Adapting COTS Technology for Big Physics Applications

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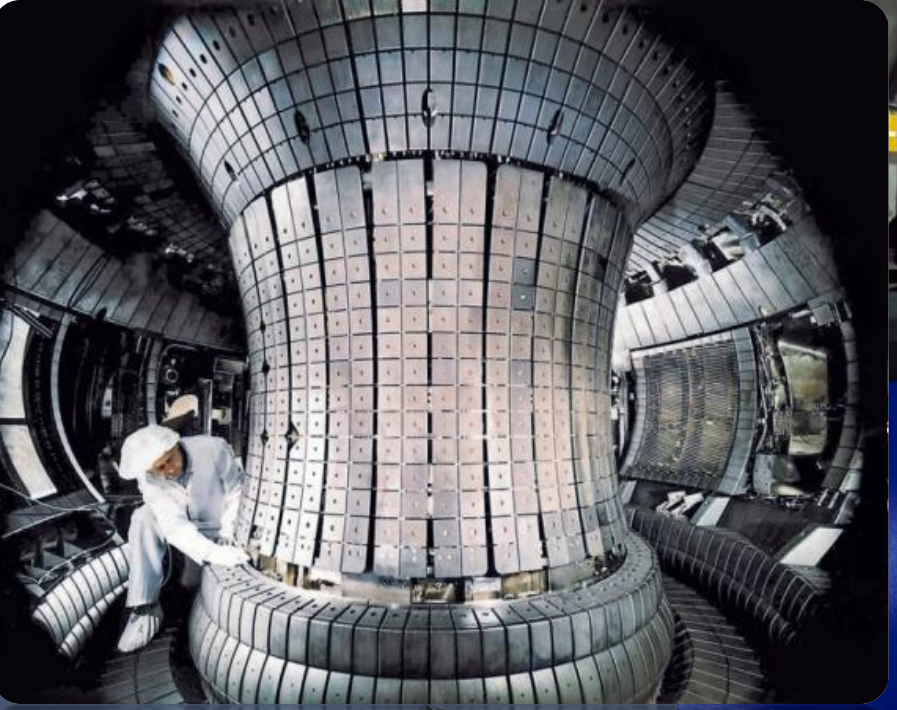
Segment Manager, Europe

NATIONAL INSTRUMENTS

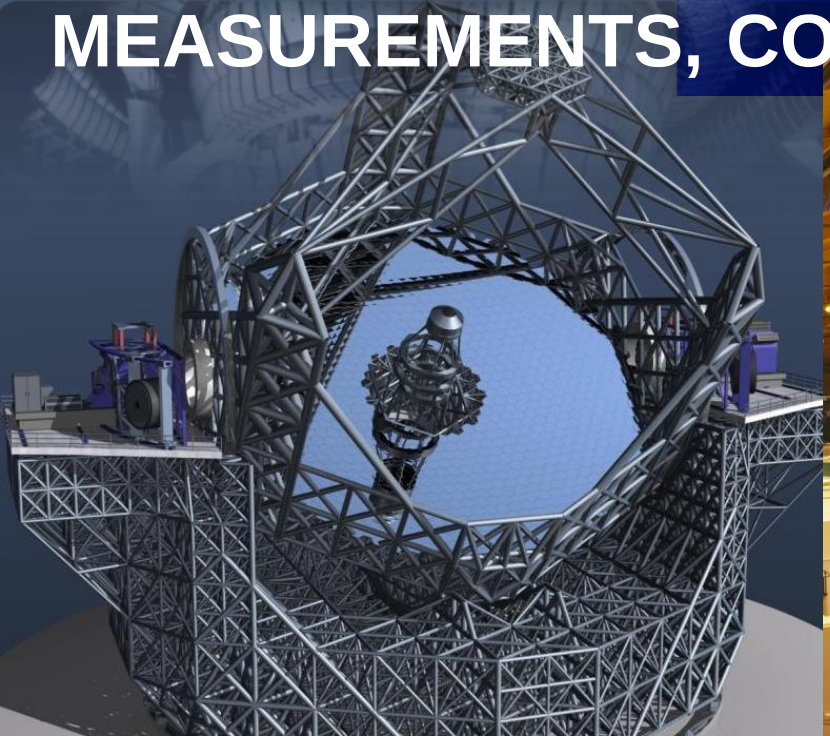
Agenda –

- Involvement in Big Physics
- Special Big Physics Application Requirements
  - Linux
  - EPICS
  - Radiation and Magnetic Field Testing
  - RASM
  - Lifecycle Management
  - Global Services

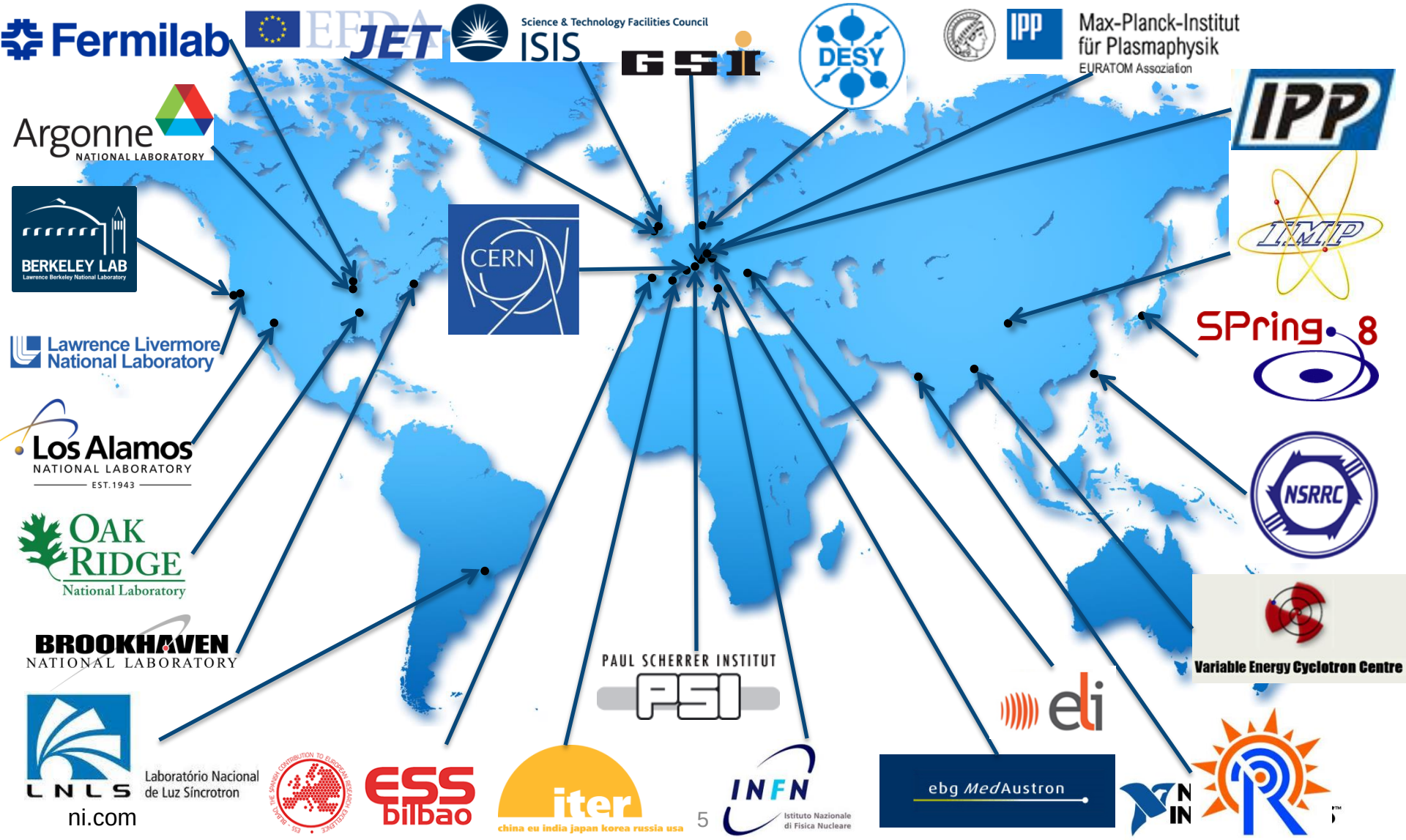
Diversity of Applications – Multitude of Benefits



MEASUREMENTS, CONTROL AND DIAGNOSTICS



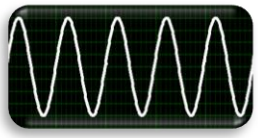
Worldwide Customers



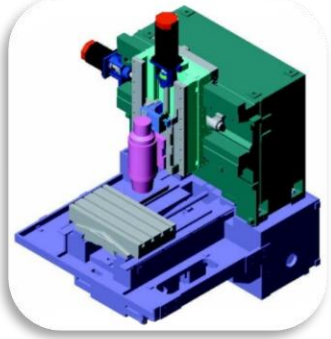
BP Application Requirements
Measurement, Control and Diagnostics

HMI

Logging, Database

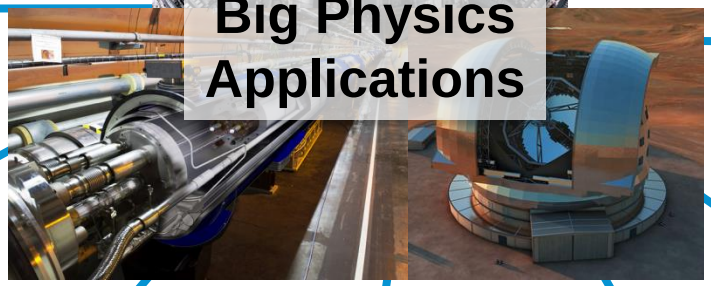


Sensors and Signal Conditioning

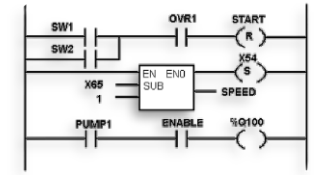


Mechanical Design

Networking



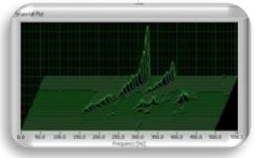
Big Physics Applications



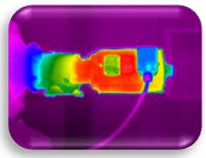
Discrete and Sequential Logic

Embedded System Design

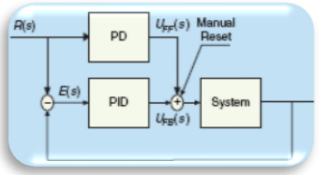
Motors and Actuators



Machine Condition Monitoring



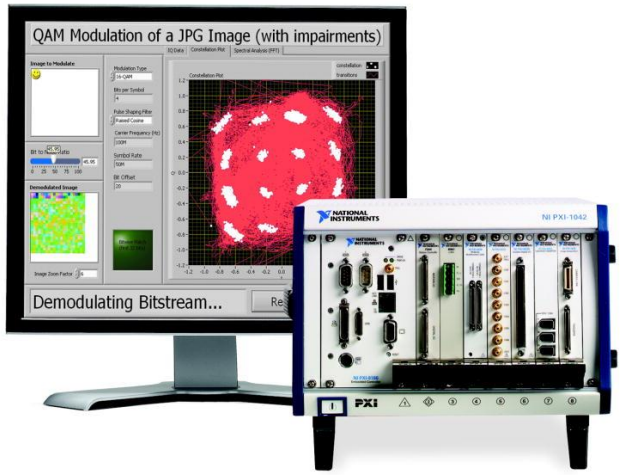
Machine Vision



Motion Control Design

NATIONAL INSTRUMENTS

Comprehensive Product Portfolio: High Performance



More than 1,500 PXI Products from More than 70 Vendors

DAQ and Control:

- Multifunction I/O
- FPGA/Reconfigurable I/O
- Digital I/O
- Analog Input/Output
- Vision and Motion
- Counter/Timers

Instruments:

- Oscilloscopes
- Digital Waveform Generator/Analyzers
- Digital Multimeters
- Signal Generators
- Switching
- RF Signal Generation and Analysis

Interfaces:

- GPIB, USB, LAN
- SCSI + Enet
- Boundary Scan/JTAG
- CAN + DeviceNet
- RS232/RS485
- VXI/VME

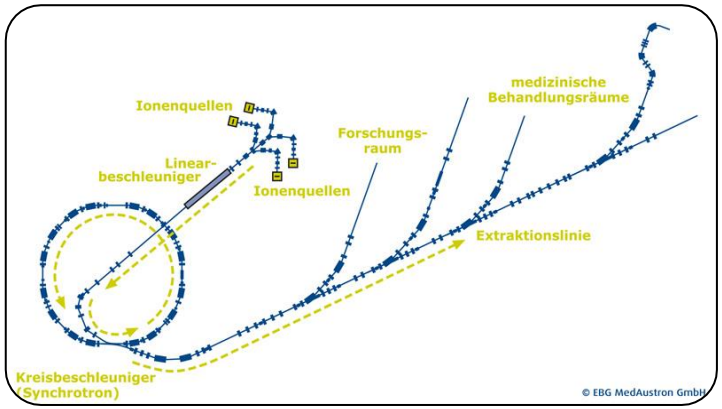
Comprehensive Product Portfolio: Low cost, robust and compact

- **Analog Input**
  - Up to 250 kS/s, simultaneous sampling
  - 4, 8, 16, and 32-ch options
  - Built-in signal condition for sensors
    - Strain gages, accelerometers, thermocouples, RTDs
  - Up to ± 60 V, ±20 mA
  - 12, 16 and 24-bit resolution
  - Available ch-to-ch isolation
- **Analog Output**
  - Up to100 kS/s simultaneous updating
  - Up to 16-ch per module
  - ±10 V, ±20 mA
  - Isolation

- **Digital I/O**
  - Up to 10 MHz timing
  - Counter/timer, PWM
  - 8 and 32-channel options
  - 5V/TTL, 12/24/48 V logic levels
- **Specialty**
  - 2-port CAN modules
  - Brushed DC servo motor drive
- **Third Party Modules**
  - LIN, Profibus, WLAN 802.11, MIL-1553, ARINC-429, GPS, and more

Beam Control System - MedAustron Ion Beam Therapy

- Custom Front End with COTS Real-Time Computing
  - 30k parameters through FPGA-based real-time computation
  - Fast, reliable power supply control for 300 magnets with high precision timing



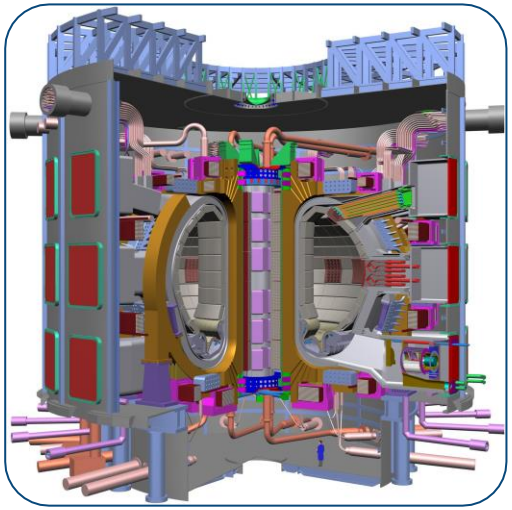
COSYLAB

Customized COTS to meet requirements and complete project on time

NATIONAL INSTRUMENTS

Fast Interlock, Control and Diagnostics - ITER

- ITER instrumentation and control requirements
  - 1 million I/O points
  - 20 GB/s archive rate
- COTS hardware with native Linux & EPIC drivers
  - Fast Control
  - Diagnostic
  - Fast Interlock for Machine Protection
  - Remote Handling
  - Quench Detection
- Special testing
  - Fast and Thermal neutrons
  - Gamma rays



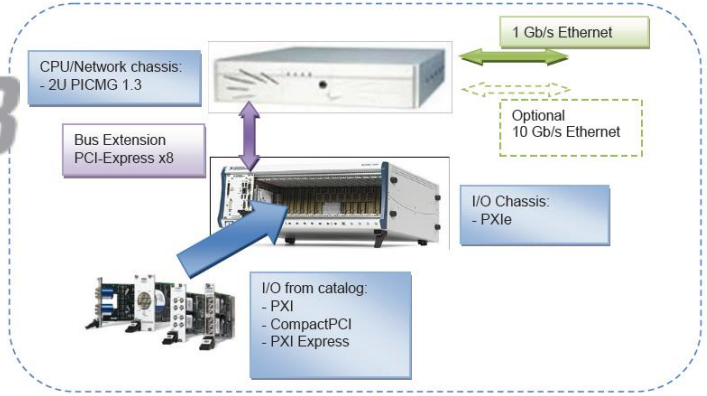
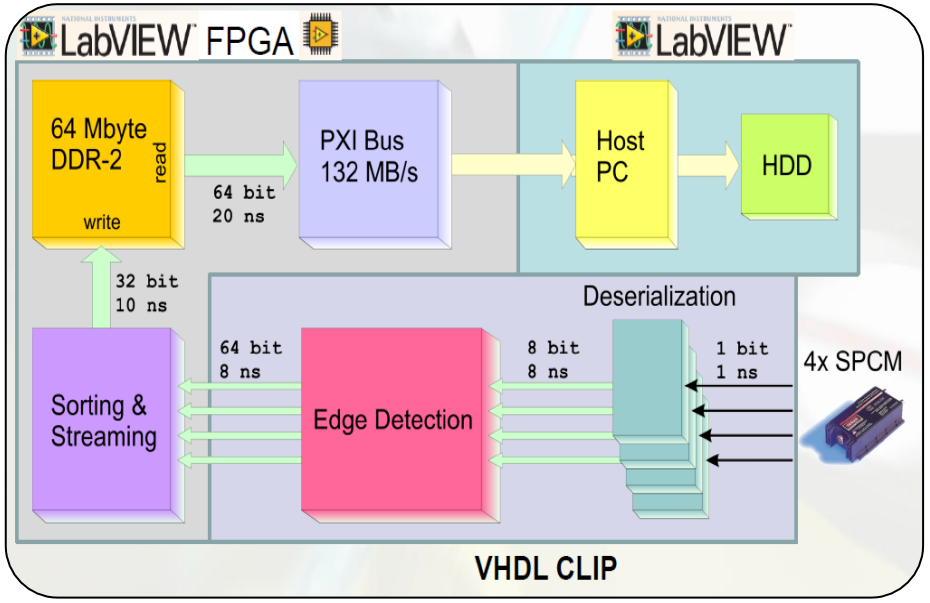


Figure 1 – A General Purpose Fast Controller

Developed custom drivers and performed special testing to meet needs

High Performance Computing with FPGA — TU Wien, Austria

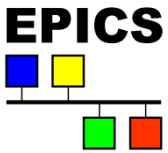
- High performance Quantum Optics Simulation using the block Fixed Point data type
- Investigated lower limit computation times of complex valued functions executed on an FPGA
- Algorithm verified with control of a laser cooled atom in a magneto-optical trap



