



THE UNIVERSITY *of*  
NEW MEXICO

# Instrumentation Integration

Accelerator Beam Diagnostics

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USPAS and University of New Mexico  
Albuquerque NM, June 23-26, 2009



USPAS09 at UNM



Accelerator and Beam Diagnostics

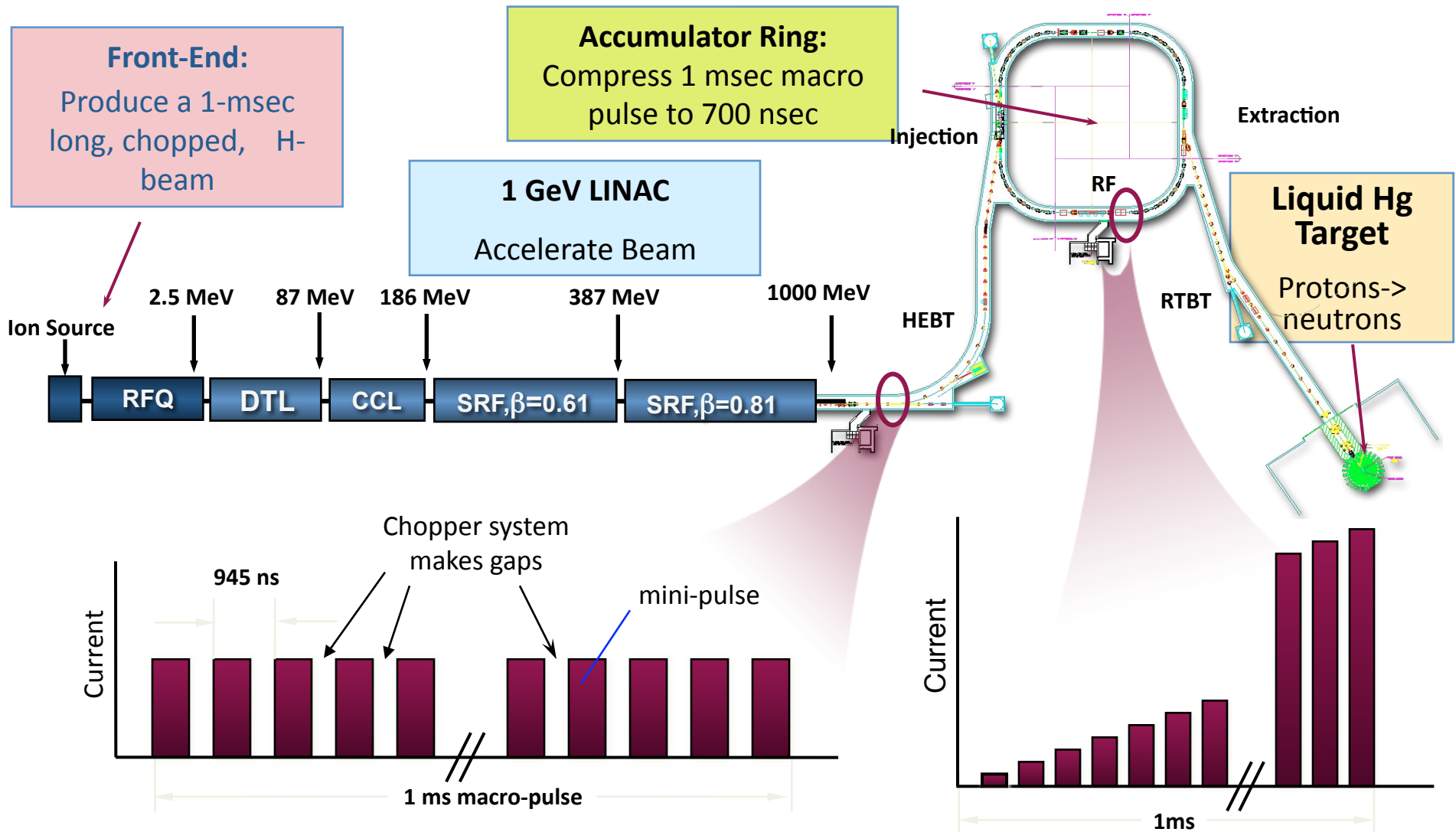
# Integration

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Instrumentation Integration is about making the results from your device available to other groups and systems.

- Beam Instrumentation
  - Life in the Accelerator Division
- Control Systems
- Integrate your instrument
  - Publish your data in the control system!
- Lab:
  - Design and implement/setup a Beam Current Monitor and publish the data to a control room console.

# Spallation Neutron Source Accelerator



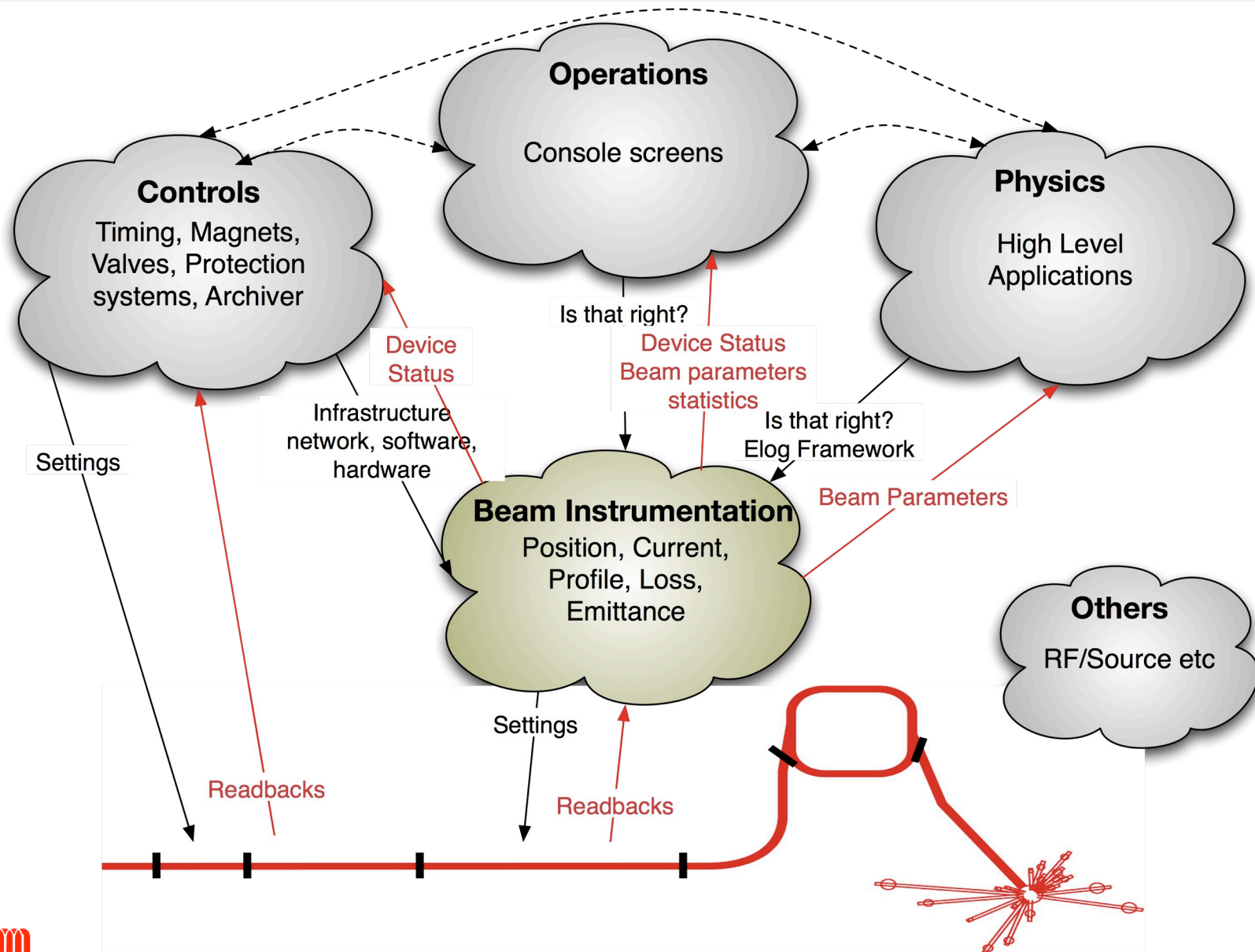
# Beam Instrumentation in Accelerators

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- Provide information about the beam or beam devices to:
  - Physics
  - Operations
  - Controls
  - Other groups: E.g. Management
- Minimize downtime and optimize performance
  - Maintain/Upgrade instruments (minimize downtime
    - Work orders, purchasing, budgets, planning, obsolescence
  - New instruments
    - Design, planning, reviews

And, of course, do this safely through many procedures.

# Beam Instrumentation in Accelerators



# Integration

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The Accelerator Control System ties the system together. Its elements are:

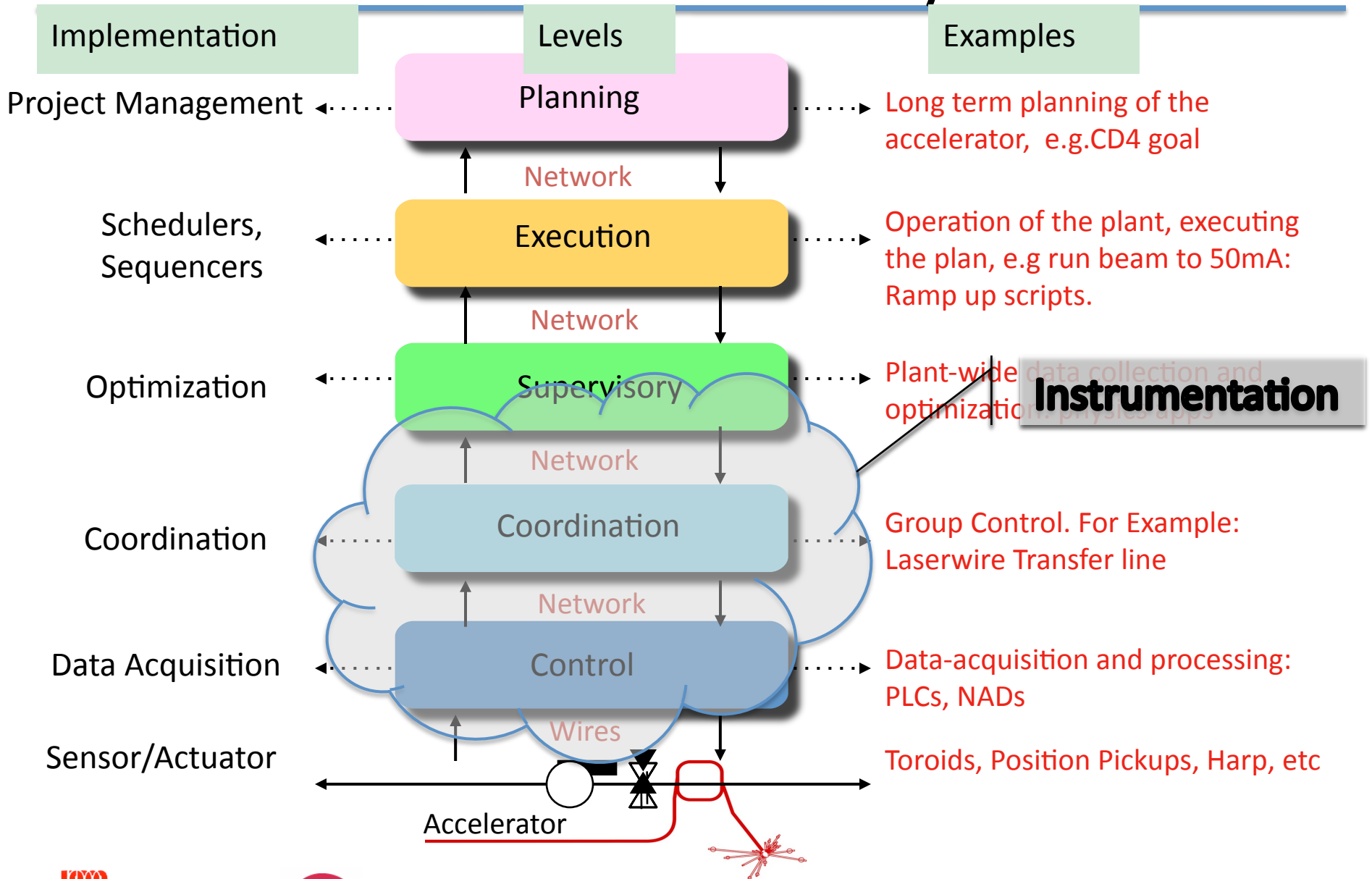
- Hardware

- Data-acquisition
- Front-ends (IOC/NAD)
- Network
- Timing
- Protection
- PLC (closed loop systems)
- Actuators/Sensors

