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Measurement Technology Trends In Instrumentation and Control

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National Instruments

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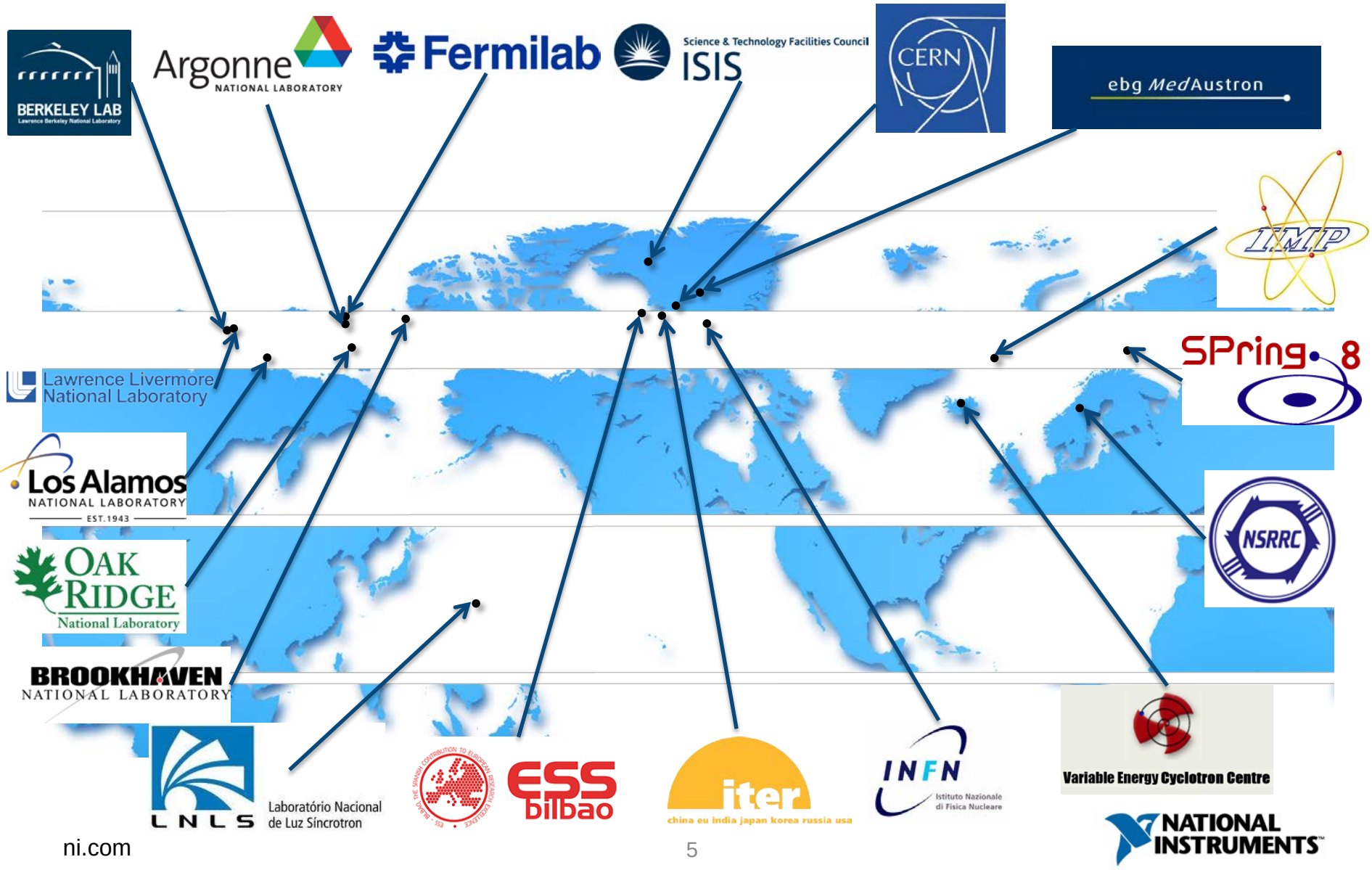
Agenda

- NI’s Involvement in Physics Research
- Technology Trends
- Platform-Based System Development
- Looking Forward

NI at Past ICALEPCS

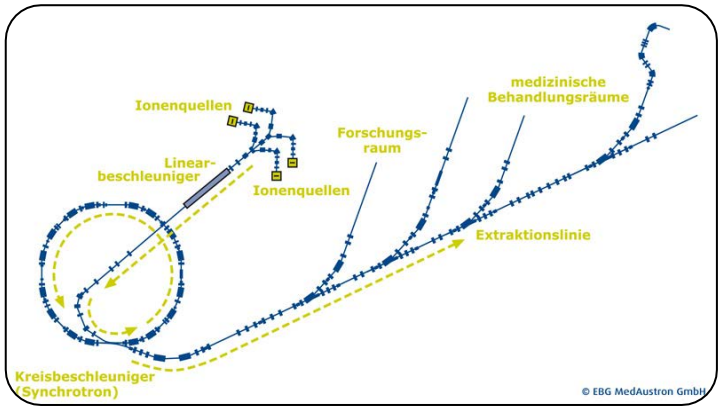
- 2007 – *It's all about time*
  - Dr. Jacob Kornerup, NI Software Architect
- 2009 – *Leverage Hardware & Software Technologies to Meet Your Control System Needs*
  - Murali Ravindran, Sr. Product Manager
- 2011 - *Customized Off-The-Shelf Technologies Through Industry/Research Facility Partnership*
  - Dr. James Truchard, NI Founder/CEO

Worldwide Collaboration



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



Customized COTS to meet requirements and complete project on time

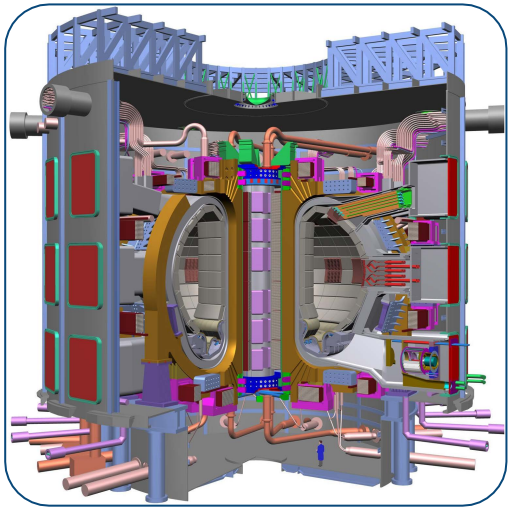
Instrumentation & Control for LANSCE LINAC

