
NATIONAL
INSTRUMENTS™

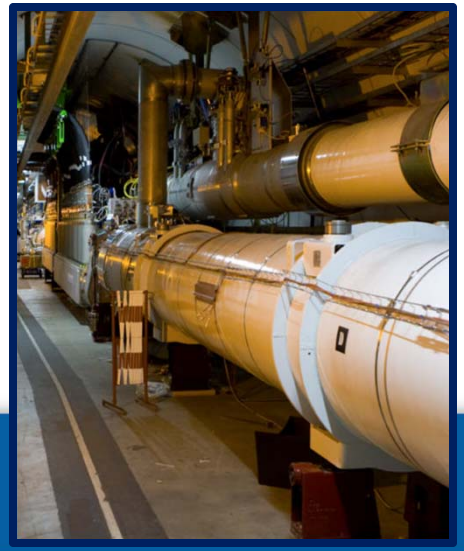
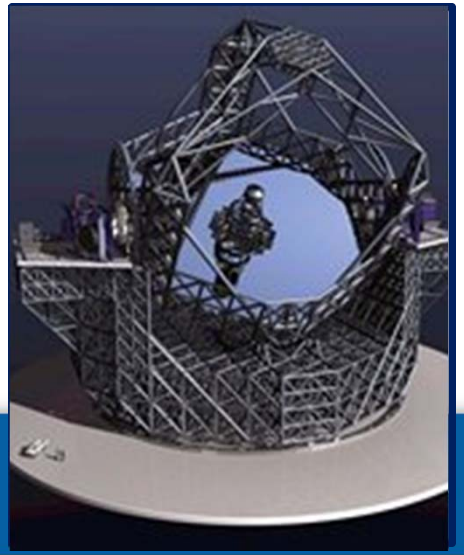
Customized Off-The-Shelf Technologies Through Industry – Research Facility Partnership

Dr. James Truchard
President, CEO & Cofounder
National Instruments

Today's Engineering Challenges

- Doing more with less
- Time to experiment
- Managing global projects
- Adapting to evolving application requirements
- Delivering on increasingly complex initiatives
- Maximizing operational efficiency
- Protecting system and resource investments



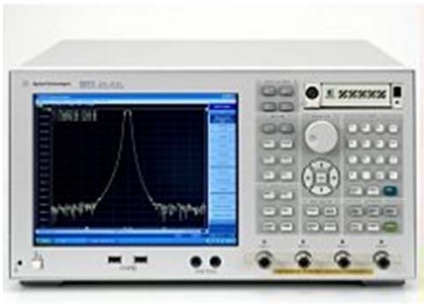
Transition to Customized COTS

Vacuum Tube

General Radio

1920

Transistor
(Integrated Circuit)



Hewlett Packard

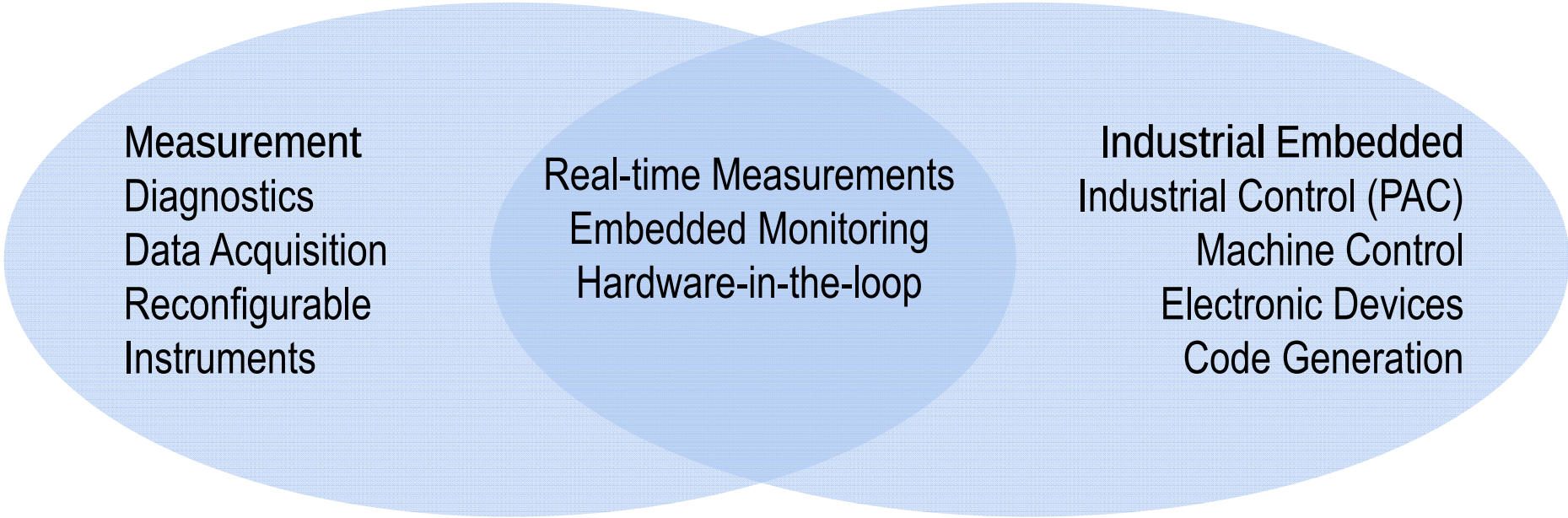
1965

Software

National Instruments

2010

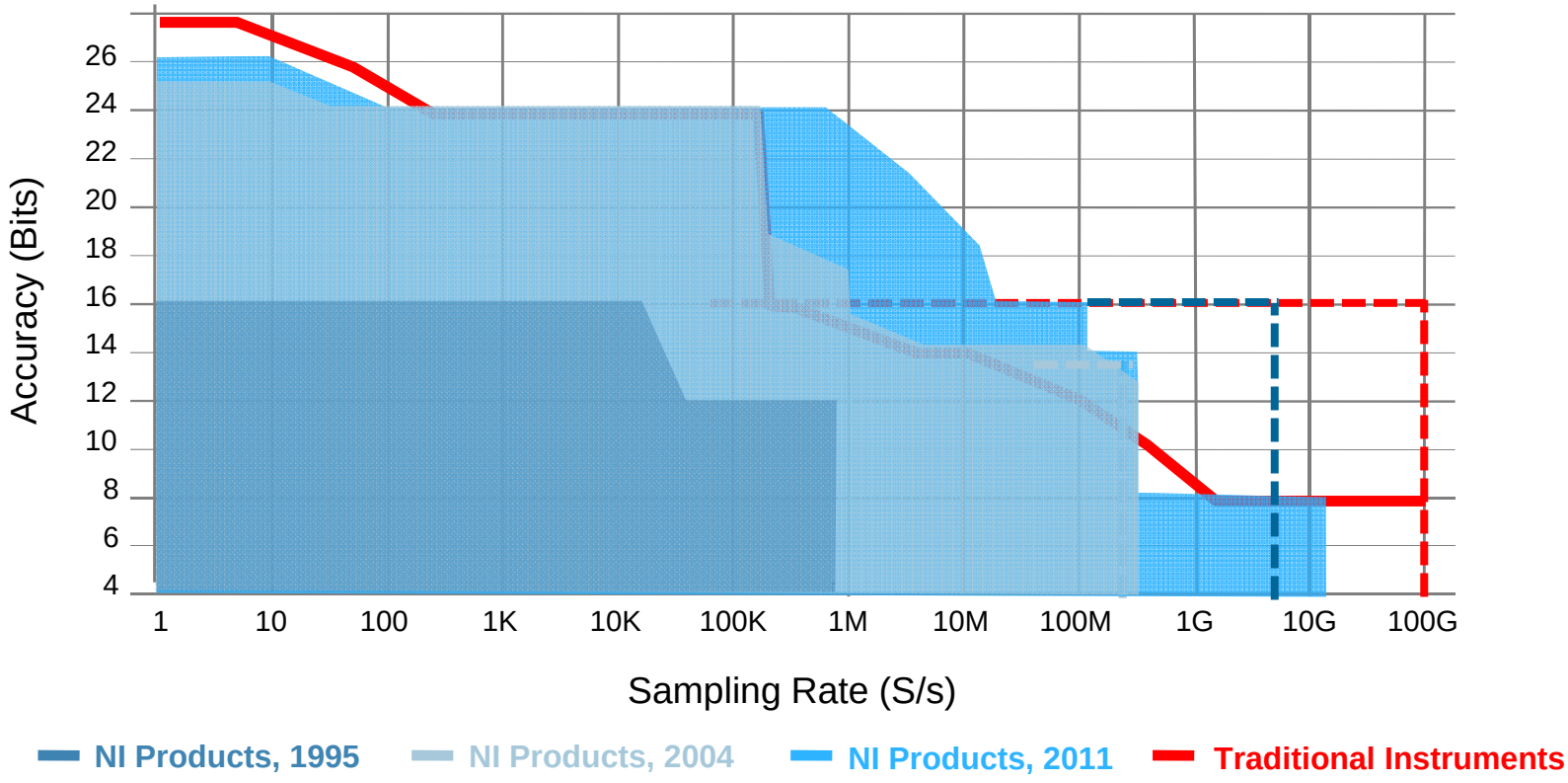
The National Instruments Vision, Evolved… Graphical System Design



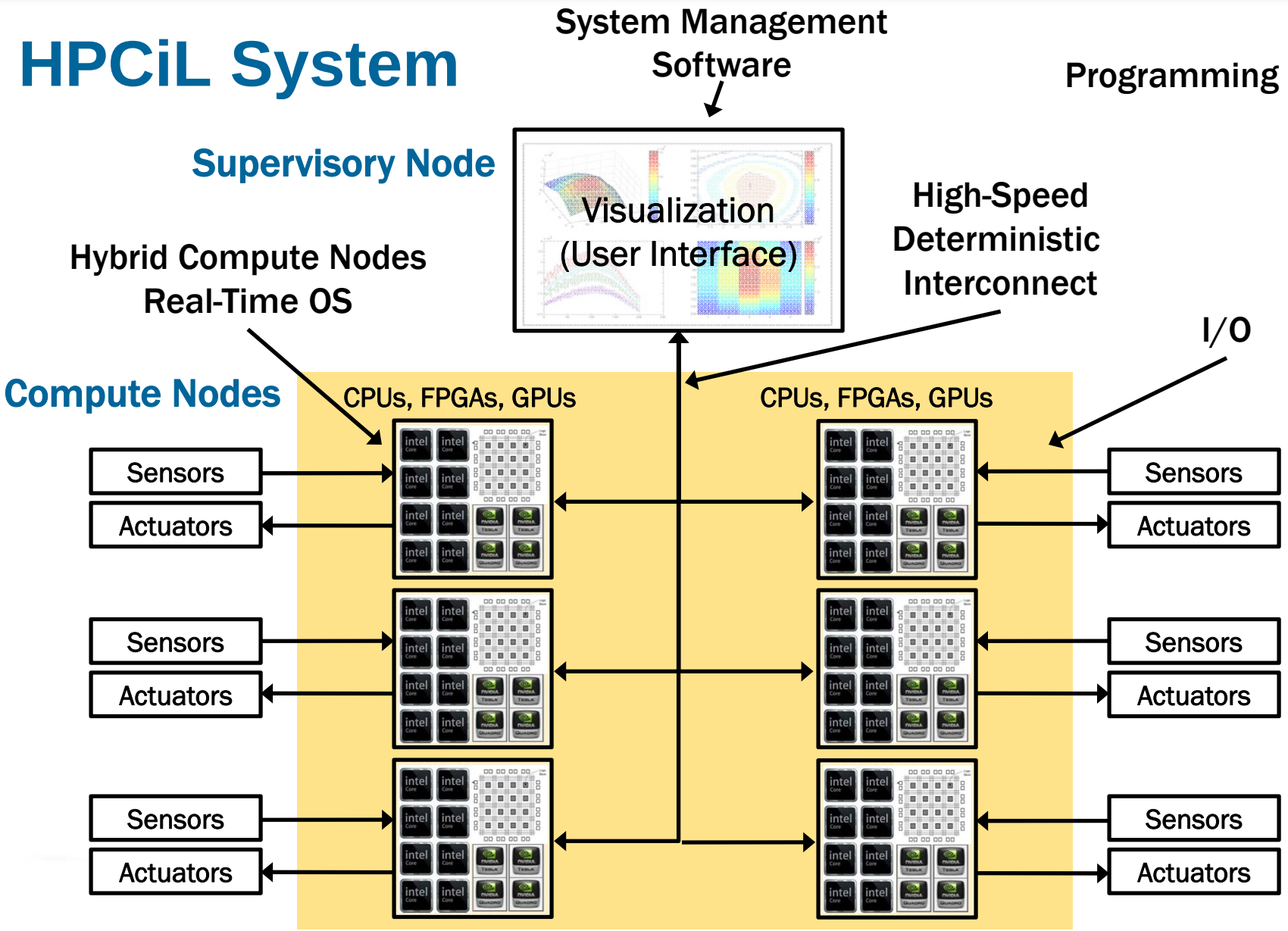
"To do for test and measurement what the spreadsheet did for financial analysis."

"To do for embedded what the PC did for the desktop."

