Instrumentation Integration

Accelerator Beam Diagnostics

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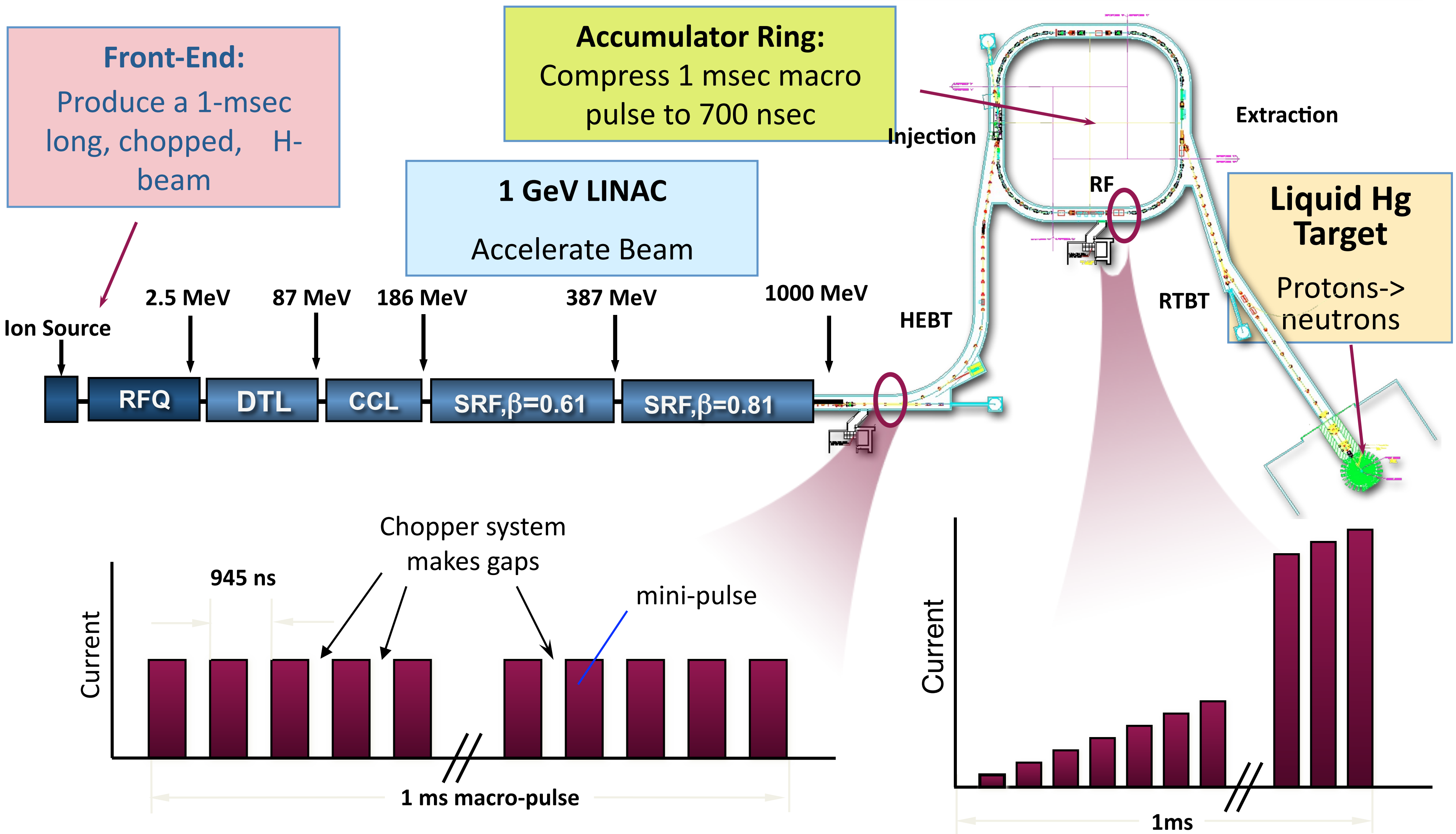
Integration