- LANSCE Upgrade project at LANL
  - ~ 10,000 I/O points for remote instrumentation and control
- Latest instrumentation and control hardware compatible with existing drivers and records
  - Existing EPICS interface and IOC records with latest hardware
  - FPGA-based motion control

Upgrading to latest technology while preserving existing investment

Fast Interlock, Control and Diagnostics - ITER

- ITER instrumentation and control requirements
  - 1 million I/O points
  - 20 GB/s archive rate
- COTS hardware with Linux drivers
- Native EPICS device drivers
- Special testing
  - Fast and Thermal neutrons
  - Gamma rays



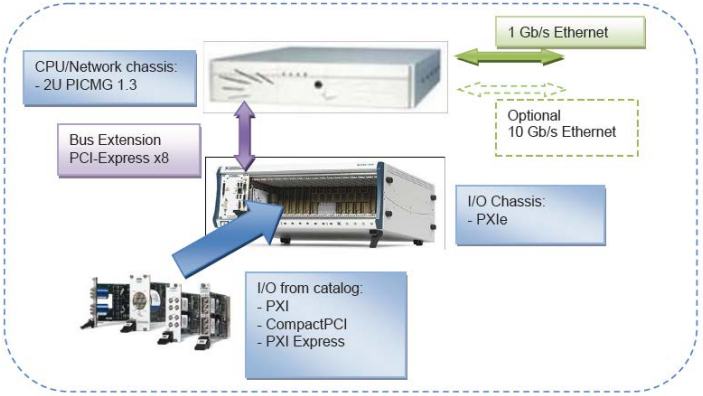


Figure 1 – A General Purpose Fast Controller

Developed custom drivers and performed special testing to meet needs

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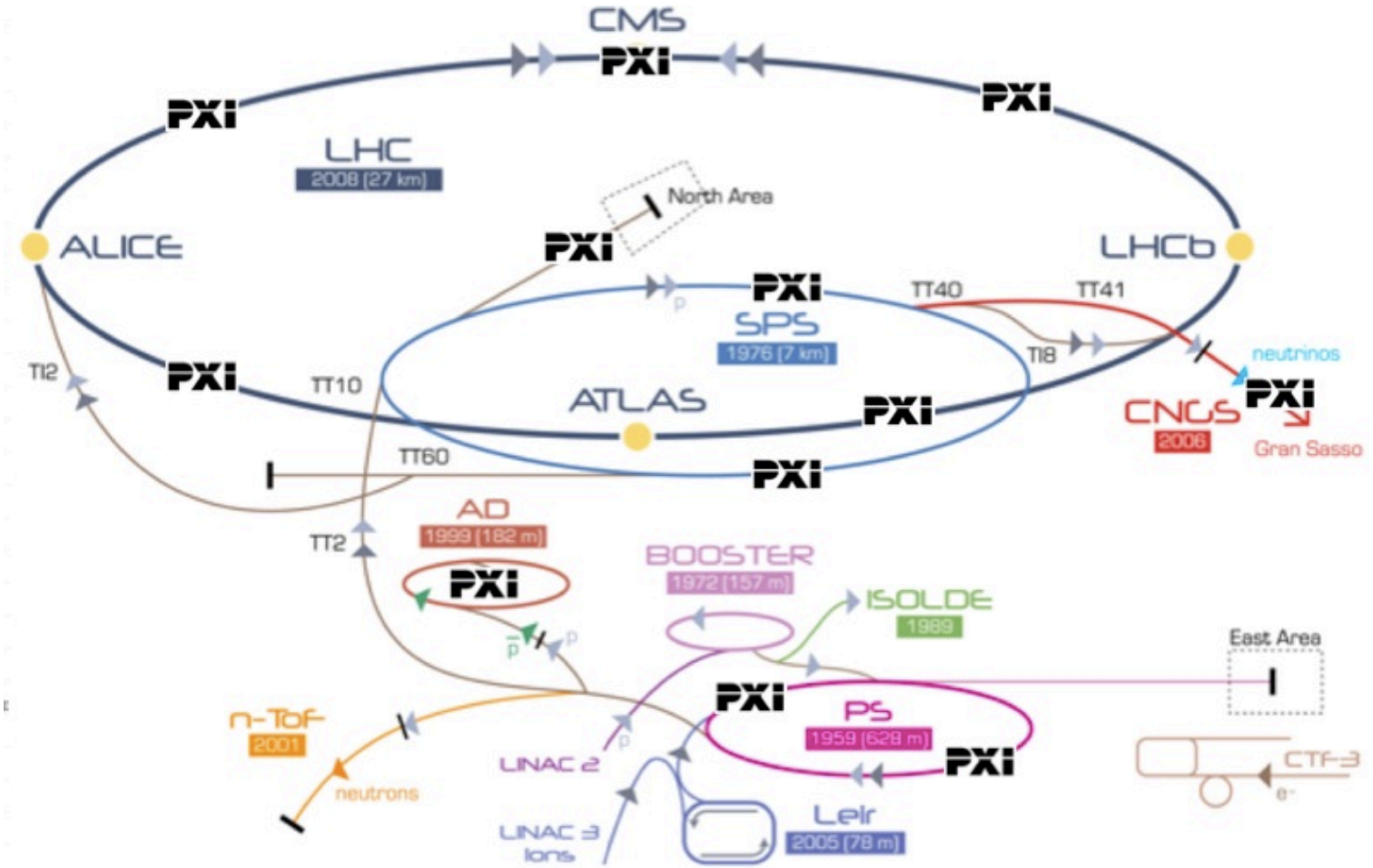
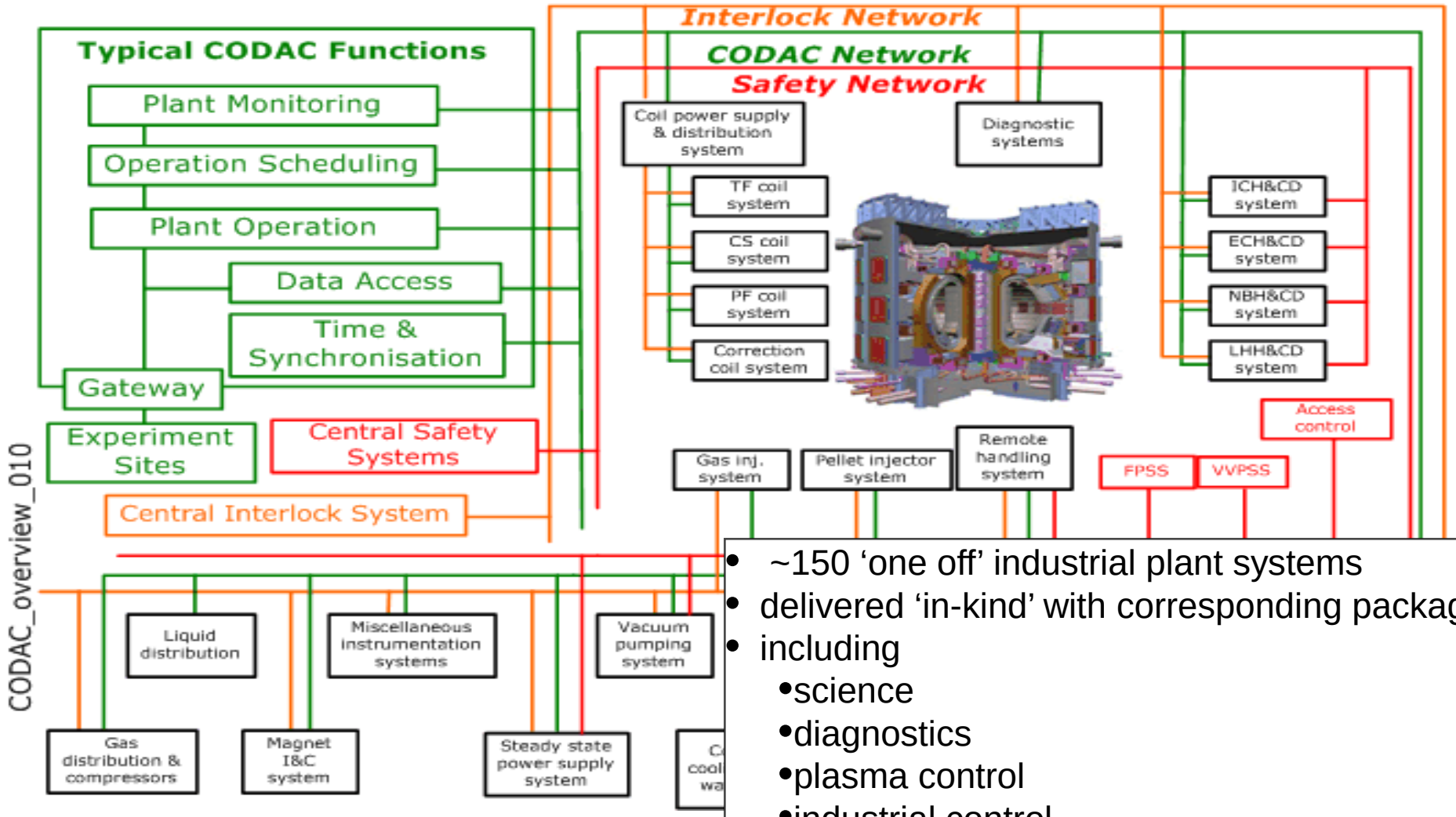
CERN Accelerator Control Systems and NI Technology



