Tailoring The Hardware To Your Control System

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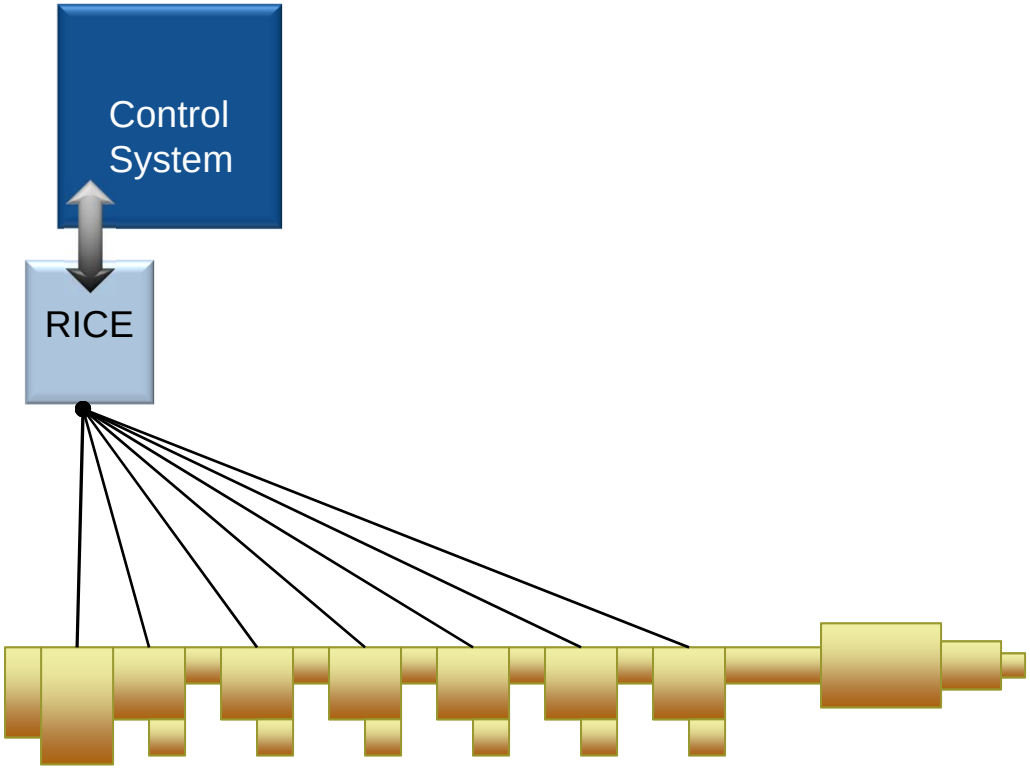
Part I

Our Journey Into Adaptation Hell

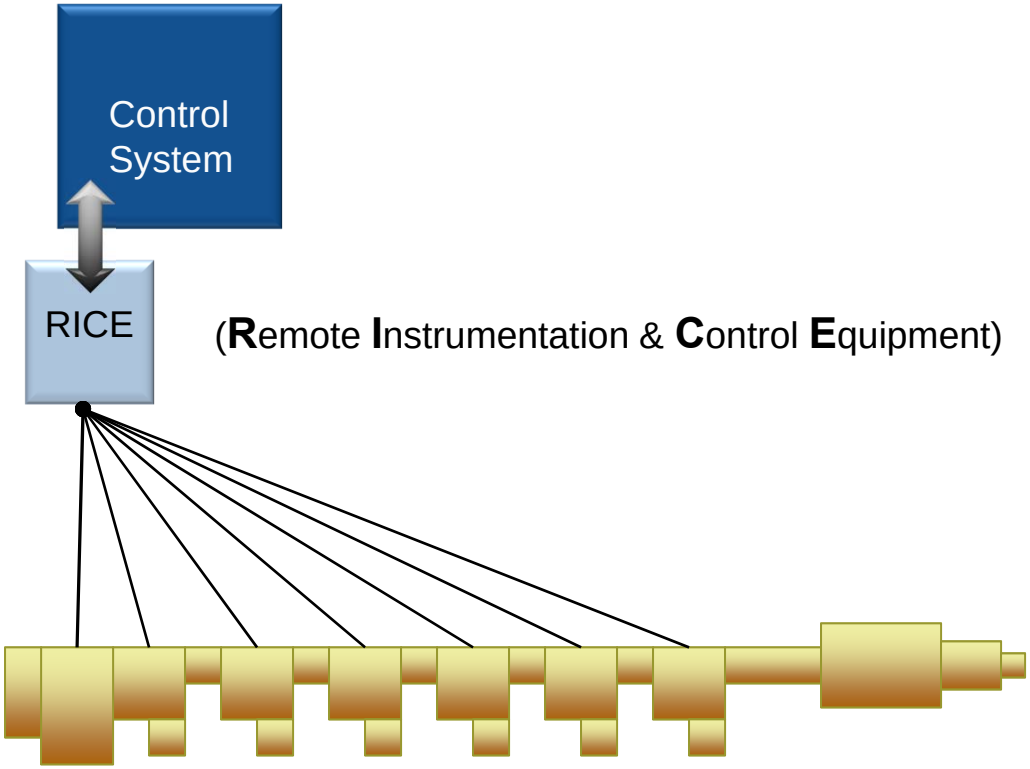
How We Got Here:

1960's



How We Got Here:

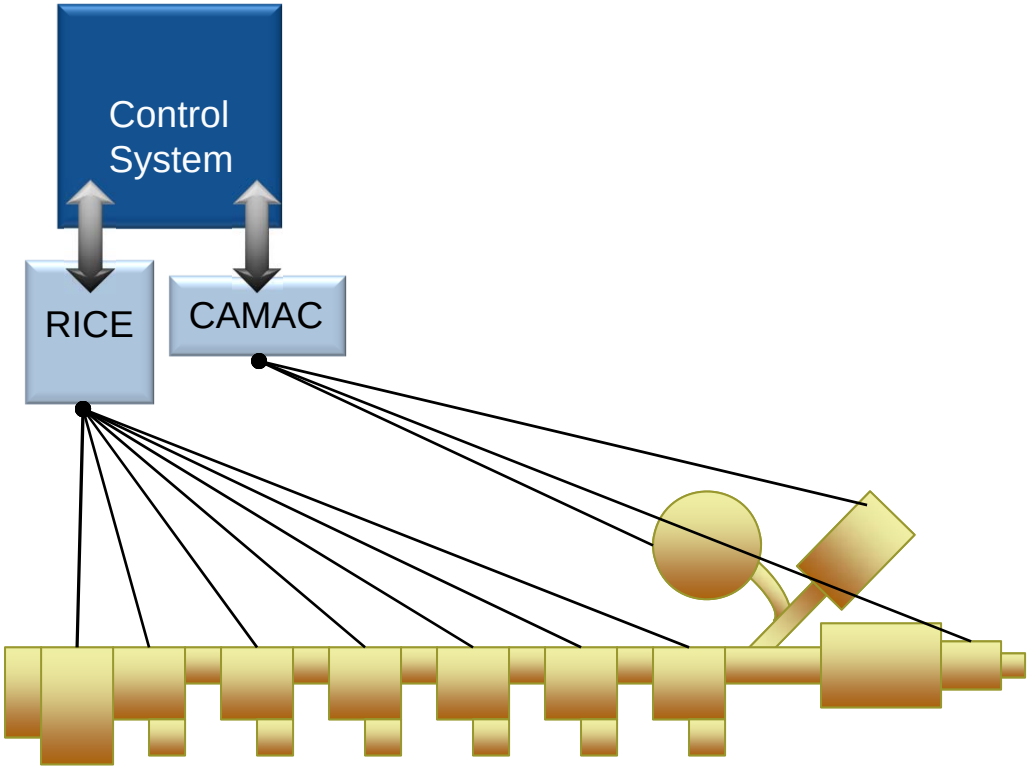
1960's



(**R**emote **I**nstrumentation & **C**ontrol **E**quipment)

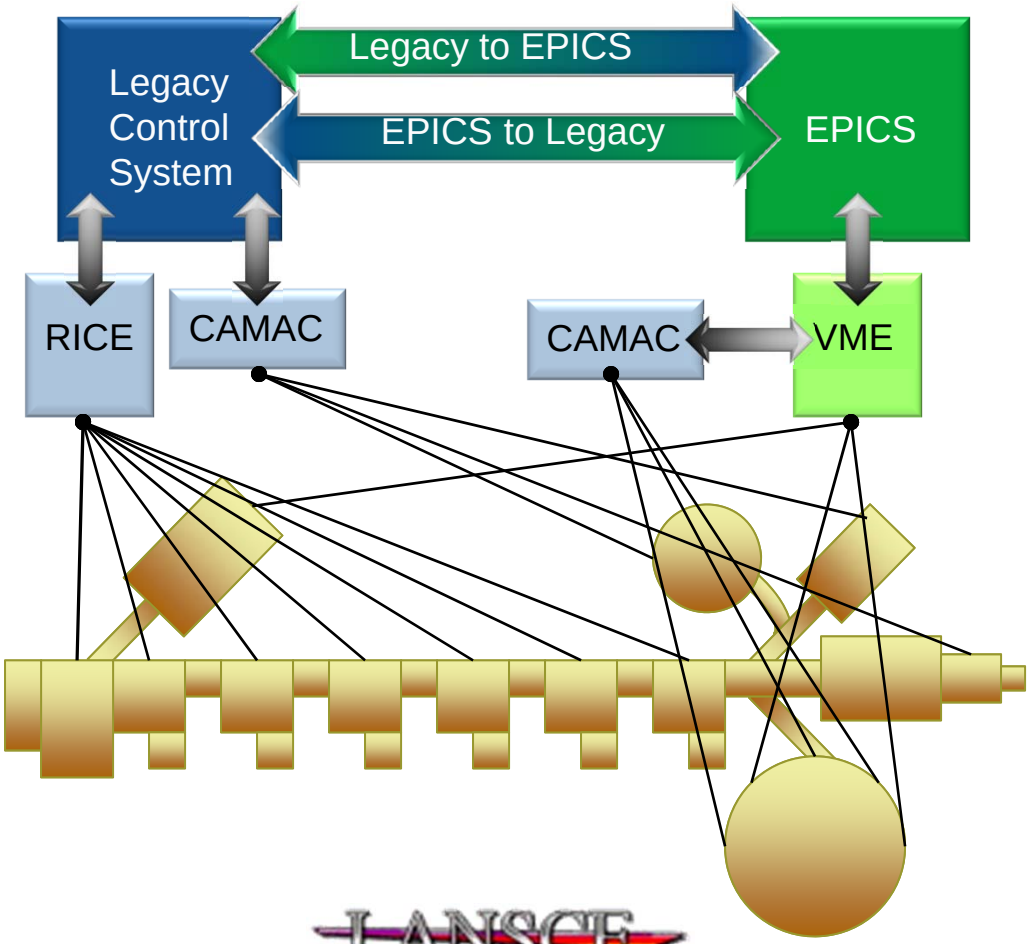
How We Got Here:

1970's – 1980's



How We Got Here:

1990's – 2000's



Part II

Tailoring The Controls Hardware To The Accelerator Equipment

Types Of Programmable Controllers

PLC
(Programmable Logic Controller)

- Long-time standard for Industrial I/O applications.
- I/O connects to proprietary bus.
- Typically programmed in Ladder Logic.
- Rugged & reliable, not particularly fast. (mSec response)
- Some are safety certified.