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

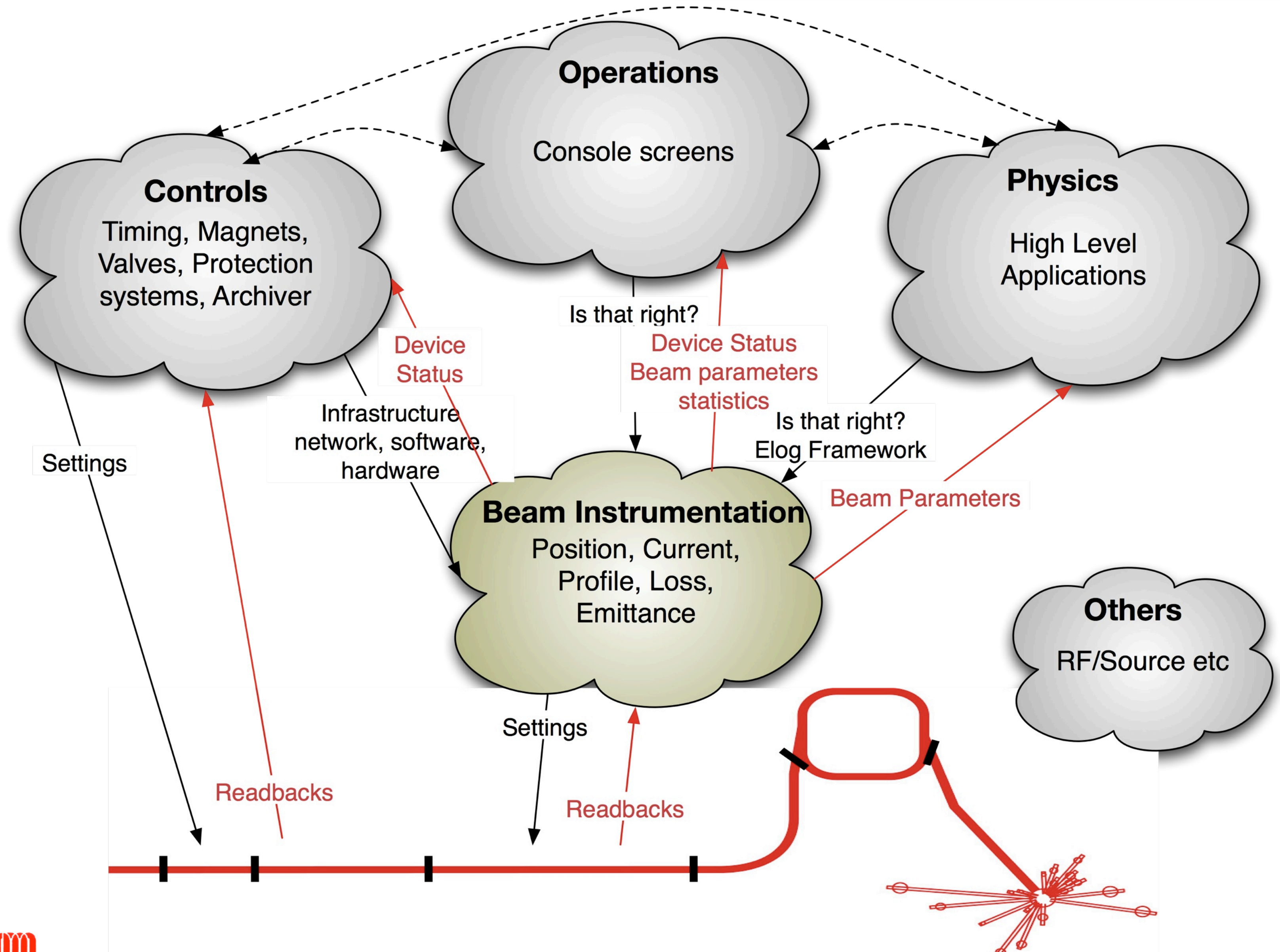


Beam Instrumentation in Accelerators

- 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



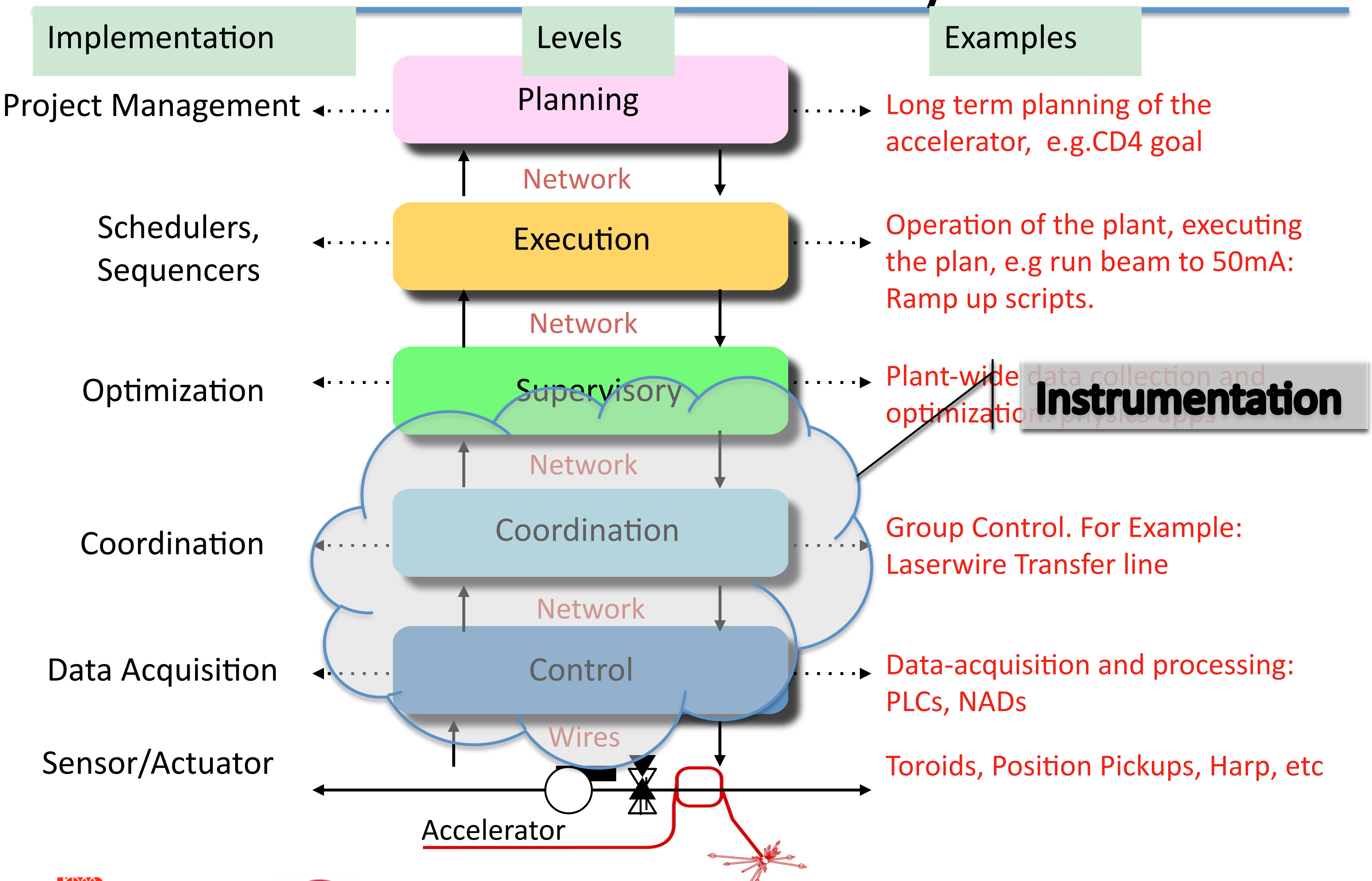
Integration

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

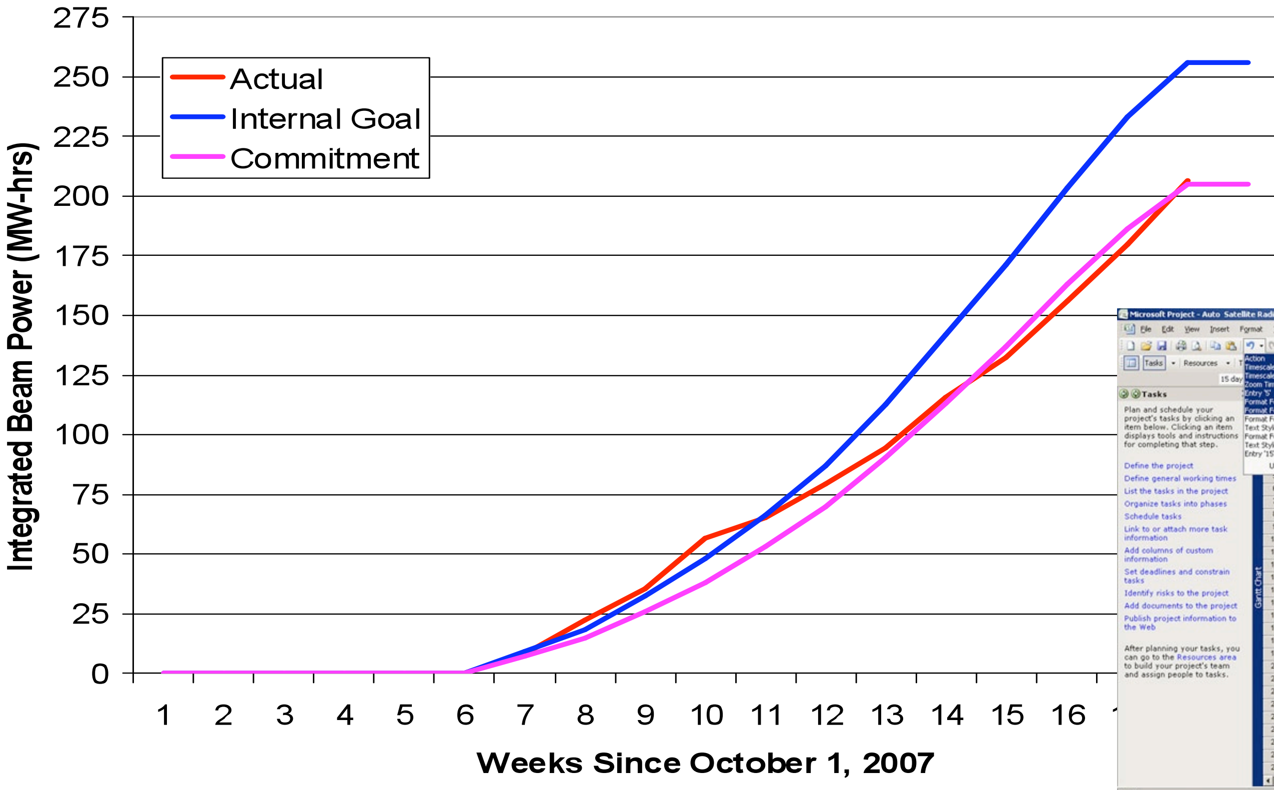
- Hardware
  - Data-acquisition
  - Front-ends (IOC/NAD)
  - Network
  - Timing
  - Protection
  - PLC (closed loop systems)
  - Actuators/Sensors

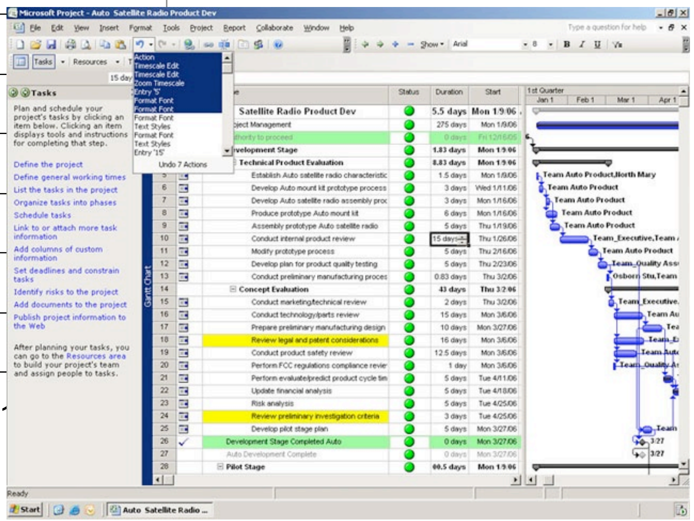
- Software
  - Communication Protocols
  - Data analysis
  - Simulation
  - Automation
  - Archiving
  - Configuration/Source code control

Hierarchical Control System



Planning Level





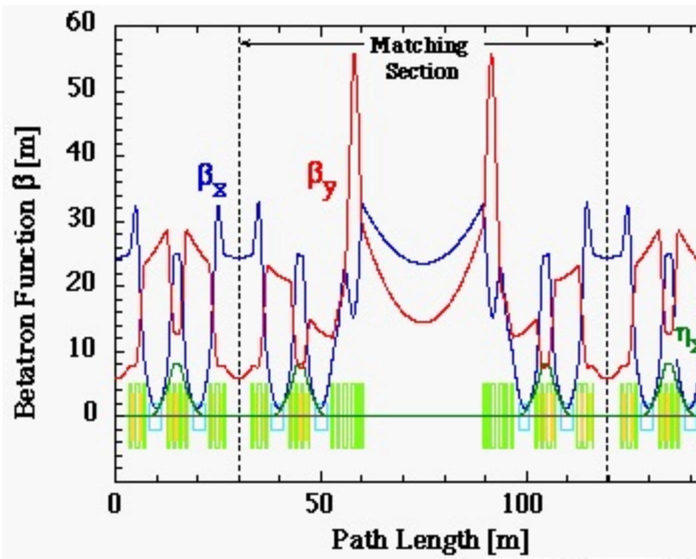
Project management

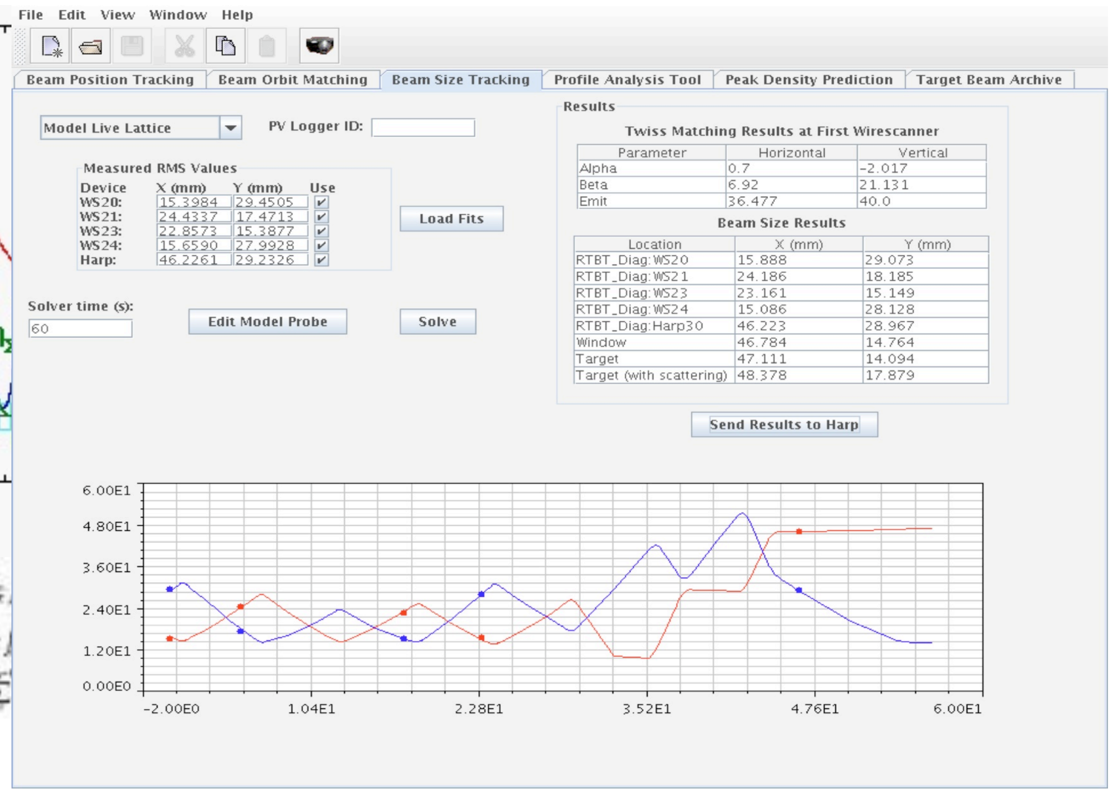
Notice the Pink (Slip) line. That is what matters for the manager: to stick with the production goals

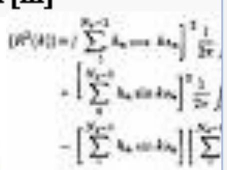
Execution Level

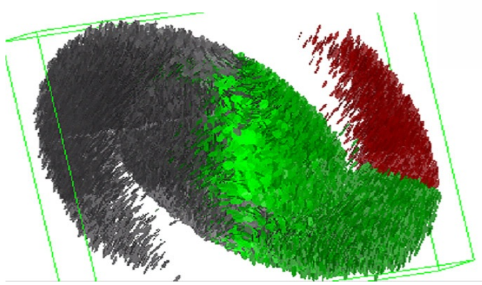
In the control the scripts and sequences are invoked after the supervisory apps have yielded satisfactory results.