BP Application Special Requirements

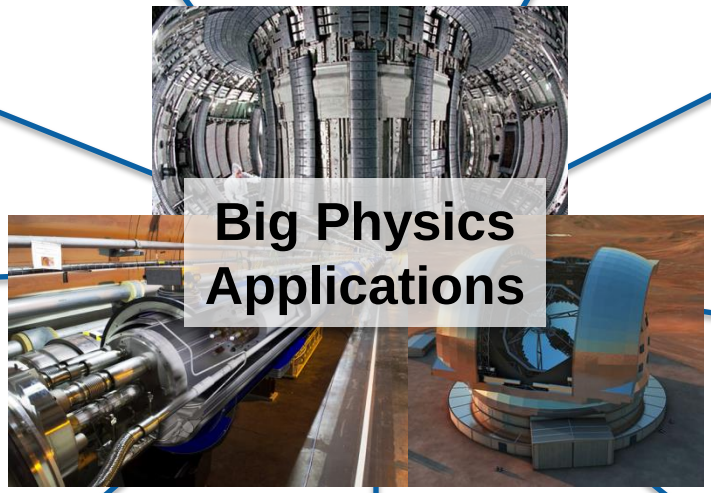
Linux Support

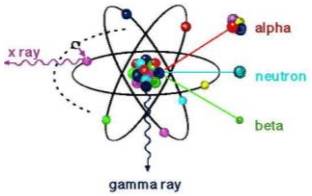
RASM



EPICS Support

Lifecycle Management





Radiation and Magnetic Field Testing

Safety : EMI, UL, CE, SIL

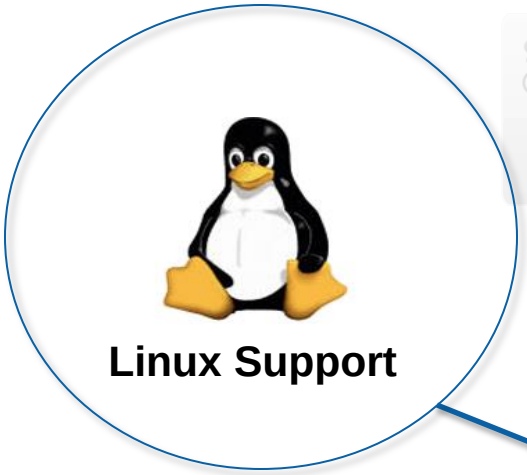
Environmental: ROHS, ChinaROHS, WEEE

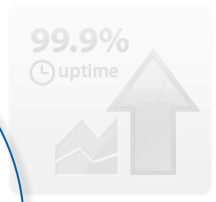
Global Technical Support

Global Calibration And Repair

NATIONAL INSTRUMENTS

Linux Support

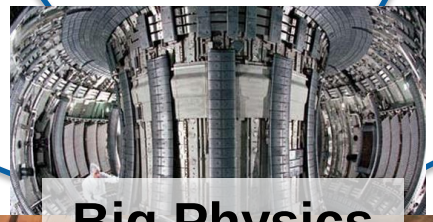


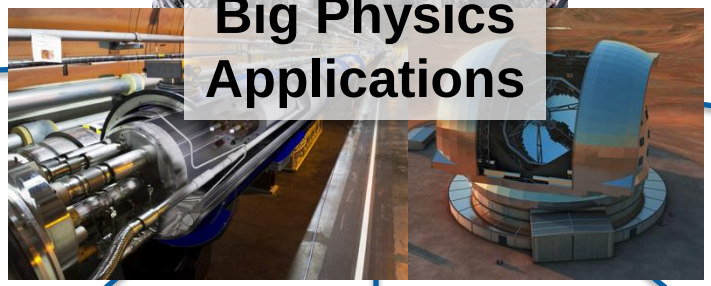


RASM

EPICS Support

Lifecycle Management





Big Physics Applications

Radiation and Magnetic Field Testing

Safety : EMI, UL, CE, SIL

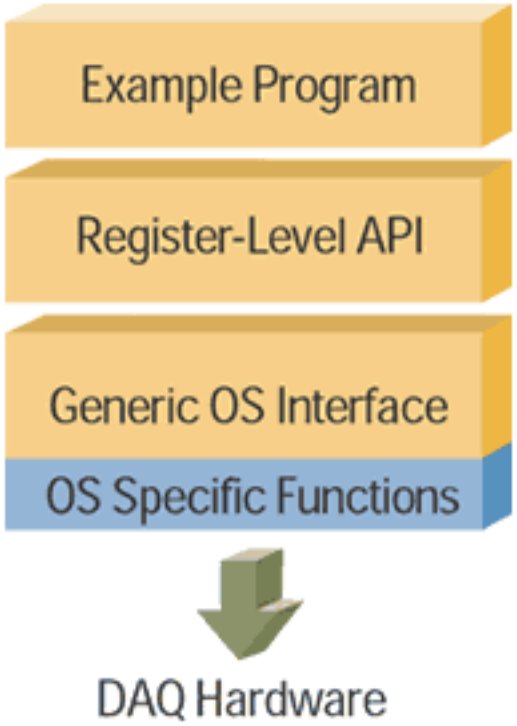
Environmental: ROHS, ChinaROHS, WEEE

Global Technical Support

Global Calibration And Repair

NI MHDDK

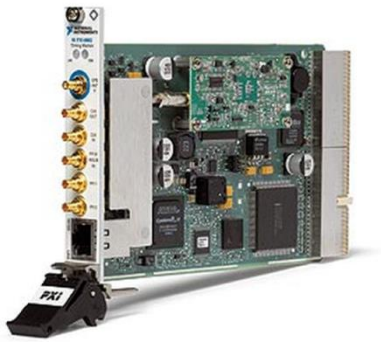
- Measurement Hardware Driver Development Kit
- Register-level programming for Data Acquisition Devices
- Multiple OS support
- Driver developed entirely by the customer
- Source code only, very small footprint



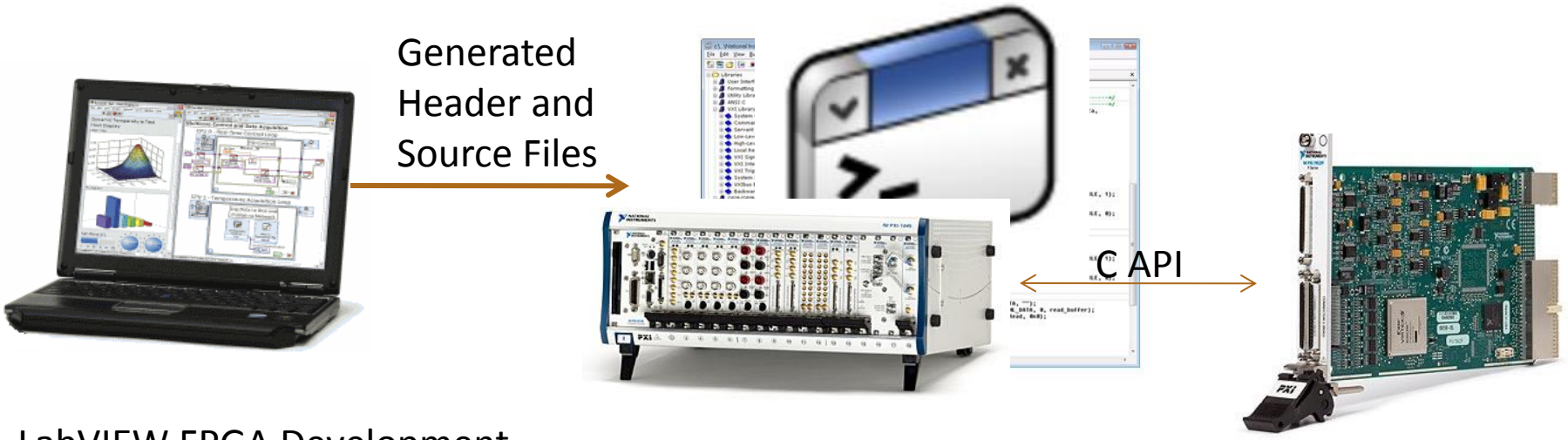
ITER DAQ MHDDK Based Drivers

- PXIe 6368: Multifunction Data Acquisition
- PXI 6259: Multifunction Data Acquisition
- PXI 6528: HV Digital I/O
- PXI 6682: Timing
- PXI 6683: Timing



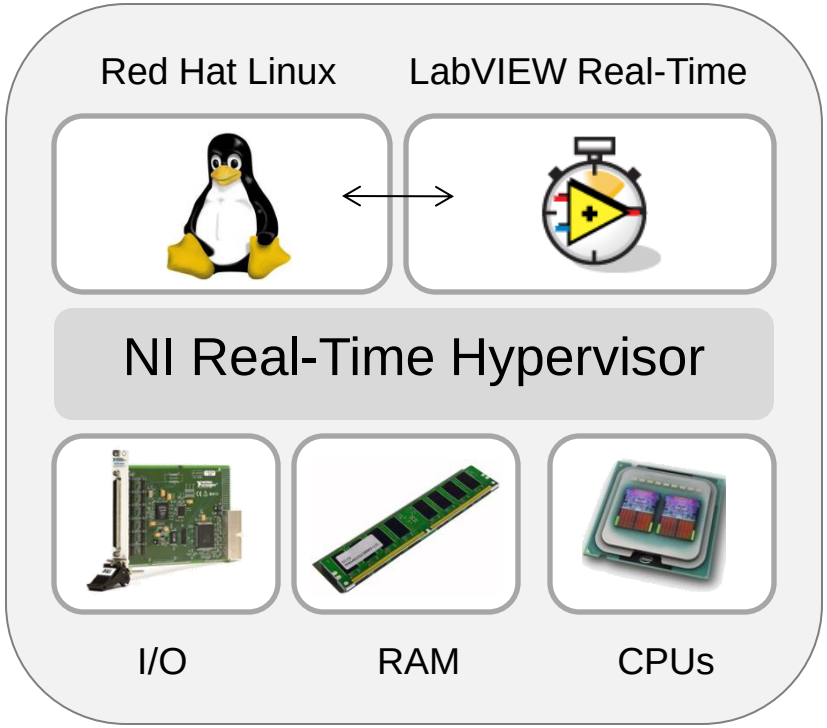


Deploying RIO Devices Under Linux



1. Develop LabVIEW FPGA VI, compile bitfile, and generate C API.
2. Develop and build C/C++ application with generated C API.
3. Deploy built application and bitfile to Linux target, and run.

NI Real-Time Hypervisor for Linux

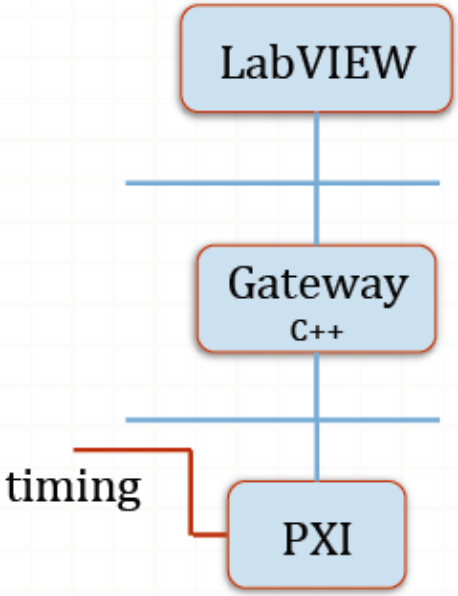


- Combine real-time processing with Linux applications
- Connect to any I/O devices supported by LabVIEW Real-Time or Linux
- Communicate between OSs with high throughput shared memory

