Global Controls: RDR to EDR

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For Controls Global Group

Outline

- Controls Reference Design highlights
- Topic areas to get to EDR readiness
- R&D examples
- Work package examples

Control system challenges

- Scalability
- High Availability
- Extensive reliance on automation and beam-based feedback to run ILC accelerator.
- Synchronous control system operation.
- Precision timing and RF phase distribution.
- Standards, standardization, quality assurance.

Challenges for RF control

- Vector-sum calibration (Ampl. & Phase).
- Operation close to performance limits.
- Exception Handling.
- Automation of operation.
- Piezo tuner lifetime and dynamic range.
- Optimal field detection and controller (robust).
- Operation at different gradients.
- Defining standards for electronics (such as ATCA).
- Interfaces to other subsystems.
- Reliability.

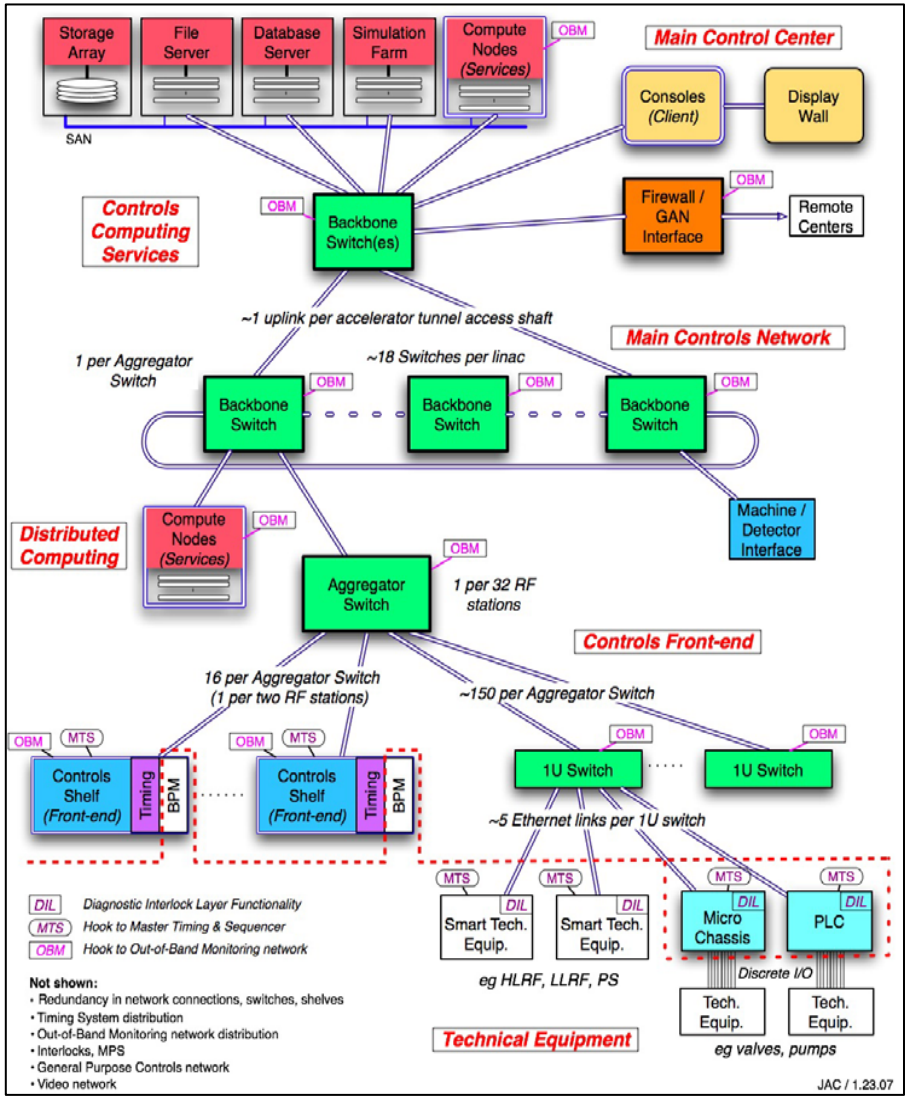
Brian Chase

Control system RDR model

- Functional model (three-tier model)
  - **Front-end: communicate with technical systems.**
  - **Services: coordination; archiver, databases, etc**
  - **Client: operator displays, scripting tools, etc**