PAC
(Programmable Automation Controller)

- Recently becoming available for Industrial I/O applications.
- I/O connects to FPGA.
- Typically programmed in VHDL/AHDL.
- Becoming rugged & reliable. Typically faster than PLCs. (µSec response)
- Unaware of any safety certified commercial PAC products.
- FPGA runs independently of processor.

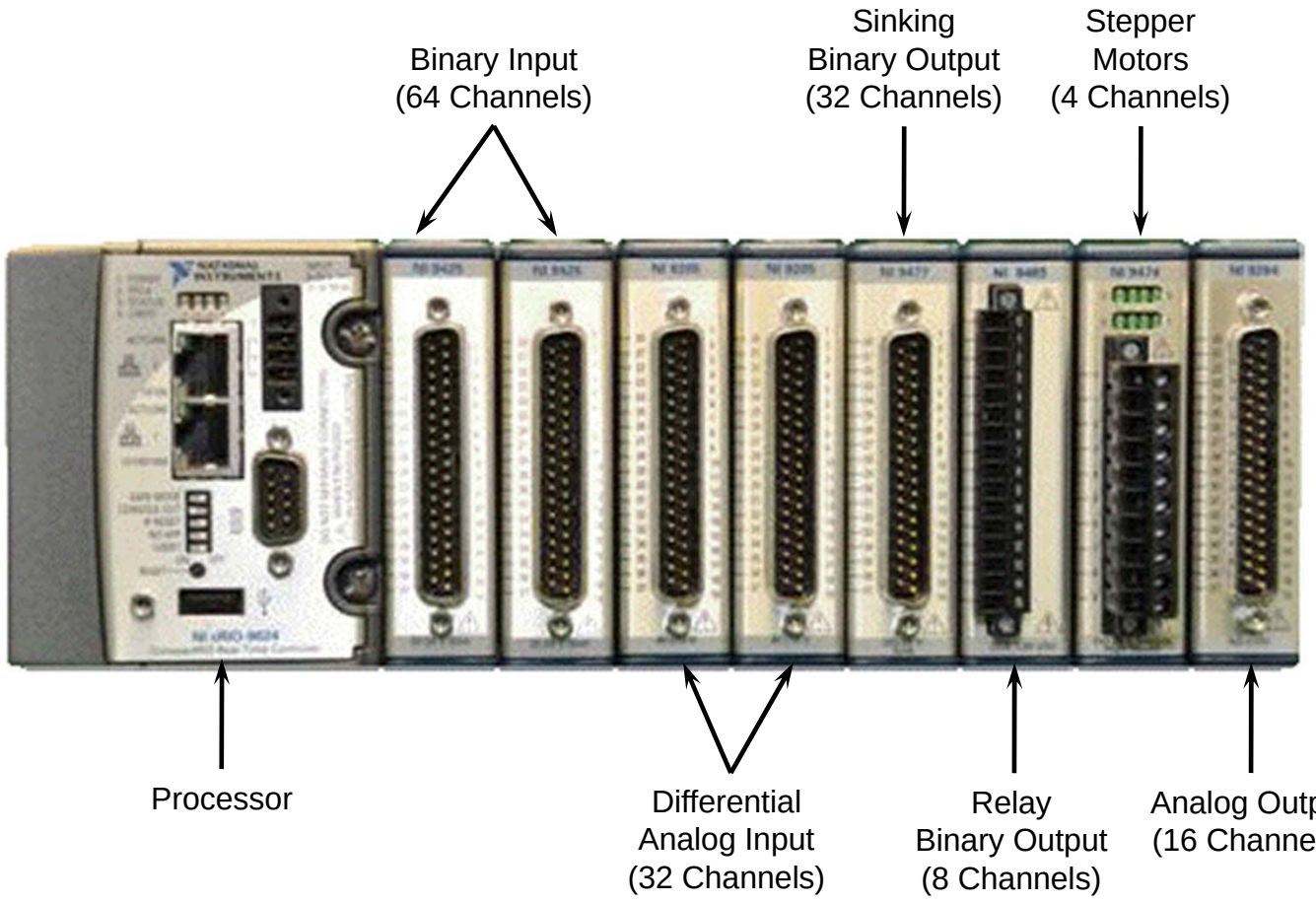
RICE Hardware Features

- **Binary Output:**
  - Four Protocols
    - Command Only, Latchback, Momentary Open, Momentary Closed
  - Protocol Selected by Jumper on Card
- **Analog Input**
  - Three ADC Ranges
    - 10 Volt, 1 Volt, 100 mVolt
  - ADC's triggered to avoid RF-induced noise.
- **Analog Output**
  - Mostly stepper motors
  - Primary operator interface is assignable control knobs
    - Custom software interface required to make EPICS work well with control knobs.

New LANSCE Industrial I/O System

- **Initially replaced the Industrial I/O functions of one RICE module with a PLC.**
  - Not quite fast enough for some of our applications.
  - 3rd party stepper motor controller was a little unreliable.
- **Second iteration replaced PLC with National Instruments Compact RIO.**
  - I/O Interfaces to FPGA.
  - FPGA interfaces to processor over PCI bus.
  - Programmed a binary output module to be a stepper motor controller.
    - Exact pulse width, speed, and ramp up we wanted.
    - Command overrides programmed in.