Expanding Measurement Capabilities



HPCiL System



Partnership with Industry

Continuous innovation

- Leverage R&D investment and latest technology
- Tools and platforms that allow faster iteration

Simplification and cost reduction

- Empower domain experts
- Open platforms to adapt vertical and emerging standards

Long term maintenance and support

- Life cycle management
- Services and consulting

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National Instruments

Corporate headquarters: *Austin, Texas*

Year established: *1976*

Revenue: $873 million in 2010

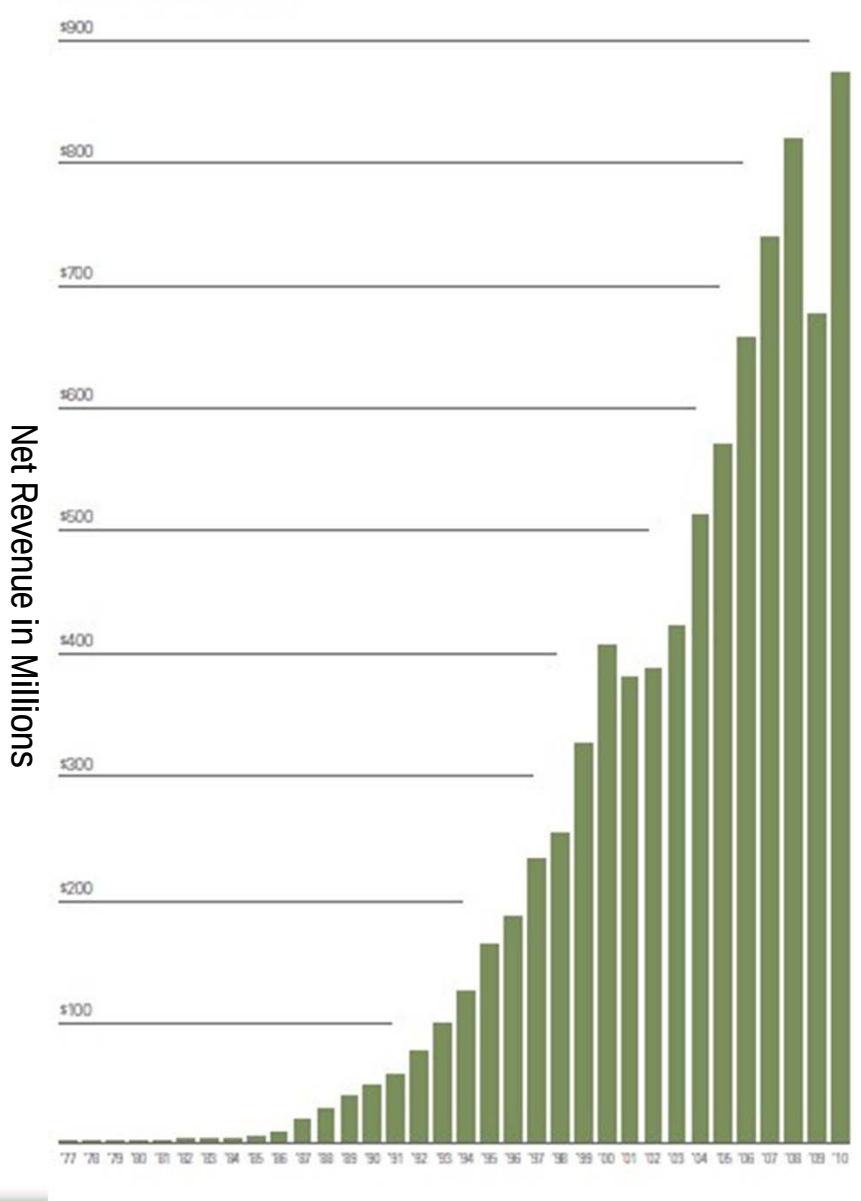
Global operations: *offices in 43 countries*

Investment in R&D: *16% of annual revenue*

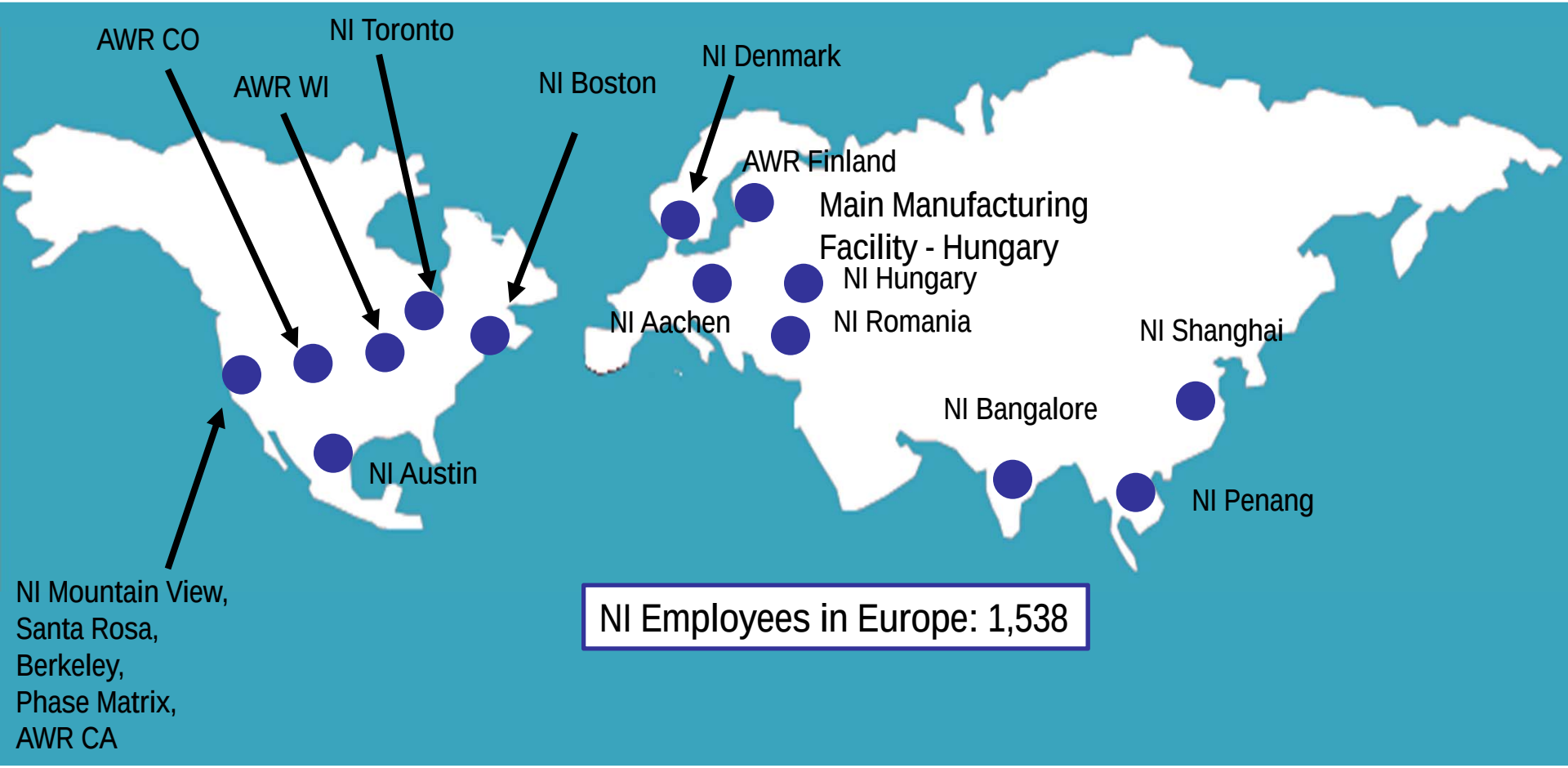
Customer base: *30,000 companies annually*

Network: More than 600 Alliance Partners

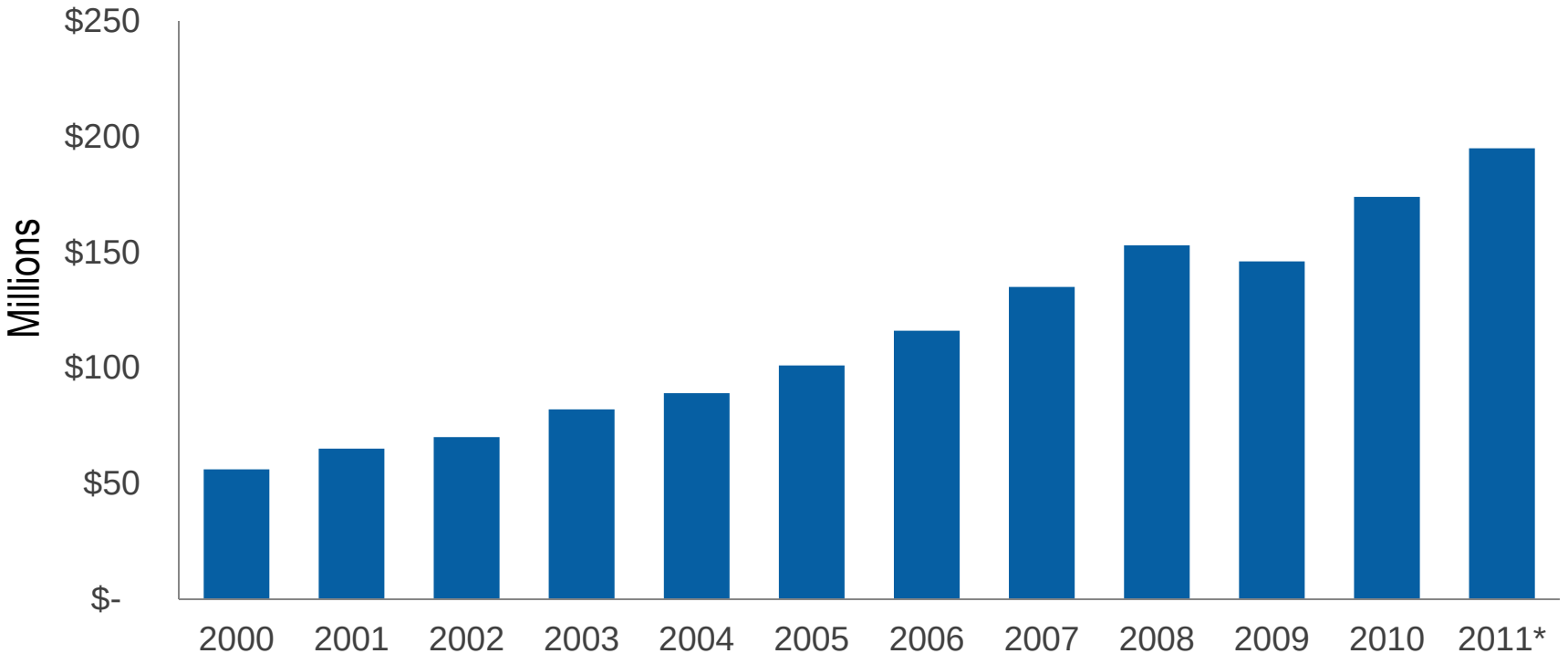
Diversity: *no industry makes up more than 15% of revenue*



NI Global R&D Organizations



NI's Increasing Investment in R&D



*Represents National Instruments expected investment, communicated June 28, 2011.

Leveraging Industry Relationships

- Apply technologies from wide array of vendors
  - Next generation FPGAs, ADCs, GPUs and processors
- High access to information
  - Regular executive meetings
  - Ability to influence roadmaps

Adapting To Changing Needs

iPhone 3

2 years

iPhone 4

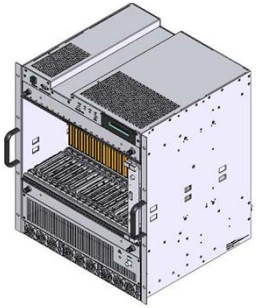
Dell Latitude 5200

3 years

Dell Latitude 6400

Custom Design

10 years



Custom Design

Keep Up With Technology While Preserving Investment

iPhone 3

2 years

iPhone 4

Dell Latitude 5200

3 years

Dell Latitude 6400

COTS Platforms

3 Years

COTS Platforms

Leveraging R&D Investment

Investment from Industry in 2010

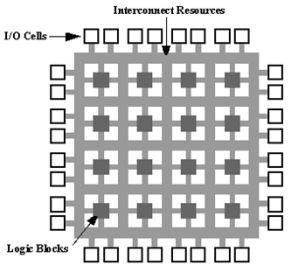
- > $170M from NI (1800 man years)
- >1,600M from Intel
- >$500M from Analog Devices

Combining Laboratory Expertise and off-the-shelf technology

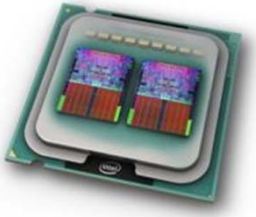
- Custom Front End
- Signal Conditioning
- Algorithm

Tools From the Industry

FPGAs

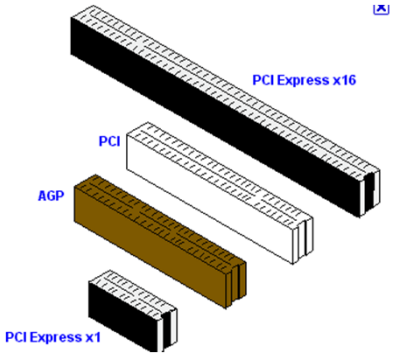


Multicore Processors



GPUs

Processors



Communication Bus

ADC/DAC

Putting it together…..

Embedded Controller
(Processor)

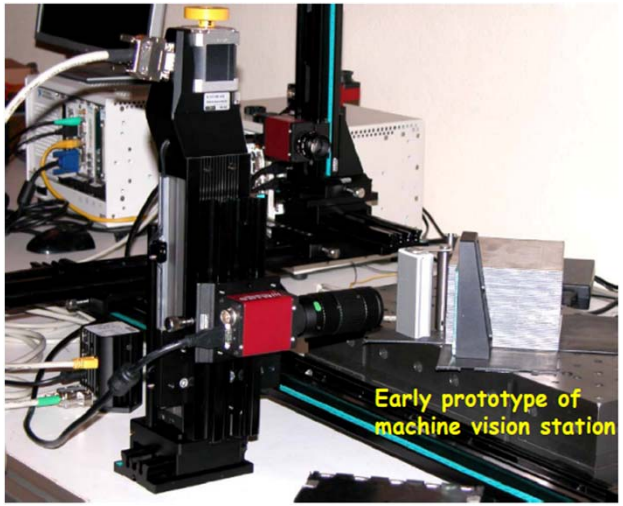
Chassis with T&S
(Communication Bus)

I/O Modules
(ADC/DAC)

INFN Gran Sasso – CERN

OPERA Detector for Neutrino Events

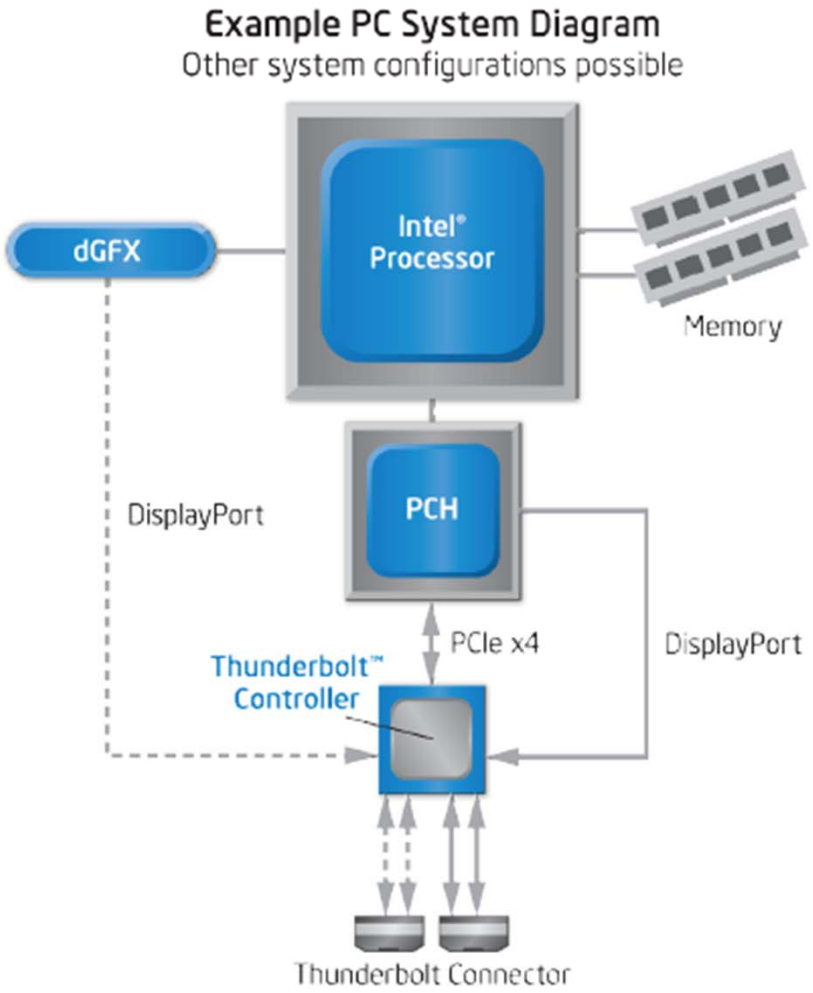
- Brick Assembly Machine for the hybrid detector
  - Machine Vision System
  - Dimensional measurements



