Indus-2 Control System
A Closer Perspective

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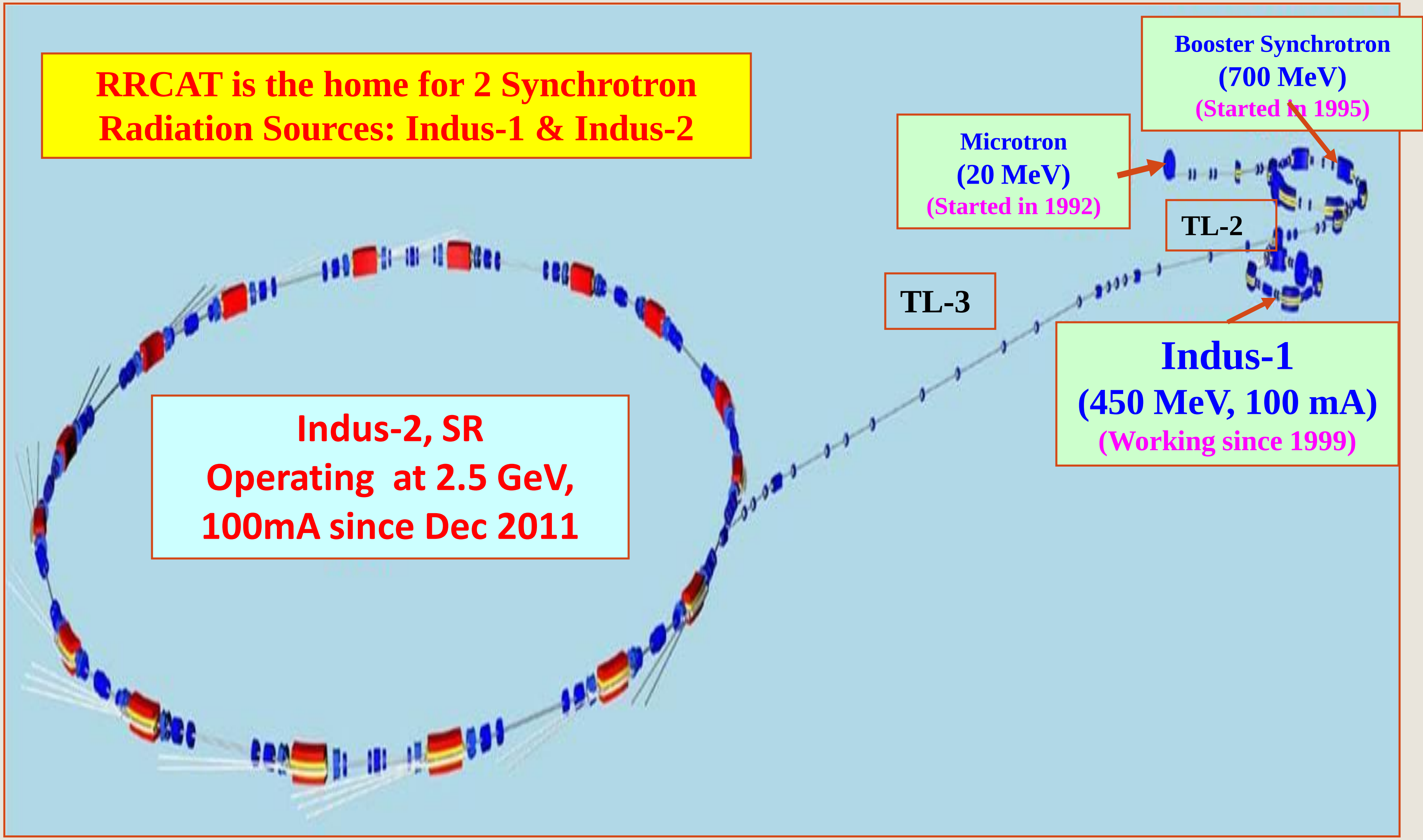
Indus Complex

This Talk is dedicated to the entire team of Indus-2, who have made country's first and essentially indigenously made SRS work well. And efforts continue…

Schematic View of Indus Complex

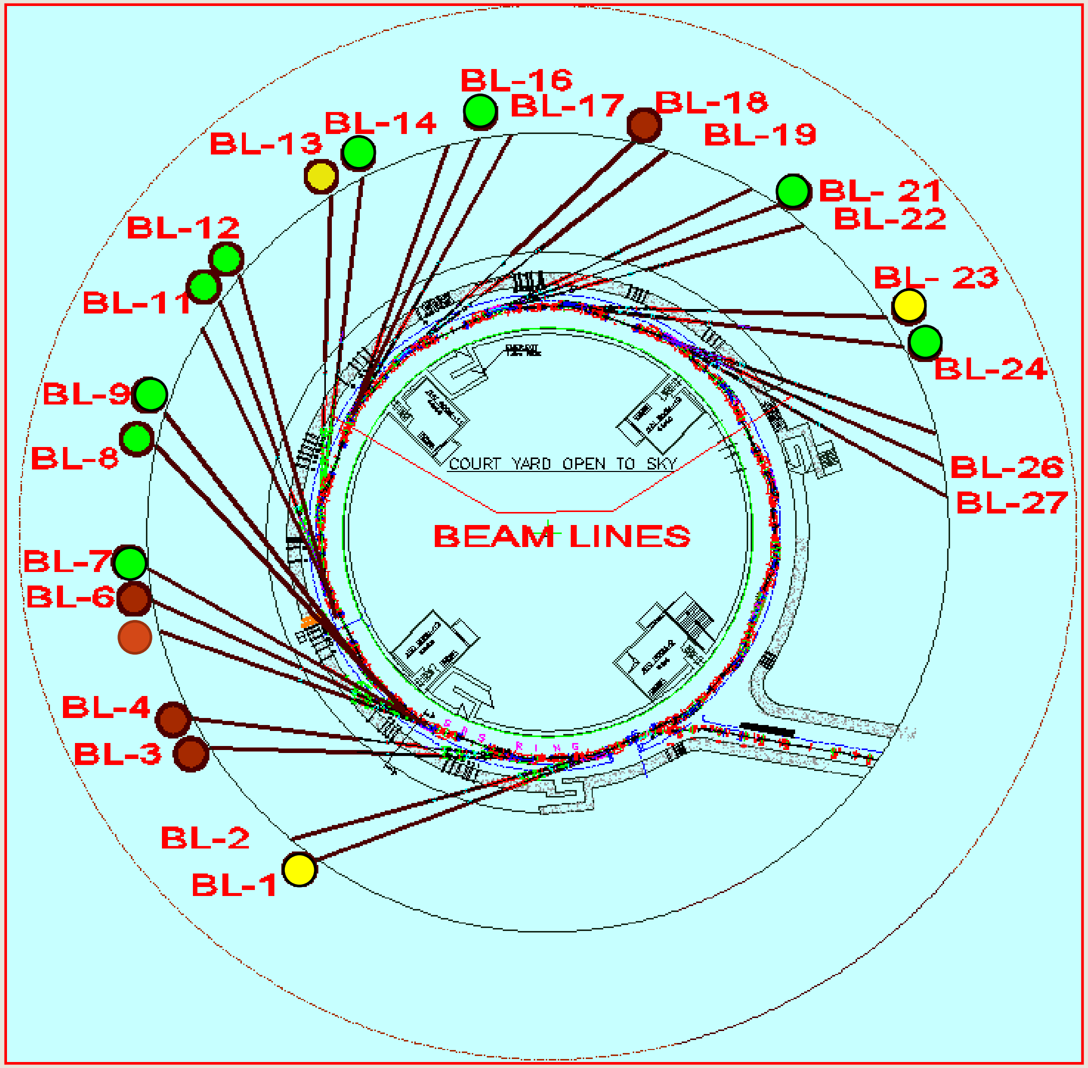


Indus-2 Ring Tunnel – Inside View

Layout of Indus-2 Beamlines

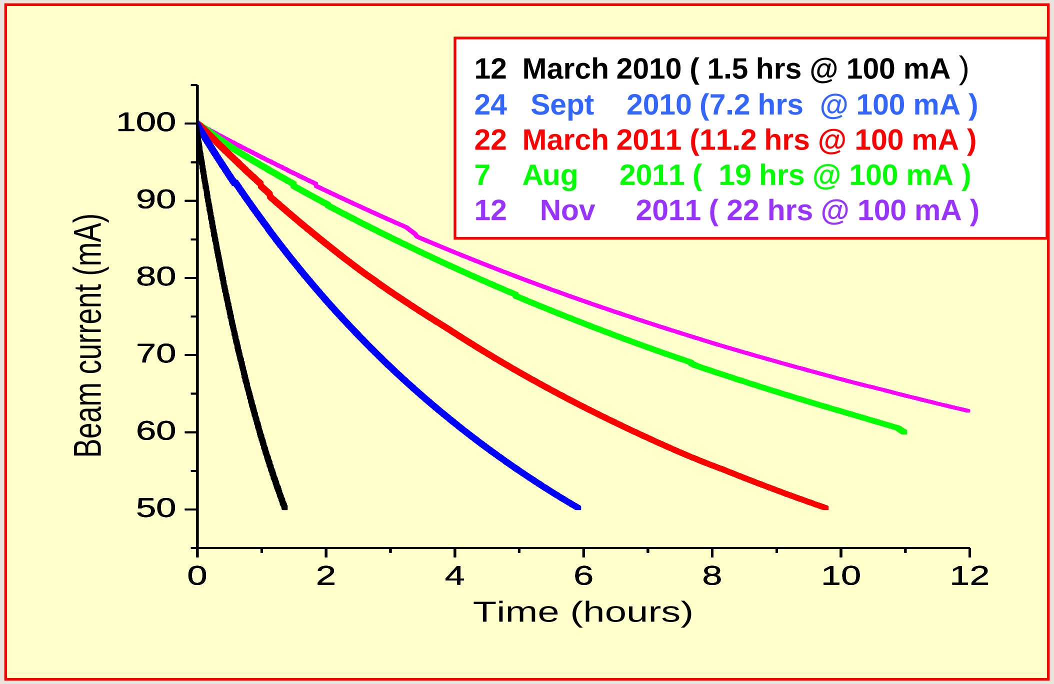
Total no. of beamline ports = 26

Ports for bending magnet beamlines = 21



	MCD/PES (BL-1)
	Soft X-ray (BL-3)
	Imaging (BL-4)
	ARPES/PEEM (BL-6)
	X-ray Lithography (BL-7)
	EXAFS (BL-8)
	EXAFS Scanning (BL-9)
	EDXRD (BL-11)
	ADXRD(BL-12)
	GIXS(BL-13)
	XPES (BL-14)
	XRF- microprobe (BL-16)
	SWAXS(BL-18)
	Protein Crystallography (BL-21)
	X-ray Beam Diagnostic (BL-23)
	Visible Beam Diagnostic (BL-24)

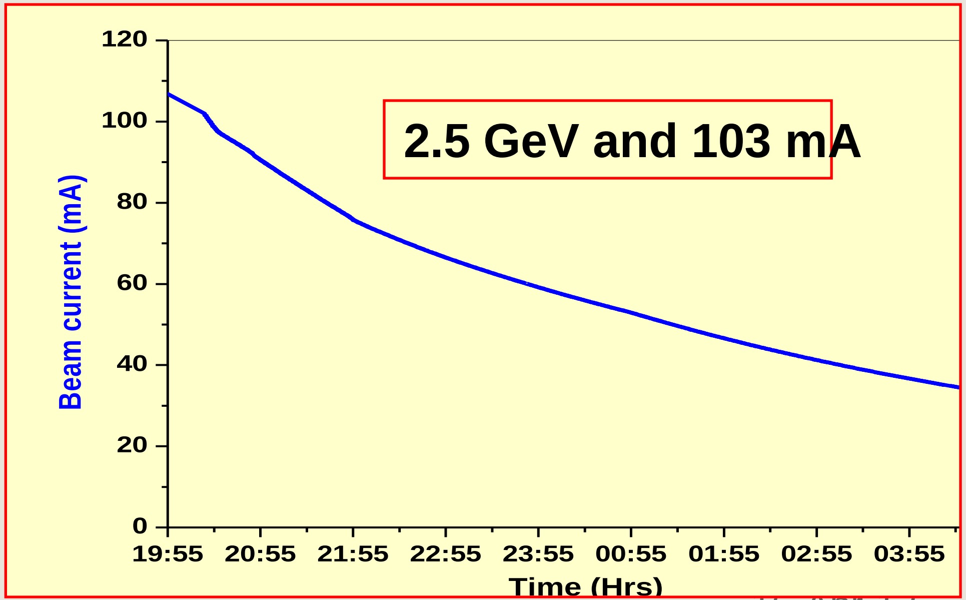
Beamlines commissioned   Beamlines under commissioning   Beamlines under development