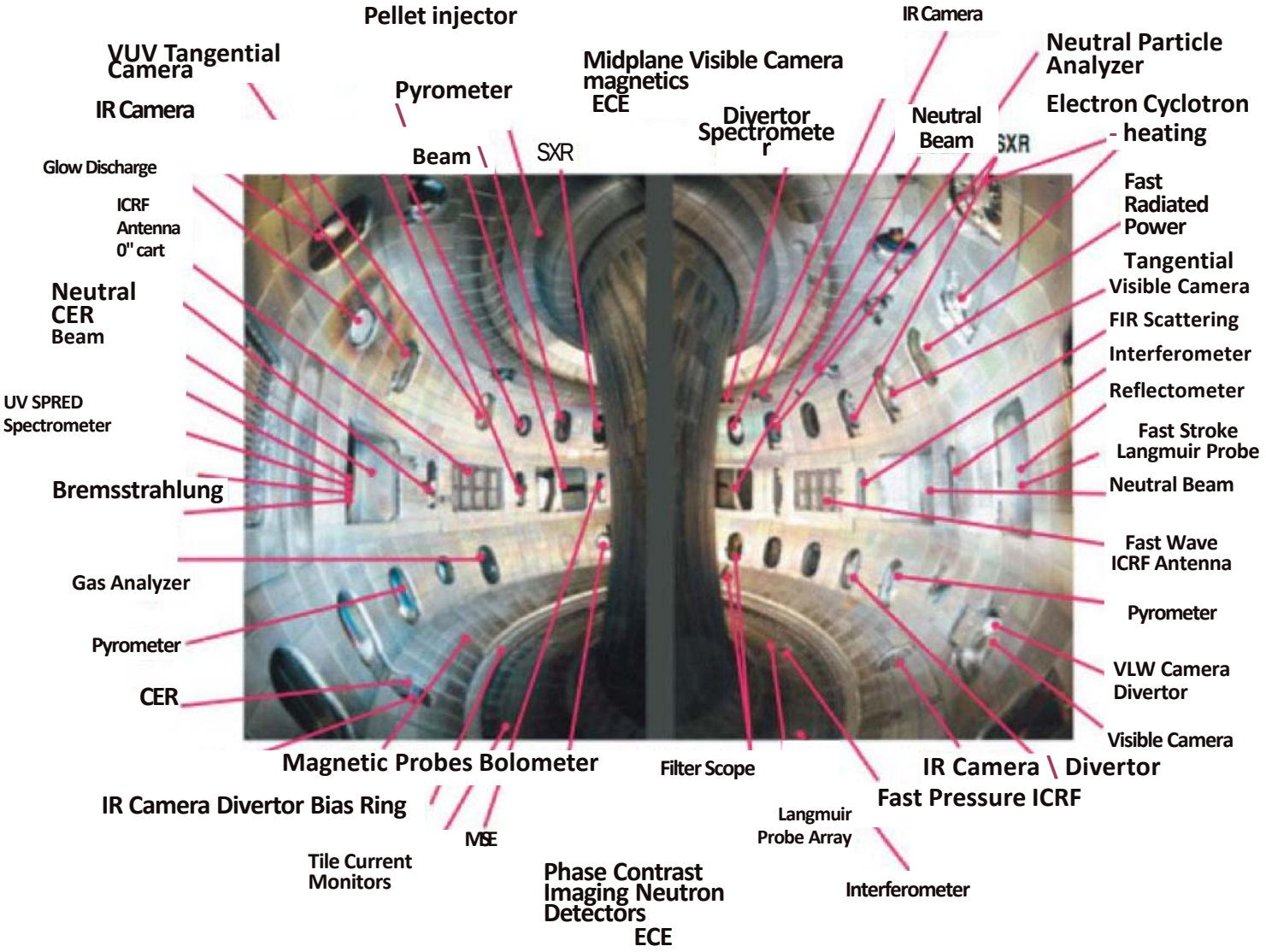
CODAC System Architecture for ITER



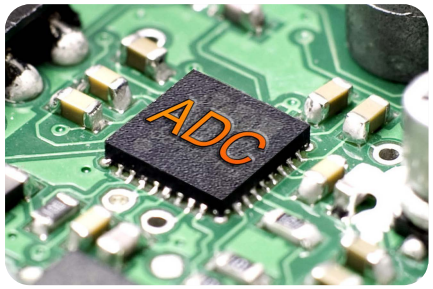
- ~150 'one off' industrial plant systems
- delivered 'in-kind' with corresponding package
- including
  - science
  - diagnostics
  - plasma control
  - industrial control
- interconnected by dedicated networks

Control, Data Access and Communication

DIII-D Example Installed Diagnostics



Technology Trends



- Data Converters

- High performance processing

- Network communication

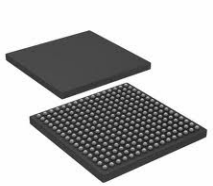
Trends in High Resolution ADC
(most bits and most speed)

1990 | 1998 | 2006 | 2012

8 bit 3MS/s Pipeline

16 bit 1MS/s SAR Hybrid

16 bit 50kS/s Σ-Δ



8 bit 50MS/S Pipeline

16 bit 1MS/s SAR monolithic

20 bit 10kS/s Σ-Δ

16 bit 250MS/s Pipeline

16 bit 3MS/s SAR monolithic

24 bit 105kS/s Σ-Δ

10 bit 5GS/s Pipeline