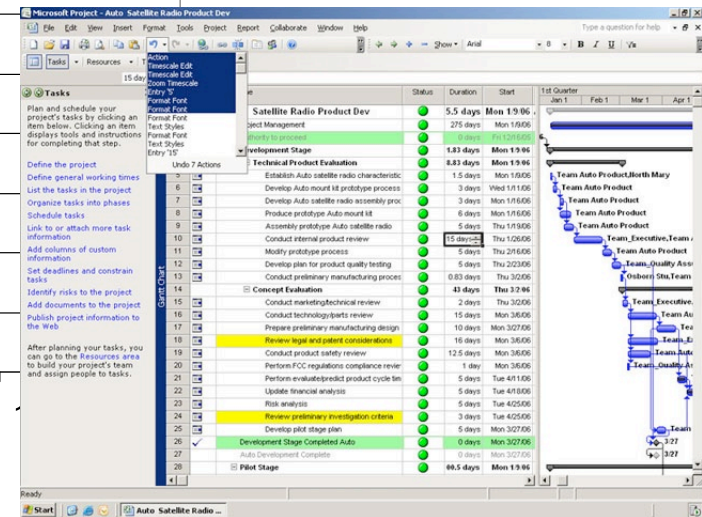
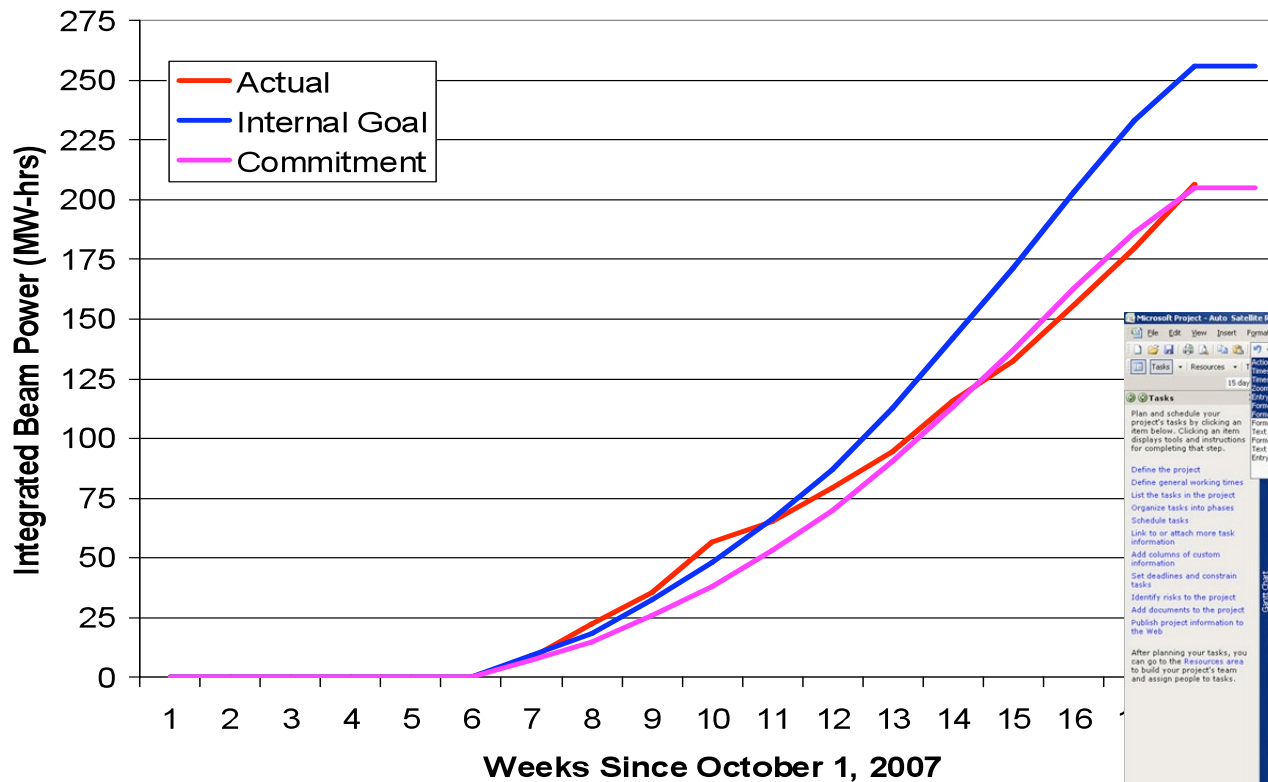
- Software

- Communication Protocols
- Data analysis
- Simulation
- Automation
- Archiving
- Configuration/Source code control

# Hierarchical Control System



# Planning Level



Project management

Notice the Pink (Slip) line. That is what matters for the manager: to stick with the production goals



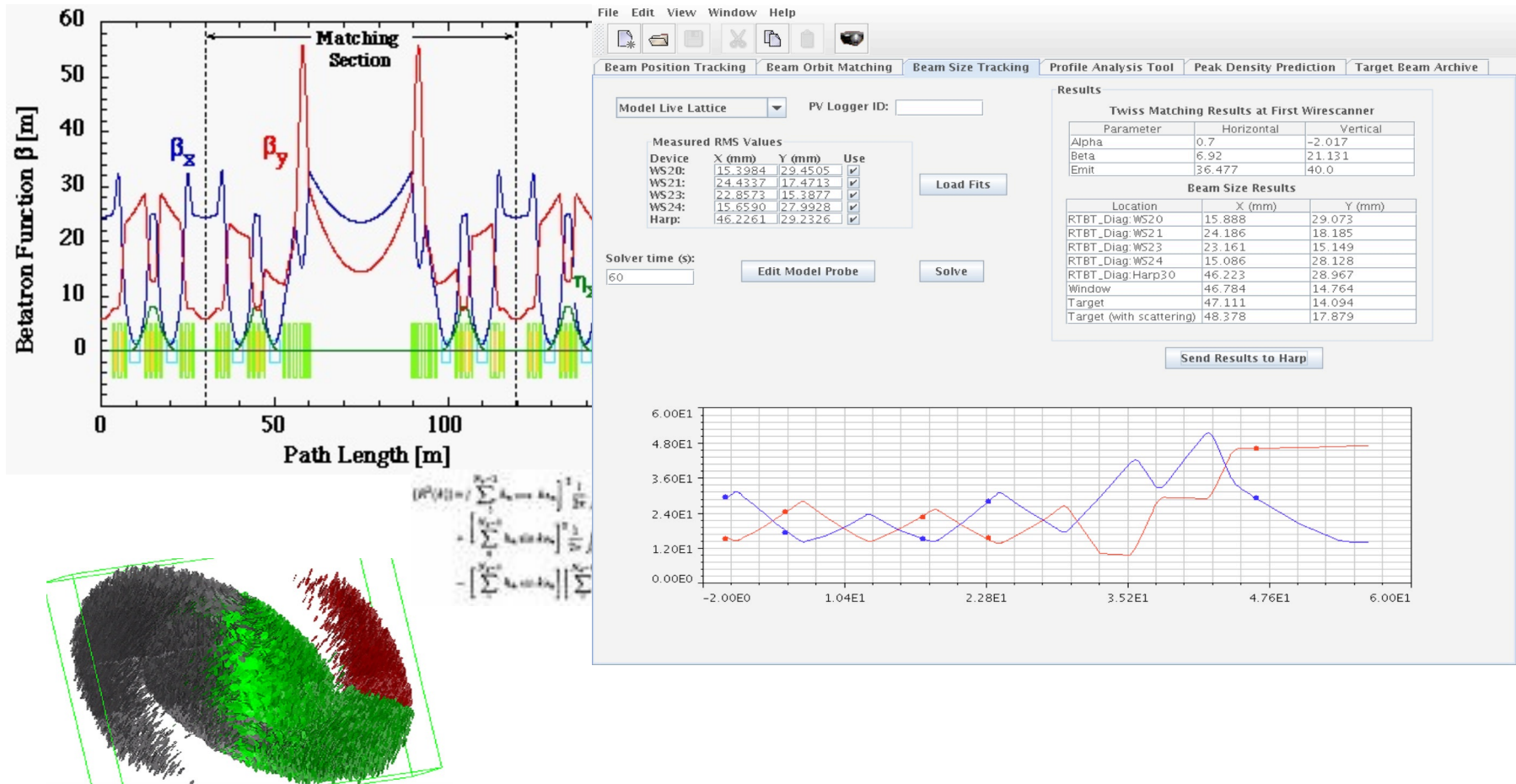
# Execution Level

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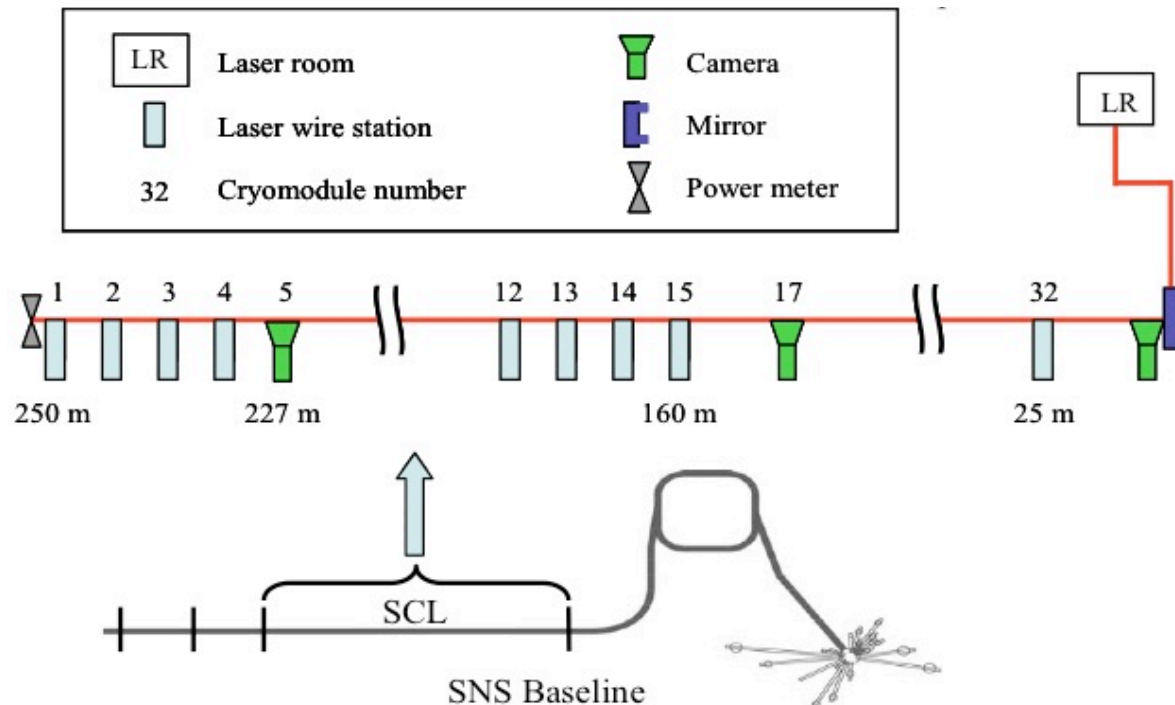
In the control the scripts and sequences are invoked after the supervisory apps have yielded satisfactory results.