Supervisory Level



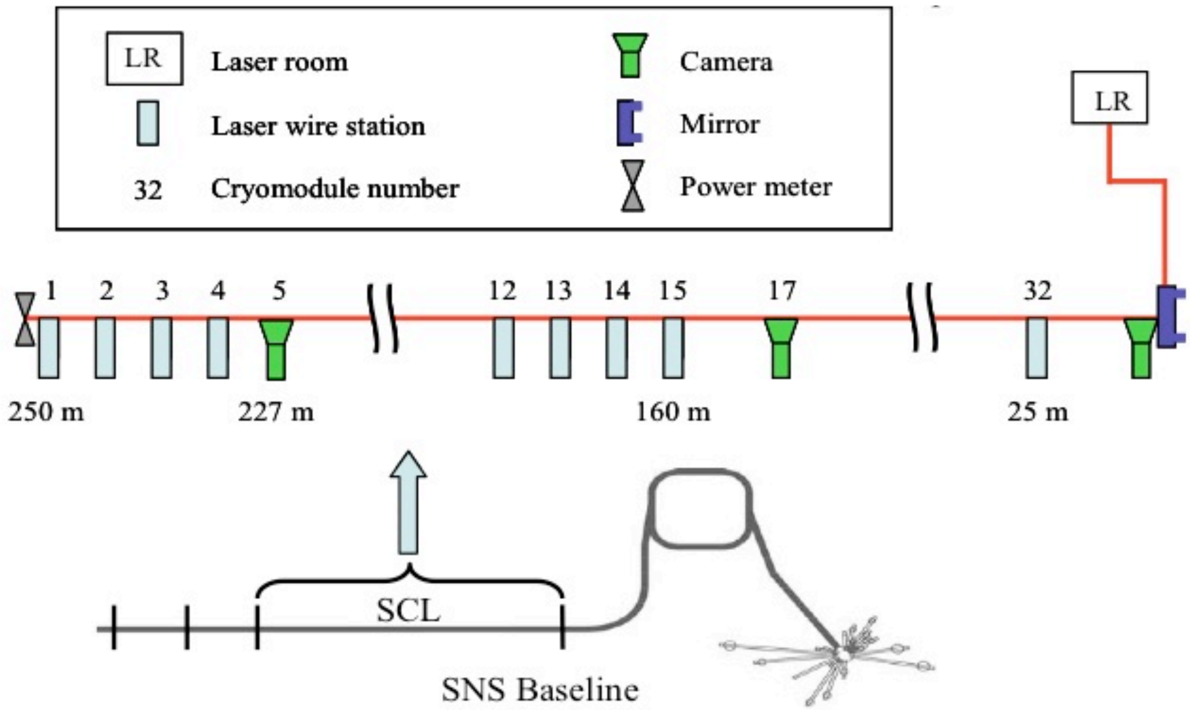






Supervisory Level often include significant modeling to provide the optimization routines -> often physics.

Group Control Level

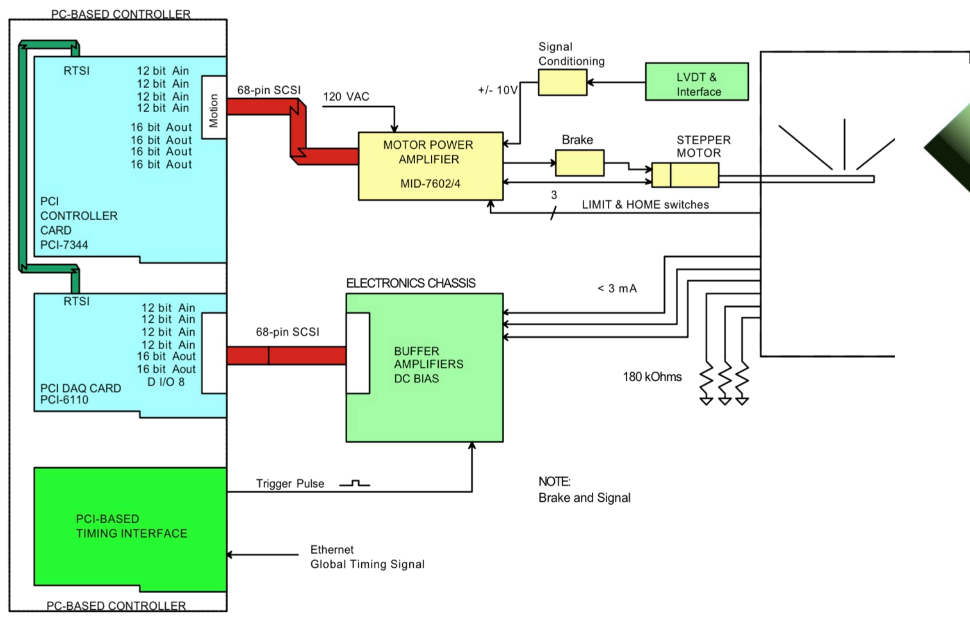


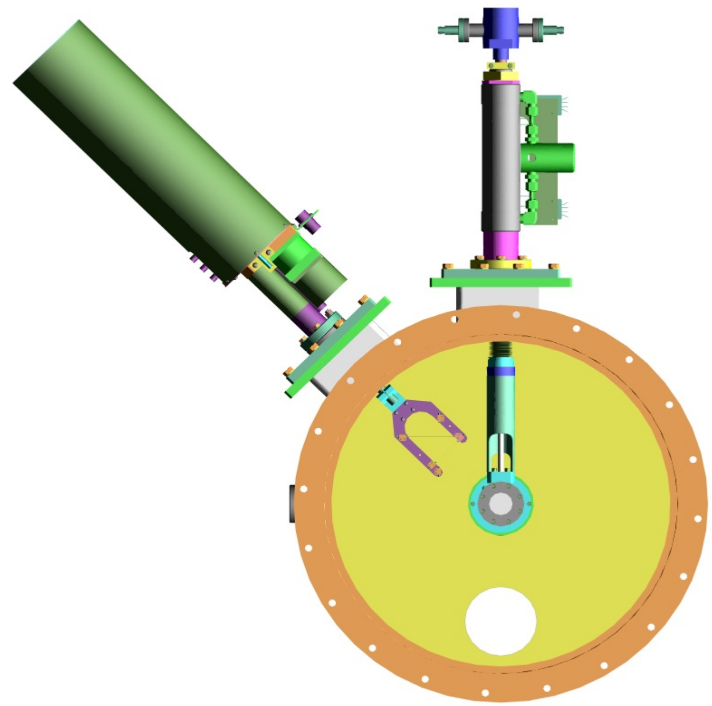
Hide the fact that the laserwire consists of 14 system distributed along the accelerator.

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

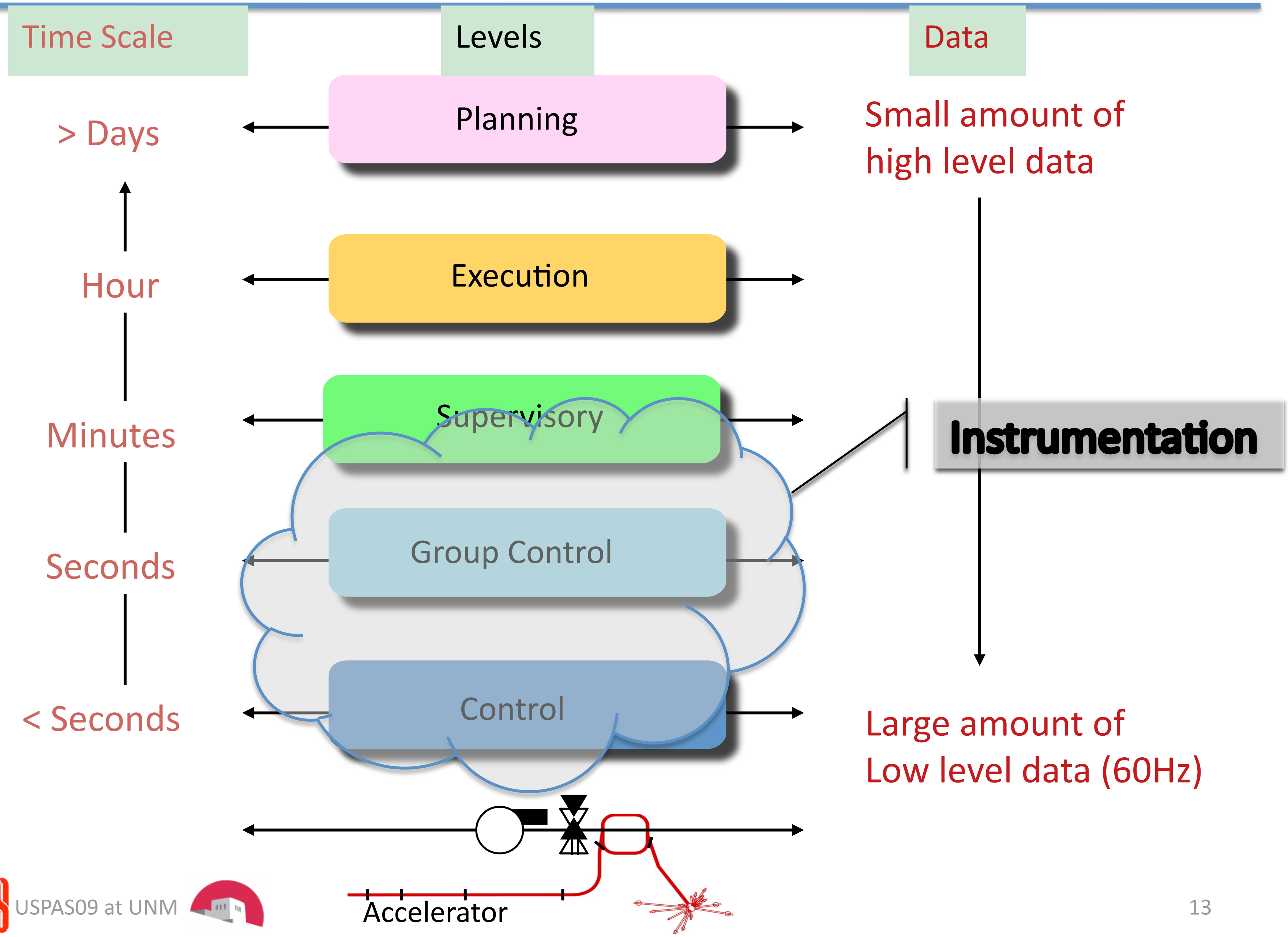




Control Level interacts with the hardware:

- Wire Scanner
- Valves

Hierarchical Control System



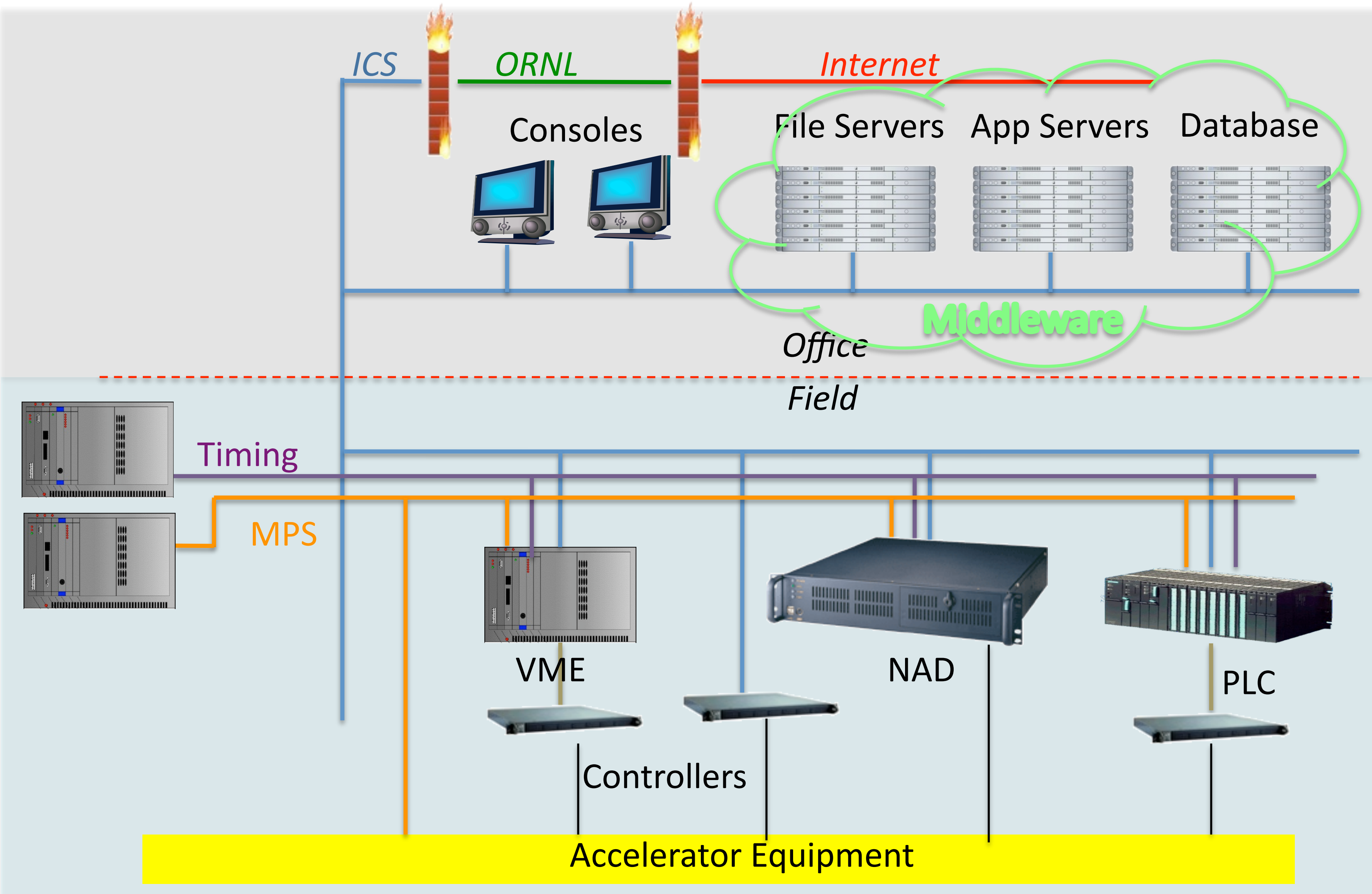
Accelerator Control System

A typical Accelerator Control System is distributed and shows some hierarchy

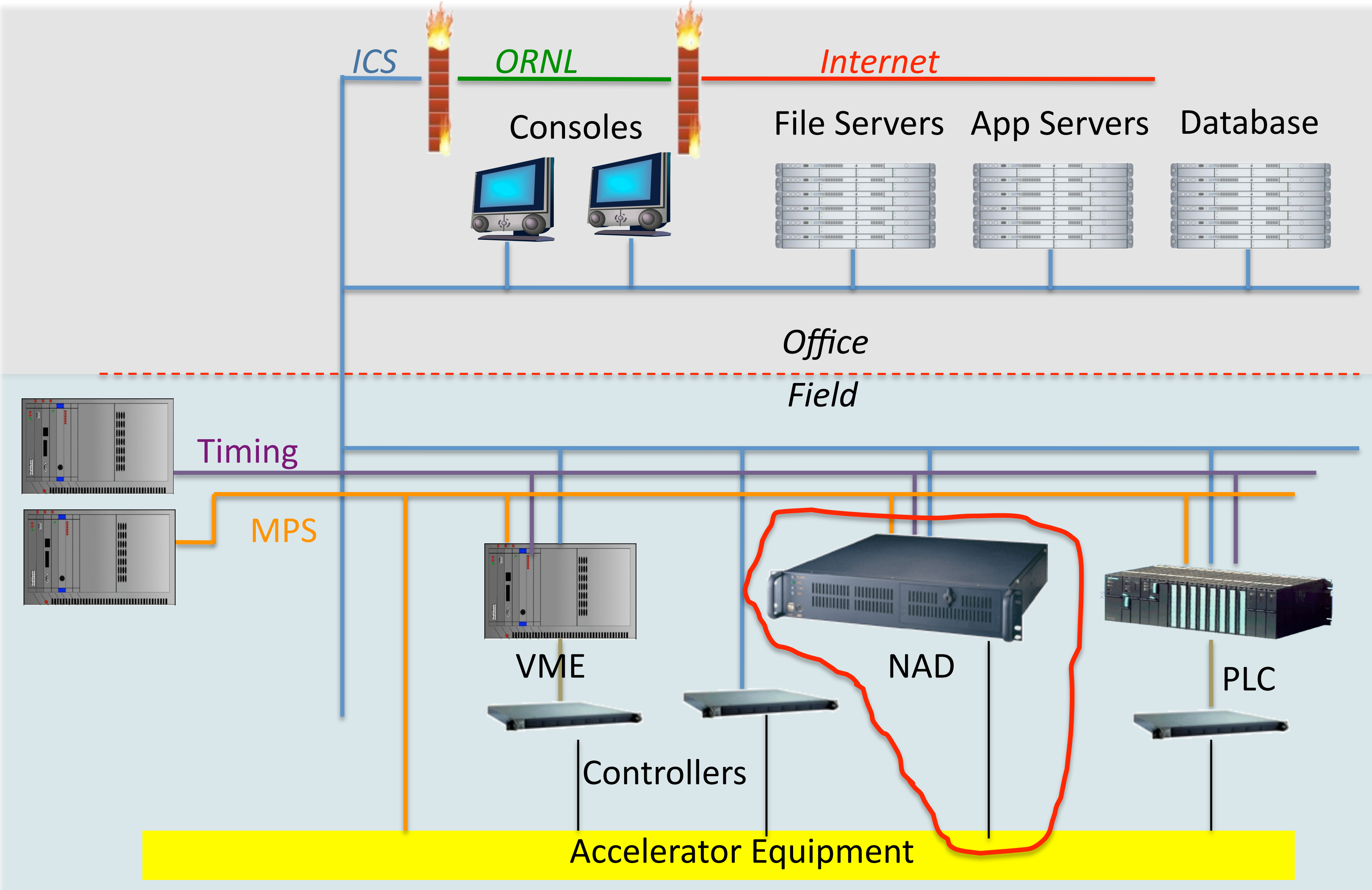
- Control: PLC/VME/NADs
- Group Control: Group Timing Controller
- Supervisory: Physics Apps, Trend analysis
- Execution: Ramp up scripts
- Planning: Project management tools

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

SNS Control System



SNS Control System



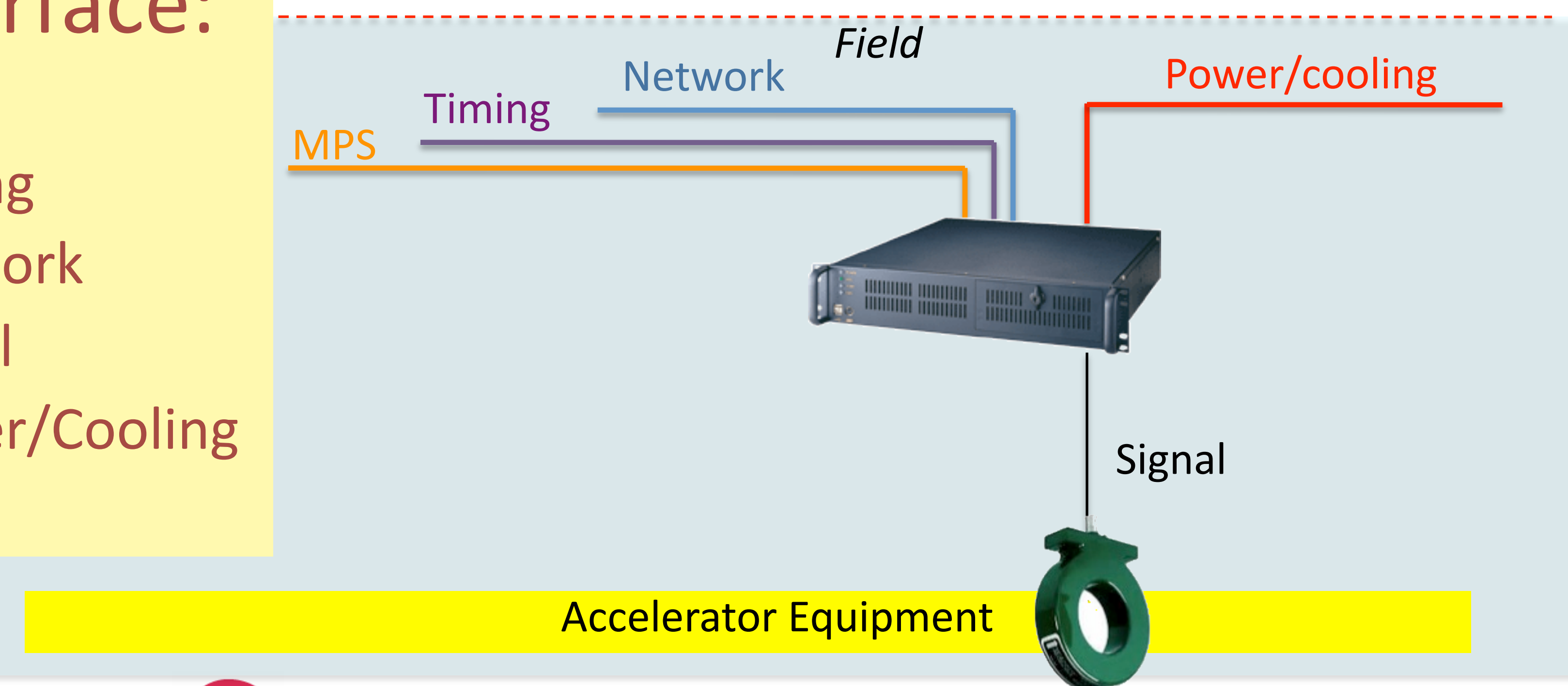
SNS Control System

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, aide 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 µsecs (the electron component) and last up to 100 µsecs 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

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

System Brochure

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.