18 bit 3MS/s SAR monolithic

24 bit 250kS/s Σ-Δ

Look for 12 to 14-bit, 5-10 GS/s Pipelines by 2016

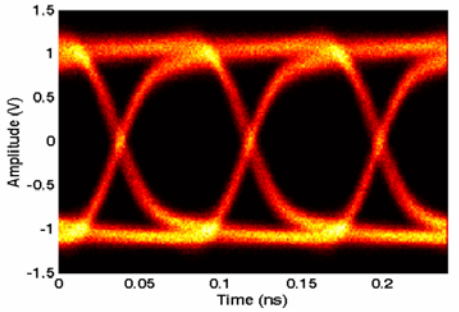
Beyond 2013

- Massively interleaved CMOS ADC's
  - 56 GSPS/8 bit (320 converters x 175 MSPS) already available
  - Magical Track and Holds
  - Designed for optical high speed communications

- Experimental Time Stretch Photonic ADCs
  - TiSER (Time Stretch Enhanced Recorder)
  - "Fits in a single room"
  - 10 Terasamples/sec transient ADC

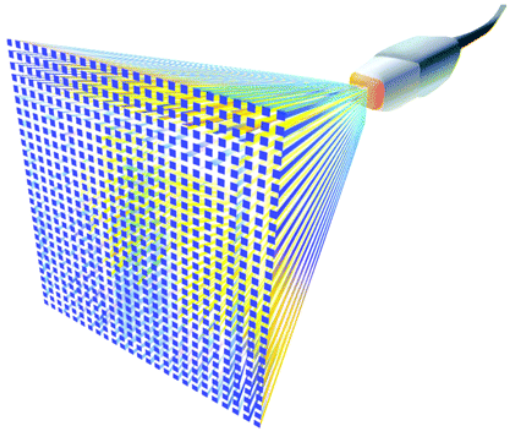
- 12 Gbps+ serial data links
  - CMOS scaling minimizes pin count/traces (JESD204B)
  - Very high bandwidth OR high channel count
  - Imaging applications

TiSER capture: 12.5-Gbit/s PRBS data eye



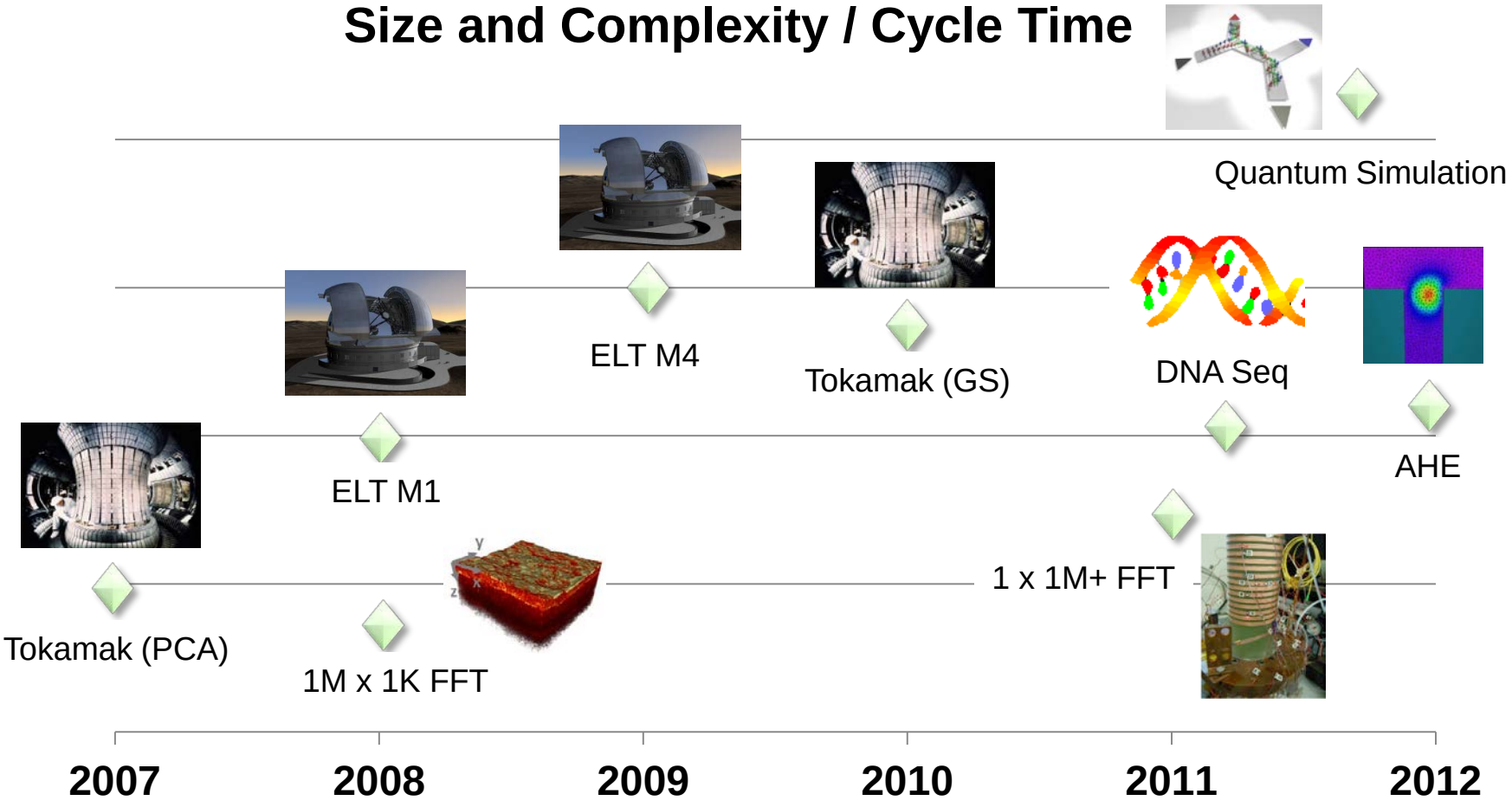
Backend Digitizer: NI-5154
(1-GHz bandwidth, 2-GS/s sample rate)
Stretch Factor: 23

Optoelectronic Circuits and Systems Laboratory 14

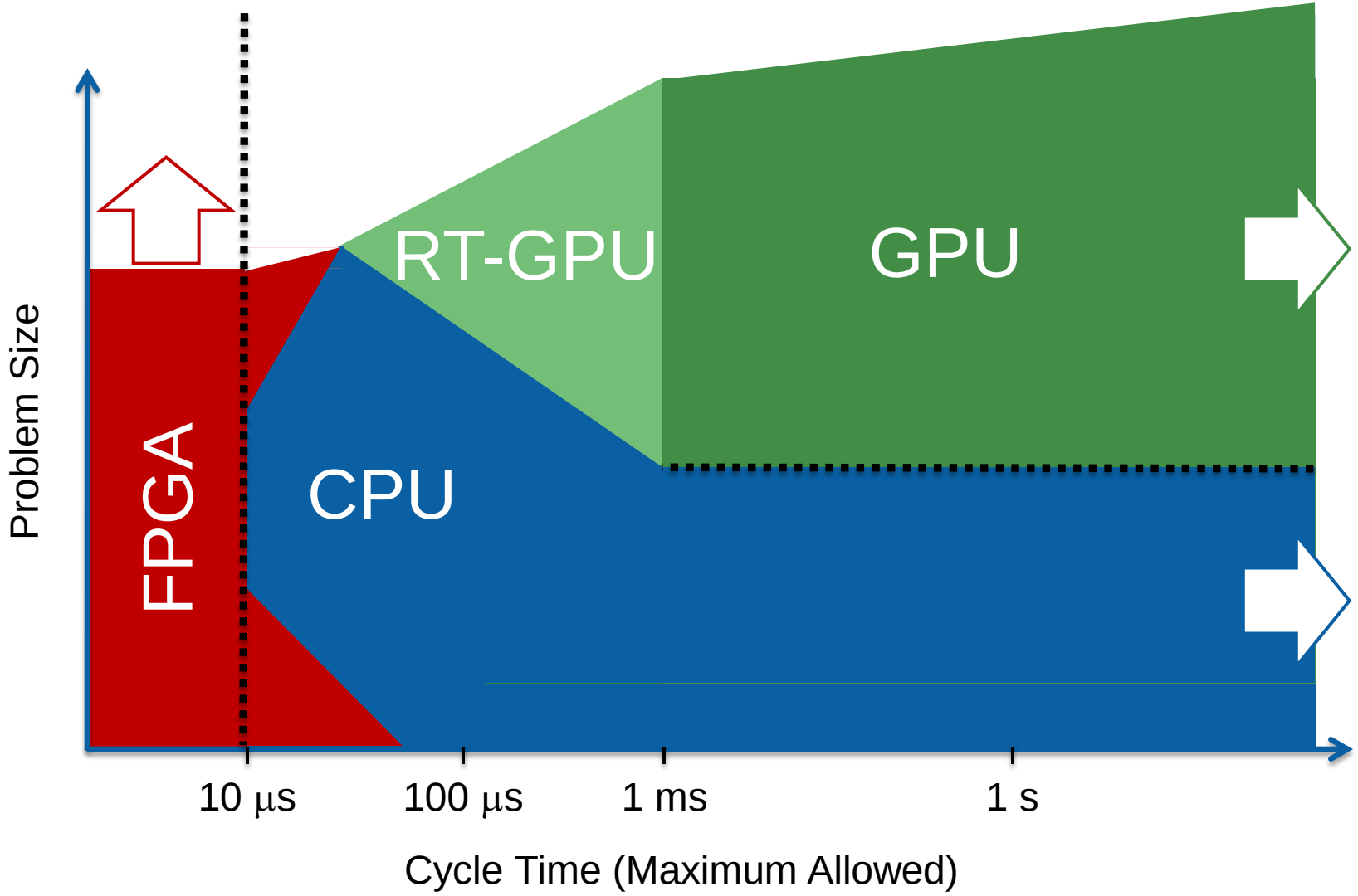


Matrix Array Transducer for Ultrasound

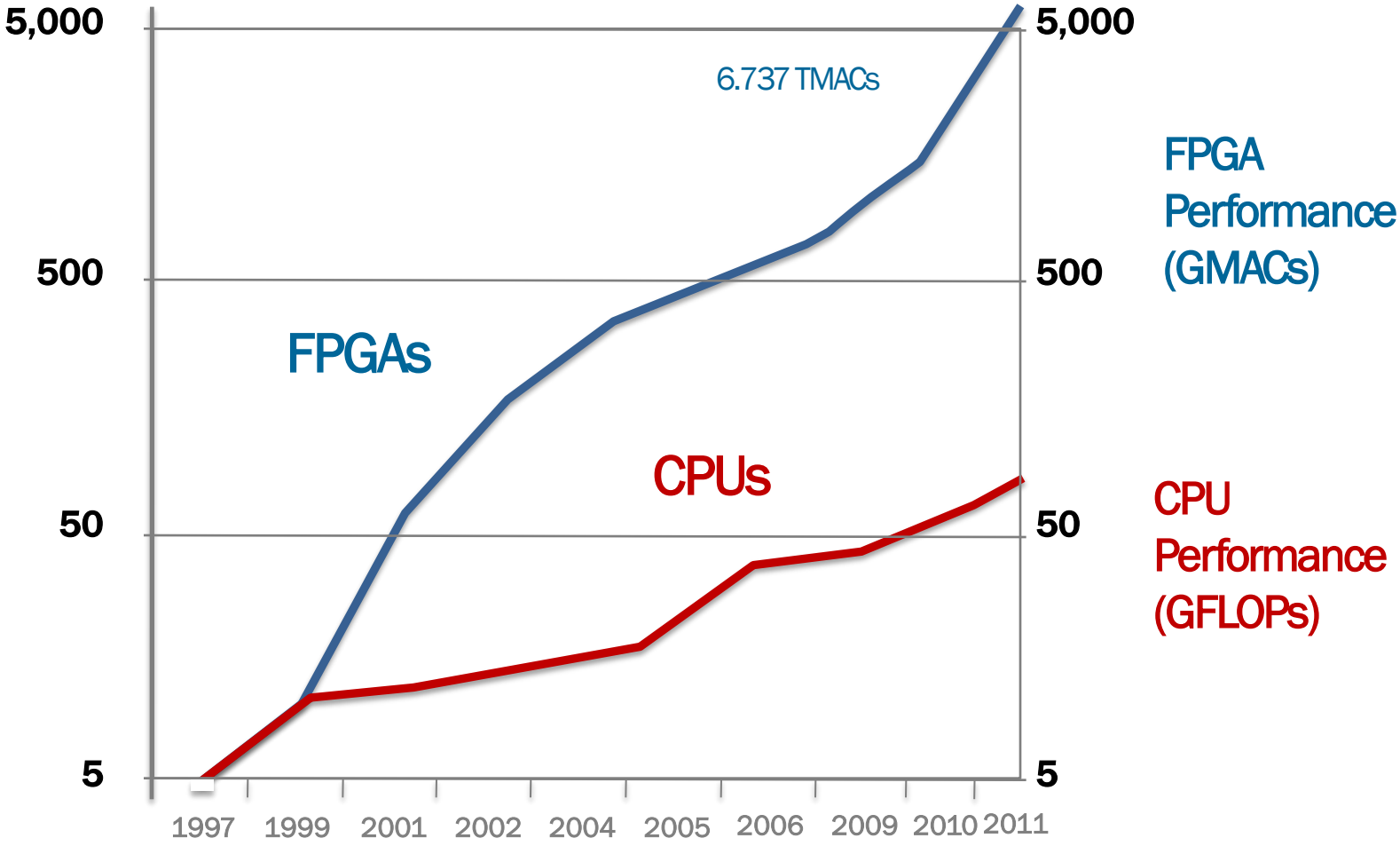
Real-Time HPC Trend



Processing Landscape for Real-time Computation

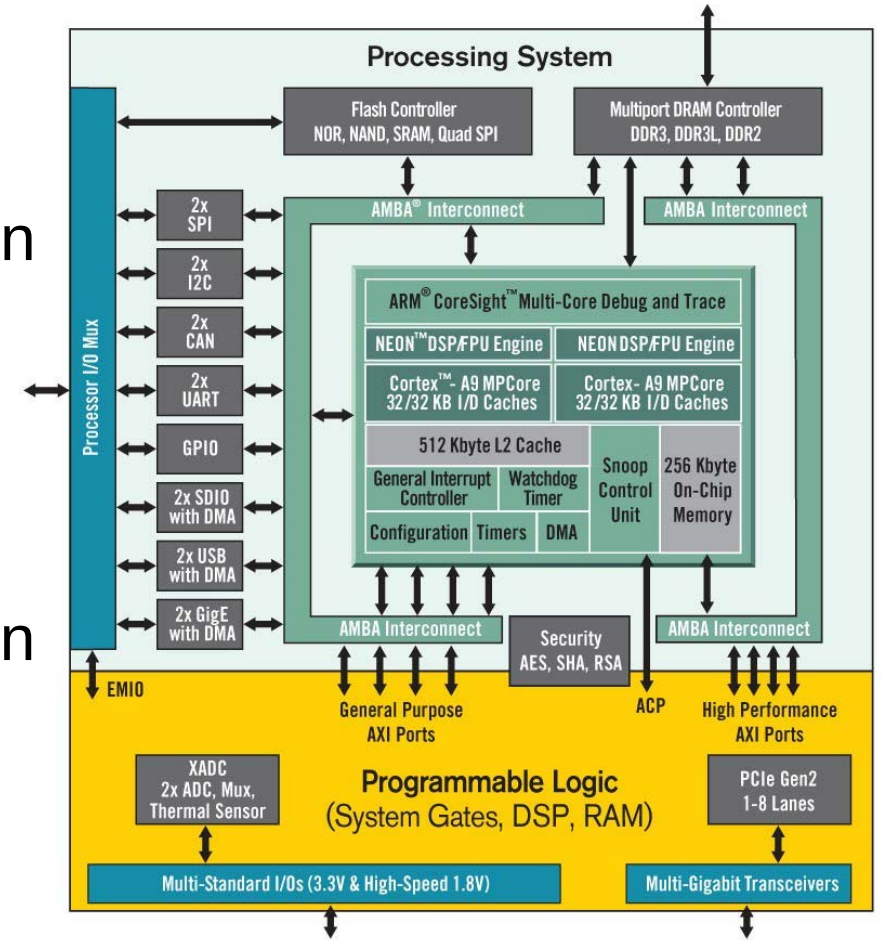


Parallel Architectures Drive Performance



Processing Subsystems on FPGAs

- Xilinx Zynq and Altera Cyclone V with HPS
- High performance application processing system on the same die
- Much higher bandwidth between the processing system and FPGA fabric than traditional architectures
- FPGA fabric offload of computations and custom instruction



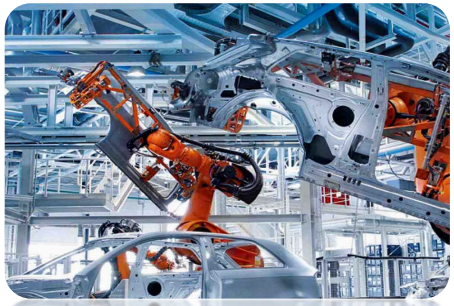
Xilinx Zynq-7000 All-Programmable SOC

IEEE 802 Ethernet Standards Activity

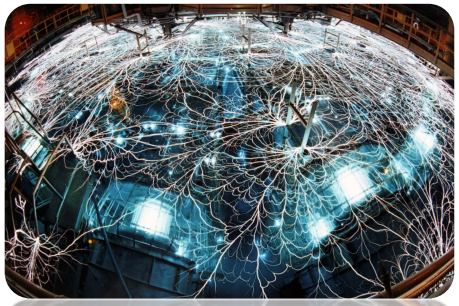
- Efforts driven by 802.1 (bridges/switches) and involve 802.3 (cabling) and 802.11 to enable reliable, high performance control applications over standard and shared Ethernet

- Representatives involved from multiple industries

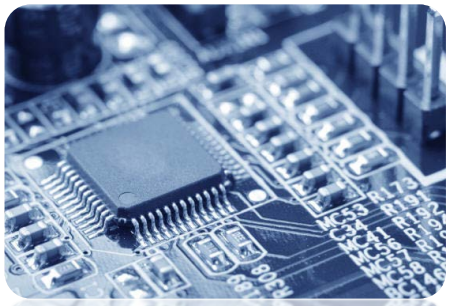
Industrial



Automotive



Scientific



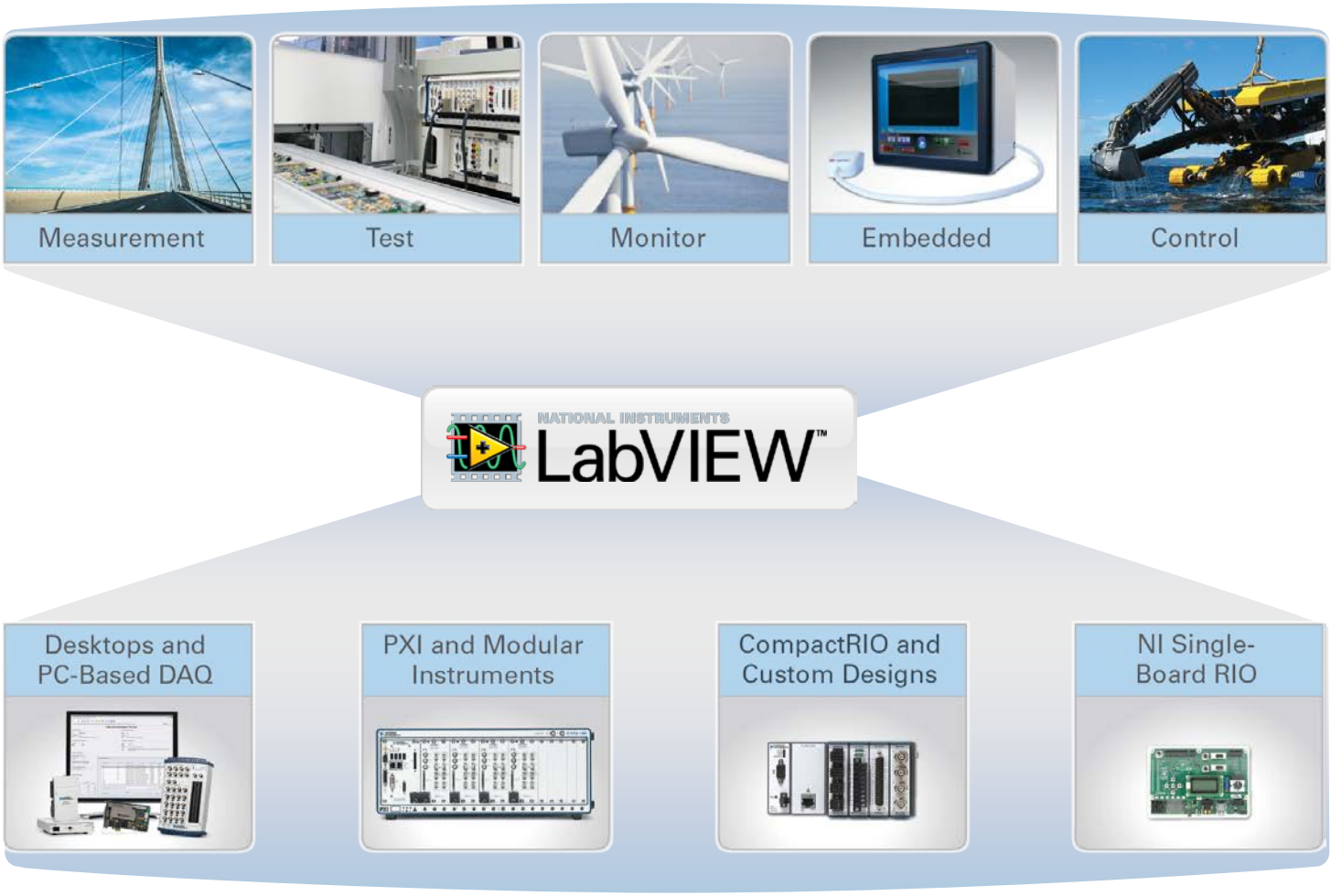
Semiconductor

Key Technical Goals of Standards Activity

- Converged network (control, streaming, "normal" traffic)
- <uS synchronization between all nodes
- Low latency (end-to-end latency of <30uS)
- Network redundancy with 0 fail over time
- Scaling with Ethernet evolution

Graphical System Design

A platform-based approach to measurement and control



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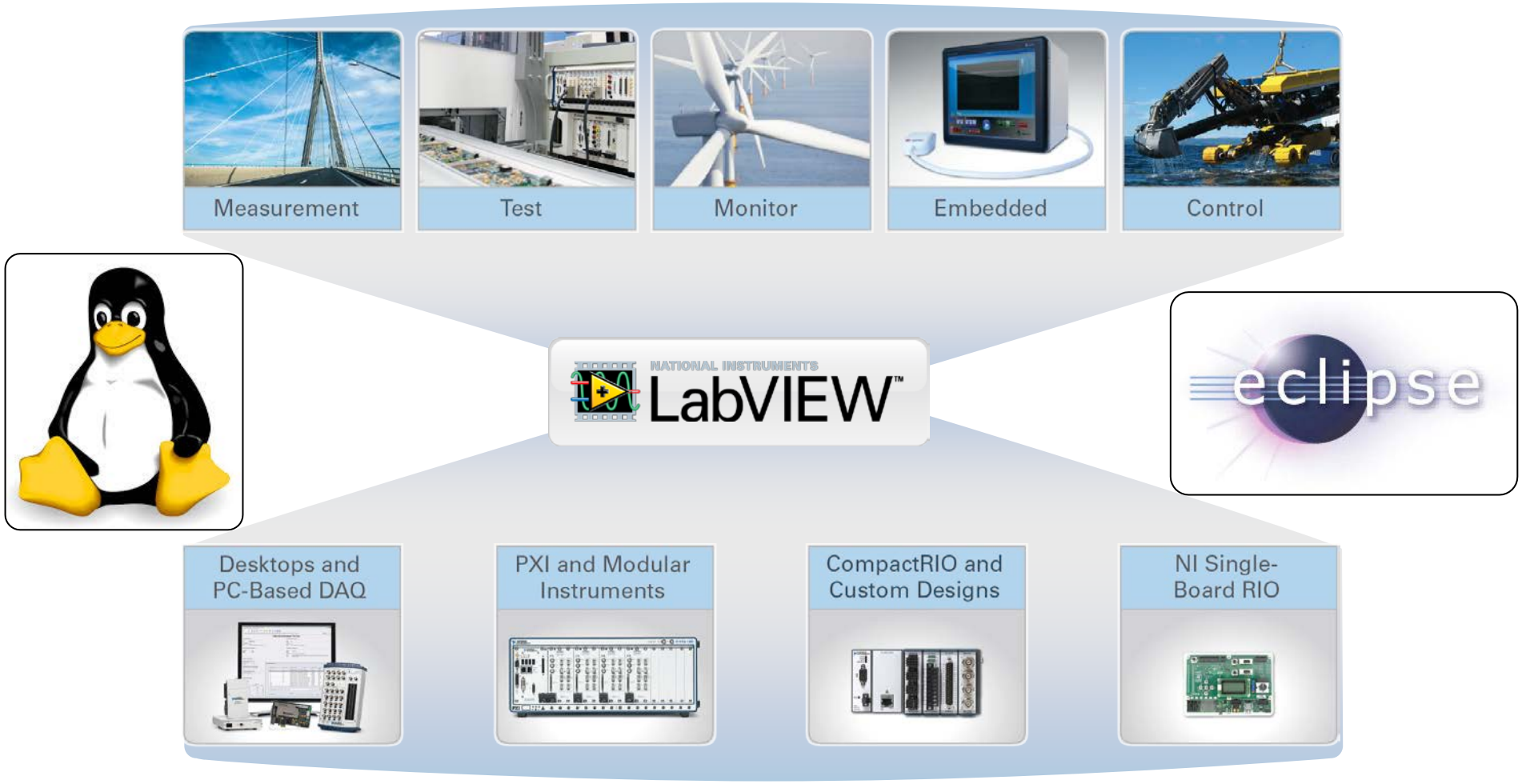
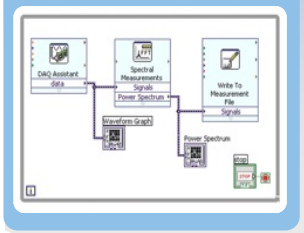
A platform-based approach to measurement and control

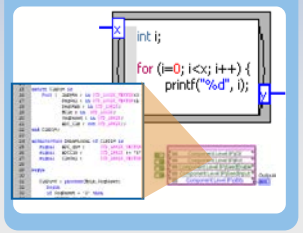


Multiple Models of Computation

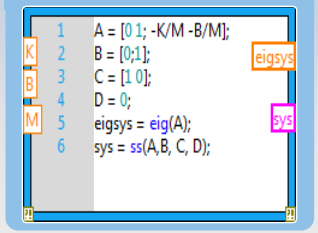
Dataflow



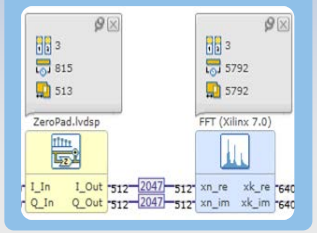
C/HDL Code



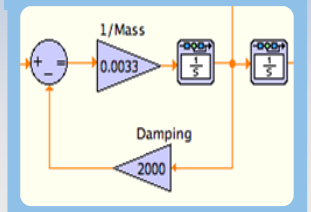
Textual Math



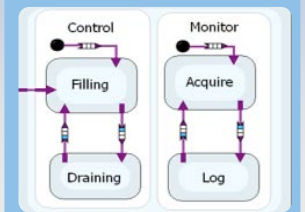
Multirate DSP



Simulation



Statechart



NATIONAL INSTRUMENTS LabVIEW™

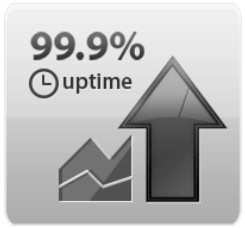
Desktops and PC-Based DAQ

PXI and Modular Instruments

CompactRIO and Custom Designs

NI Single-Board RIO

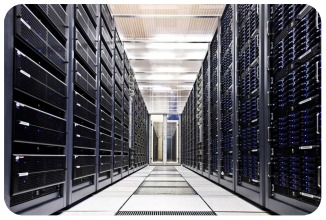
Other Relevant Technology Trends in Industry



1. Highly Available and Reliable Instrumentation Systems

2. Hardware monitoring and failure prediction

1. Seamless large scale deployment



2. Tools for Big Analog Data

Looking Forward

- Physics research applications are extremely demanding for measurement and control systems
- Many unique needs can be met with off-the-shelf technology
- A platform-based approach enables use of standard technology in a way that supports
  - Efficient development of highly-customized solutions
  - Extensive collaboration with commercial vendors
  - Long-term support and evolution of systems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