- Physical model
  - **Front-end interface to technical systems.**
  - **Synchronous and general purpose networks.**
  - **Distributed and centralized processors.**
  - **Computing, data storage, control room, etc.**
  - **Pulse-to-pulse feedback infrastructure.**
  - **Diagnostic Interlock Layer.**

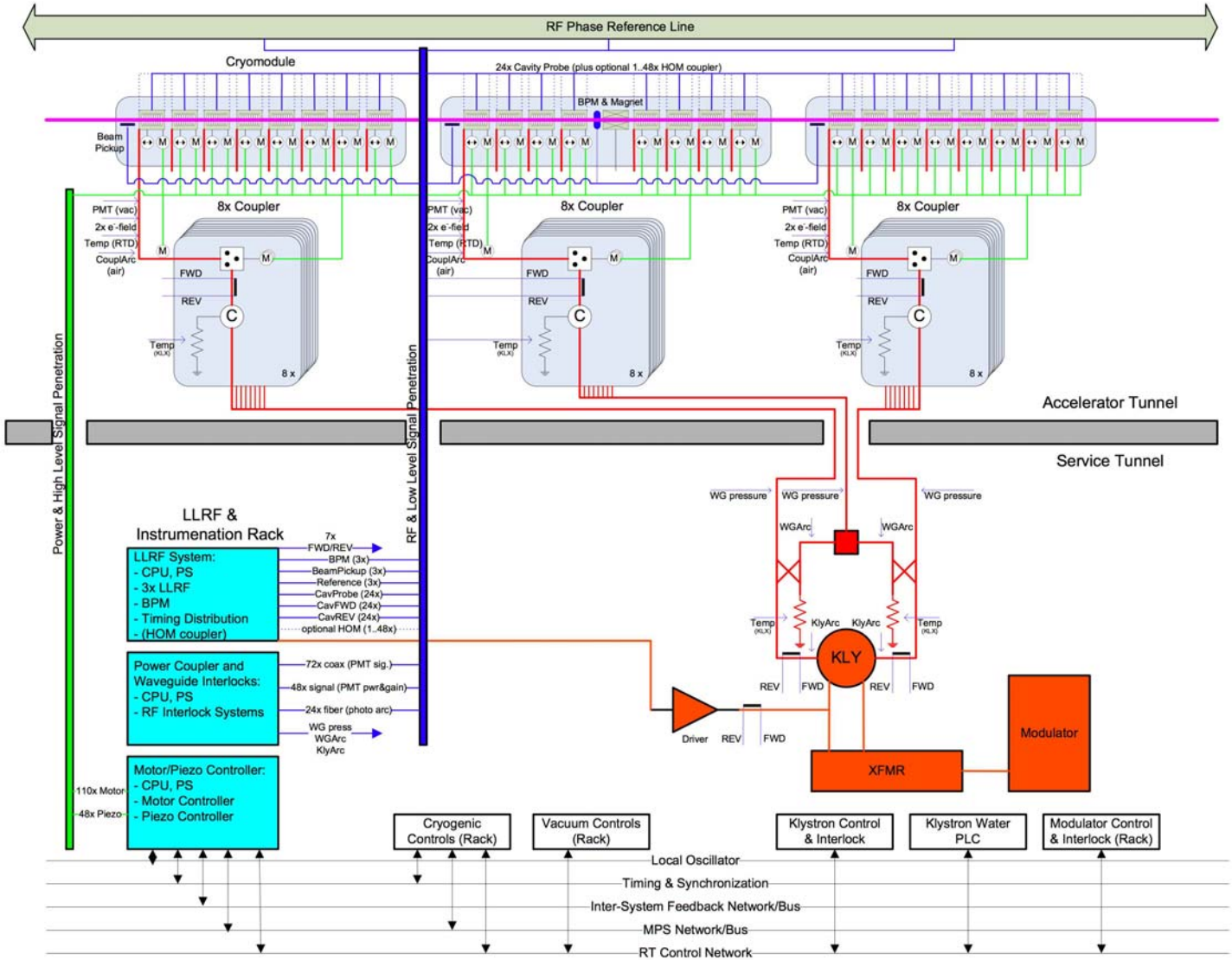
Physical model from RDR



Some items of note:

- Physical model identifies some technology (eg ATCA), but is not technology dependent.
- No software framework selected, but we assume derivation from an existing framework.
- Assessments indicate that future ‘commodity computing’ will meet performance requirements.
- Some design concepts require validation during EDR phase.

LLRF model


RF Phase Reference Line
Cryomodule
24x Cavity Probe (plus optional 1..48x HOM coupler)
BPM & Magnet
Beam Pickup
8x Coupler
PMT (vac)
2x e⁻-field
Temp (RTD)
CouplArc (air)
FWD
REV
Temp
8 x
Power & High Level Signal Penetration
RF & Low Level Signal Penetration
Accelerator Tunnel
Service Tunnel
LLRF & Instrumenation Rack
LLRF System:
- CPU, PS
- 3x LLRF
- BPM
- Timing Distribution
- (HOM coupler)
7x FWD/REV
BPM (3x)
BeamPickup (3x)
Reference (3x)
CavProbe (24x)
CavFWD (24x)
CavREV (24x)
optional HOM (1..48x)
Power Coupler and Waveguide Interlocks:
- CPU, PS
- RF Interlock Systems
72x coax (PMT sig.)
48x signal (PMT pwr&gain)
24x fiber (photo arc)
WG press
WGArc
KlyArc
Motor/Piezo Controller:
- CPU, PS
- Motor Controller
- Piezo Controller
110x Motor
48x Piezo
WG pressure
WGArc
KlyArc
KLY
Driver
REV
FWD
XFMR
Modulator
Cryogenic Controls (Rack)
Vacuum Controls (Rack)
Klystron Control & Interlock
Klystron Water PLC
Modulator Control & Interlock (Rack)
Local Oscillator
Timing & Synchronization
Inter-System Feedback Network/Bus
MPS Network/Bus
RT Control Network

From RDR to EDR…

- Develop RDR models into engineering design.
- Validate/prototype key concepts in RDR models, eg
  - **Network architecture.**
  - **Front-end model, technical system interfaces.**
  - **Synchronous 5Hz feedback infrastructure.**
  - **Standards, standardization, QA.**
  - **Diagnostic Interlock Layer.**
- Perform targeted R&D where it is needed, eg
  - **RF field regulation (phase & amplitude).**
  - **High availability implementation.**
  - **Fault detection and recovery.**
- Controls & LLRF support for test facilities.

Status of EDR/R&D planning

- R&D objectives and model validation tasks for EDR are broadly understood.
- Initial list of specific work packages have been developed as part of the Americas region planning.
- Need to develop a more comprehensive list of specific tasks to get to EDR readiness.

LLRF R&D from S2 tasks

- Heavy focus on accomplishing S2 tasks, including
  - ***Test beam-based feedbacks.***
  - ***Develop RF fault recognition & recovery software.***
  - ***Check beam phase and energy stability.***
  - ***Demonstrate to us and the world that we can make an RF unit to spec.***
  - ***Understand RF control issues in a system with many cavities and cryomodules distributed over a large physical space.***

- LLRF R&D is dependent on beam-based test facilities. Strong LLRF development focus at ILCTA, XFEL,…

- Test facilities require Controls and LLRF infrastructure.

LLRF R&D for SCRF

- RF Field Regulation
  - **Maintain Phase and Amplitude of the accelerating field within given tolerances to accelerate a charged particle beam to given parameters**
    up to 0.5% for amplitude and 0.03 deg. for phase

- Minimize klystron Power needed for control
  - **RF system must be reproducible, reliable, operable, and well understood**.
  - **Active Piezo tuner feedback system**
  - **HINS- Fast Ferrite Vector Modulator control**

- Other performance goals
  - **build-in diagnostics for calibration of gradient and phase, cavity detuning, etc.**
  - **Interface with Machine Protection, exception handling capabilities**
  - **meet performance goals over wide range of operating parameters**

Brian Chase

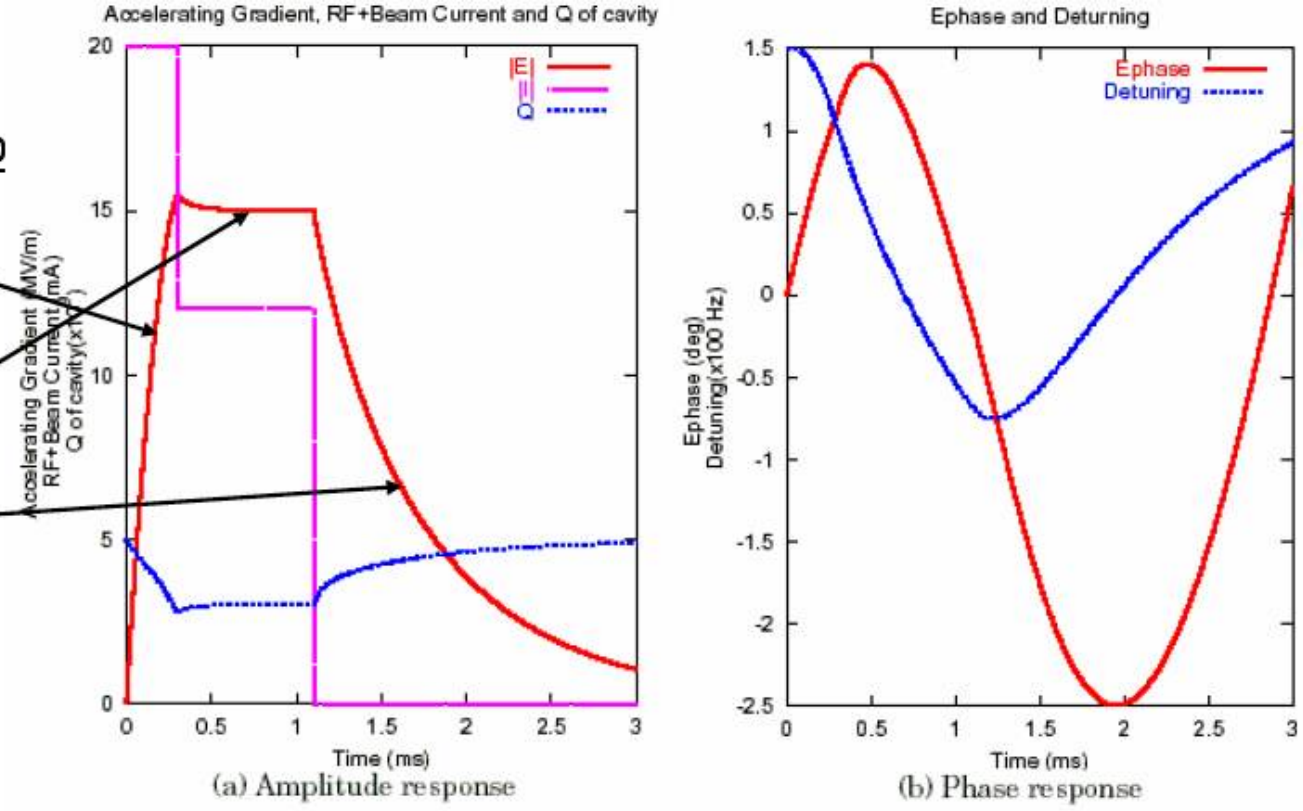
Real Time Cavity Simulator

Test run of ILC Cavity Simulator (no beam)

1)fill: 0 - 0.3 ms at 20 mA (full power)

2)flat-top: 0.3 -1.1 ms at 12 mA

3)cavity emptying, decay curve shows high Q of cavity.



Compare with TESLA cavity measurements: **Shapes are similar, model is working.**

IF in these simulations is 50 MHz.

Justin Keung, UPenn

High Availability

- HA is a requirement for all the technical systems.
- Need to investigate techniques, implications, and cost-benefit for meeting reliability requirements.

- Control system hardware & software are both impacted.

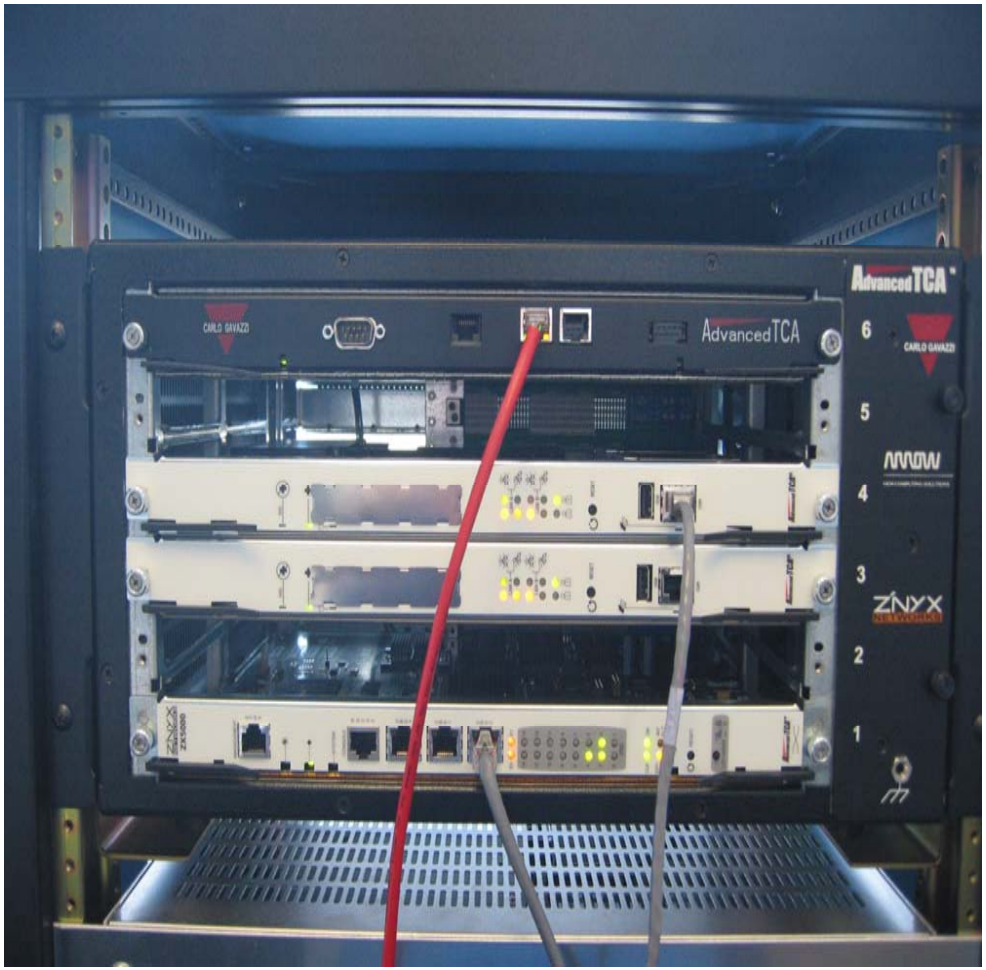
- Methodology component:
  - **Design techniques, robust design.**
  - **Quality Control / extensive testing.**
  - **Standardization.**
- Engineering component:
  - **Reliably detect and then recover from faults.**
  - **Introspection, diagnostic tools,…**
  - **Redundancy, hot spares, remote power on/off,…**

Some ongoing HA activities

- Implement bpm electronics in ATCA crate (Fermilab).
- Implement Simcon board in ATCA crate (DESY).
- Redundant I/O controller for XFEL cryo-plant control system (DESY).
- Investigate I/O controller fail-over techniques using EPICS on ATCA (ANL).
- Study Shelf Manager operation and implementation (Univ. Illinois, UC).
- Diagnostic processor for Marx modulator (SLAC).

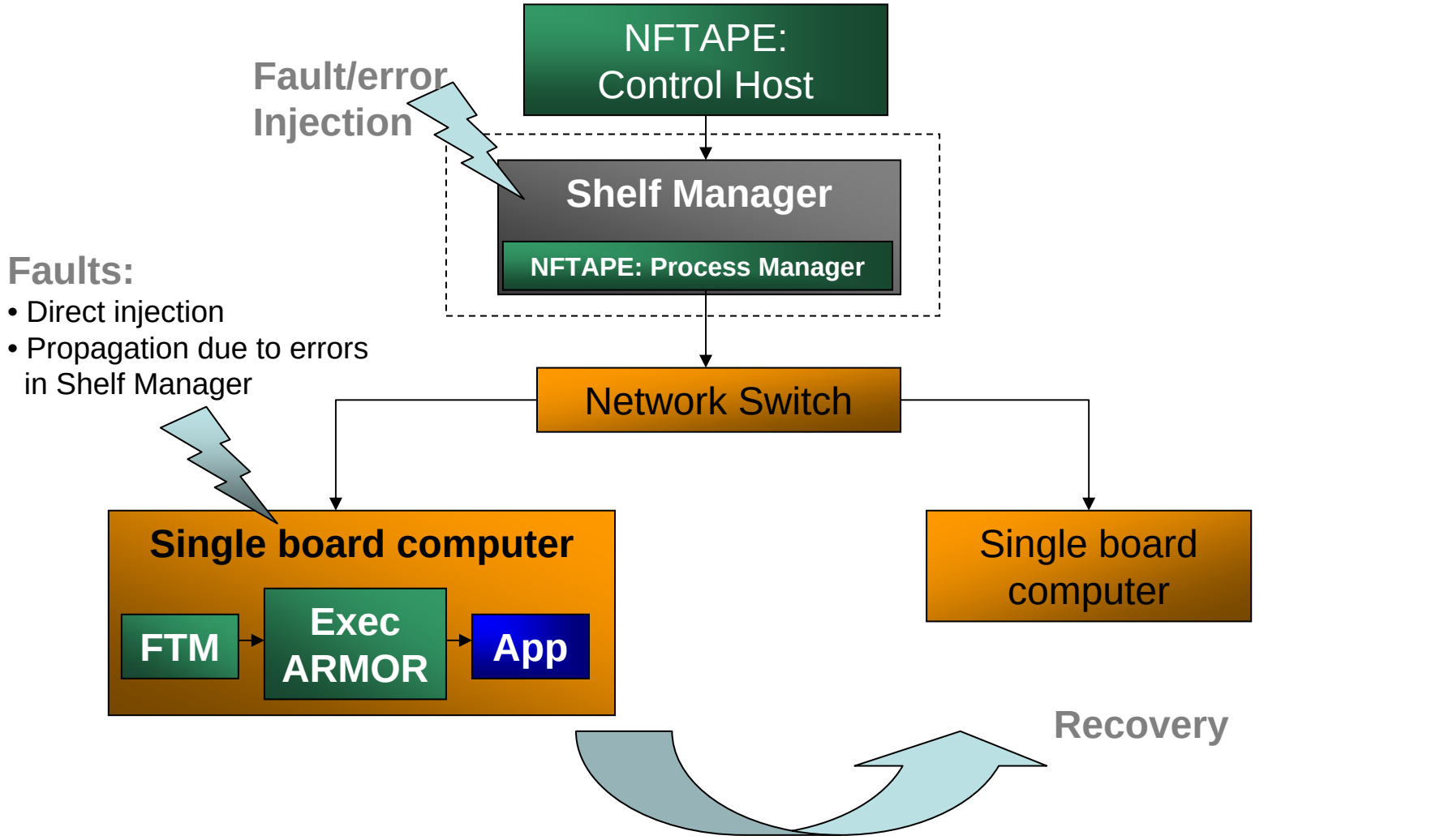
ATCA hardware test setup

- Shelf manager
- 2xIntel Blade
  - **Dual Xeon processors**
  - **Three watchdogs**
  - **Redundant embedded BIOS**
  - **Hotswappable**
- Switch: ZNYX ZX5000
  - **Layer 2 switching and layer 3 routing**
  - **16 ports 10/100/1000 Mbps Ethernet**
- Host PC: server



Shifu Xu, ANL

Fault Detection & Recovery (Univ. Illinois, UC)



Z. Kalbarczyk, UIUC

High Availability in EPICS

- Functions to implement redundant IOCs in EPICS are being developed for XFEL cryo-system (M. Clausen)
  - ***Redundancy Monitor Task.***
  - ***Continuous Control Executive Task.***

- EPICS has been ported to ATCA under linux-ha, and two incremental steps demonstrated (Shifu Xu)
  - **Live migration of EPICS IOC running on one ATCA processor to another ATCA processor.**
  - **Auto fail-over from an active IOC running on one ATCA processor to a backup IOC on another processor without loss of connection to external process.**

WP example: HA control systems

- *Investigate high availability design approaches, implications, and cost-benefit for the ILC control system.*

- Example work package items:
  - **Develop & evaluate controls failure modes and machine impact. Determine priorities for meeting overall availability.**
  - **Explore techniques such as virtual machine migration (Xen), clustering (heartbeat), redundant I/O controllers, etc. using [EPICS, DOOCS, Tango, …] on ATCA.**
  - **Evaluate and prototype second-tier HA techniques, eg: automated diagnosis, configuration management, coding standards.**
  - **Build vertical demonstration of all tiers of control system with HA techniques applied. Perform fault injection to test and evaluate.**
  - **Evaluate and prototype "Shelf-manager' functionality in control system infrastructure for technical system fault management.**

WP example: ATCA evaluation

- *Investigate suitability of ATCA as a high availability compliant electronics platform for ILC control system.*

- Example work package items:
  - **Prototype a precision instrumentation digitizer for beam position monitors. Evaluate analog & digital performance.**
  - **Prototype electronics functions to the AMC mezzanine card, and integrate with the IPMC diagnostic module. Write software drivers.**
  - **Evaluate cabling options for ATCA and AMC cards**
  - **Port [EPICS, DOOCS, Tango,…] to the ATCA platform, integrate and evaluate “Shelf Manager” functionality.**

WP example: diagnostic processor

- *The diagnostic processor (DP) is conceived as the key element in the Diagnostic Interlock Layer (DIL).*

- Work package example items:
  - **Continue development of DP hardware for Marx and 4+1 supplies. Develop generic family of DP hardware (including chip-level) suitable for integration into various technical systems.**
  - **Develop on-board software to integrate DP with IPMI-based relay rack monitoring. Client software will be developed/acquired to provide a uniform management interface to all relay racks based on current standards.**

WP example: RF phase distribution

- *Perform essential R&D on distribution techniques for the 1300 MHz timing distribution system.*

- Example work package items:
  - **Investigate & evaluate strategies for phase stabilizing long fiber links modulated at 1.3 GHz.**
  - **Demonstrate critical time of arrival stabilization at a dummy Interaction Point using NML beam test facility.**
  - **Investigate feasibility of using a beam-derived reference for locking a local phase reference.**
  - **Prototype a redundant phase reference receiver with decision logic to auto-switch upon detected failure.**

Summary

- RDR models for Controls and LLRF provide a starting point for the EDR phase.

- Top level goals and topic areas for EDR are known.
- Initial set of work packages has been developed.
- Must develop a more thorough list of topics and work packages needed to get to EDR readiness.