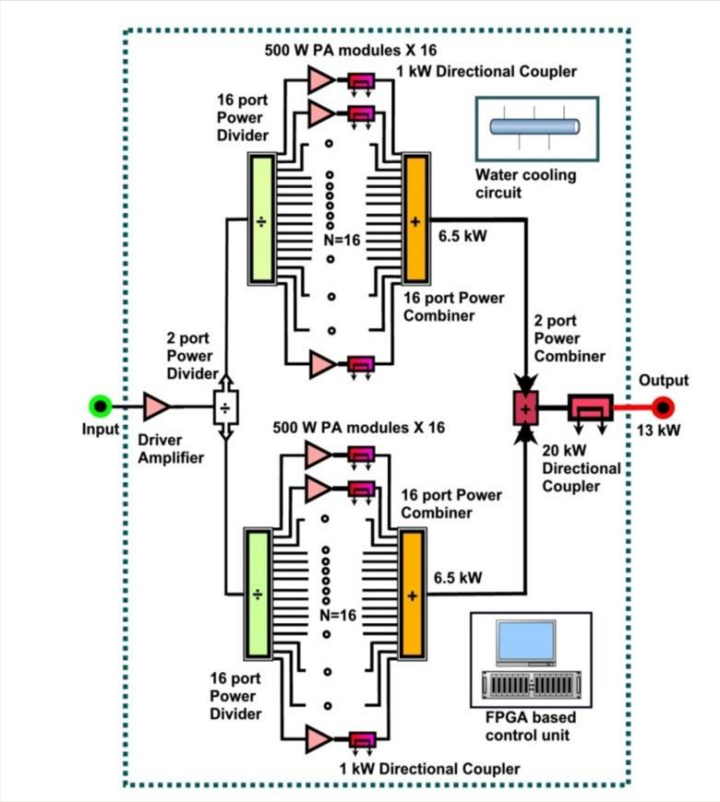
2 GeV and 100 mA operation since March 2010 till Nov 2011

Improvement in beam lifetime from 3 hrs to more than 24 hrs.

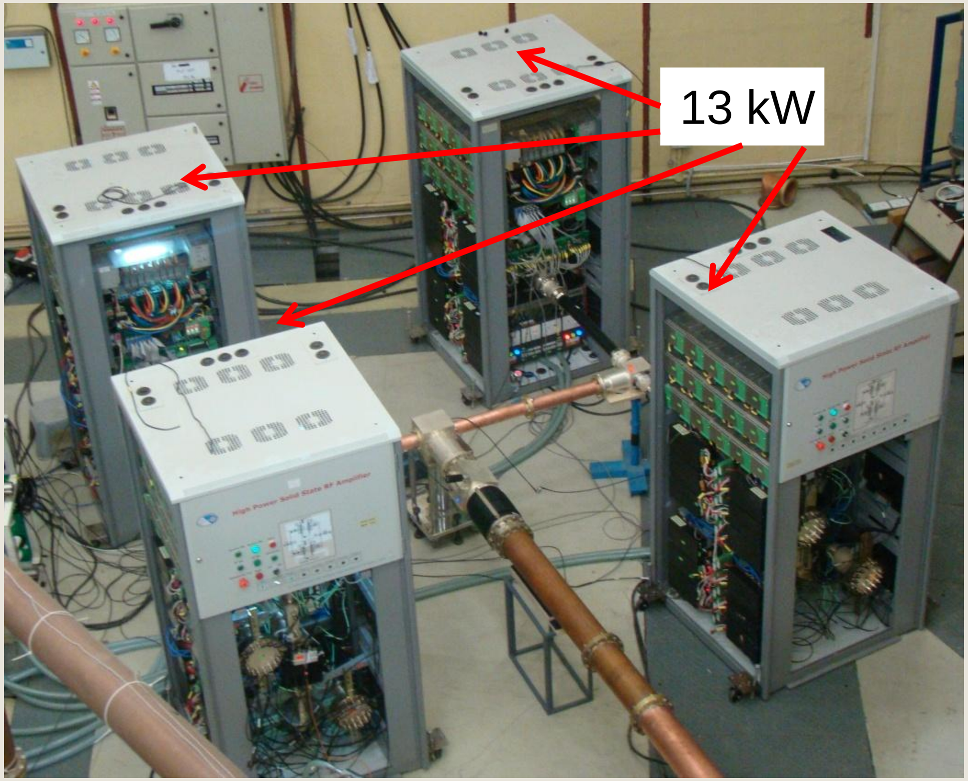
2.5 GeV and 100 mA operation on 6-7 Dec 2011 with addition of Solid State RF amplifier



Indigenous development of Solid State RF amplifier



13 kW RF module



50 kW Solid State RF amplifier Combination of four 13 kW units

13 kW employs 32 power amplifiers each operating at 500 W. RF power from two 13 kW amplifier combined in a 2-way combiner to get 25 kW RF power. Two such 25 kW devices are combined to get 50 kW RF power using 2-way high power combiner. With additional 100 kW of RF power Indus-2 has been operating at 2.5 GeV and 100 mA

Indus-2 – Current Status

- ✓Regular Operation in 3 shifts @100 mA/2.5GeV
- ✓COD Correction
- ✓Slow Orbit Feedback operational
- ✓Tune feedback operational
- ✓Diagnostic Beamline recently commissioned
- ✓Fast Orbit Feedback is being implemented
- ✓Instability feedback – transverse and longitudinal being implemented
- ✓Work started for having beamlines based on Insertion device

A View of the Indus-2 User hall with Beam line Hutches

What is expected out of a Control System for an SRS

- Supervision ,Monitoring & Controlling of a complex piece of machine with stringent requirements
- Generate stable and precise reference signals for various devices
- Machine Timing – precise triggers, accurate programmable delays, timing inter-dependencies
- Filling Patterns
- Synchronous Energy Ramping, Magnets Cycling
- Extensive and flexible Alarm handling
- Machine safety Interlocks
- Orbit Controls, Instability Control, Tune feedback
- Beamline Front End Controls
- Extensive Data Logging
- Web services
- System operation recepies
- Convenient mechanism of experimenting with machine
- Expandable & adaptive to newer requirements and challenges
- Do everything well – Repeatable and Reliable Actions

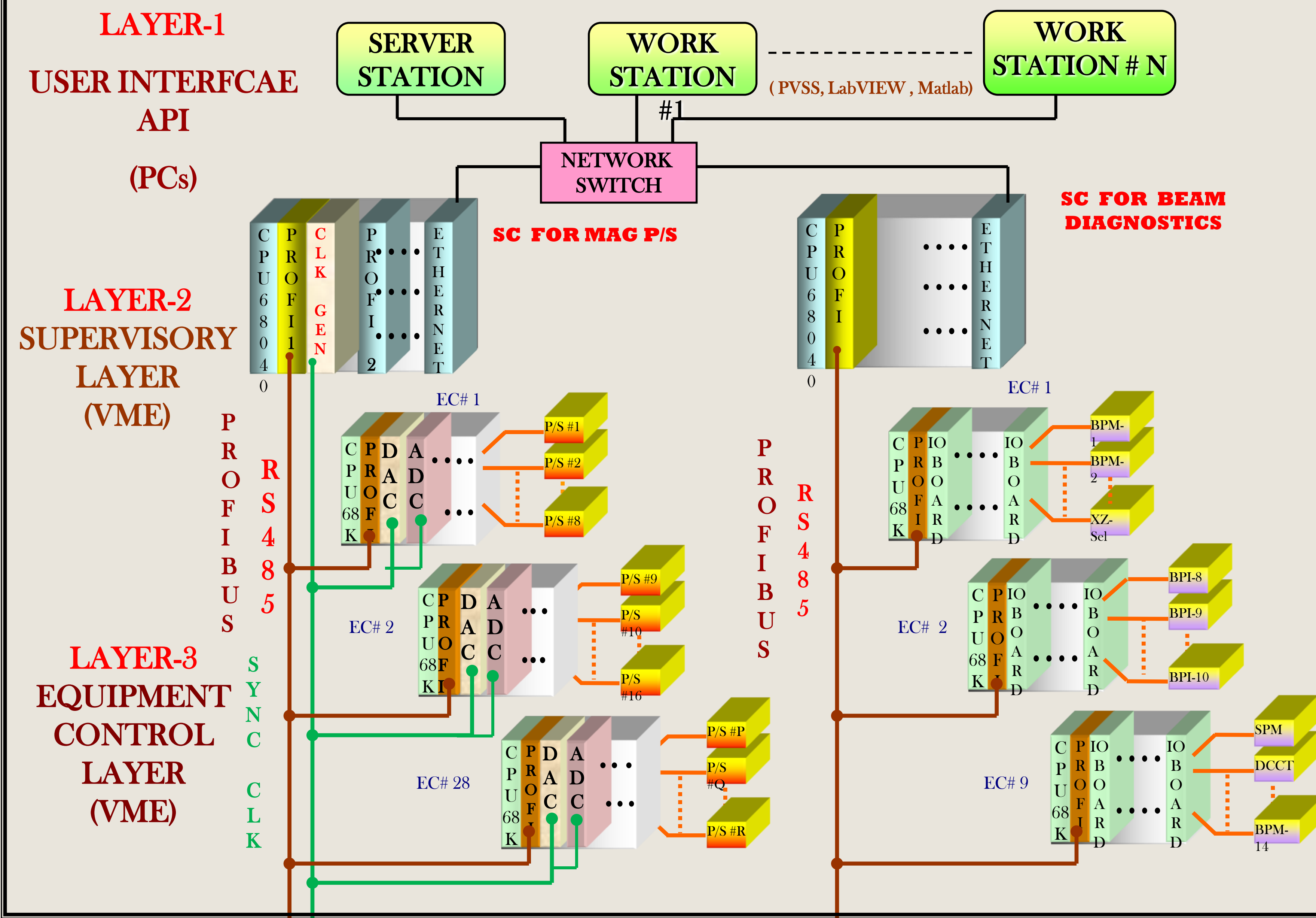
Indus-2 Control System ↔ Machine Sub-systems

- Magnet Power Supply Systems
- RF Systems
- Beam Diagnostics Systems
- Vacuum Systems
- Timing Systems
- Radiation Monitoring Systems
- Beam Line Front End Systems
- Interlocks
- Aux Systems – LCW, Pneumatic, AHU, Electrical SCADA, Access Control, etc.

Indus-2 Control System : Salient Features…

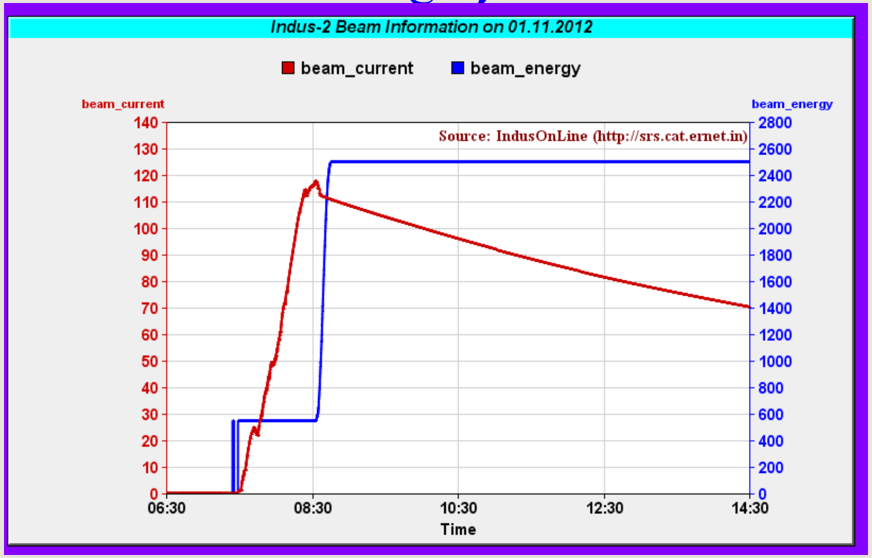
- Three Layer Distributed Architecture
- L1-PC Based User Interface clients and application servers, file, DB, Web servers, Gateway…
- L2-VME based Supervisory Controllers
- L3- VME based Eqpt. Controllers
- VME Boards and Equipment and Supervisory Controllers were developed In-house.
- 100 Mbps Switched Ethernet for L1-L2 & PROFIBus for L2-L3 Communications for individual sub-system control segments