# Supervisory Level



Supervisory Level often include significant modeling to provide the optimization routines -> often physics.

# Group Control Level

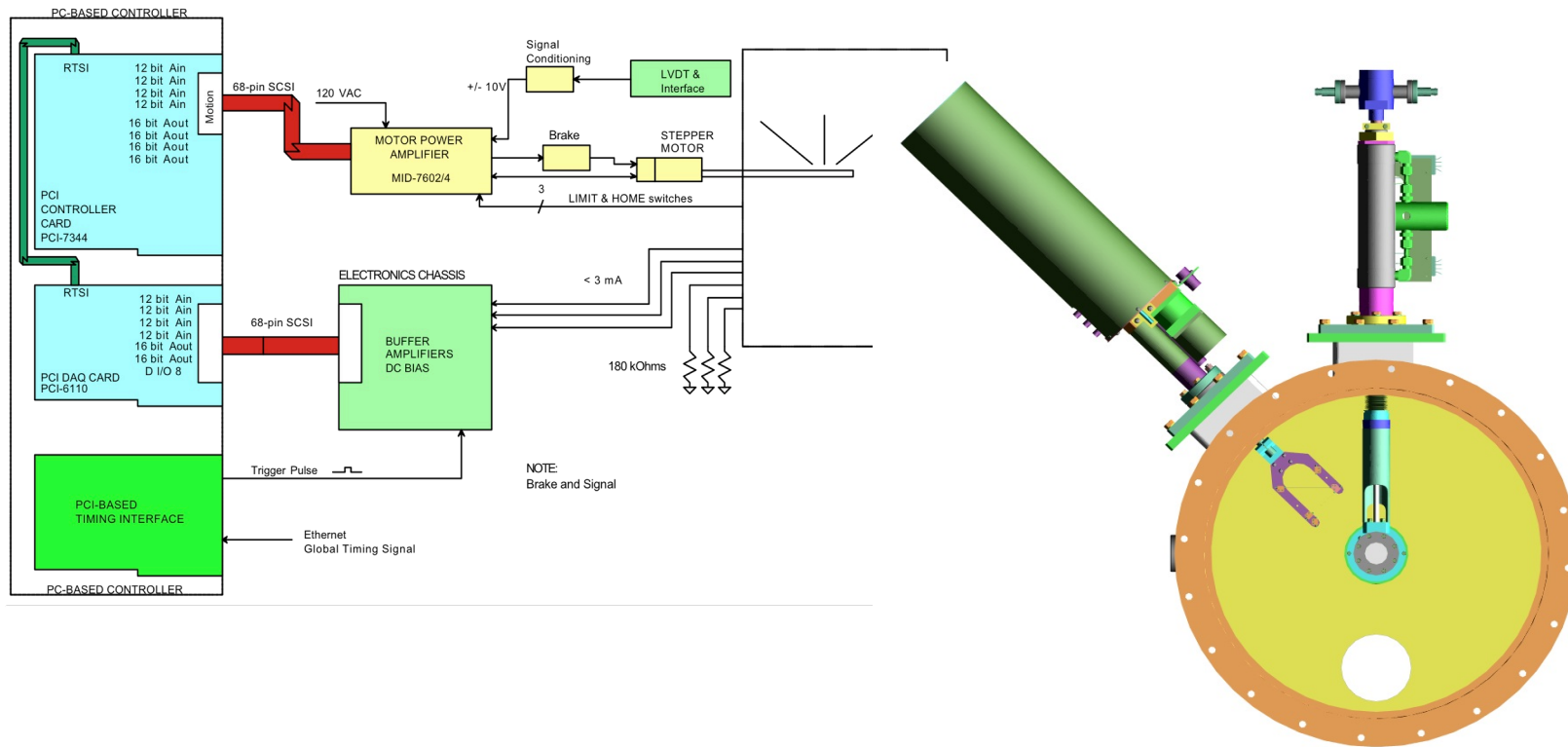


Hide the fact that the laserwire consists of 14 system distributed along the accelerator.

Do a scan:

- Setup laser [PC01]
- Tune steering mirror position, setup drift compensation [PC05]
- Insert pickup mirror [PC12]
- Move position mirror and acquire signal [PC06]

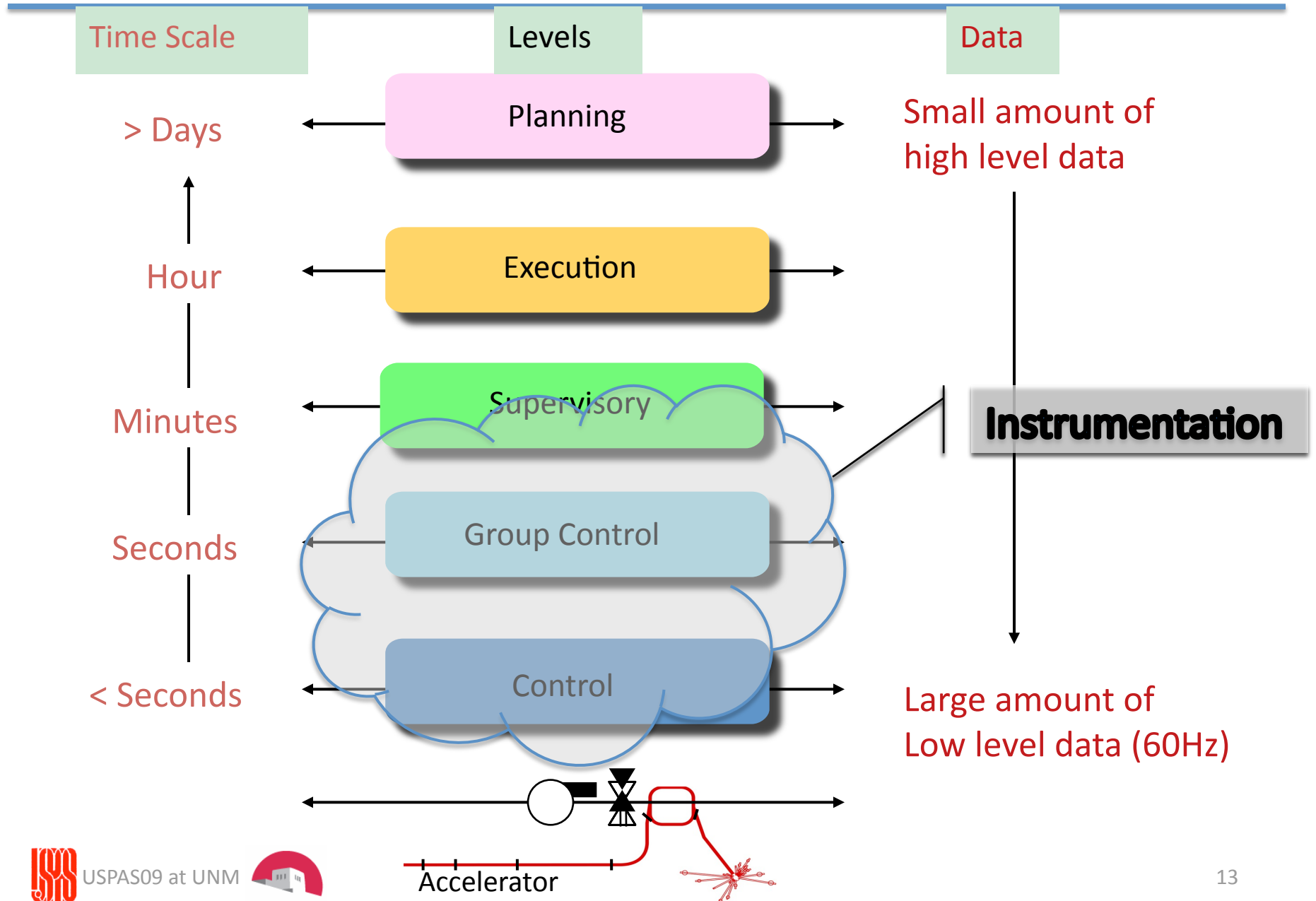
# Control Level



Control Level interacts with the hardware:

- Wire Scanner
- Valves

# Hierarchical Control System



# Accelerator Control System

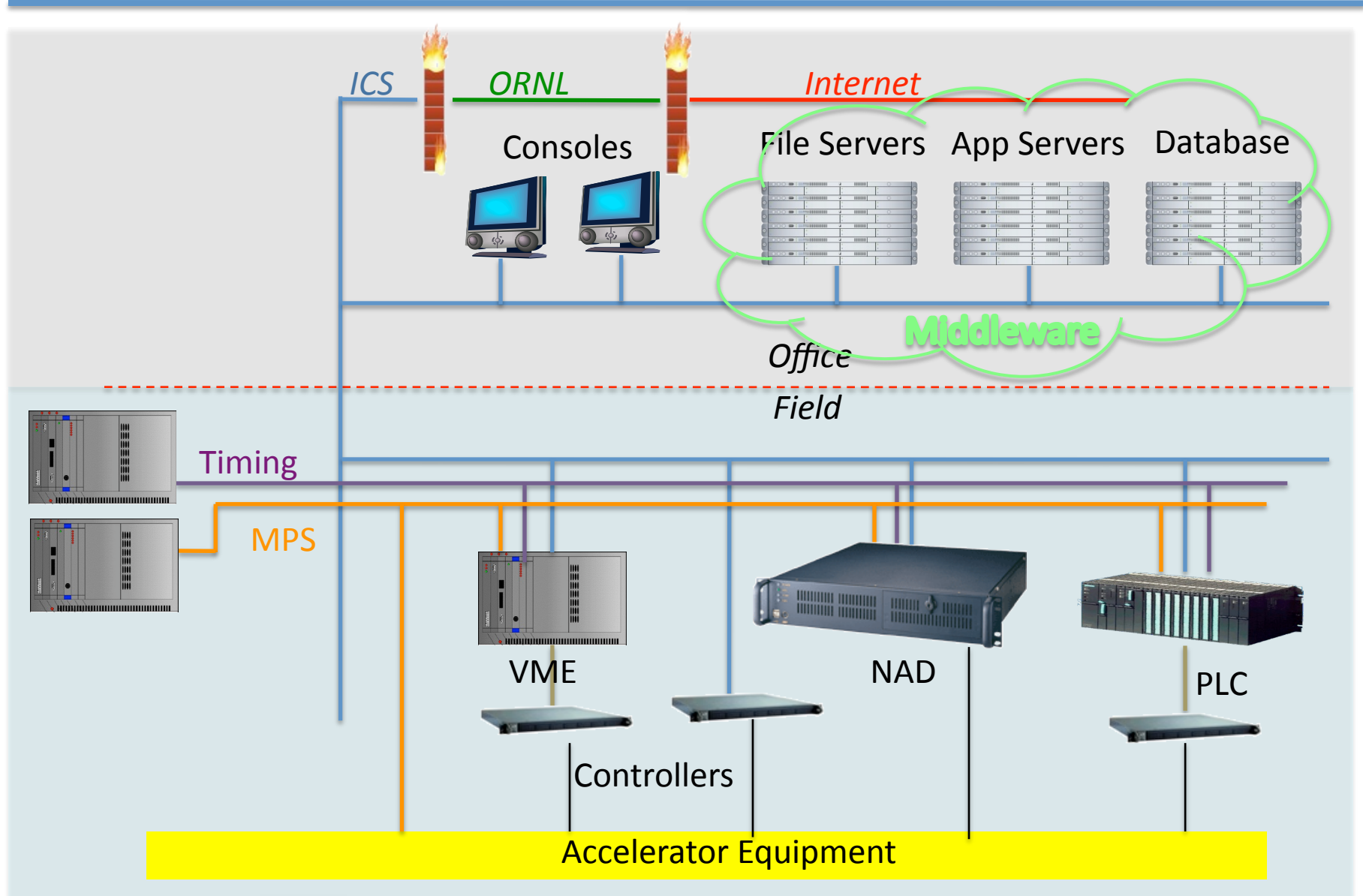
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A typical Accelerator Control System is distributed and shows some hierarchy

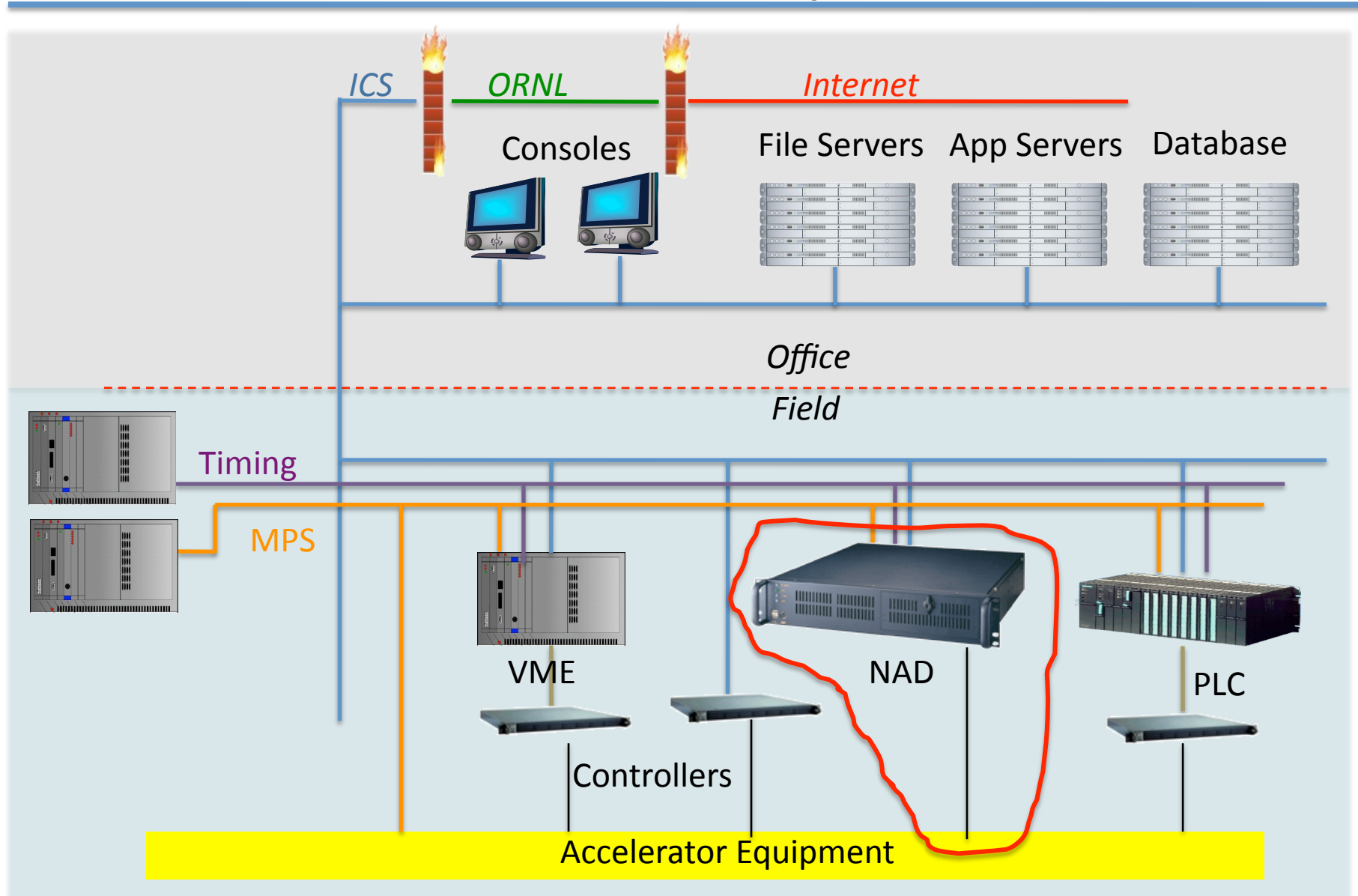
- Control: PLC/VME/NADs
- Group Control: Group Timing Controller
- Supervisory: Physics Apps, Trend analysis
- Execution: Ramp up scripts
- Planning: Project management tools

But it is often not an integrated design and managed by different groups

# SNS Control System



# SNS Control System





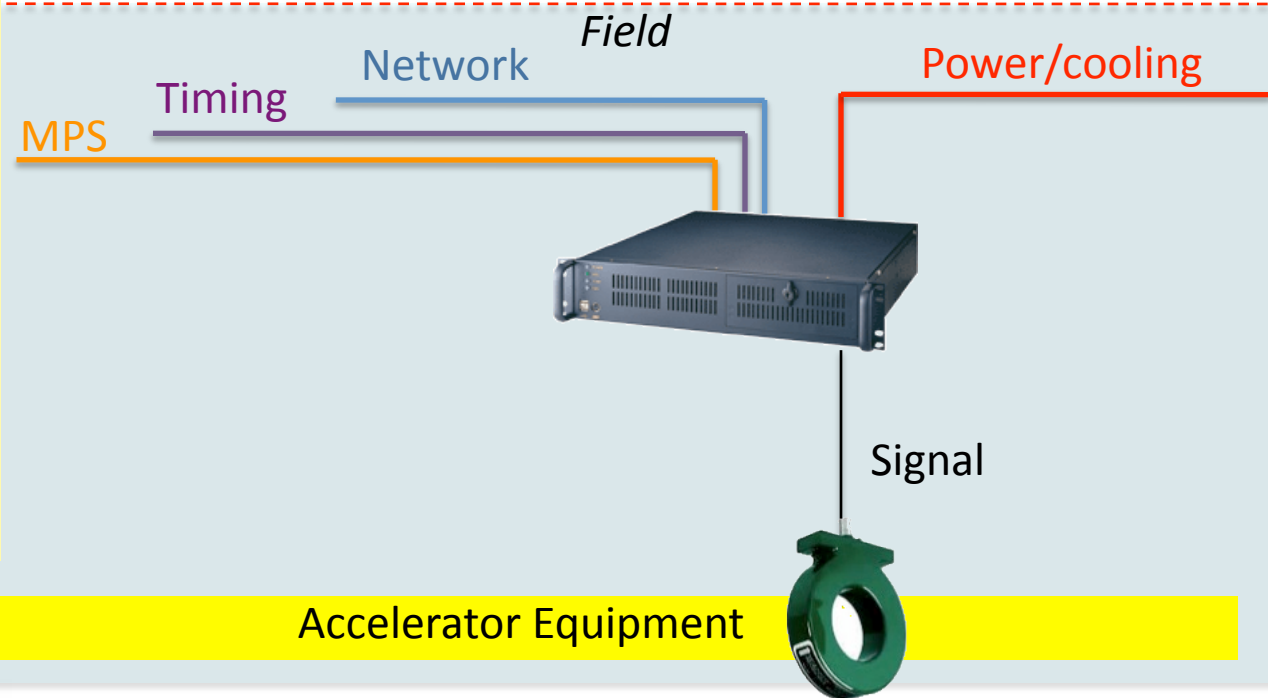
# SNS Control System

To design an instrument you need the definition of the interface. One such document is the ICD (Interface Control Document):

- Defines the capabilities
- Defines the environment

## Interface:

- MPS
- Timing
- Network
- Signal
- Power/Cooling



# Interface Control Document

The ICD describes a lot about the instrument in terms of specifications and the environment it has to exist.

The implementation should not be included. (But often are e.g. someone else already decided). The document directs the designer.

But there are always details left out and specs open to interpretation.

That is where the designer comes in.

## Preface

The Beam Loss Monitor (BLM) System includes the distributed Ion Chamber monitors and the Neutron Detectors (NDs) concentrated in the Linac. Fast BLMs will be used in the HEBT, Ring and RTBT.

## Overall Description

The BLM System will be distributed throughout SNS to measure the radiation produced by lost beam. It will provide data on the beam loss distribution, aid in minimizing those losses, and provide signals to the Machine Protection System (MPS) in the event of excessive loss.

Approximately 300 cylindrical argon-filled ion chambers will be used as the detectors, typically with several per Linac cavity, and one per magnet elsewhere. BLM signals will be conditioned in an analog front end (AFE) circuit. The signals will rise in a few  $\mu\text{s}$  (the electron component) and last up to 100  $\mu\text{s}$  after the macro-pulse due to ion transit times. These signals will be digitized and processed in a dedicated VME crate. Fast beam inhibit and low-level, long-term loss warnings will be generated to provide machine protection. The fast loss data will have a bandwidth of 35 kHz. The low level, long term loss data will have much higher sensitivity but only be available over a 10 second average.

NDs will be used in the Linac area. A distribution of 30 photomultipliers will be used for this purpose. Signals from the PMTs will be conditioned with the same electronics as the ion chambers.

The FBLMs will require HV power supply control but the signals will be acquired by fast ADCs housed in the BCM PCI crates. The analog signal handling is not part of this ICD.

External timing is required to synchronize the data acquisition with the macro-pulse structure and provide time stamping.

## General Capabilities

1. Detailed time history within the macro-pulse for each BLM.
2. Total losses for each BLM each macro-pulse.
3. Long-term history, both for wideband and low level losses for each BLM.
4. Gain setting and readback for each BLM.
5. Fast Loss output for the Machine Protect System.
6. Long-term, low level beam loss alarm on exceeding 1 W/m.
7. Remote/local system test
8. Remote/local Bias Voltage setting.
9. System Calibration.

# Implementation

## System Brochure

The designer uses the ICD to create an implementation.

- Hardware: parts must be selected/designed. For example, vacuum parts, detector, cabling, acquisition system
- Software: programming environment, routines, API

### BPM System Brochure

#### Numbers of installed PUE's:

Ring: 21 cm	Open Stripline	250 mm	70 degree	quantity 28
Ring: 26 cm	Open Stripline	250 mm	70 degree	quantity 8
Ring: 30 cm	Open Stripline	250 mm	70 degree	quantity 8
RTBT: 21 cm	Shorted Stripline	250 mm	70 degree	quantity 15
RTBT: 30 cm	Shorted Stripline	250 mm	70 degree	quantity 2

#### AP requirements:

Intensity:	5e10 to 2e14 Protons
Pulse Length	0.3 to 1000 uS
Range:	+/- 100 mm ( 20 mm )
Accuracy:	±1 mm
Resolution:	0.15 mm ( 0.5 mm for 15mA beam)

#### Target requirements – AP requirements as above plus:

Bandwidth:	7 MHz.
Update rate:	6 Hz.
Calibration:	On board cal. pulse to PUE and Beam Based Alignment
Raw data output available on command, at reduced update rates (~1 Hz).	
Sample rate:	between 32 and 64 x Revolution Frequency.

#### Process Variables:

X position averaged over the macropulse (mm)  
Y position averaged over the macropulse (mm)  
X position array, holding position over each minipulse (mm)  
Y position array, holding position over each minipulse (mm)  
X position array, holding position over each minipulse (mm)  
Y position array, holding position over each minipulse (mm)  
Length of the averaged period (microseconds)  
Delay time from Cycle Start to beginning of average period (microseconds)

# Application Programming Interface

Another Interface:

- Describes the interface as to how your instrument can be read out and controlled
- For the next level up

## Wire Scanner Application Programming Interface

### Setting up the acquisition

You can set up various aspects of the data-acquisition but for almost all cases, you will only have to modify the gain to adjust for the beam intensity, see the table acquisition settings.

Table 1. Acquisition settings

Parameter	PV	Range	Meaning	XAL
Scanrate	Test_Diag:WS:Acq_Scanrate_rb Test_Diag:WS:Acq_Scanrate_set	100-5M	Digitizer sampling rate keep at 1M	Opt
Length	Test_Diag:WS:Acq_Length_rb Test_Diag:WS:Acq_Length_set	0.1-2ms	Trace length to sample. Keep long, 1ms, to avoid timing issue	Opt
Gain	Test_Diag:WS:Acq_Gain_rb Test_Diag:WS:Acq_Gain_set	0,1,2	0 = low gain, 1= medium, 2= high gain. Needed to adjust for beam intensity	Yes
Time-out	Test_Diag:WS:Acq_Time-out_rb Test_Diag:WS:Acq_Time-out_set	20-300	Time-out interval after which fork will be retracted if there was no beam trigger	Yes
BitEn	Test_Diag:WS:Acq_BitEn_rb Test_Diag:WS:Acq_BitEn_set	0,1	Hardware test purposes	No

### Setting up the analysis

A trace is taken at each position and data within the trace from start to start+length is averaged to come up with an intensity value for that position. If you had declared more than one trace per position, the intensity value becomes the average of the averages of the traces.

# Beam Instrumentation in Accelerators

Group	System	Reliability	Failure Consequence	Response Time	Uptime	Comments
<b>Controls</b>	Machine Protection	Ultra	Harm to hardware	RT	24/7	
	Timing	Very	Downtime	RT	24/7	
	Vacuum	Very	Downtime	~10ms	24/7	
<b>Instrumentation</b>	Beam Position	Medium	No Info/ Downtime	~200 ms	24/7	Partial failures allowed
	Beam Current	Medium	No Info/ Downtime	~200 ms	24/7	Partial failures allowed
	Beam Accounting	High	Downtime	RT	24/7	
	Wire Scanners	Medium	No Info/ Downtime	~200 ms	Interactive	Partial failures allowed Display can fail but not logging
	Report	High	No Info	Minutes	Interactive	
<b>Physics</b>	Magnet Bumps	Low	Restart of app	~200 ms	Interactive	Apps can crash but wrong calculations can be bad
	Tune-up Apps	Low	Restart of app	~200 ms	Interactive	
<b>Operations</b>	Scripts	Low	Restart of app	~200 ms	Interactive	Apps can crash but wrong calculations can be bad

# Control Rooms



The AGS control rooms at Brookhaven in 1964, 1989, 1998 and the SNS Control Room in 2006

# SNS Console Demo

http://ics-srv-web2.sns.ornl.gov/archive/cgi/edmDemo/navwogif.edl

[First Fault](#) [Temperatures](#) [MPS](#) [IOC Status](#) [Cooling Overview](#) [Diagnostics](#) [ODH](#) [PPS](#) [MagPS](#) [Timing](#) [Misc Tools](#) [ArchiveViewer](#) [Physics Apps](#) [Help](#)

[Kicker Reset](#) [RFQ 65KV](#) [Reset](#) [Reset](#) [PLC](#) [MPS to PPS](#)

**Smoke Alarms** [Main Smoke Page](#)  
 RFQ Mod1 DTL Mod3 DTL Mod5 CCL Mod1 CCL Mod2 CCL Mod3 CCL Mod4  
 CO2 DISCHARGE CO2 DISCHARGE CO2 DISCHARGE CO2 DISCHARGE CO2 DISCHARGE CO2 DISCHARGE CO2 DISCHARGE  
 SCL Mod01 SCL Mod05 SCL Mod09 SCL Mod12 SCL Mod14 SCL Mod15 SCL Mod18 SCL Mod21  
 CO2 DISCHARGE CO2 DISCHARGE CO2 DISCHARGE CO2 DISCHARGE CO2 DISCHARGE CO2 DISCHARGE CO2 DISCHARGE CO2 DISCHARGE

*Note: The CO2 discharge button remains below the associated modulator. When the smoke detector indication is present, discharge requires confirmation.*

[Checklist Script](#) [Proj. View](#) [Errant Beam All-in-One](#) [Summations](#) [Spark Counter](#) [Site Map](#) [ChMPS](#)

Current Rep-Rate **1.0 @ 0 Watts**  
 to **Linac Dump** **1060 turns**

[Single Shot](#) [Trigger](#) [Chief Unlock](#) [Beam Enabled](#) [Beam Enabled](#) [Ramp Up](#) [Goto 1 Hz](#)

**Front End** **DTL** **CCL** **Medium Beta SCL** **High Beta SCL** **CHL** **RFTF** **CUB** **Primary Substation**

HPRF Smoke [Gate Keeper](#) [E-Kickers Ring](#) [PwrSups](#) [HEBT](#) [Momentum Dump](#) [RTBT](#) [Target](#)

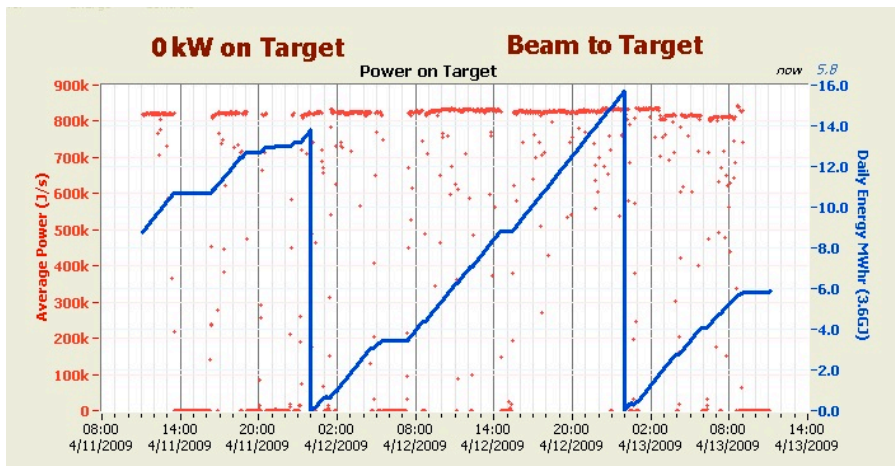
RCCS Summary [New RF! TRY ME!](#)

Beam Loss Monitor Summary  
 DTL CCL SCL #LDmp  
 Ring RTBT/EDmp

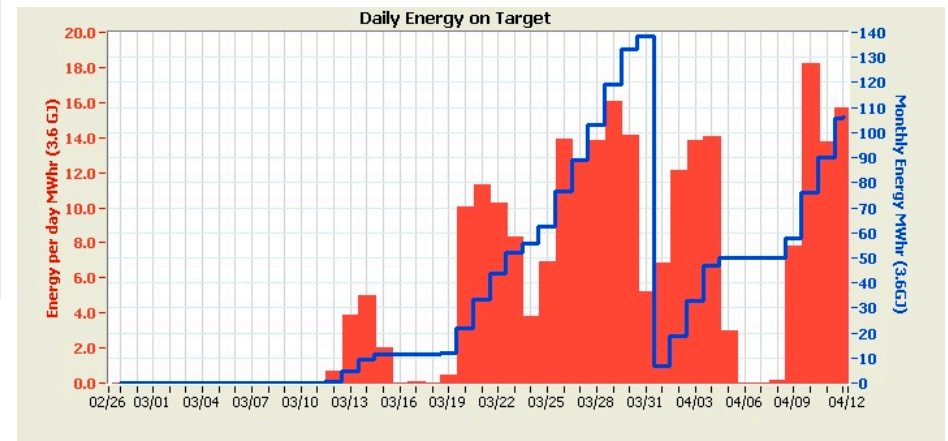
Beam Halo One Minute Avg Temps on Target  
 91.1 F 91.7 F 91.2 F  
 92.0 F  
 None

# System Integration

Here is an example of system integration that you have seen before:



SNS Power on target

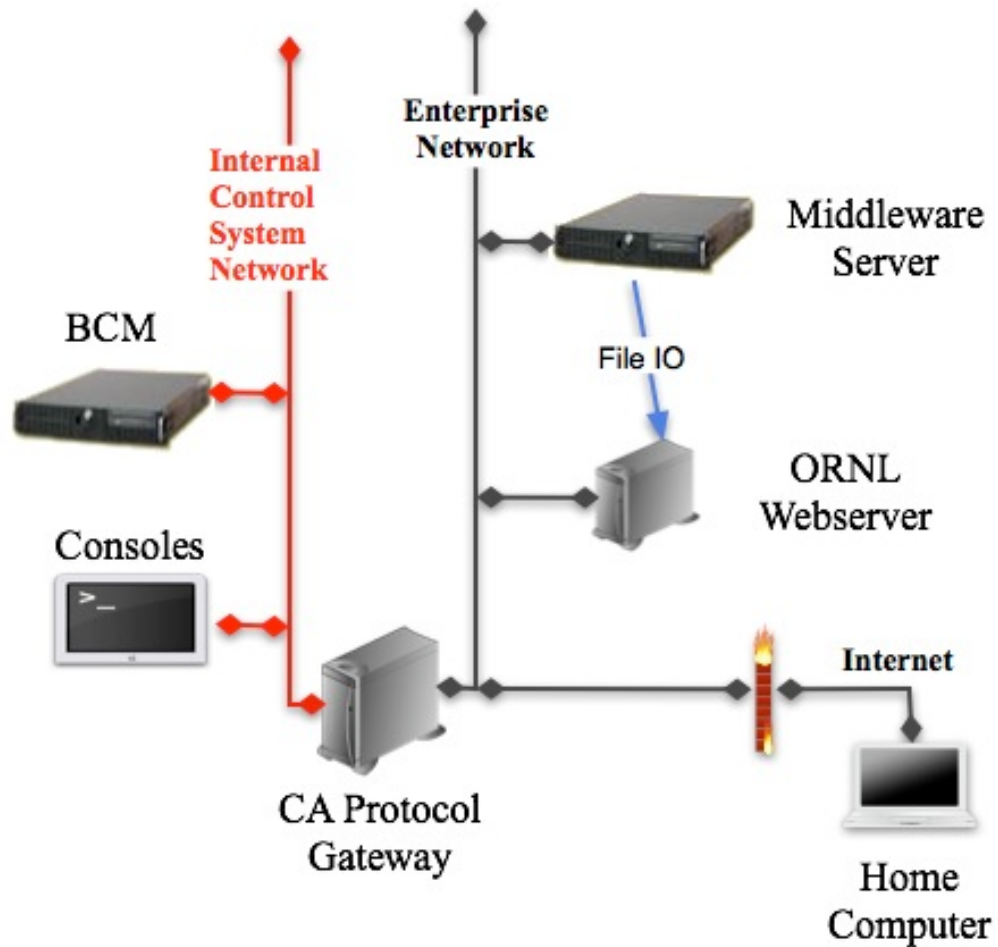


SNS Energy delivered to target

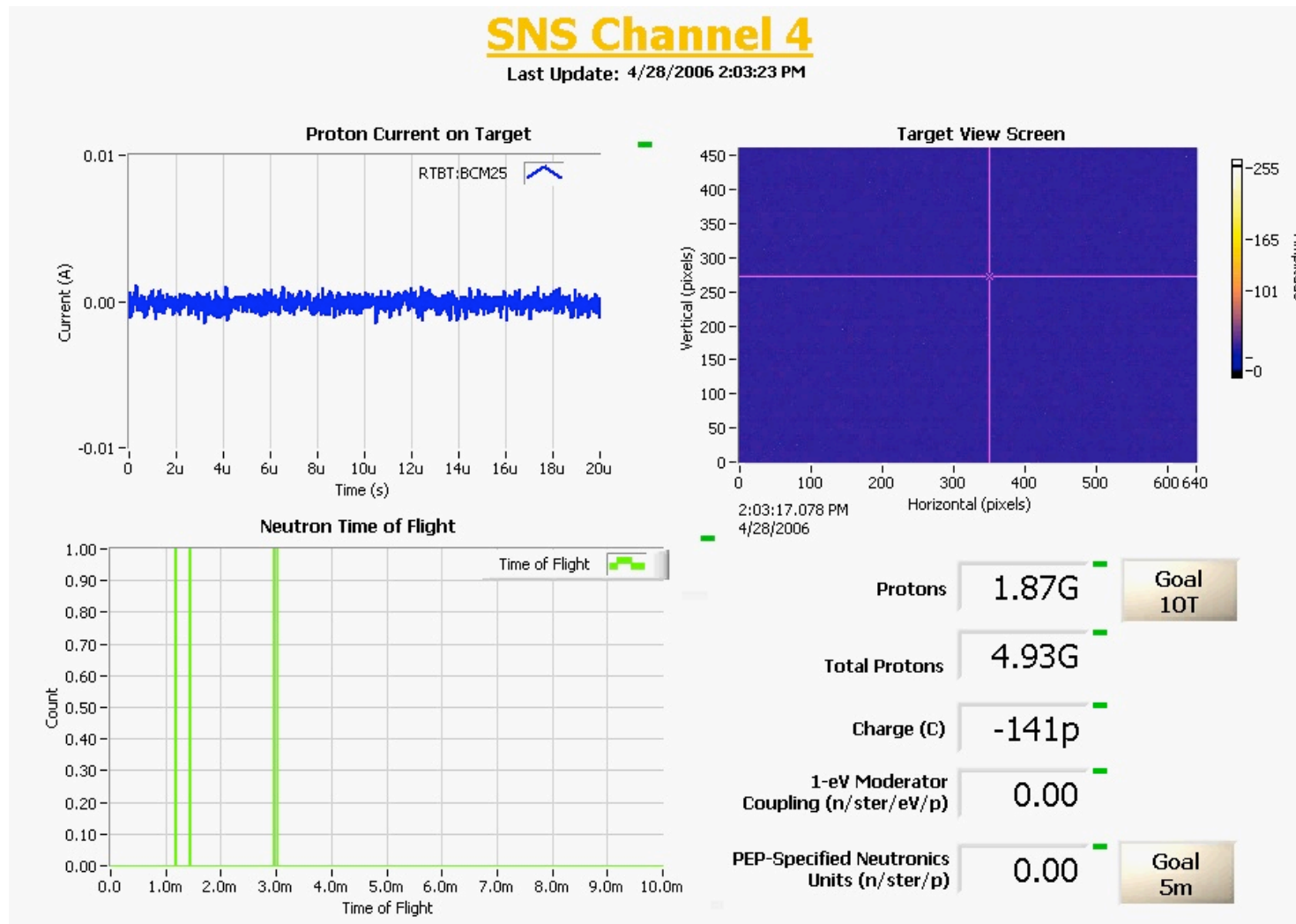


# System Integration

- How was this published?

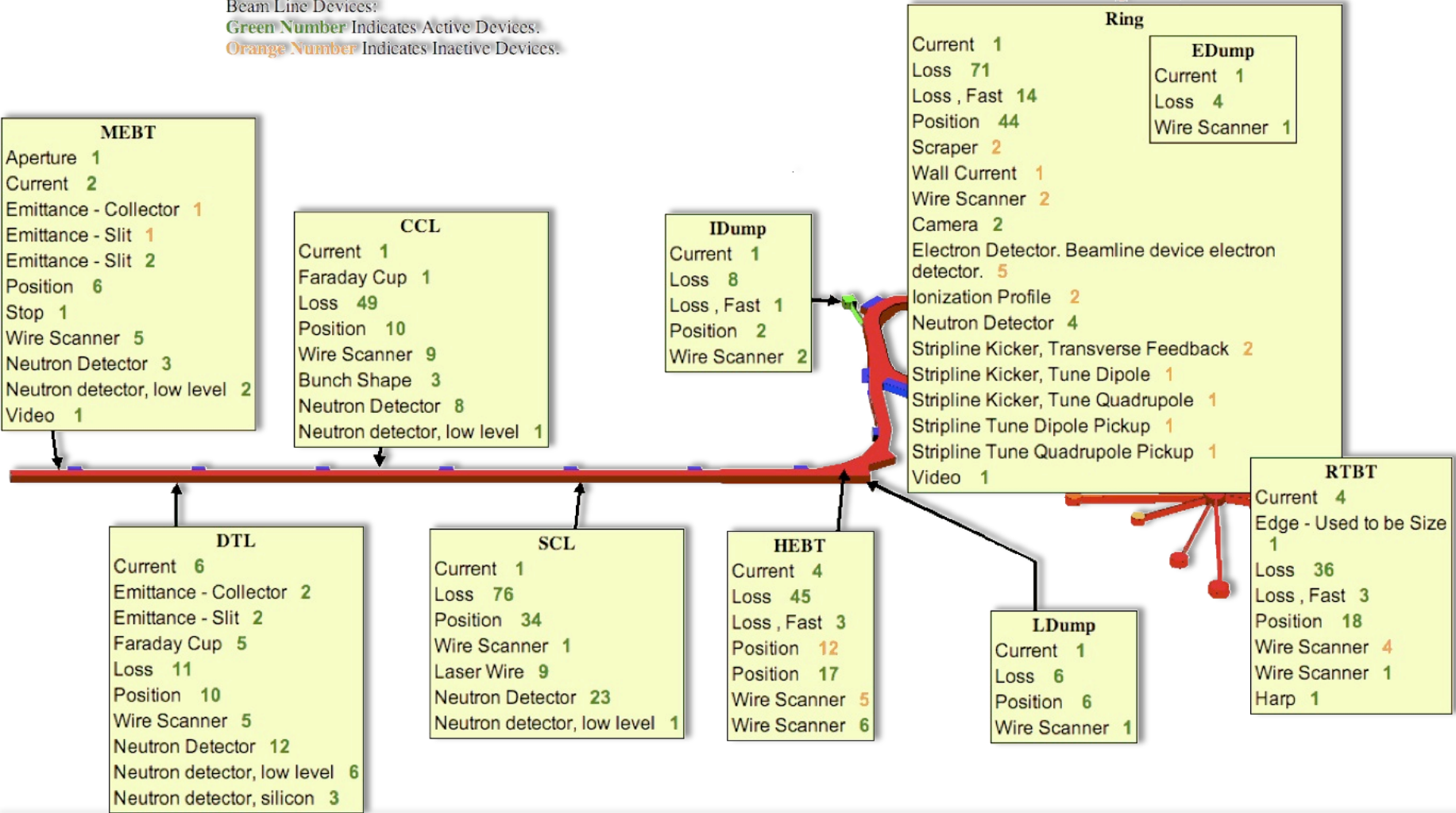


# Data Publishing: Commissioning



# Instrumentation

Beam Line Devices:  
**Green Number** Indicates Active Devices.  
**Orange Number** Indicates Inactive Devices.



# Instrumentation Infrastructure

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- People
  - Engineers, Physicists, Technicians, Programmers
- Hardware
  - Test equipment
  - Detectors/Actuators
  - PCI/PXI/cRIO/VME
- Software
  - Management of IOCs (PC: Altiris)
  - Configuration Control
  - Standards
  - Interface to Control System (EPICS)
  - Debugging tools: Remote access



# Instrumentation Infrastructure

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## PC management

- XP embedded for smaller images
- Altiris for image management of Xpe (Cloning)
- Workstation with disk array
- Remote Reboot through APC on ethernet
- Remote Desktop for remote control
- File configuration (Oracle)

# Instrumentation Infrastructure



Mass Imaging of computers

**BI Group Home**

Try this before using old remote desktop or RPC procedures.  
**New Remote Desktop and Remote Power Control Start Page**  
(If you find problems, let Dave know.)

[Network Registration System](#)

[Remote Power Control](#)

[SNS Logbook](#)

[IOC Configuration](#)

Active	Configuration	Date	Author	Comment
<input type="checkbox"/>	25.1	Nov 26, 2008 12:52	900870	Upload INI File
<input type="checkbox"/>	24.4	Feb 12, 2009 16:47	900870	Upload INI File C:\Config\BCM_Config.txt
<input type="checkbox"/>	24.3	Nov 26, 2008 12:52	900870	Upload INI File C:\Config\BCM_Config.txt
<input type="checkbox"/>	24.2	Nov 26, 2008 14:09	900870	Upload INI File C:\Config\BCM_Config.txt
<input type="checkbox"/>	24.1	May 09, 2008 17:19	900870	Upload INI File C:\Config\BCM_Config.txt

Activation notes:

Activate

**BCM Diagnostic Device Active Configurations:**

Device	Active Configuration	Date	Editor	Comment
CCL_Diag_IOC_BCM002	2.2	Jun 07, 2007 09:27	900870	Took out 3 db pad
DTL_Diag_IOC_BCM009	24.1	Nov 24, 2008 09:21	900870	Change name of second channel from 248 to 2006
DTL_Diag_IOC_BCM048	1.1	Apr 10, 2007 11:54	900870	First Upload
DTL_Diag_IOC_BCM009	2.2	Nov 24, 2008 10:12	900870	Changed Tr to 1.32ms to correct waveform
DTL_Diag_IOC_BCM028	2.2	Apr 26, 2007 12:41	900870	Added Timing Task
DTL_Diag_IOC_BCM600	2.2	Apr 26, 2007 12:57	900870	Added Timing Task
DTL_Diag_IOC_BCM622	2.2	Apr 26, 2007 13:23	900870	Added Timing Task
EDiag_Diag_IOC_BCM02	11.1	Apr 27, 2007 11:13	900870	First upload
HEBT_Diag_IOC_BCM01	2.2	Apr 26, 2007 15:06	900870	Added Timing Task
HEBT_Diag_IOC_BCM09	2.4	Nov 24, 2008 11:36	900870	Tr to 1.30ms
HEBT_Diag_IOC_BCM20	2.2	Apr 26, 2007 15:18	900870	Added Timing Task

Management of computers

# Instrumentation Infrastructure

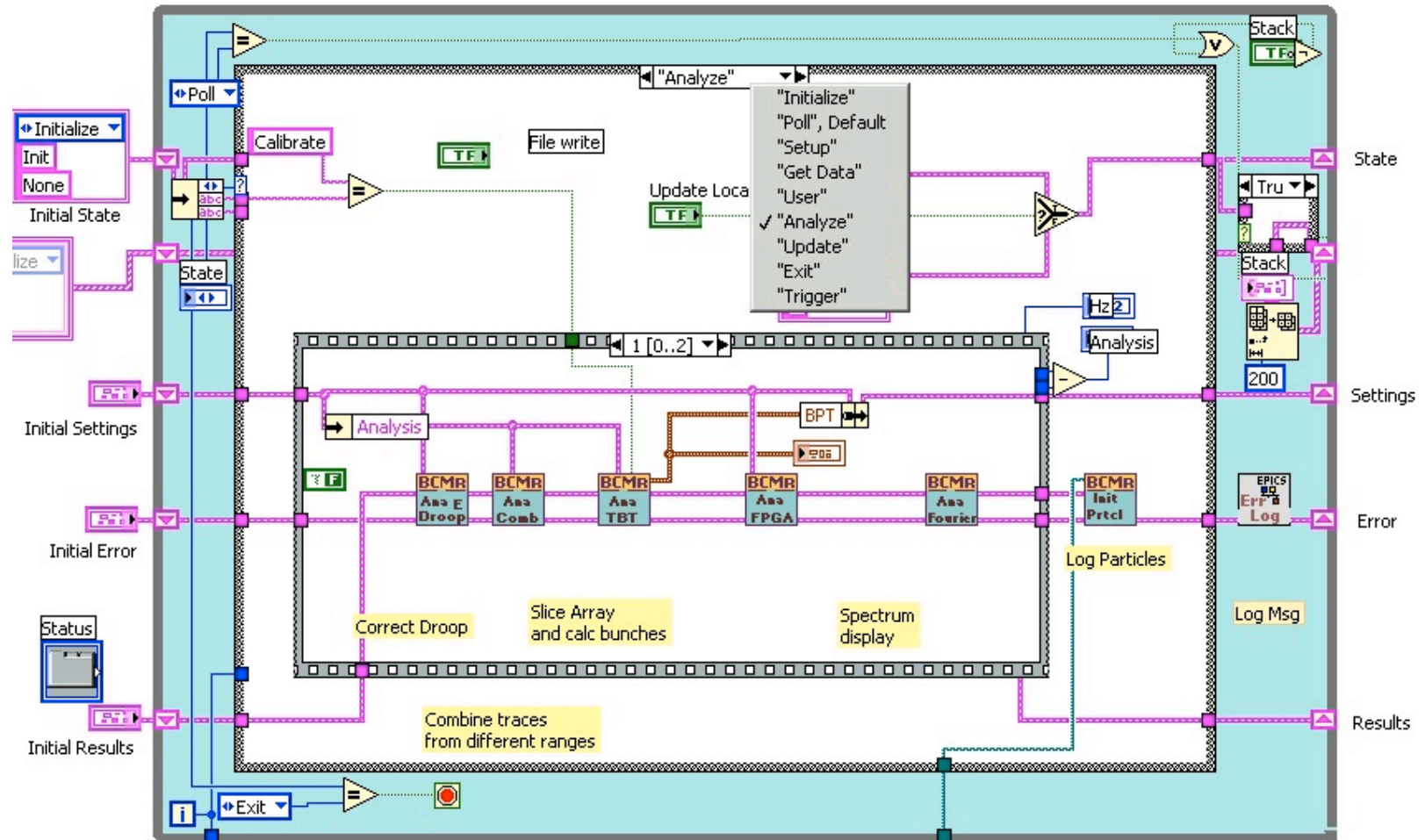
The screenshot displays a LabVIEW application window titled "Harp\_TopLevel.vi" running on a Windows desktop. The interface is divided into several sections:

- HARP Status:** Shows "RTBT HARP" Version 1.4 Nov 2007. It includes tabs for Mechanism, Density, RMS, and Take Baseline. A table displays Harp Norm Densities and Peak Densities for X, Y, and Z axes.
- Graph:** A plot of Voltage (0 to 6) versus Position (mm) (-200 to 200). It shows a bell-shaped curve with data points and a fit line.
- Parameters:** Includes fields for RTBT Delay (1), FRev (1.038), Delay (0), Gain (1), Bias Voltage (50), and Polarity.
- Task Status:** Features buttons for Start IOC, Update Local, Log?, and State Get Data.
- Message Window:** Displays a red error message: "Error 0 occurred at Error accessing PV Harp30Command (104) at SM\_Oct4.rvi. Harp\_TopLevel.vi".
- IOC Command List:** A scrollable list of IOC commands such as "10:SigmaZ\_Rb", "10:SigmaY\_Rb", "10:RMSZ\_Rb", etc.

Red arrows point from the text labels "LabVIEW", "Shortcut", and "IOC" to their respective elements in the screenshot. The desktop background is blue with various icons, and the taskbar at the bottom shows the Start button, several open applications, and the system clock at 5:30 PM.

# Instrumentation Infrastructure

- Software Templates



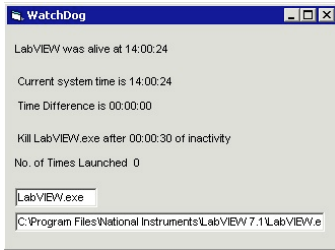


# Beam Current Monitor

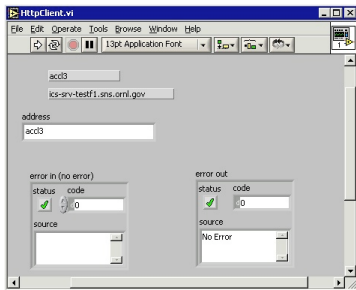
A Beam Current Monitor acquires the beam-induced signal from a toroid. The waveform is integrated to calculate the charge.

BCM	Waveform	Beam Accounting	Ring	Target
Real-time	No	Yes	Yes	Yes
Rep-rate	6 Hz	60 Hz	6Hz	60Hz
Samples/sec	20-500Mhz	20-50Mhz	20-50Mhz	100Mhz
Range	30mV	30mV	30mV-30V	30mV or 30V
Accuracy	2%	1-5%	5%	1-5%
DAQ	DP235	PXI-5122	PCI-5122	PXI-5122EX
OS	XPe	XPe ->LV RT	XPe	XPe

# Beam Current Monitor



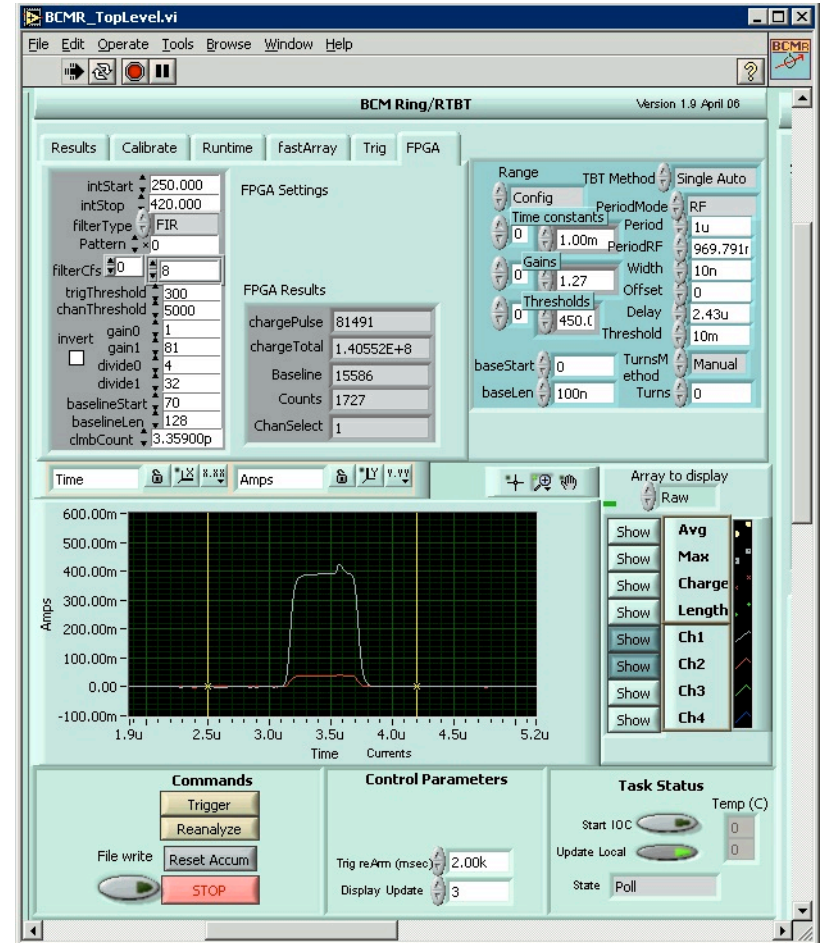
WatchDog



Configuration file downloader



Timing Task



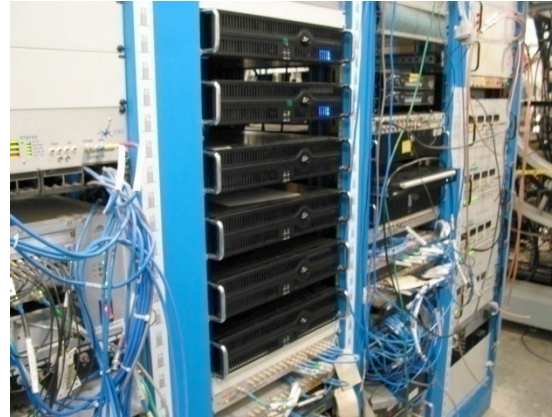
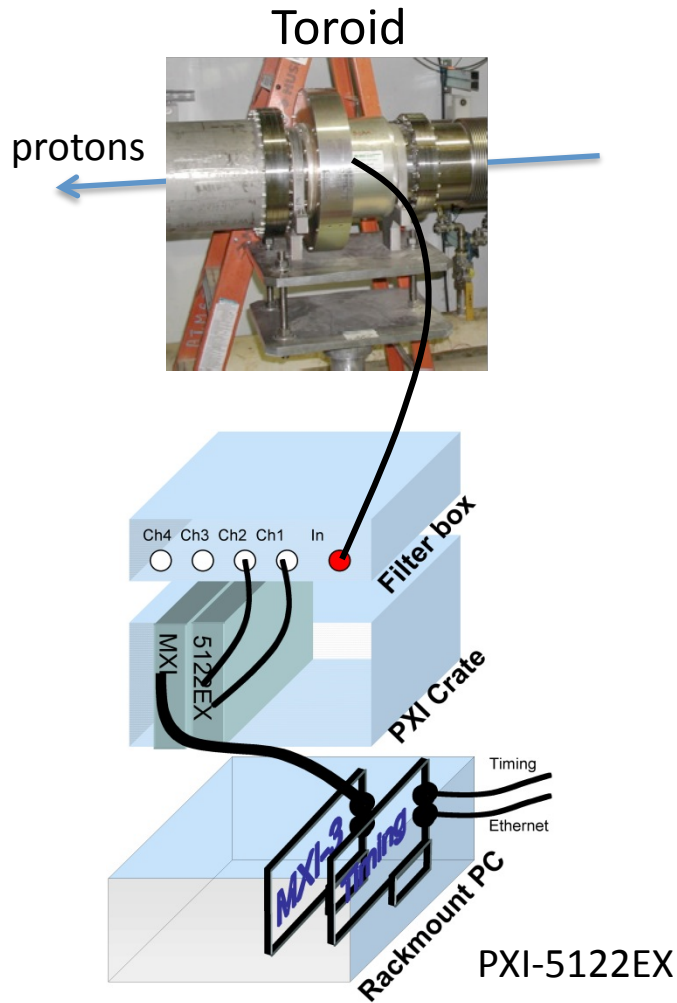
Main Program

```

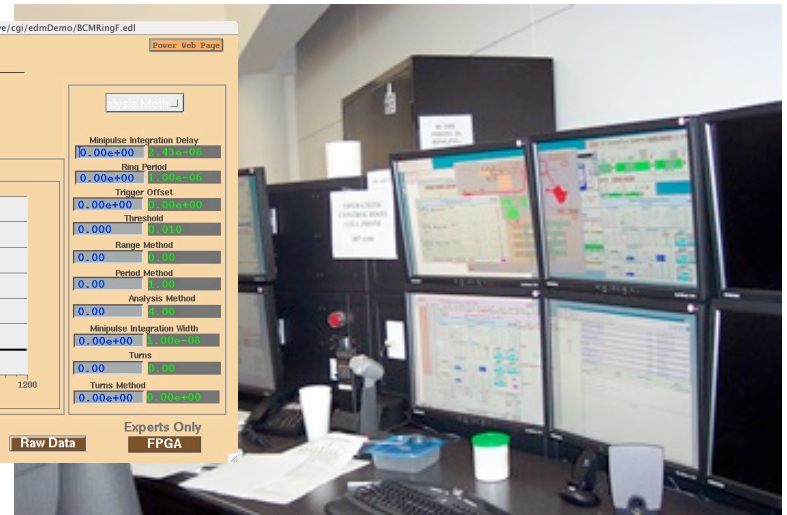
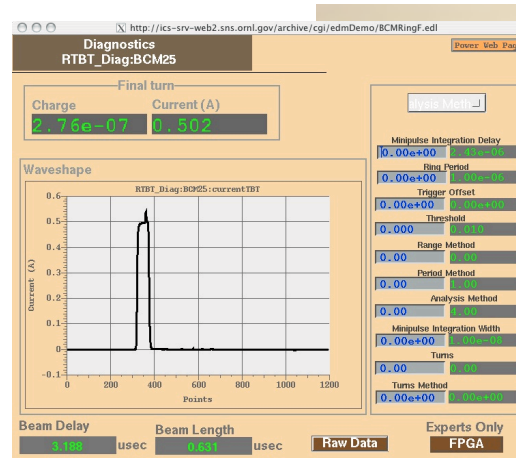
C:\Program Files\SharedMemoryIOC\bin\win32-x86\epics5M.exe
dbLoadDatabase(".../db/epics5M.dbd",0,0)
epics5M_registerRecordDeviceDriver(pdbbase)
dbLoadRecords(".../db/BCMR.db","SS=RTBT_Diag,IOC=BCM25_A=BCM25_B=BCM25F,C=none")
iocInit()
Starting iocInit
##### EPICS IOC CORE built on Feb  8 2005
##### EPICS R3.14.7 $R3-14-7$ $2004/12/06 22:31:52$
#####
iocInit: All initialization complete
#seq sncExample "$S=RTBT_Diag,IOC=BCM25_A=BCM25_B=BCM25F,C=none"
Shared memory IOC built on Apr  4 2005
epics> missed interrupt 4 RTBT_Diag:BCM25:tFastArrayPeriod
missed interrupt 4 RTBT_Diag:BCM25:tFastArrayPeriod
missed interrupt 4 RTBT_Diag:BCM25:tFastArrayPeriod
db1
RTBT_Diag:BCM25-Delay00_Rb
RTBT_Diag:BCM25-Delay01_Rb
RTBT_Diag:BCM25-Delay02_Rb
RTBT_Diag:BCM25-Delay03_Rb
RTBT_Diag:BCM25-Enable00_Rb
RTBT_Diag:BCM25-Enable01_Rb
RTBT_Diag:BCM25-Enable02_Rb
RTBT_Diag:BCM25-Enable03_Rb
    
```

Shared Memory IOC

# Beam Current Monitor



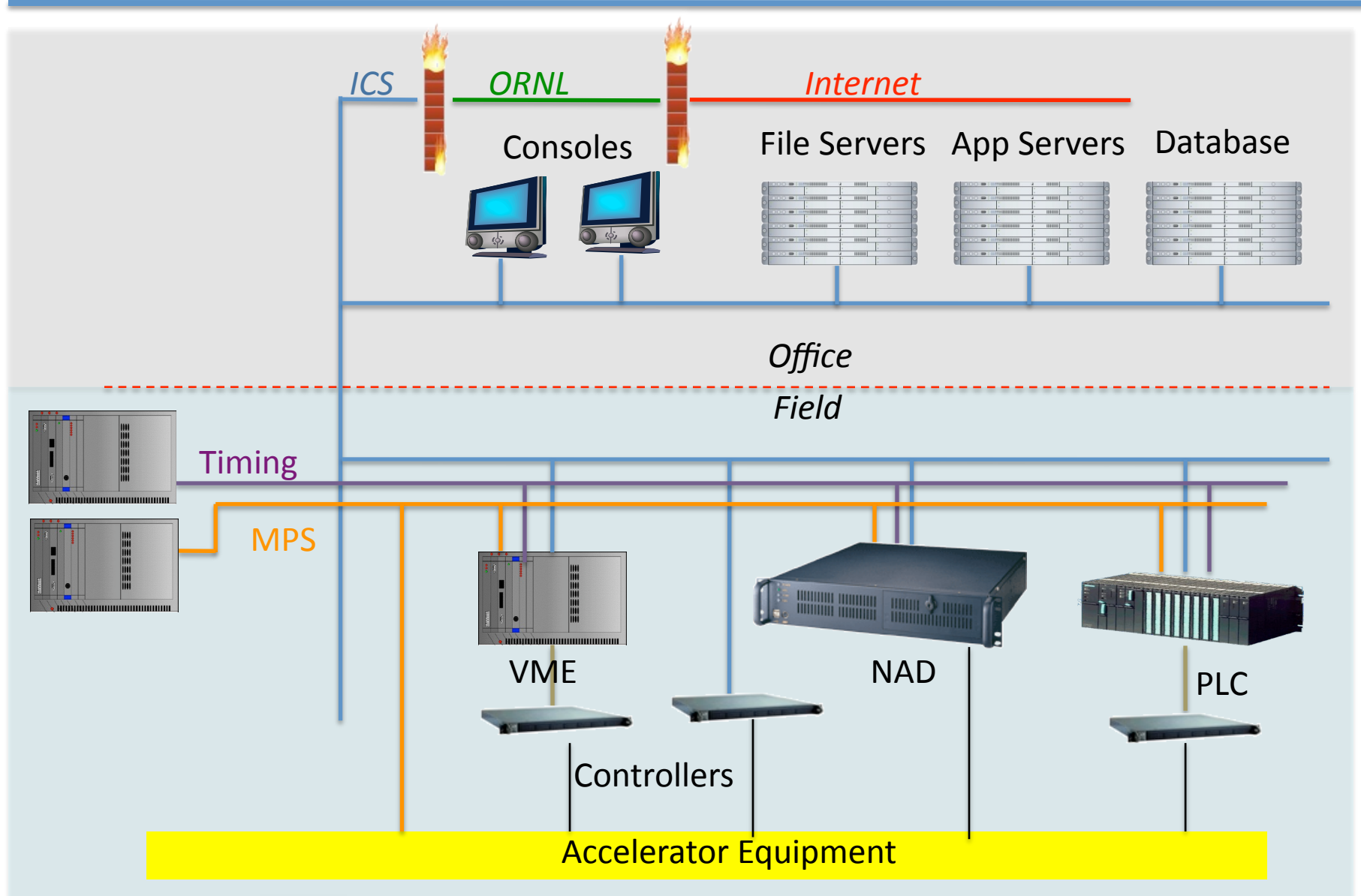
Rack Installation



Control Room

Control Room Consoles

# Accelerator Control System



# Integration Lab: Current Monitor

You will:

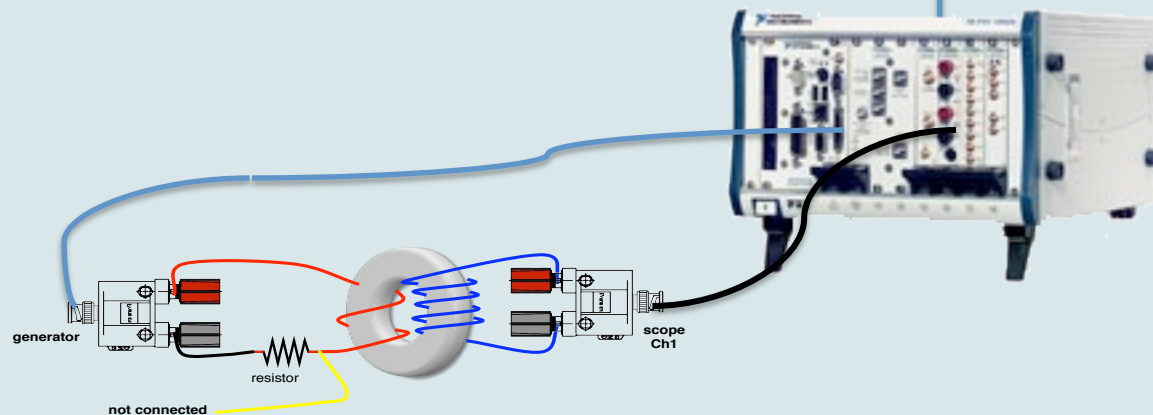
1. Read your ICD
2. Design your current monitor
3. Implement
4. Document
5. Calibrate
6. Publish the required data

*Local*

EDM Console



*Office  
Field*



Accelerator Equipment



# References

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- [1] Murphy D., Purcell D., “LARGE-SCALE PC MANAGEMENT AND CONFIGURATION FOR SNS DIAGNOSTICS ”, AIP Conf. Proc. 732, 379 (2004), DOI:10.1063/1.1831172
- [2] Shea T. , “Control System Integration”, ORNL.