ESS Ion Source

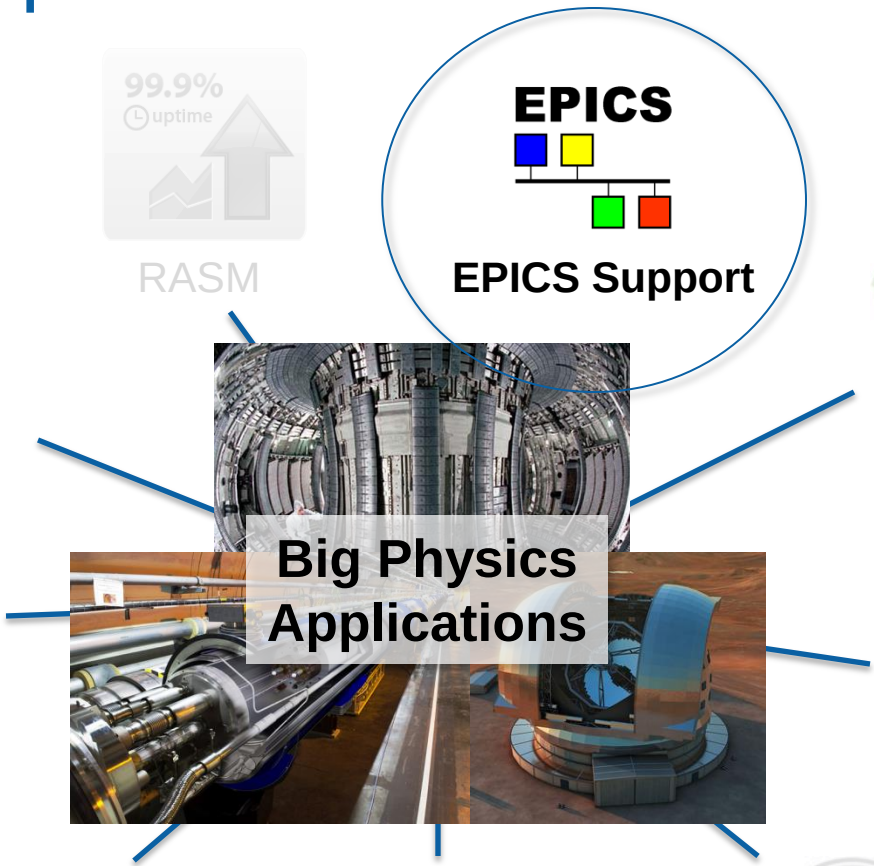
- Controlling and monitoring a ion source (ISHN) at ESS
- PXI and FPGA running LabVIEW interfacing with Linux operator interface through EPICS on real-time controller

Requirements for PXI integration



Requirement	Solution	Status
Long term collaboration	NI + CERN	OK
Support for spares, intervention, calibration	NI + CERN	OK
LabVIEW interf. to CMW	CERN	OK
LabVIEW 64-bit SLC	NI + CERN	2013
PXI to CMW	NINETV	2013
FMC carrier	INCAA + CERN	2013
Dual OS, Linux + LV-RT	NI Hypervisor	2014
NI-Scope + drivers+ GPIB	NI	2014
GMT timing card	CERN	2014
WR timing card	NI	2015

EPICS Support



RASM

Linux Support

Lifecycle Management

Radiation and Magnetic Field Testing

Safety : EMI, UL, CE, SIL

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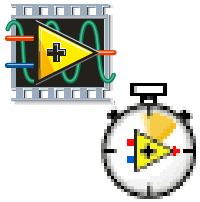
Global Technical Support

Global Calibration And Repair

EPICS Integration



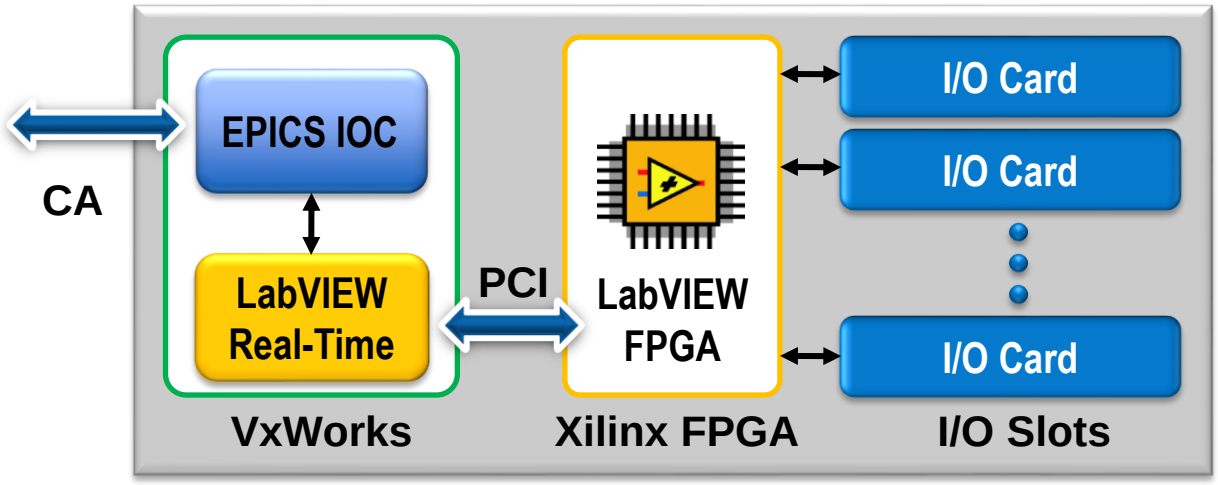
LabVIEW	I/O Server	EPICS CA Client or Server

LabVIEW RT on cRIO	Shared Memory	EPICS IOC on VxWorks
LabVIEW RT on PXI	Hypervisor Shared Memory	EPICS IOC on Linux

PXI / cRIO 906x (No LabVIEW)	Linux Driver Device Support	EPICS IOC on Linux

Embedding EPICS IOC on CompactRIO

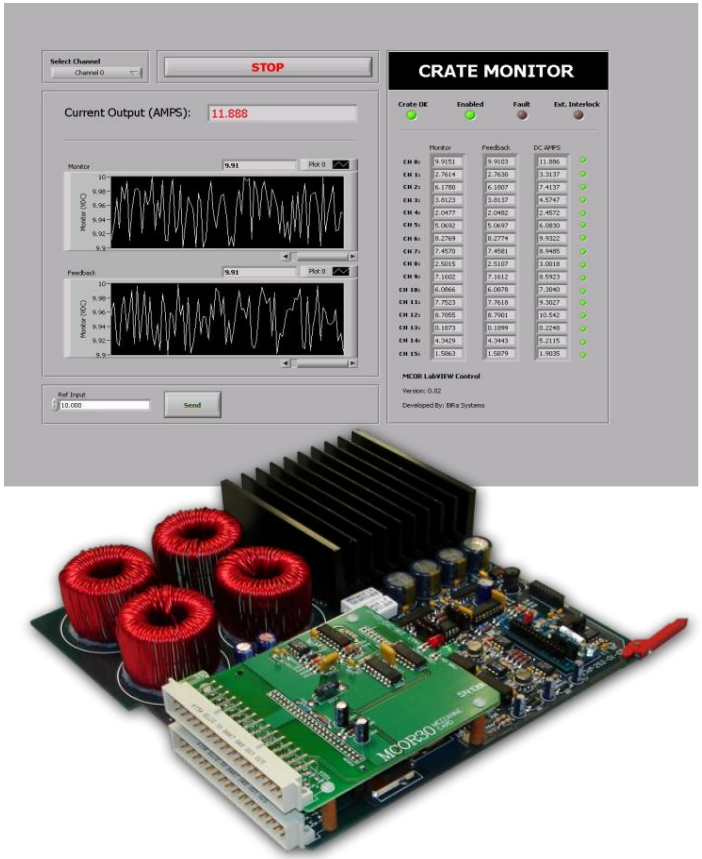
- EPICS IOC and LabVIEW Real-Time running simultaneously
- Take advantage of FPGA platform with CompactRIO



CompactRIO Architecture

BiRa's Power Supply

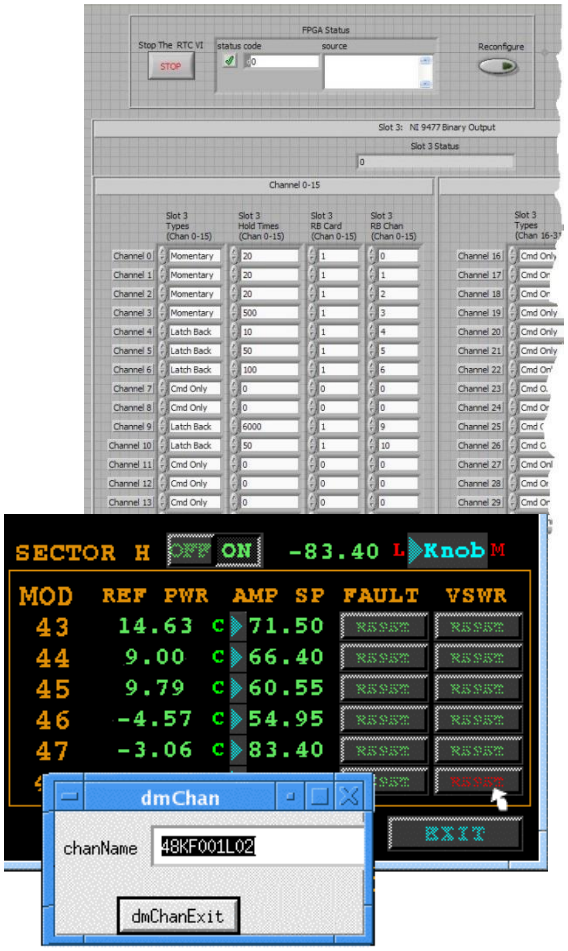
- 16 channels of high precision bipolar DC power
- Mainly used for corrector magnets in particle accelerators
- Running LabVIEW EPICS CA Server on an embedded real-time controller



BiRa

Los Alamos LANSCE

- Migration to a cRIO with embedded EPICS
  - 12 binary outputs
  - 36 binary inputs
  - 12 analog inputs
  - 5 stepper motor channels
- Full IOC functionality allows access to all record fields and EPICS utilities
- Maximum flexibility for partitioning the problem
  - LabVIEW for beam diagnostic
  - EPICS for industrial control



Case Study

ni.com

IOC Server on PXI

Network Traffic
(Channel Access Protocol)

Channel Access Protocol Server
Publishes values from the database onto the network using Channel Access protocol.

Sequencer
(Finite State Machine)
Reads values from the database to drive state changes in the IOC control application.

