Distributed Control System for the National Ignition Facility

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Christopher M. Estes
ICCS
Lawrence Livermore National Laboratory

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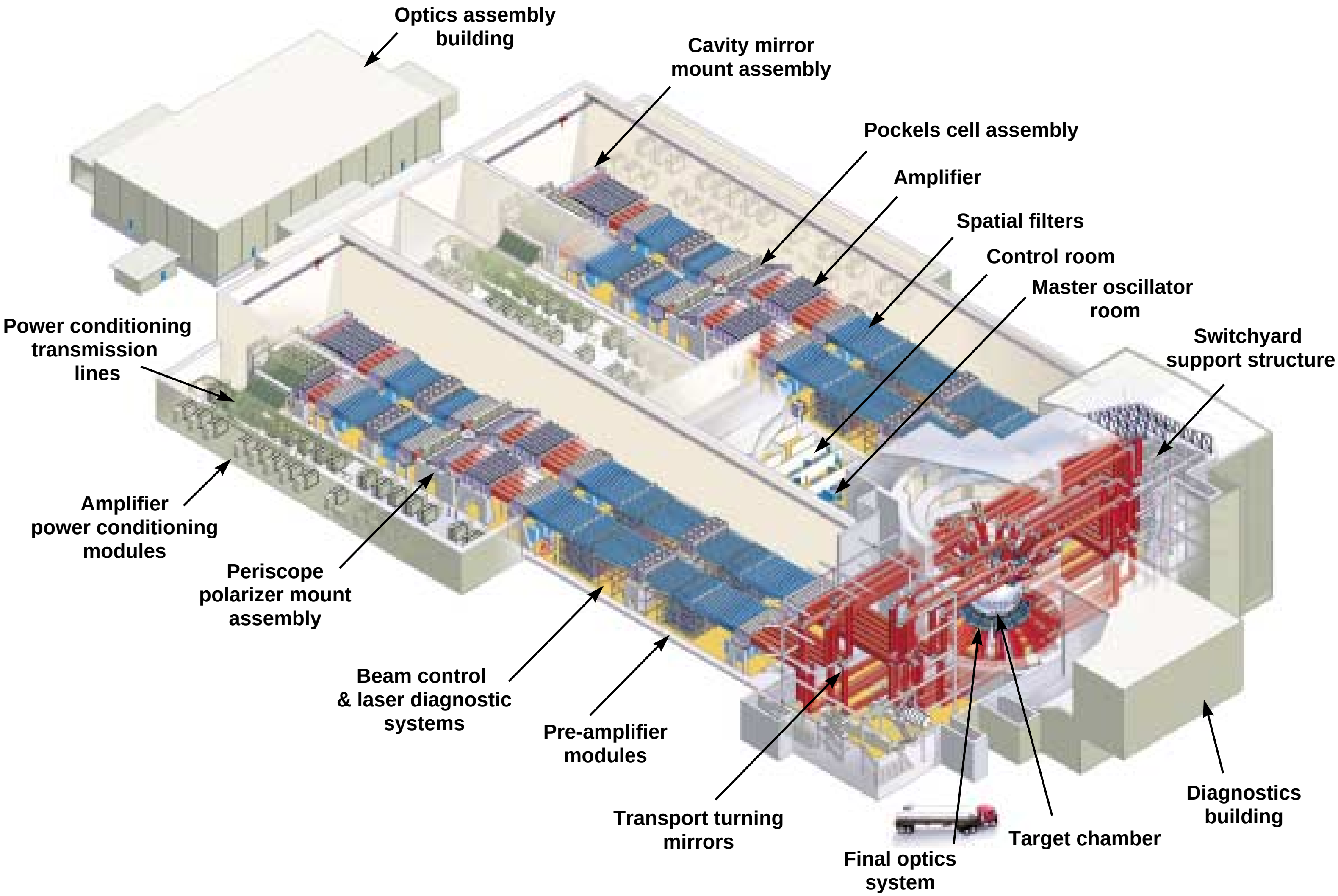
The National Ignition Facility is a high-energy laser for inertial confinement fusion research



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The NIF requires a control system of large scale that is enduring and flexible

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- 60,000 control points and 500 node network
- Automated 7 by 24 operation over 30 year lifetime
- Event driven control system conducts shot every 8 hours
- Designed for computer upgrades and software enhancements

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ICCS is a distributed system that does not have hard real time requirements

- Supervisory software is event driven
  - Speed requirements derive from operator needs for interactive response
  - Status information is propagated from the laser to updates on graphic user screens
- No process-related hard deadlines must be met
  - Several hours of preparation precede shot
  - Shot executes in microseconds, controlled by dedicated hardware
- Some process controls are encapsulated in our embedded systems

Control functions are physically distributed, logically separated, and hierarchically layered

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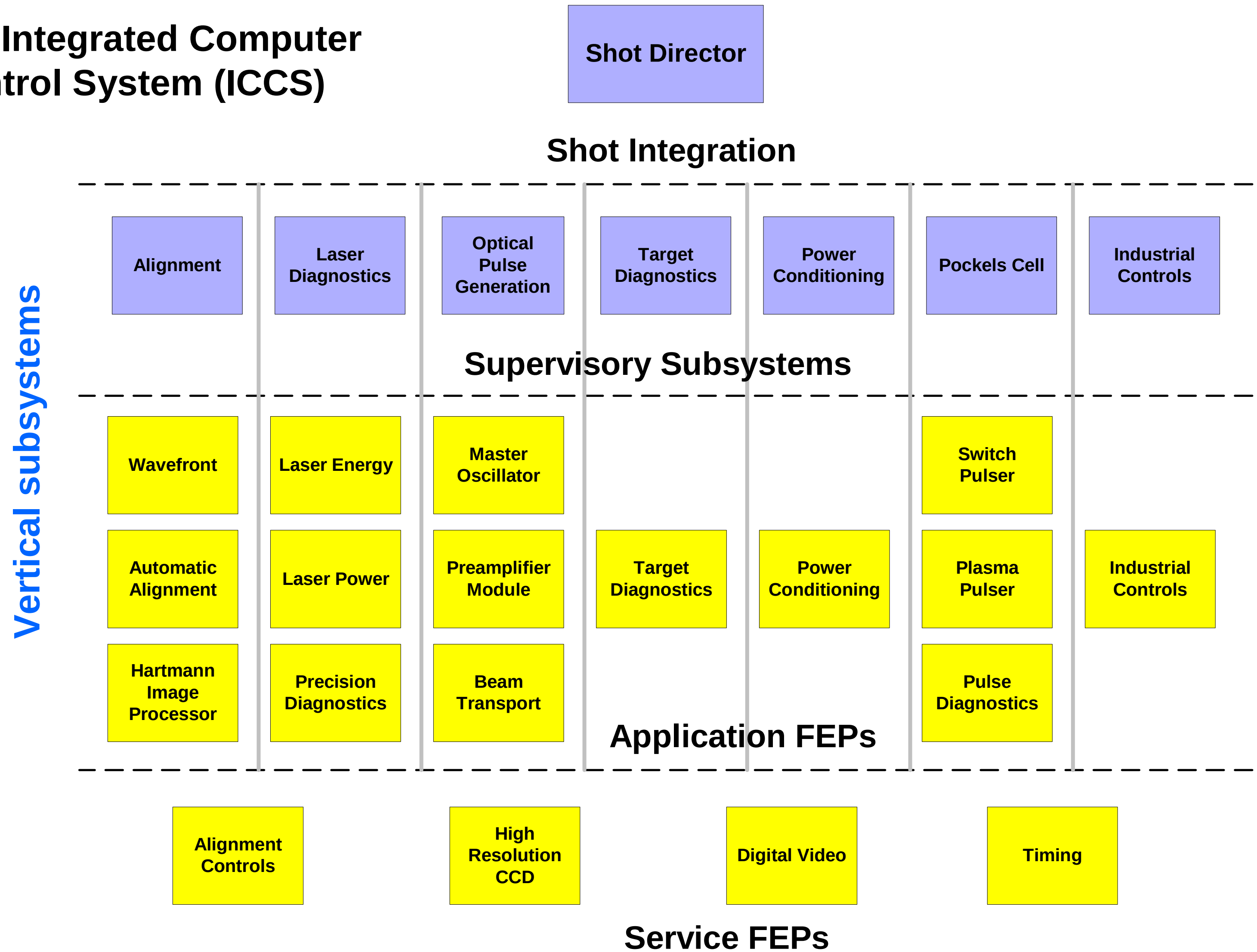
NIF Integrated Computer Control System (ICCS)



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Software applications are built the same way using a framework of distributed services

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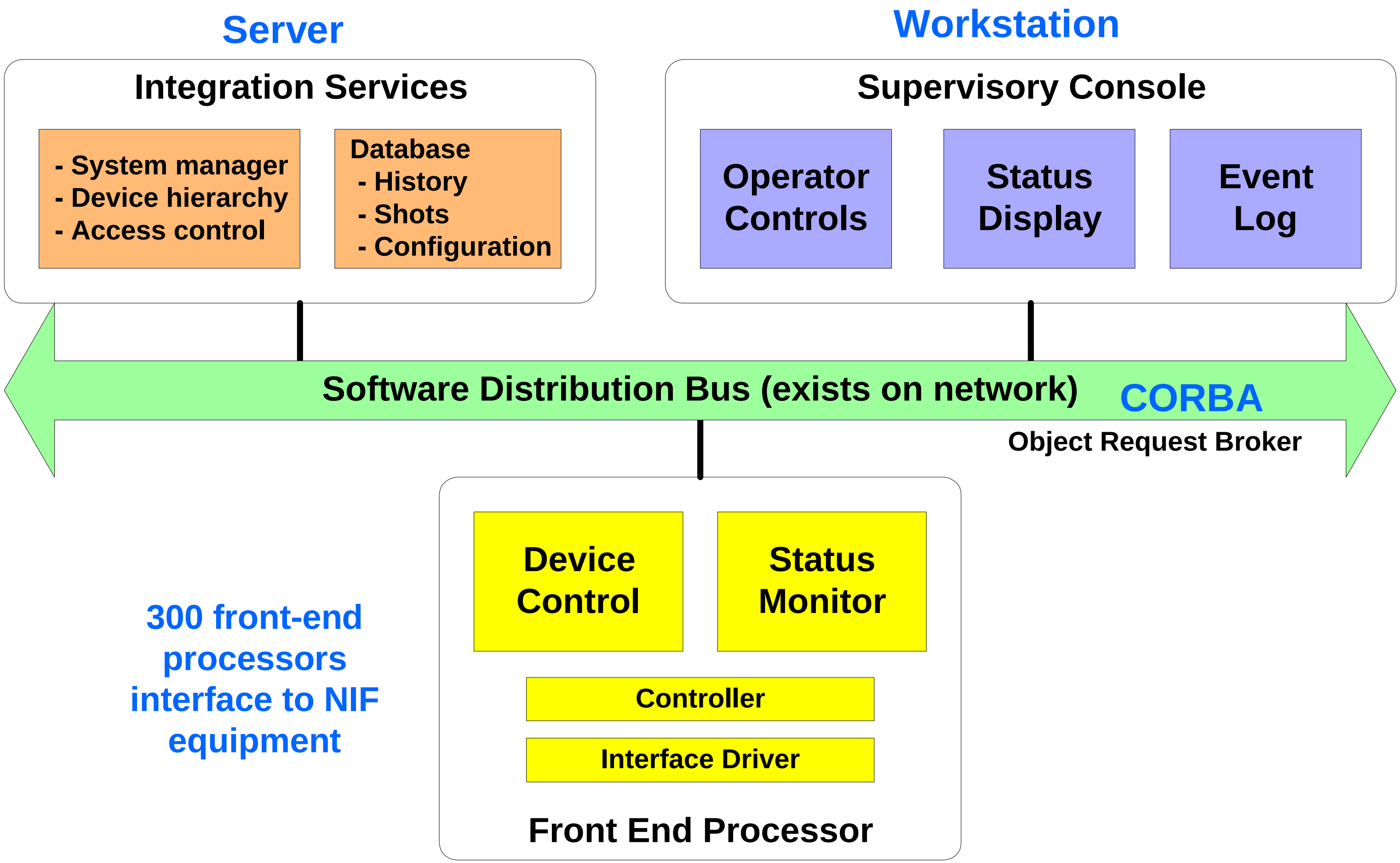

Software objects representing control points "plug in" to the software distribution bus

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Computers and programming languages used to build NIF controls

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Testbed Operator Workstation

Tool Category	Product
Computers	- Sun Ultra Sparc - Power PC - Pentium - Allen-Bradley
Operating systems	- Solaris UNIX - VxWorks real-time - WindowsNT
Programming languages	- Ada 95 (applications) - C (drivers) - Java (user interfaces) - Rockwell (industrial)
Distribution - CORBA	- ORBexpress for Ada 95 - Visibroker for Java

Emulation techniques are employed to test software in advance of hardware availability

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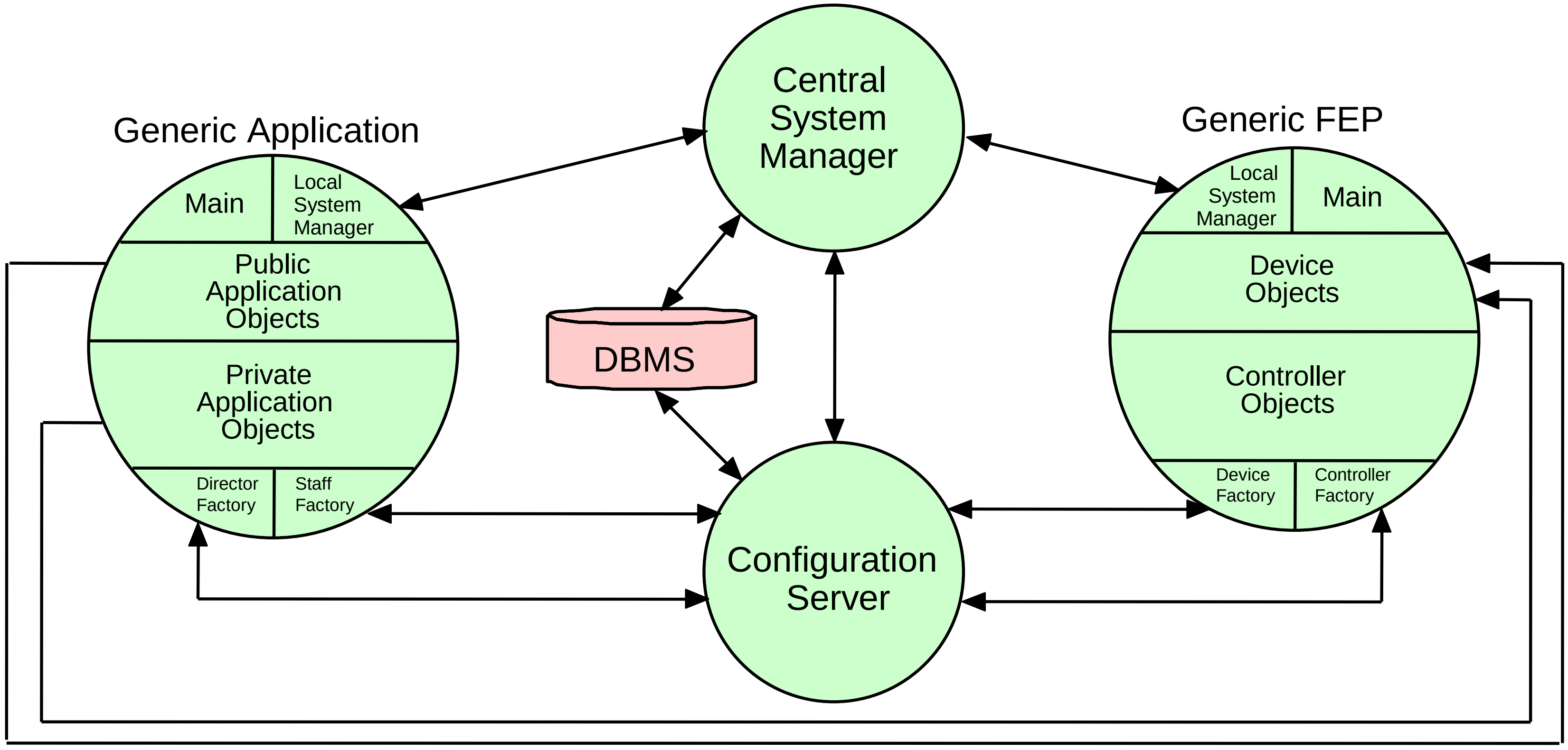
Almost all of our Ada programs are built by elaborating a generic template



Each of 300 FEP computers has a single server process

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- FEP’s are implemented on VxWorks and on Solaris
- Naming service is implemented on a relational database
  - Each device is directly accessible from anywhere in the system
- Central process-management service maps references to processes
  - Each process reports a heartbeat
  - Central server can restart a failed process
  - But numerous clients have copies of Ref’s
    - Invoking a failed ref raises an exception
    - Reconnection is proving challenging to manage
  - Perhaps every client call needs to be wrapped?

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FEP's are constructed to house devices and controllers

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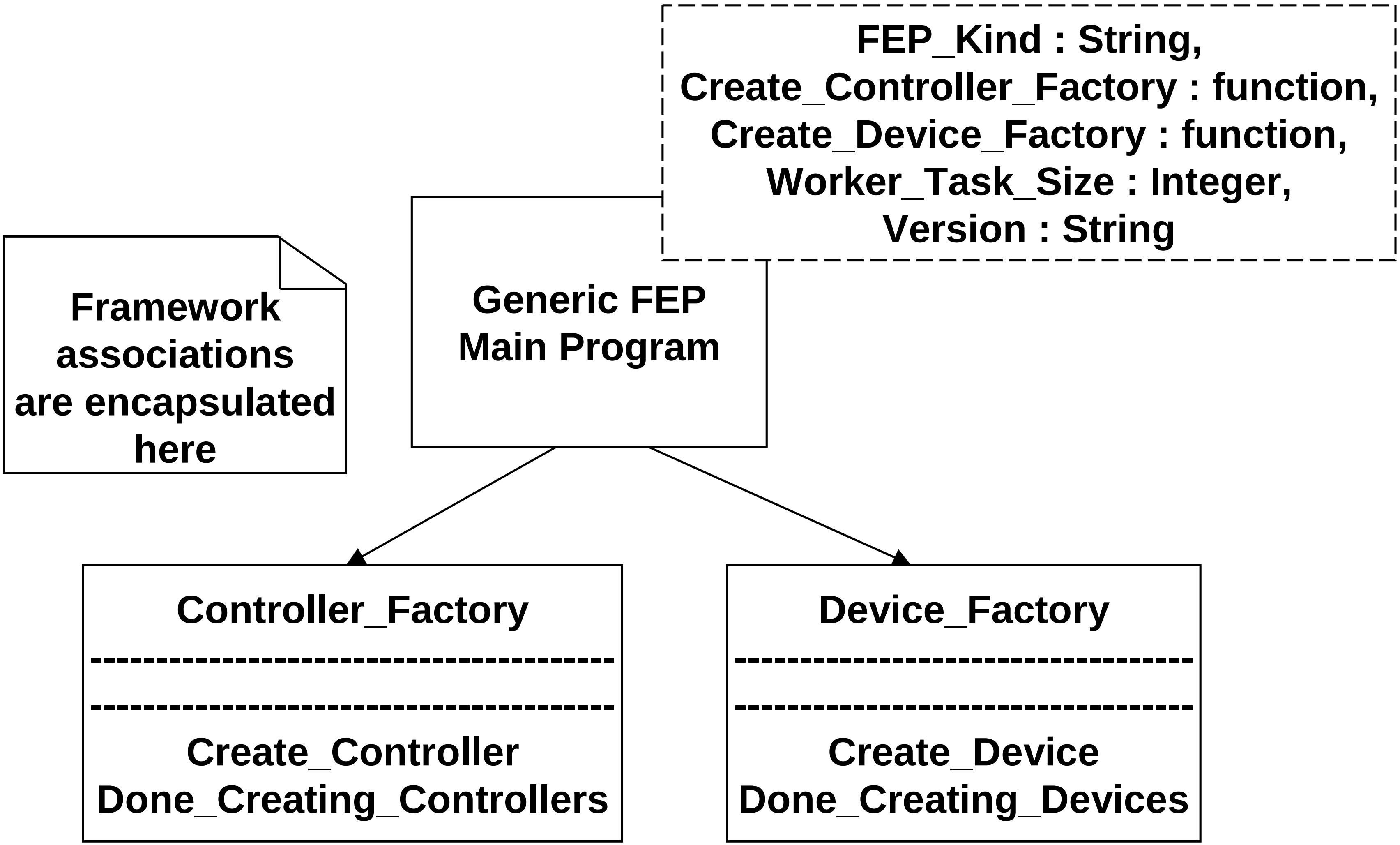

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Devices are CORBA objects, while Controllers are not

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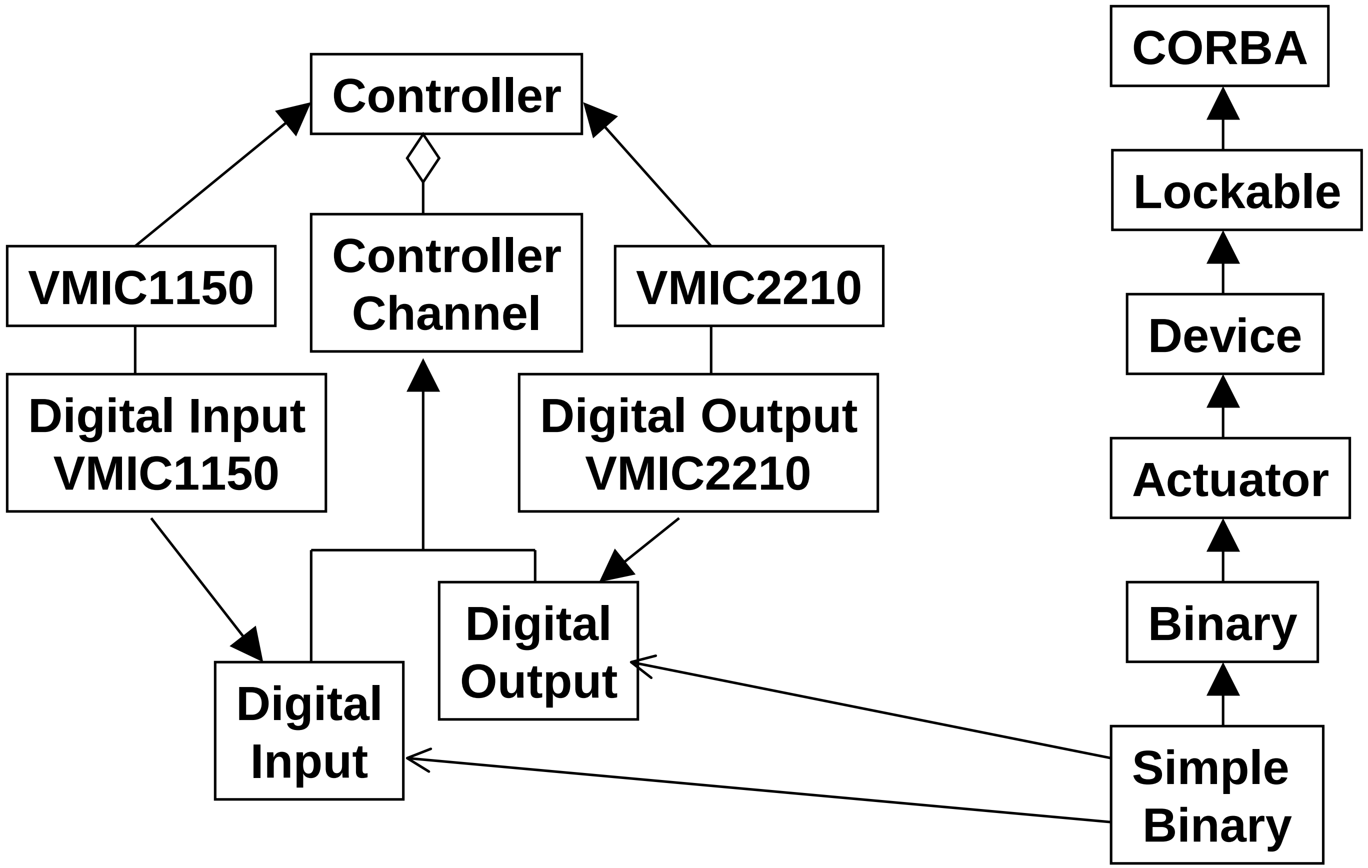

Fine-grained CORBA objects are individually named and managed

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- Each is implemented as an instance of a class derived from "Device"

- The Device class is an abstract superclass
  - This base class defines interfaces applicable to all devices
    - for naming
    - for reserving on behalf of an operator
  - Several dozen derived classes control physical equipment
    - Diverse actions defined for motors, power supplies, diagnostic instruments, precision timing and triggering
    - Initialization from a central database

- The majority of NIF's CORBA objects are long-lived

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Expect 60,000 distinct device objects in FEP's

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- There are about 130 subclasses
- Each is implemented as a CORBA object
- Each has a structured name that expresses its "taxonomy"
- All are available from anywhere in the system
- Each has a client that potentially needs connection management

User Interfaces are a very thin layer written in Java

- The control points are relatively inflexible
- By contrast, the user interfaces and experimental execution plans will evolve more rapidly
- Java offers a useful set of tools for interface construction
- ICCS builds Java classes for status display and control input, and connects to Ada servers through CORBA
- Early experiments using Javascript and Jython show promise for testcase generation
  - Visibroker intercepts interactions that can lead to auto script generation
  - Scripts execute methods on CORBA objects

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CORBA interoperability has been key

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- Interoperability has been almost seamless
- Only a few issues
  - Different CORBA versions affect legal IDL
    - Visibroker 3.4 based on CORBA 2.0
    - ORBexpress based on CORBA 2.1/2.2
    - Visibroker 4.1 based on CORBA 2.3
  - Language differences do seep into our designs
    - Java has no unsigned types
      - Poor IDL to Java mapping for unsigned types
        - » $65535 \neq -32768$
    - Modules map differently between languages
      - Ada packages are different from Java packages
        - » Coding standards and tool switch selection can provide reasonable compromises
- To ensure interoperability, an OMG validation suite might be of great help

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System status and control is accessed through a hierarchy of user interfaces

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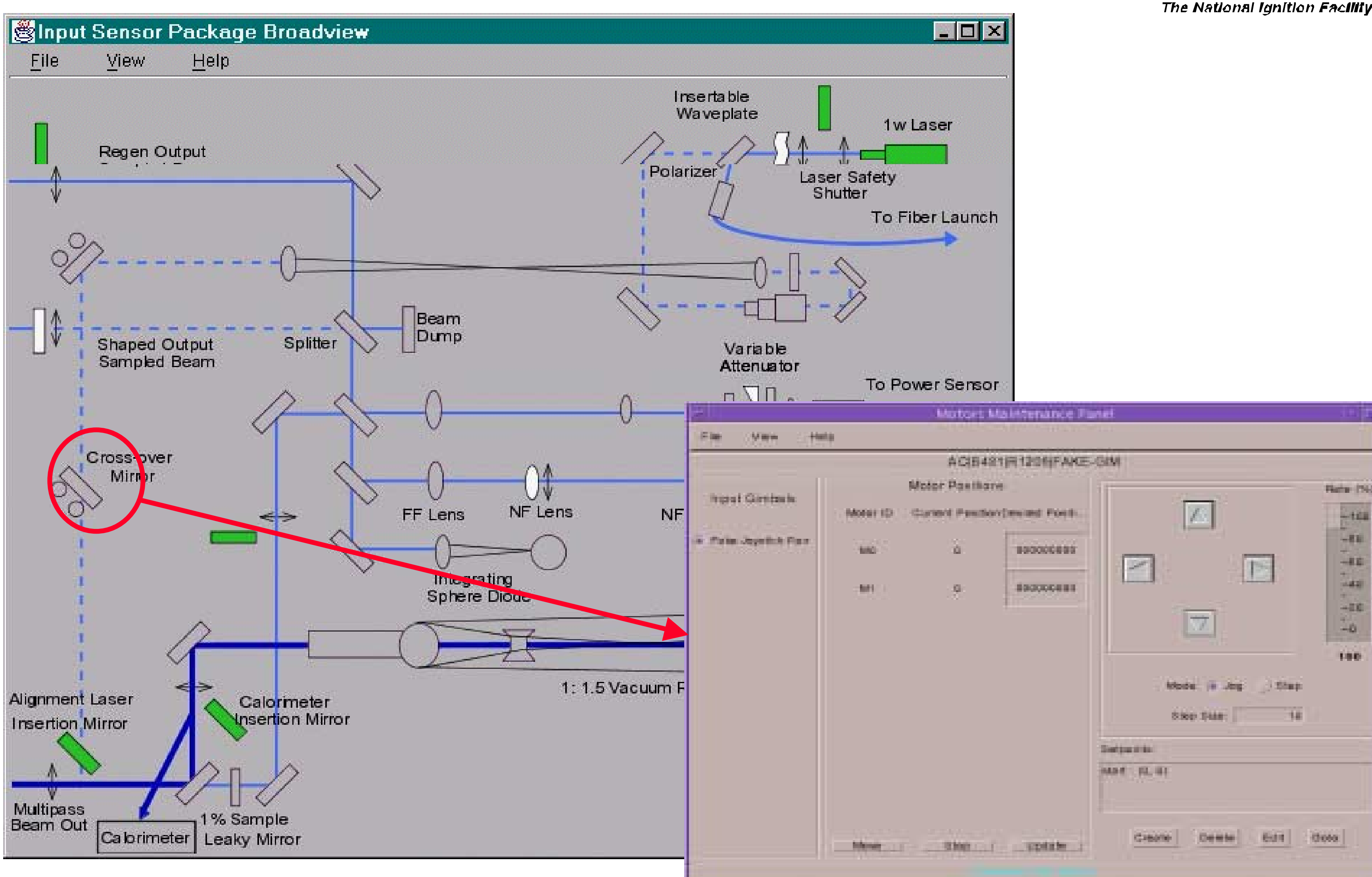

High level and detailed information is available to users

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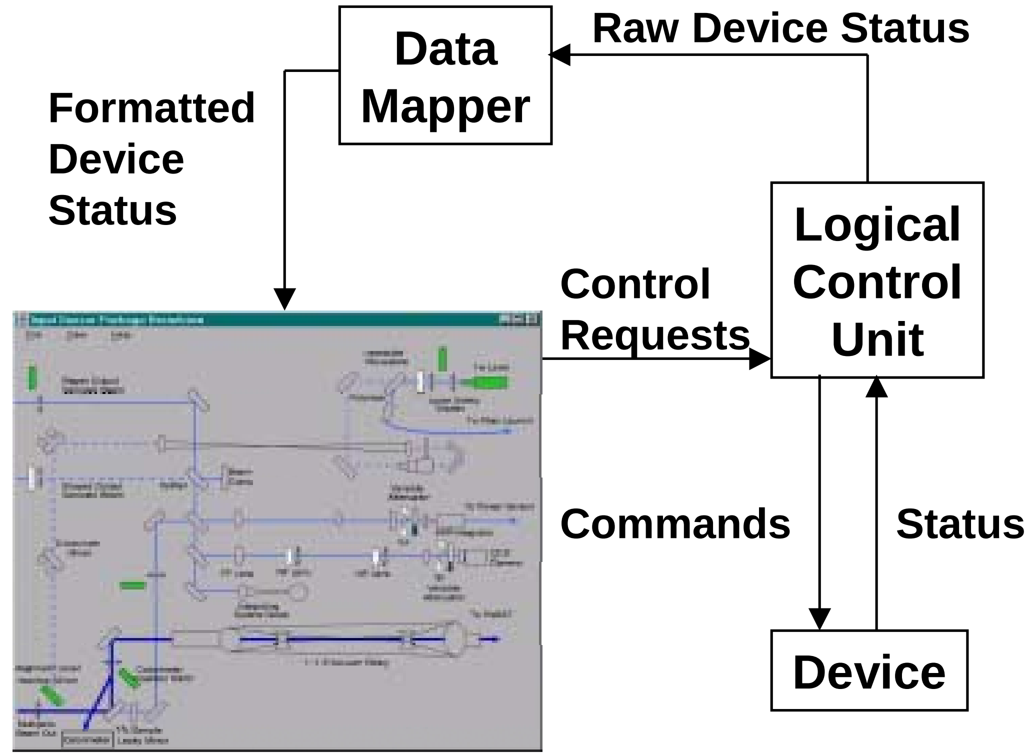
Broadview Panels are thin designs

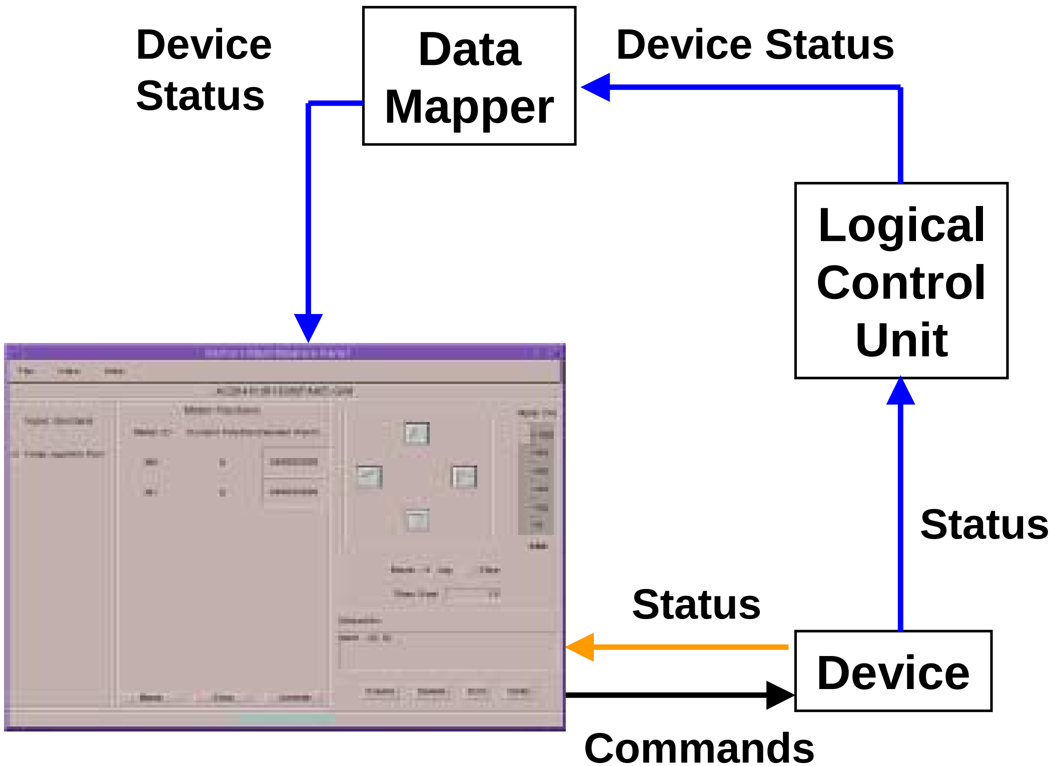
- Java schematic broadview GUIs control devices via an Ada Logical Control Unit process

- The Logical Control Unit is actually a data concentrator that can update multiple GUI clients simultaneously

- Data Mappers, also written in Ada, format the device specific data into basic types that can be easily displayed on the broadview GUI



Maintenance and Control Panels have two modes



- Device level Java GUIs issue commands directly to Ada devices

- In standalone or development mode, GUIs poll Devices directly for status

- In normal integrated mode, status is pushed up to the Logical Control Unit. As with the Broadview GUI, the Logical Control Unit can update multiple GUI clients. This client data flows through a Data Mapper on its way to the GUI.

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An integrated laboratory test is exercising four subsystems on prototype equipment

- Front-End Integrated System Test experience report ...
  - 225K lines of code
    - 158K in Ada
    - 16K in C
    - 52K in Java
  - 53 Programs built from 223 components
  - 18 Java user interfaces
  - Deployed on 11 computers
    - 6 running Solaris
    - 5 running VxWorks
  - Operating a front-end portion of the NIF beamline
    - Approximately 104 control points
    - Starting at the Master Oscillator Room
    - Conditioned by a Preamplifier Module
    - Measured by an Input Sensor Package
  - Experience in experiments
    - CORBA reconnection mechanisms need to be explored

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