New LANSCE Industrial I/O System



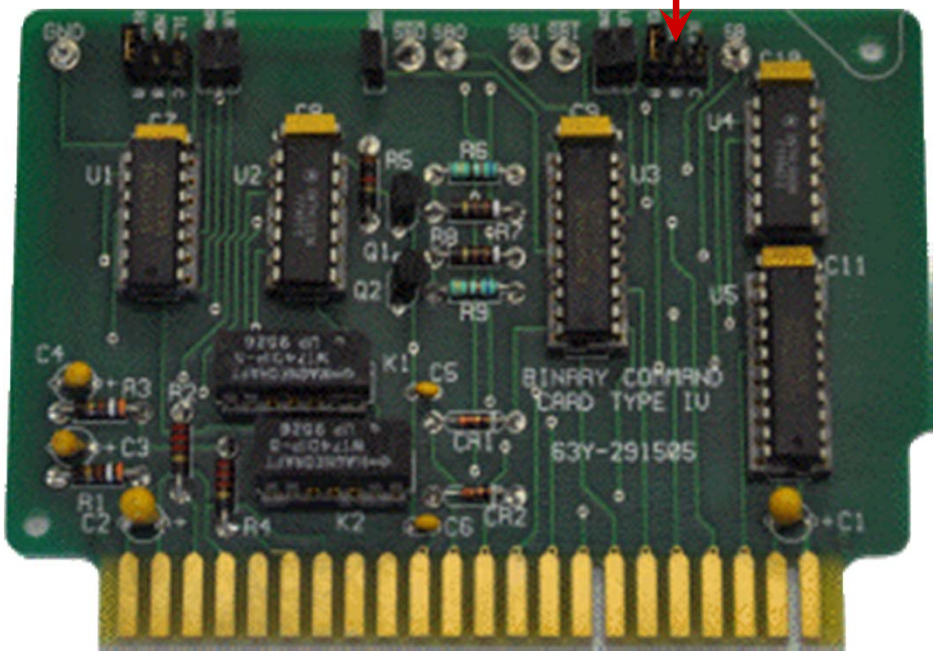
Part III

Reconfiguring The Hardware

Reconfiguration With RICE

RICE Binary Output Channels

- **Binary Output Protocol Changed With Jumpers**
- **Only Disrupts The Channel You Are Modifying**



Reconfiguration With PLC/PAC

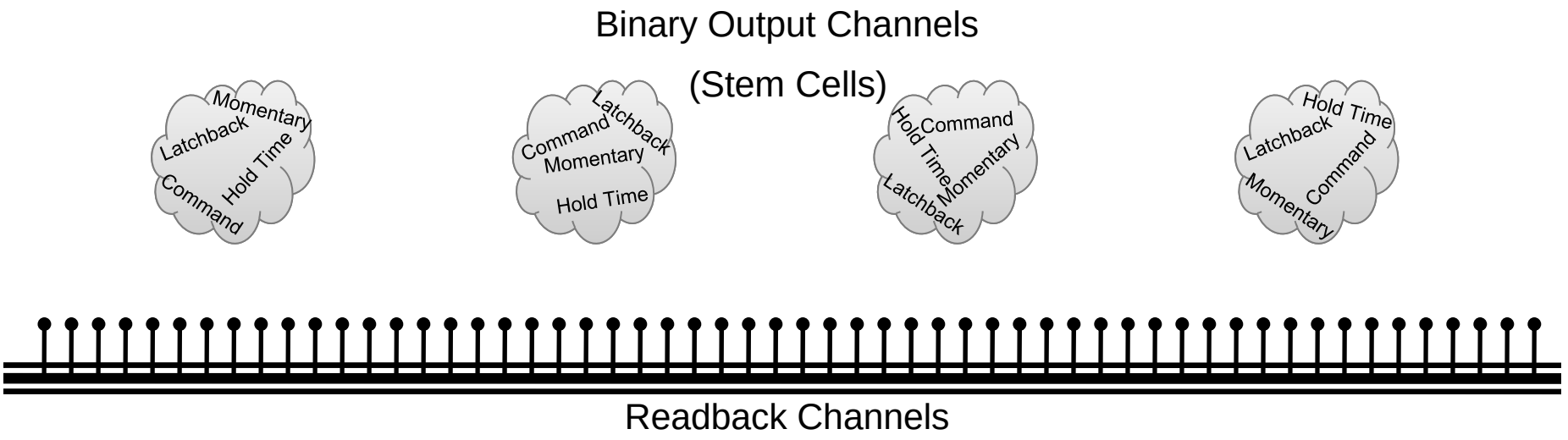
Ladder Logic (PLC)

- Modify Ladder Logic
- Take Controller Off-Line
- Load New Ladder Logic
- Take Controller On-Line