EPICS Database

Shared Memory

Database Engine

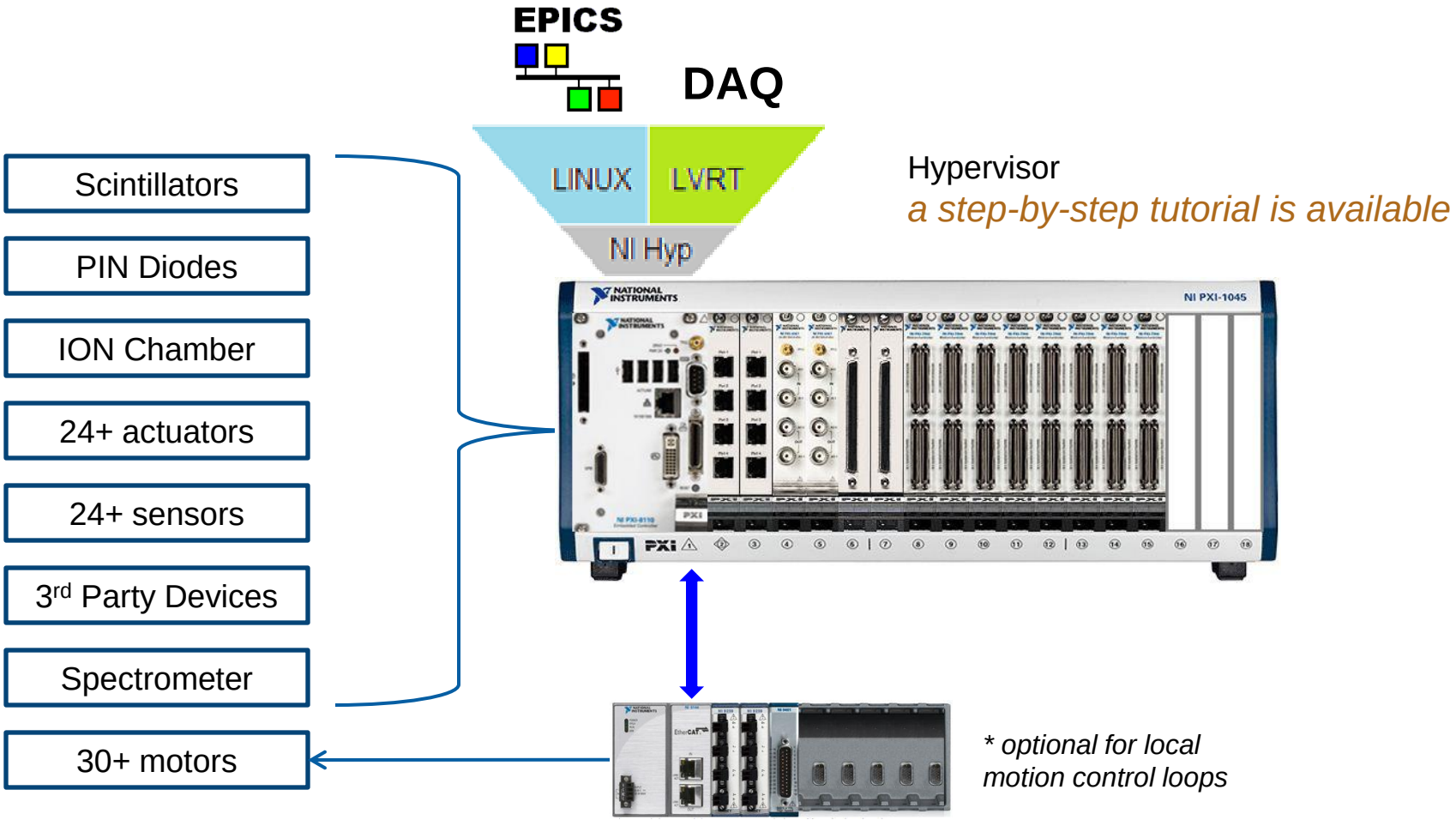
LabVIEW Application

Hardware

IOC Server on PXI – Shared Memory

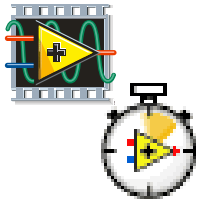
- PXI controller runs Linux, hypervisor, and LV RT
- Implemented via hypervisor shared memory
- Interface to hardware via LabVIEW RT and FPGA (FlexRIO)
- EPICS Device Support needs to be developed by customer or integrator

Beam Line Proposed Automation



National Instruments Confidential

EPICS Integration Summary



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Radiation and Magnetic Field Testing

RASM

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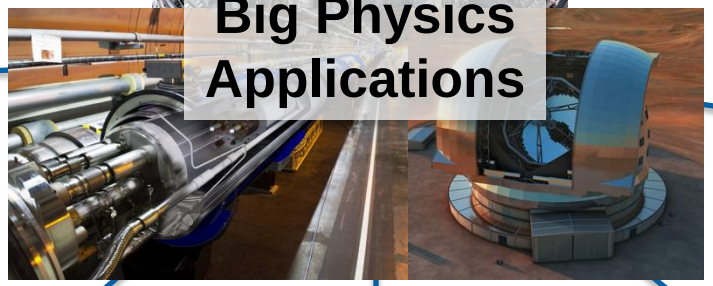
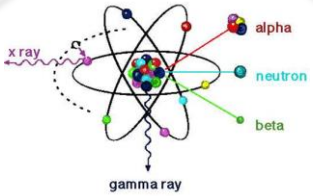
Linux Support

Lifecycle Management



Big Physics Applications



Radiation and Magnetic Field Testing

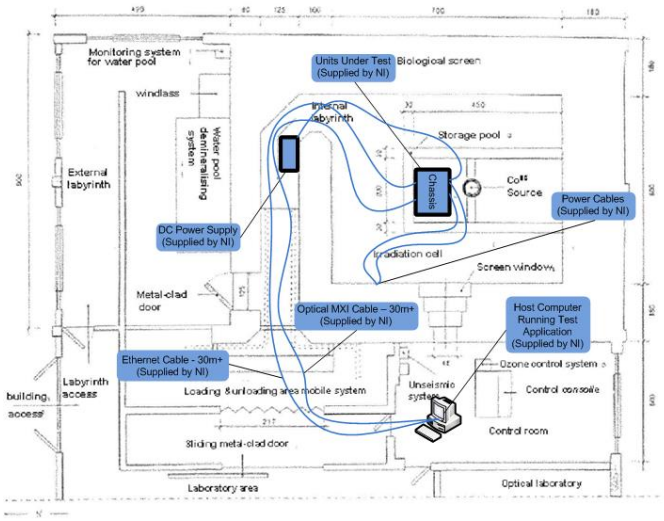
Safety : EMI, UL, CE, SIL

Environmental: ROHS, ChinaROHS, WEEE

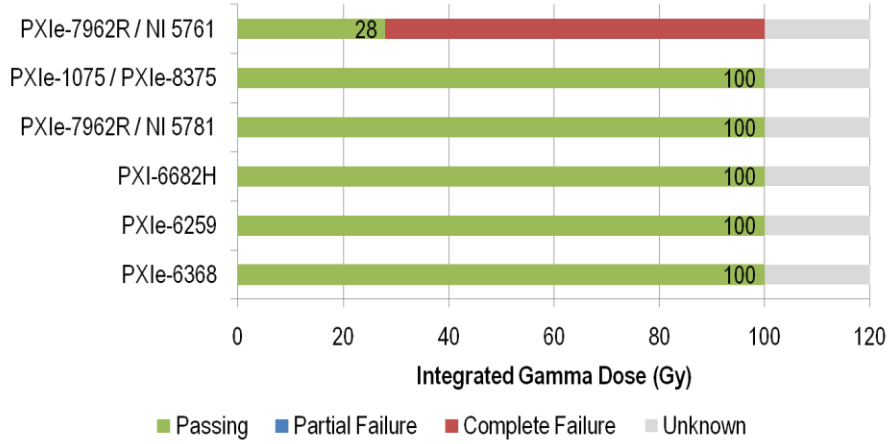
Global Technical Support

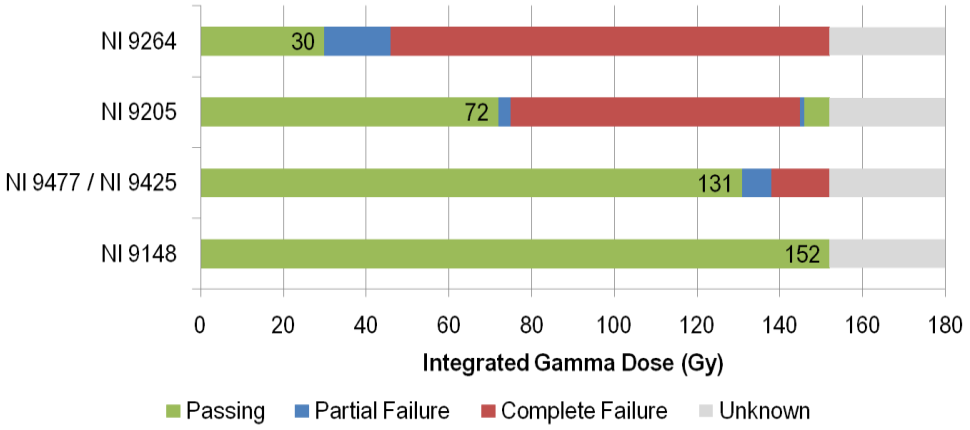
Global Calibration And Repair

Calliope Gamma Research Lab at ENEA Casaccia



PXIe and cRIO Gamma Testing



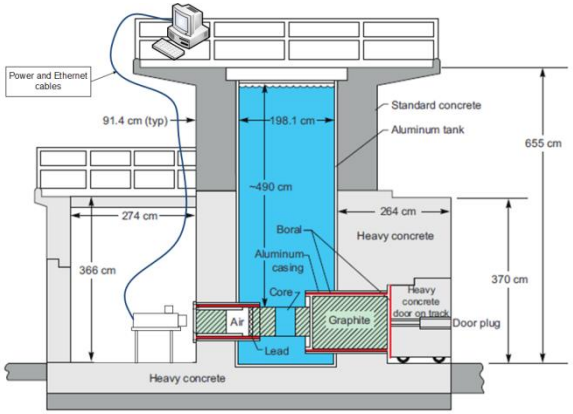


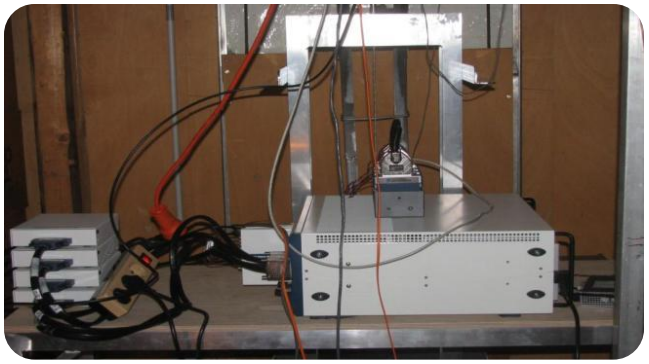
- Cumulative effects are evident in the gamma testing
- Most (1 PXI / 1cRIO) failed devices exceeded expected failure dose of 50Gy
- More than half of the devices exceeded the maximum expected failure dose of 100 Gy

