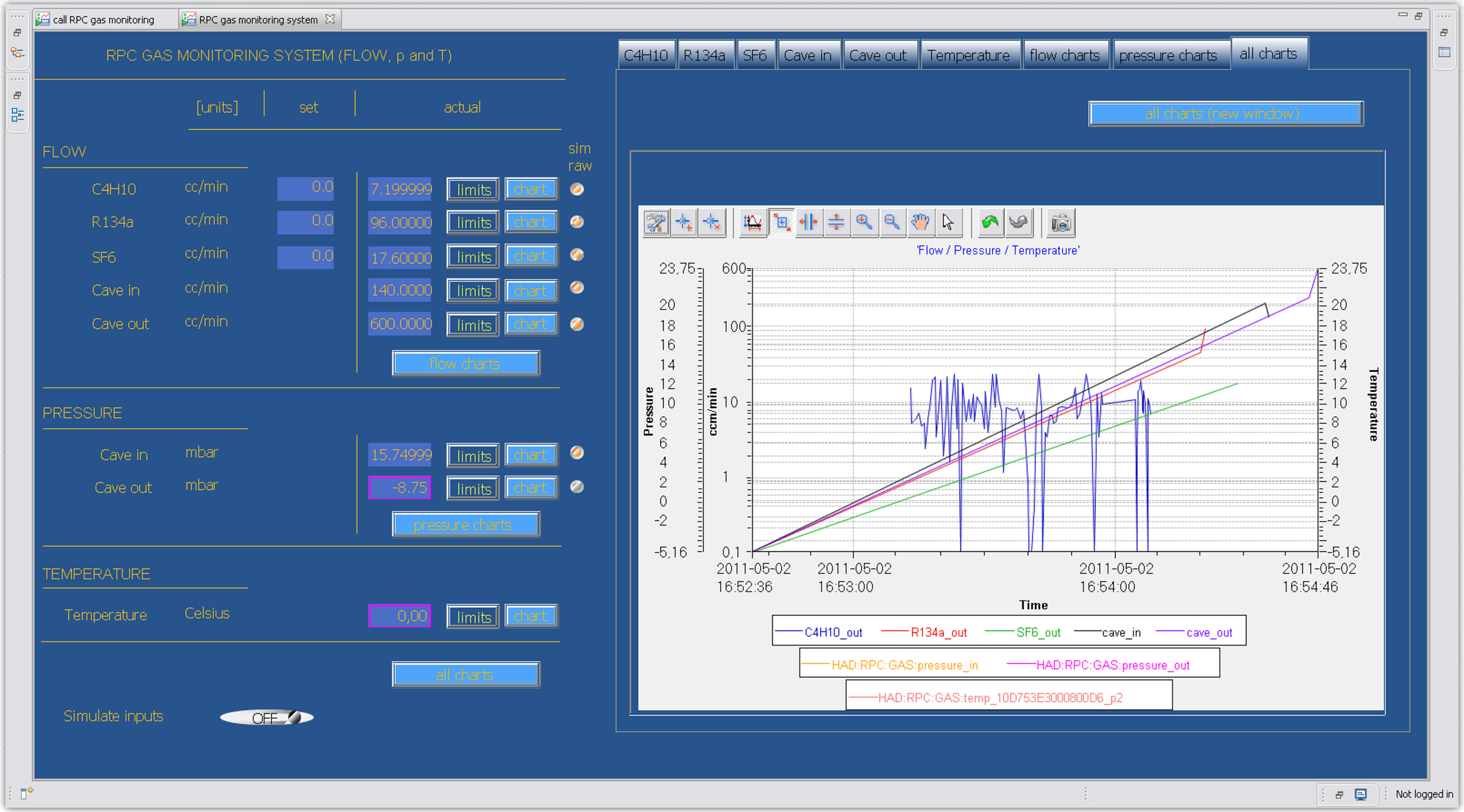
pt	ena	scaler	large delay	small	dsc pt	scaler	width	disable gating
1	🟢	0	LDEL 10	SDEL 0.00	DSC 0x0	0	WIDTH 5	🟢
2	🟢	0	LDEL 0	SDEL 0.00	DSC 0x0	0	WIDTH 53	🔴
3	🟢	0	LDEL 0	SDEL 0.00	DSC 0x0	0	WIDTH 5	🟢
4	🟢	237400	LDEL 0	SDEL 0.00	DSC 0x0	237400	WIDTH 5	🟢
5	🟢	71249688	LDEL 0	SDEL 0.00	DSC 0x0	71249687	WIDTH 5	🟢
6	🟢	98348	LDEL 0	SDEL 0.00	DSC 0x0	98348	WIDTH 5	🟢
7	🟢	817	LDEL 0	SDEL 0.00	DSC 0x0	817	WIDTH 5	🟢
8	🟢	142847	LDEL 0	SDEL 0.00	DSC 0x0	142847	WIDTH 5	🟢