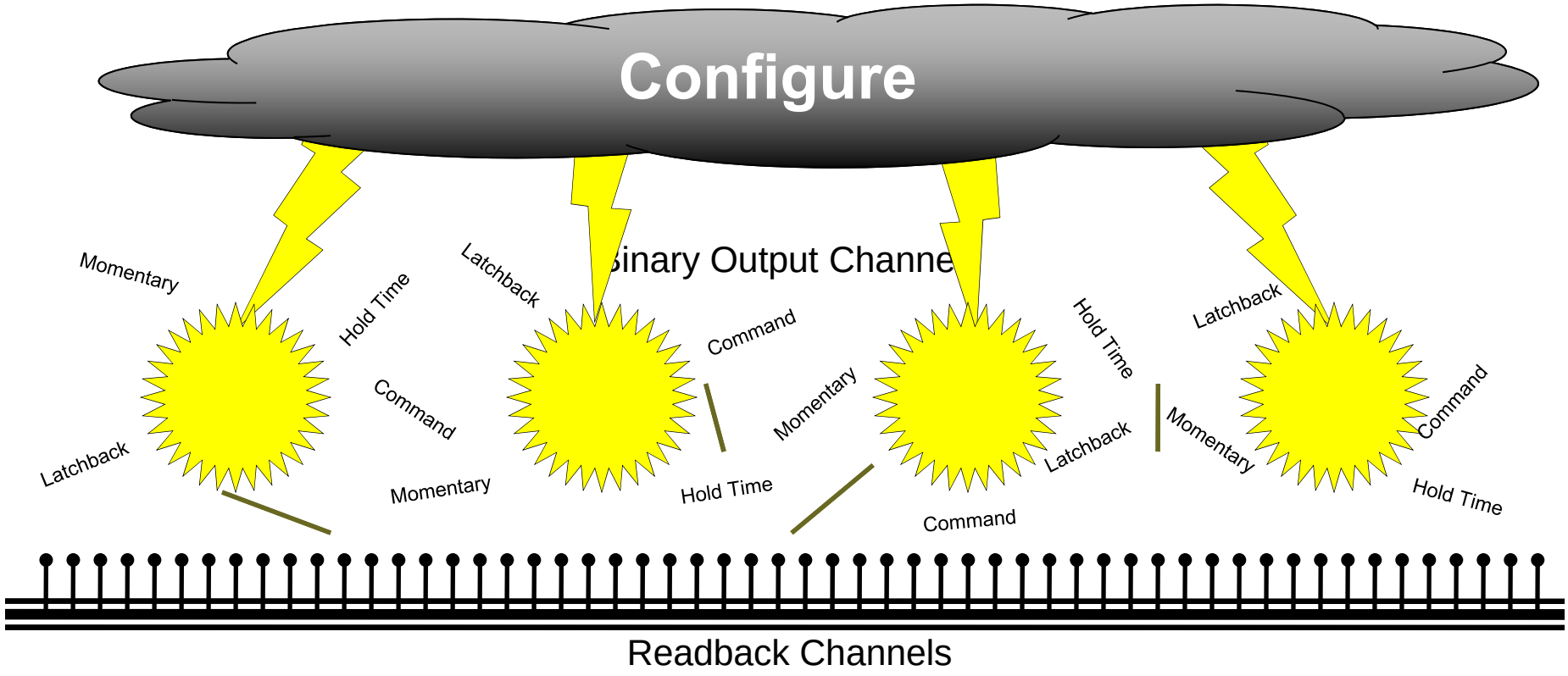
FPGA (PAC)

- Modify FPGA Code
- Compile FPGA Code Into Bitmap (lengthy)
- Take Controller Off-Line
- Flash New Bitmap
- Take Controller On-Line