Fast and Thermal Neutron Testing

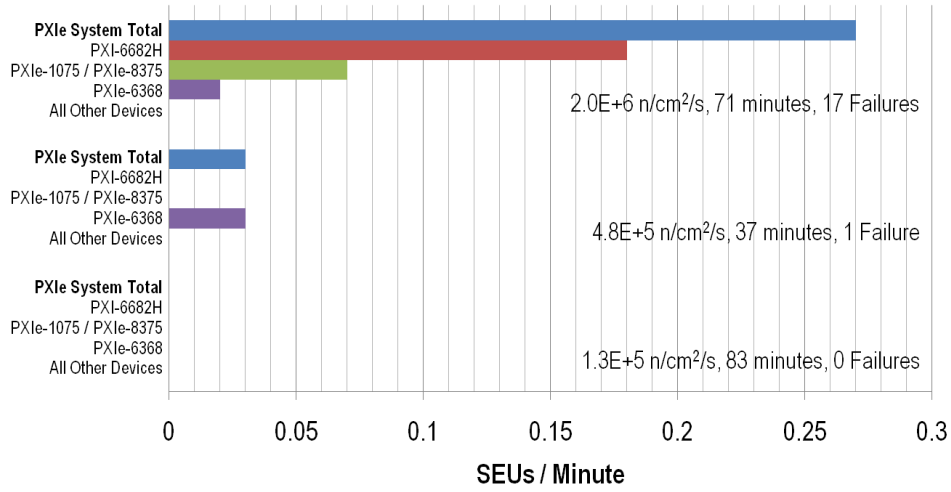
Frascati Neutron Generator, ENEA, Italy (**Fast**)

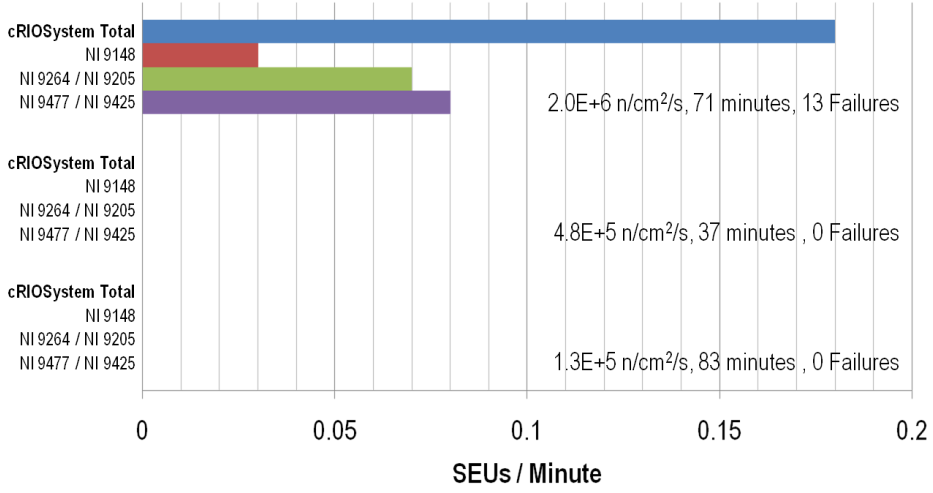
TRIGA Reactor, JSI, Slovenia (**Thermal**)





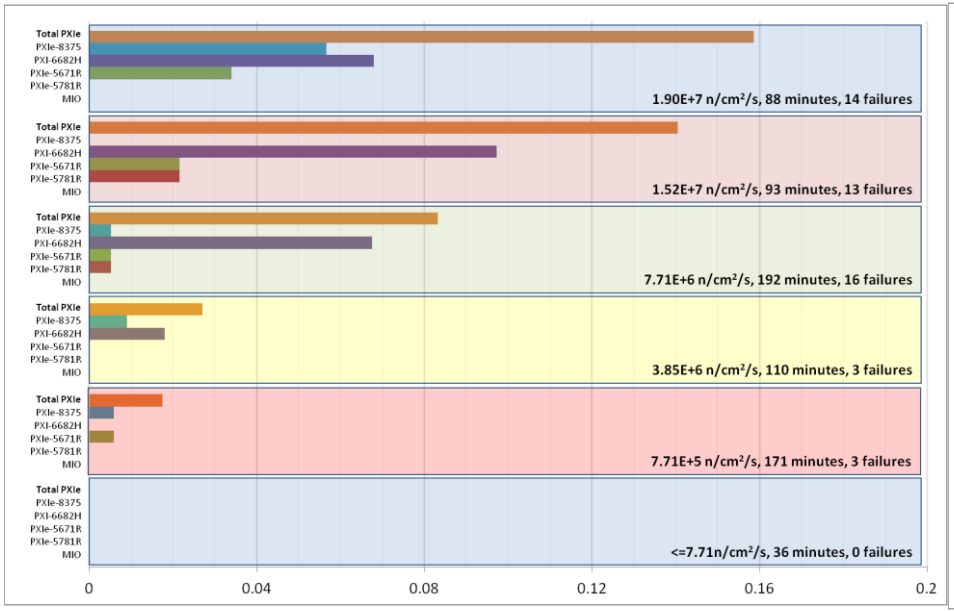
Fast Neutron Results (SEUs/Min)

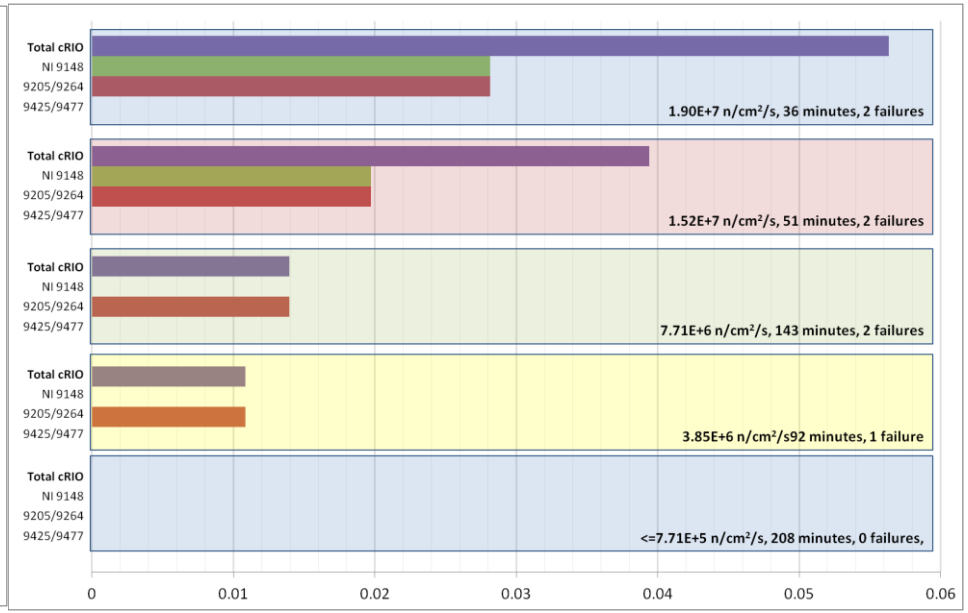




- Single Event Upsets dominated the neutron results generally meeting ITER requirements
- Did not see permanent damage

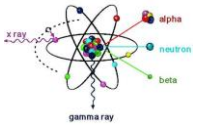
Thermal Neutron Results (SEUs/Min)





- Where able to test, are almost 1 order of magnitude more flux compared to fast neutrons
- Failure rates were less than or equal to what was seen with fast neutron testing
- MIO hardware handled thermal much better than fast (0 failures)

Radiation Testing Conclusions



- Gamma Testing
  - Most devices exceeded expected failure dose of 50Gy
  - Cumulative effects are evident in the gamma testing
- Fast Neutron Testing
  - Single Event Upsets dominated the neutron results generally meeting ITER requirements
  - Did not see permanent damage
- Thermal Neutron Testing
  - Were able to test are almost 1 order of magnitude more flux compared to fast neutron
  - Failure rates were less than or equal to what was seen with fast neutron testing
  - MIO hardware handled thermal much better than fast (0 failures)

Magnetic Field Testing at DESY: Phase 1

PXI Chassis

- Fans fail between 15mT - 25 mT
- Investigation to find fans tolerant to higher field continues

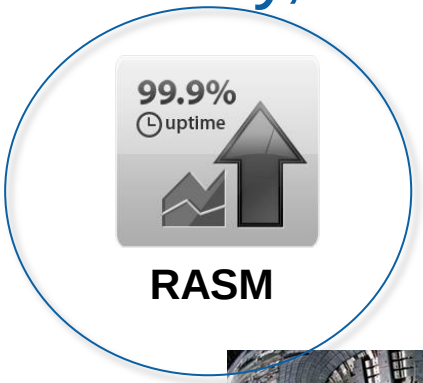
NI 9148 (cRIO Ethernet Chassis)

- Chassis works well up to 60 mT
- Permanent HW damage at 230 mT

cRIO-9205 & cRIO-9263

- Works well up to 40 mT
- Data error between 40 and 50 mT
- Permanent HW failure after several minutes at 50 mT