MDCB	11	0
MDCA	14	0
LVL1 Wid	0	0
self trigger	198	0

OR on/off		coinc	accepted
🔴	1		0
🔴	2		0
🔴	3	0	0
🔴	4	0	0
🔴	5	0	0
🔴	6	0	0
🔴	7	0	0
🔴	8	0	0
🔴	9	0	0
🔴	10	0	0
🔴	11	0	0
🔴	12	0	0
🔴	13	0	0
🔴	14	0	0
🔴	15	0	0
🔴	16	0	0
🔴	17	0	0
🔴	18	0	0
🔴	19	0	0

GUI

- CSS



call RPC gas monitoring | RPC gas monitoring system

RPC GAS MONITORING SYSTEM (FLOW, p and T)

	[units]	set	actual			sim raw
FLOW						
C4H10	cc/min	0.0	7.199999	limits	chart	
R134a	cc/min	0.0	96.00000	limits	chart	
SF6	cc/min	0.0	17.60000	limits	chart	
Cave in	cc/min		140.0000	limits	chart	
Cave out	cc/min		600.0000	limits	chart	
PRESSURE						
Cave in	mbar		15.74999	limits	chart	
Cave out	mbar		-8.75	limits	chart	
TEMPERATURE						
Temperature	Celsius		0,00	limits	chart	

flow charts

pressure charts

all charts

Simulate inputs: OFF

C4H10 | R134a | SF6 | Cave in | Cave out | Temperature | flow charts | pressure charts | all charts

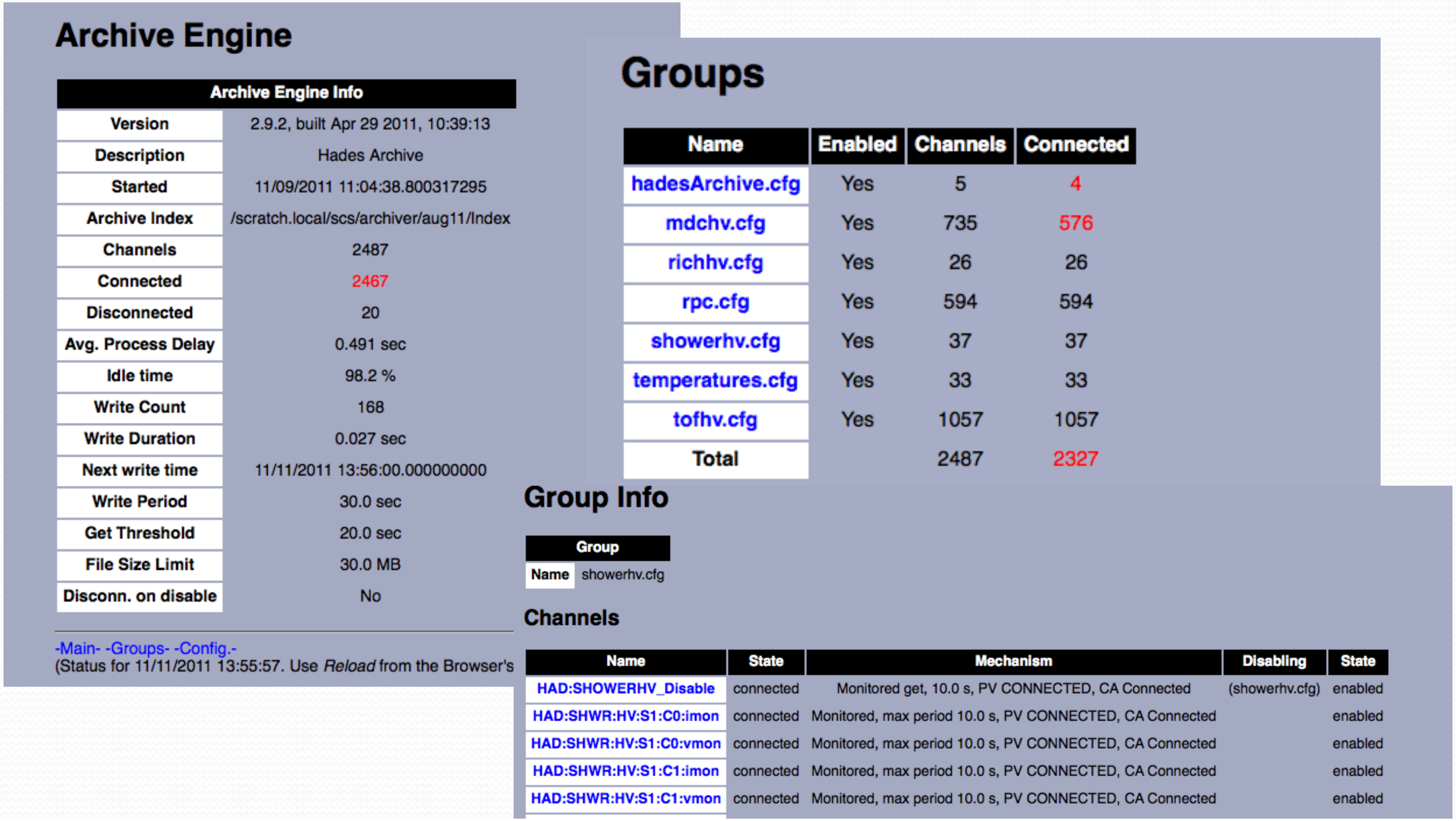
all charts (new window)