Control System Architecture



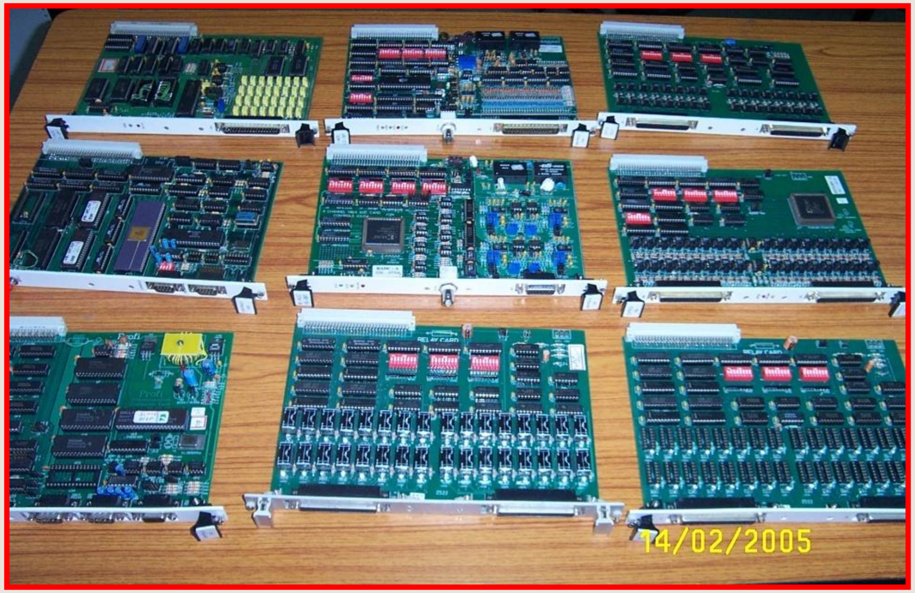
Indus Control Systems – Salient Features

- ~10,000 I/O signals
- Commercial SCADA (PVSS II) For Overall Process Supervision and Control
- RDBMS for Parameter database
- (MS SQL)
- Web Server for providing Machine Information over campus network
- Machine Safety Interlock System
- Alarm Handling System



Indus Control Systems – Nitty Gritty

- ✓ **Galvanic Isolation** has been provided on Profibus at all the stations.
- ✓ **Parity check** on byte level for Profibus telegrams (packets). Every byte of the profi telegram has even parity included.
- ✓ **Frame checksum** at packet level has been provided. Each profi telegram consists of a checksum byte that helps in checking the data integrity.
- ✓ **Multiple attempts**: Provision for up to 3 attempts has been included at L-2 for each command that is sent to L-3 in case of no- reply /frame-error.



Equipement Control & Supervisory Layers

- ✓ EC Layer – M 68 K with OS9
- ✓ SC Layer – M68040 with OS9
- ✓ Profibus- Master- Slave, 750 K Baud, Indigenously developed Profi Controller
- ✓ More than 20 types of VME Boards developed and deployed for Indus-2
- ✓ CPU, ADC, DAC, Opto-in, Relay, Ramp controller, Clock generator, Timing delay generator, Coincidence generator, C-V converters etc.

Communications

- ✓ The L1-L2 communication uses TCP/IP datagram sockets.
- ✓ TCP/IP protocol uses its own error detection mechanisms.
- ✓ L1-L2 communication sockets form one-to-one dedicated connections, thus avoiding problems of multicast or broadcast.
- ✓ Every command is followed by a response that reflects the result of the service.

GUI Layer Facilities

- Group setting to increment decrement a set of power supplies in proportionate mode.
- File based setting of a group of power supplies.
- Support for standby power supply.
- Trend display.
- Configurable selection of status signals for every power supply with configurable display text and active state.
- Programmable Calibration facility.
- Temperature monitoring of the DAC environment.
- Monitoring of errors of the Layer-3 station including its communication status, bus error status, CPU in proper program loop status.
- A debug panel is also provided to monitor reference-out, DAC input code.

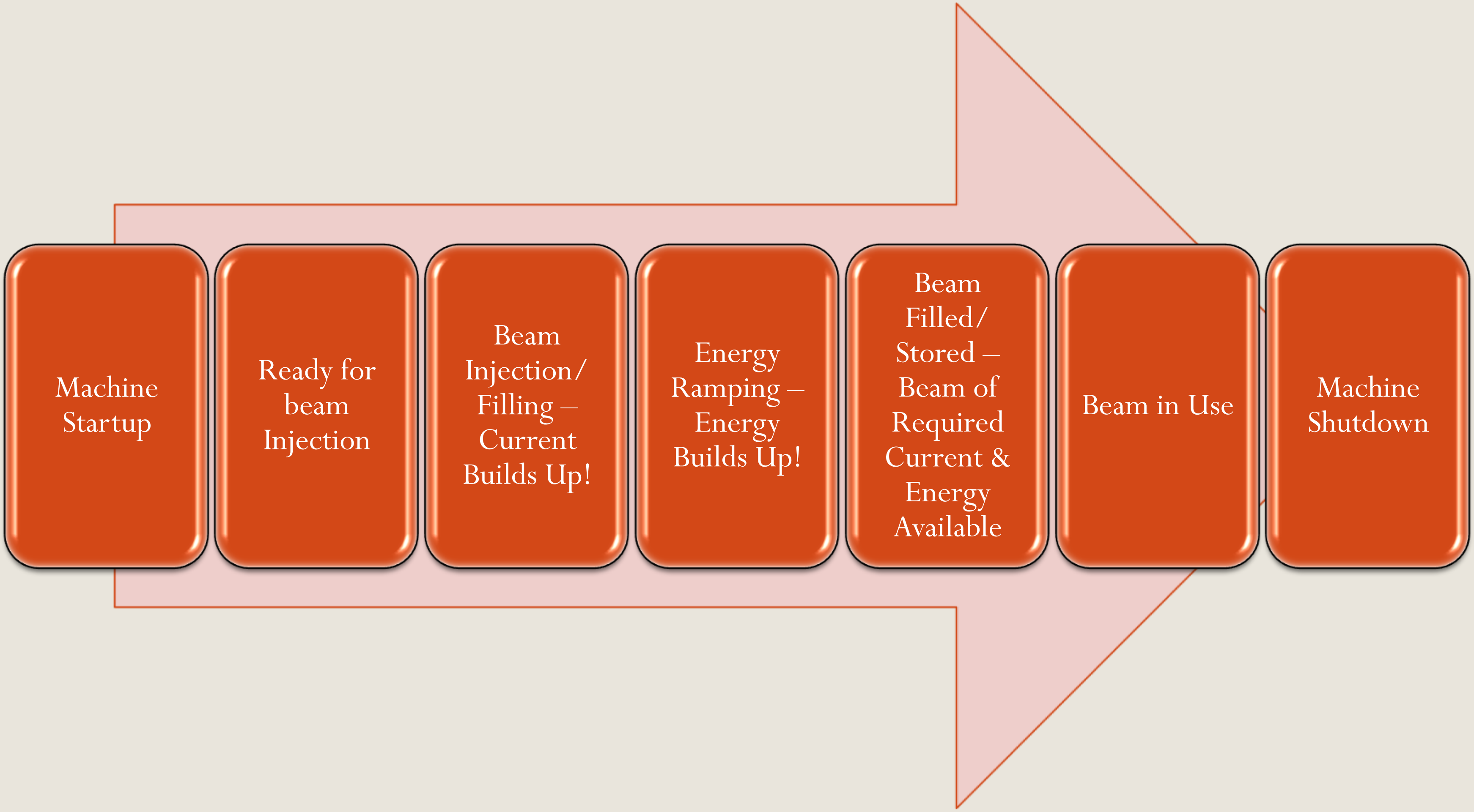
How Does The Control System Steer Indus-2 to Deliver

- User Authentication, Machine startup, pre condition checks
- Loading of required system parameter files
- Generate stable and precise reference signals for various devices
- Sub-system tuning & optimisations
- Preparation of Ramp Files for XX power supplies (1 DP, 28 QPs, 2 SPs, 40 HSC, 48 VSC, RF Cavities)
- Selection of Filling Patterns – Single bunch, Equal-spaced, Multi bunch
- Filling: Injecting e- bunches from injector and building up (accumulating) current
- Ramping

How Does The Control System Steer Indus-2 to Deliver

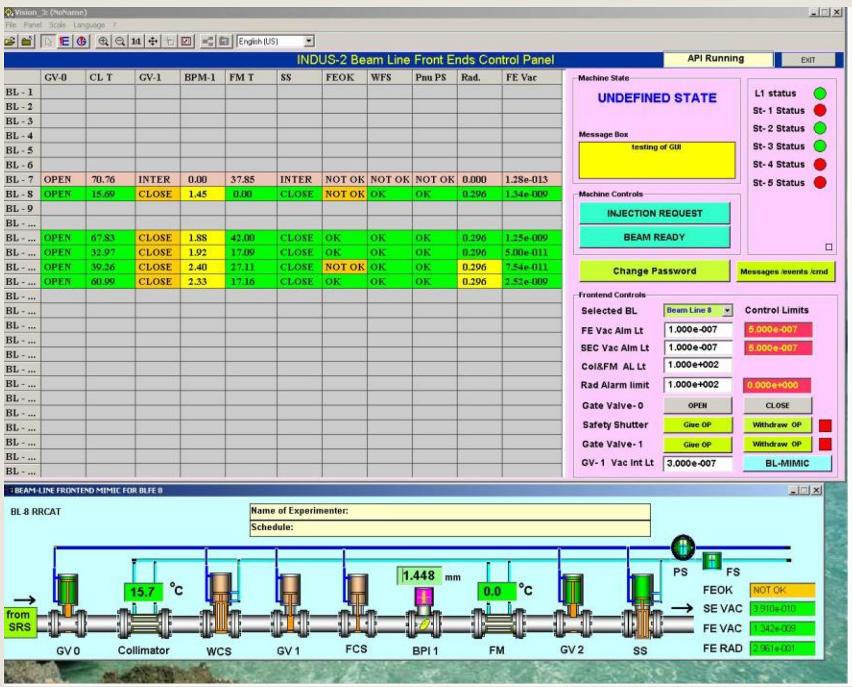
- Applying bumps –orbit correction
- Tune feedback
- Beamline Front Ends – Coordination & Control :Permitting & regulating users on the beamlines
- Machine safety, radiation surveillance, general services
- Whole system is on Check - Alarms and Interlocks
- Data logging, machine history
- Machine Diagnostics
- Safe, orderly shutdown