Reliability, Availability, Serviceability, Maintainability



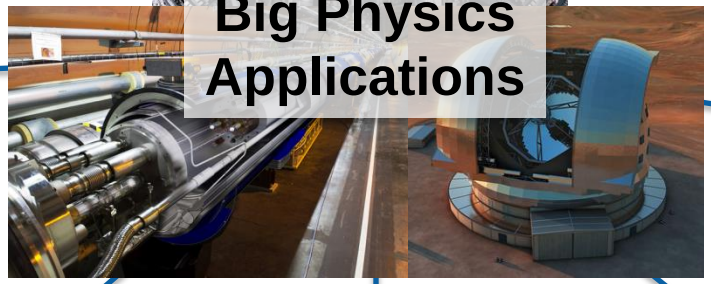
RASM

EPICS Support

Linux Support

Lifecycle Management

Big Physics Applications



Radiation and Magnetic Field Testing

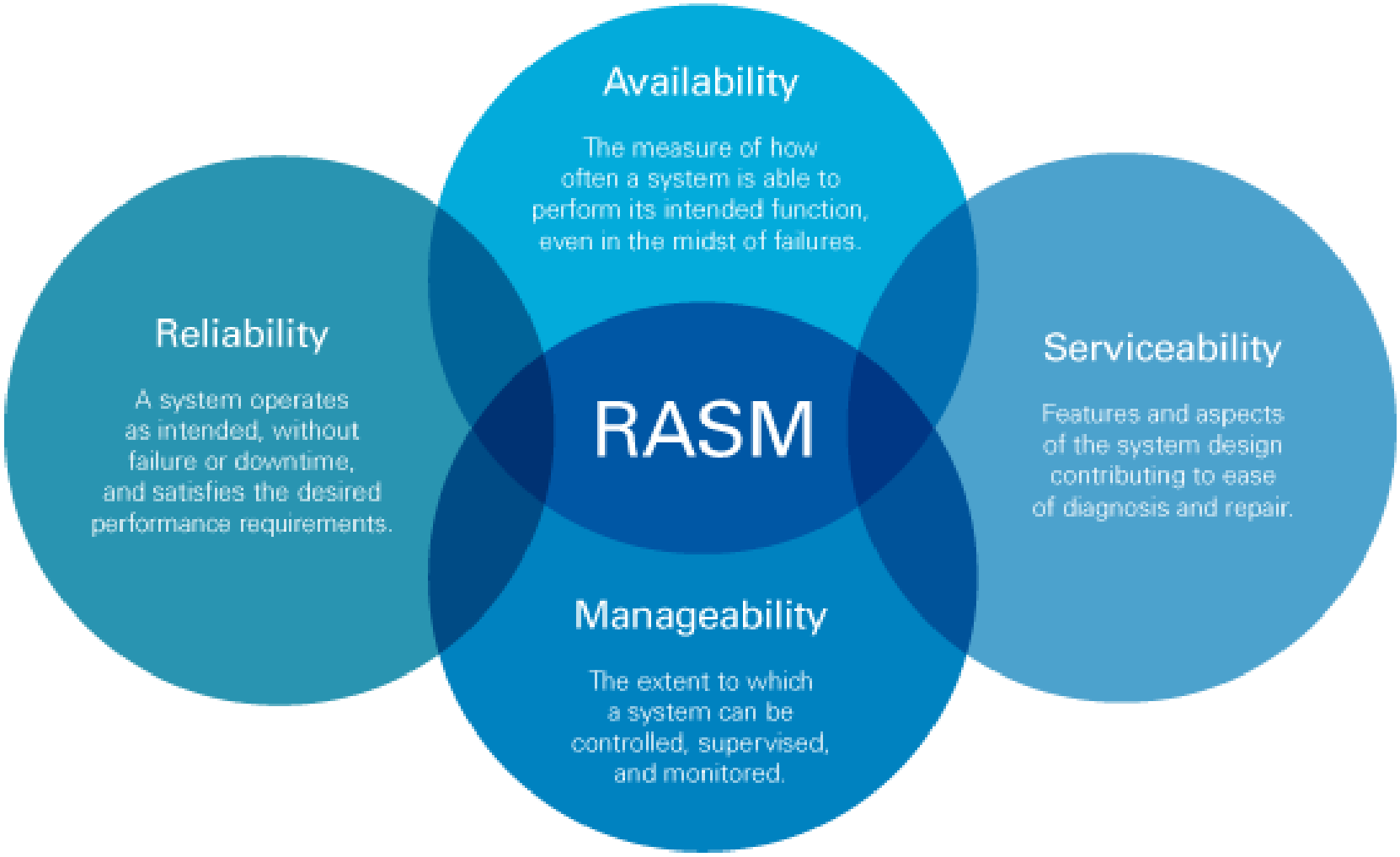
Safety : EMI, UL, CE, SIL

Environmental: ROHS, ChinaROHS, WEEE

Global Technical Support

Global Calibration And Repair

RASM


Availability
The measure of how often a system is able to perform its intended function, even in the midst of failures.
Reliability
A system operates as intended, without failure or downtime, and satisfies the desired performance requirements.
RASM
Serviceability
Features and aspects of the system design contributing to ease of diagnosis and repair.
Manageability
The extent to which a system can be controlled, supervised, and monitored.

System Reliability Lab (SRL)

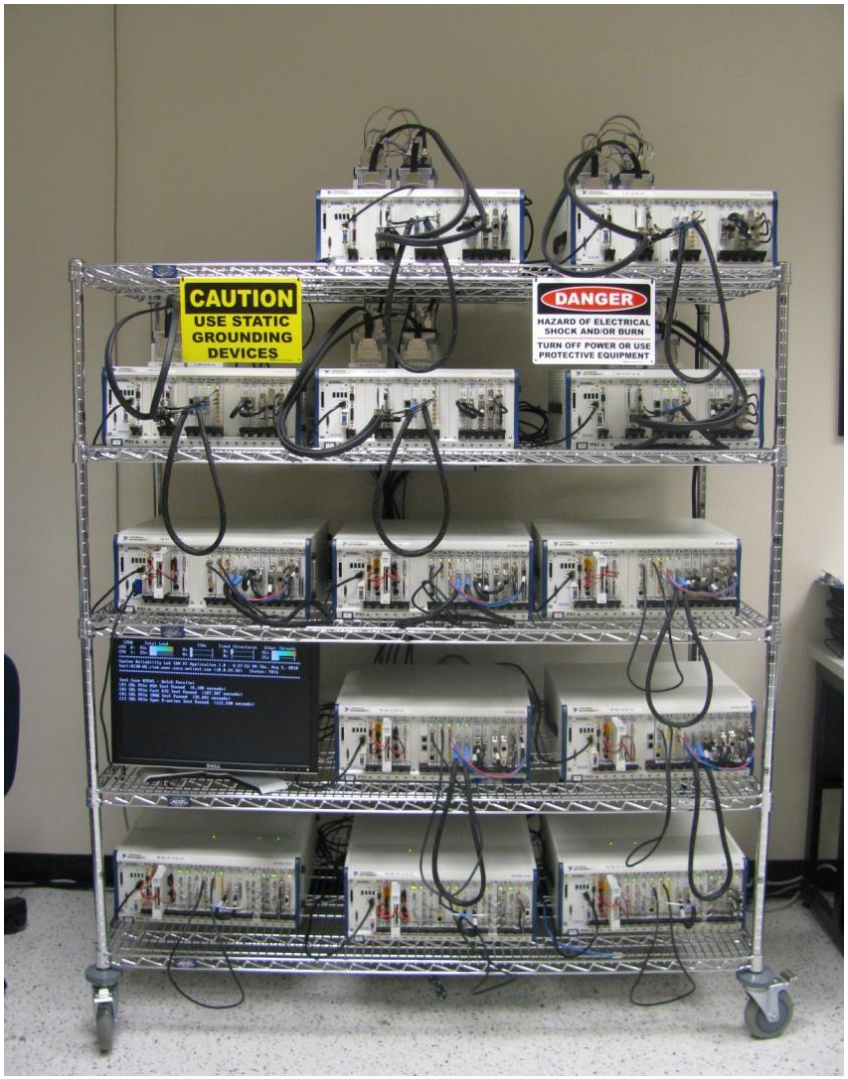
Mission:

Assess the reliability of National Instruments product-based systems and drive product improvements

- Created to focus on system reliability for the:
  - Compact RIO and PXI / PXIe hardware platforms
  - LabVIEW software platform

SRL PXI/PXIe Testing

- 20 systems
  - 18 systems at room temperature
  - 2 systems in temperature chamber (cycles between 5°C and 5°C)
  - 5 systems running on dirty power
- 3 different hardware configurations
- 32 test applications
- 24/7 execution during missions



SRL cRIO Testing

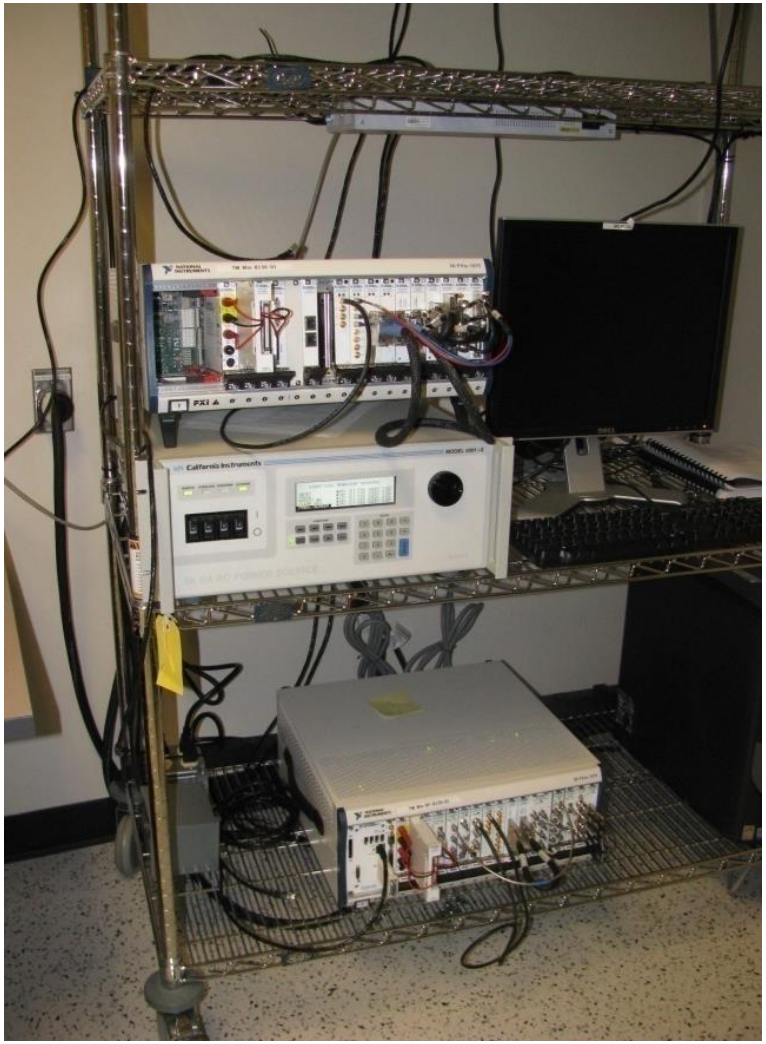
- 40 systems
  - 32 systems at room temperature
  - 8 systems in temperature chamber (cycles between -40 and 70°C three times per day)
  - 8 systems running on dirty power
- 4 unique cRIO applications
- 24/7 execution during mission

SRL Temperature Chamber

- Cycle Temperature three times per day for months
- 2 to 8 Systems run for months at time in this environment
- PXI / PXIe: 5°C to 50°C
- cRIO: - 40°C to 70°C

SRL Dirty Power Test Station

- Simulates a bad power grid
- 5 to 8 Systems run for months at time in this environment
- Vary frequency from 47 to 63 Hz
- Vary voltage level from 90 to 264 V



SRL MTBF Numbers

- **PXIe 8130 controllers** have over 40 years of run-time data and 1 failure = 40 yrs / 1 failure = **40 years per failure**

- **PXIe 1075 chassis** have over 40 years of run-time and 2 failures = 40 yrs / 2 failures = **20 years per failure**

- **cRIO 9014** controllers have over 76 years of run-time data and 2 failures = **38 years per failure**

- **cRIO 9104 chassis** have over 76 years of run-time and 0 failures **>76 years per failure**

CERN High Availability Chassis

- Redesigned to mechanically fit into a custom rack
- Independently powered, redundant hot swap power supplies and fans
- Remote Monitoring : Chassis Temperature, Fan Status, Power Supplies

Lifecycle Management

Big Physics Applications

Lifecycle Management

Linux Support

RASM

EPICS Support

Radiation and Magnetic Field Testing

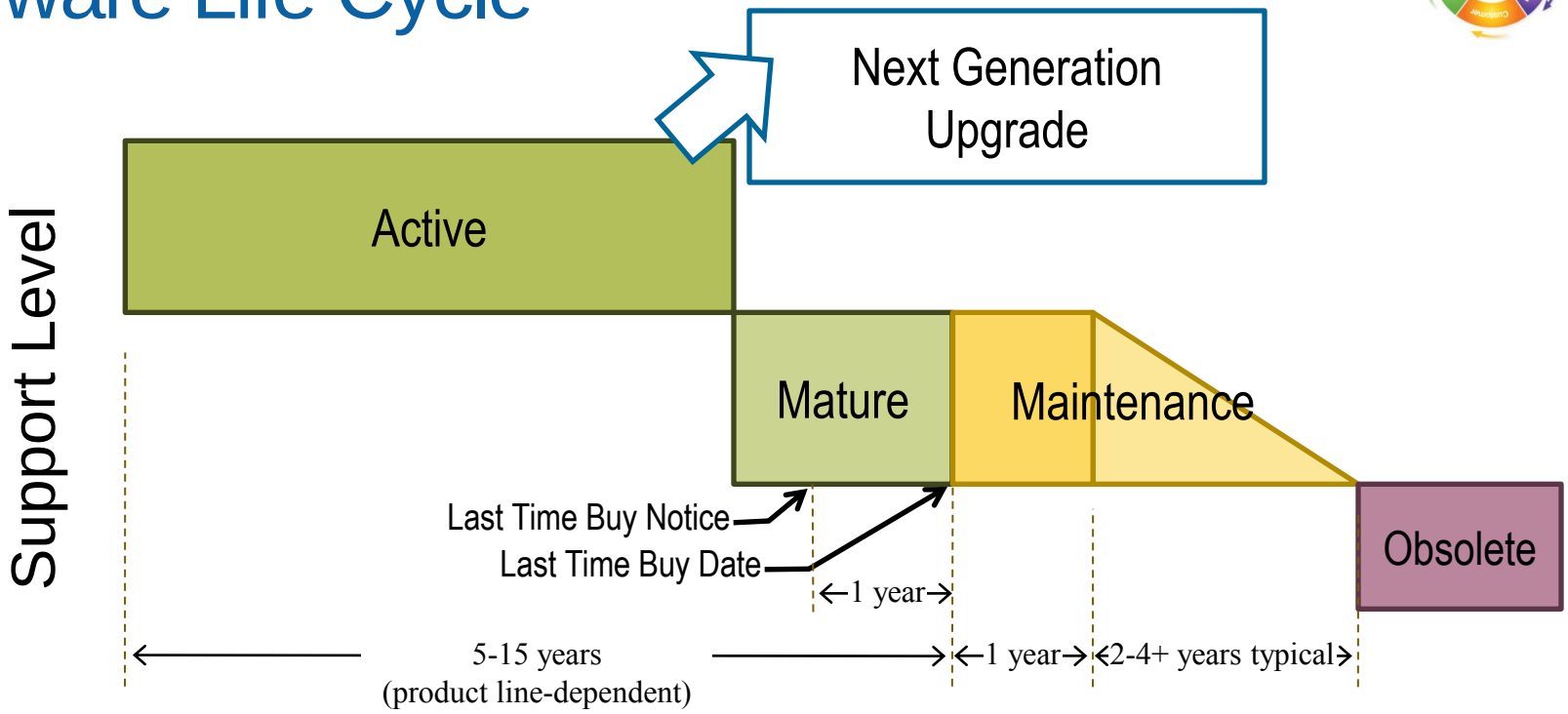
Safety : EMI, UL, CE, SIL

Environmental: ROHS, ChinaROHS, WEEE

Global Technical Support

Global Calibration And Repair

Hardware Life Cycle



	Active	Mature	Maintenance		Obsolete
Purchase new	Yes	Yes	No	No	No
Repair	Yes	Yes	Yes	Reasonable effort	No
Calibration	Yes	Yes	Yes	Reasonable effort	No
Service Agreements	Yes	Yes	Yes	Yes	Yes

Global Services

Linux Support

RASM

EPICS Support

Lifecycle Management

Radiation and Magnetic Field Testing

Safety : EMI, UL, CE, SIL

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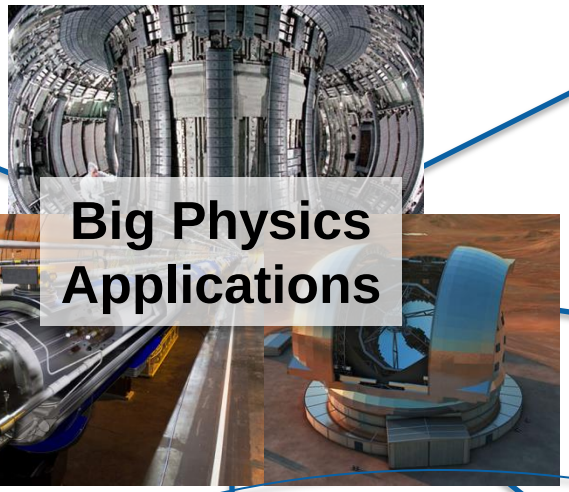


Global Technical Support

Global Calibration And Repair

NATIONAL INSTRUMENTS

Safety Certifications

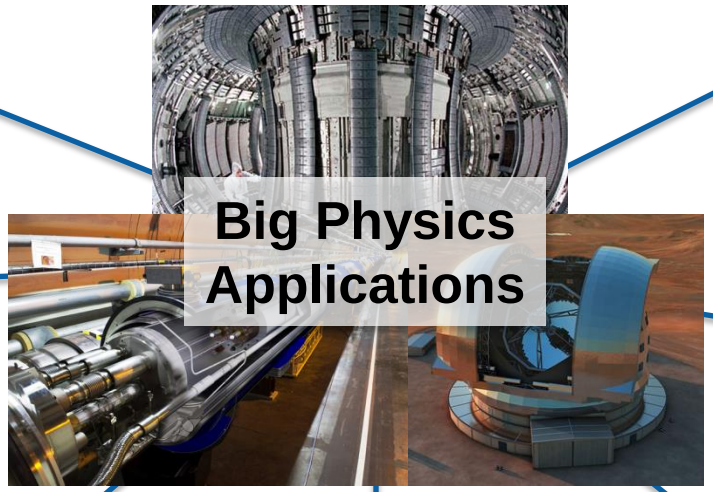
Linux Support

RASM

EPICS Support

Lifecycle Management

Radiation and Magnetic Field Testing



Big Physics Applications

Safety : EMI, UL, CE, SIL

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Global Technical Support

Global Calibration And Repair

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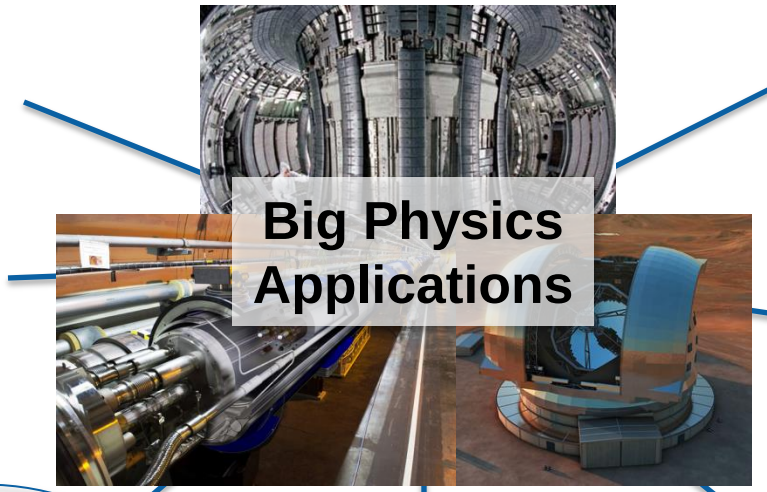
Lifecycle Management



Radiation and Magnetic Field Testing

Safety : EMI, UL, CE, SIL

RoHS

Environmental: ROHS, ChinaROHS, WEEE

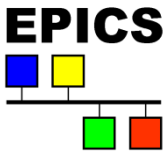
Global Technical Support

Global Calibration And Repair

Summary of NI Offerings

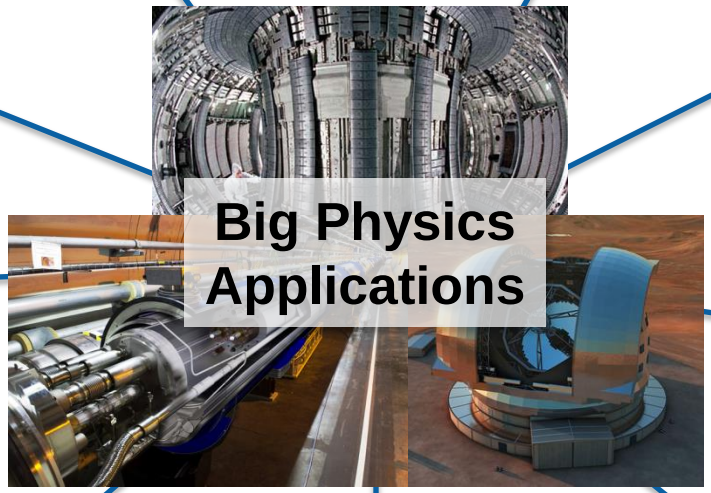
Linux Support

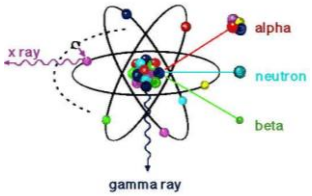
RASM



EPICS Support

Lifecycle Management





Radiation and Magnetic Field Testing

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Global Technical Support

Global Calibration And Repair

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