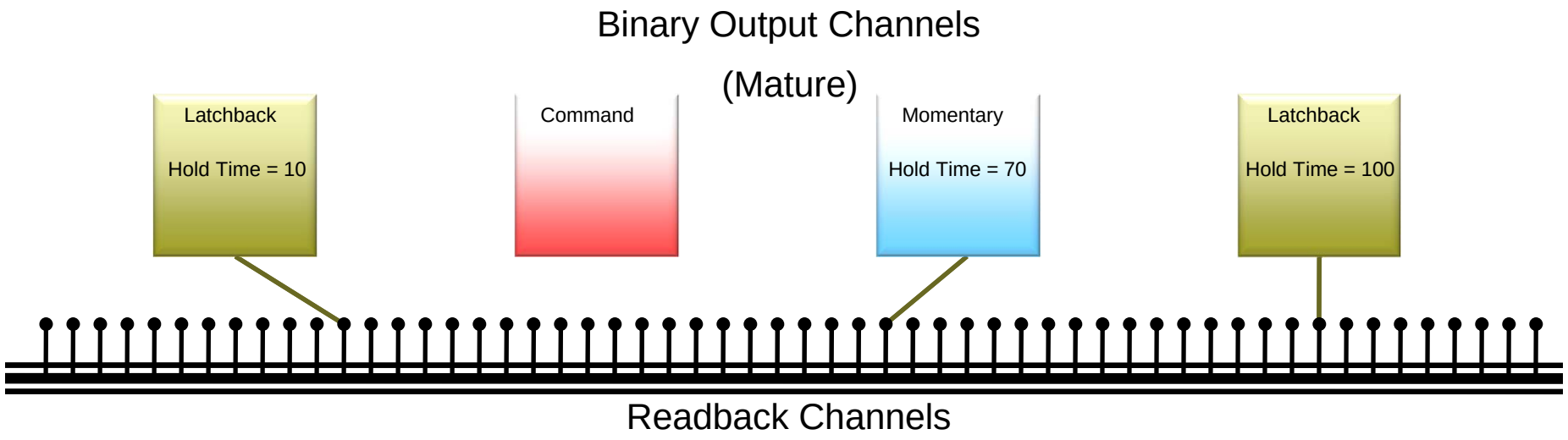
Reconfiguration With Stem Cells



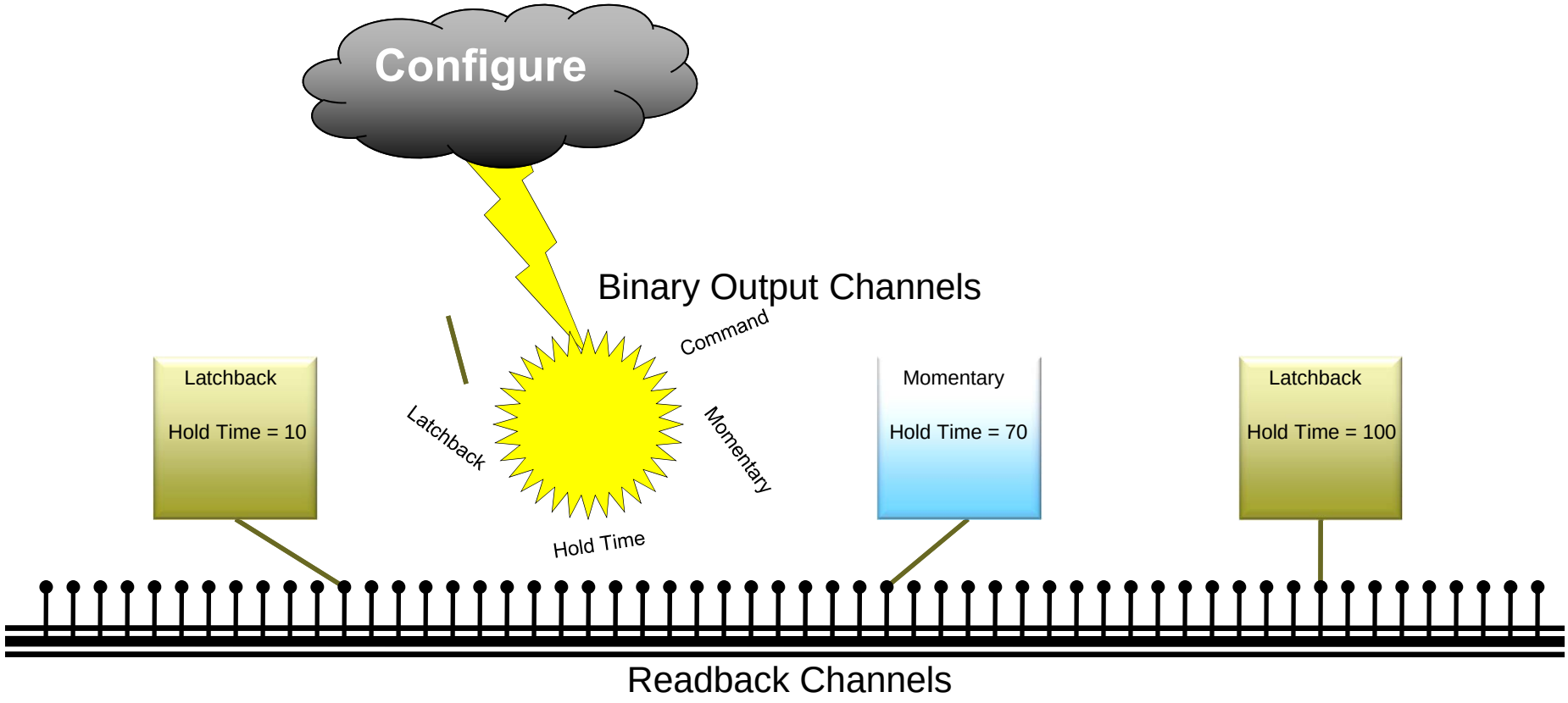
Reconfiguration With Stem Cells



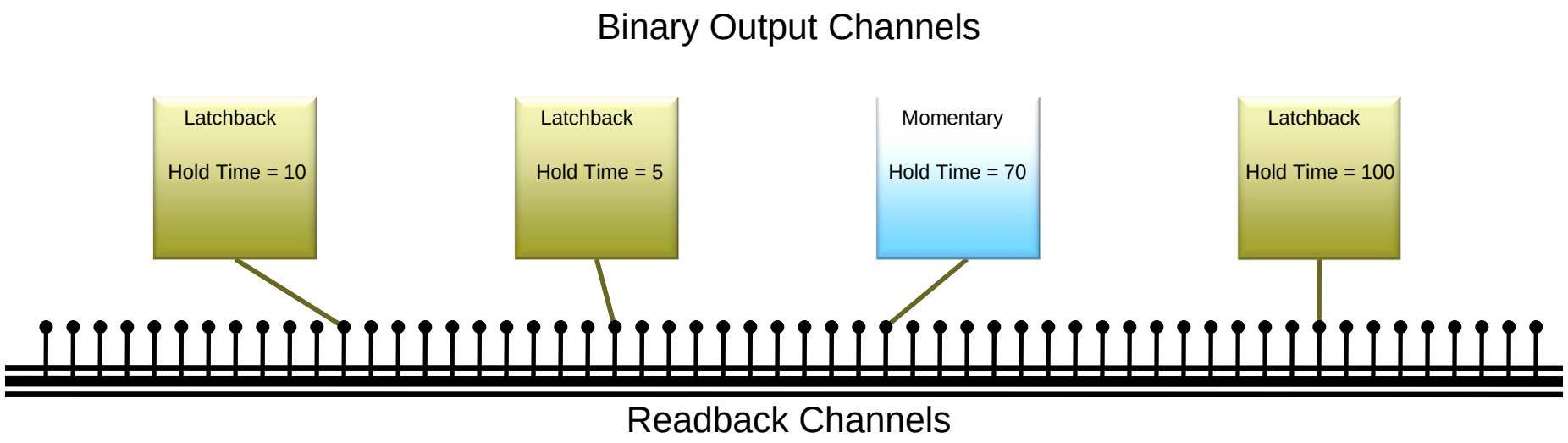
Reconfiguration With Stem Cells



Reconfiguration With Stem Cells



Reconfiguration With Stem Cells



Reconfiguration With Stem Cells

Other Stem Cell Types

- **Analog Inputs**
  - ADC Range
  - Trigger/No-Trigger
  - Trigger Delay
- **Stepper Motors**
  - Pulse Rate
  - Ramp Speed
- **Counters**
  - Integration Time