Machine States



Control & Integration - Beam Line Front Ends

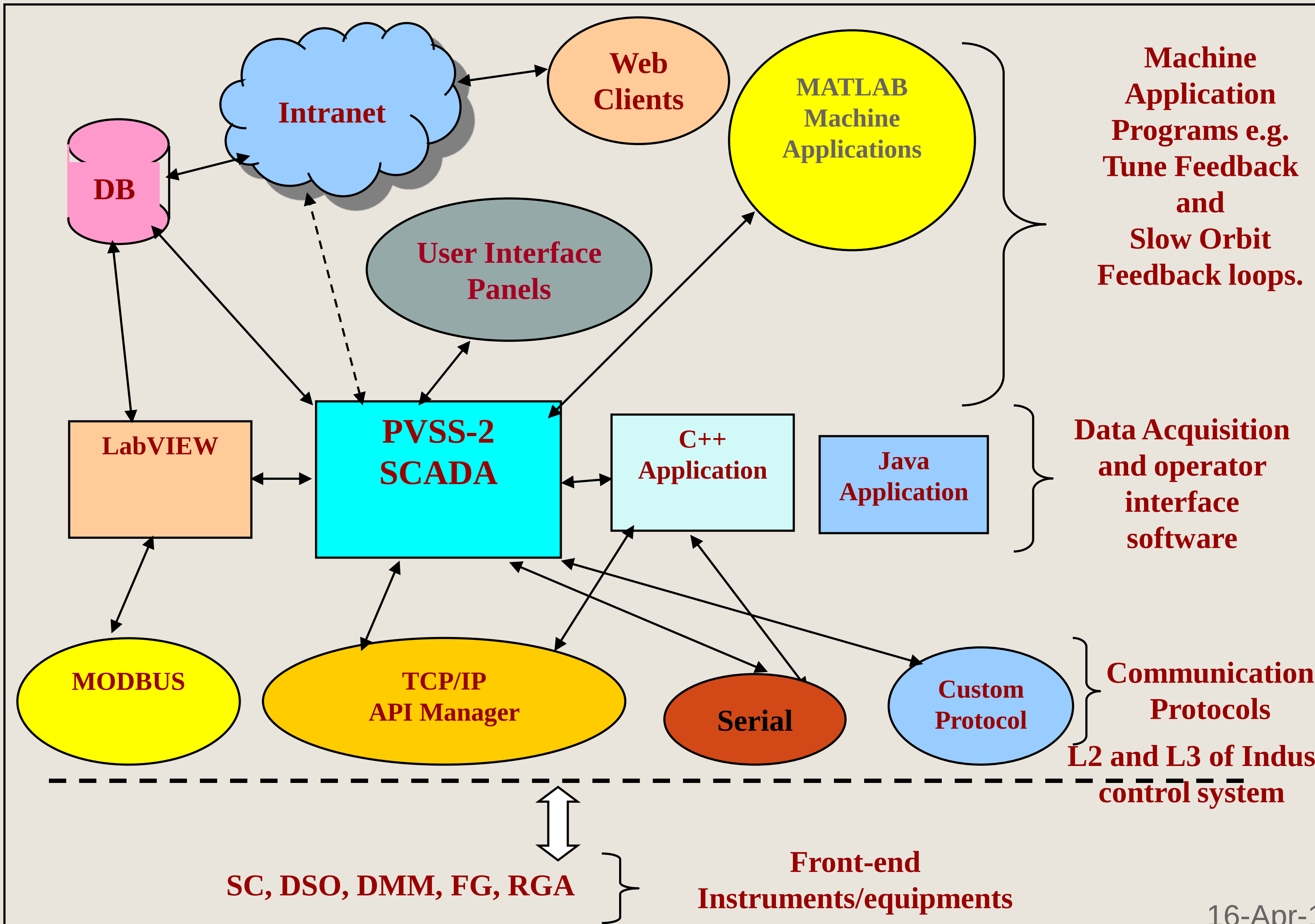
A beam line front end (BLFE) is typically the part of beam line which is inside the in-accessible, shielded ring area and connects the actual beam line to the ring with needed regulating and controlling mechanisms for synchrotron beam and vacuum.
Gate valves, named GV0s and located at the periphery of Indus-2 ring separate the machine vacuum envelope from those of the beam lines. These are installed at the beginning of beam line front ends (BLFE).



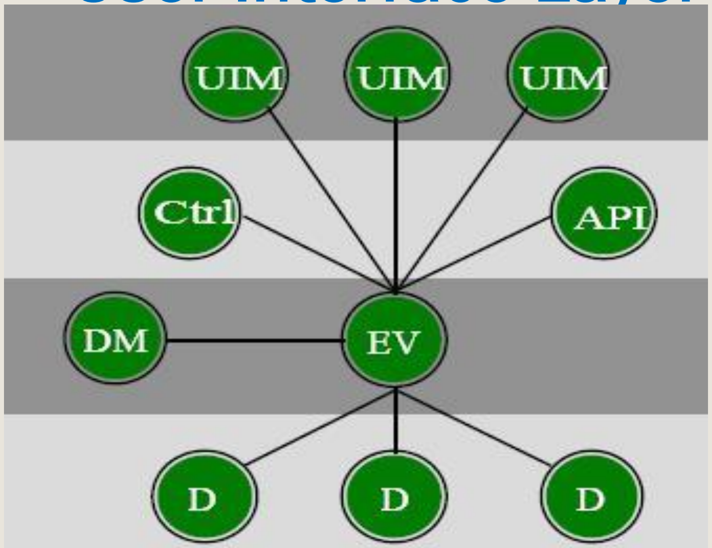
- Front end nos. 7, 8, 9, 11, 12, 14, 16, 21, 23
- Pneumatic gate valves
- Strategic for machine vacuum protection
- Sensitive to heat flux due to synchrotron radiation
- Valve control, status monitoring, interlocks, alarms and data logging
- Access Control - Any action taken on GV0s is authenticated and logged
- Critical actions are authenticated and arbitrated by control room through handshaking

Beam Line front ends are added gradually, in course of time. So, control and integration should allow adding new FEs without affecting normal machine operation

Software Architecture for Indus-2 Control System

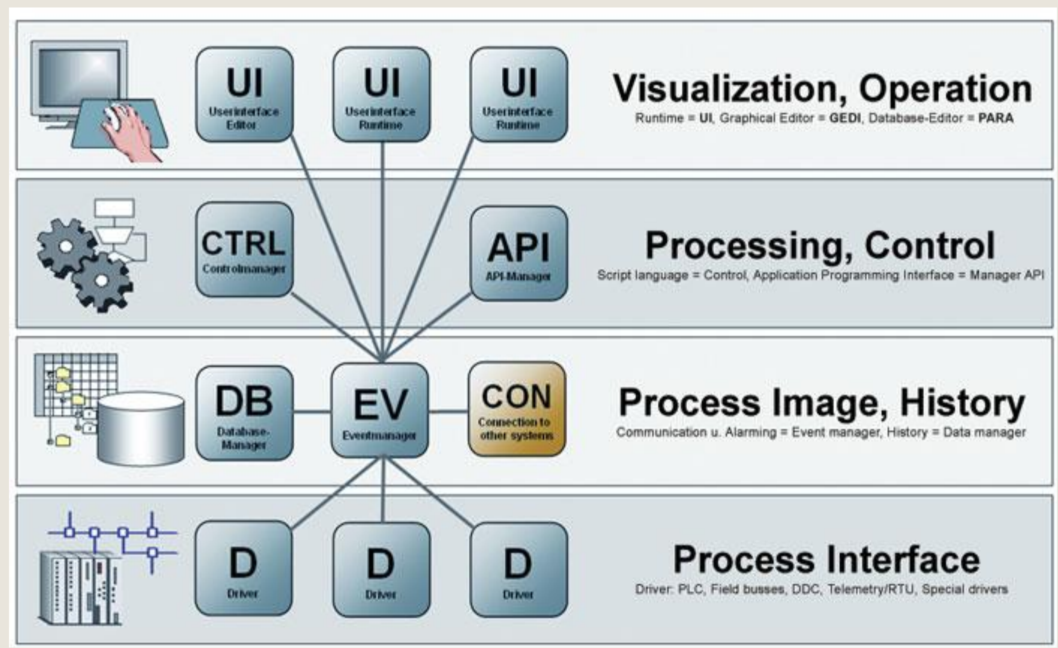


User Interface Layer Software – PVSS SCADA



✓PVSS is used to connect to hardware (or software) devices, acquire the data they produce and use it for their supervision, i.e. to monitor their behaviour and to initialize, configure and operate them.

✓PVSS Managers
✓Data Point Concept
✓GUI & Scripting
✓Alarm concept
✓Archiving, Trending & other features
✓Distributed and Redundant systems
✓Managing PVSS projects
✓Interface to External Applications



The system is awaiting machine time for integration trials

Features implemented for Indus Controls using PVSS SCADA

- Configuration file based data point definitions.
- Automatic connection to Layer-2 VME Systems.
- Error log with millisecond time stamp and auto rename when file size limit exceeds.
- On change value update to PVSS DB.
- Custom Driver developed for communication to Supervisory Layer VME System.
- Conversion from engineering to Physical format.
- Group setting to increment decrement a set of power supplies in proportionate mode.
- File based setting of a group of devices.
- Saving the current setting to a file which can be loaded later on.
- Configuration of devices: min, max, Full scale value, default slope, names, etc.
- Trend display.

Various Useful PVSS Logs at Various Levels

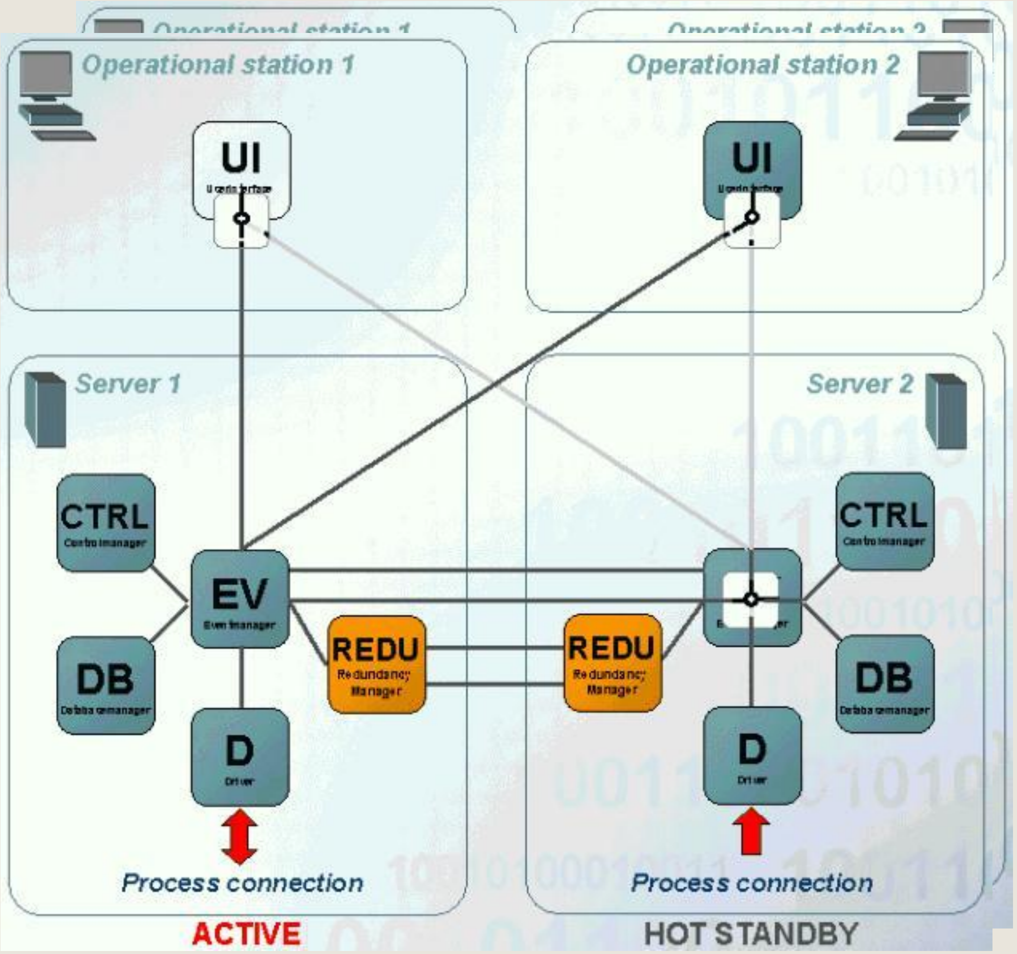
- **Pmon Log**: Process monitor log
- **PVSS_II Log**
  - error informations are saved by the managers as variables of the data type errClass (respectively dyn_ErrClass) and normally output on the PVSS II log file.
  - An CTRL error message contains, amongst other information, the file and line number in which the error occurred.
- **Log of each running manager**
- **API manager generated log**
  - Log file is automatically named and a new file is created when size exceeds a limit.
  - Logs all the commands received and sent to L2
  - All communication history and in error case received string from L2.
- **UIM log at remote machine**
  - Log of various user actions
  - Panel script messages.

Facilities of PVSS Found Useful

Information regarding--

- Sequence of operation performed by user.
- Values sent and received by the system.
- Start and stop timings of various managers in the PVSS system.
- Internal states of SCADA system and reason of any error condition.
- On-line Engineering access and changes.
- Security features:
    - Access control, no activity logout etc.