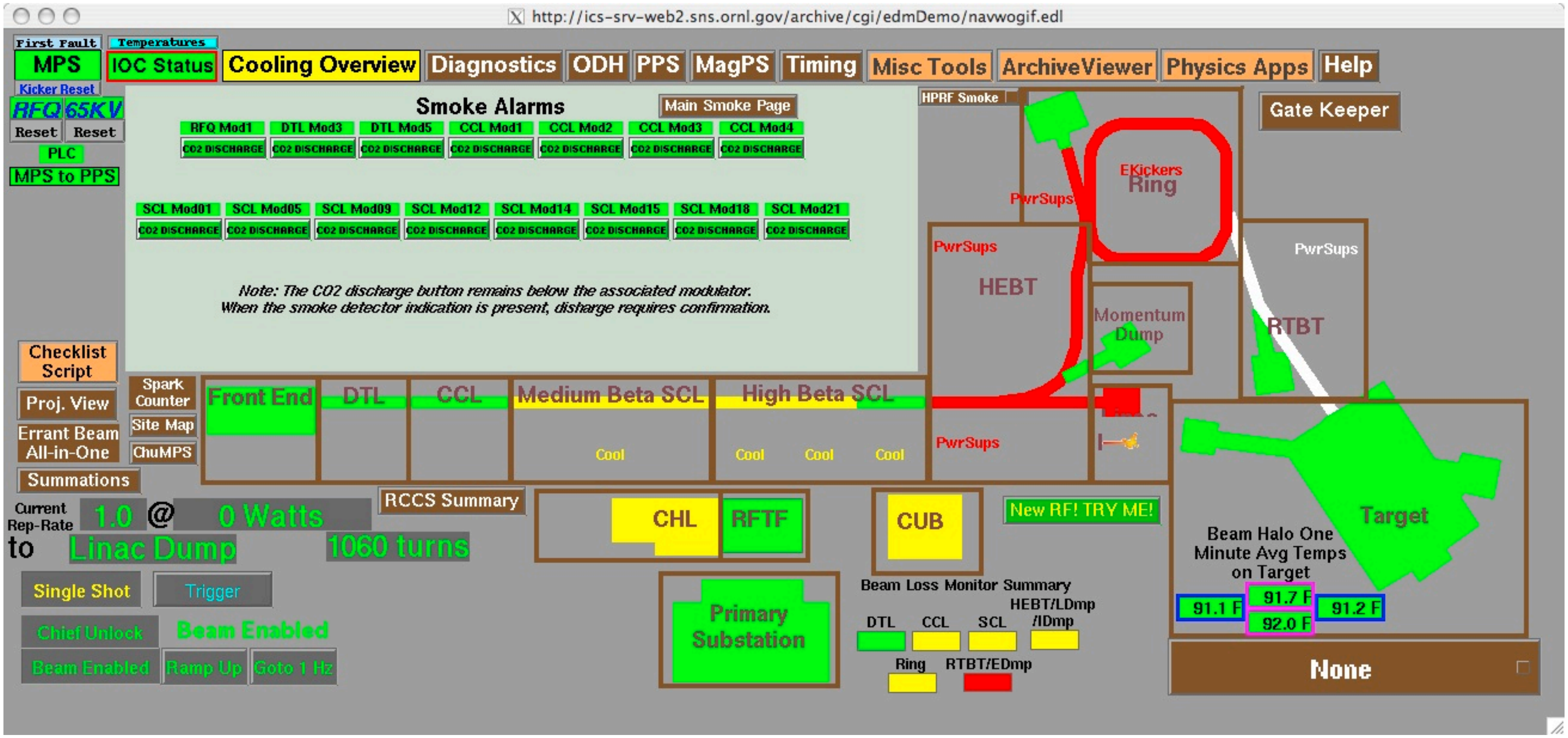
Beam Instrumentation in Accelerators

Group	System	Reliabil-ity	Failure Consequence	Response Time	Uptime	Comments
Controls	Machine Protection	Ultra	Harm to hardware	RT	24/7	
	Timing	Very	Downtime	RT	24/7	
	Vacuum	Very	Downtime	~10ms	24/7	
Instrumen-tation	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
	Report	High	No Info	Minutes	Interactive	Display can fail but not logging
Physics	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	
Operations	Scripts	Low	Restart of app	~200 ms	Interactive	Apps can crash but wrong calculations can be bad

Control Rooms

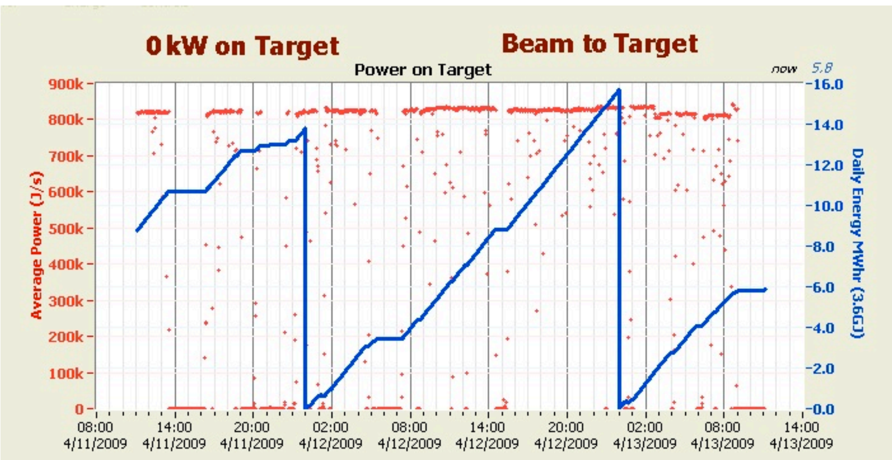
The AGS control rooms at Brookhaven in 1964, 1989,1998 and the SNS Control Room in 2006