Reconfiguration With Stem Cells

Advantages

- **Reconfiguration time as fast or faster than hardware.**
- **Reconfiguration does not interrupt service.**
- **Can use the same bitmap for all controllers.**

Disadvantages

- **Uses More FPGA Real-Estate**
  - Virtex 2 only had room for 11 binary output stem cells
  - Virtex 5 had room for more than 40 binary output stem cells

Part IV

Tailoring The Hardware To The Software

Tailoring The Hardware To The Software

- **Perhaps the ultimate way to tailor the hardware to your control system is to actually embed the control system within the hardware.**
- **Many commercial products have embedded processors with network access and a real-time (or soft real-time) operating system.**
- **Some can allowing your control system (or at least the front-end) to run on the processor and interact with the vendor's code.**
  - Vendor may do the embedding.
  - Vendor may supply interface for embedding.
- **Power of Collaborations**

Tailoring The Hardware To The Software

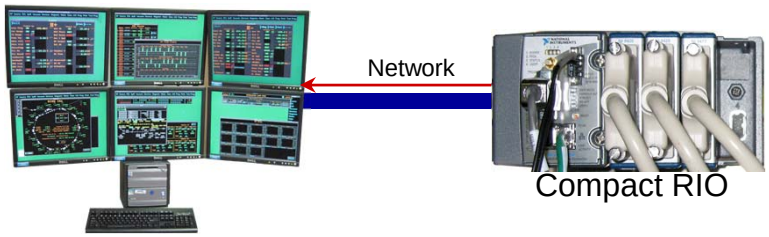
Some Vendors That Have Already Supported Embedding

- **Instrumentation Technologies**
- **Moxa**
- **National Instruments**
- **Yokogawa**
- **ZTEC Instruments**

Embedded Control Systems

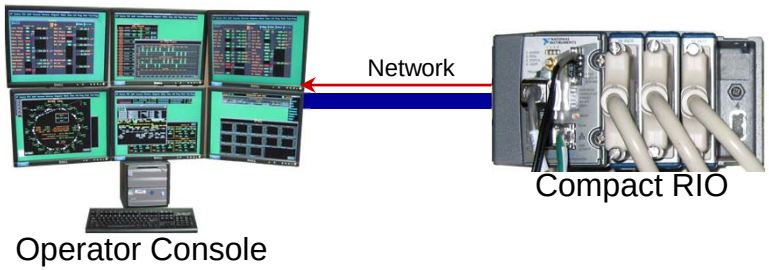
Controller With Embedded Control System

- **One Network Trip**



Embedded Control Systems

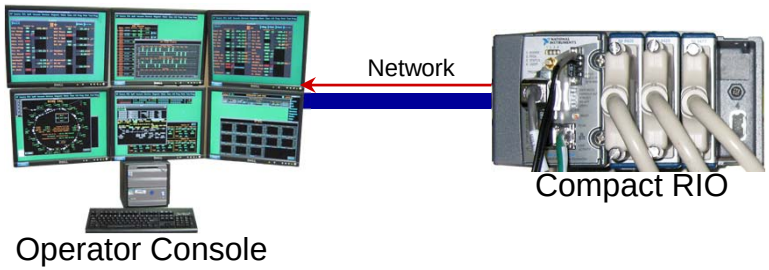
Controller With Embedded Control System



- **One Network Trip**
- **Access To Standard CS Utilities**
  - Access Control
  - Archiving
  - Performance Monitors
  - Diagnostics

Embedded Control Systems

Controller With Embedded Control System



- **One Network Trip**
- **Access To Standard CS Utilities**
  - Access Control
  - Archiving
  - Performance Monitors
  - Diagnostics
  - Our Custom Knob Software