Redundancy Concept in PVSS



PVSS SCADA – Performance & Figures

System Name	~ No of Signals
MPS	4200
Vacuum	1600
RF	400
Timing	100
BDS	500
RSSS	300
BLFE	300
Interlock	700
LCW	1200
Orbit Correction	200
Total	~10,000

SCADA Configuration

Physical I/Os ~ 10,000

data points ~ 20,000

Alarms ~ 4,000

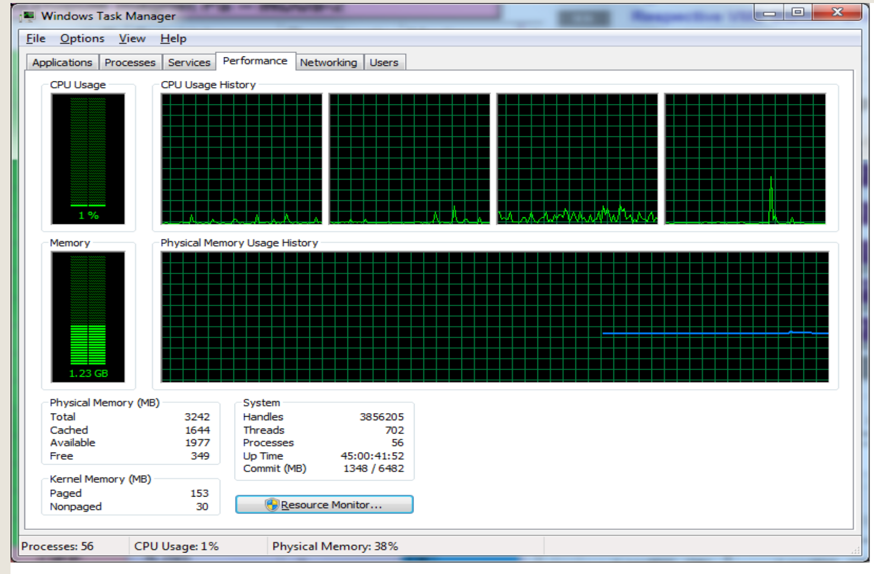
Events ~ 900 per sec

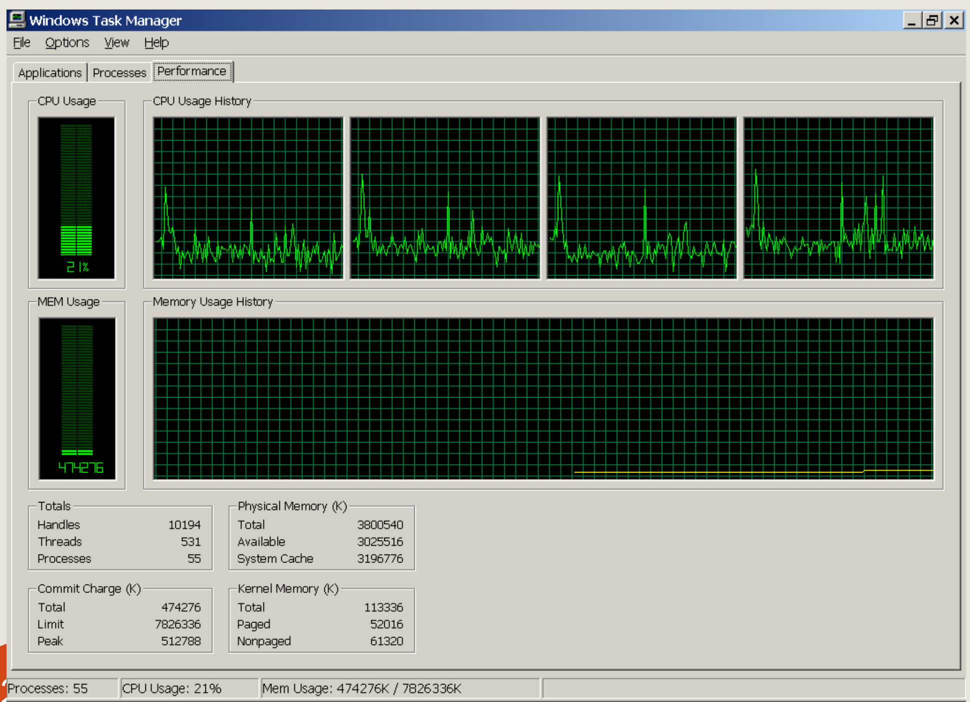
Dynamic Performance Parameters

Events per sec.~ 900
Data log rate ~ 10, 000 parameters /sec.
Data is logged to external RDBMS (MS-SQL server)

Server machine configuration:

- Intel Pentium-4 Xeon 2.8 Ghz, 512 KB cache, 4 GB RAM DDR-2100 machine., Dual Processor.
- RAID 5 + HSPS SCSI HDDs
- CPU utilisation: ~20 %
- Memory Utilisation ~25-40 %
- Windows 2000 Advanced server.





Client machine configuration:

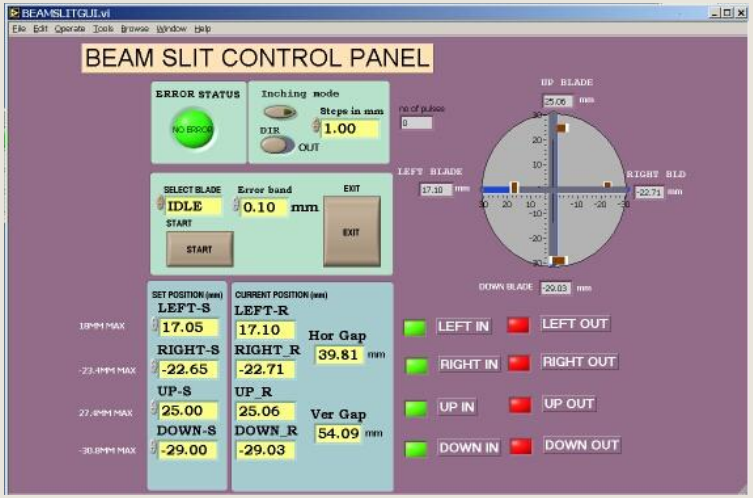
- Intel Core2 duo Processor.
- CPU utilisation: ~ 2-10 %
- Memory Utilisation ~ 10-20 %
- Windows XP and Windows-7

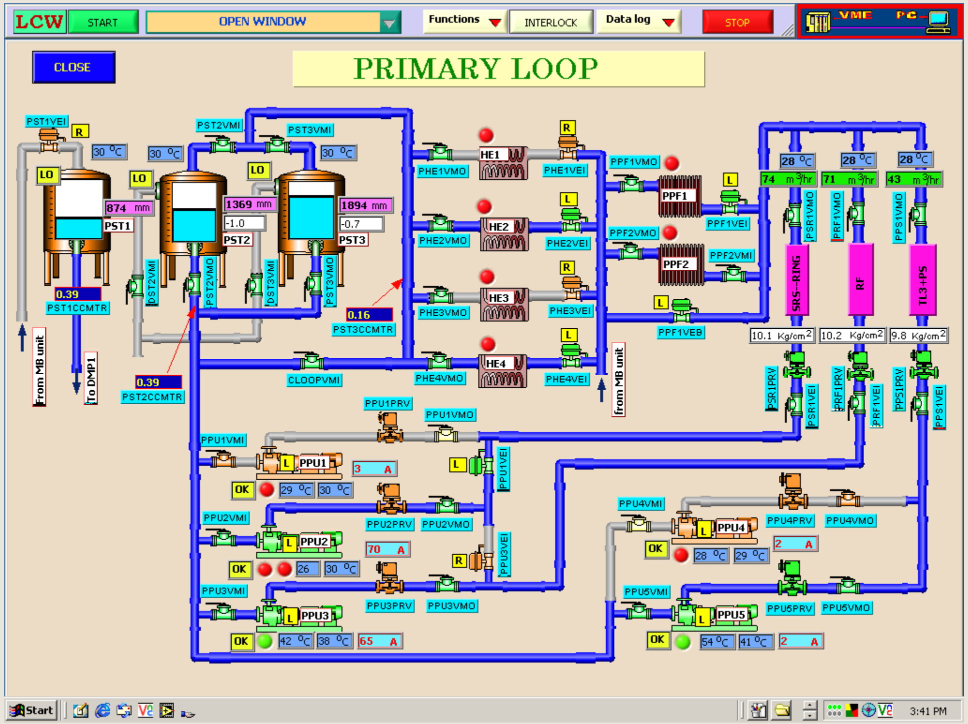
14 User interface Clients

More than nearly 100 GUI Panels

LabVIEW Developments

- ✓ Indus-1 & 2 LCW plant and field SCADA system (PANI) - ~700 parameters in each
- ✓ Indus-2 RGA Interface Software
- ✓ Indus-2 Ring VAC Chamber Temperature Monitoring System
- ✓ Global Slow Orbit Control Software
- ✓ Most of Indus-1 GUIs are in LabVIEW

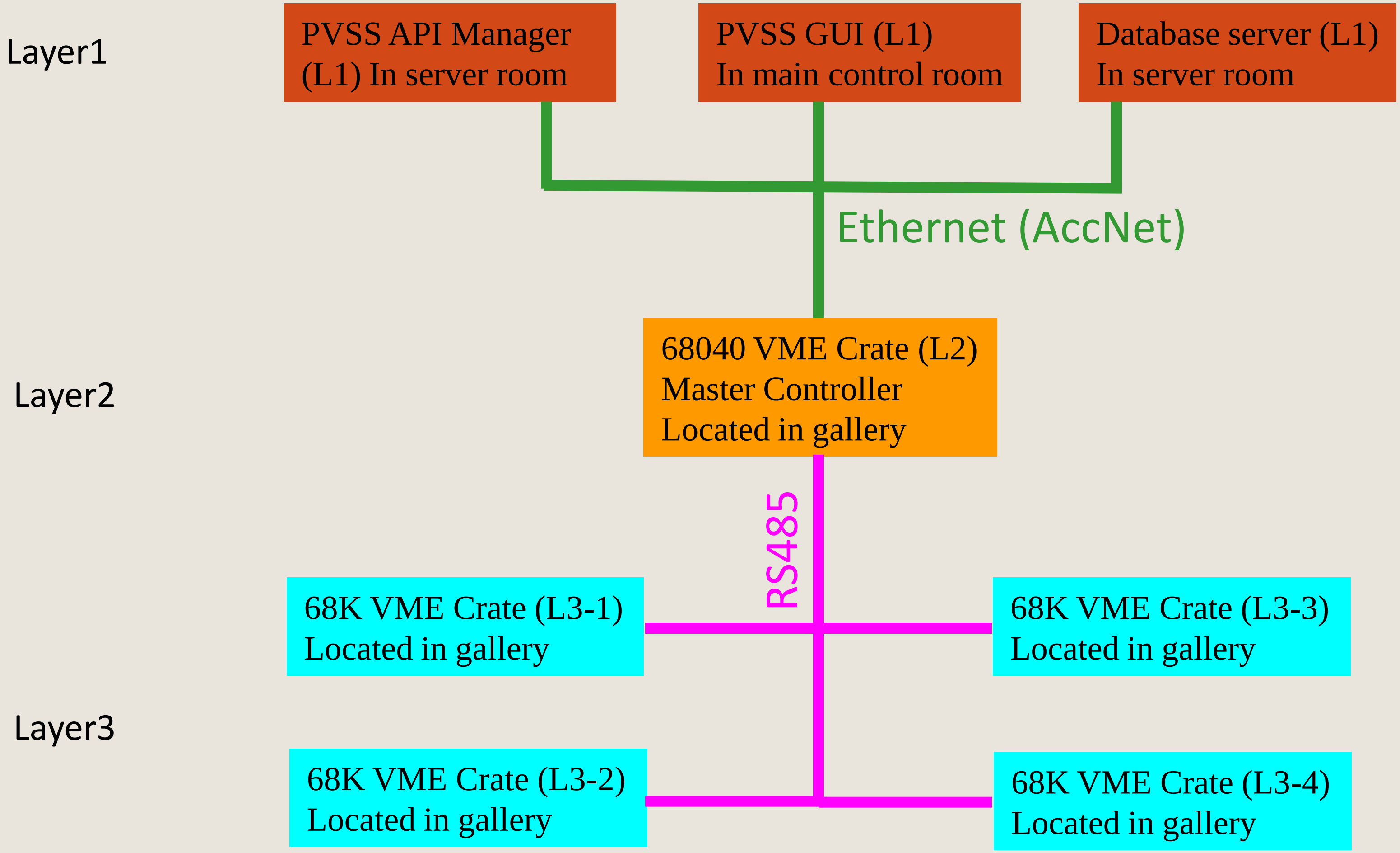




Machine Safety Interlock System (MSIS) – Input Parameters

1. Over temperature status of all Dipole, Quadruple, Sextuple magnets, Photon chambers, vacuum chambers and DCCT.
2. Open status of all Sector valves.
3. Indus-2 Search status.
4. Open and valve ready status of all GV0s
3. Open status of Water Cooled Sutter (WCS)
4. Close status of GV1
5. OK status of Beam Line Front End (FE OK)
6. Close status of Safety Sutter (SS Close)
7. Status of BL under maintenance (FE Maint)
8. Request of Beam Dump from any BL

Architecture of Indus-2 safety Interlock system



Timing System

- Sequencing and Synchronization of various timing events with RF frequency and 1 Hz master trigger from Microtron.
- Starting of Booster Ramp cycle.
- Injection of Beam in Booster
- Extraction of Beam From Booster at different energy.
- Injection of Beam in Indus-1 ring
- Injection of Beam in Indus-2 Ring
- Control of Pulsed Power supplies (Kicker and Septum)
- Providing trigger signals for synchronization of different beam diagnostic devices and other instruments used

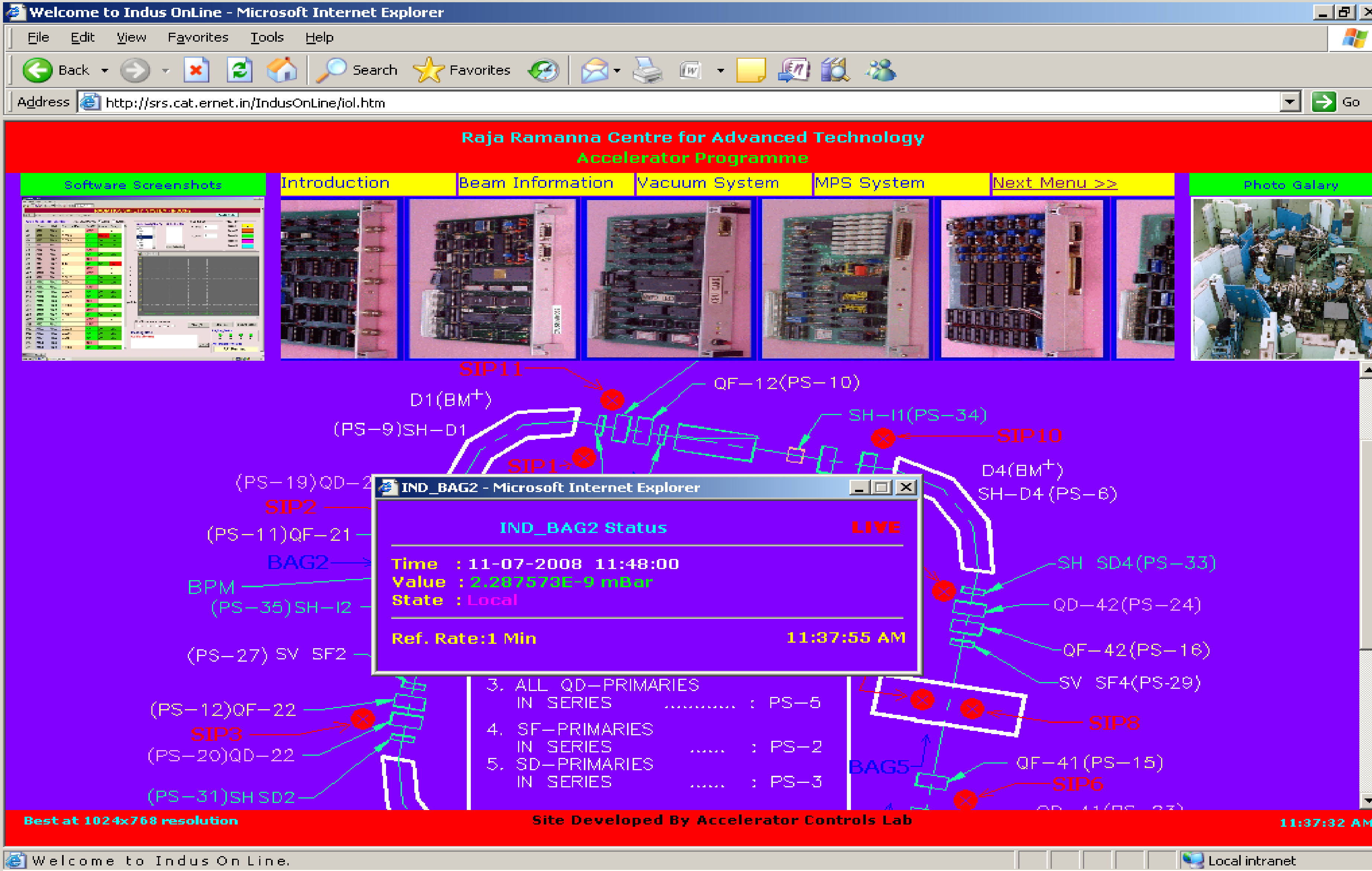
Main requirements of I-2 Timing

- Four injection kickers are to be triggered with 3 nano seconds delay between them.
- Extraction kicker of Booster and Injection kickers of I-2 should be synchronized to coincidence frequency and I-2 RF(505.8 MHz)
- Jitter in the trigger signals should be less than 5 nano seconds
- Bucket selection should be done with pico seconds accuracy and jitter should be less than 100 pico seconds.
- The fast pulsed supplies generate high switching noise, so adequate noise filtering and isolation of all field signals is necessary.

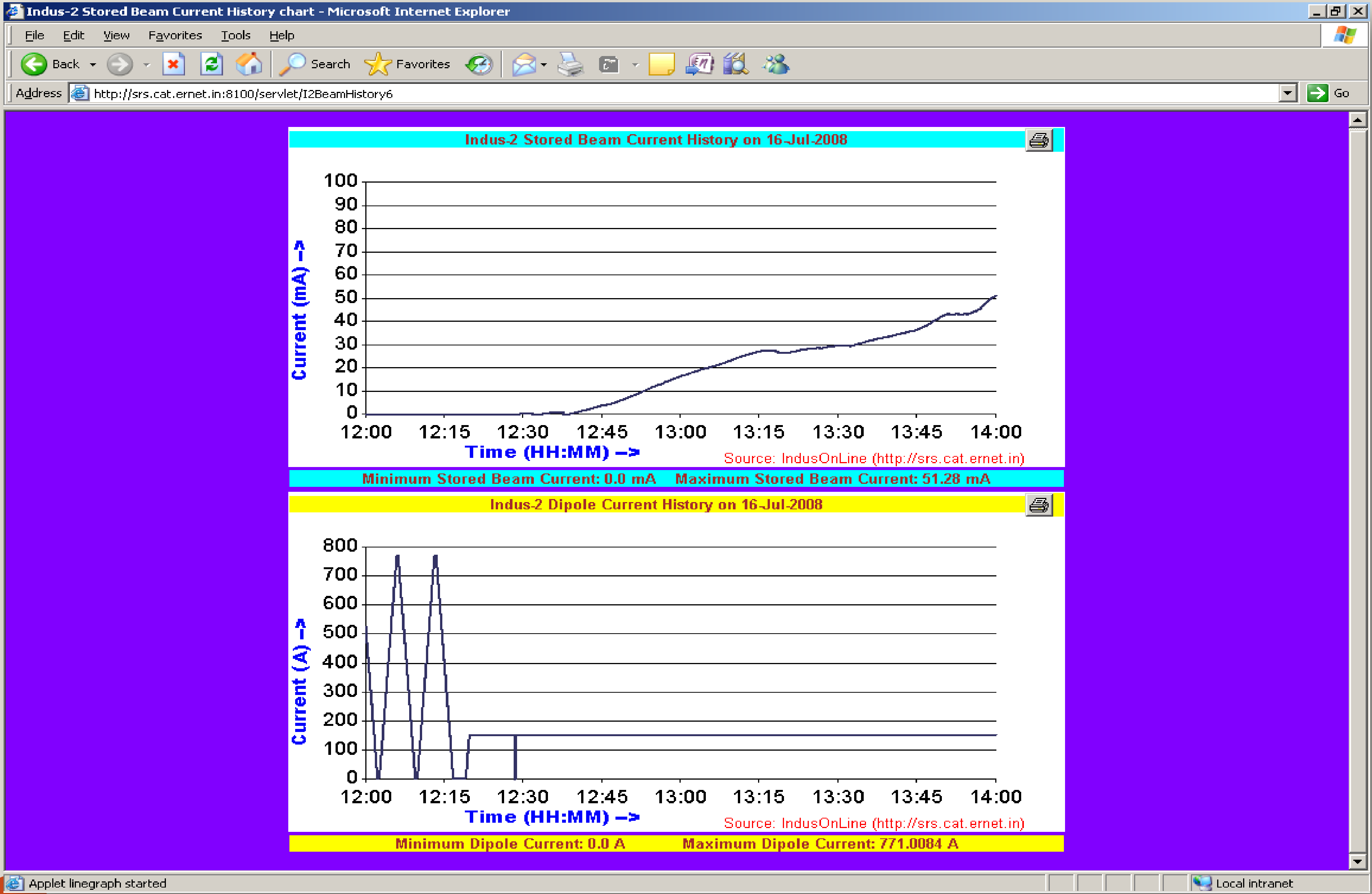
Web Applications

- **Indus OnLine - Live (Text/Synoptic), History (Tabular/ Graph)**
- **Machine Status Display System (Text, Graph)**
- **Fault Information System – Fault Tracking**
- **FLogBook – Online fault logging & email**
- **Elog: Electronic Logbook – comprehensive machine and shift logs**

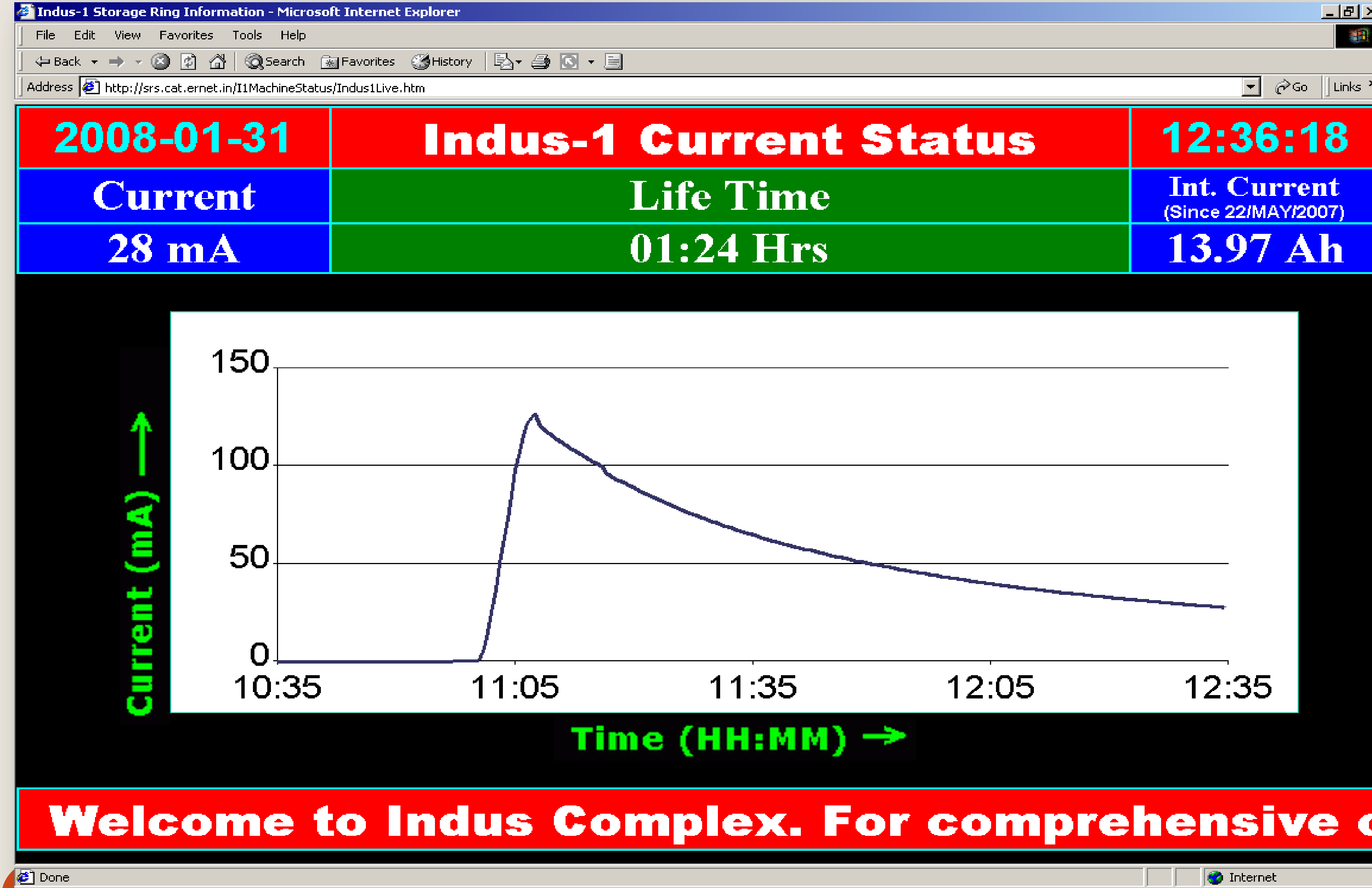
Screenshot: IndusOnLine (Synoptic Display)



Screenshot: IndusOnLine (Data Query Result)



Screenshot: Indus Machine Status Display



Screenshot: FIS (Fault Explorer Query Result)

Indus Fault Information System - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites

Address http://srs.cat.ernet.in/fis/newfis.htm Go

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Indus Fault Information System

Faults & Modifications: [Indus-1 TL-3 Indus-2] Shift Summary: [Logger Viewer] Options: [Back Hide/Show Images Logout]

Indus-1 Building | Indus Control Room | Microtron | Booster Synchrotron | Indus-1 Storage Ring | Indus-1 B

Indus-2 Historical Faults

Print

Fault Id	Fault Time	System Name	Fault In	Faulty System	Fault Description	Action Taken	Time Tal
29	01-08-2008 09:00 Hrs	Indus-2 Magnet Power Supplies Control System	PS-44 SS-SF	VME	STN # 26 of PS SS-SF & SS-SD was showing active on STN. STATUS DIAGONASTIC PANEL.but on MPS panel PS status was showing gray colour XXXXXX.observed on L3 INFO PANEL CPU satus was red colour.	Observed on VME there was no abnormal condition was seen.and CPU was not seen in halt condition.halt LED was not faulty.	0 hrs 2 mins
33	01-08-2008 13:30 Hrs	Indus-2 Timing & PPS Control System	Indus-2 Injection Kicker	VME	Thin septum trigger pulse was shifted to 20 micro sec respect to kicker trigger pulse showing on control room CRO.	Inform to Mr. parate & madam sampa.both were attended the problem.pre trigger and main trigger delay of B ext. kicker was found 70 micro sec(normal 90 micro sec).putting power off/on timing system .problem was solved	1 hrs mins
40	07-08-2008	Indus-2 Timing & PPS Control	VME	VME	Booster ext kicker pulse delayed 20-30micro sec.with respect to ext	L3 station put OFF/ON and reset	0 hrs 2

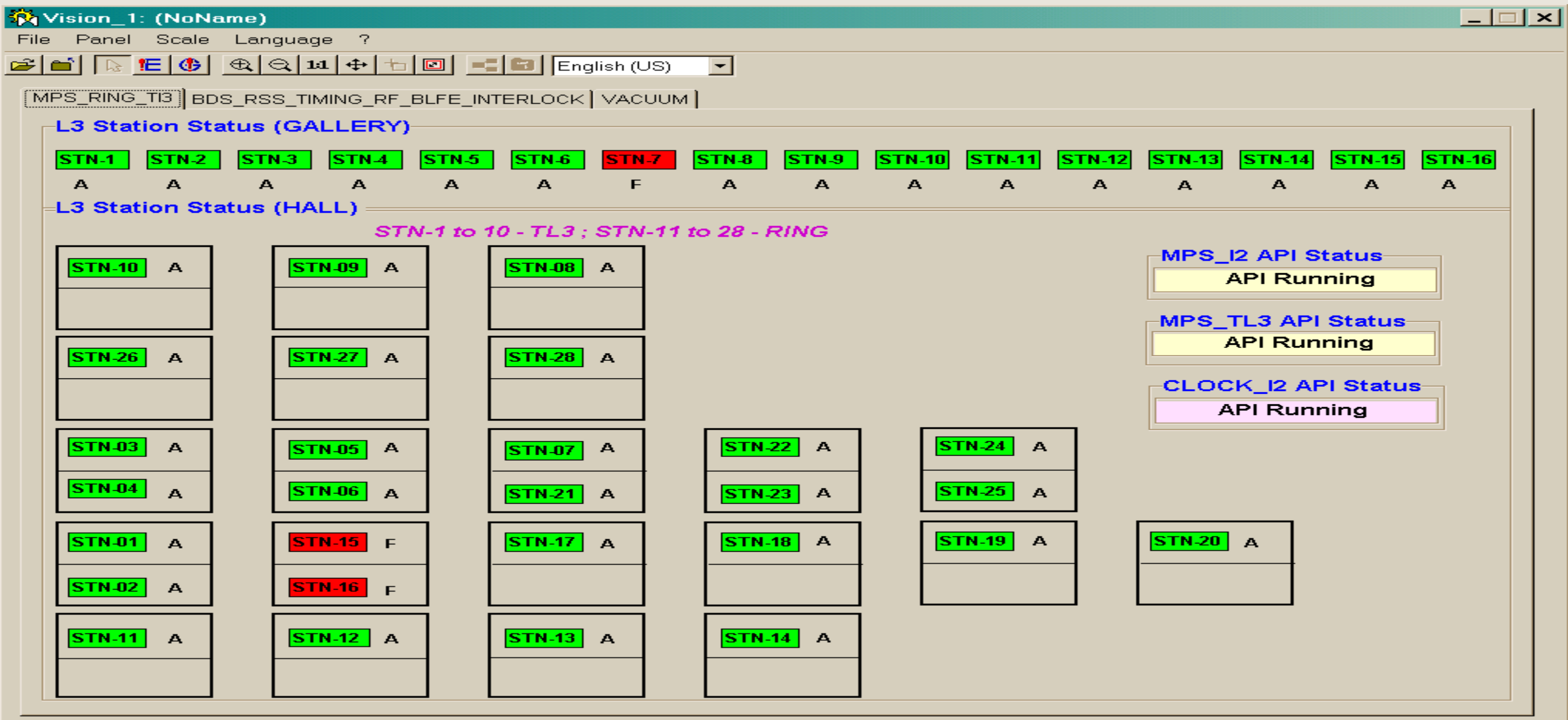
Best at 1024x768 resolution | Developed By Accelerator Controls Lab | 3:58:25 PM

dus Fault Information System (FIS) | Local intranet

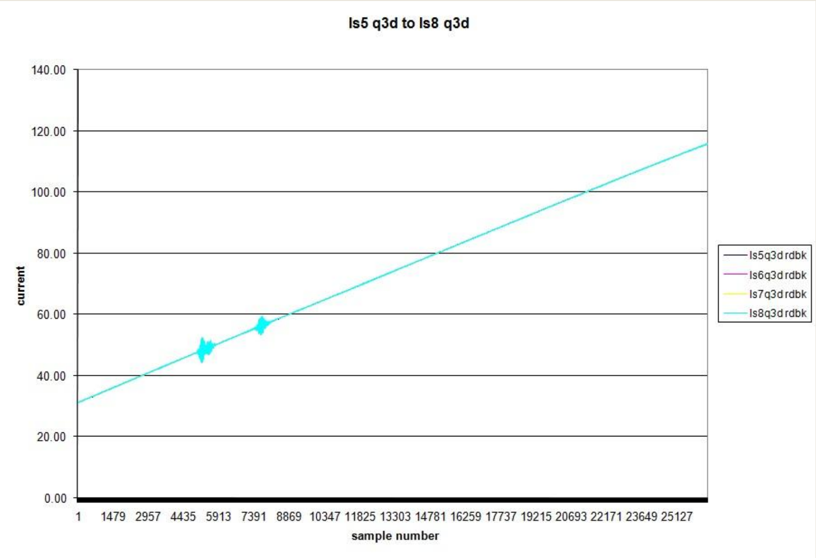
System Diagnostics

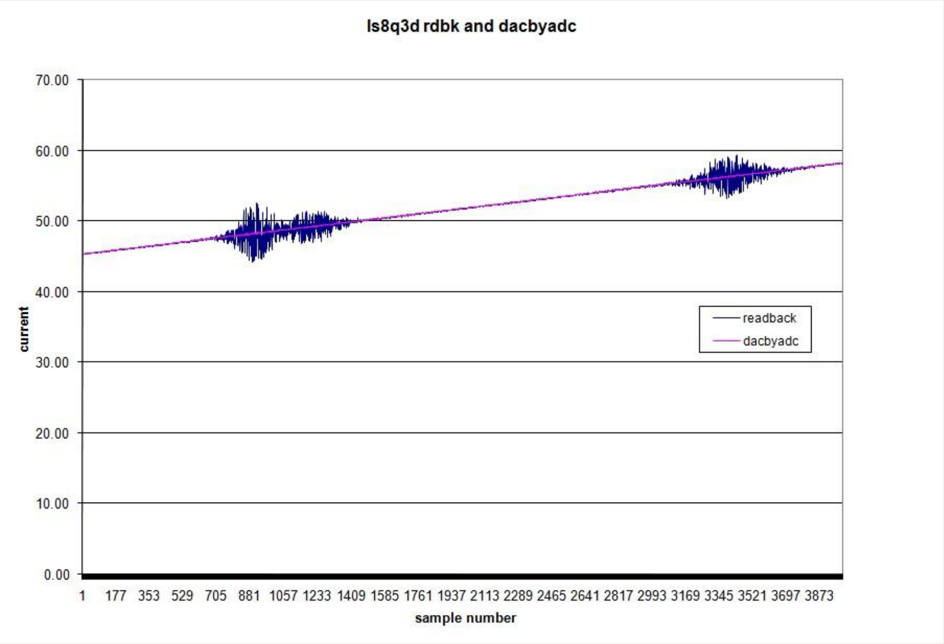
- ✓L-3 station status at L-2 and L-1 (A Active/ S-**S**tart / F-**F**ail / U- **U**pdate Fail)
- ✓Bus-error status of L-3 cards at L-1
- ✓L-3 CPU running state at L-2 and L-3.
- ✓L1-L2 communication status

- ✓API running status at GUI
- ✓Error and information logs at various levels in PVSS SCADA.
- ✓Alarms on internal system states.
- ✓DAC readback by ADC for end-to end confirmation (in MPS system)
- ✓Board temperature info for L-3 I/O boards at L-1 (in MPS system)



Transient Data Capture System



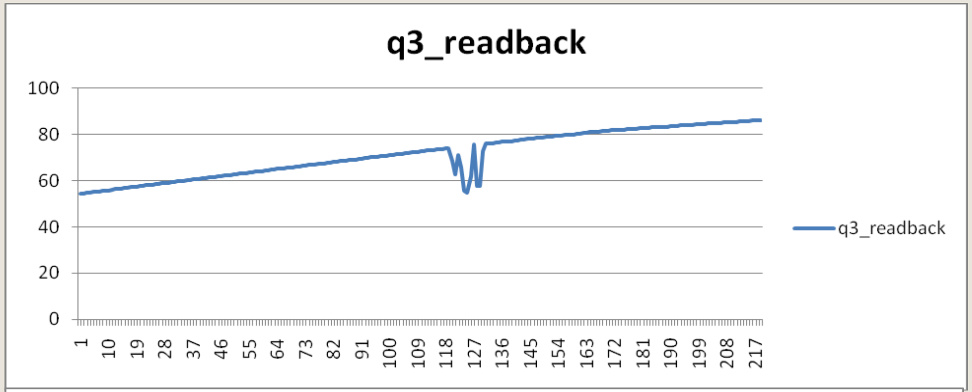


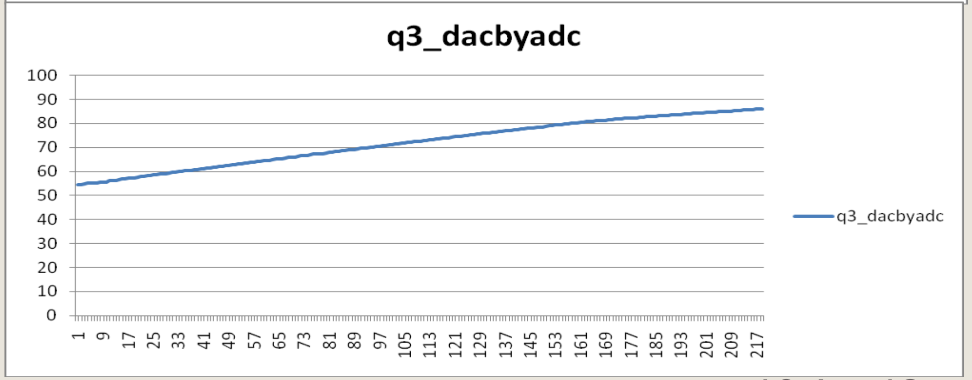
System Diagnostics Information

- L-3 station status at L-2 and L-1 (A-**A**ctive/ S-**S**tart / F-**F**ail / U-**U**pdate Fail)
- Bus-error status of L-3 cards at L-1
- Board temperature info for L-3 I/O boards at L-1 (in MPS system)
- L-3 CPU running state at L-2 and L-3.
- L1-L2 communication status
- API running status at GUI
- DAC readback by ADC for end-to end confirmation (in MPS system)
- Error and information logs at various levels in PVSS SCADA.
- Alarms on internal system states.

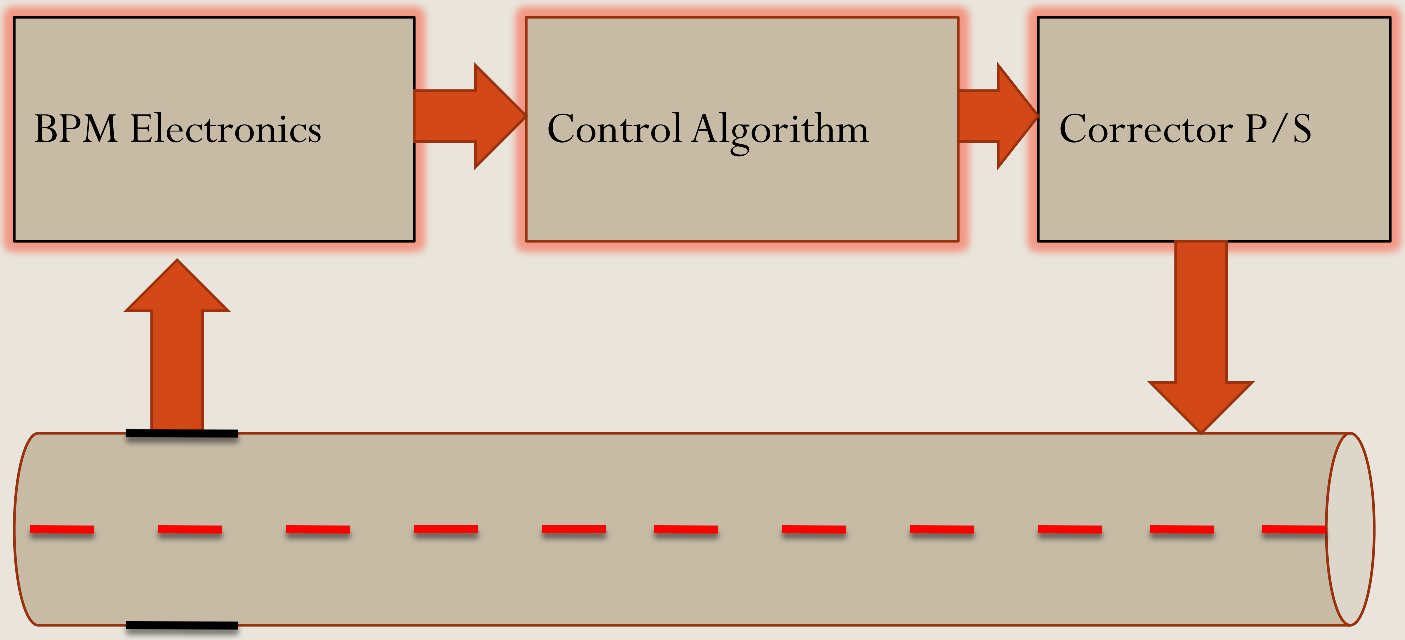
Data Diagnostics

- Web data browsing
- Uses normal history data logging of machine parameters
- Detects beam current fall by selectable value
- On those time stamps, finds culprit power supplies
- Whose Set – R/B values might have changed by more than a certain value
- Graphical and textual display



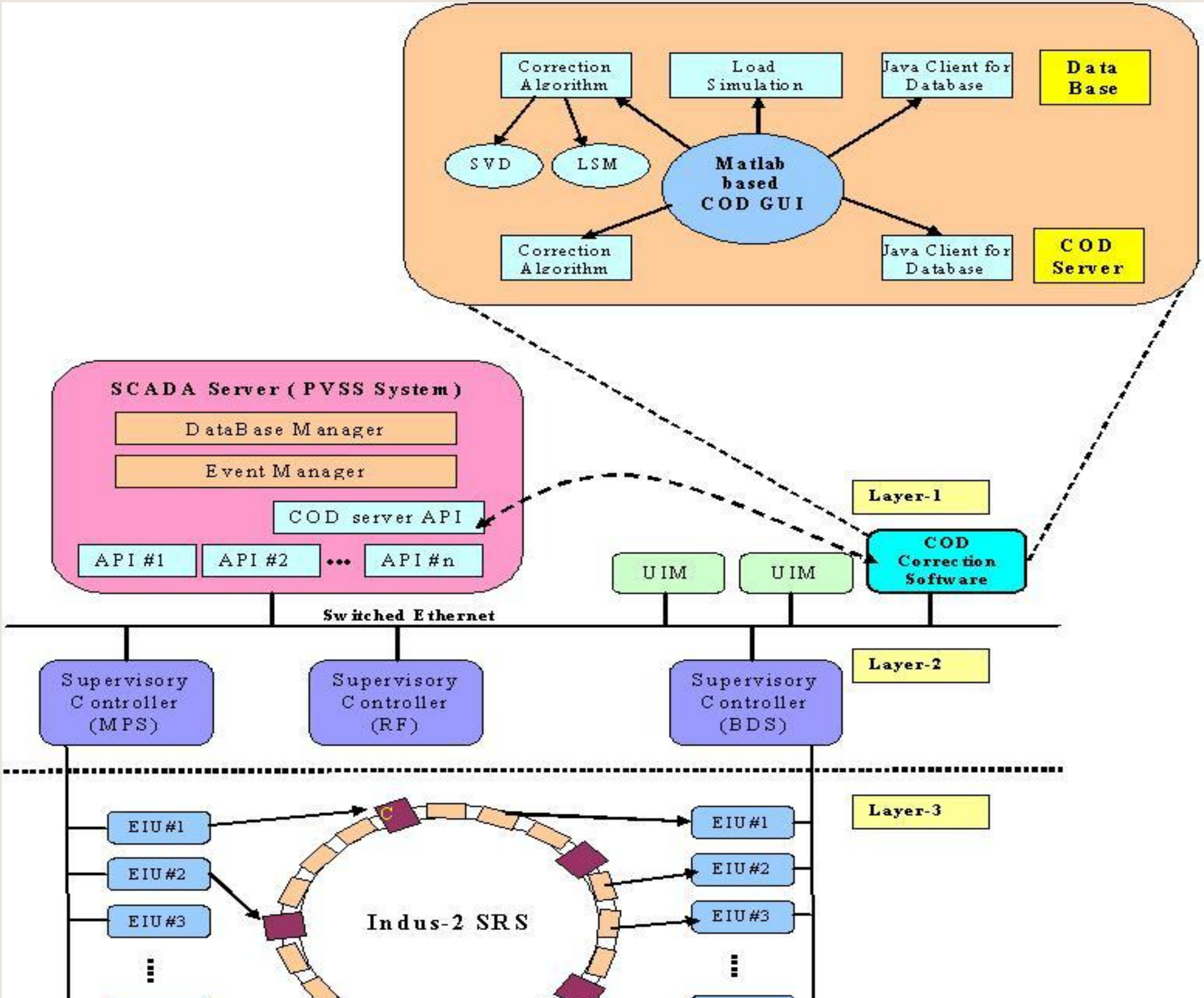


Orbit Feedback Control Systems



- Slow orbit control *correction rate < 10 corrections /second*
- Fast orbit control *correction rate > 1000 corrections /second*

‘Global Slow’ Orbit Feedback Control Scheme



Indus-2 Fast Orbit Correction

❖ **Aim**: To control the beam position and angle at all the bending magnet photon source points all over the ring.

❖ **Sources of beam disturbances**: **Vibrations** – machines, traffic, ground ,cooling water flow, AHU, operational component movements- IDs, Valves, **Temperature variations-** cooling water, components, ambient, **Ground settlements** etc.

❖ **Strength** and **frequency** of correction depends on the observation of beam position variation in the ring at different photon source points.

❖ **Identification of vibration sources** is an important task to adapt proper control strategy.

❖ **Closed Orbit Distortion (COD) correction** presently less than 1mm rms in H&V planes to make the beam available to all the users in Indus-2. Global slow Orbit Feed-back would maintain this average beam orbit. Global slow orbit correction to be achieved in the closed loop mode.

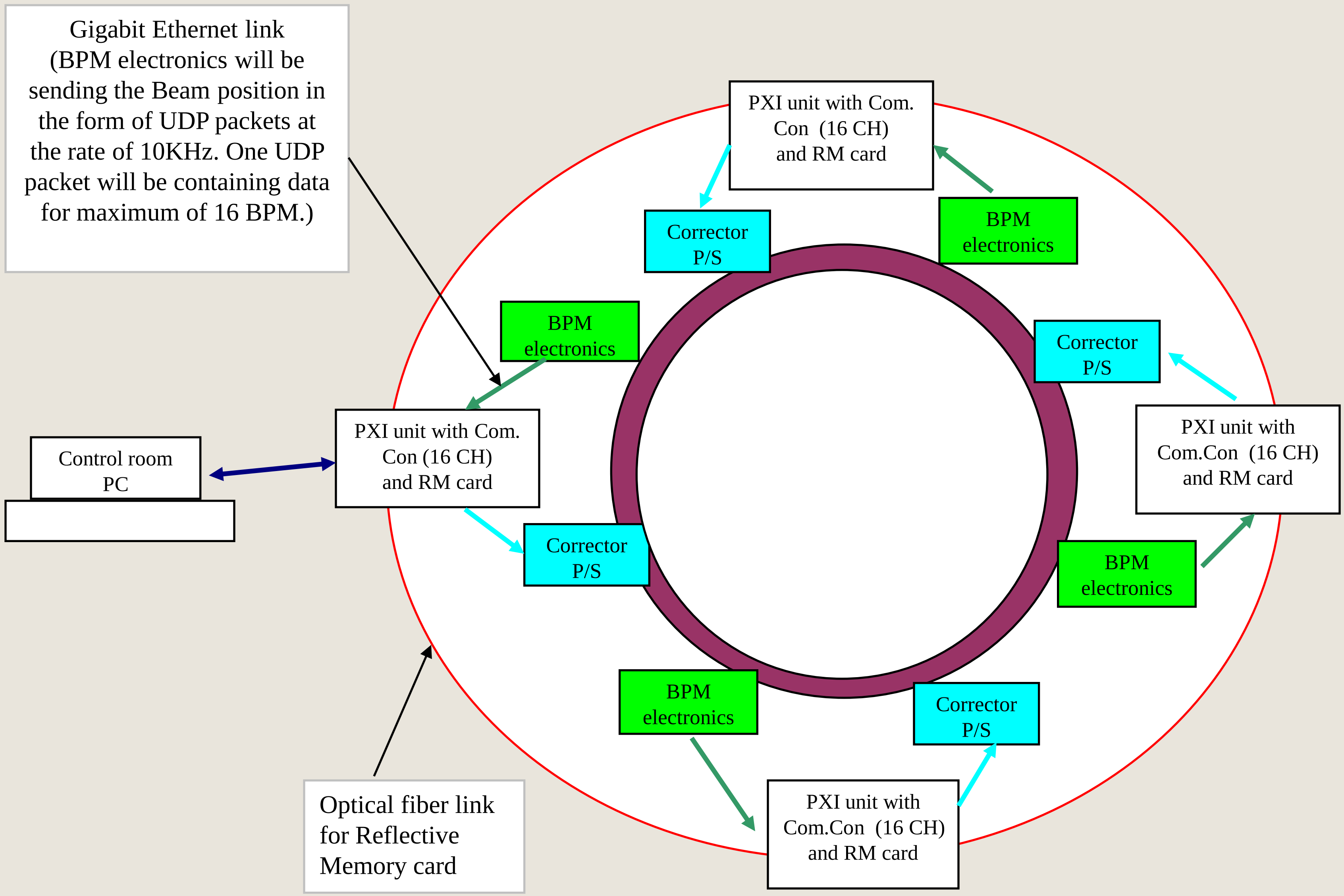
❖ **Faster beam variations** (positions and angle) around this average beam orbit would be affecting some beam lines (more to ID beam lines)

❖ **Beam stability** around this average beam orbit is important and will be maintained by **Fast Orbit Correction.**

❖ **Beam Stability Required**: to control the beam movement **< 1/10th of the beam sizes**.

❖ **Target Beam Stability**: at present lattice with 1% coupling: ~10μm or better (position), ~ 3μrad or better (angle) and correction bandwidth of ~100 Hz.

FOFB Scheme For INDUS-2



Status

- All sub-systems completely interfaced
- Bunch filling modes qualified
- Power supply reference stabilities – qualified
- All MPS Cycling in place
- Energy Ramping has been proven
- Alarm handling system - proven
- Major noise issues overcome, some still pending.
- Complete machine data logged
- Data integrity - qualified
- All machine parameter data available over campus intranet
- Machine safety interlocks in place
- Slow orbit feedback ready
- System keeps evolving, rapidly!

THANK YOU