- NI platforms provide hardware and software
  - LabVIEW programming environment
  - IMAQ Vision Libraries

Technology Architecture

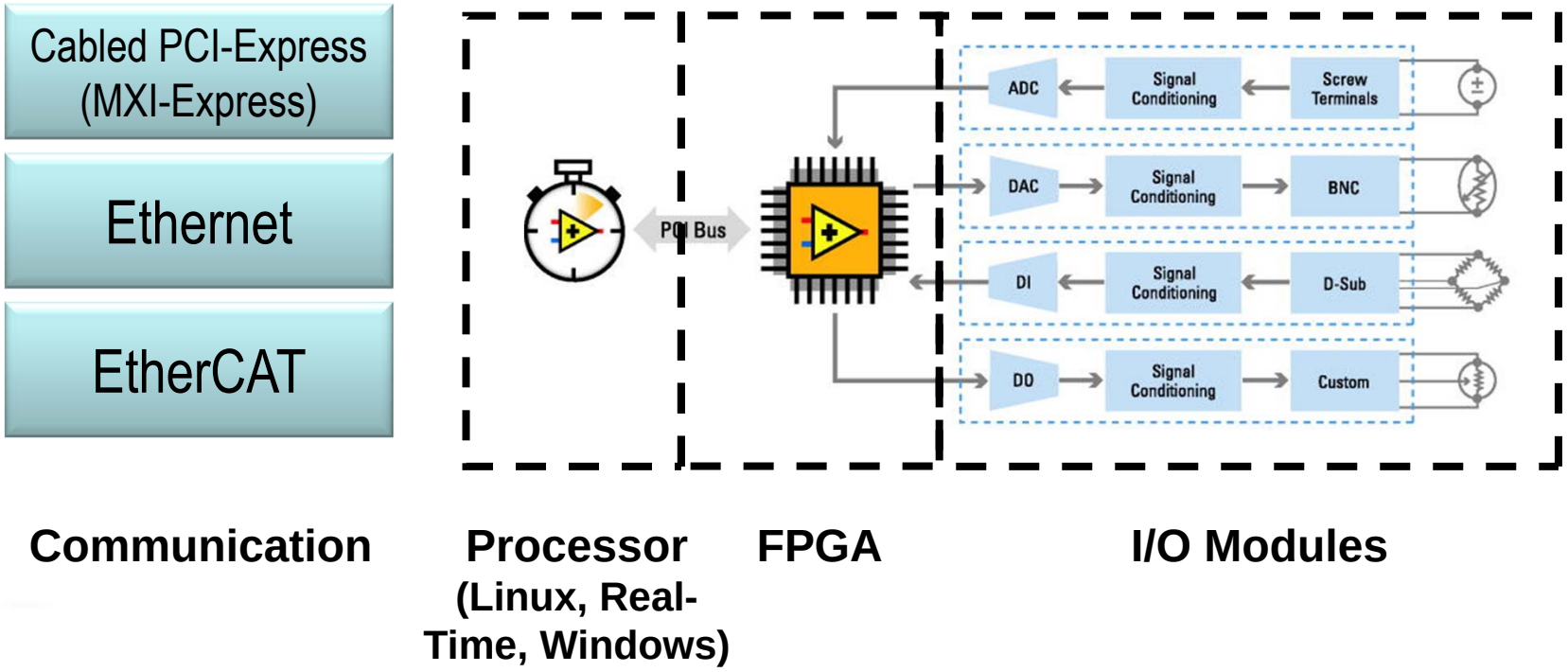
- 10Gbps per channel, bidirectional performance
  - 2 channels per cable
- Native PCIe* and DisplayPort* protocols
  - Uses native PCIe and DP drivers
- Compatible with standard DisplayPort
  - Thunderbolt™ ports can operate in native DP mode
- Small connector with cable options
  - Active electrical cable (up to 3m) w/ 10W power, or can be extended with…
  - Active optical cable (up to tens of meters)
- Daisy chain topologies
  - 6 Thunderbolt devices and 1 native DisplayPort display



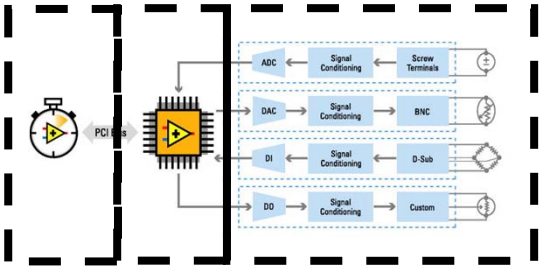
THUNDERBOLT™

IDF2011
INTEL DEVELOPER FORUM

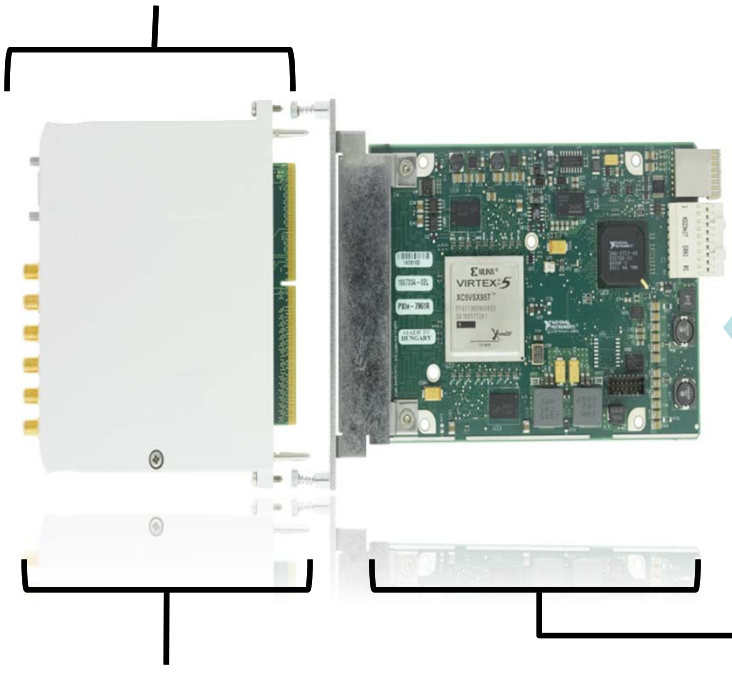
Combining COTS With Your Design: *RIO Architecture*



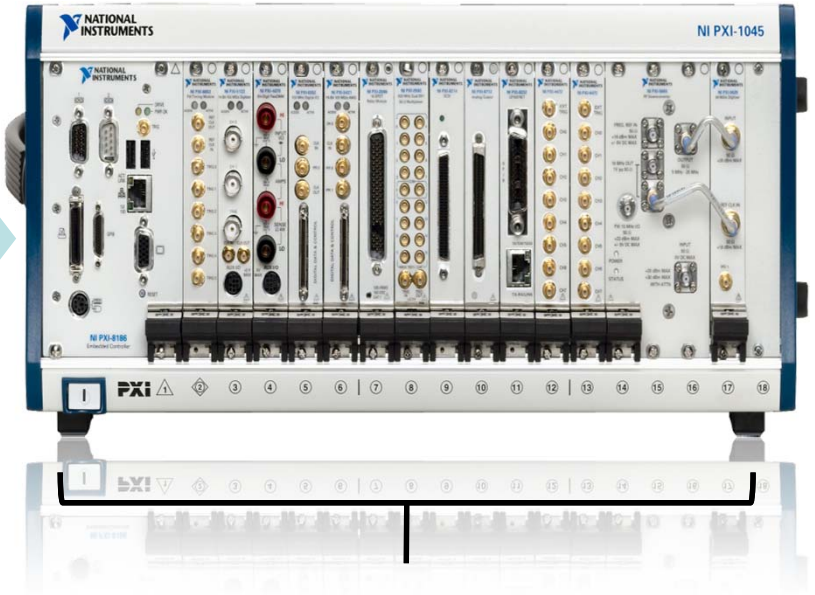
FlexRIO Architecture



Customizable
Front-End



PXI/ PXIe



NI FlexRIO Adapter Module

- Interchangeable I/O
- Digital or analog
- NI FlexRIO Adapter Module Development Kit (MDK)

NI FlexRIO FPGA Module

- Virtex-5 FPGA
- 132 digital I/O lines
- Up to 512 MB of DRAM
- Peer-to-peer data streaming

PXIe Platform

- Data transfer
- Synchronization
- Clocking/triggers
- Power/cooling

Released FlexRIO Adapter Modules

Digital

100 MHz SE DIO

200 MHz LVDS DIO

200 MHz SE/LVDS DIO

Camera Link

RS-485/422

Analog

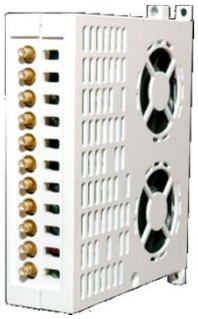
2 ch. 100 MS/s AI/AO

32 ch. 50 MS/s AI

4 ch. 250 MS/s AI

16 ch. 50 MS/s AI

Custom FlexRIO Modules



100 MHz PPMU

Camera Link and GigE

Multi-gigabit optical

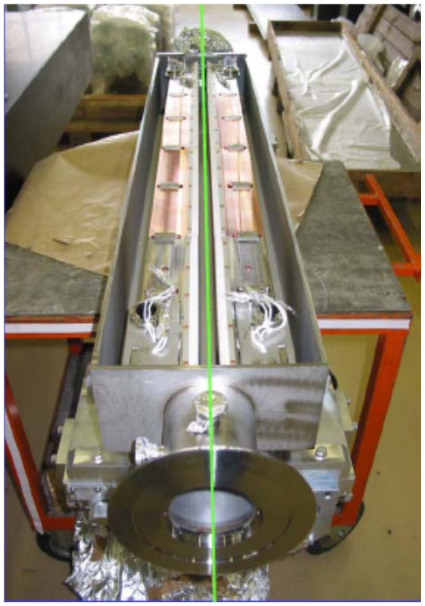
Dual gigabit Ethernet

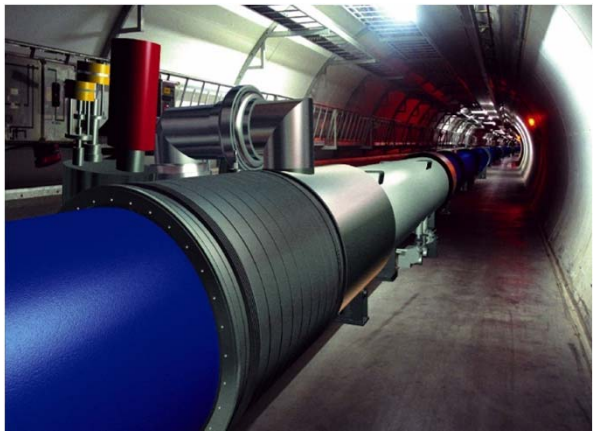
Video and Automotive

Time to Digital Converter

Example - CERN Collimator Alignment

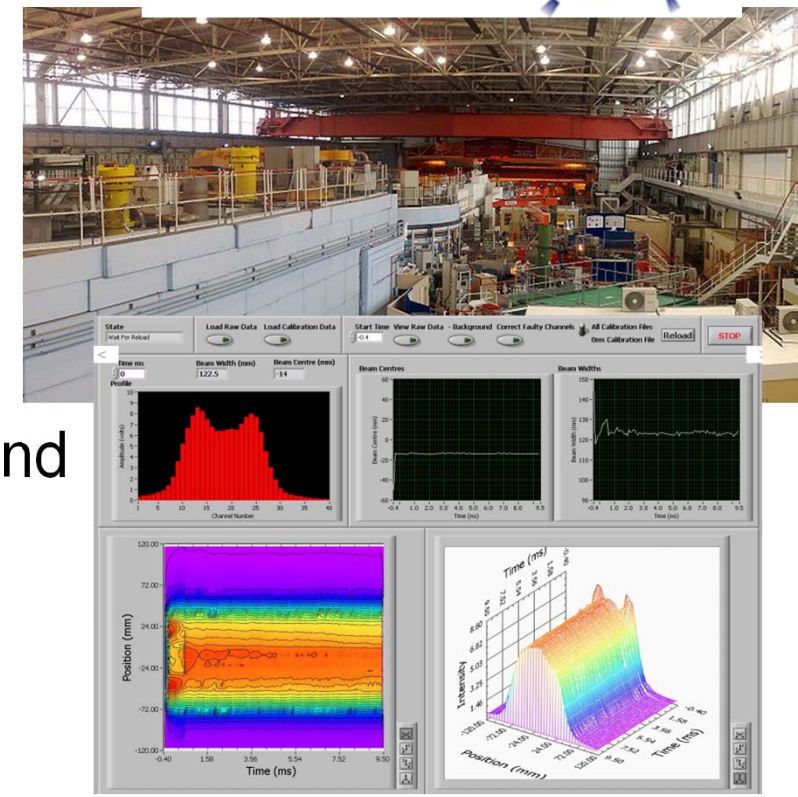
- 550+ axes of motion
- Across 27 km distance
- The jaws have to be positioned with an accuracy which is a fraction of the beam size (200µm)
- Synchronized to
  - < 5ms drift over 15 minutes
  - Maximum jitter in µs



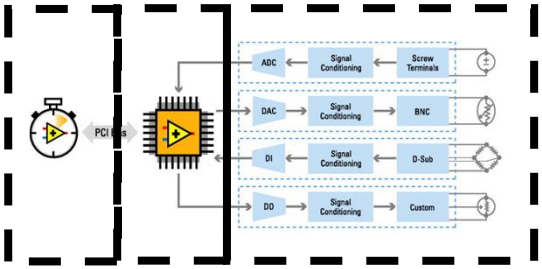


ISIS Synchrotron, Rutherford Appleton Labs

- Beam data acquisition and analysis
  - Beam loss monitoring
  - Beam position monitoring
  - Multichannel profile monitoring
- Hardware based on PXI platform
  - High speed digitizers
  - Timing and synchronization
- LabVIEW based control system and process display data



CompactRIO Architecture



FPGA

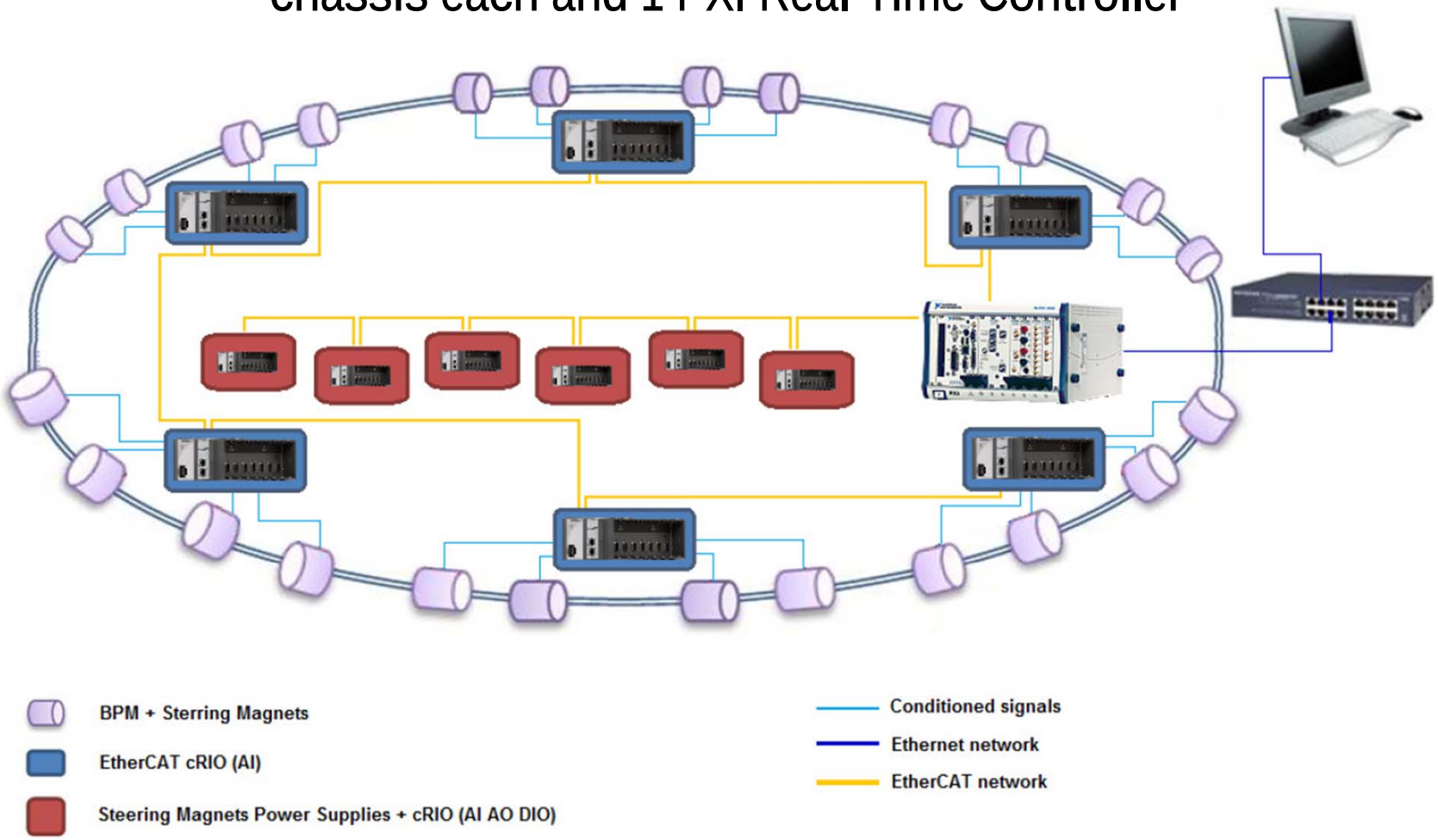
Host Processing Real-Time

Varied Modular I/O for any signal

LNLS – Brazilian Synchrotron

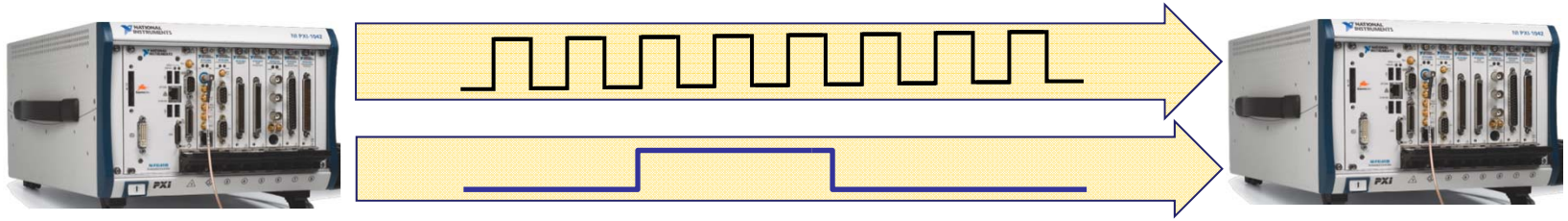
Fast Orbit Feedback Control System

New orbit control system topology: 2 EtherCAT loops with 6 cRIO chassis each and 1 PXI Real-Time Controller



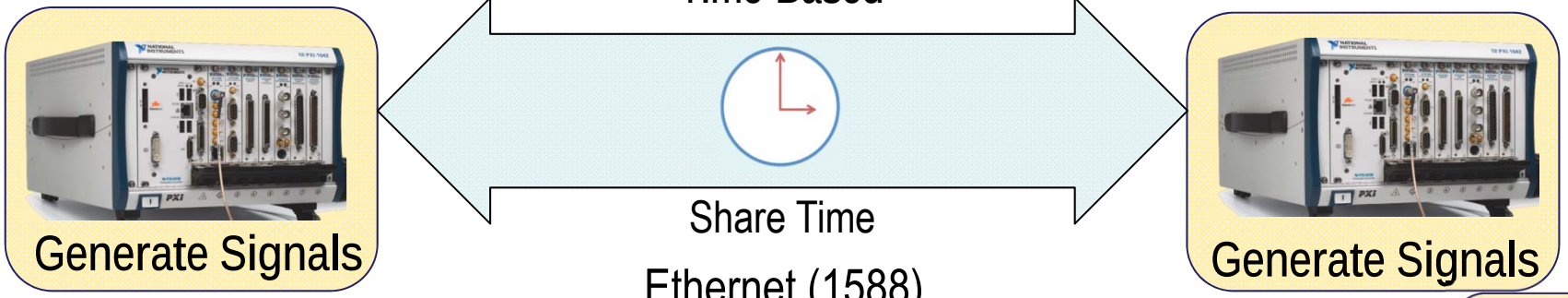
Signal vs. Time-Based Synchronization

Signal-Based



Share Physical Clocks / Triggers

Time-Based



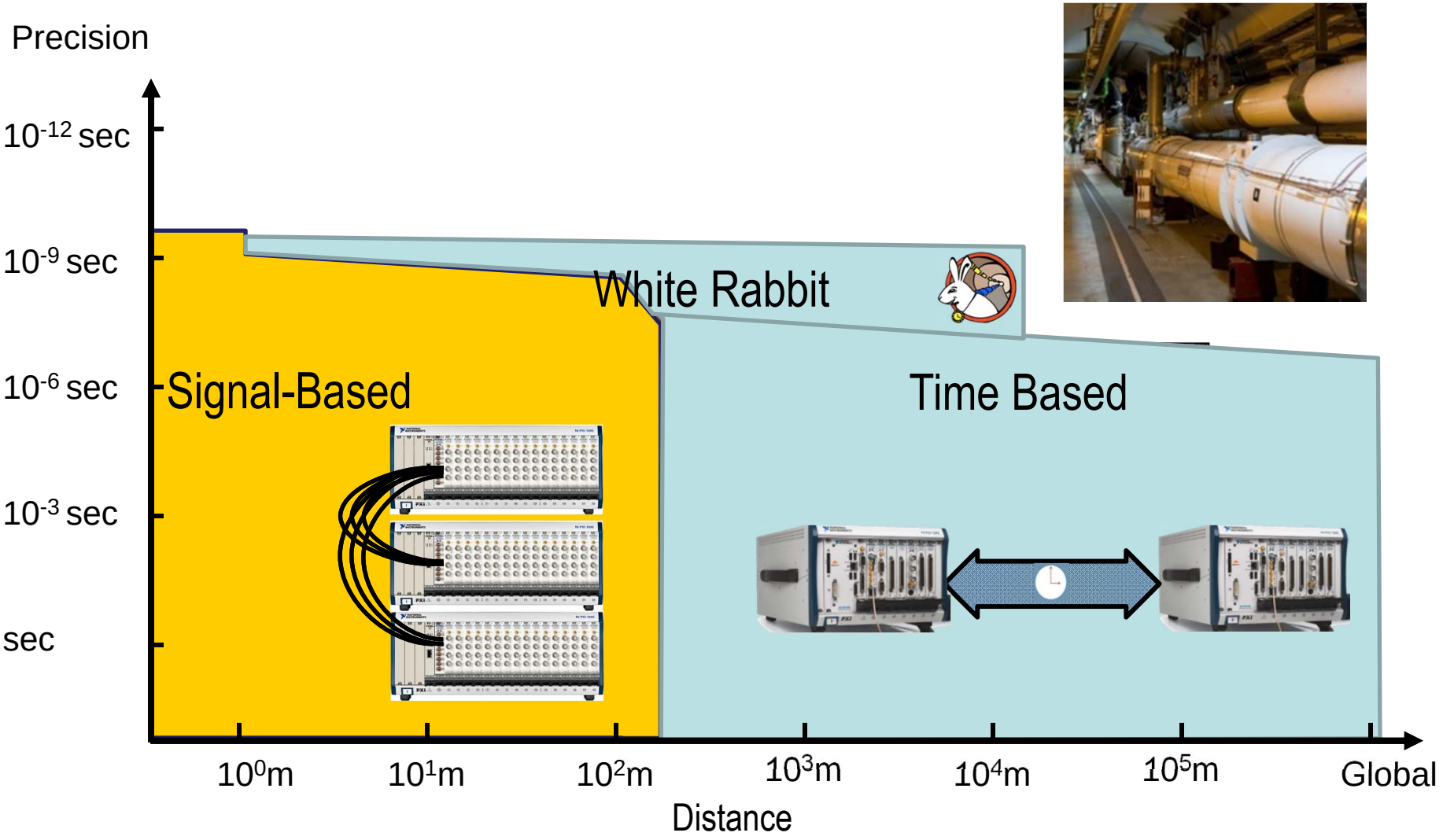
Generate Signals

Share Time

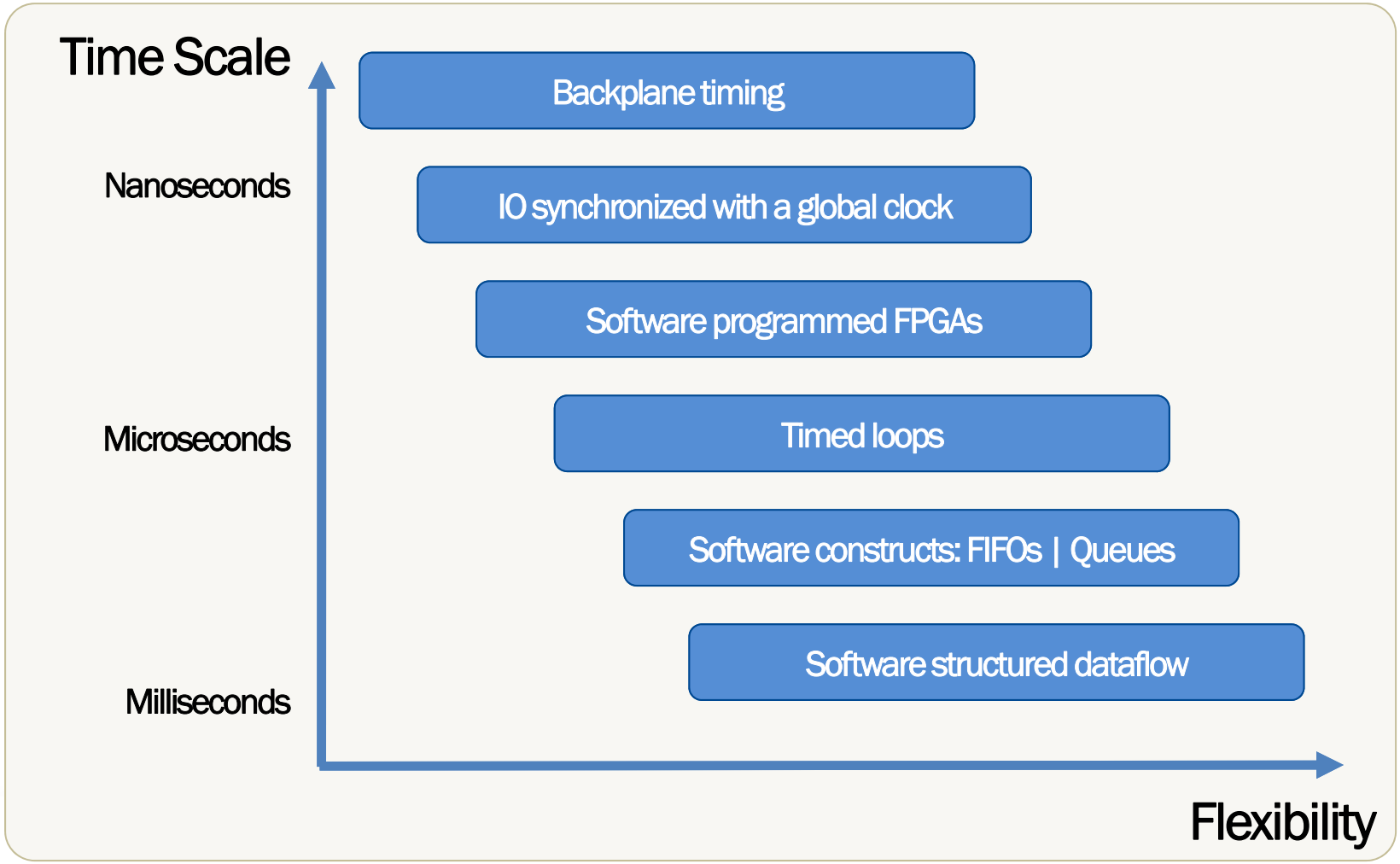
Ethernet (1588)
IRIG
GPS
Etc.

Generate Signals

White Rabbit: Synchronization over Distance



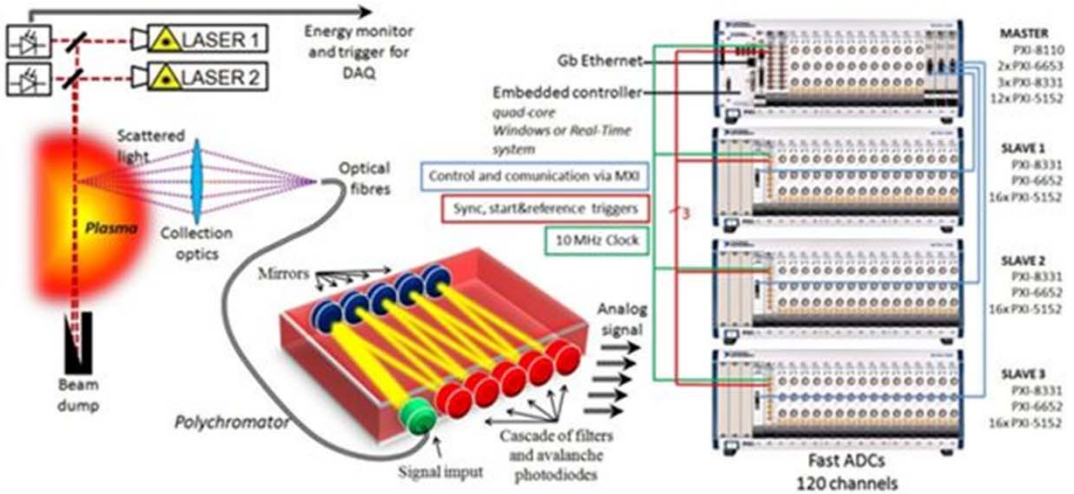
Technologies for Time and Concurrency



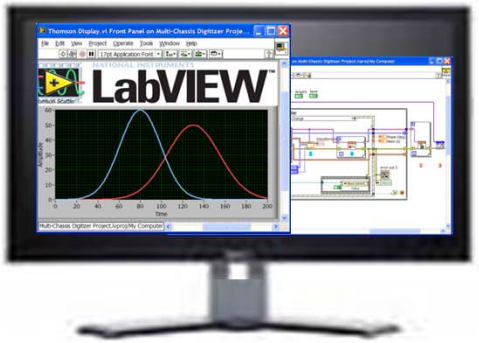
Cooperation: NI and CERN White Rabbit

- Partnering with CERN in developing White Rabbit (WR)
- Performance
  - **Distance:** > 10 km
  - **Scale:** > 2000 nodes
  - **Accuracy:** < 1ns skew, < 100 ps jitter
    - Compensates for propagation delay (cable length, temperature variation, etc.)
- Leverage Industry standards (802.x, IEEE 1588, SyncE)
  - Gigabit Ethernet communication with deterministic capability
- Generally Applicable
- Leverage for future PXIe modules

Czech Institute of Plasma Physics



- Thomson scattering system
- Synchronized high speed data acquisition
  - 120 channels running at 1GS/s
  - Tight synchronization over 4 PXI chassis
  - Skew < 500 ps



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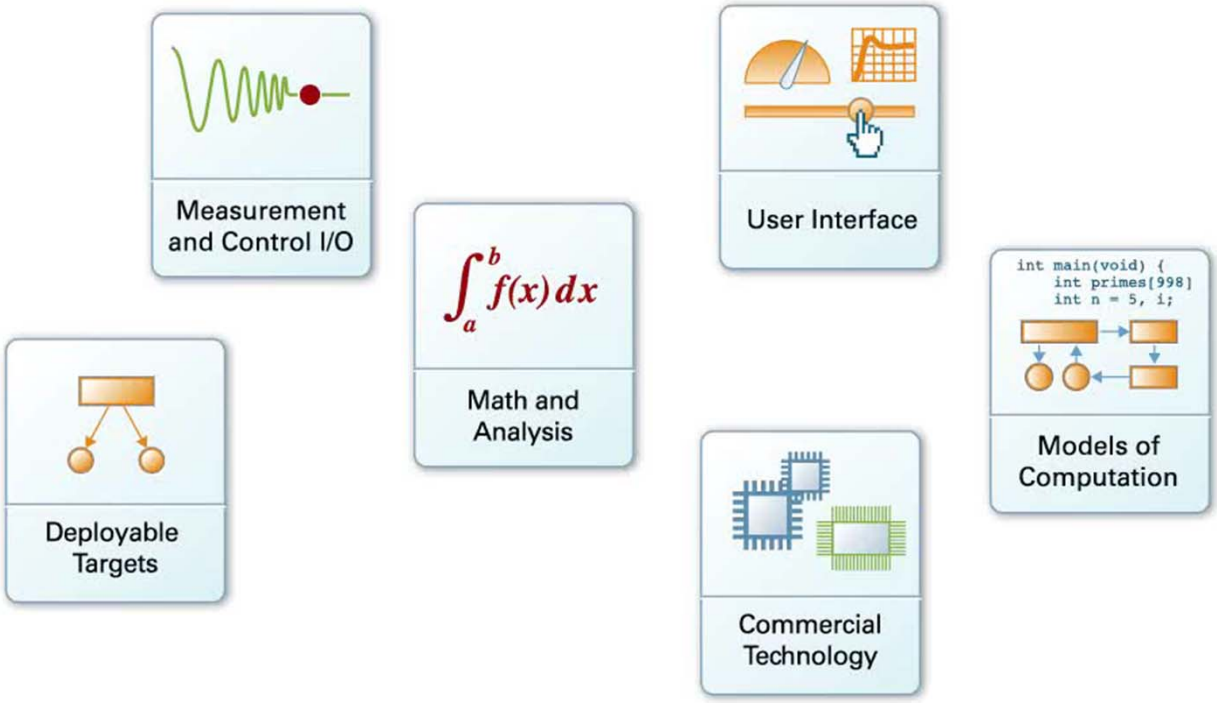
Integrating Elements of Graphical System Design



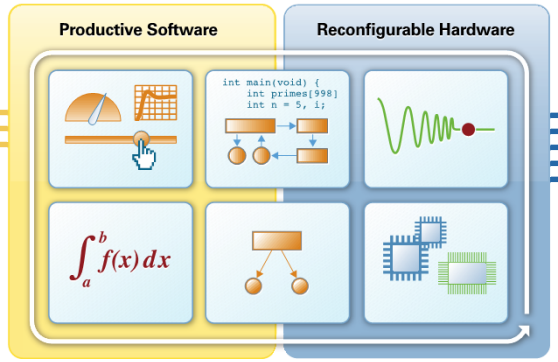
Graphical System Design

Software

COMMUNITY
140,000+ online members
250+ registered user groups
1000+ job postings online
400K+ children through LEGO

CONNECTIVITY
9000+ instrument drivers
8000+ example programs
1000+ motion drives
1000+ smart sensors
1000+ Third-party PAC devices

COLLABORATION
280+ third-party add-ons
400+ Solution partners
1000+ value added resellers
35+ training courses



A WORLD-CLASS TECHNOLOGY ECOSYSTEM

Hardware

PROCESSOR
Intel, Microsoft, Freescale, Wind River
Multi-core and real-time technology

FPGA
Xilinx Virtex & Spartan
Reconfigurable hardware

IP
Control & signal processing IP & I/O drivers
Built-in graphical IP, integrate user IP

I/O
Analog Devices, Texas Instruments
Connect to any sensor & actuator

BUS
PCI/PCIe, Enet, USB, wireless, deterministic Enet, Open architecture

Graphical System Design

A Platform-Based Approach

Test

Monitor

Embedded

Control

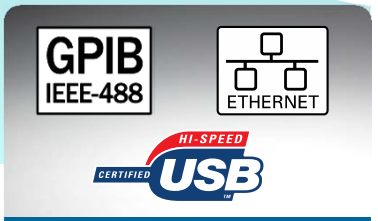
Cyber Physical

NATIONAL INSTRUMENTS LabVIEW™

Desktops and PC-Based DAQ

PXI and Modular Instruments

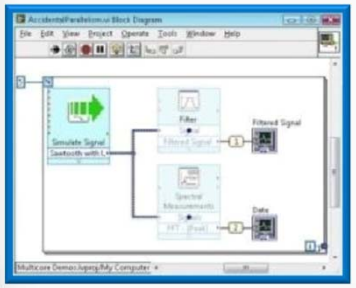
RIO and Custom Designs



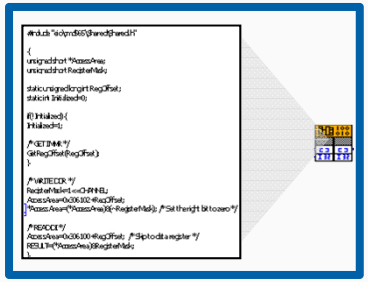
Open Connectivity with 3rd Party I/O

High-Level Design Models

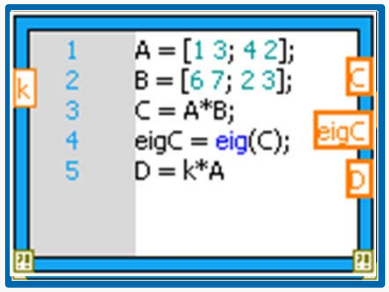
Data Flow



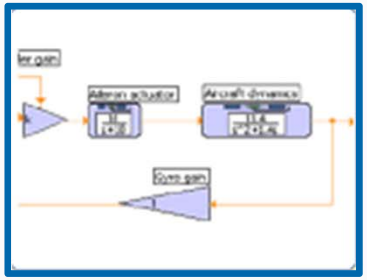
C Code



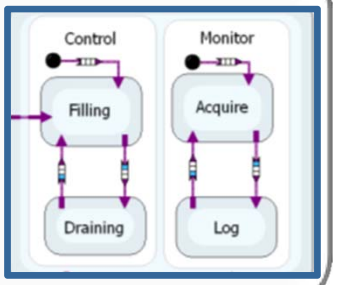
Textual Math



Simulation



Statechart



NATIONAL INSTRUMENTS LabVIEW™

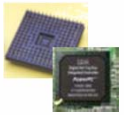
Graphical System Design Platform

PC/Mac/Linux

PXI

CompactRIO

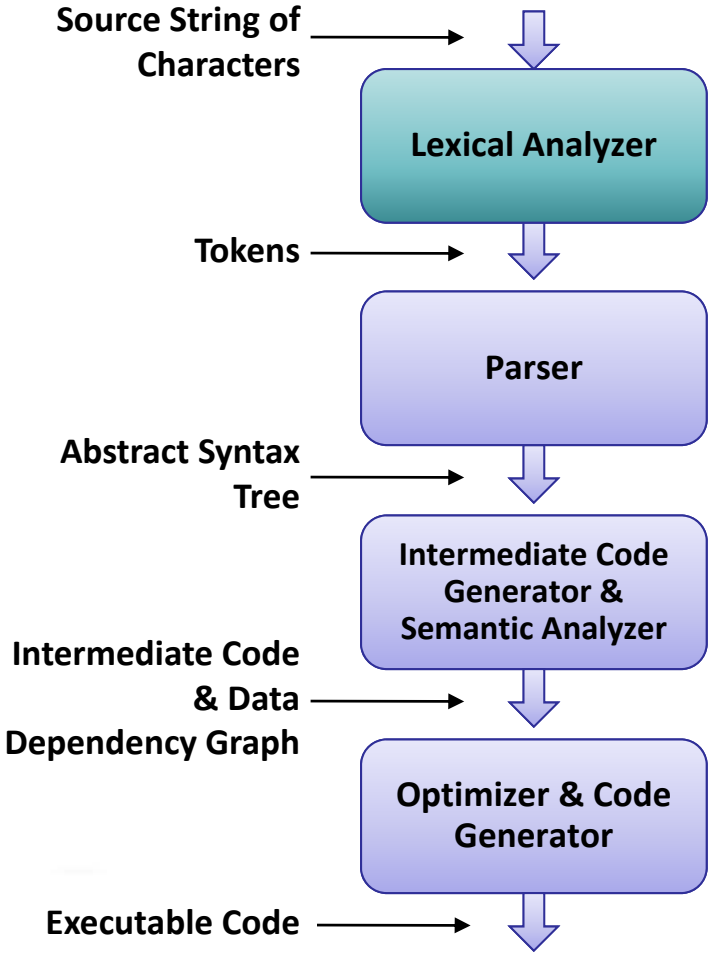
FlexRIO



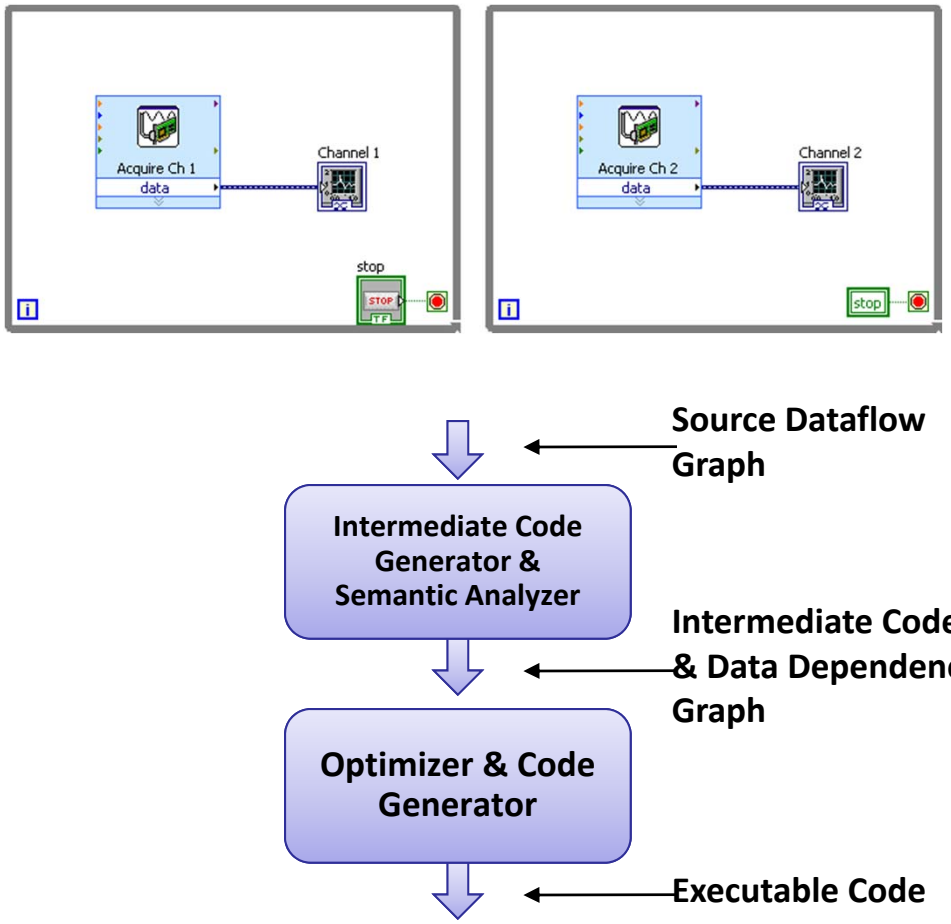
Custom

Eliminating Artificial Complexity

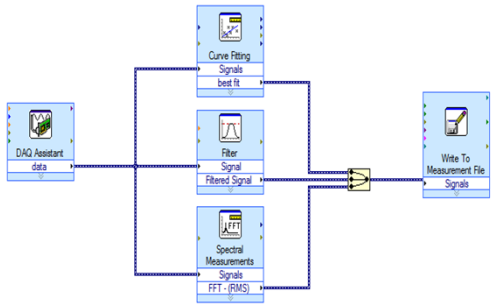
Text-based Compiler



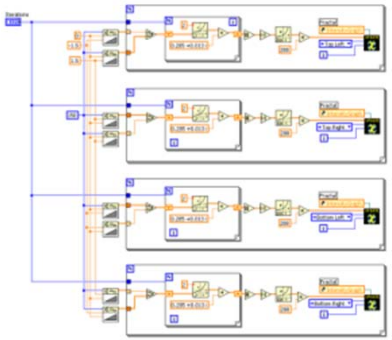
LabVIEW Compiler



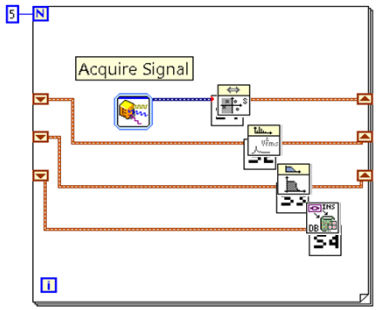
Parallel Programming with LabVIEW



Task Parallelism

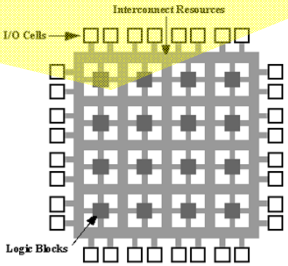


Data Parallelism



Pipelining

Multicore Processors

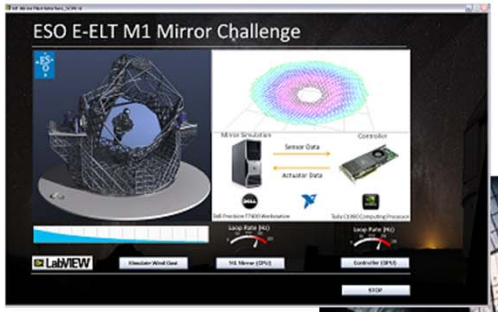


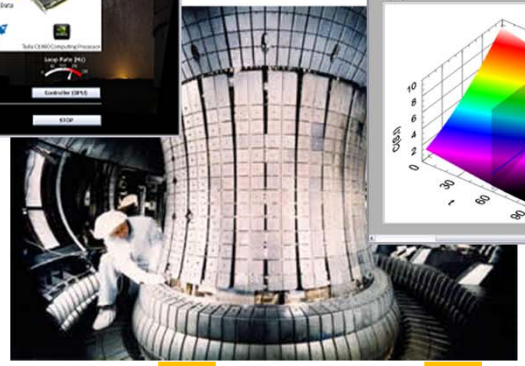
FPGAs

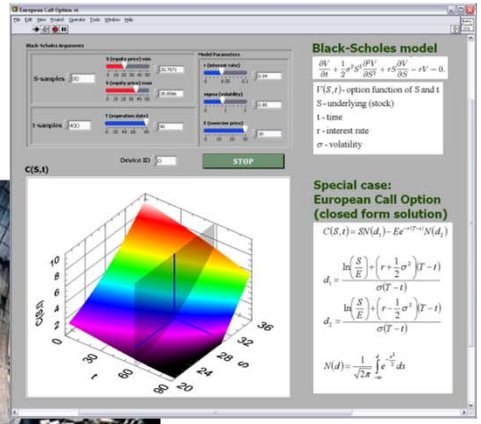
LabVIEW's GPU Computing Module

POWERED BY

NATIONAL INSTRUMENTS LabVIEW™







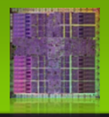
C
C++

OpenCL™

DirectX
Compute

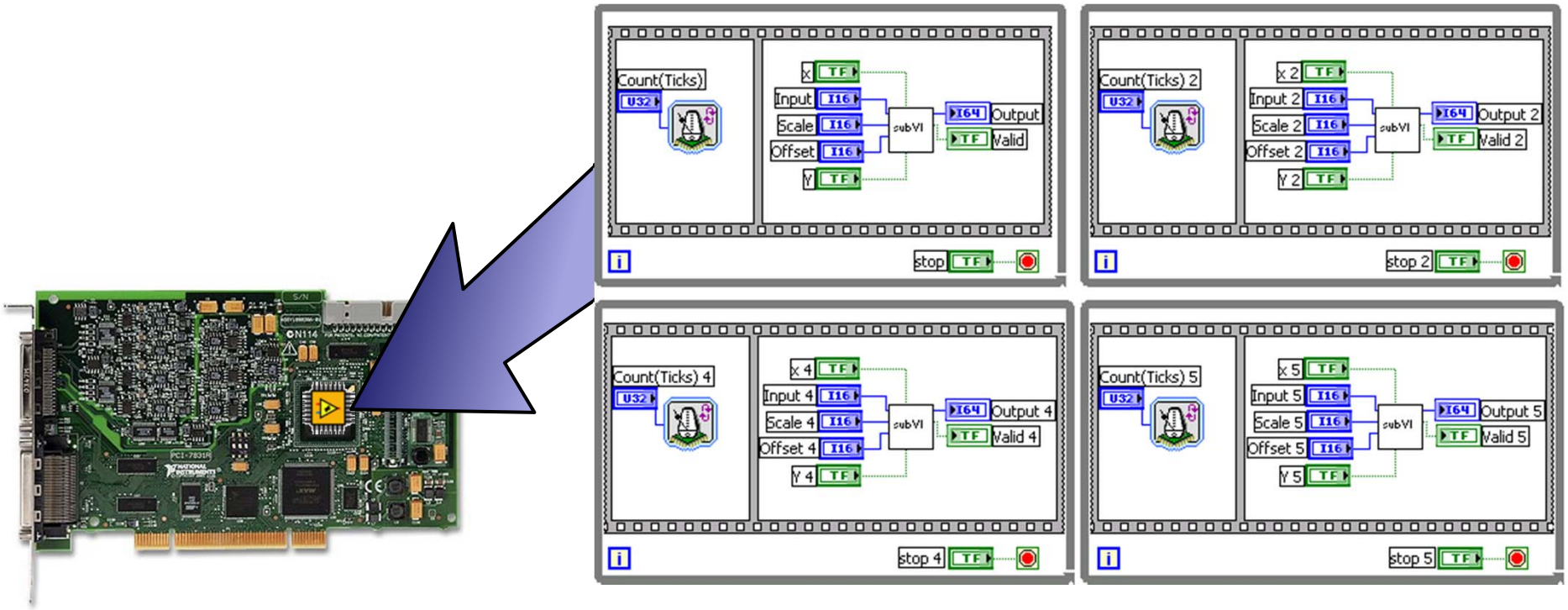
FORTRAN

Java and
Python



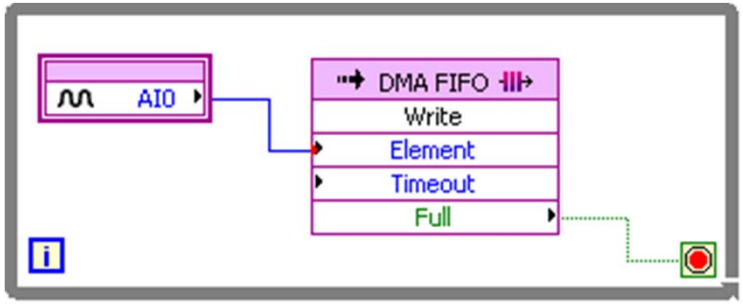
NVIDIA GPU
with the CUDA Parallel Computing Architecture

FPGA Programming: Multicore, Multiprocessor Development



Abstraction to the Pin

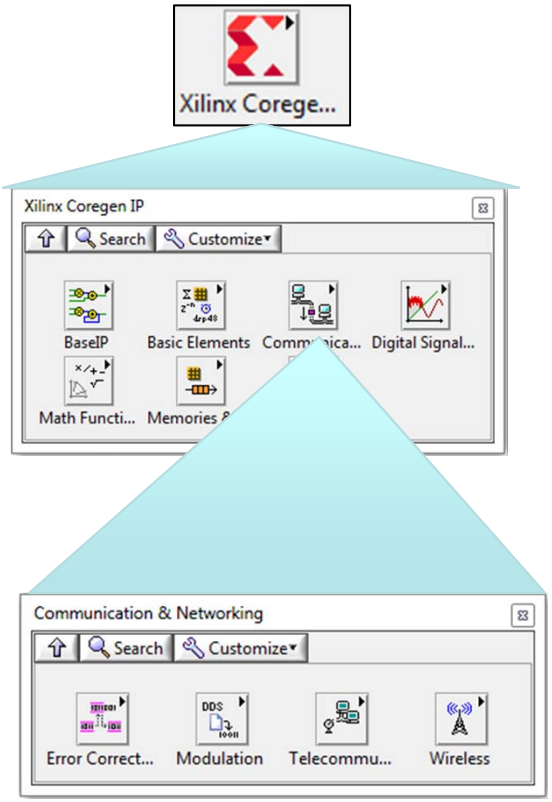
VHDL

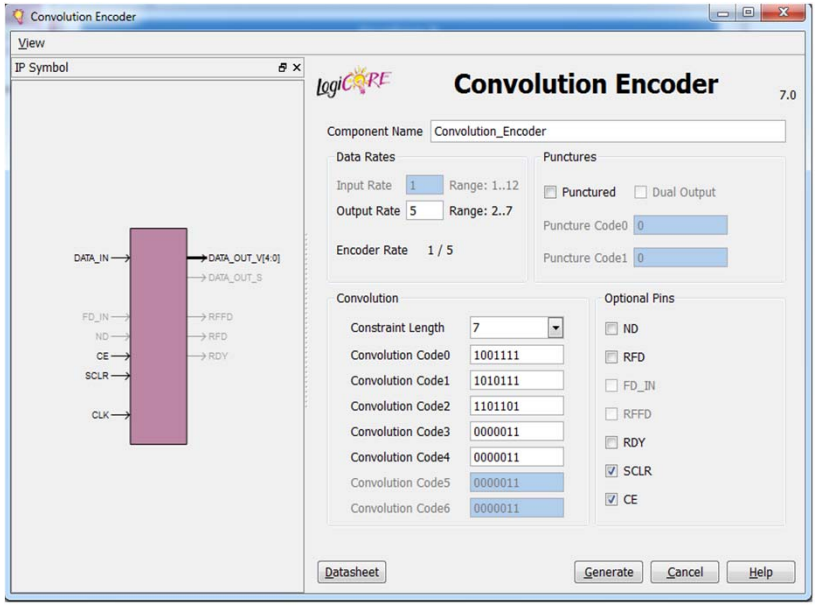


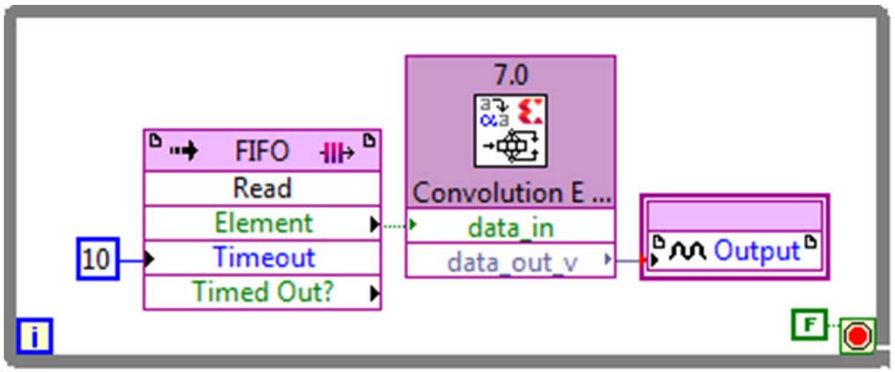
LabVIEW FPGA

LabVIEW FPGA

Direct Access to Preexisting Xilinx CORE Generator IP Libraries







LabVIEW FPGA IP Integration Node

1

Use Core Generator or Custom VHDL

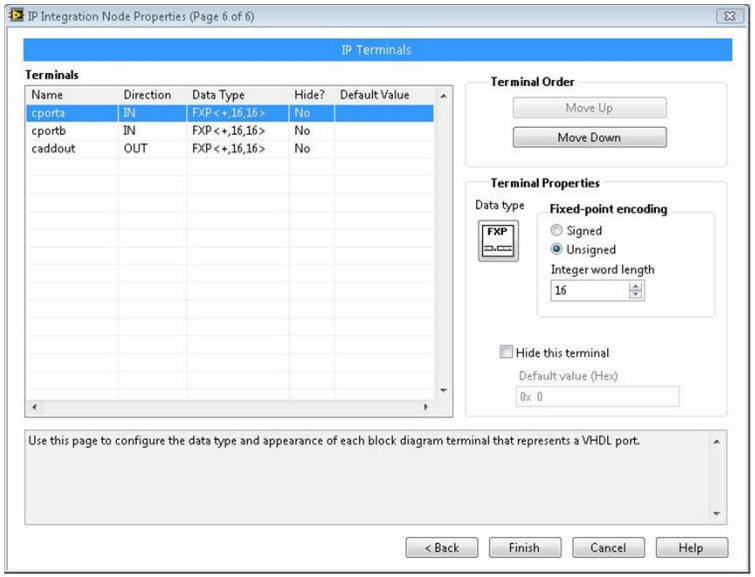
XILINX®

LogiCORE

```
aclr : in    std_log
clk  : in    std_log
a    : in    std_log
b    : in    std_log
q    : out   std_log
```

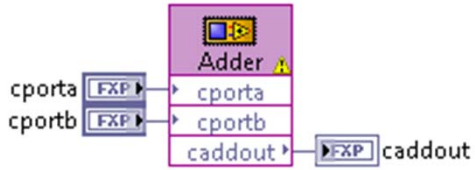
2

Configure IP Integration Node and Generate Simulation Model



3

Use the IP Block Using Standard LabVIEW I/O Interfaces



Cycle-Accurate Simulation with ModelSim

LabVIEW
Platform

LabVIEW FPGA

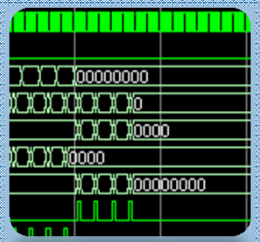
Xilinx IP

VHDL

HDL IP

Simulation Export

ModelSim/iSim



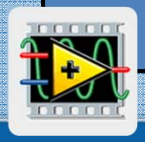
VHDL

Test Bench

I/O Nodes
Controls/Indicators
DMA FIFOs
CLIP I/O

VHDL

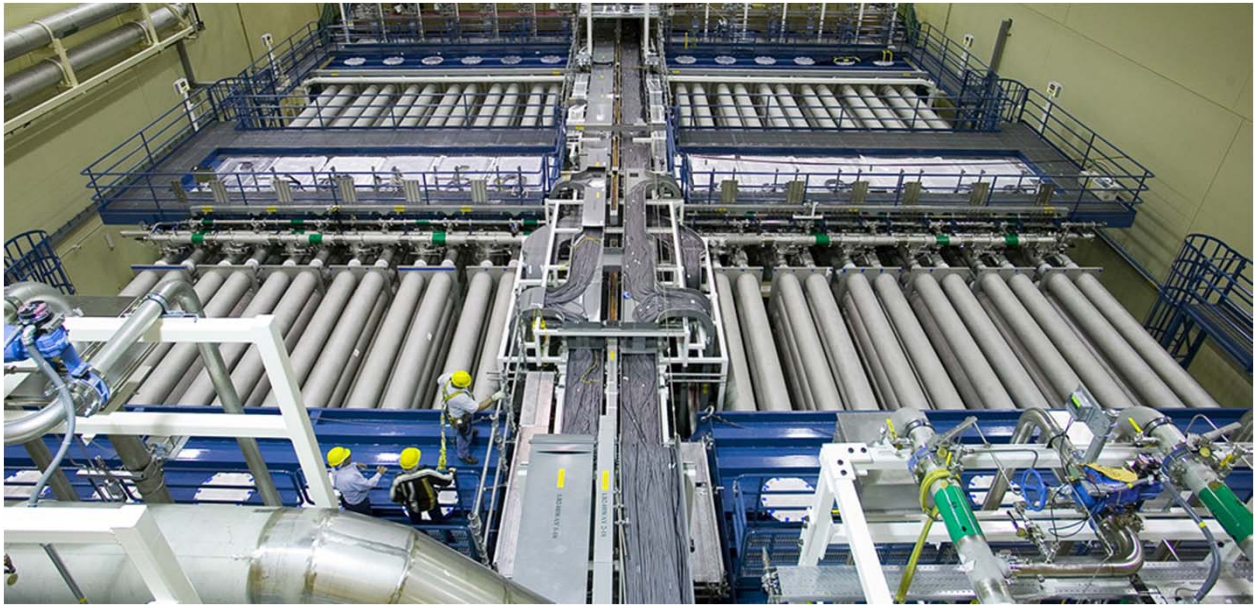
Generated VHDL



Lawrence Livermore National Labs

Developed automated maintenance process for world's largest laser array at the National Ignition Facility using NI LabVIEW and PXI

- LabVIEW increased productivity by 3X over Java and C++
- Developed complex application consisting of over 1,000 VIs

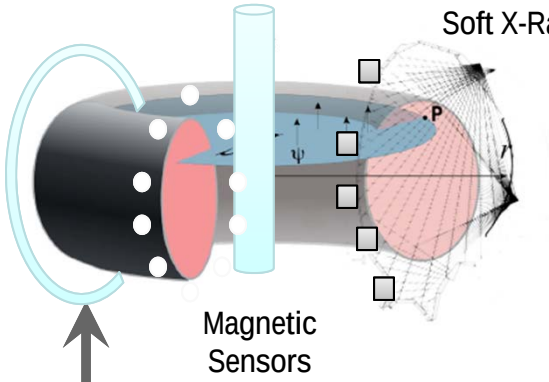


An overhead view of one of the main laser chambers

"The value in using the graphical dataflow language is the speed in which a team can deliver a robust solution while still using proper software engineering practices.

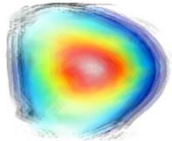
- Glenn Larkin, LLNL

Example -Tokamak – Shape Control



Bolometric Sensors

Tomography



Grad-Shafranov Solver

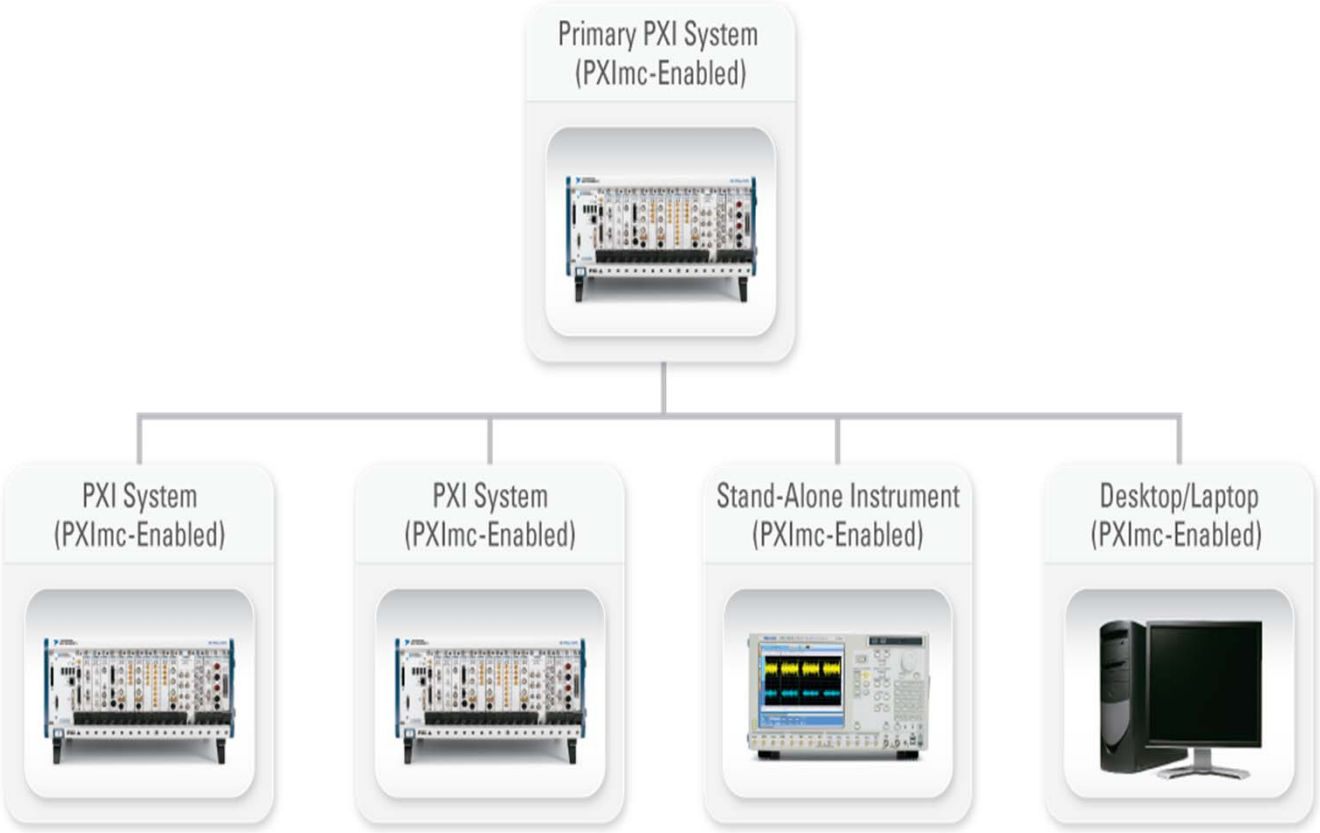
Shape Reconstruction

$$R\frac{\partial}{\partial R}\left(\frac{1}{R}\frac{\partial \psi}{\partial R}\right)+\left(\frac{\partial^2 \psi}{\partial Z^2}\right)=-\mu_o R j_\vartheta$$

Controller
PID, MIMO

Target Shape

PXI Multi-Controller (PXImc)



One Way Latency = 6 uS, Throughput = 670 MB/S

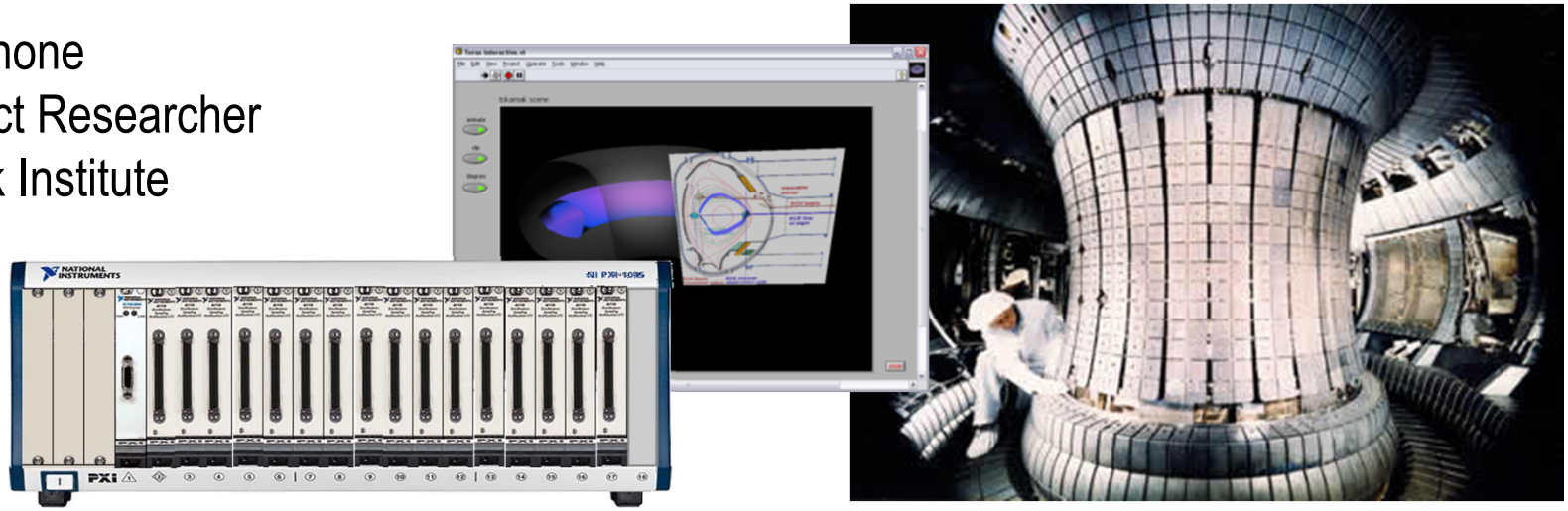
Plasma Diagnostics & Control with NI LabVIEW RT

Max-Planck-Institut für Plasmaphysik

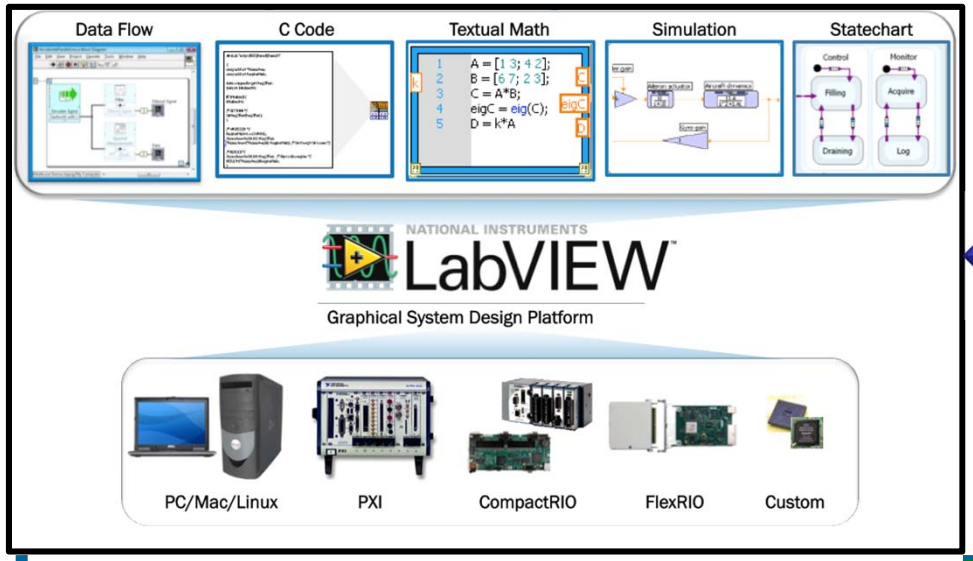
- Max Planck Institute
- Plasma control in nuclear fusion Tokamak with LabVIEW on an eight-core real-time system

*"…with LabVIEW, we obtained a 20X **processing speed-up** on an octal-core processor machine over a single-core processor…"*

Louis Giannone
Lead Project Researcher
Max Planck Institute



Open Architecture



Standard Middleware API

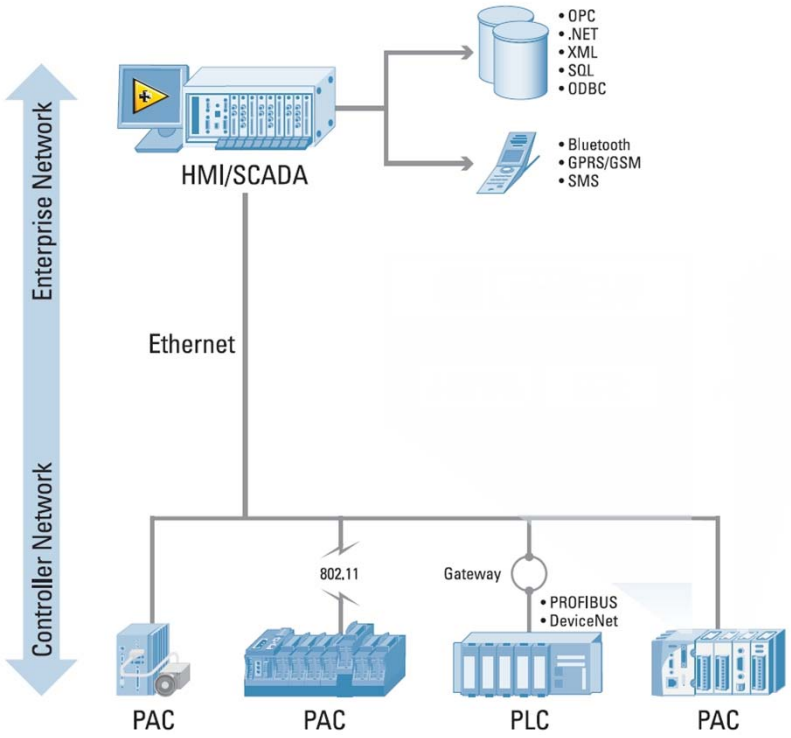
Enterprise Software (For SCADA, data storage,..)

Domain Specific Language

General Purpose Language

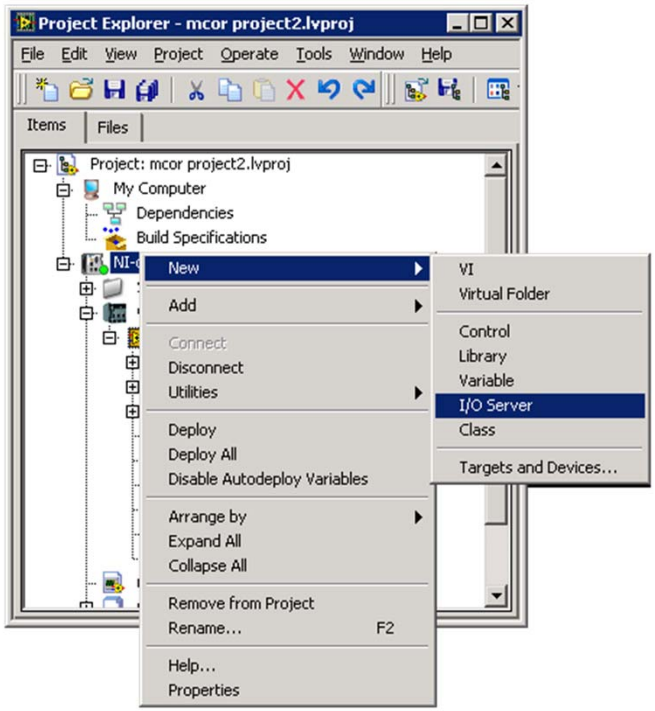
Open Architecture

- Controls standards
  - EPICS, TANGO, CORBA, TINE, C
- Connectivity to different devices
  - OPC, Modbus, TCP/IP, UDP, EtherCAT, Serial
- Flexibility
  - Windows, RTOS, FPGA



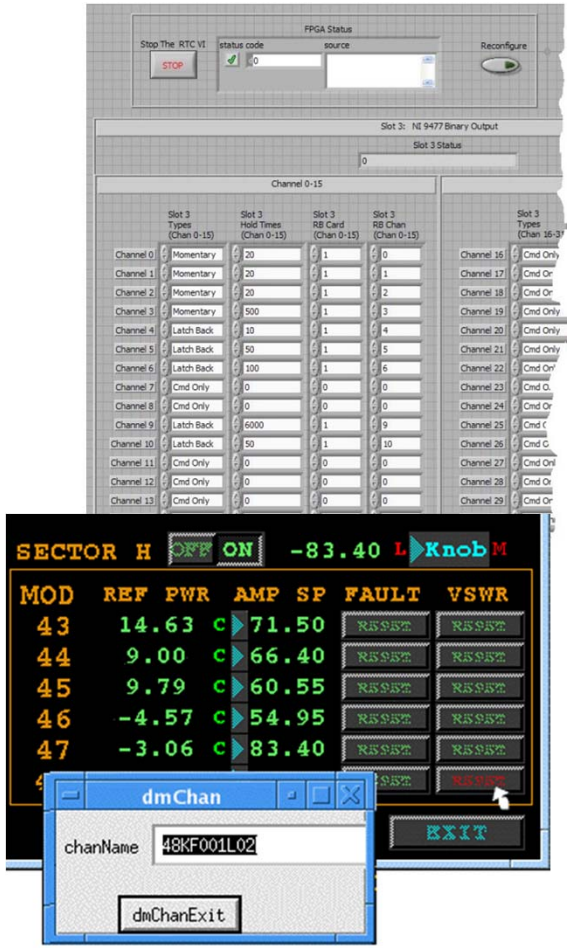
EPICS Integration With LabVIEW

- Native LabVIEW support for Channel Access server and client
  - Windows
  - RT - VxWorks & Pharlap (Server only)
- Option to run full EPICS IOC server side by side with LabVIEW RT
  - Custom option for CompactRIO
- Prototype EPICS device driver support for FPGA-based products
  - Linux
- Linux support with Hypervisor



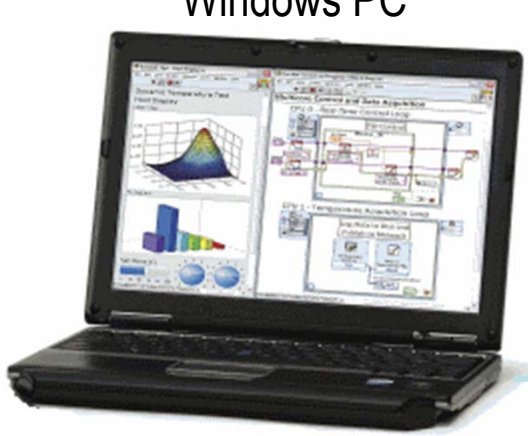
Example – Los Alamos LANSCE

- Ongoing migration to a cRIO system with embedded EPICS
- Full IOC functionality
- Maximum flexibility for partitioning the problem
  - LabVIEW for beam diagnostic
  - EPICS for industrial control



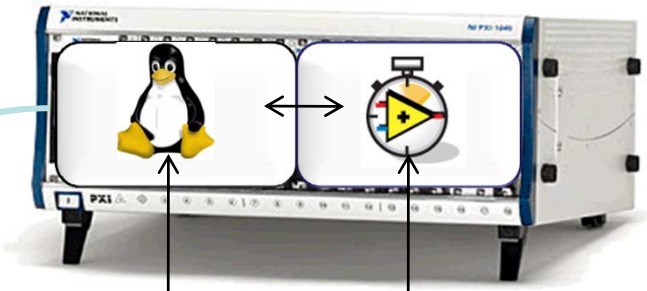
Real-Time Hypervisor for Linux

Windows PC



*Must program LabVIEW Real-Time application from Windows

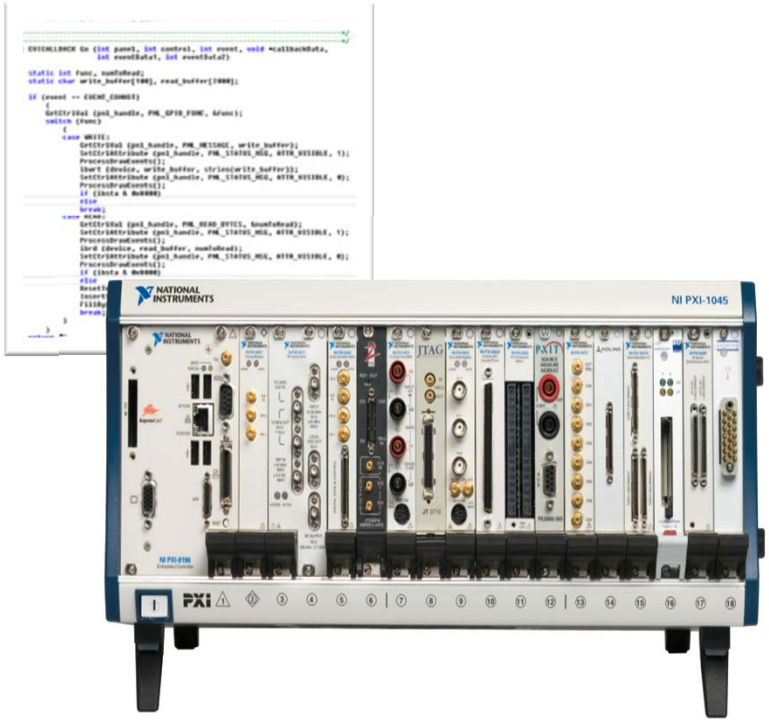
Hypervisor System*



Supported Linux I/O

Supported RT I/O

FPGA Interface C API for Linux



Linux Target (RHEL or Scientific)

FPGA Interface
C API

NI FPGA Device

Examples – FPGA Interface C API for Linux

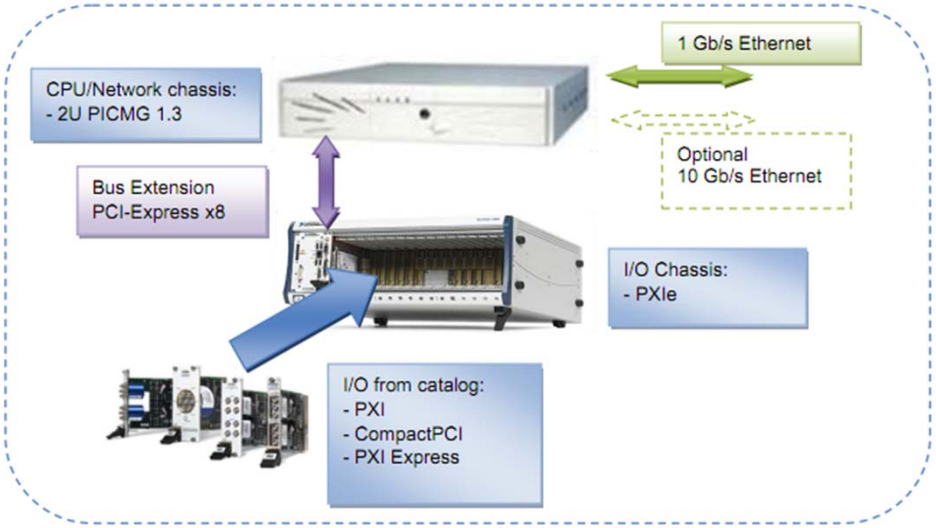


Figure 1 – A General Purpose Fast Controller

Courtesy: www.ITER.org

- Prototype for ITER Fast Controller
  - PXI FlexRIO
- Prototype for ITER Interlocks
  - CompactRIO expansion chassis

- Project under work at
  - SPring8
  - NIFS
  - PSI

Partnership with Industry

Continuous innovation

- Leverage R&D investment and latest technology
- Tools and platforms that allow faster iteration

Simplification and cost reduction

- Empower domain experts
- Open platforms to adapt vertical and emerging standards

Long term maintenance and support

- Life cycle management
- Services and consulting

Local Support around the Globe

Direct Operations in more than 40 Countries

- Global team of technical sales engineers
- Local technical support worldwide
- Systems engineers to assist with reference and application designs
- Active online user community and extensive online support 24 hours a day

NI Services

Minimize Project Risk | Save Development Time | Reduce Deployment Costs

Software Services

Software Subscriptions

Volume Programs

Hardware Services

Warranty and Repair

Calibration

System Services

Training and Certification

Product Training

Custom Training Plans

Professional Certifications

Value-Added Services

Technical Support Programs

Professional Services

Partner-Provided Services

Alliance Partners Program

Worldwide network with 600+ companies in 40+ countries offering:

Services
Consulting, programming, integration, and project management

Products
Toolkits, sensors, cameras, motors, add-ons, and more

Systems
customized turn-key solutions, productized systems, and more

NI & Physics Community

35 Years of Successful Cooperation

Continuous innovation

- Leverage R&D investment and latest technology
- Tools and platforms that allow faster iteration

Simplification and cost reduction

- Empower domain experts
- Open platforms to adapt vertical and emerging standards

Long term maintenance and support

- Life cycle management
- Services and consulting

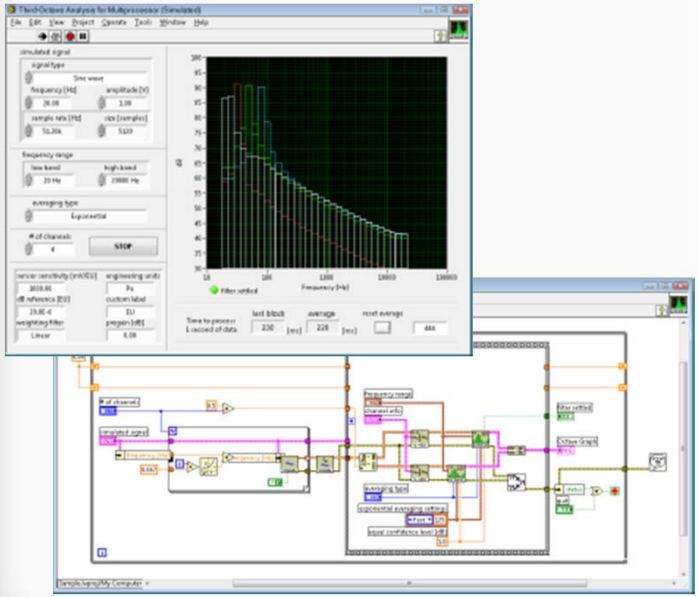
Graphical System Design

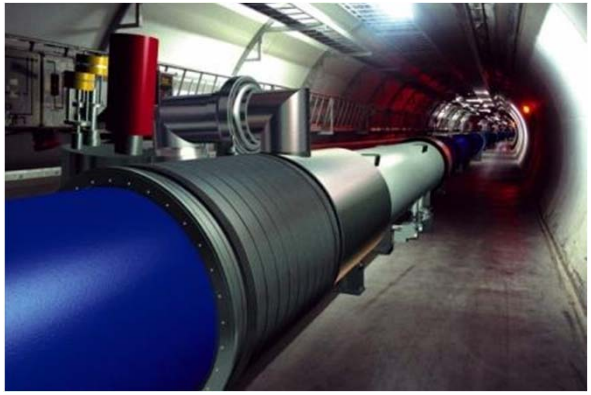
LEGO® MINDSTORMS® NXT

"the smartest, coolest toy of the year"

POWERED BY

NATIONAL INSTRUMENTS LabVIEW™





CERN Large Hadron Collider

"the most powerful instrument on earth"


NATIONAL
INSTRUMENTS™