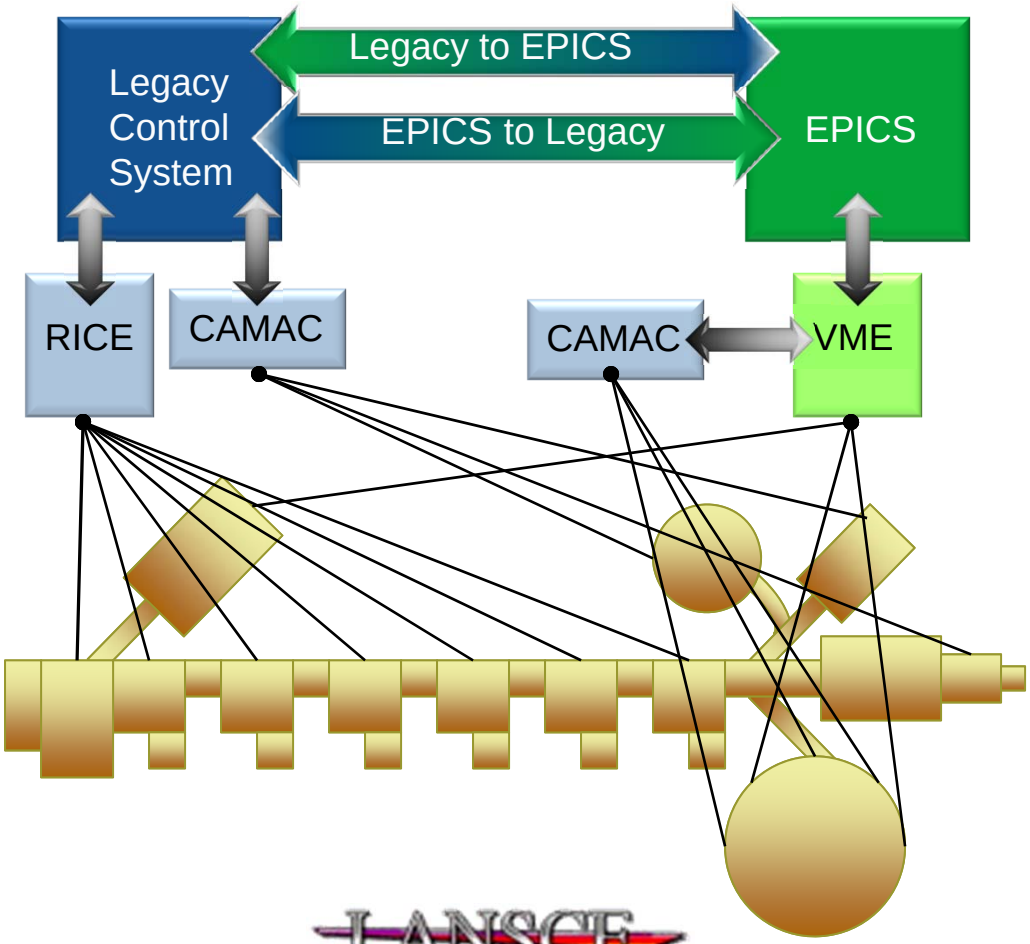
Part V

Conclusions

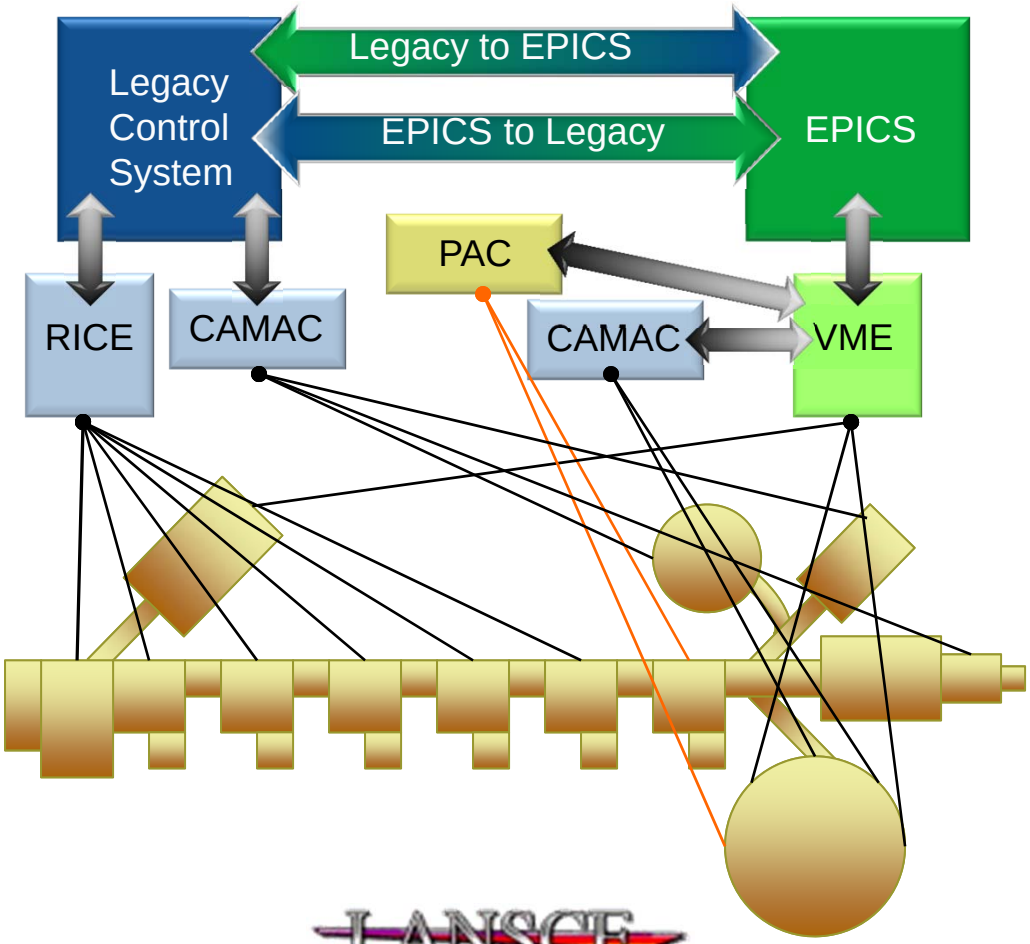
Conclusions:

- Programmable controllers can simplify interfacing to the equipment.
- Embedding the control system in the controller can simplify interfacing to the software.
- “Stem Cells” can simplify hardware reconfiguration.
- Our standard Compact RIO IIO system is working well as a replacement for the industrial I/O functions of our old RICE system.
- With a few tweaks, it has also worked well as a replacement for our old CAMAC equipment.
- To date we have replaced two RICE modules and two CAMAC crates with IIO systems.

Where We Were:



Where We Are Today:



Where We Are Headed: