NATIONAL INSTRUMENTS™

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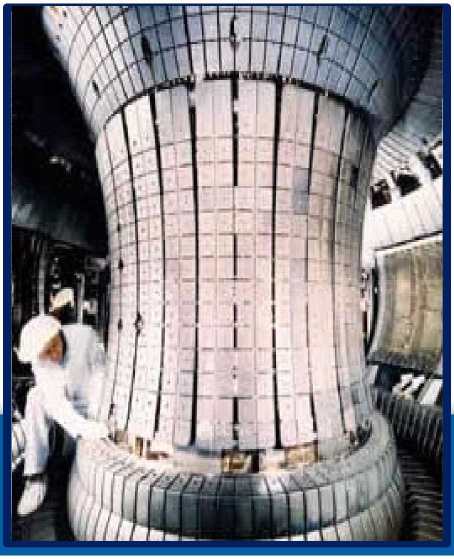
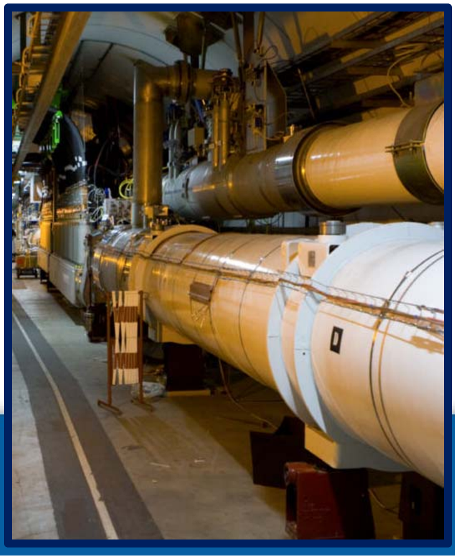
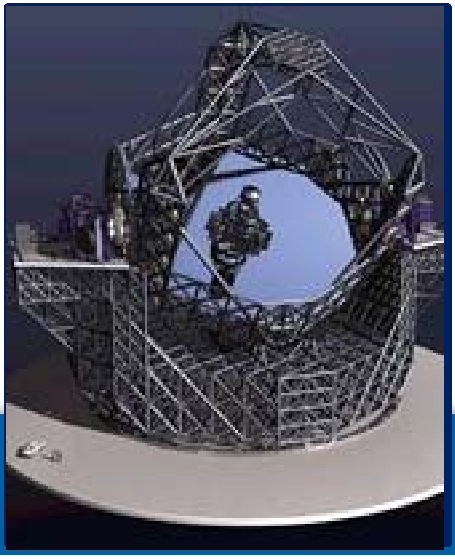
Customized Off-The-Shelf Technologies Through Industry – Research Facility Partnership

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

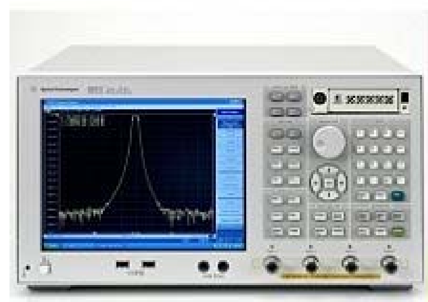
Vacuum Tube

General
Radio

1920

Transistor

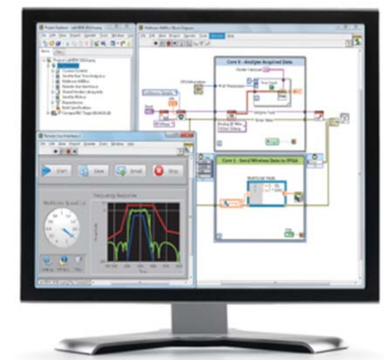
(Integrated Circuit)



Hewlett
Packard

1965

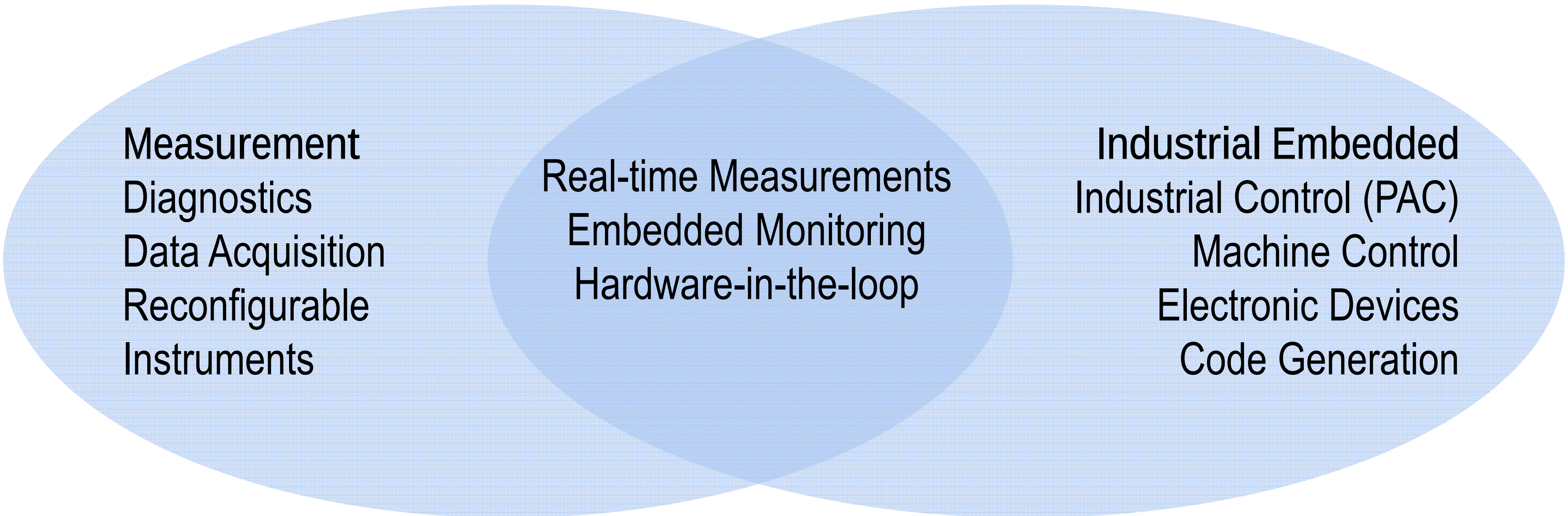
Software



National
Instruments

2010

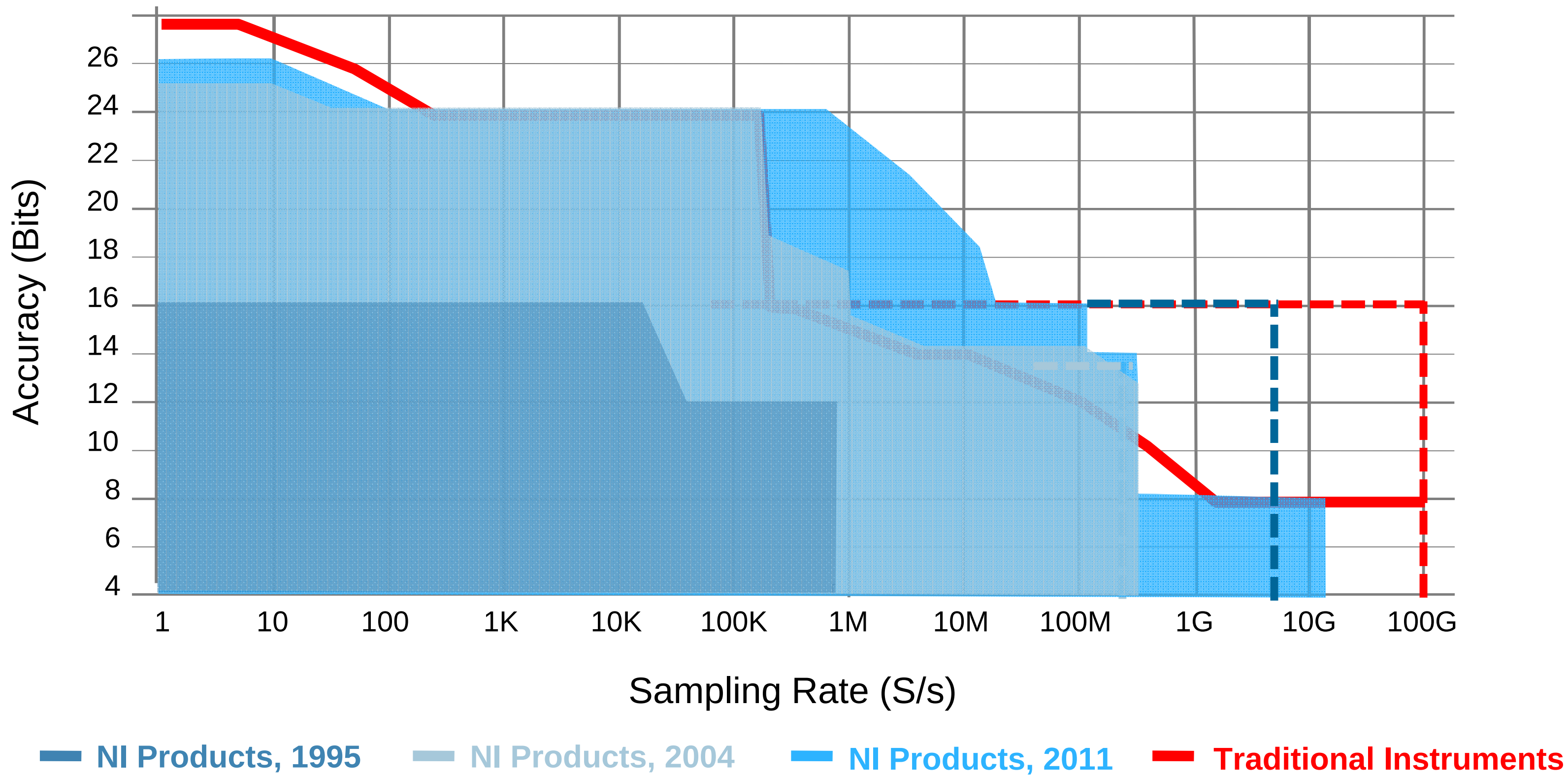
The National Instruments Vision, Evolved… Graphical System Design



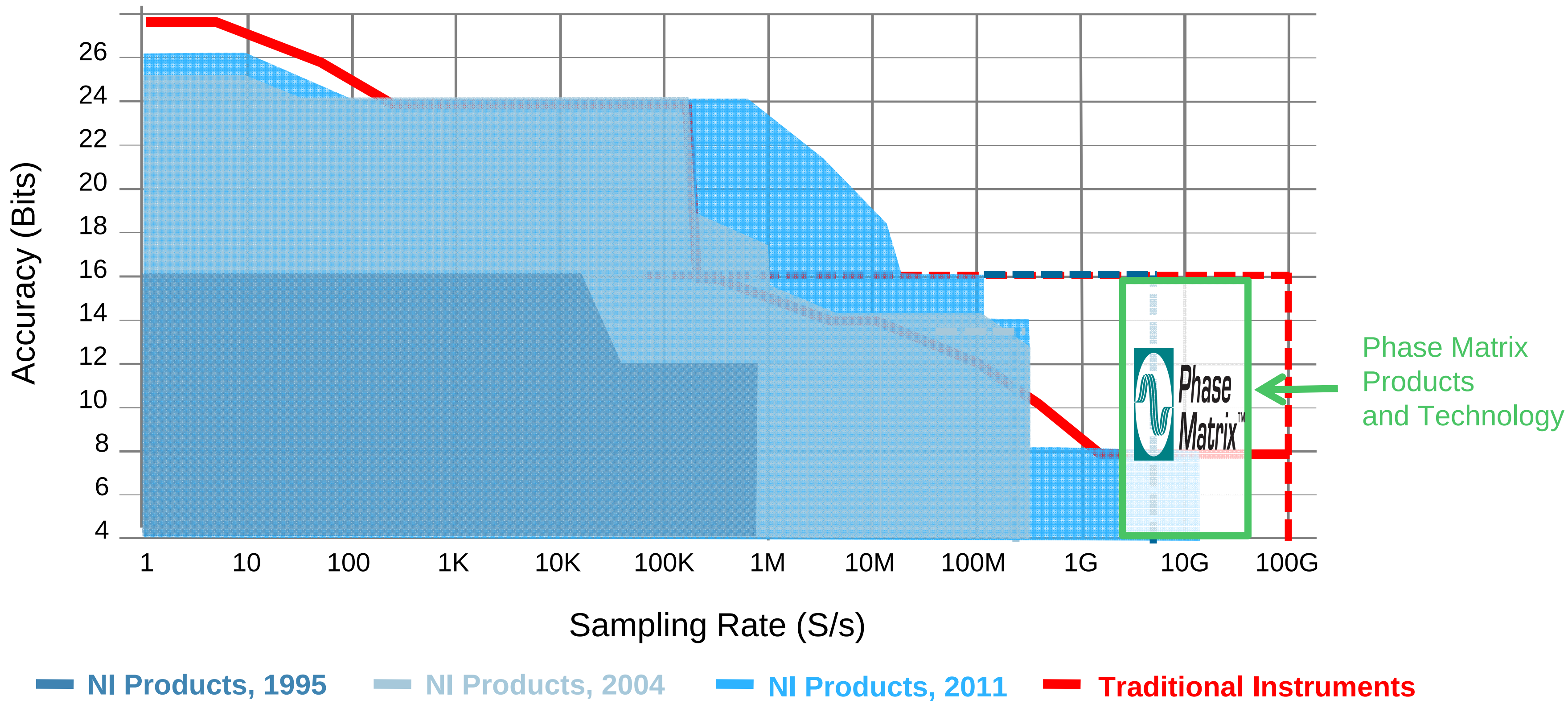
"To do for test and measurement what the spreadsheet did for financial analysis."

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

Expanding Measurement Capabilities

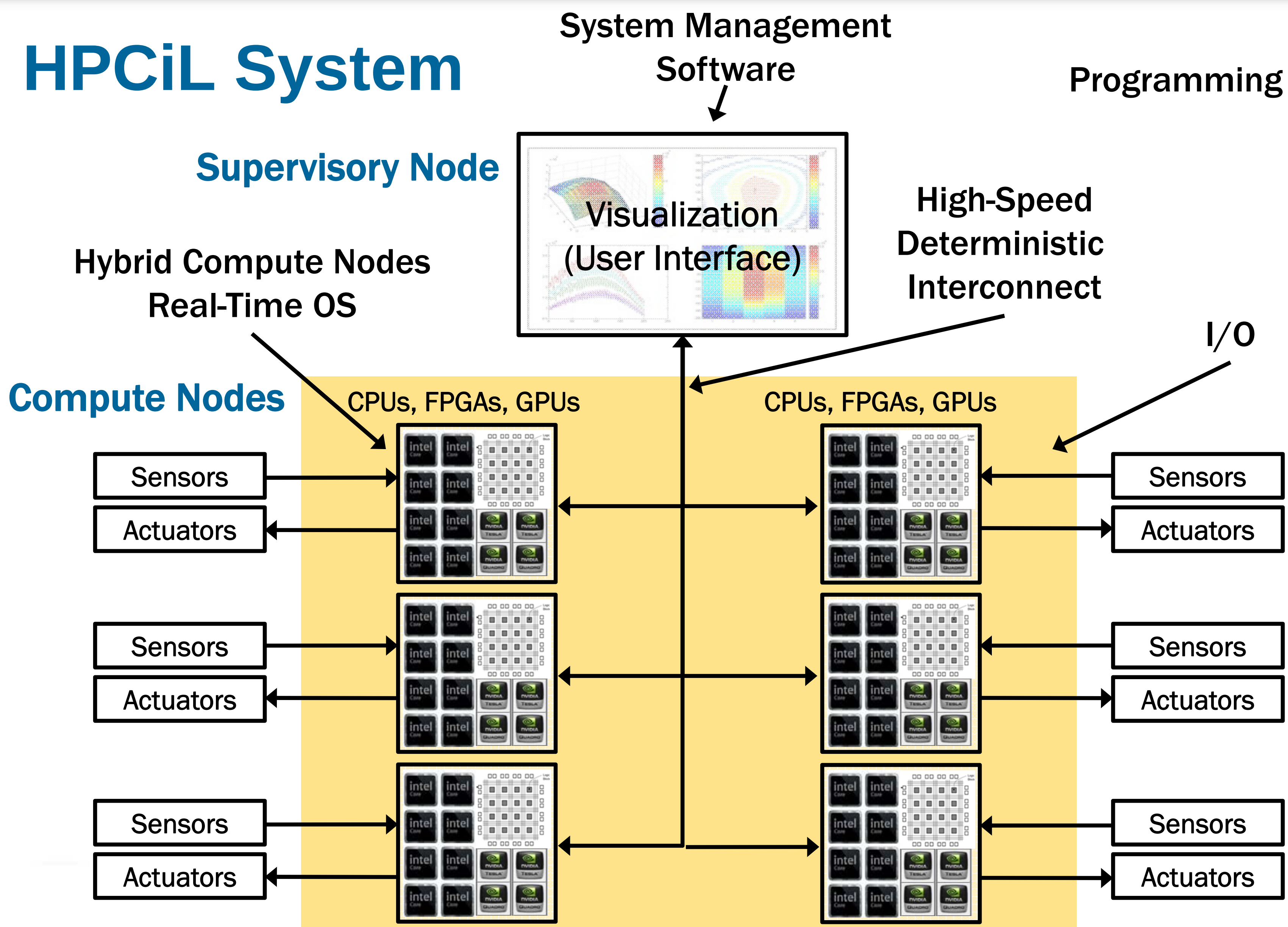


Expanding Measurement Capabilities



HPCiL System

Programming Tools



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

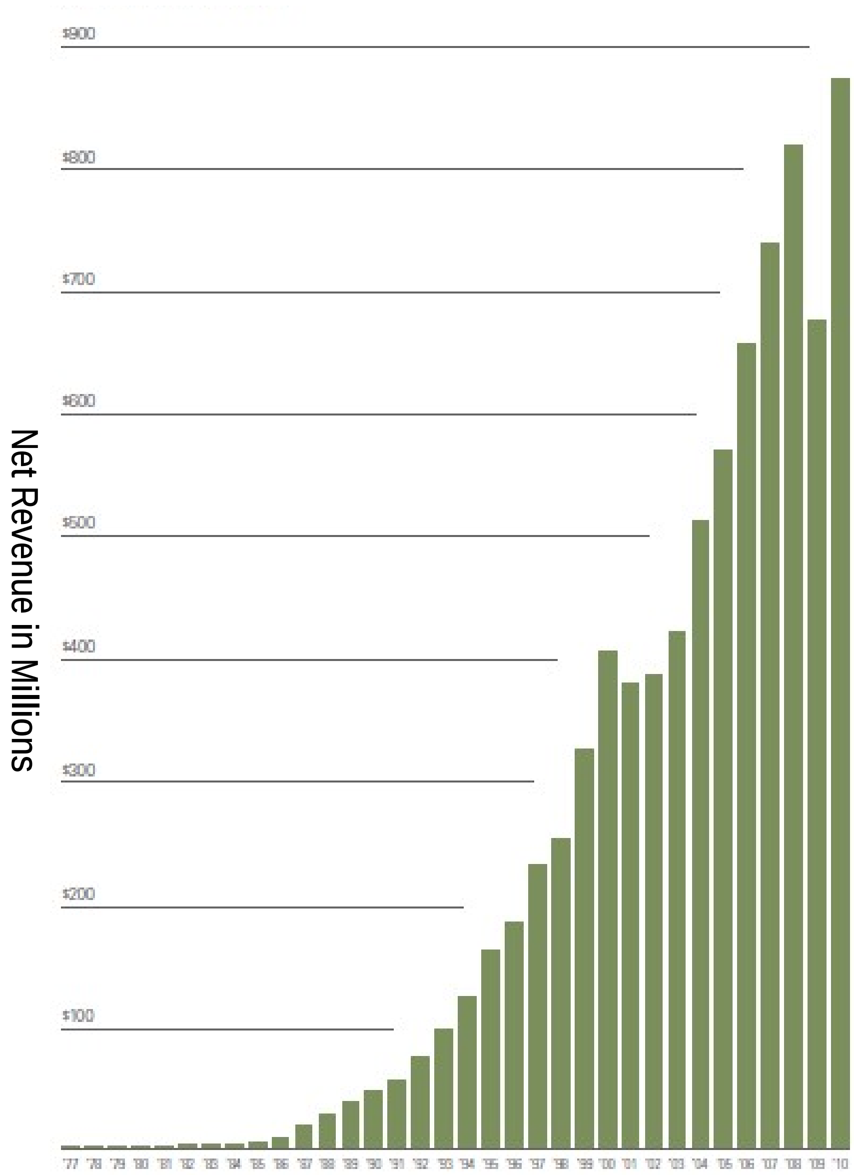
Global operations: *offices in 43 countries*

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

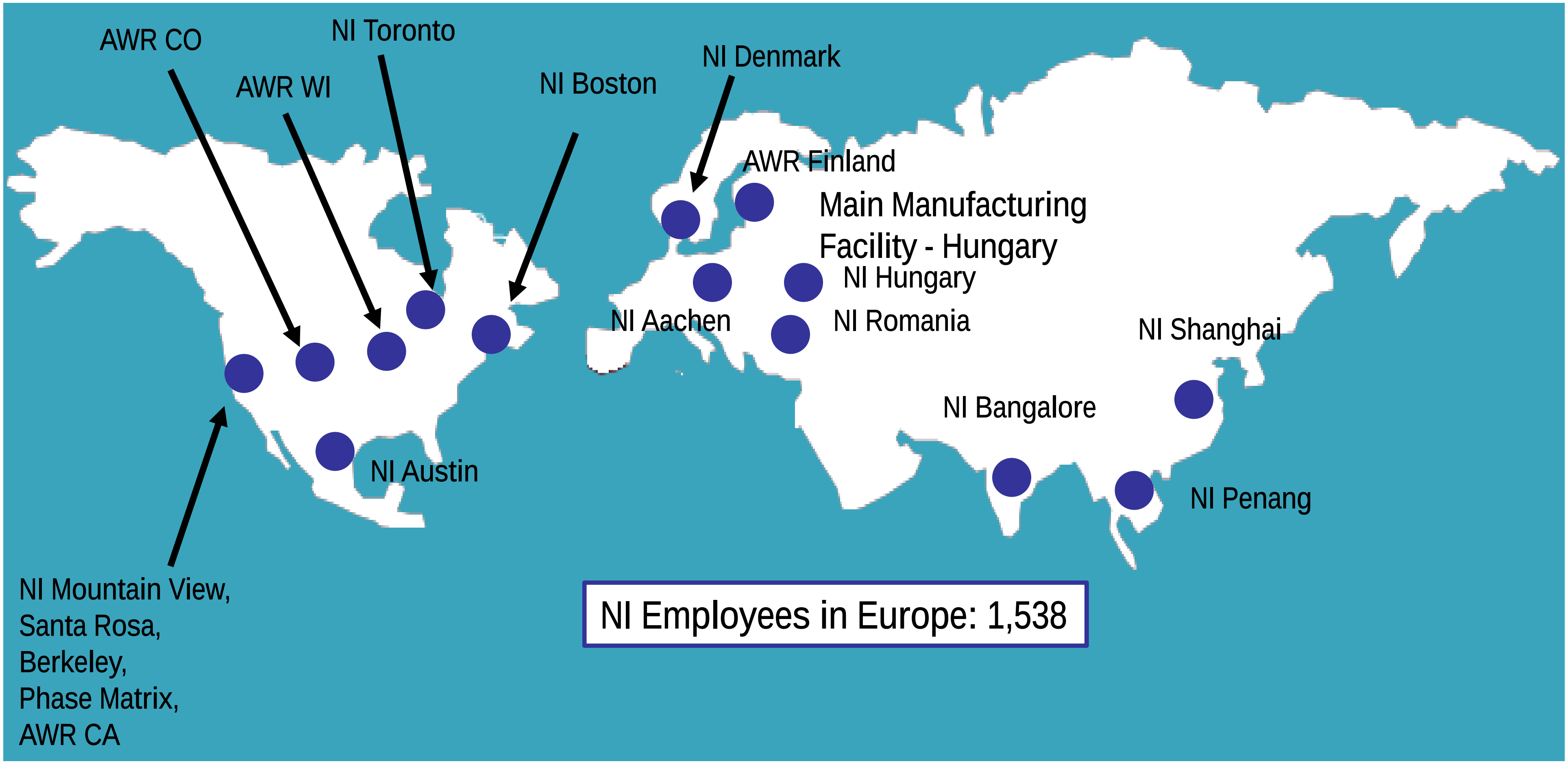
Customer base: *30,000 companies annually*

Network: More than 600 Alliance Partners

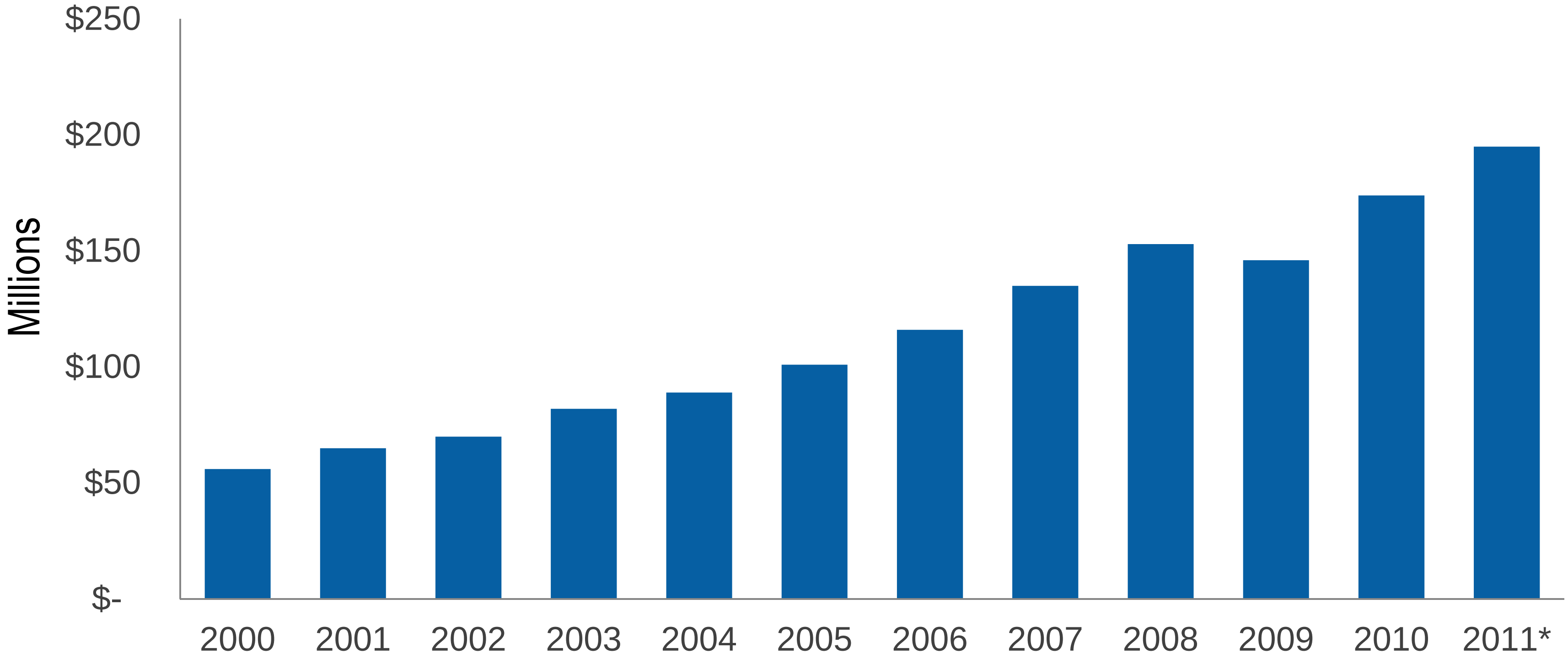
Diversity: *no industry makes up more than 15% of revenue*



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

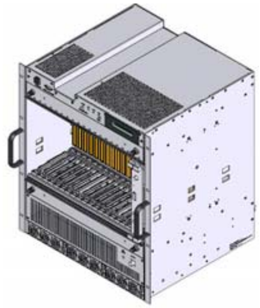
MacBook Pro

3 years

MacBook Air

Custom Design

10 years



Custom Design

Keep Up With Technology While Preserving Investment

iPhone 3

2 years

iPhone 4

MacBook Pro

3 years

MacBook Air

COTS Platforms

3 Years

COTS Platforms

Leveraging R&D Investment

Investment from Industry

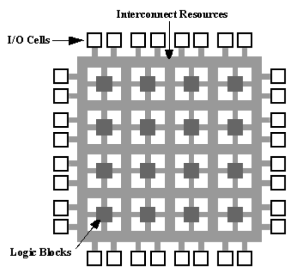
- > $170M from NI in the year 2010
- >1,600M from Intel in 2010
- >$500M from Analog Devices

Combining Laboratory Expertise and off-the-shelf technology

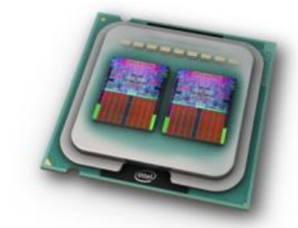
- Custom Front End
- Signal Conditioning
- Algorithm

Tools From the Industry

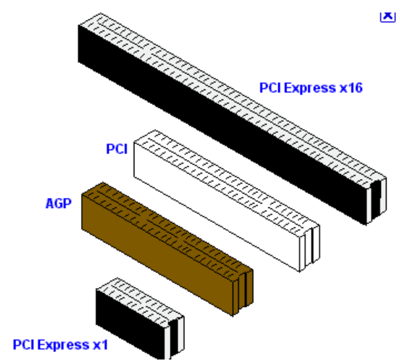
FPGAs



Multicore Processors



GPUs



Processors

Communication Bus

ADC/DAC

Putting it together…..

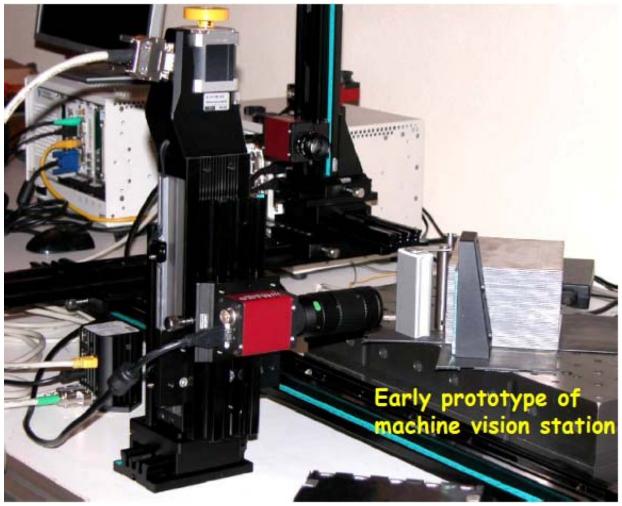
Embedded Controller
(Processor)

Chassis with T&S
(Communication Bus)

I/O Modules
(ADC/DAC)

INFN Gran Sossa – CERN
OPERA Detector for Neutrino Events

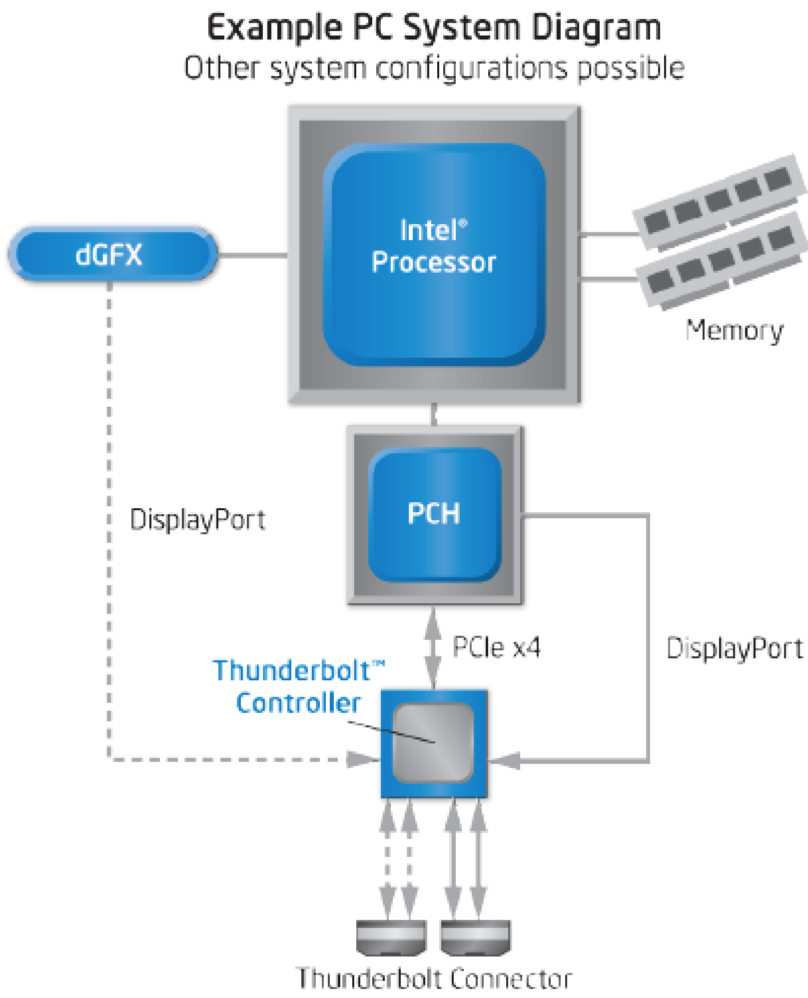
- Brick Assembly Machine for the hybrid detector
  - Machine Vision System
  - Dimensional measurements



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

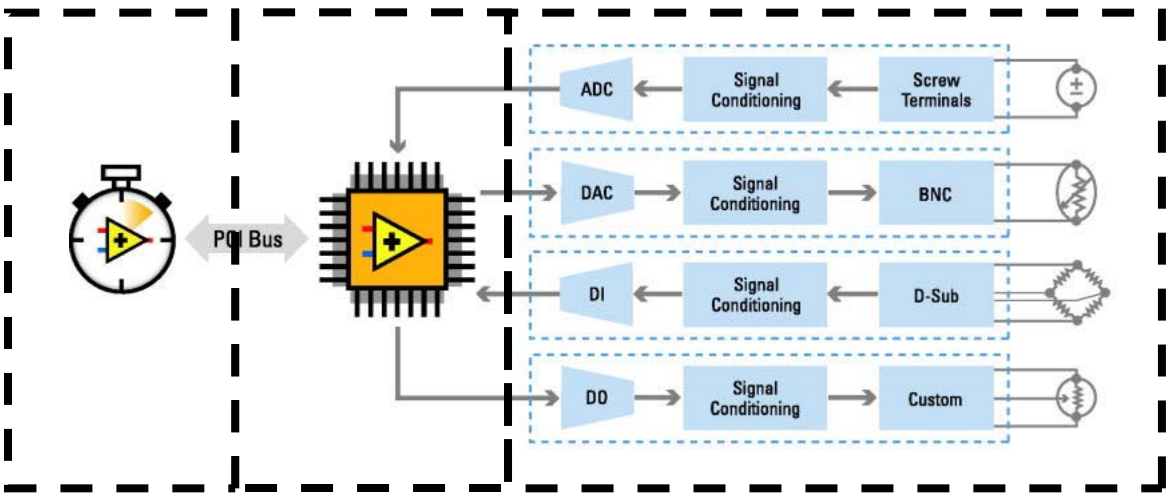
Technology Architecture

- 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



Combining COTS With Your Design: *RIO Architecture*

Communication
Cabled PCI-Express (MXI-Express)
Ethernet
EtherCAT



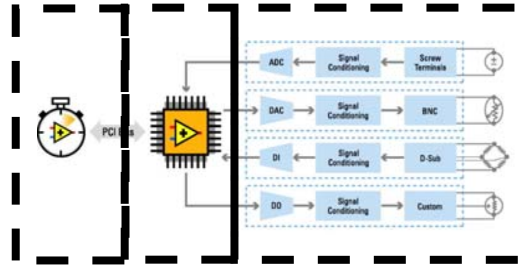
Communication

Processor (Linux, Real-Time, Windows)

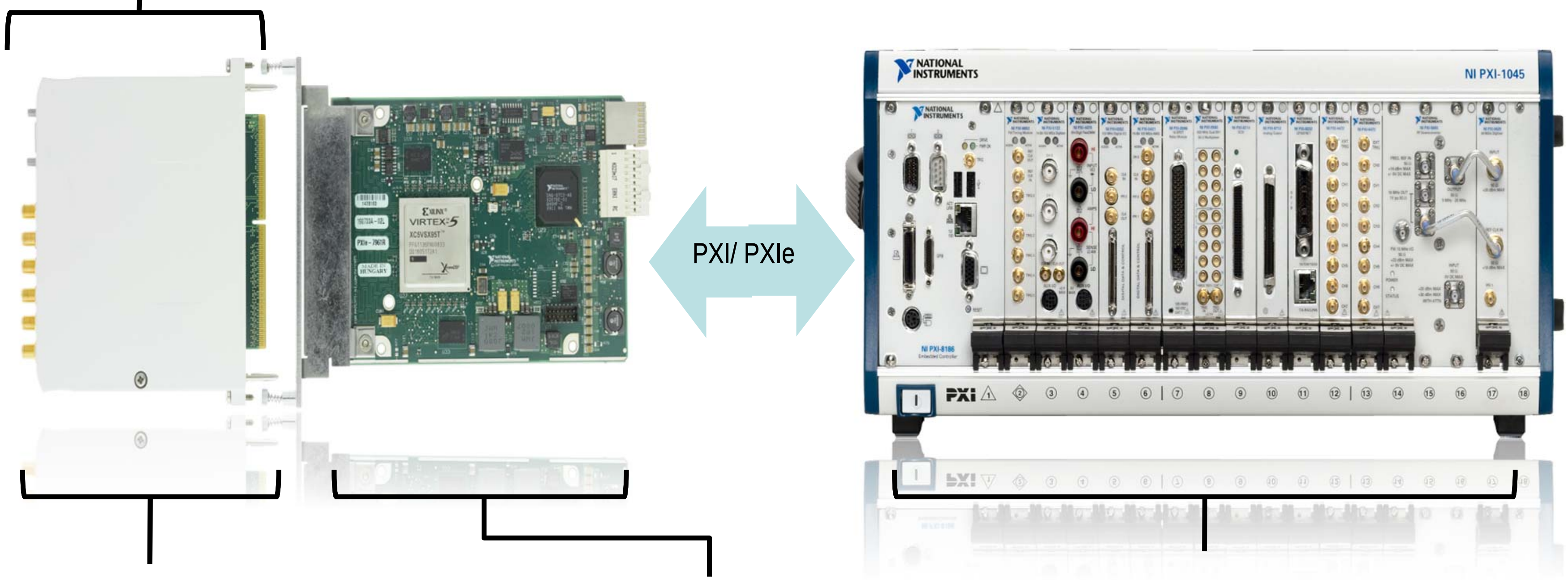
FPGA

I/O Modules

NI FlexRIO Architecture



Customizable
Front-End



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 NI 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

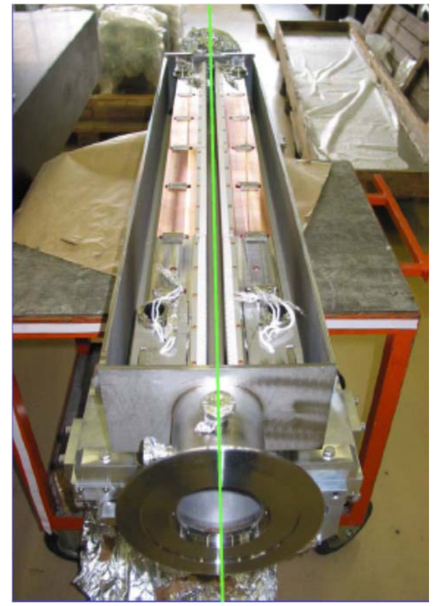
4 ch. 250 MS/s AI

16 ch. 50 MS/s AI

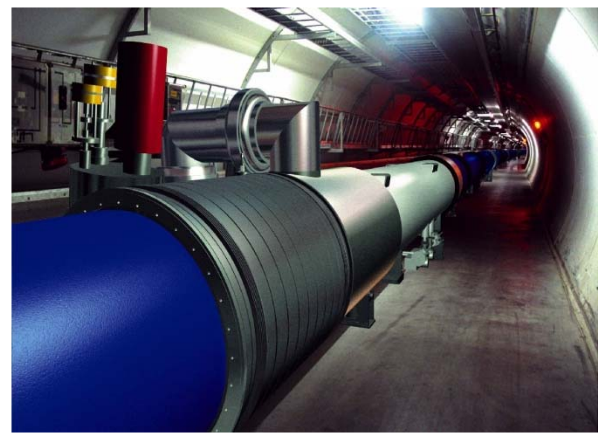
NI FlexRIO Partner Modules

T2 Integrated Solutions	ADSYS Controls Inc.	IRS	Prevas	alfamation	Q-Tech
100 MHz PPMU	Camera Link and GigE	Multi-gigabit optical	Dual gigabit Ethernet	Video and Automotive	Time to Digital Converter

Example - CERN Collimator Alignment

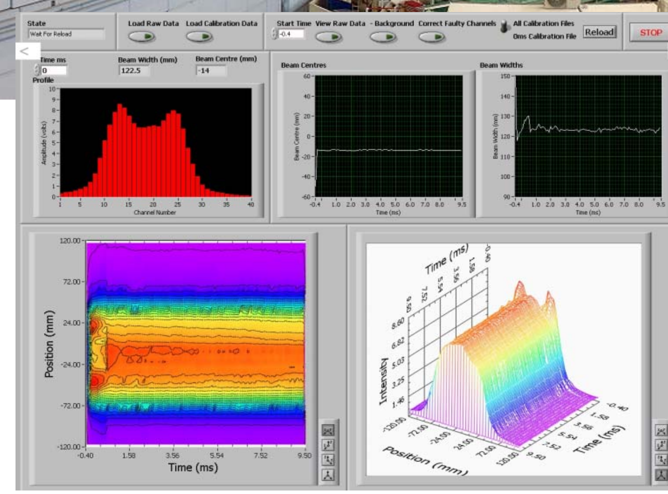


- 550+ axes of motion
- Across 27 km distance
- The jaws have to be positioned with an accuracy which is a fraction of the beam size (200µm)
- Synchronized to
  - < 5ms drift over 15 minutes
  - Maximum jitter in µs

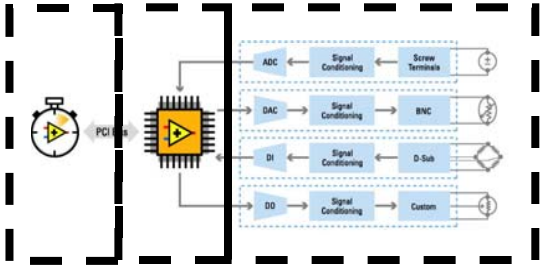


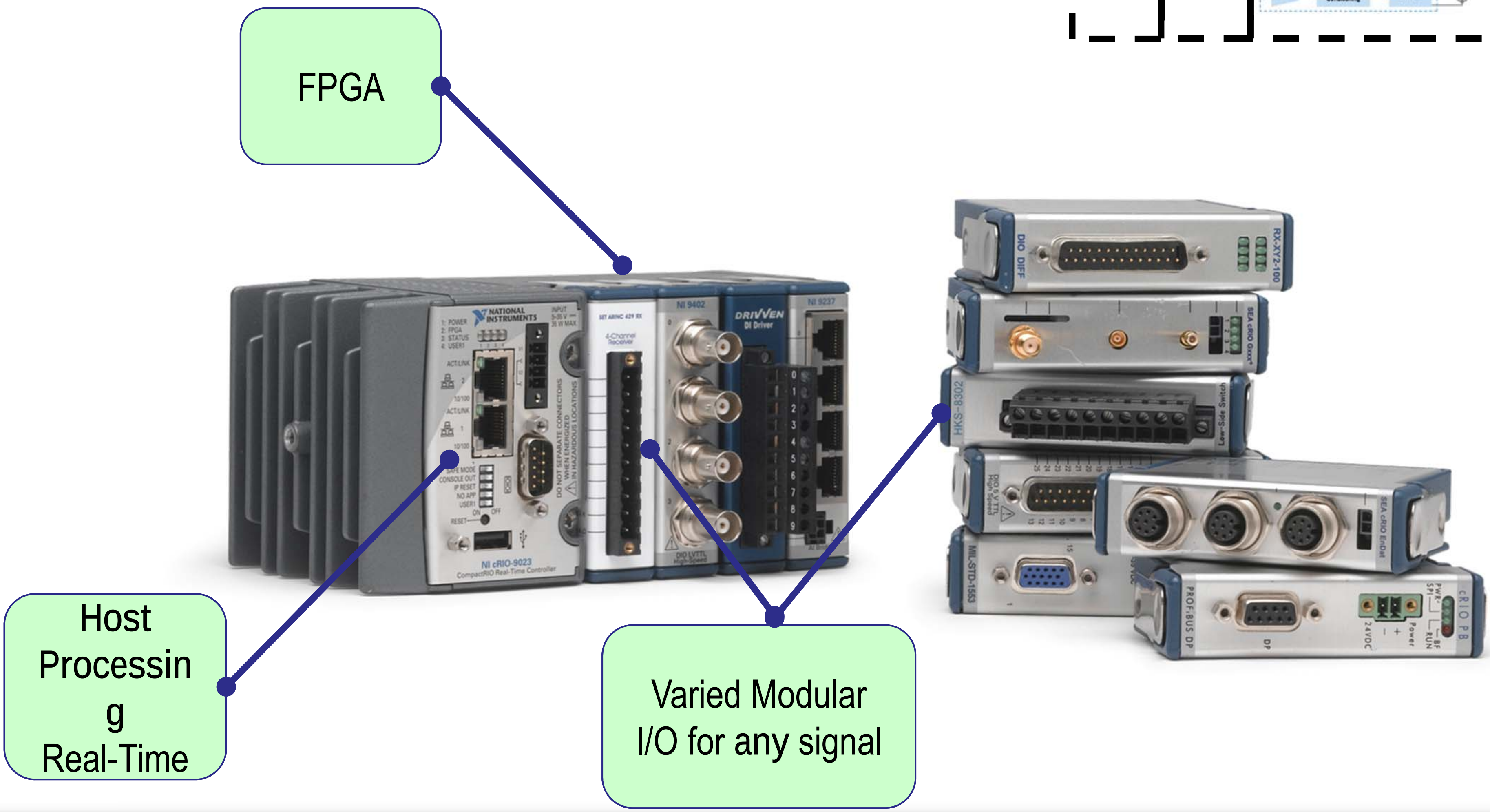
ISIS Synchrotron, Rutherford Appleton Labs

- 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



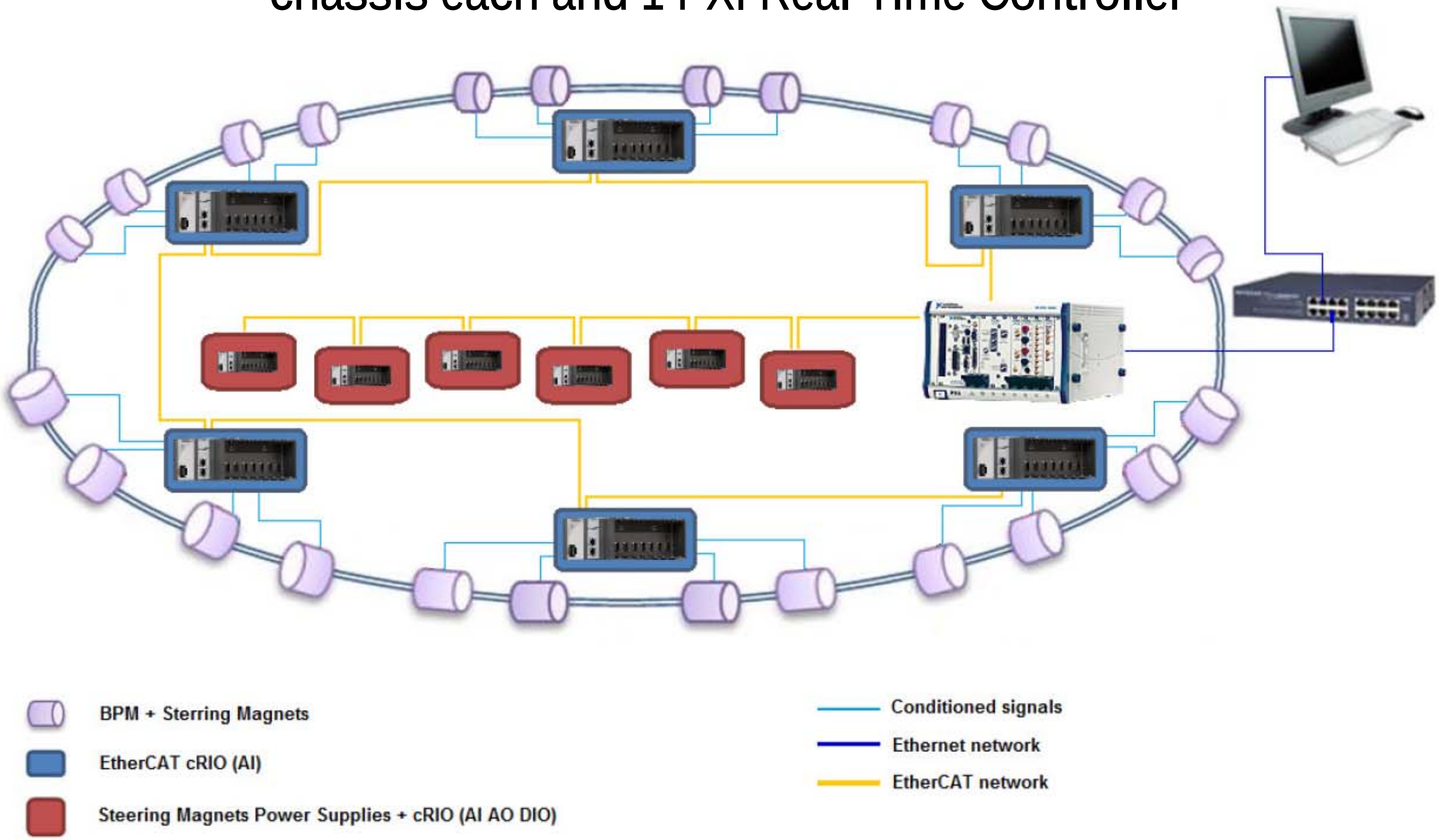
NI CompactRIO Architecture



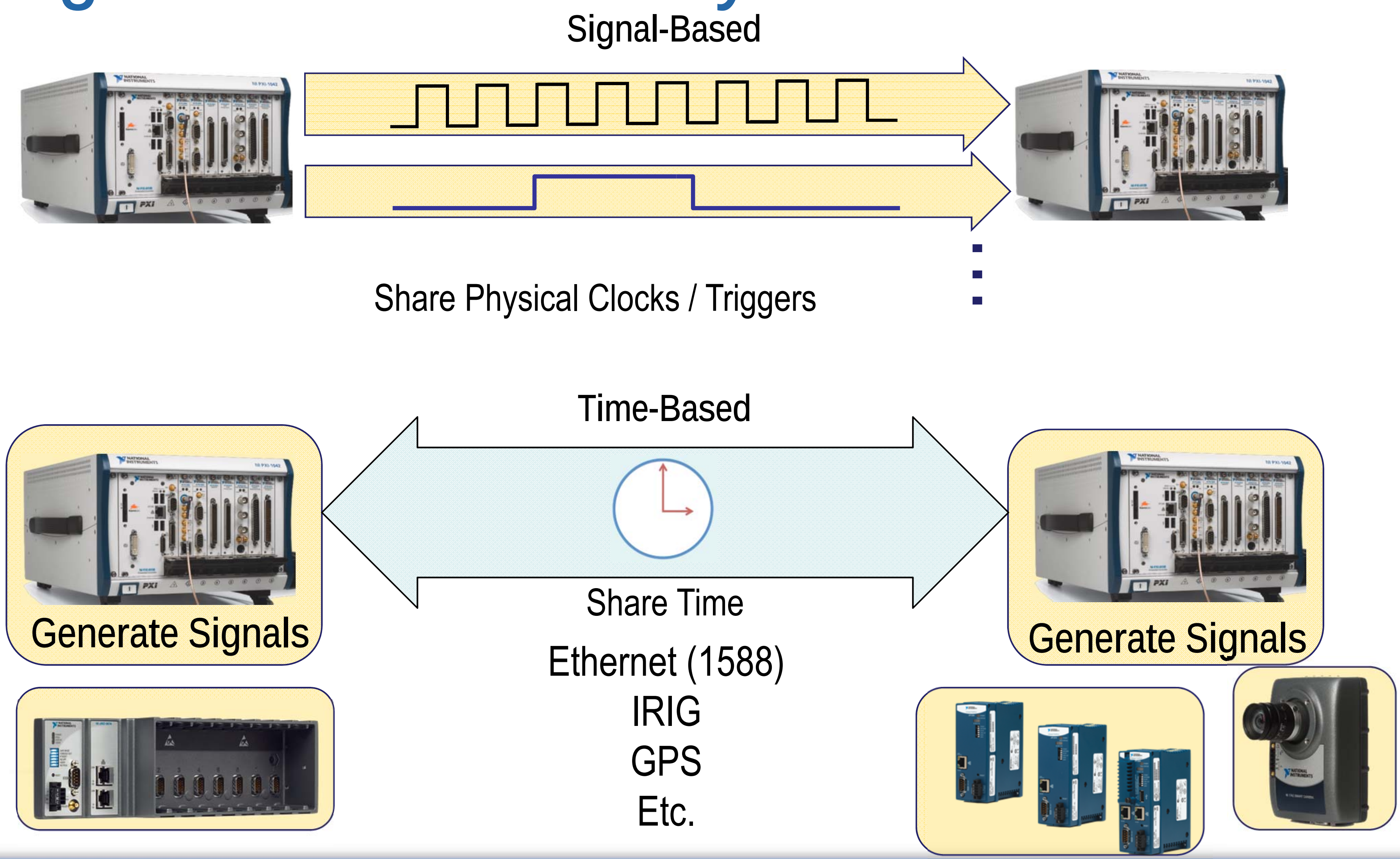


LNLS – Brazilian Synchrotron
Fast Orbit Feedback Control System

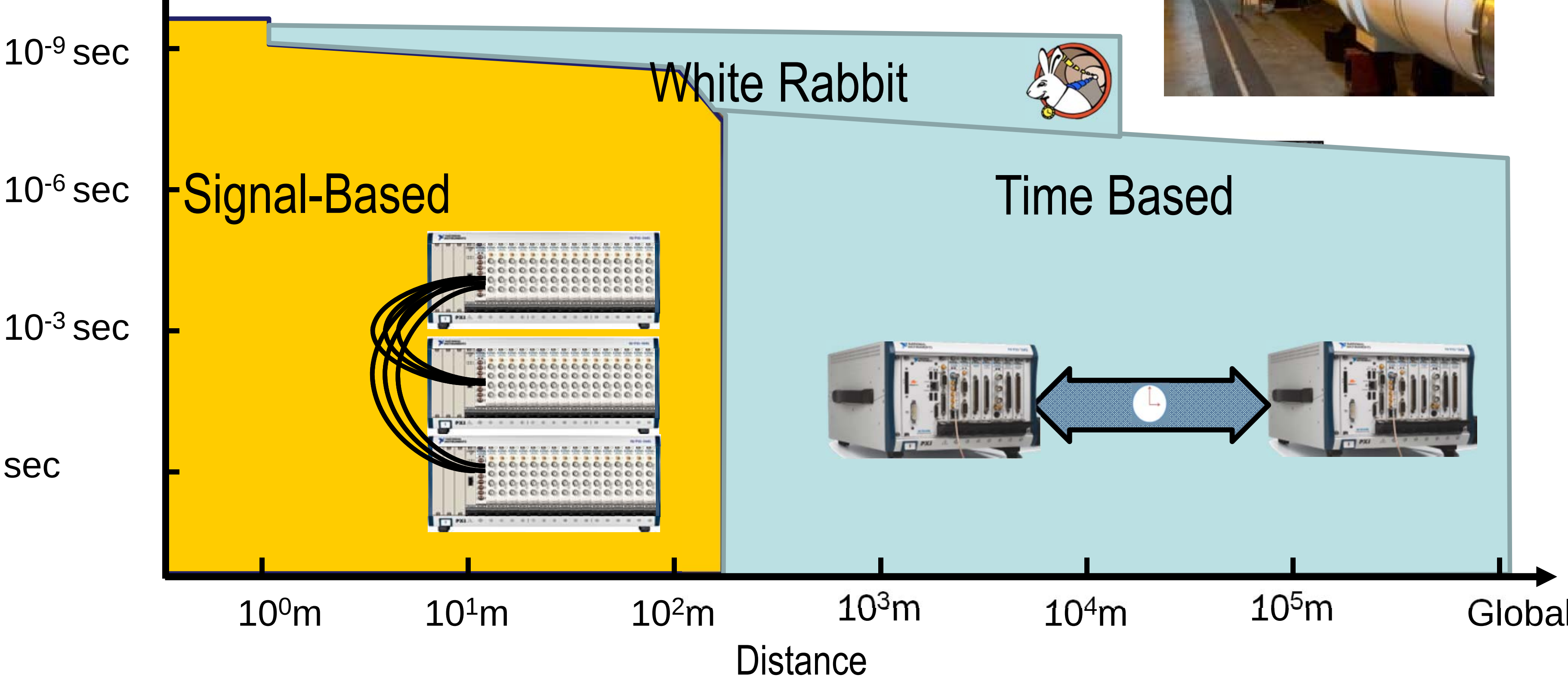
New orbit control system topology: 2 EtherCAT loops with 6 cRIO chassis each and 1 PXI Real-Time Controller



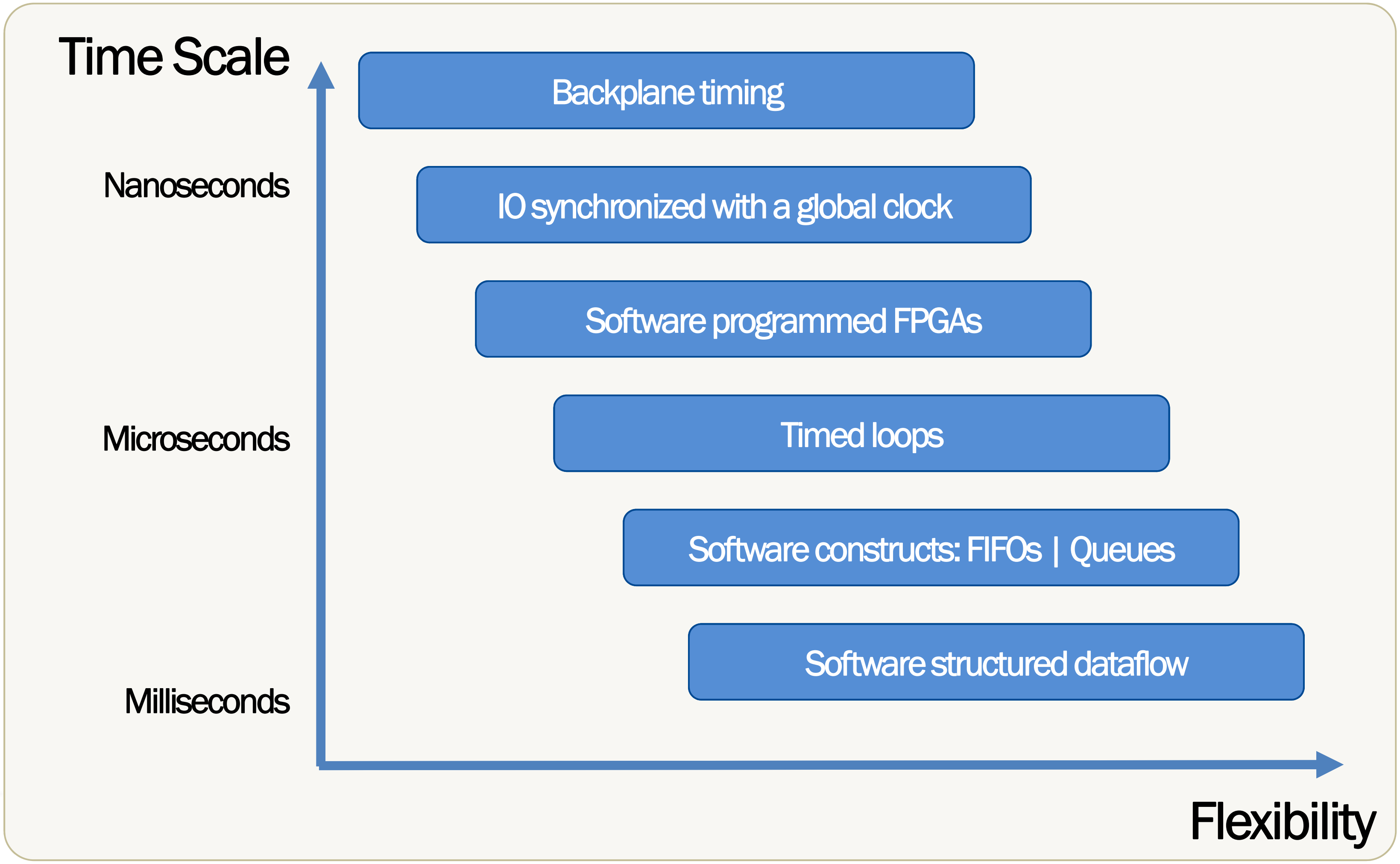
Signal vs. Time-Based Synchronization



White Rabbit: Synchronization over Distance



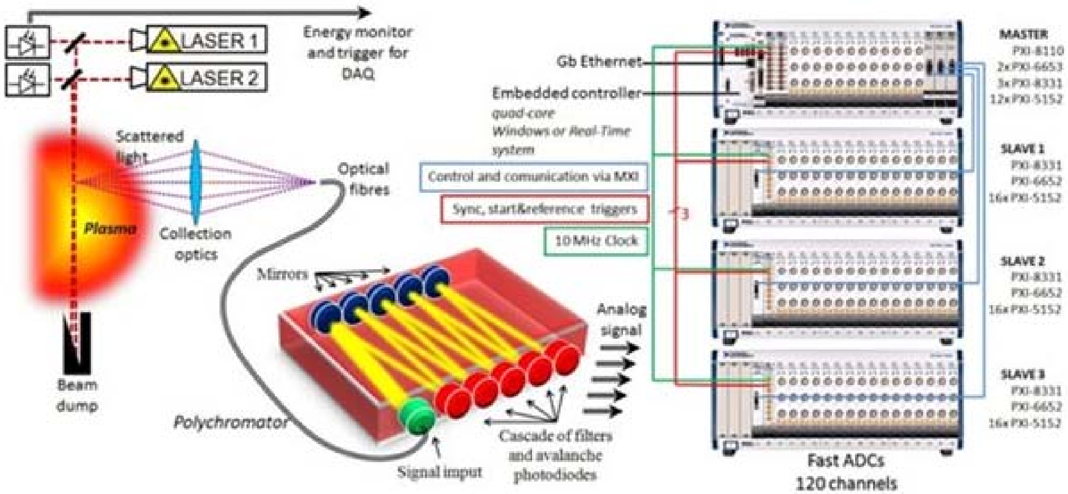
Technologies for Time and Concurrency

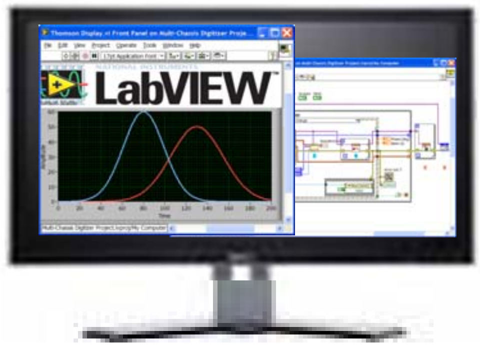


Example NI and CERN White Rabbit

- 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

Partnership with Industry

Continuous innovation

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

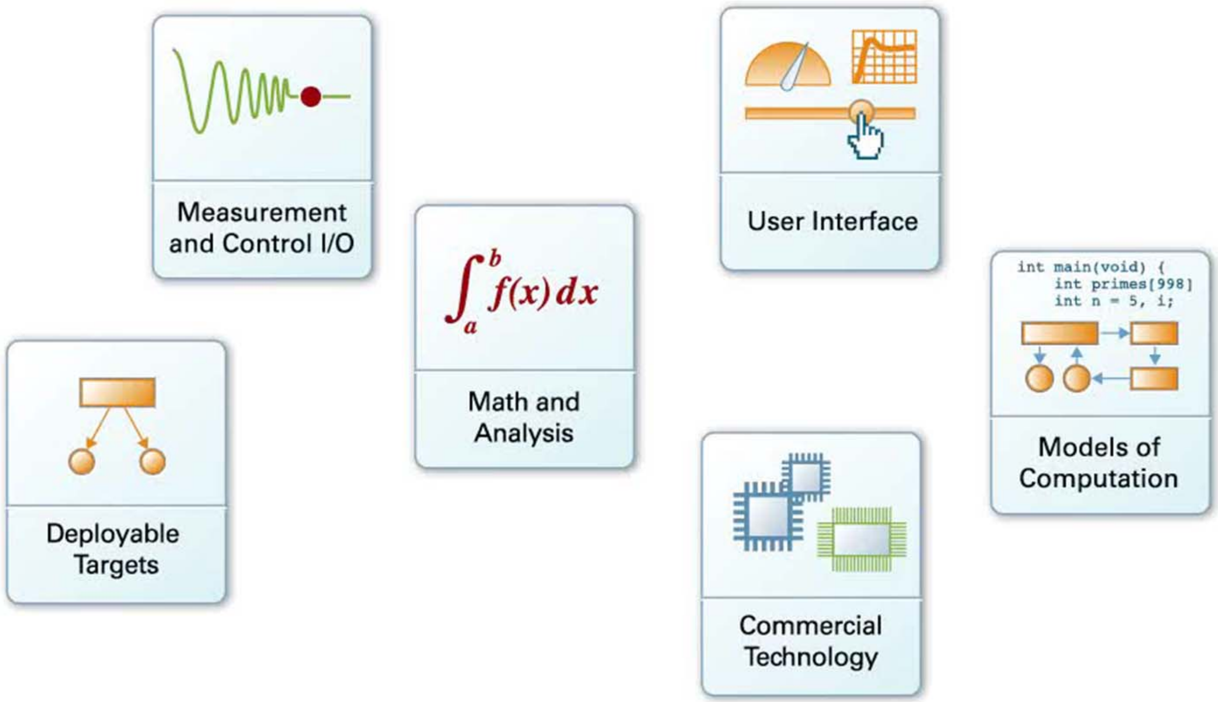
Simplification and cost reduction

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

Long term maintenance and support

- Life cycle management
- Services and consulting

Integrating Elements



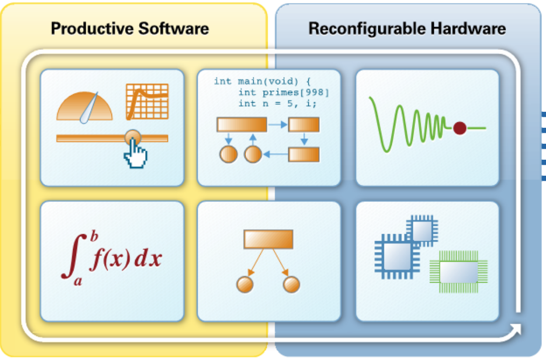
Software

Hardware

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



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

FPGA
Xilinx Virtex & Spartan
Reconfigurable hardware

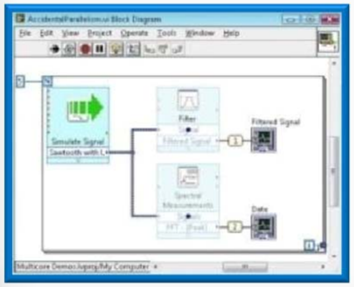
IP
Control & signal processing IP & I/O drivers
Built-in graphical IP, integrate user IP

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

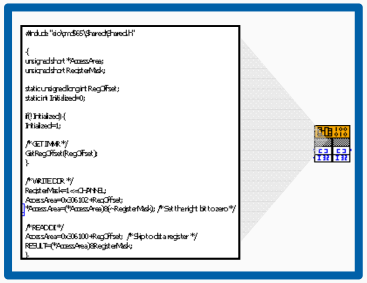
BUS
PCI/PCIe, Enet, USB, wireless, deterministic Enet, Open architecture

High-Level Design Models

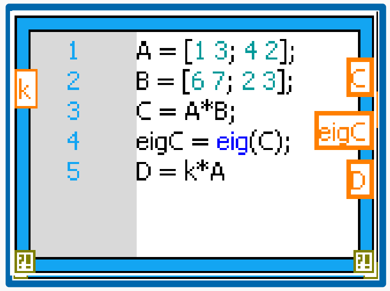
Data Flow



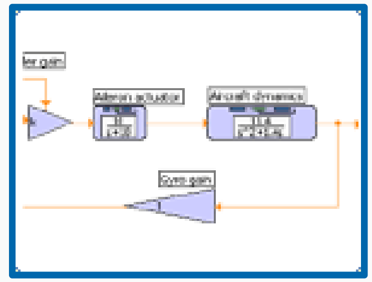
C Code



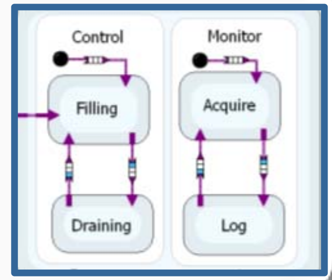
Textual Math



Simulation



Statechart



NATIONAL INSTRUMENTS LabVIEW™

Graphical System Design Platform

PC/Mac/Linux

PXI

CompactRIO

FlexRIO

Custom

Eliminating Artificial Complexity

Text-based Compiler

Source String of Characters →

Lexical Analyzer

Tokens →

Parser

Abstract Syntax Tree →

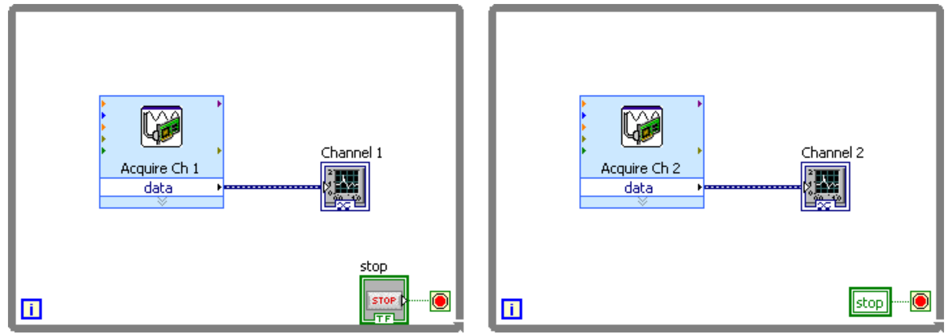
Intermediate Code Generator & Semantic Analyzer

Intermediate Code & Data Dependency Graph →

Optimizer & Code Generator

Executable Code →

LabVIEW Compiler



← Source Dataflow Graph

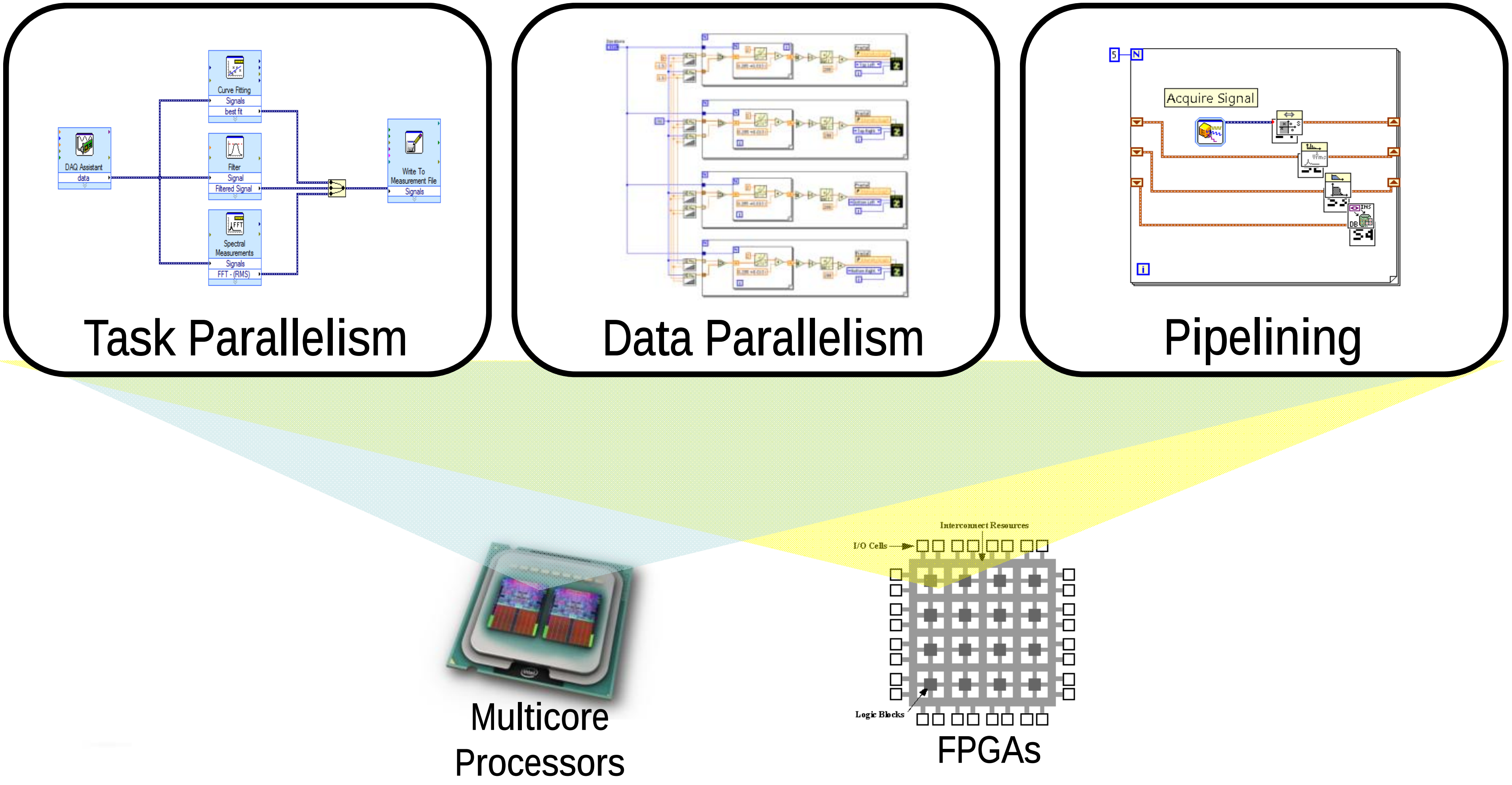
Intermediate Code Generator & Semantic Analyzer

← Intermediate Code & Data Dependency Graph

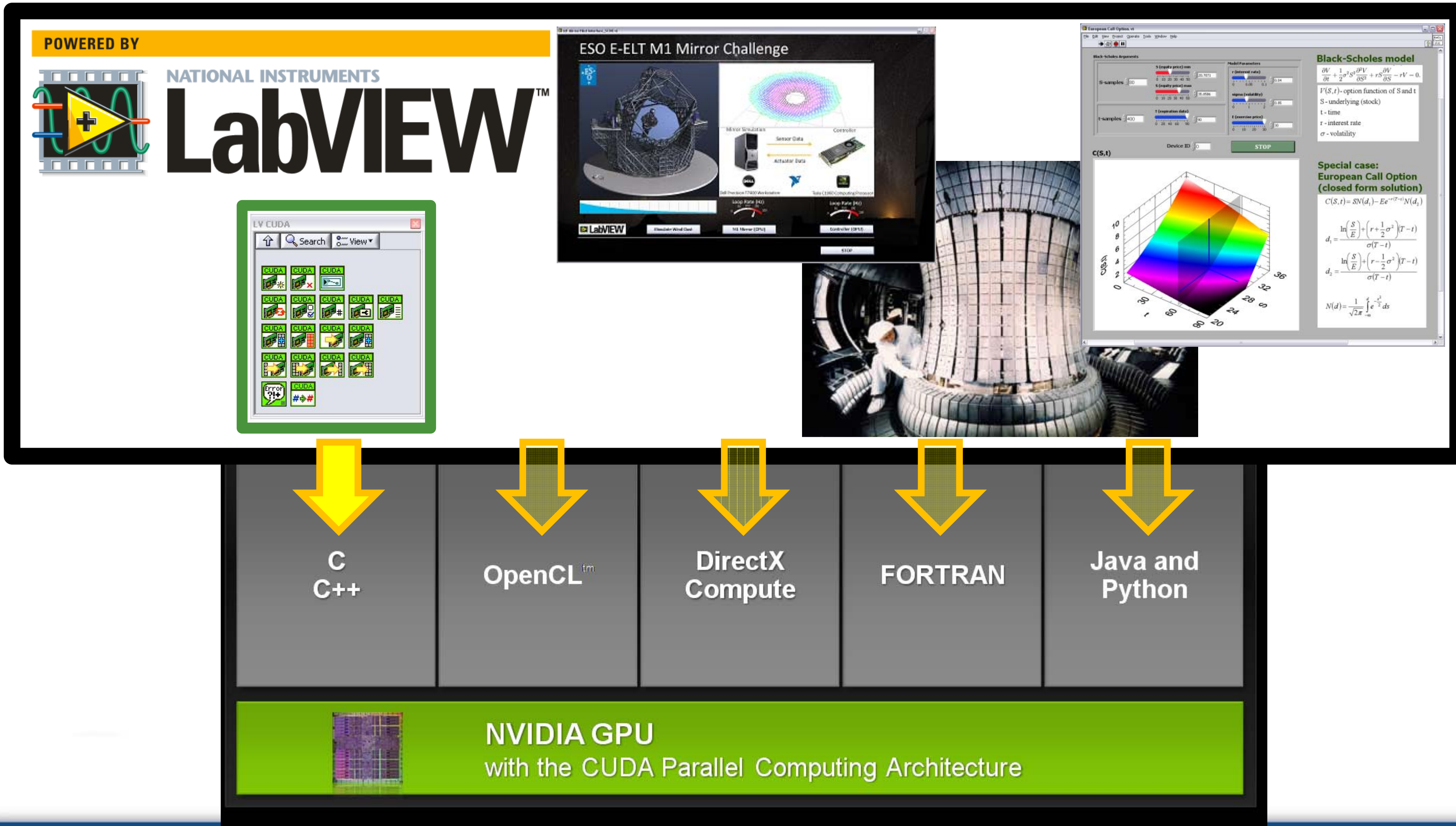
Optimizer & Code Generator

← Executable Code

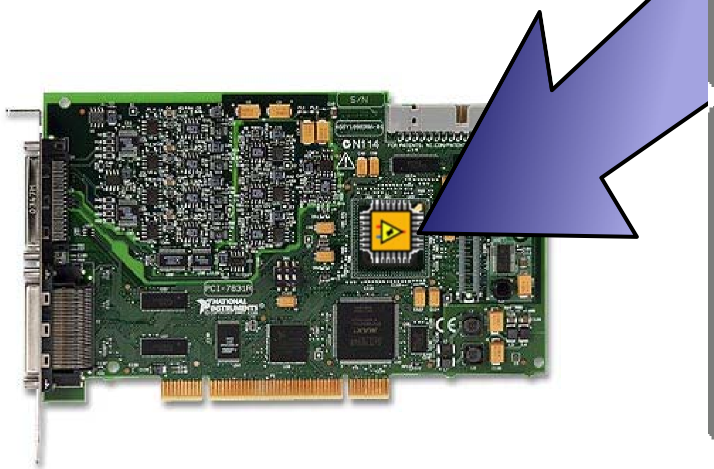
Parallel Programming with LabVIEW

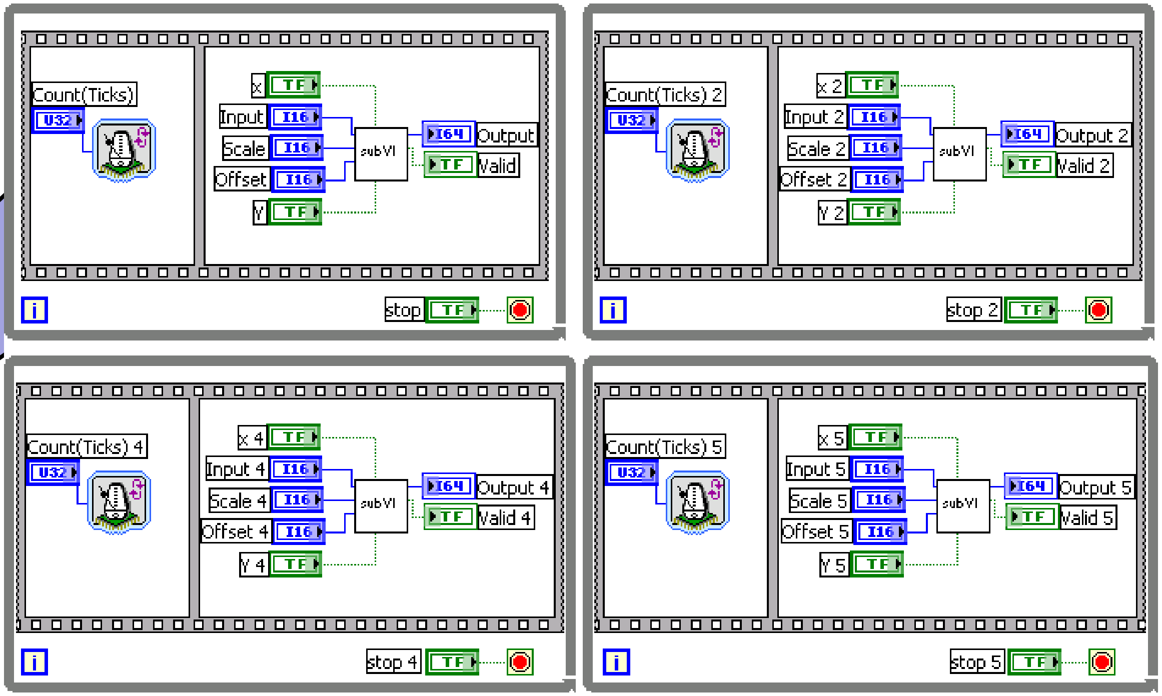


LabVIEW's GPU Computing Module



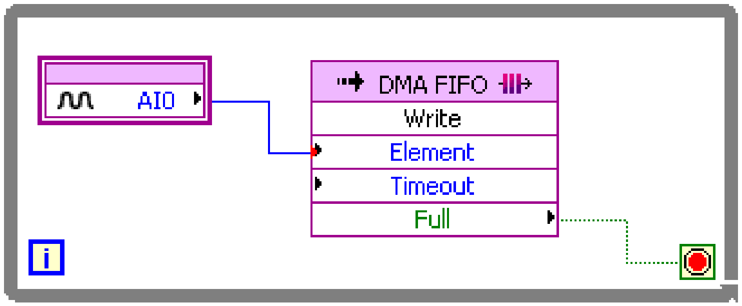
FPGA Programming: Multicore, Multiprocessor Development





Abstraction to the Pin

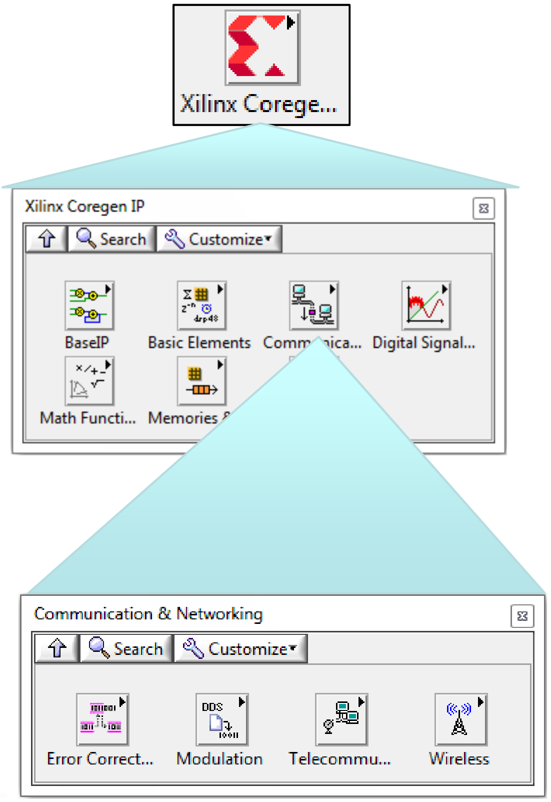
VHDL

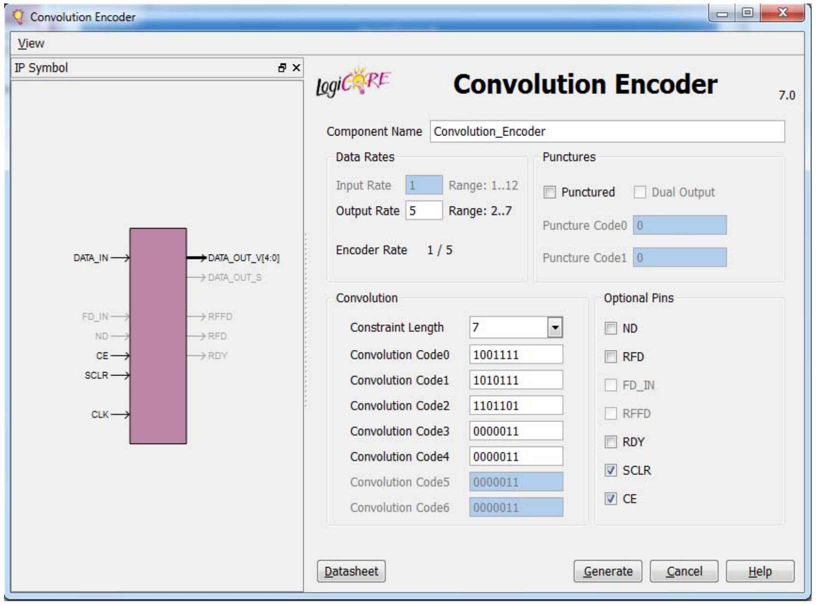


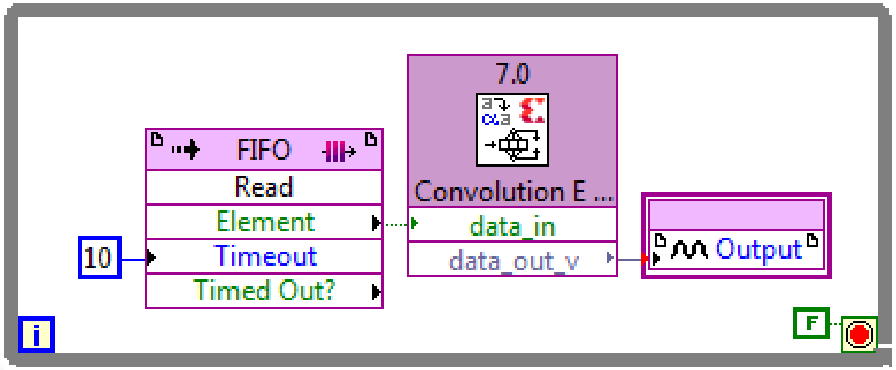
LabVIEW FPGA

LabVIEW FPGA

Direct Access to Preexisting Xilinx CORE Generator IP Libraries





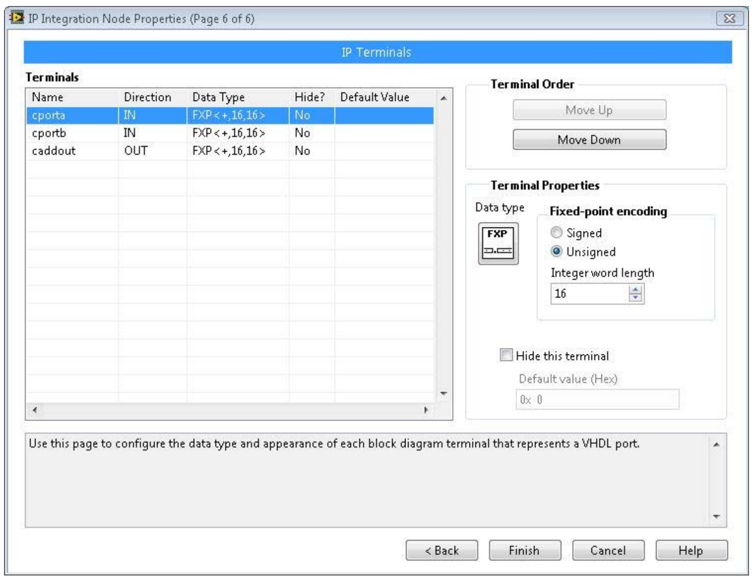


LabVIEW FPGA IP Integration Node

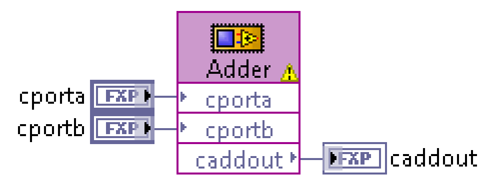
1 Use Core Generator or Custom VHDL

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

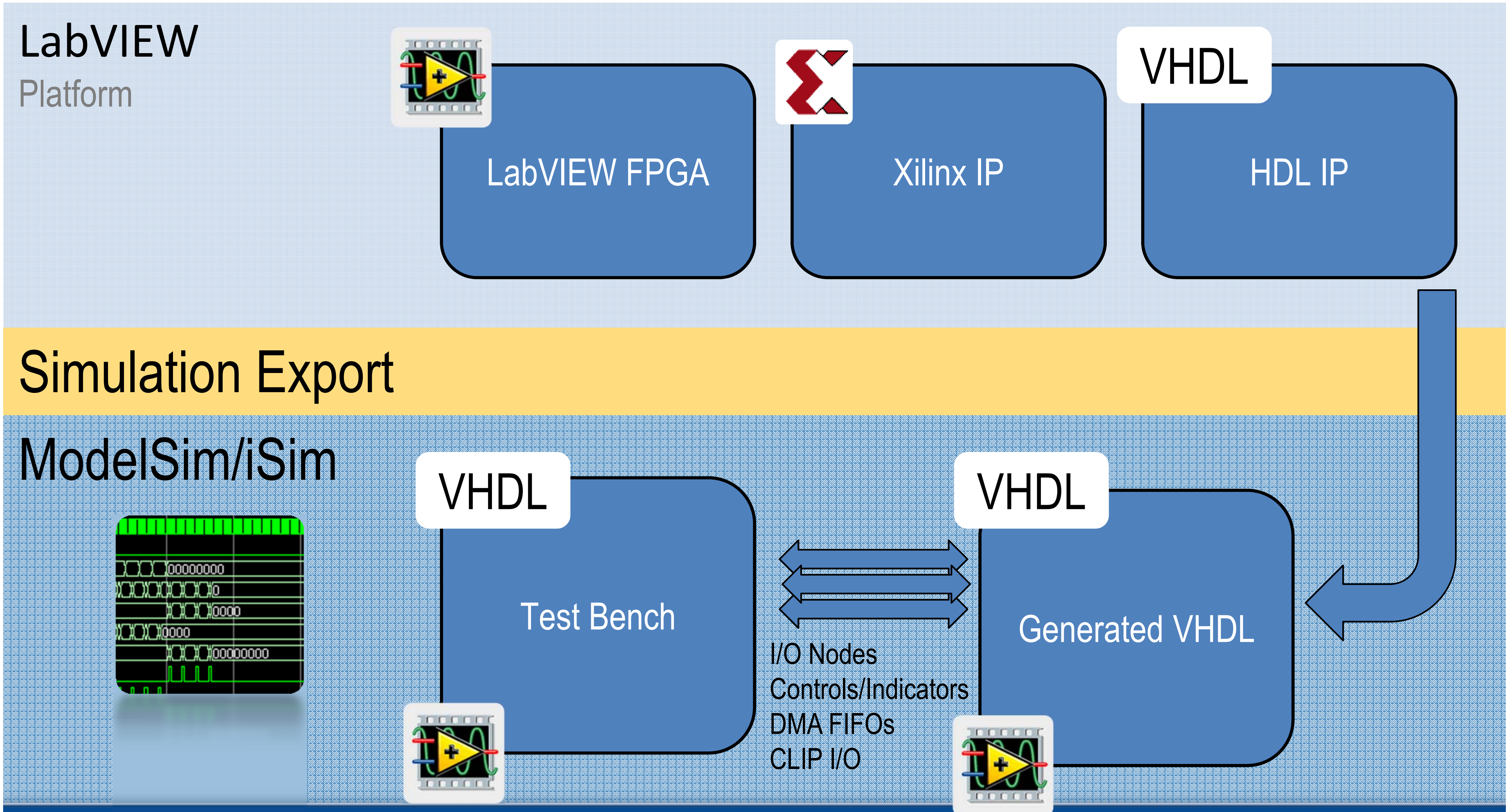
2 Configure IP Integration Node and Generate Simulation Model



3 Use the IP Block Using Standard LabVIEW I/O Interfaces



Cycle-Accurate Simulation with ModelSim



Lawrence Livermore National Labs

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

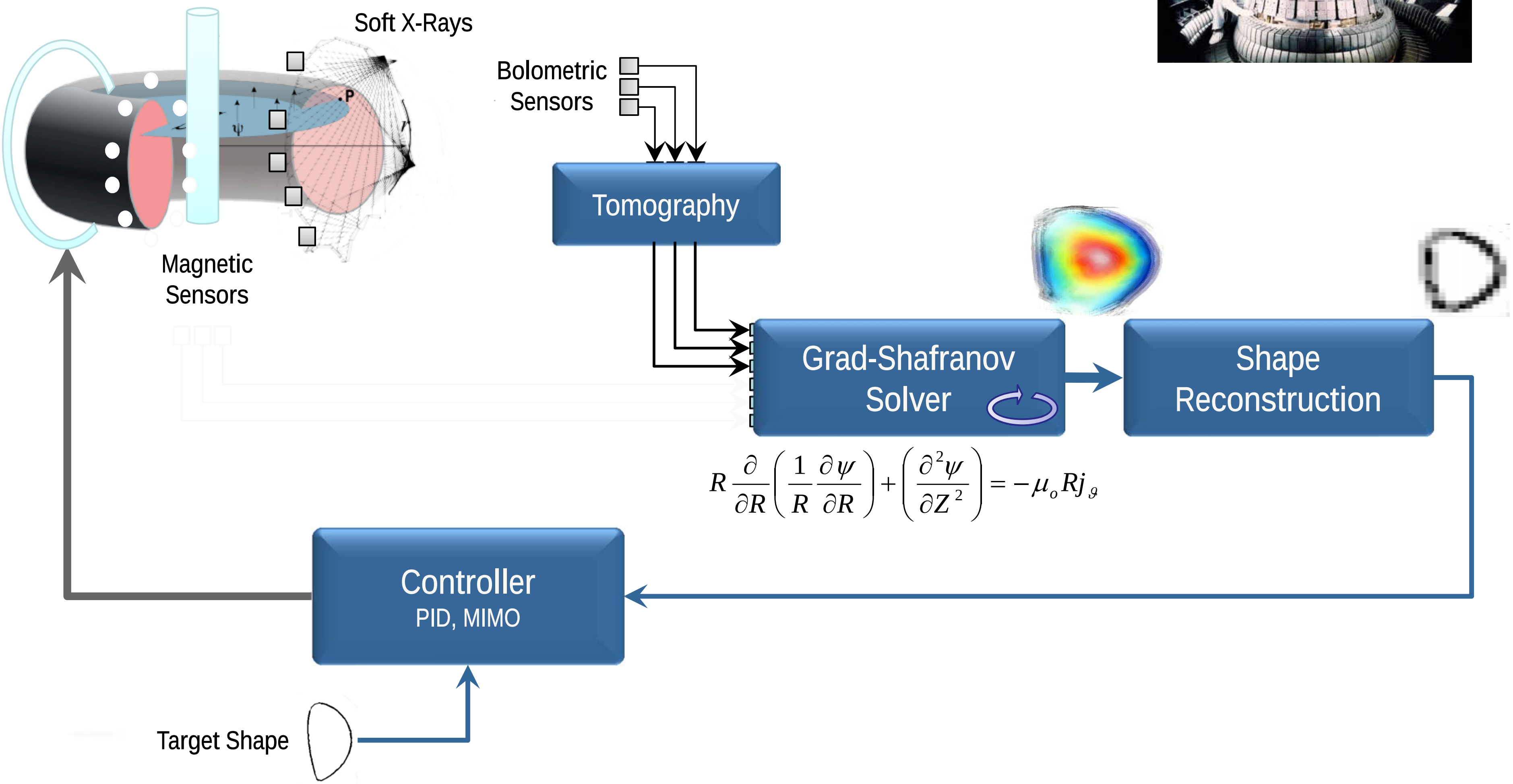
- LabVIEW increased productivity by 3X over Java and C++
- Developed complex application consisting of over 1,000 VIs

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.

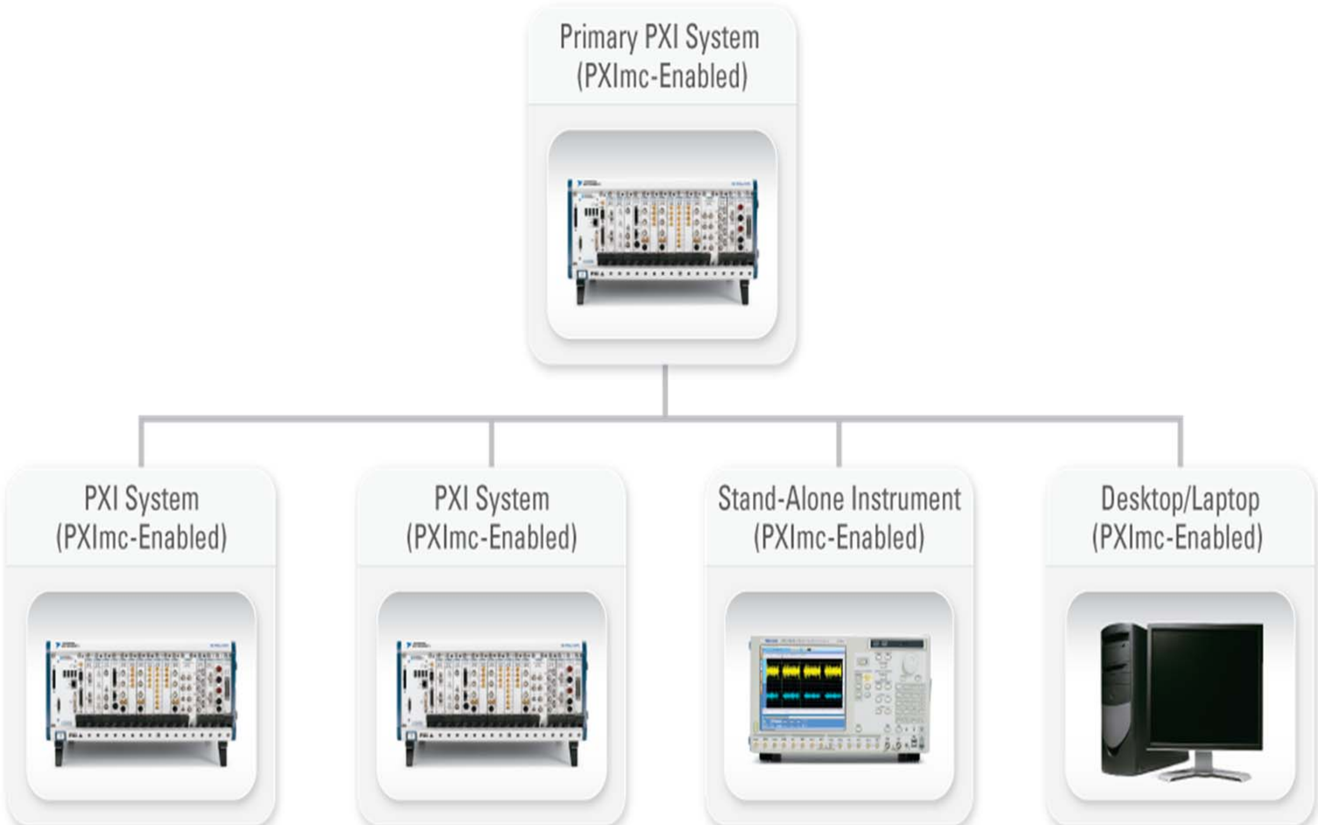
- Glenn Larkin, LLNL

Example -Tokamak – Shape Control



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

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

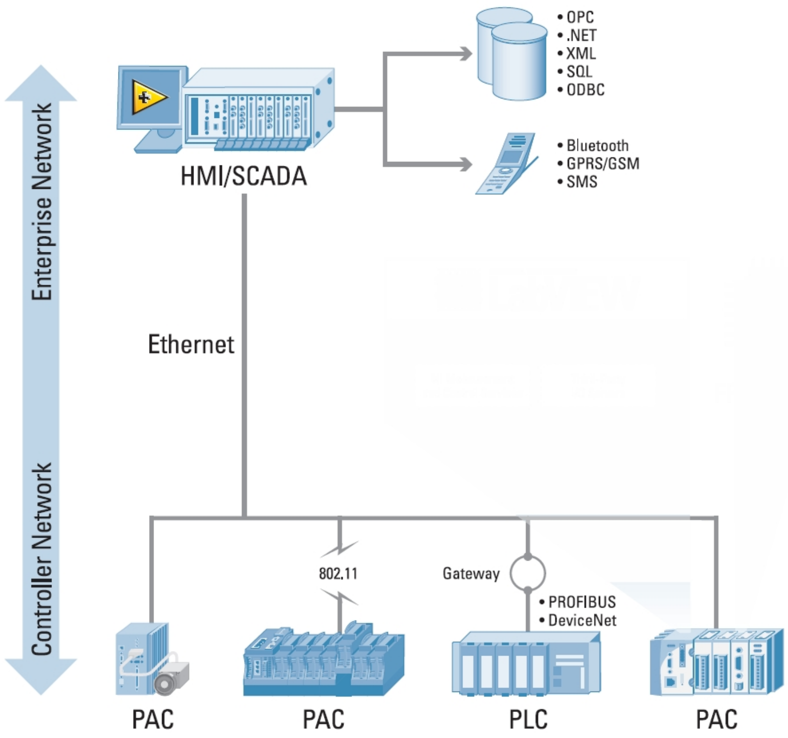
- Max Planck Institute
- Plasma control in nuclear fusion Tokamak with LabVIEW on an eight-core real-time system

"…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

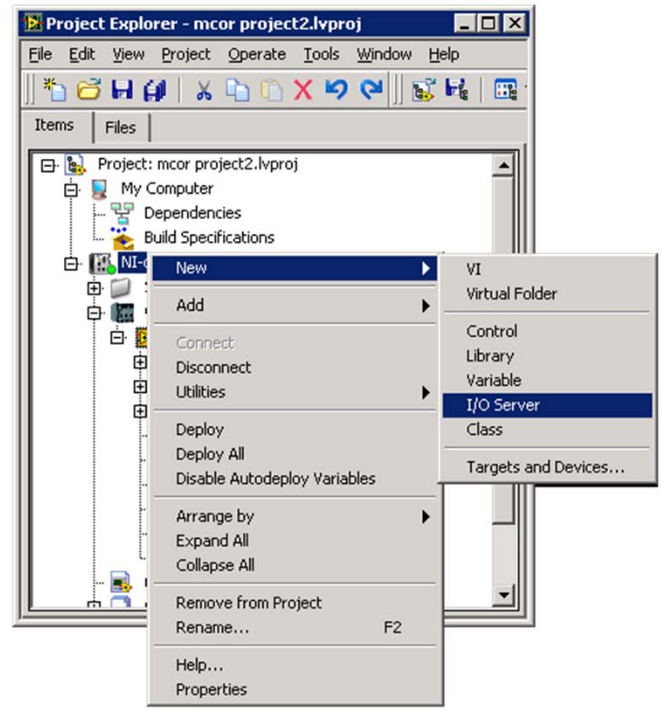
Open Architecture

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



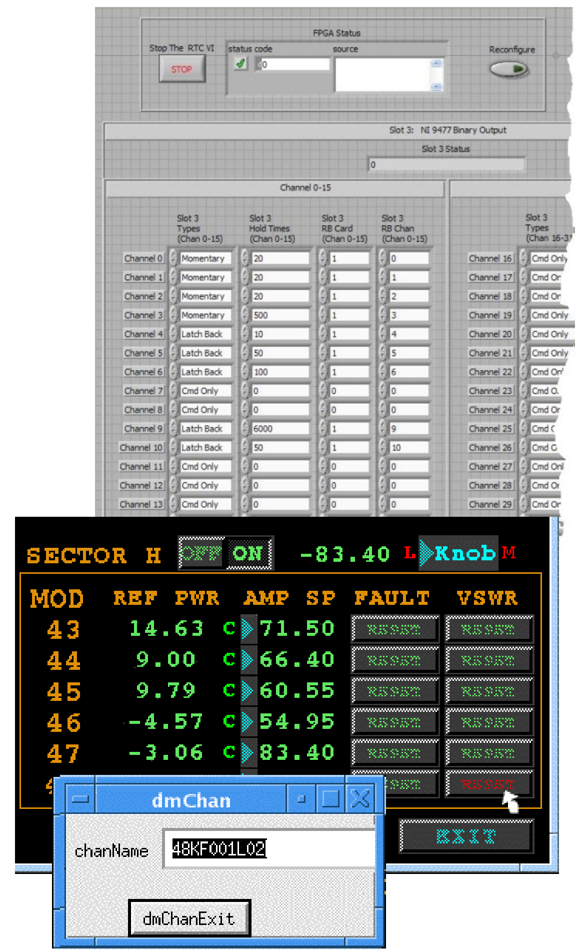
EPICS Integration With LabVIEW

- 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

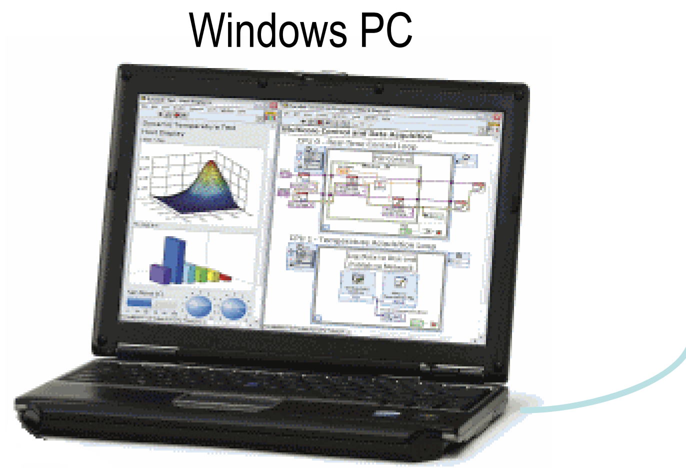


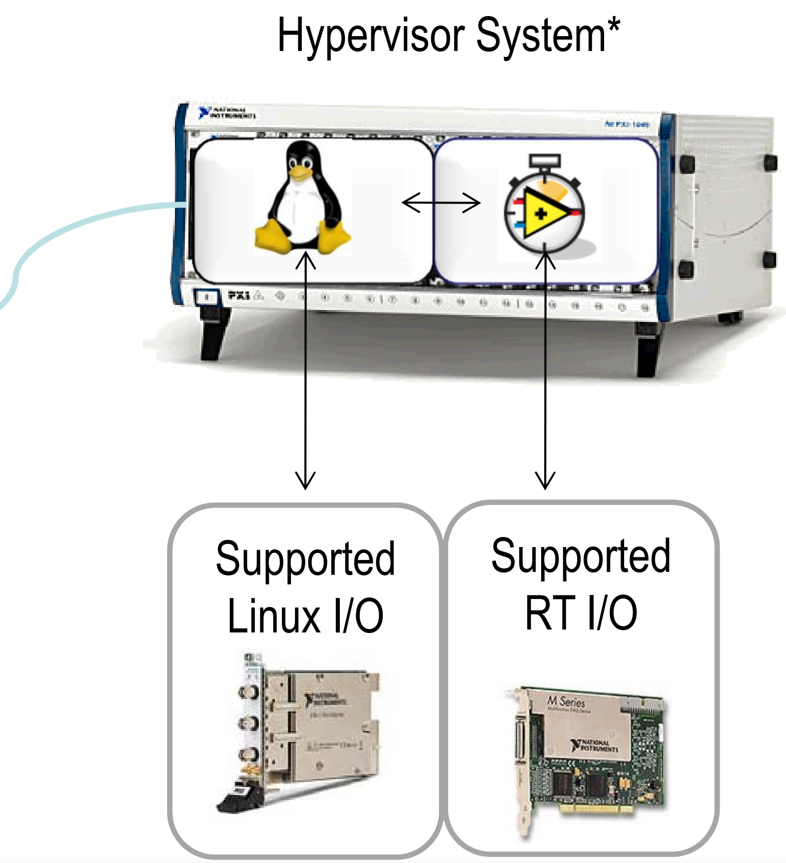
Example – Los Alamos LANSCE

- 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



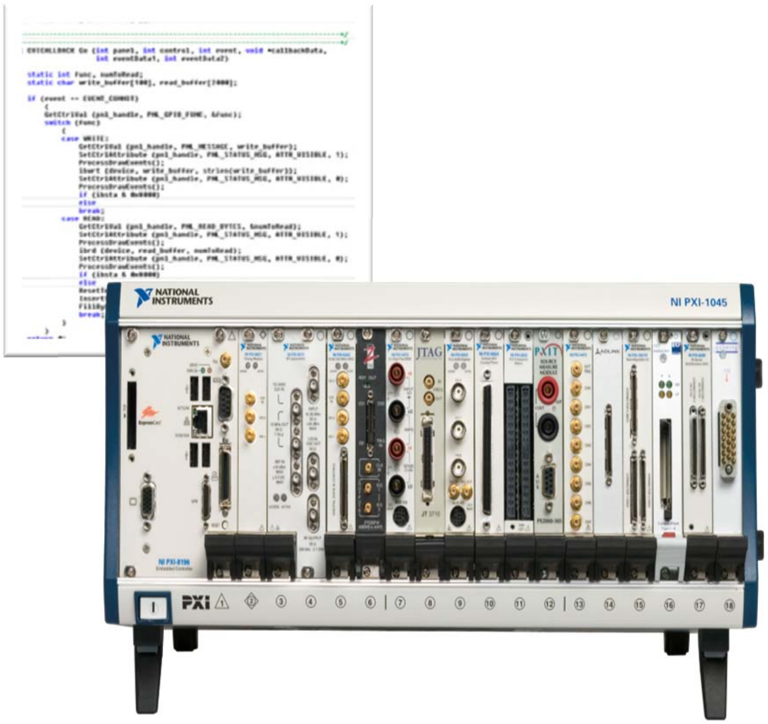
NI Real-Time Hypervisor for Linux





*Must program LabVIEW Real-Time application from Windows

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

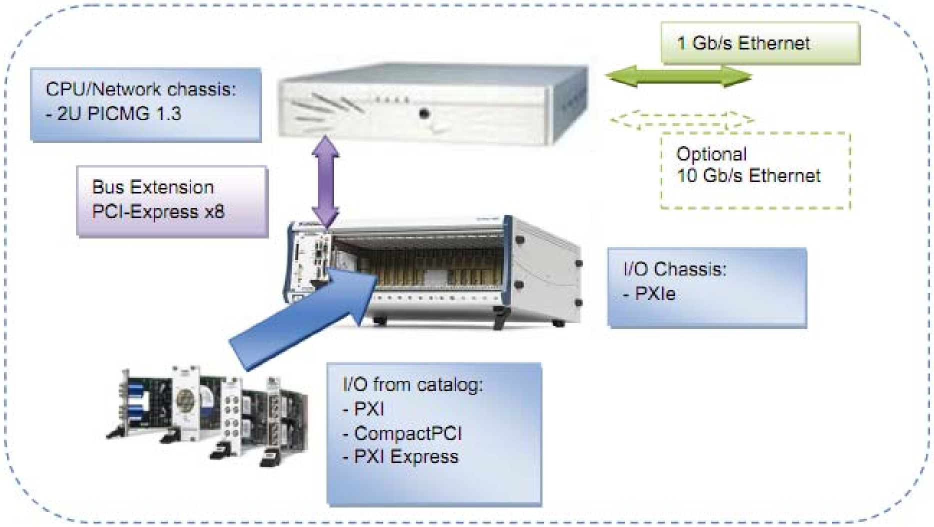


Figure 1 – A General Purpose Fast Controller

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

NATIONAL INSTRUMENTS Alliance Partners — 20 YEARS

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

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NATIONAL INSTRUMENTS™

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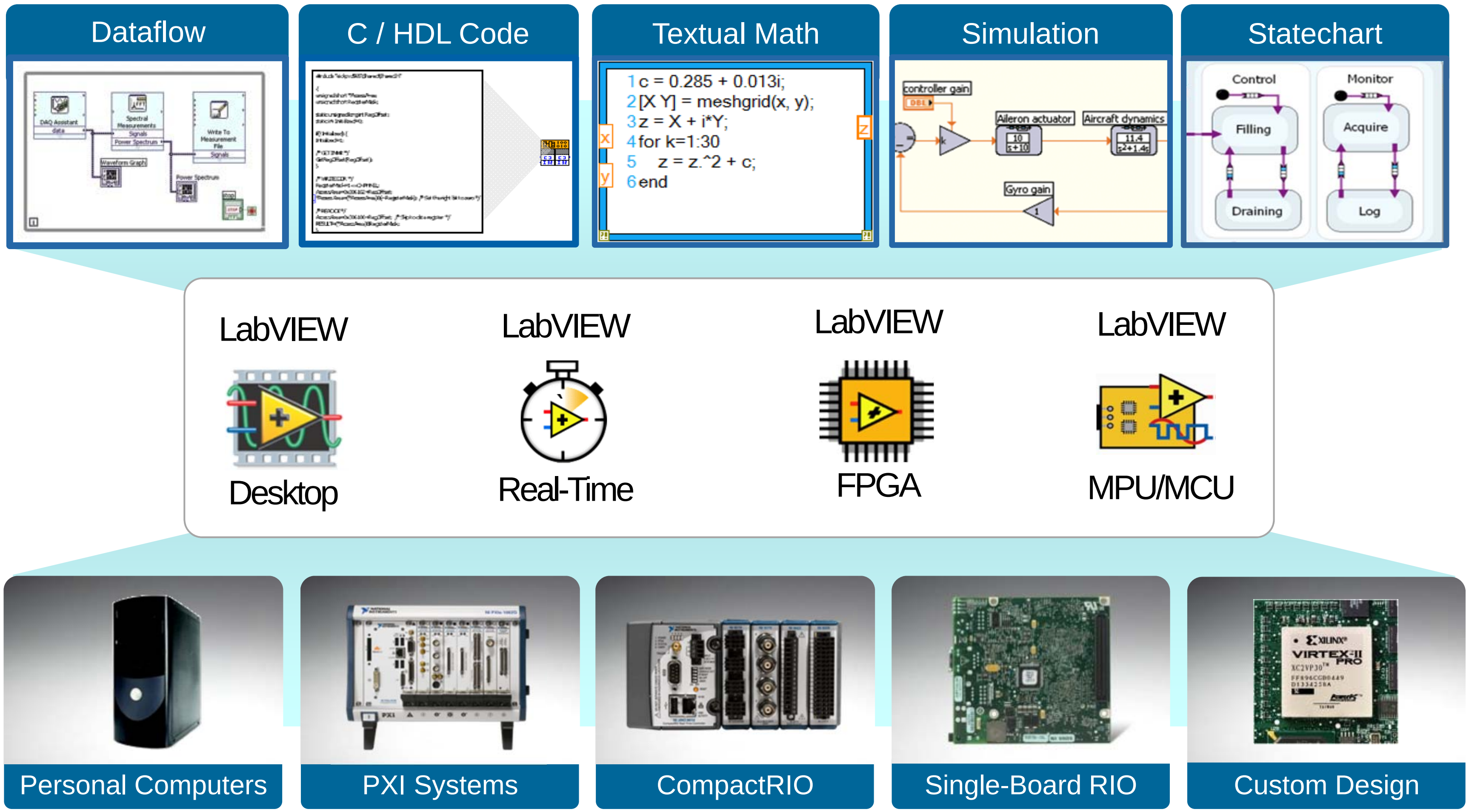
System Design to Deployment



Abstract

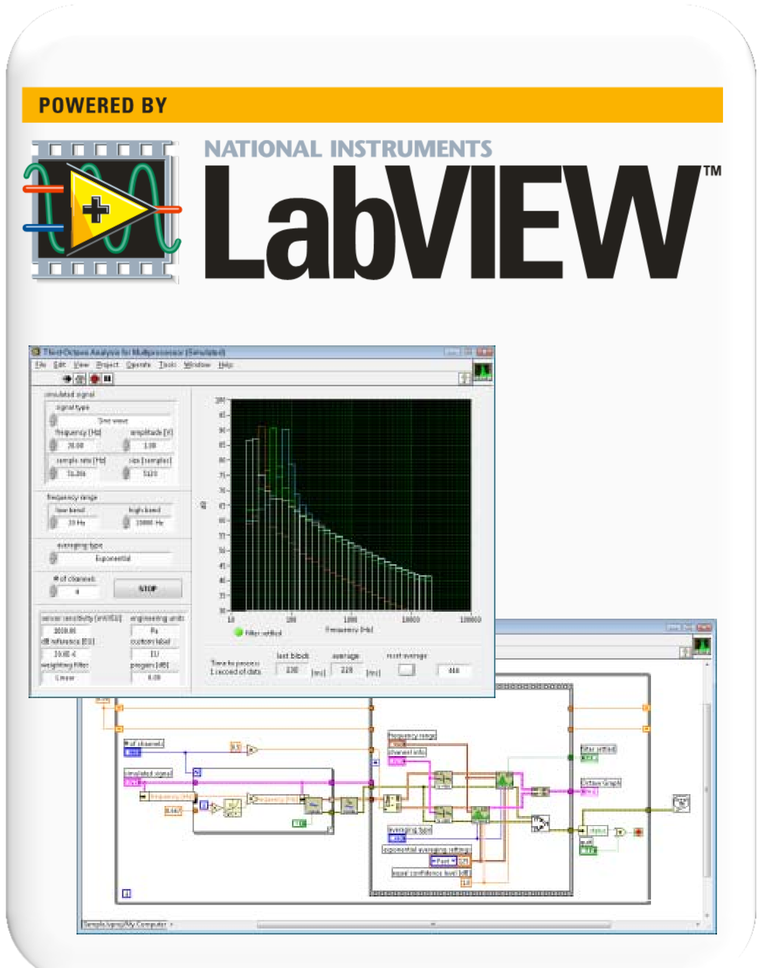
The current economic climate has put even more focus on keeping projects under budget and on time while using the latest technology to meet the needs of measurement, diagnostic, and control systems. Commercial off-the-shelf (COTS) systems take advantage of innovations in the computer industry and the hundreds of millions of dollars devoted to R&D – domain experts can now benefit from FPGAs as wells as multicore CPUs and GPUs without being specialists on these technologies. Through collaborations between industry and research facilities, engineers can customize these technologies while keeping costs low to achieve faster computing and loop rates.

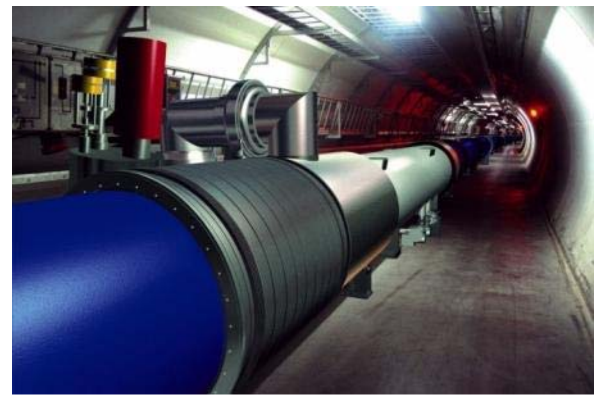
With every project lasting 15 to 20 years, obsolescence management is yet another key benefit of industry-research collaborations. At this session, examine the technological and business benefits of this type of partnership.

Graphical System Design

LEGO® MINDSTORMS® NXT

"the smartest, coolest toy of the year"





CERN Large Hadron Collider

"the most powerful instrument on earth"

The Parallel Programming Challenge

"The concurrency revolution is likely to be more disruptive than the OO revolution…"

- Herb Sutter, CEO, Microsoft, The Free Lunch is Over

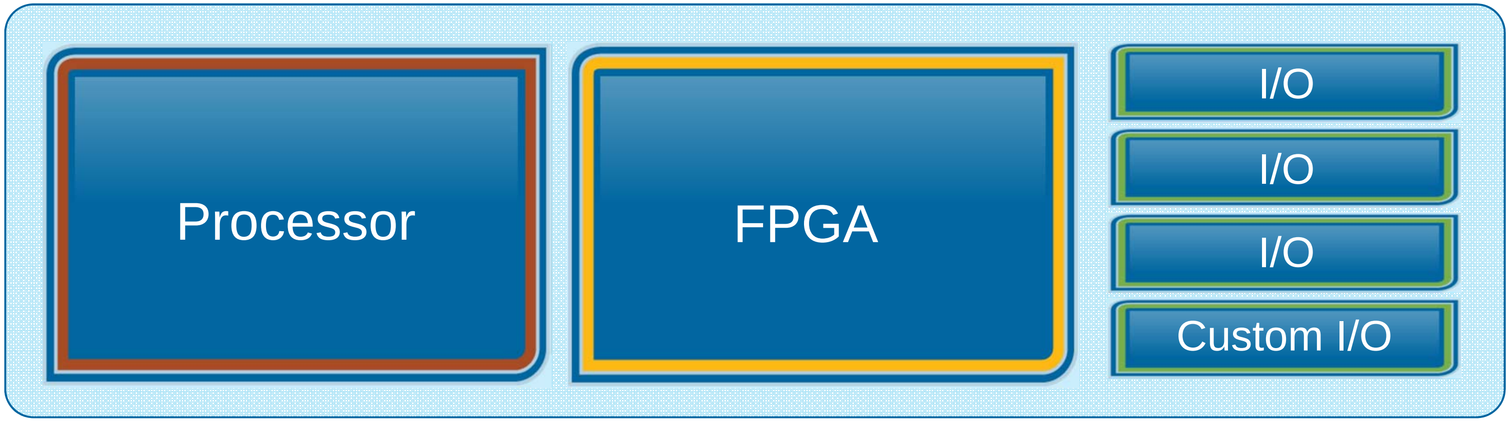
"Parallel programming is perhaps the largest problem in computer science today"

- Stanford CS Department chair Bill Dally

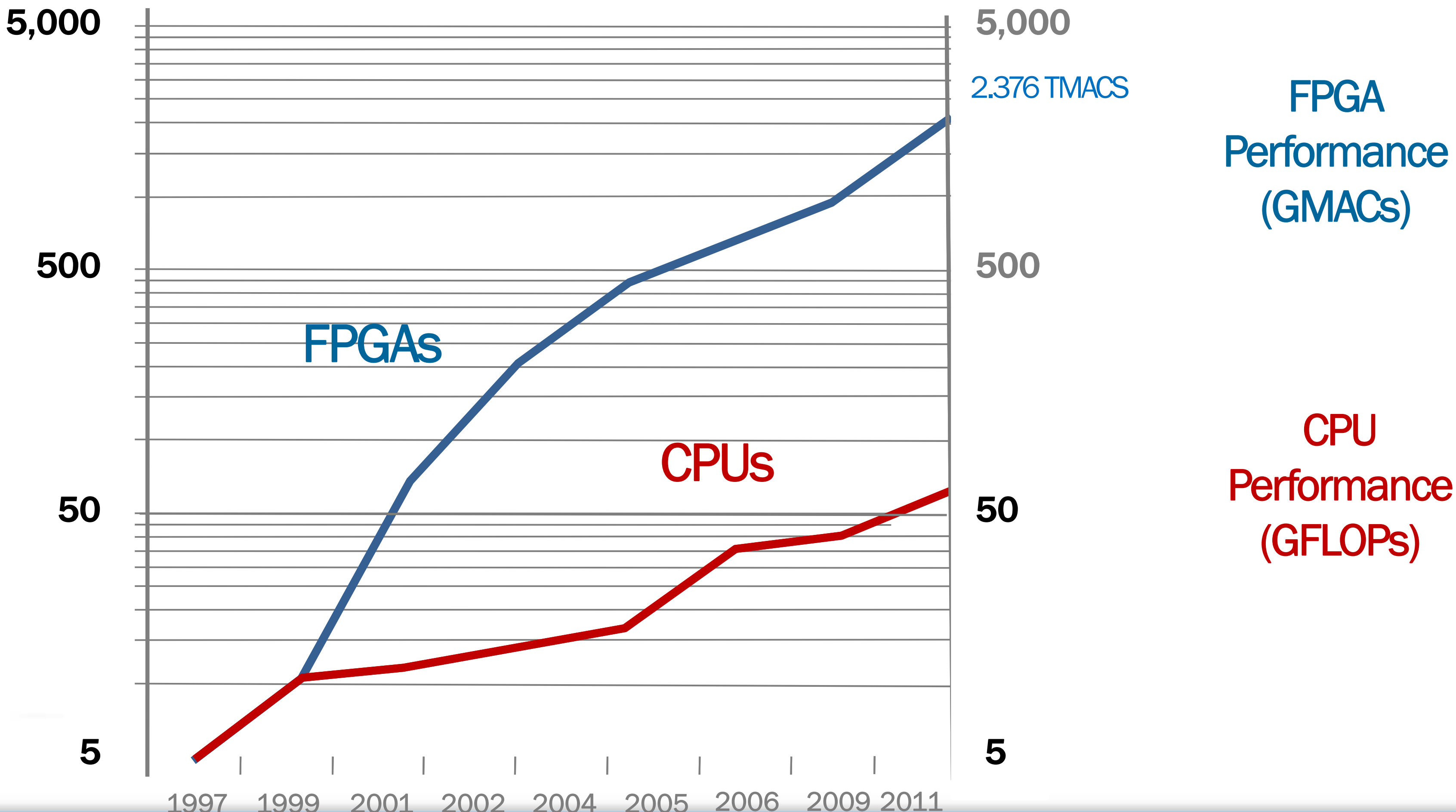
"Nobody knows how to program those things"

– Steve Jobs talking about multicore processors

Reconfigurable I/O (RIO) Architecture



Parallel Architectures Drive Performance



Accelerating Innovation and Discovery with Graphical System Design

Build Better Systems Faster

Better
Integration

Lower
Costs

Higher
Performance

Challenges to Engineering and Science

Grand Challenges

Closer relationship between industry and academia

Maximum Profit

Less Resources

Shorter time to market

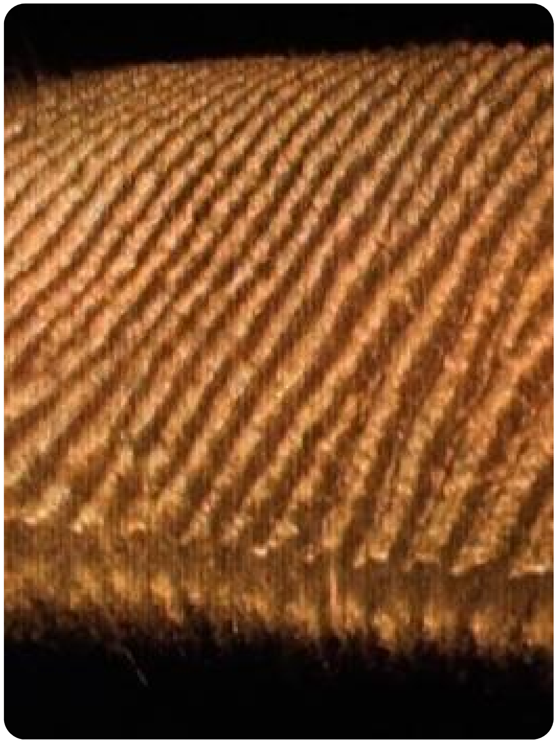
Competitive Pressure

Challenges to Individual Engineers

Globalization
Limiting tools
Deadline pressures
Collaboration
Satisfaction of true impact
Reliance on domain expertise
Integration (code/system)
Individual competitive pressures
ROI and longevity of tools

NI 1976

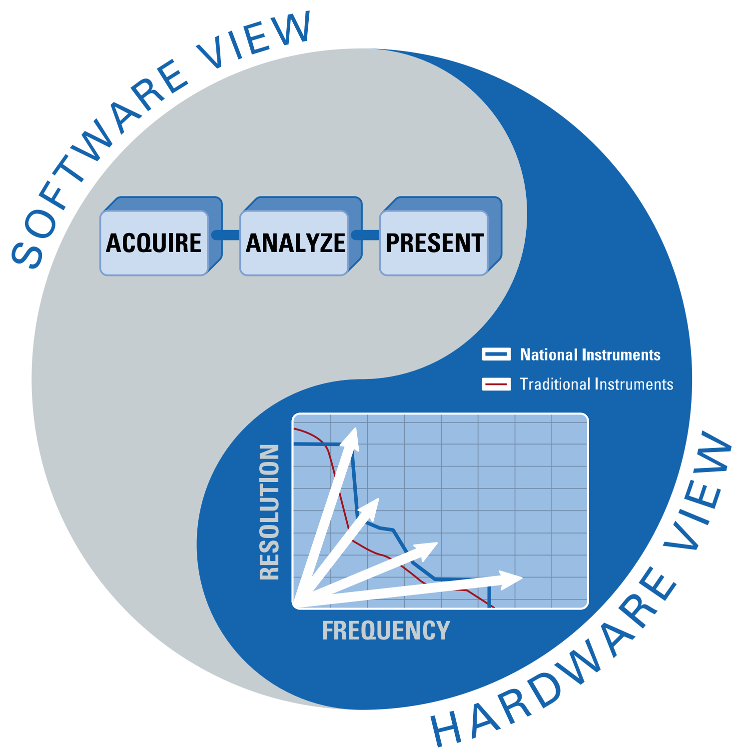
Innovation



Discovery

Sometimes tools get in the way.

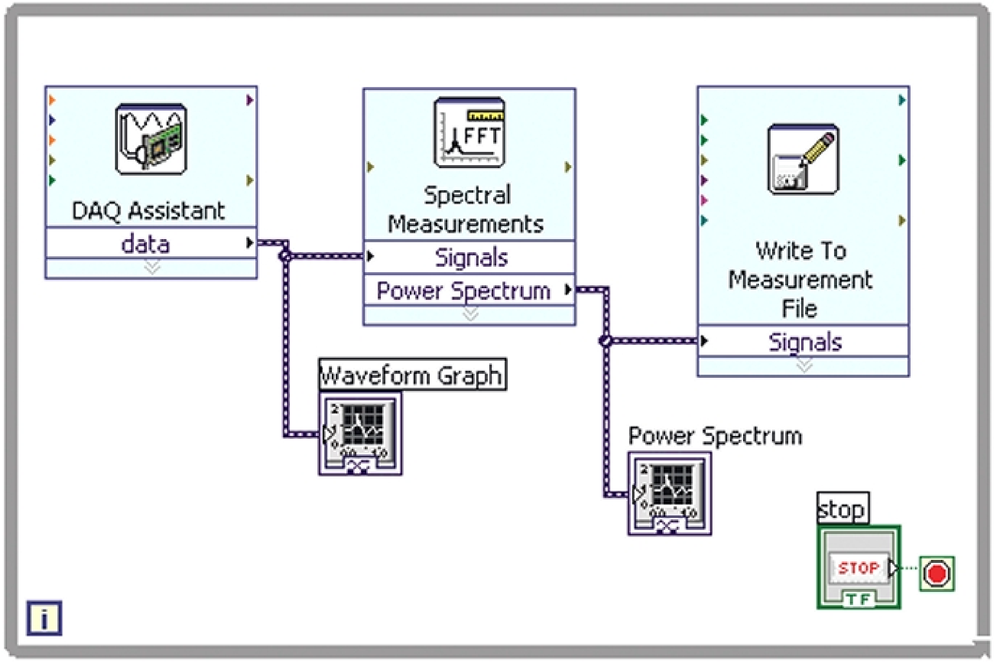
The Virtual Instrumentation Approach



The Software Is the Instrument

Virtual Instrumentation

The Software is the Instrument



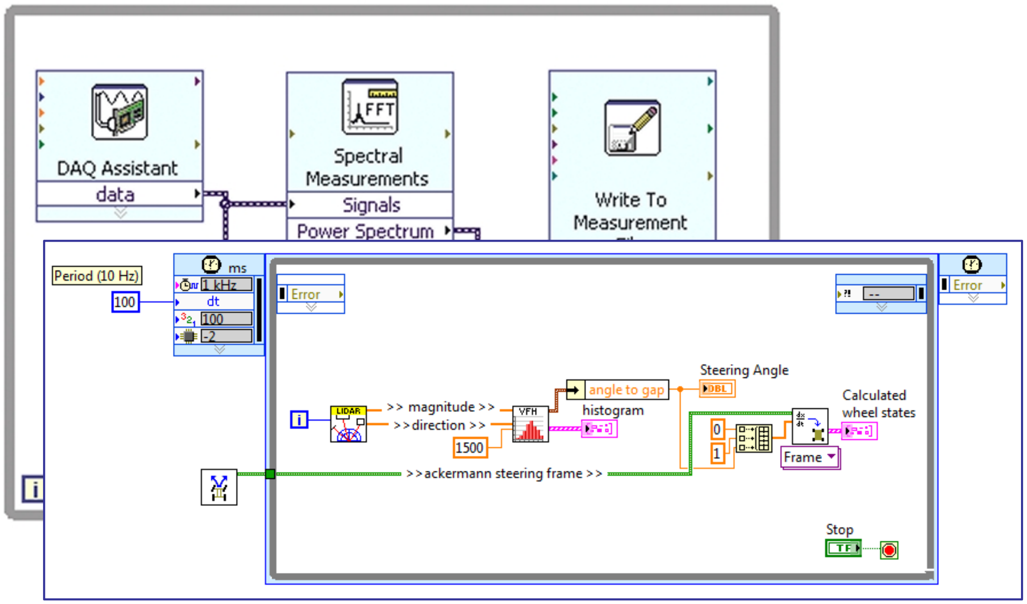
PC-Based DAQ

Modular Instruments

Test, measurement, data acquisition systems.

Graphical System Design

A Platform-Based Approach for Measurement and Control



PC-Based DAQ

CompactRIO

Modular Instruments

Single Board RIO

Virtual instrumentation, embedded control, monitoring, robotics and more.

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

GPIB IEEE-488

ETHERNET

CERTIFIED HI-SPEED USB

Open Connectivity with 3rd Party I/O

Integration of Modular I/O and Commercial Technology

Box Instruments

PXI Modular Instruments

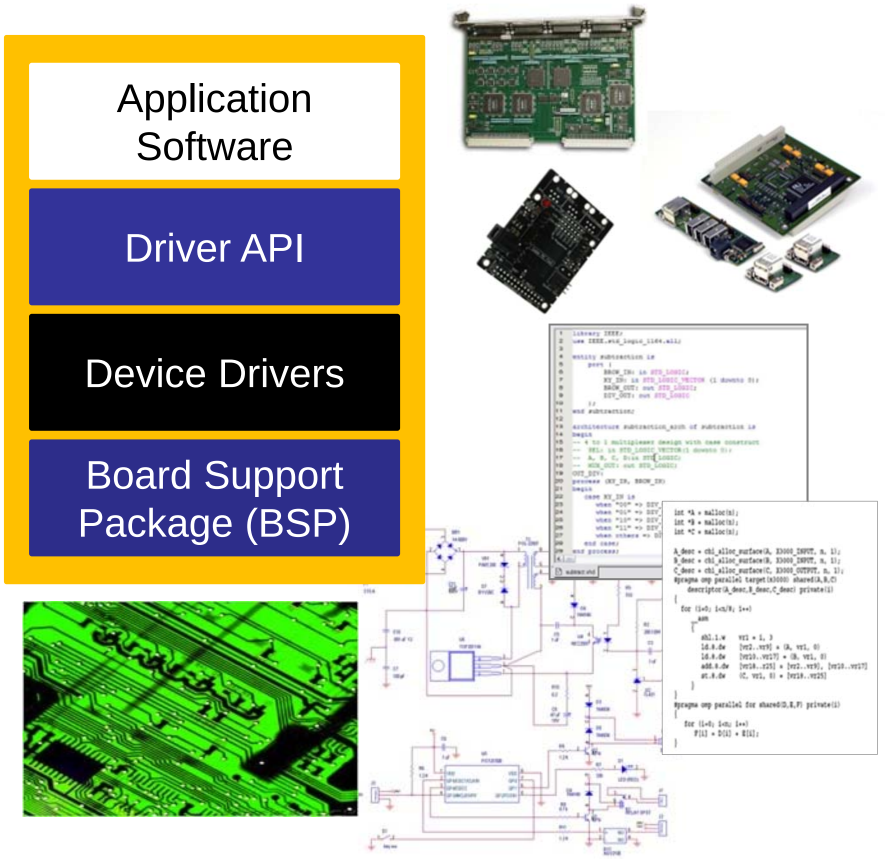
Faster System Development

Application Software

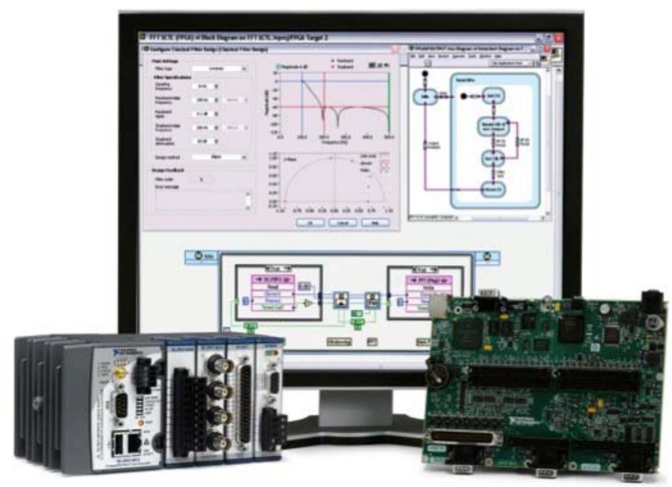
Driver API

Device Drivers

Board Support Package (BSP)

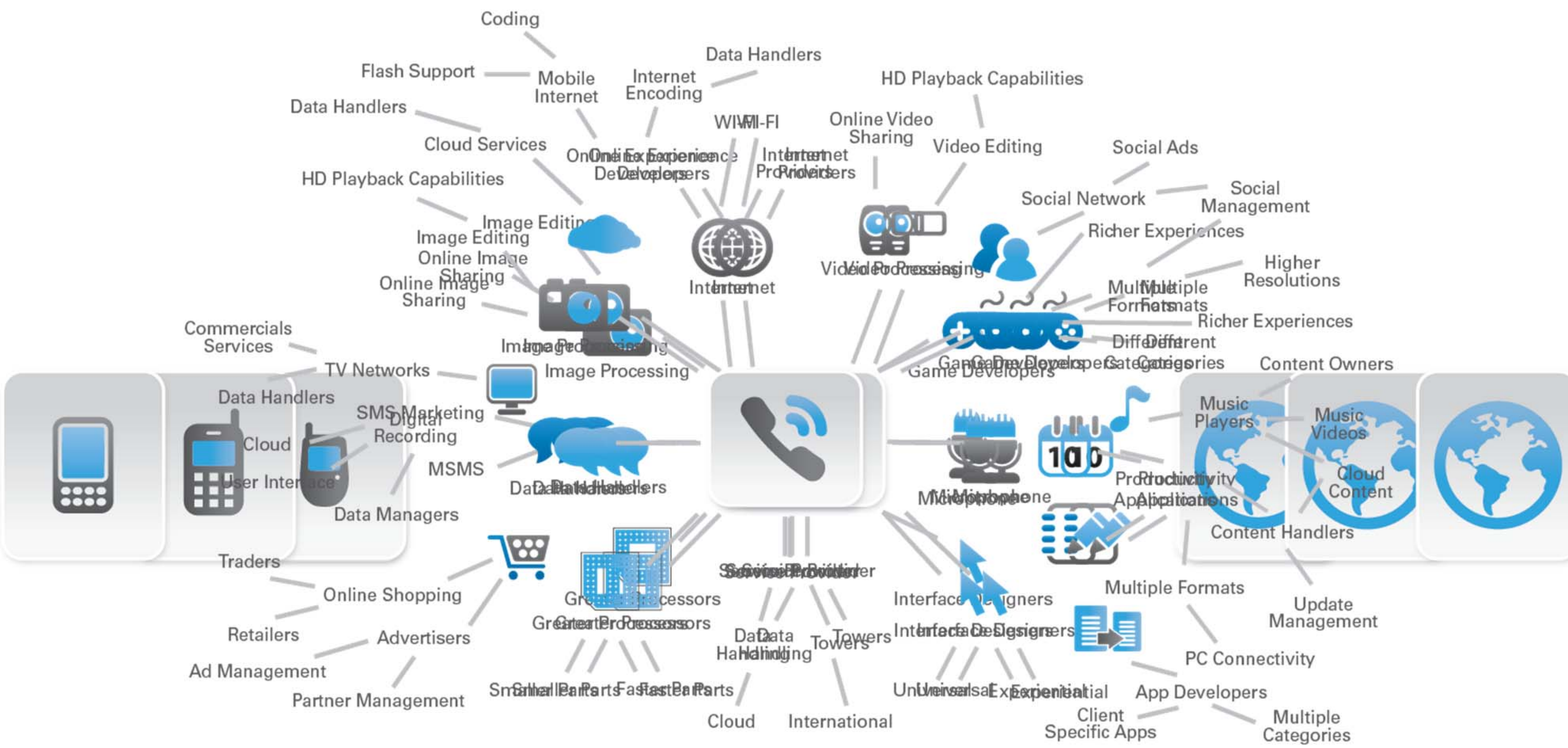


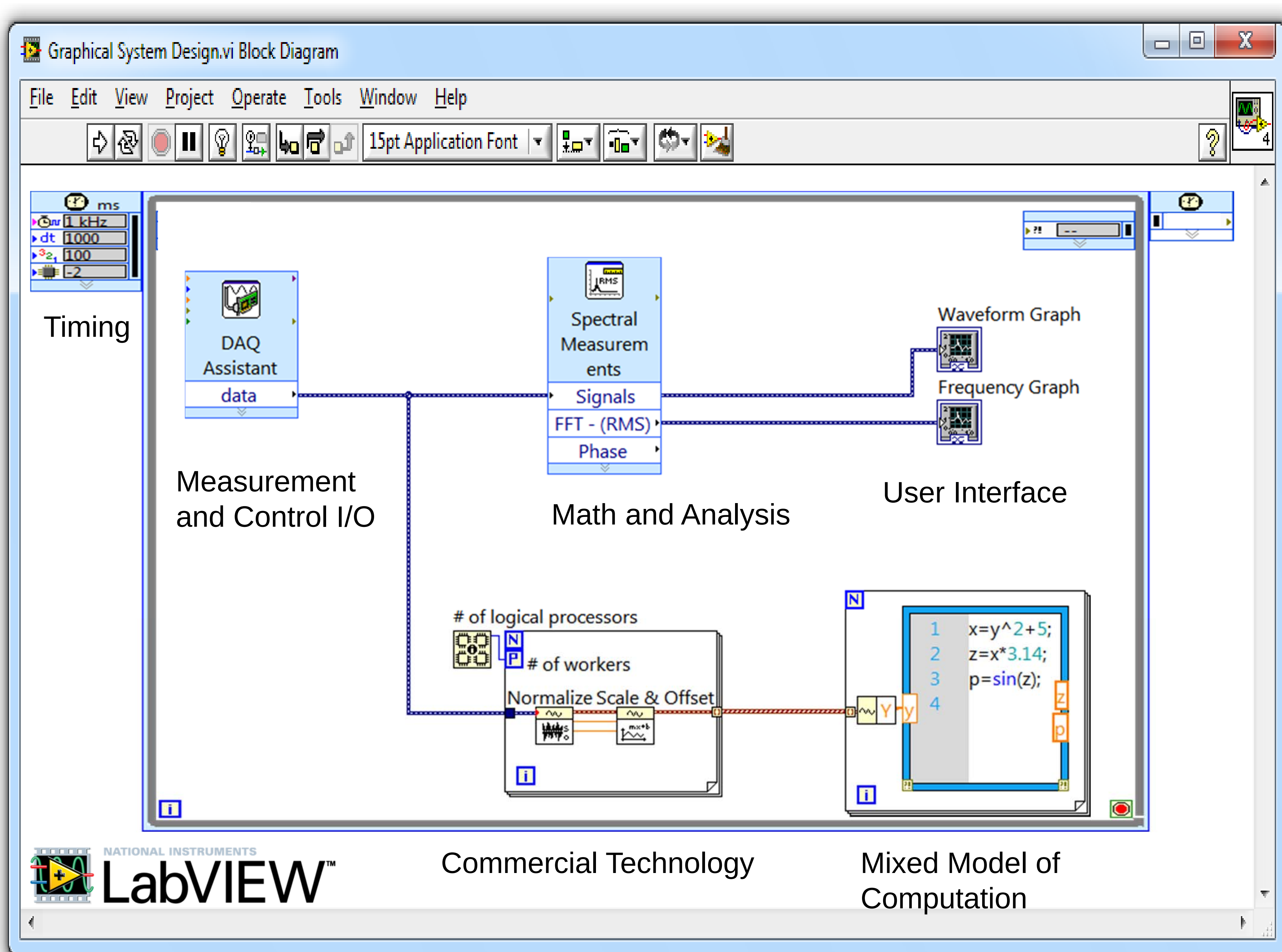
Integrating Components



Integrated System Platform

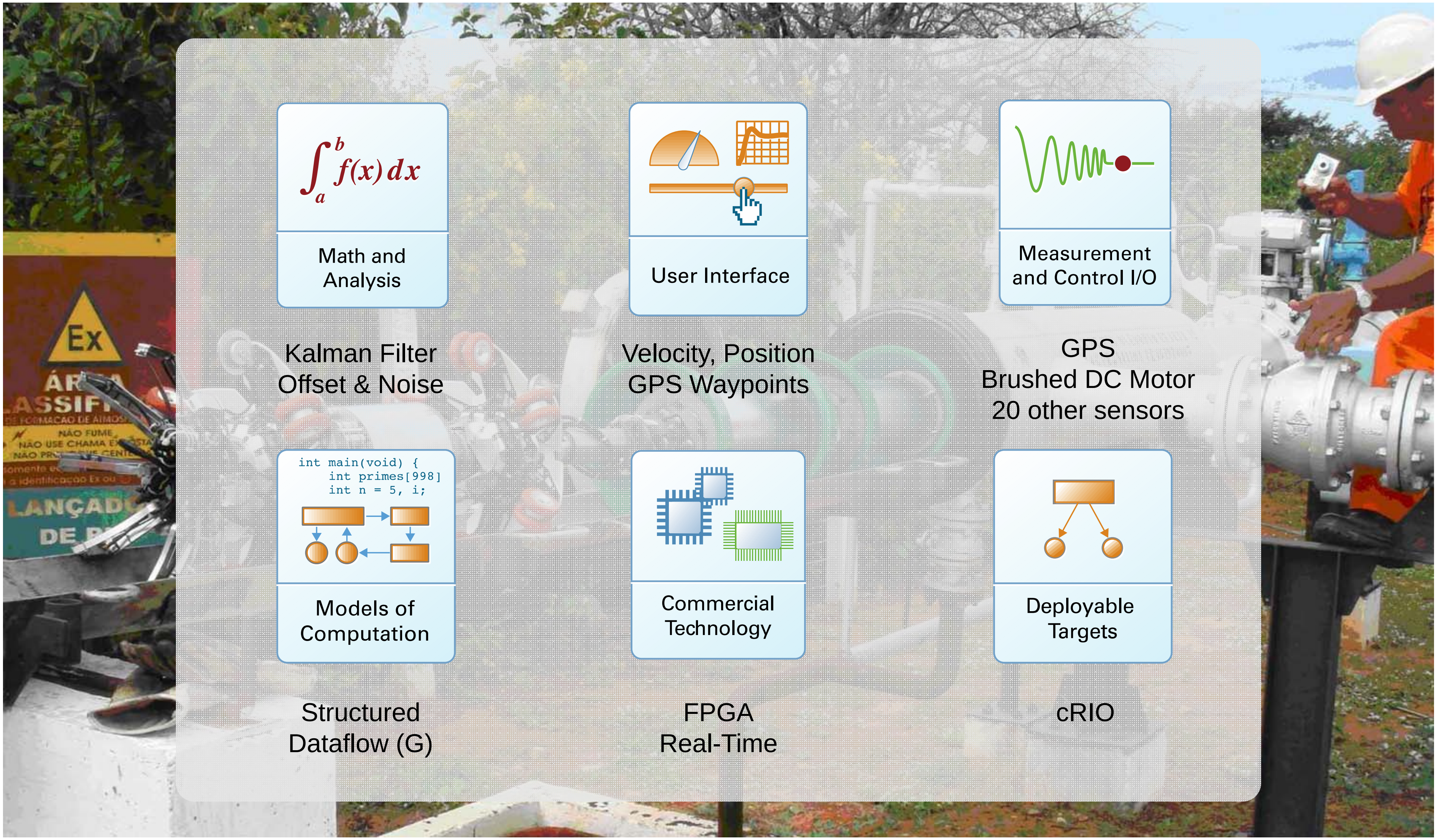
Escalating Complexity over Time




Graphical System Design.vi Block Diagram
File Edit View Project Operate Tools Window Help
15pt Application Font
Timing
DAQ Assistant
data
Spectral Measurements
Signals
FFT - (RMS)
Phase
Waveform Graph
Frequency Graph
Measurement and Control I/O
Math and Analysis
User Interface
# of logical processors
# of workers
Normalize Scale & Offset
x=y^2+5;
z=x*3.14;
p=sin(z);
NATIONAL INSTRUMENTS
LabVIEW
Commercial Technology
Mixed Model of Computation

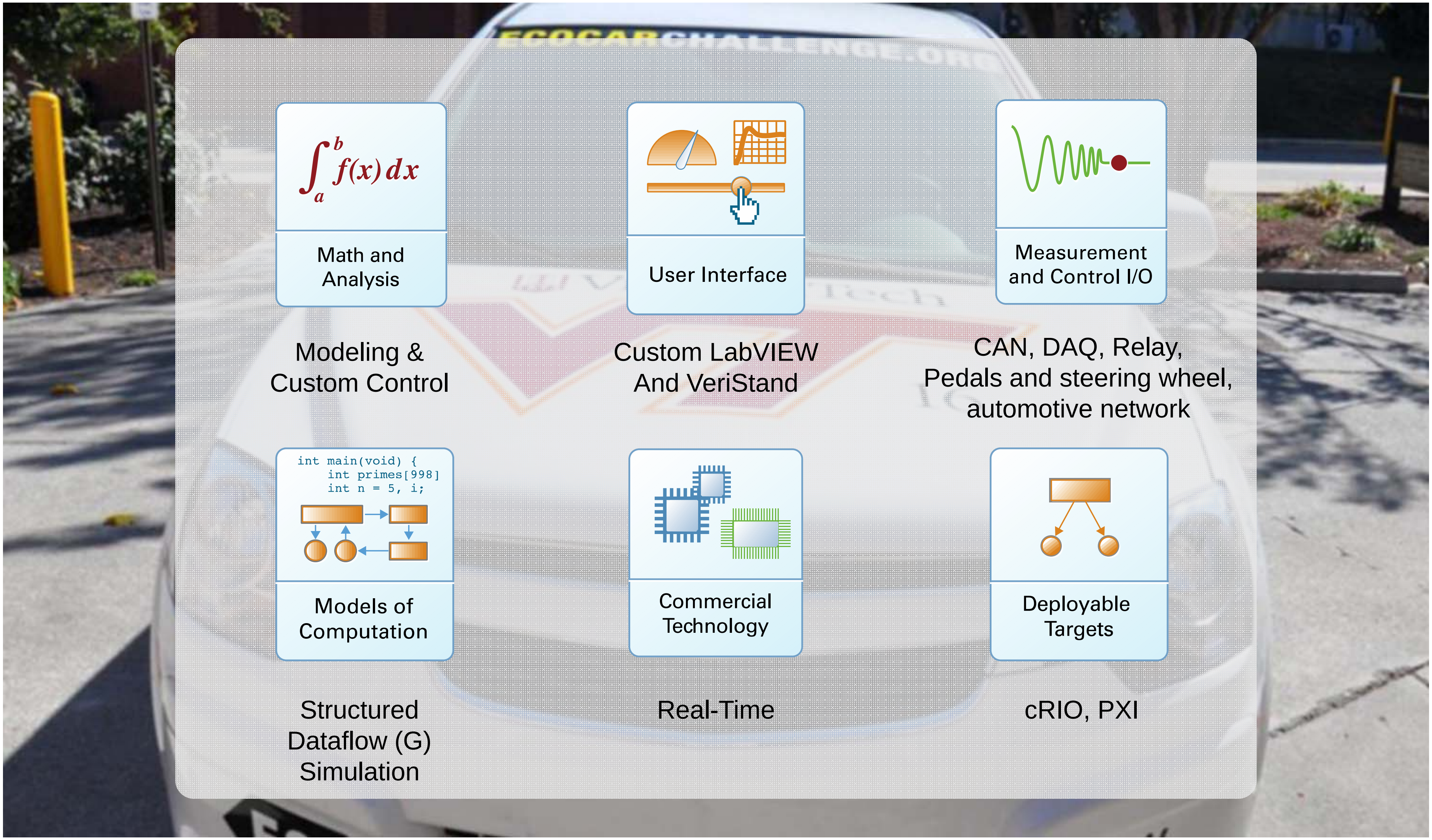
Semiconductor Test

Analog Devices



Pipeline Test and Validation

Inertial Pipeline
Inspection Gauge



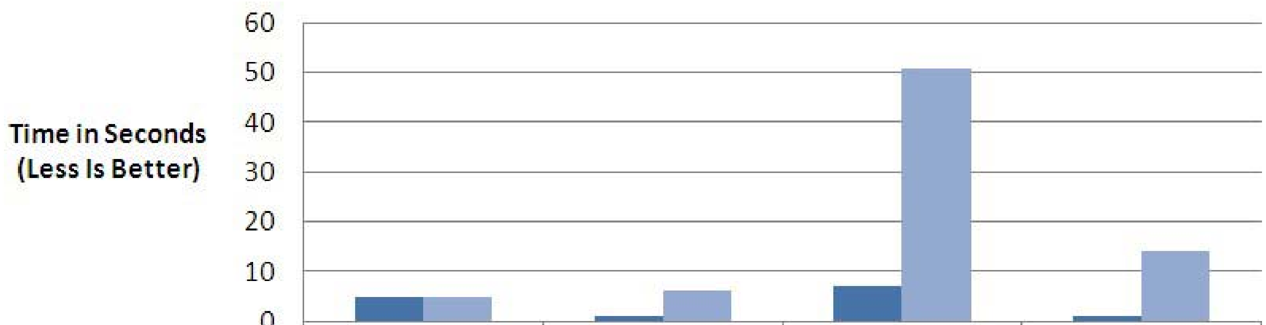
EcoCAR Challenge

Virginia Tech – 1^{st} Place 2011

Maximize the Platform

Abstract Complexity AND Gain Higher Performance

Test Time Comparison

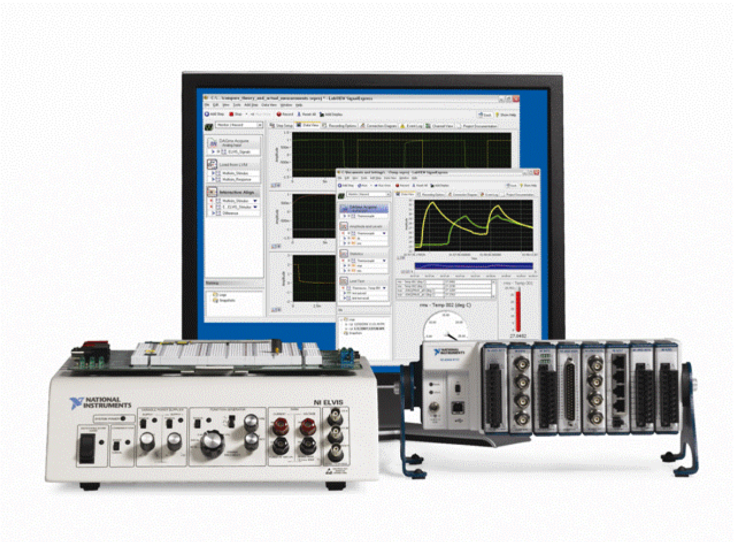


	Communicate to DUT	Switch Settle Time	Measurement	LabVIEW/Test Stand
PXI	5	1	7	1
Standard Bench	5	6	51	14

"Using the National Instrument PXI platform, we were able to **reduce test time by almost six times** and develop a cost-effective, long-term RF test bench solution."

Min Xu - Texas Instruments

Leverage a Framework AND Significantly Reduce Costs



"It previously cost us as much as **$1.5 million USD** to build a console, but with the LabVIEW Real-Time and PXI framework, the most complex console **now costs us only $250,000 USD** to build. In addition, our application development time dropped from two years to less than eight months."

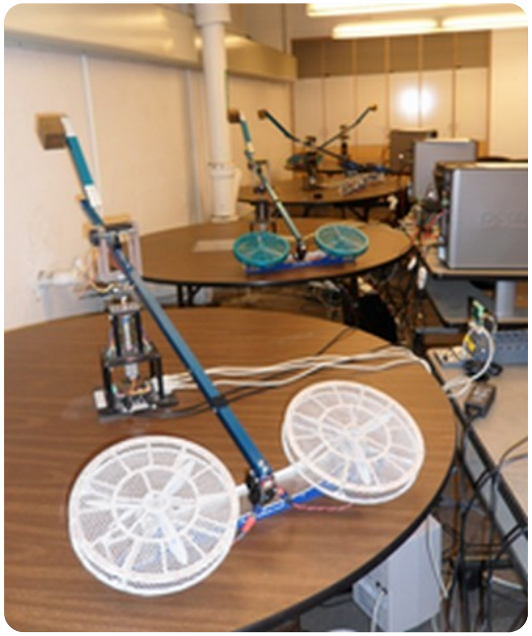
Royal Cook, Parker Hannifin

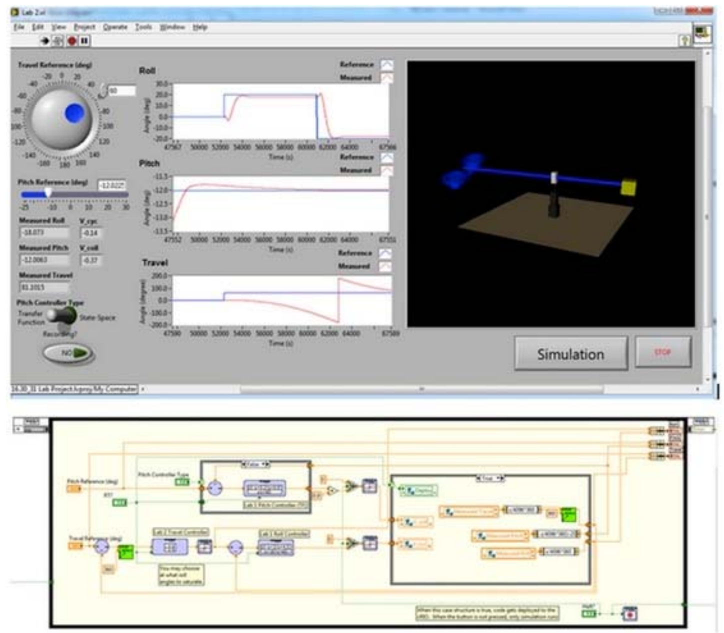
Gain Flexibility AND Focus on Functionality

“We found that the combination of LabVIEW and NI hardware was **infinitely configurable** to meet our needs, leading to rapid development, continuous improvements throughout the life cycle of the product, and, **most importantly, a compact and simple controller architecture**.”

Daniel Giroux - PBS Biotech, Inc.

Focus on the Design, Not the Tools





"Overall, the LabVIEW framework gave students the freedom to take **greater control of the hardware controller design process**."

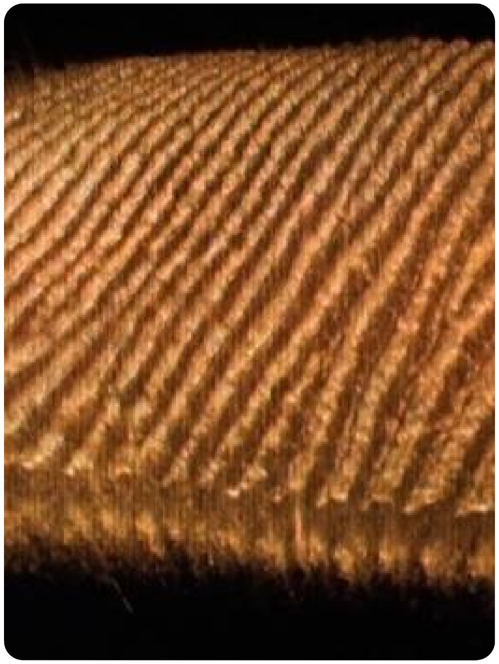
Professor Jonathan How - Massachusetts Institute of Technology

Graphical System Design is Your Competitive Advantage

"In the past, we would have needed a team of four people – a controls expert, a mechanical engineer, an electrical engineer, and a programmer, now it takes only one person."

Sean Dougherty, Mechatronics Supervisor for MacDonald Dettwiler and Associates – U.S.

Innovate. Discover. Invent. *Faster.*



"…World's first real-time 3D optical coherence tomography imaging system…"

Dr. Kohji Ohbayashi, Kitasato University