'Flow / Pressure / Temperature'

Not logged in

Archiving

- ChannelArchiver



Archive Engine

Archive Engine Info	
Version	2.9.2, built Apr 29 2011, 10:39:13
Description	Hades Archive
Started	11/09/2011 11:04:38.800317295
Archive Index	/scratch.local/scs/archiver/aug11/Index
Channels	2487
Connected	2467
Disconnected	20
Avg. Process Delay	0.491 sec
Idle time	98.2 %
Write Count	168
Write Duration	0.027 sec
Next write time	11/11/2011 13:56:00.000000000
Write Period	30.0 sec
Get Threshold	20.0 sec
File Size Limit	30.0 MB
Disconn. on disable	No

-Main- -Groups- -Config.-
(Status for 11/11/2011 13:55:57. Use *Reload* from the Browser's

Groups

Name	Enabled	Channels	Connected
hadesArchive.cfg	Yes	5	4
mdchv.cfg	Yes	735	576
richhv.cfg	Yes	26	26
rpc.cfg	Yes	594	594
showerhv.cfg	Yes	37	37
temperatures.cfg	Yes	33	33
tofhv.cfg	Yes	1057	1057
Total		2487	2327

Group Info

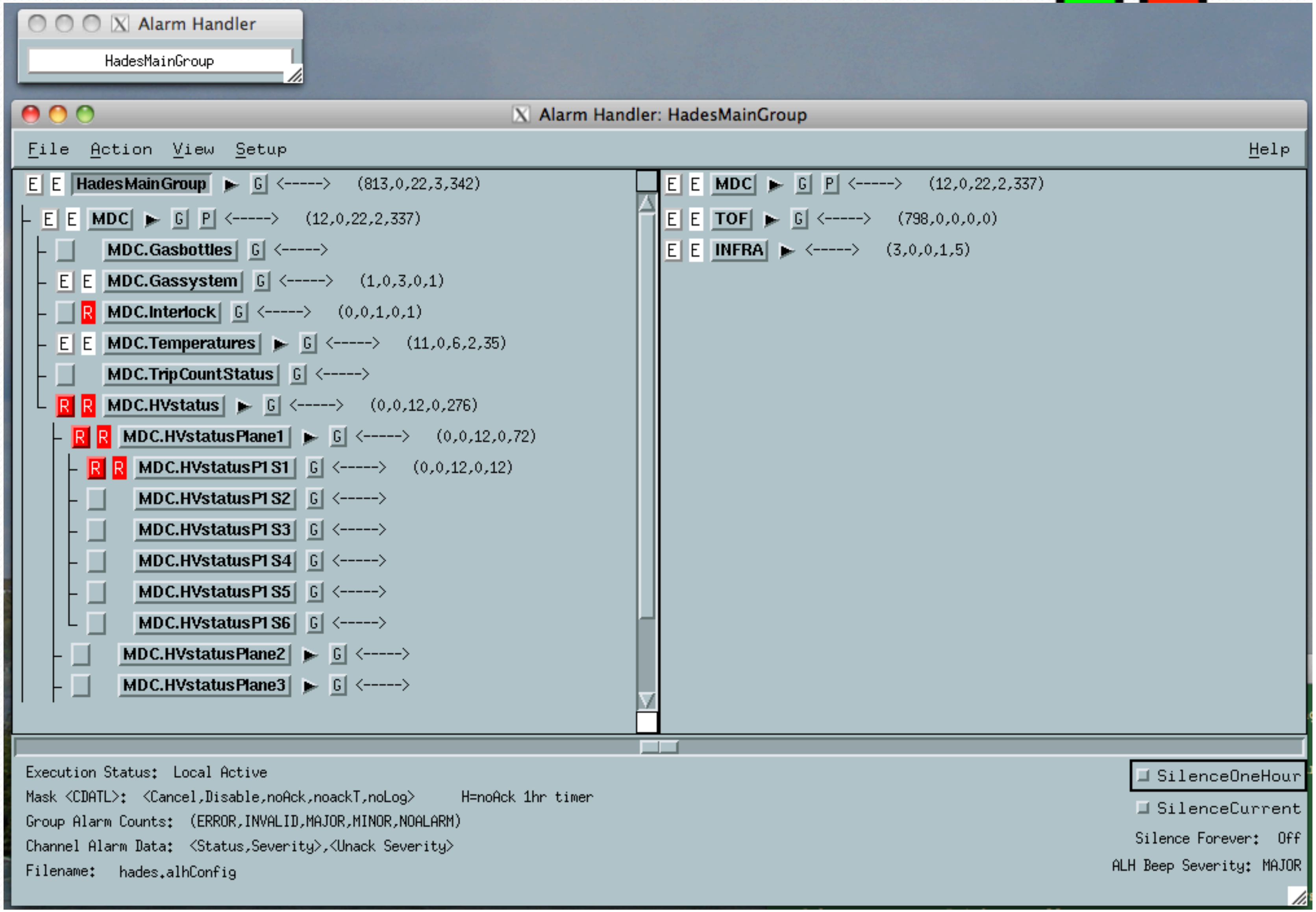
Group	
Name	showerhv.cfg

Channels

Name	State	Mechanism	Disabling	State
HAD:SHOWERHV_Disable	connected	Monitored get, 10.0 s, PV CONNECTED, CA Connected	(showerhv.cfg)	enabled
HAD:SHWR:HV:S1:C0:imon	connected	Monitored, max period 10.0 s, PV CONNECTED, CA Connected		enabled
HAD:SHWR:HV:S1:C0:vmon	connected	Monitored, max period 10.0 s, PV CONNECTED, CA Connected		enabled
HAD:SHWR:HV:S1:C1:imon	connected	Monitored, max period 10.0 s, PV CONNECTED, CA Connected		enabled
HAD:SHWR:HV:S1:C1:vmon	connected	Monitored, max period 10.0 s, PV CONNECTED, CA Connected		enabled

Alarm handling

- alh



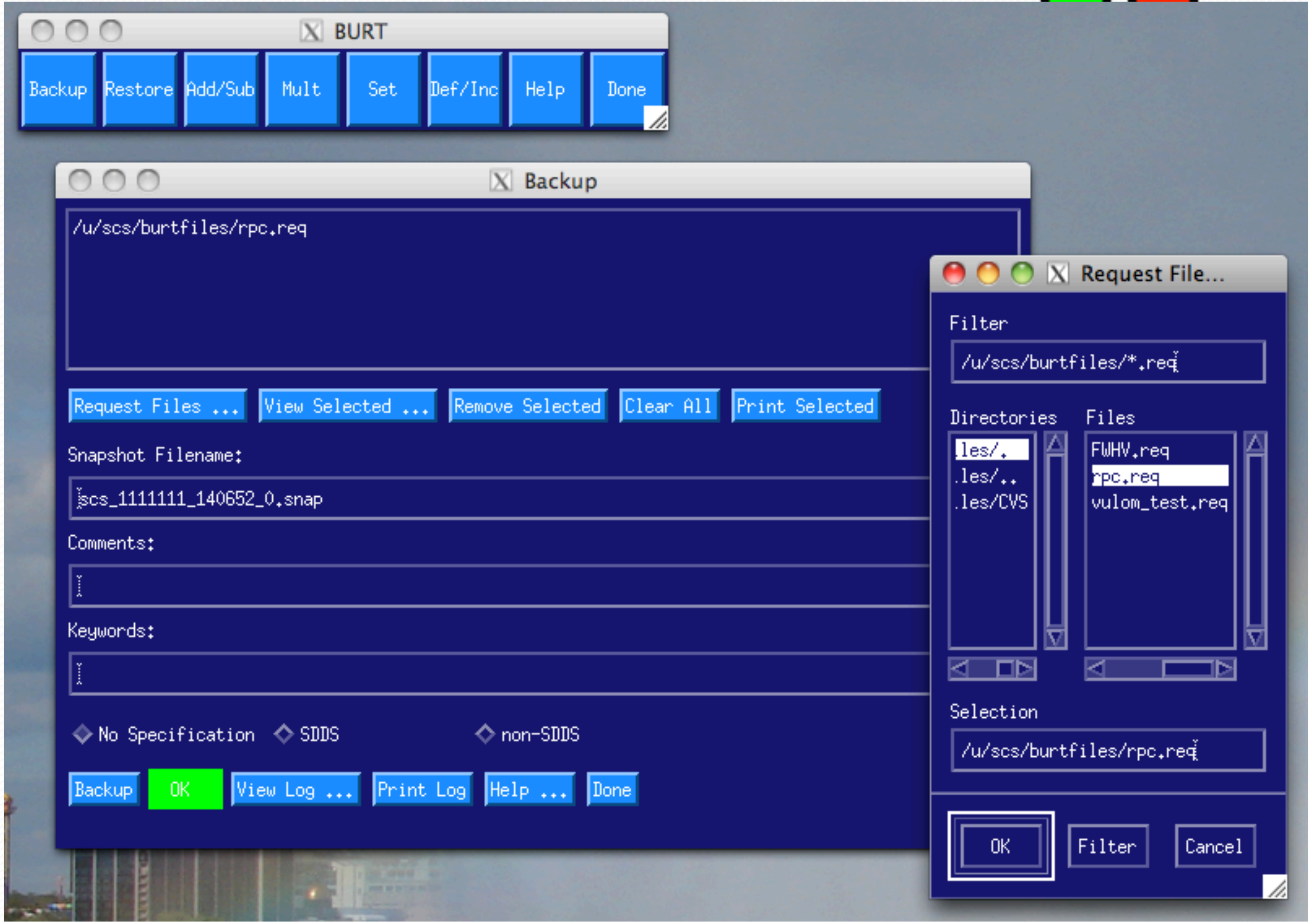
```
E E HadesMainGroup ▶ G <-----> (813,0,22,3,342)
  E E MDC ▶ G P <-----> (12,0,22,2,337)
      MDC.Gasbottles G <----->
  E E MDC.Gassystem G <-----> (1,0,3,0,1)
    R MDC.Interlock G <-----> (0,0,1,0,1)
  E E MDC.Temperatures ▶ G <-----> (11,0,6,2,35)
      MDC.TripCountStatus G <----->
  R R MDC.HVstatus ▶ G <-----> (0,0,12,0,276)
    R R MDC.HVstatusPlane1 ▶ G <-----> (0,0,12,0,72)
      R R MDC.HVstatusP1S1 G <-----> (0,0,12,0,12)
          MDC.HVstatusP1S2 G <----->
          MDC.HVstatusP1S3 G <----->
          MDC.HVstatusP1S4 G <----->
          MDC.HVstatusP1S5 G <----->
          MDC.HVstatusP1S6 G <----->
        MDC.HVstatusPlane2 ▶ G <----->
        MDC.HVstatusPlane3 ▶ G <----->

E E MDC ▶ G P <-----> (12,0,22,2,337)
E E TOF ▶ G <-----> (798,0,0,0,0)
E E INFRA ▶ <-----> (3,0,0,1,5)
```

```
Execution Status:  Local Active
Mask <CDATL>:  <Cancel,Disable,noAck,noackT,noLog>     H=noAck 1hr timer
Group Alarm Counts:  (ERROR,INVALID,MAJOR,MINOR,NOALARM)
Channel Alarm Data:  <Status,Severity>,<Unack Severity>
Filename:   hades.alhConfig
```

```
□ SilenceOneHour
□ SilenceCurrent
Silence Forever:  Off
ALH Beep Severity: MAJOR
```

Backup and restore

- burt



/u/scs/burtfiles/rpc.req

Snapshot Filename: scs_1111111_140652_0.snap

Comments:

Keywords:

◇ No Specification ◇ SDDS ◇ non-SDDS

Filter: /u/scs/burtfiles/*.req

Directories	Files
les/.	FWHV.req
.les/..	rpc.req
.les/CVS	vulom_test.req

Selection: /u/scs/burtfiles/rpc.req

This was a short introduction

- Now a small demo
- You can build this on your own computer and play with it
- All you need is here:
- http://www.aps.anl.gov/epics/download/base/baseR3.14.12.1.tar.gz
- Unpack
- (gnu)make
- Build the example app

Thank you for your attention