SNS Console Demo

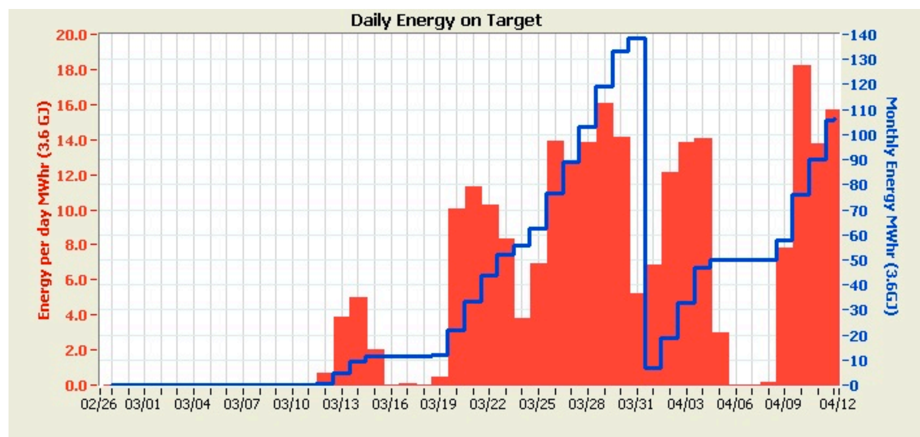


System Integration

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



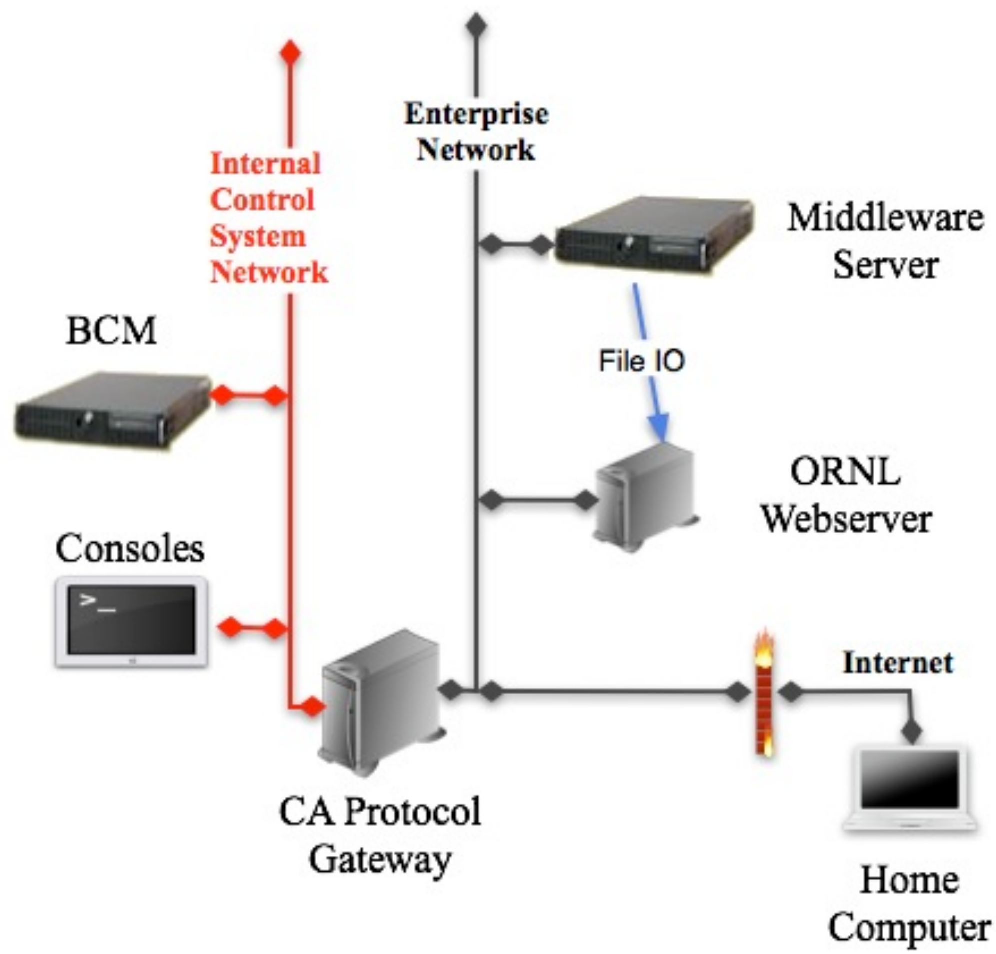
SNS Power on target



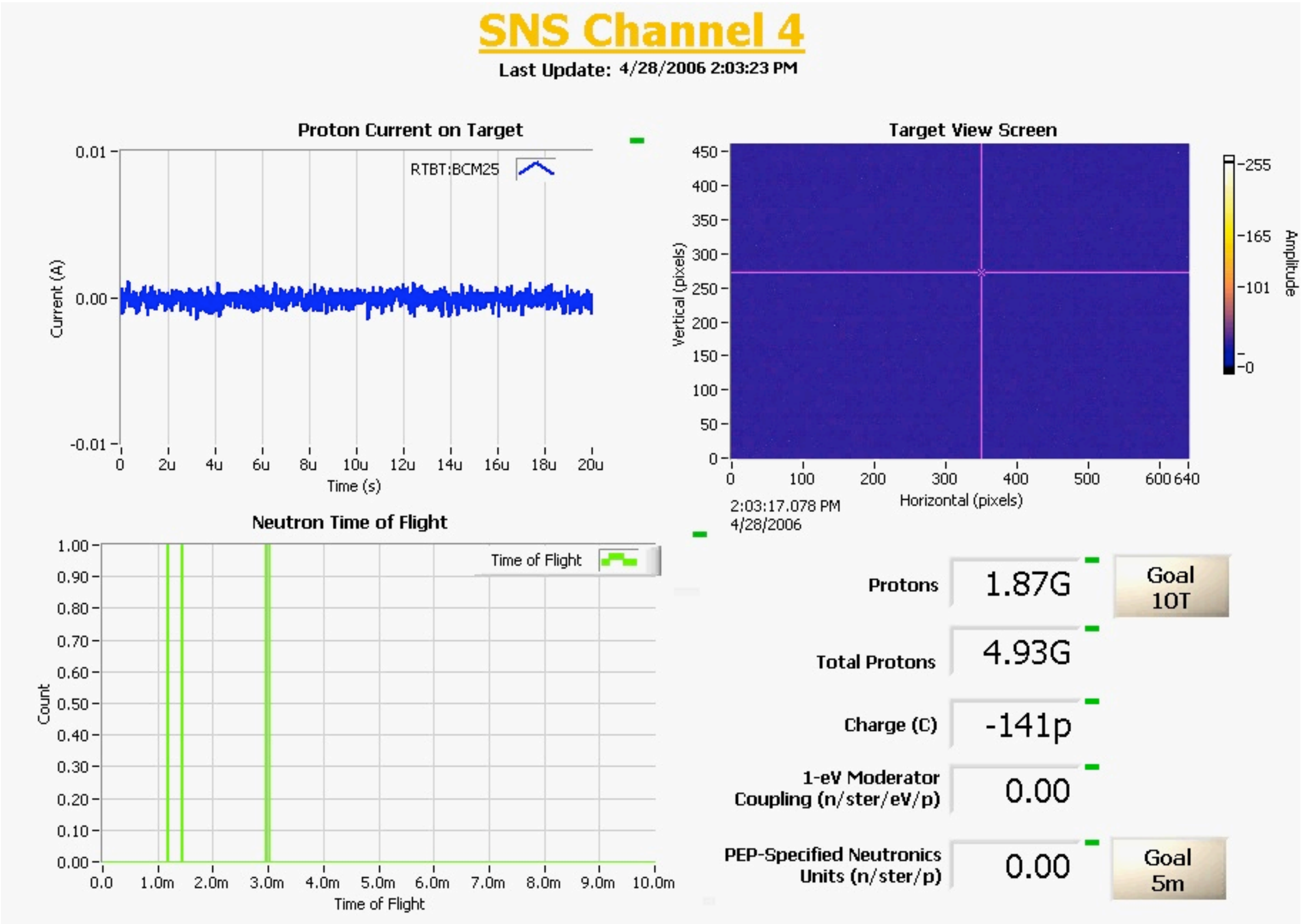
SNS Energy delivered to target

System Integration

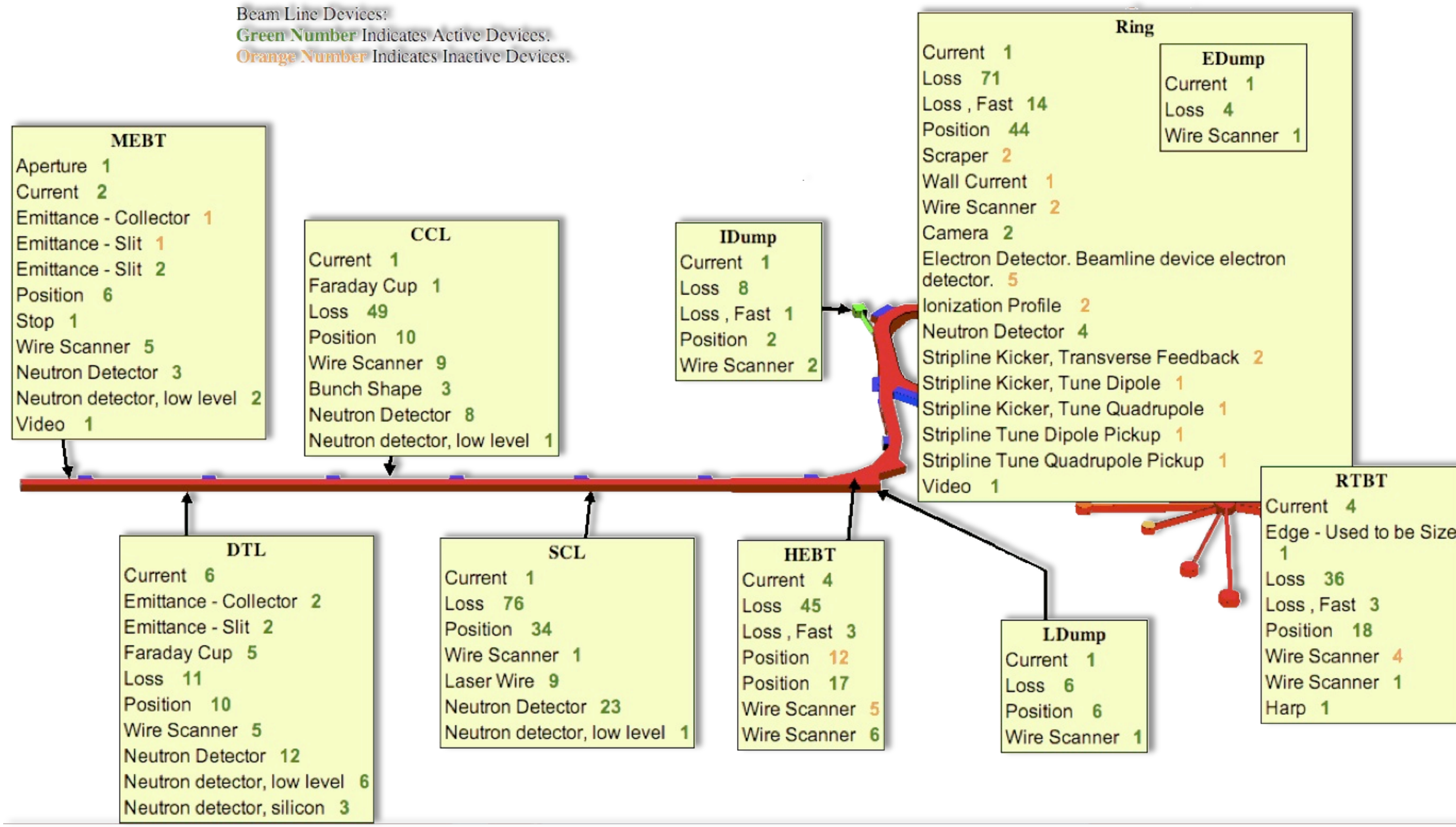
- How was this published?



Data Publishing: Commissioning



Instrumentation



Instrumentation Infrastructure

- 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

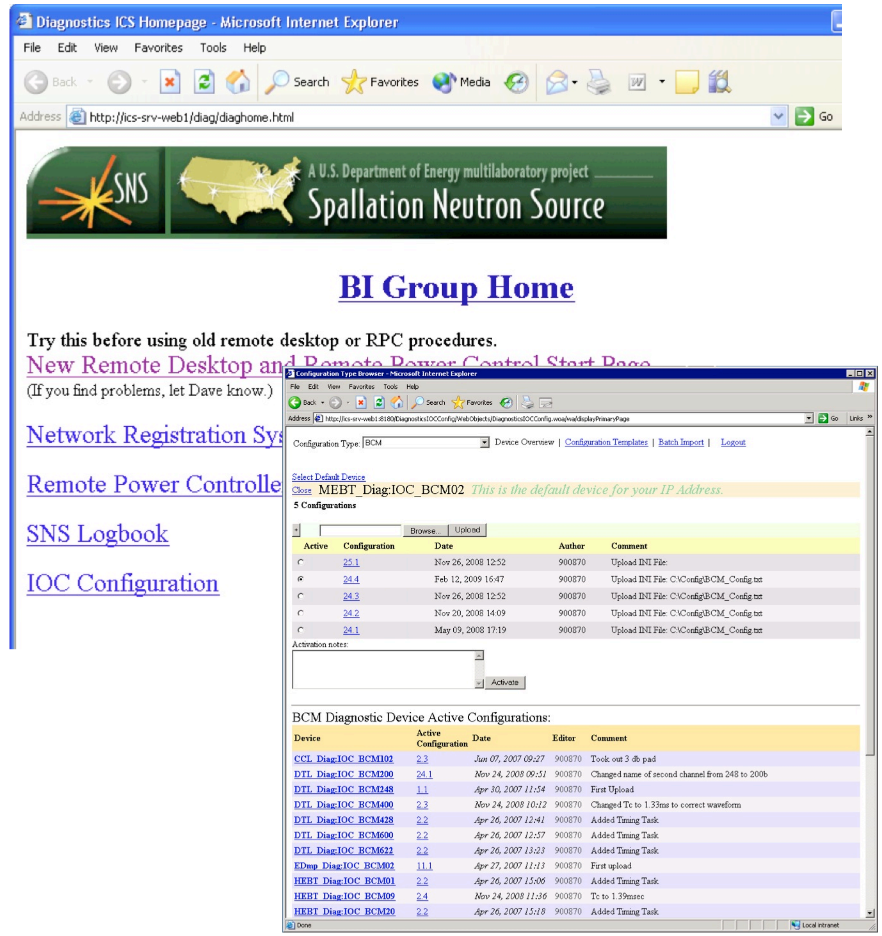
Instrumentation Infrastructure

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)

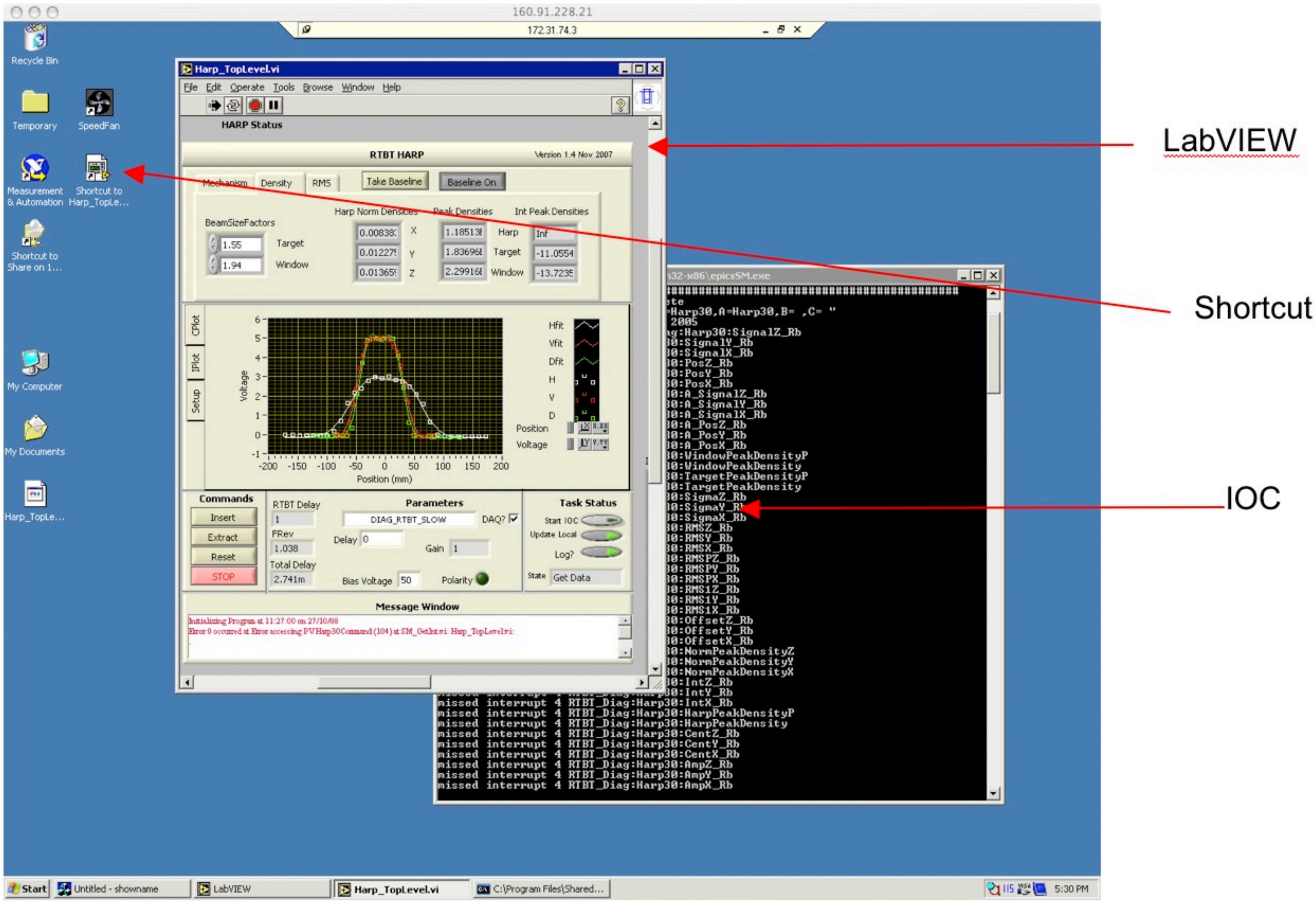
Instrumentation Infrastructure

Mass Imaging of computers



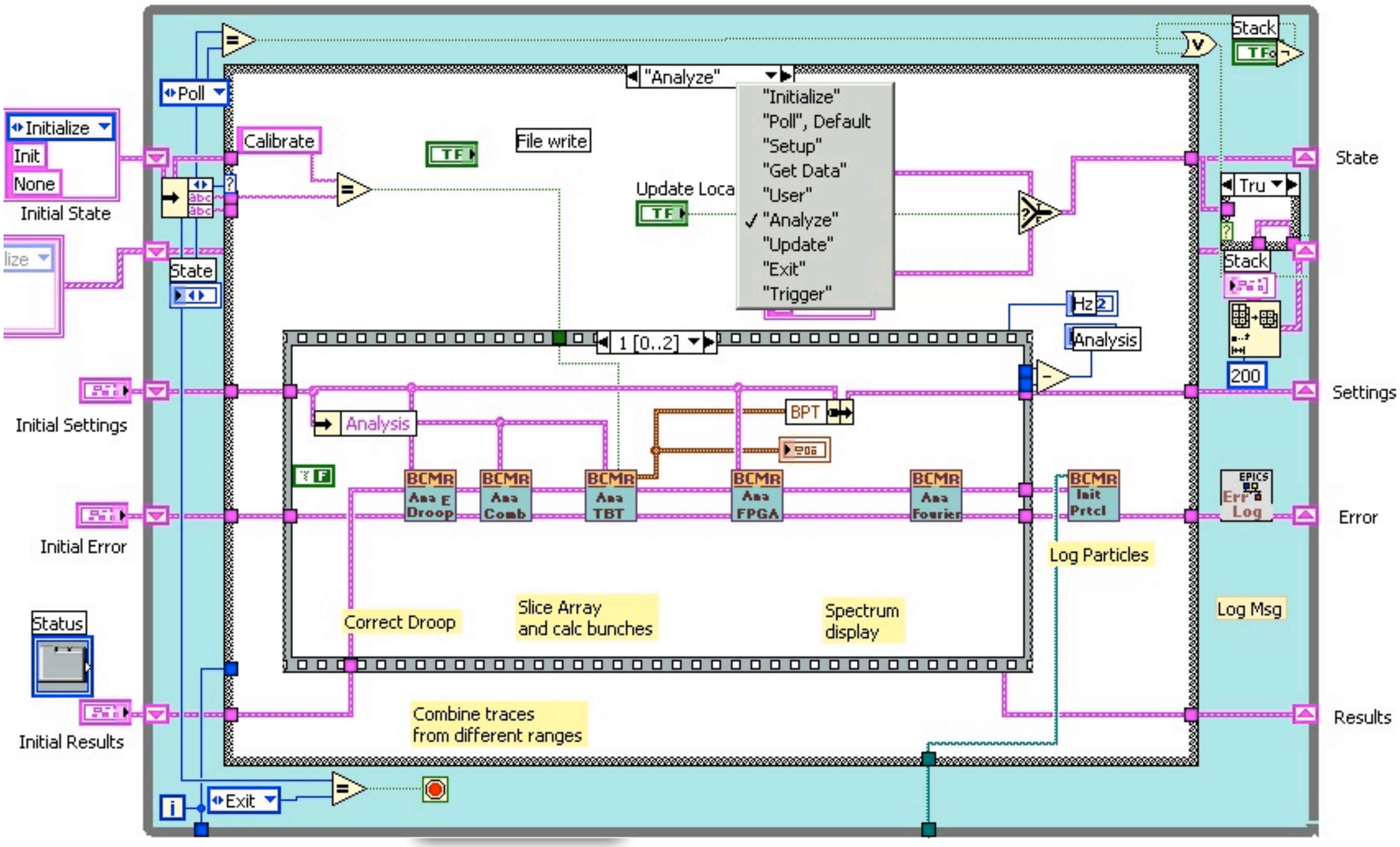
Management of computers

Instrumentation Infrastructure



Instrumentation Infrastructure

- Software Templates

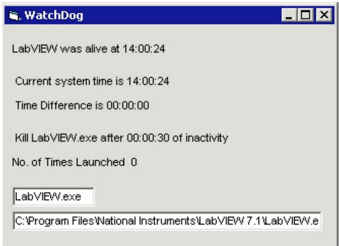


Beam Current Monitor

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

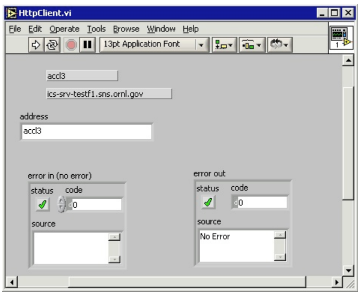
BCM	Waveform	Beam Accounting	Ring	Target
Real-time	No	Yes	Yes	Yes
Rep-rate	6 Hz	60 Hz	6Hz	60Hz
Samples/sec	20-500Mhz	20-50Mhz	20-50Mhz	100Mhz
Range	30mV	30mV	30mV-30V	30mV or 30V
Accuracy	2%	1-5%	5%	1-5%
DAQ	DP235	PXI-5122	PCI-5122	PXI-5122EX
OS	XPe	XPe ->LV RT	XPe	XPe

Beam Current Monitor

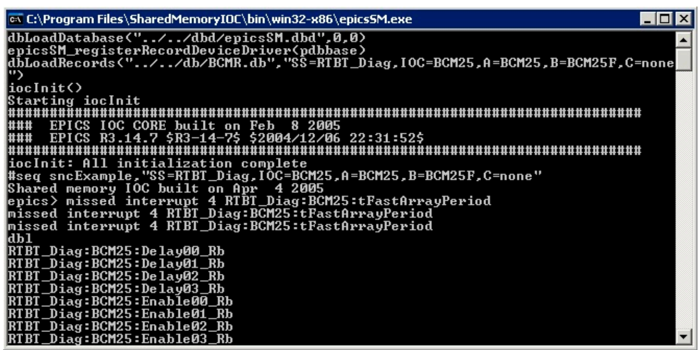


WatchDog

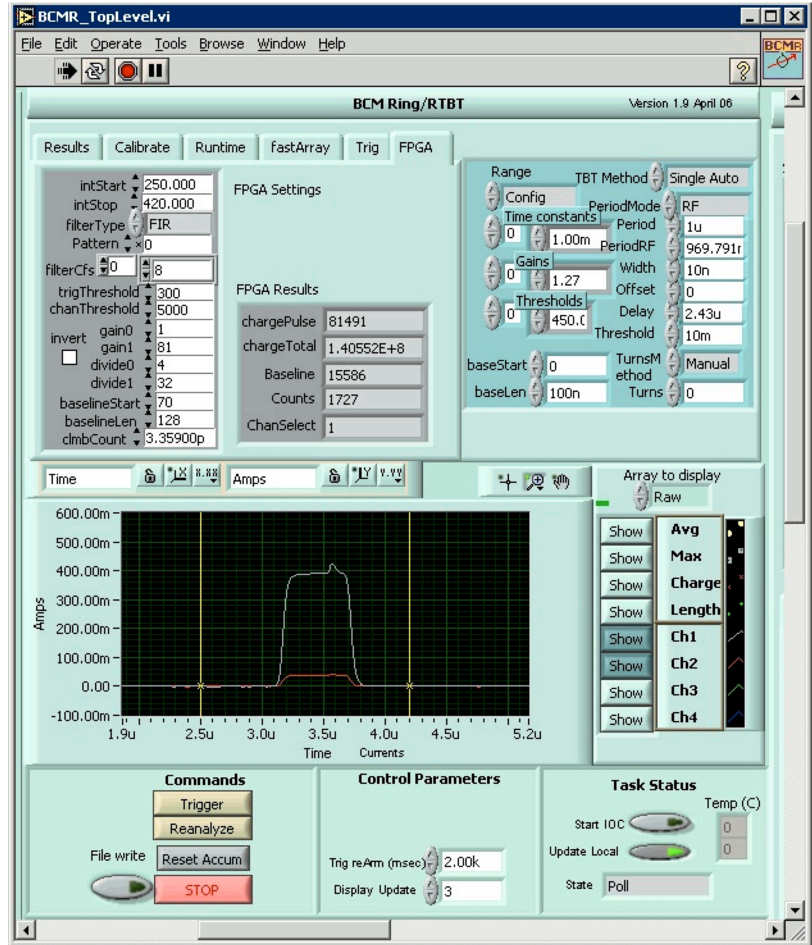
Timing Task



Configuration file downloader



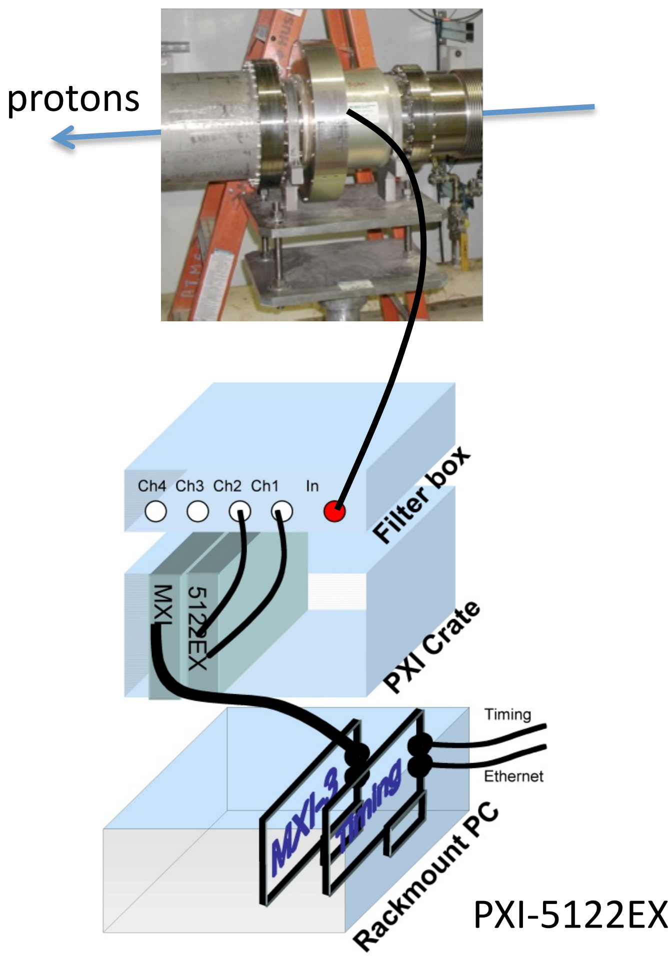
Shared Memory IOC



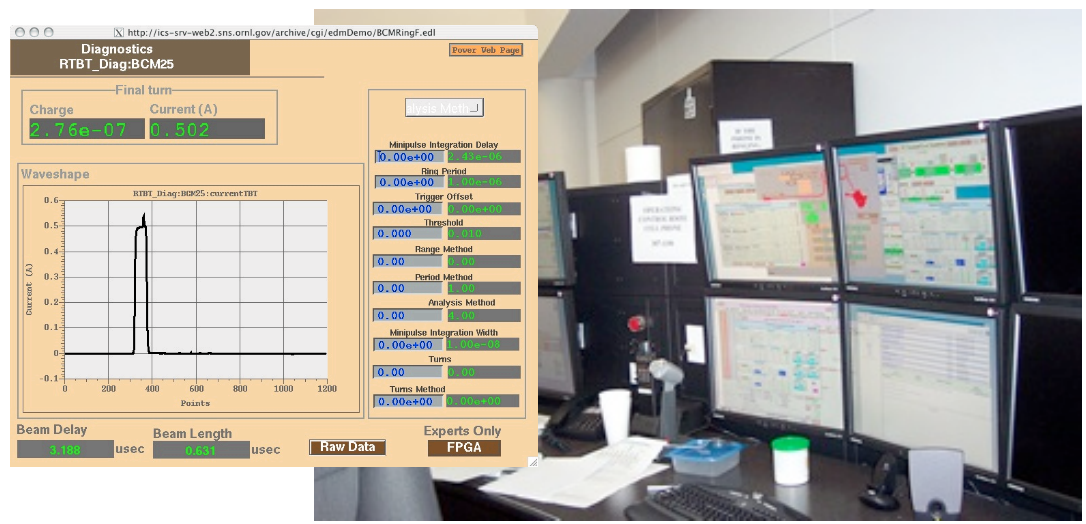
Main Program

Beam Current Monitor

Toroid



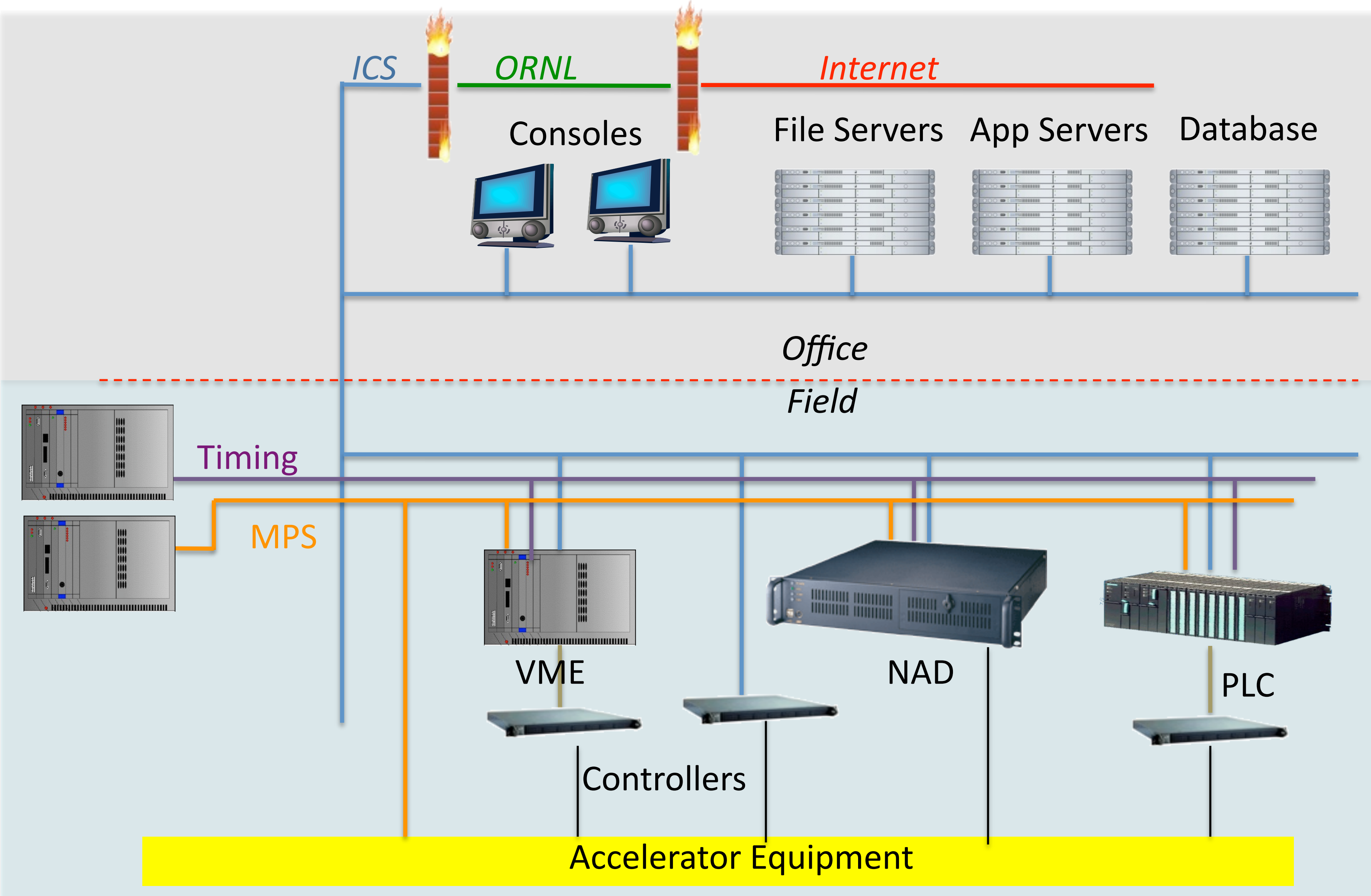
Rack Installation



Control Room Consoles

Control Room

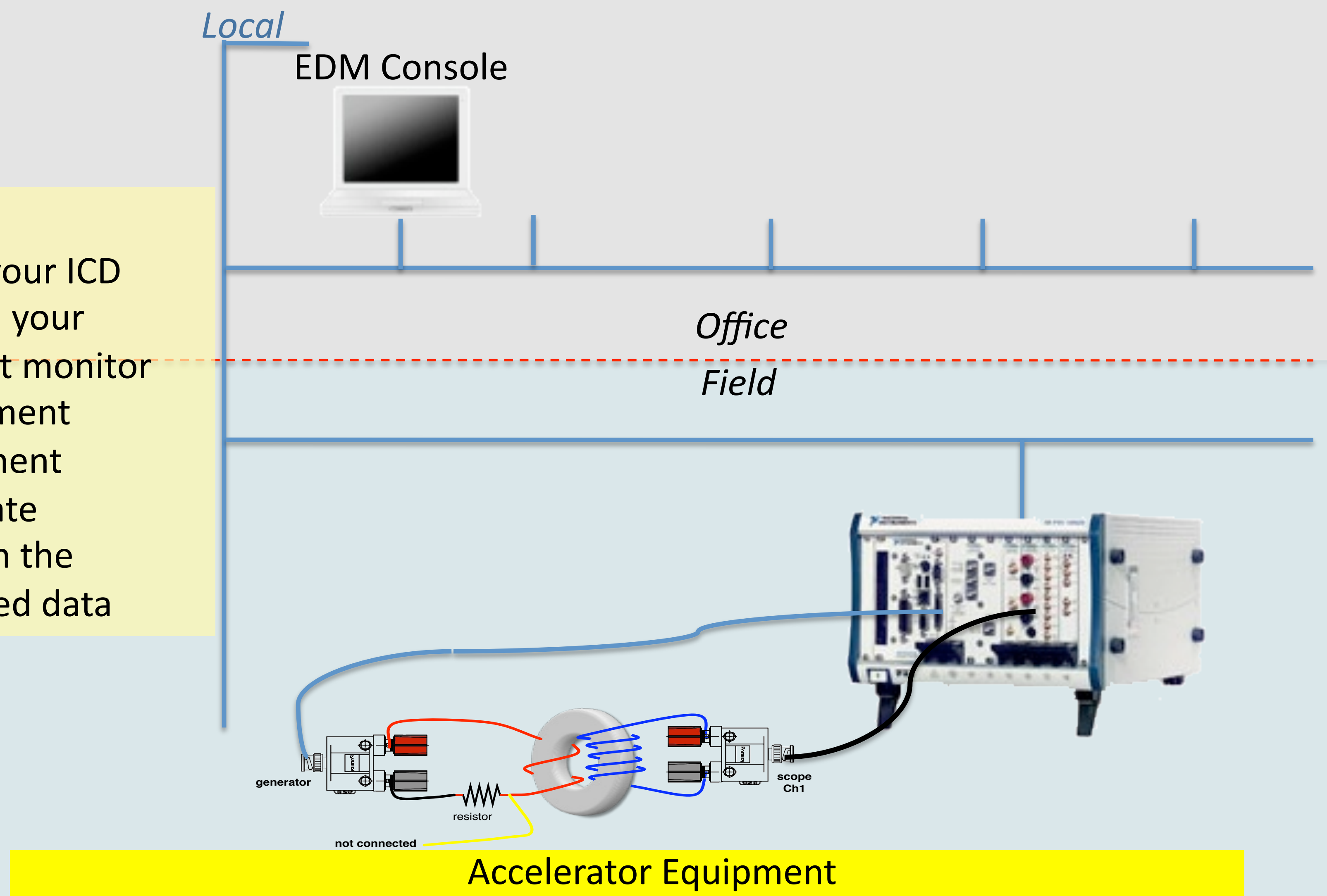
Accelerator Control System



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



References

[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.