Global Control System

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- *Requirements, challenges*
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Scope of Controls

- ***Computing Infrastructure***
  - Computer Center
  - Business Computing
  - Computing Networks
  - Desktop Support
  - Engineering Support
  - Computer Security
  - Management
- ***Controls System***
  - Central Computers
  - On Site Control Room
  - Controls Services
    - Operator Interface
    - Automation
    - Logging
    - databases
    - Data Archival
    - Alarms
    - Diagnostics
- ***Interfaces to Technical Systems***
  - Front Ends
    - Hardware
    - software
  - Cabling
- ***Protection Systems***
  - Machine Protection
  - Personnel Protection
  - Beam Containment
- ***Network Infrastructure***
- ***Assembly and Testing of Controls Racks***

Controls requirements

- ***All the usual requirements of an integrated control system…***
  - Control & monitoring, GUI, archiver, save/restore, alarm handler,…
- ***Technical challenges driven by ILC scale & complexity***
  - 100,000 devices, several million control points
  - Main linacs: 640 RF klystrons, 2000 cryomodules, 16,000 cavities
  - Control system: 1000+ front-end crates
- ***System integration, standardization of interfaces.***
- ***Accelerator operations: reliance on automation & feedback***
- ***Accelerator availability goal of 85%*** *(control system: 99%)*
- ***Precision timing & synchronization over 10's km.***
- ***ILC funding model: multi-national in-kind contributions.***

And then…

- ***Controls has to be ready before anything else…***
  - Support technical system test & commissioning
  - Support staged (parallel) accelerator commissioning.

Addressing the challenges

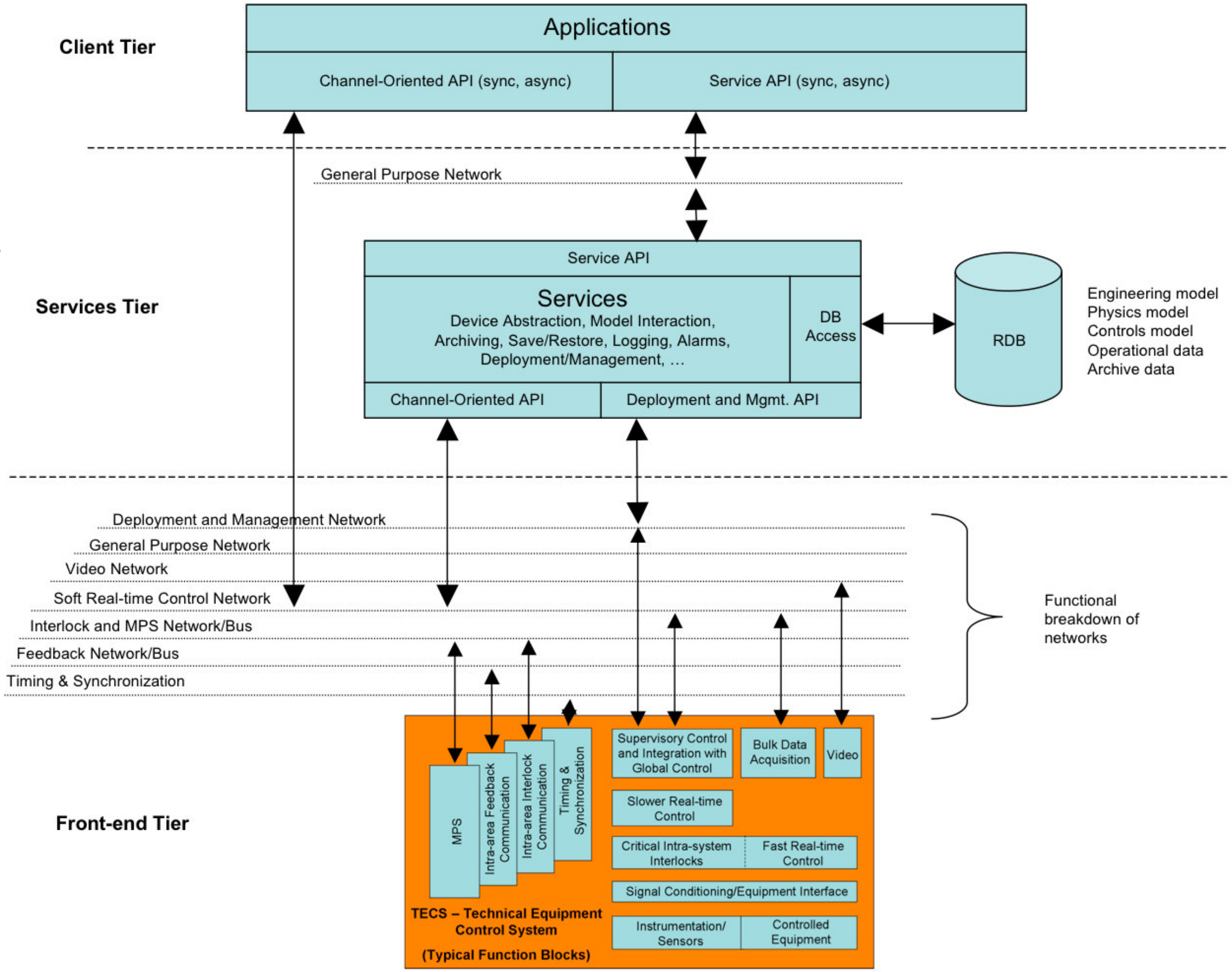
- ***Large scale deployment***
  - Strong emphasis on diagnostics, quality assurance.
  - Evaluate High Availability techniques
  - Resource management
  - Emphasize standards-based solutions.
- ***Extensive reliance on automation and 5Hz feedback***
  - Automation and feedback engines implemented in Services.
  - Make all control & monitor points available to feedback engine, synchronize control and monitor actions to 5Hz beam pulses.
- ***Controls integration of in-kind contributed equipment***
  - Scope, span of control, treaty points…
  - Rely on experience from XFEL, ITER

Control System functional model

Client Tier
- GUIs
- Scripting
- HMI for high level apps

Services Tier
- "Business logic"
- Device abstraction
- Feedback engine
- State machines
- Online models…
- High level apps run in the Services tier
- "Run control"

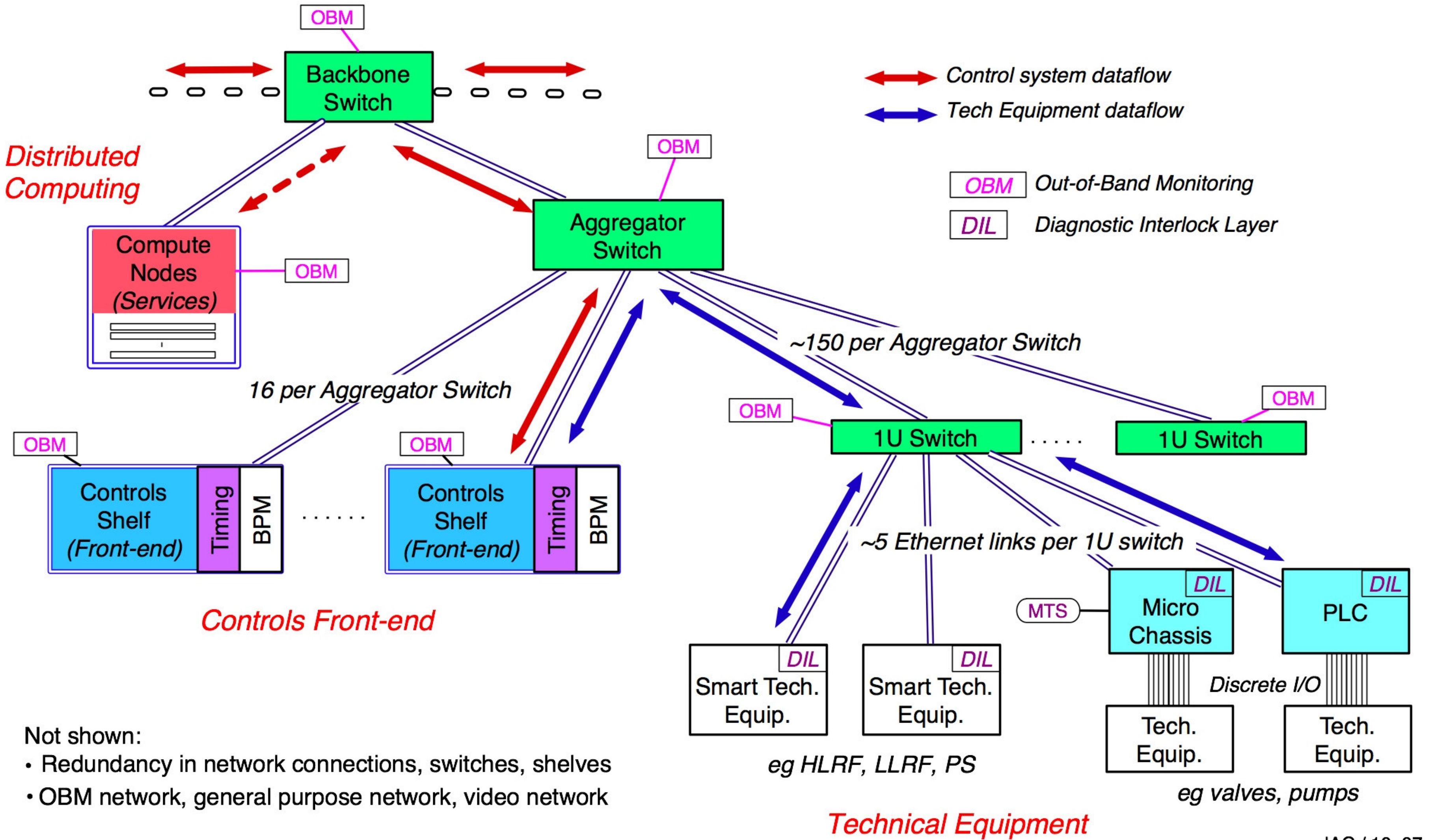
Front-End Tier
- Equipment Interfaces
- Control-point level



Examples of Services

- *Script execution service*
- *Archiving service*
- *Logging service*
- *Data processing & visualization*
- *Save, Compare, Restore*
- *Alarm Management*
- *RDB calls*
- *Locking (channel, instance,…)*
- *Math & logic functions*
- *Event sequencer / synchronizer*
- *Device server*
- *Data concentrator*
- *Feedback / dynamical control*
- *Video processing, compression*
- *Out of Band monitoring*
- *Exception handling*
- *Resource management*
- *Authentication / access control*
- *Notification (email, phone, sms,…)*

Physical model: front-end

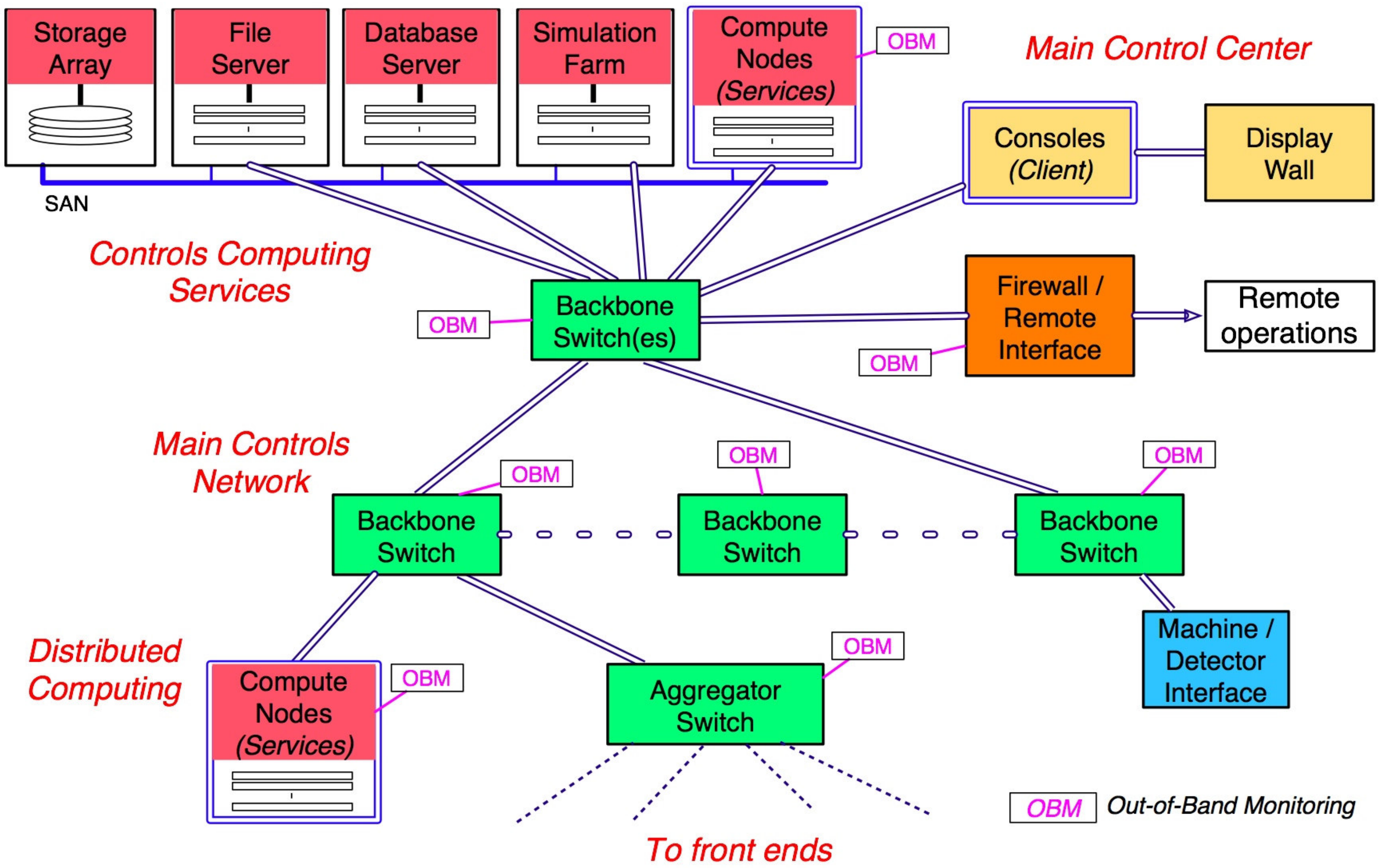


Not shown:

- Redundancy in network connections, switches, shelves
- OBM network, general purpose network, video network

JAC / 10..07

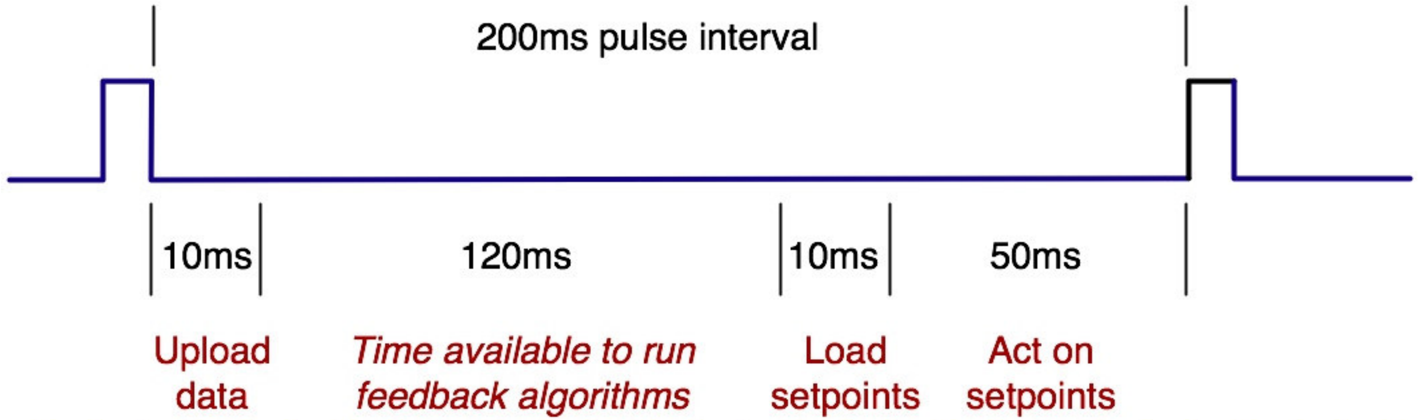
Physical model: global layer

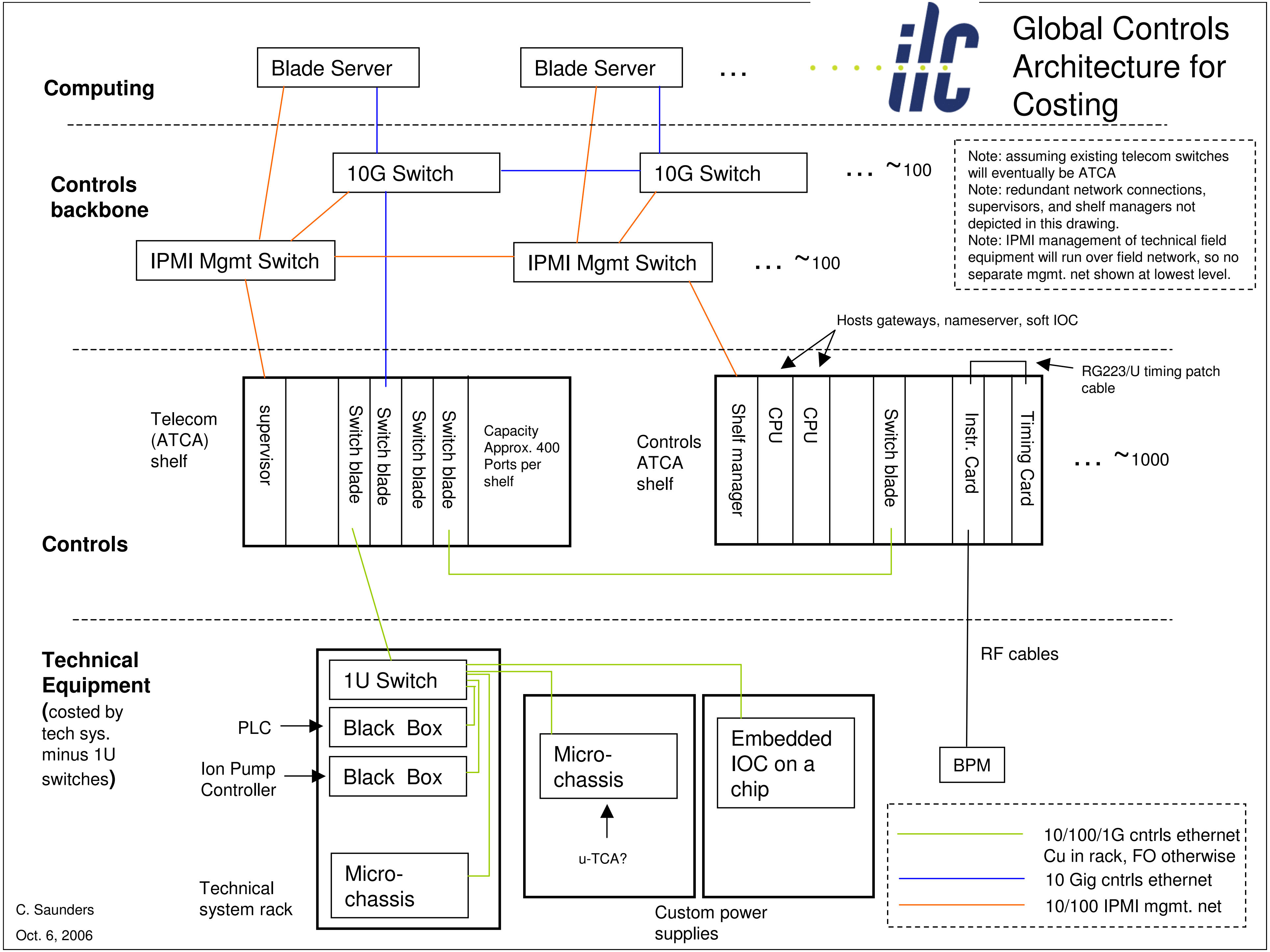


Feedback Infrastructure model

- ***Physical model assumes that all control and monitoring points are available for use in a 5Hz synchronous feedback loop***
  - Allows ad-hoc feedback loops to be create using high level applications without prior assignment of sensors or actuators.
- ***Feedback algorithms are implemented in Controls Services Tier.***

- ***Requires synchronous operation of technical systems and of the controls network.***





Global Controls Architecture for Costing
Computing
Blade Server
Blade Server
...
Controls backbone
10G Switch
10G Switch
... ~100
IPMI Mgmt Switch
IPMI Mgmt Switch
... ~100
Note: assuming existing telecom switches will eventually be ATCA
Note: redundant network connections, supervisors, and shelf managers not depicted in this drawing.
Note: IPMI management of technical field equipment will run over field network, so no separate mgmt. net shown at lowest level.
Hosts gateways, nameserver, soft IOC
RG223/U timing patch cable
Telecom (ATCA) shelf
supervisor
Switch blade
Switch blade
Switch blade
Switch blade
Capacity Approx. 400 Ports per shelf
Controls ATCA shelf
Shelf manager
CPU
CPU
Switch blade
Instr. Card
Timing Card
... ~1000
Controls
Technical Equipment
(costed by tech sys. minus 1U switches)
RF cables
1U Switch
PLC
Black Box
Ion Pump Controller
Black Box
Micro-chassis
Technical system rack
Micro-chassis
u-TCA?
Embedded IOC on a chip
Custom power supplies
BPM
10/100/1G cntrls ethernet Cu in rack, FO otherwise
10 Gig cntrls ethernet
10/100 IPMI mgmt. net
C. Saunders
Oct. 6, 2006

Standardized interfaces

- ***A high degree of standardization is assumed for the interfaces from technical systems to the control system***
  - Not simply defining the interface as "Ethernet", but also specifying protocols, equipment behavior, functionality, etc

- ***Standardization is necessary to…***
  - Reduce controls manpower.
  - Provide consistent look/feel for similar equipment.
  - Ensure that equipment coming from many sources can be fully integrated into the control system.

Front-end equipment costing model

- ***Common model for front end equipment based on ATCA with redundant processors***
  - ATCA is targeted at the Telco industry, but has HA features of interest to other "up time" critical systems.
- ***High-level (Ethernet) interfaces assumed in most cases, with discrete I/O largely eliminated from costing model***
  - Reflects trend to embed processors in technical equipment
  - Pushes some front-end 'Controls' costs into the technical equipment.
- ***In some cases, TS interface electronics are installed in Controls crates (eg bpm instrumentation).***
- ***Bottom-up estimates of front-end equipment using device counts from each AS group (still in flux).***

Front End Equipment and Device Counts

Controls equipment required…

Components	e- source	e+ source	DR	RTML	Linac	BDS
CPU Card Total	150	248	546	430	650	366
Payload Card Total	445	892	1,962	1,546	1,461	1,317
1U Switch Total	67	831	1,346	708	4,453	951
Switch Blade Total	4	18	29	15	93	20
Telecom Shelf Total	3	4	8	3	36	17
Controls Shelf Total	75	124	273	215	325	183
Rack Total	39	64	141	109	181	100
Cables						
Cat 5E	400	4,982	8,072	4,244	26,713	5702
RG223/U	240	911	3,037	1,600	1,940	1332
Fiber Optic	268	3,324	5,384	2,832	17,812	3804

for control of …

these Area System devices (note: LLRF motor-controllers and cryo not listed here)

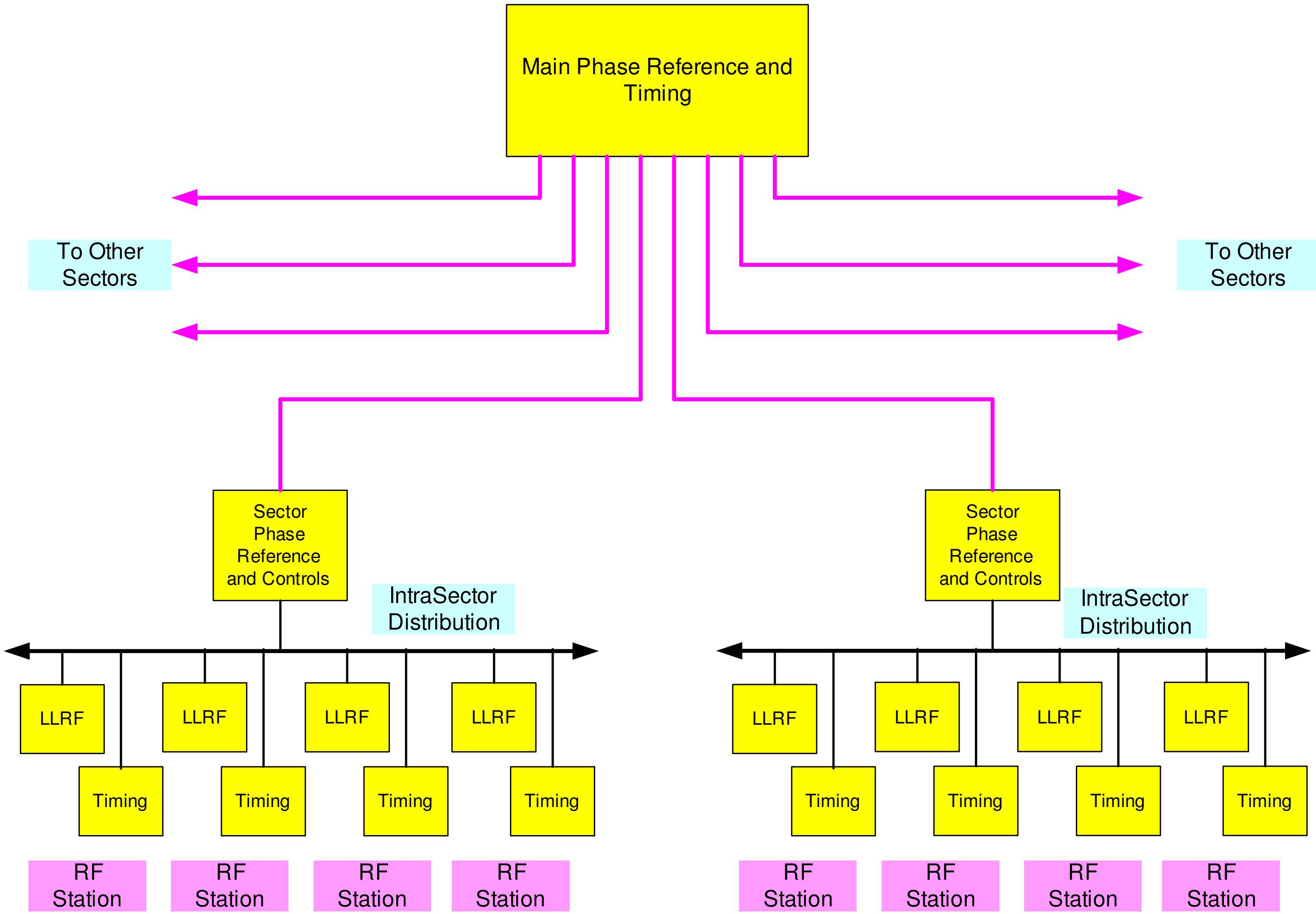
ILC Technical Equipment Totals by Category and Area System							
	Area System						
TECS Category	BDS	DR	e-	Linac	e+	RTML	
							Total By Category
Power Supply	654	3866	171	3722	2267	1442	12122
Instrumentation	744	1580	165	2024	749	1418	6680
Vacuum	1787	464	20	6733	219	632	9855
Motor System	234	0	0	0	0	0	234
Feedback system	14	4	5	20	10	4	57
							0
Other	176	0	4	1215	4	48	1447
Total By Area	3609	5914	365	13714	3249	3544	
Total	30395						

Damping Ring device counts

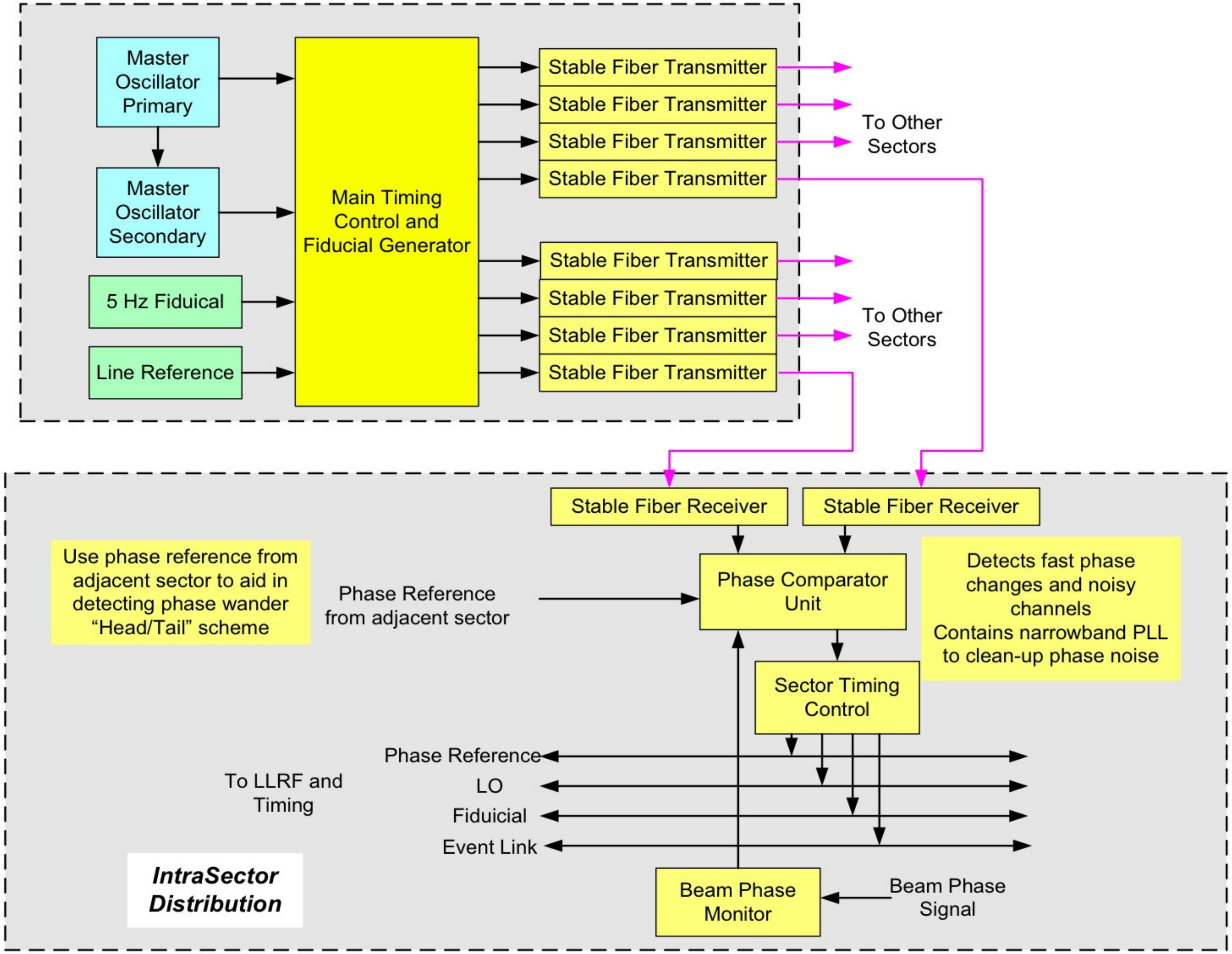
Component Type		Total
B Magnet (chained)	Main PS	32
B Magnet (individual)	PS	0
Q Magnet	Main PS	2
	Shunt PS	1646
Q Magnet	PS	0
Skew Q Magnet	PS	0
S Magnet	PS	1008
O Magnet	PS	0
Corrector magnet	PS	900
Septum	PS	8
Stripline Kicker	PS	120
Wiggler	PS	160
	Cryo	160
Magnet mover		0
		0
Cavity BPM (warm)		0
Cavity BPM (cold)		0
Button BPM		1494
LOLA monitor		0
Laserwire		2
BLM		80
Wirescanner		0
Beam current monitor		2
Optical monitor		2
Spectrometer		0
Polarimeter		0
Feedback - special		4
		0
		0
		0
Ion Pump		464

Device counts and equipment types need validation in ED phase

Timing System Overview



Phase & timing distribution



F. Lenkszus

Availability

- ***ILC control system availability goal: 99% by design***

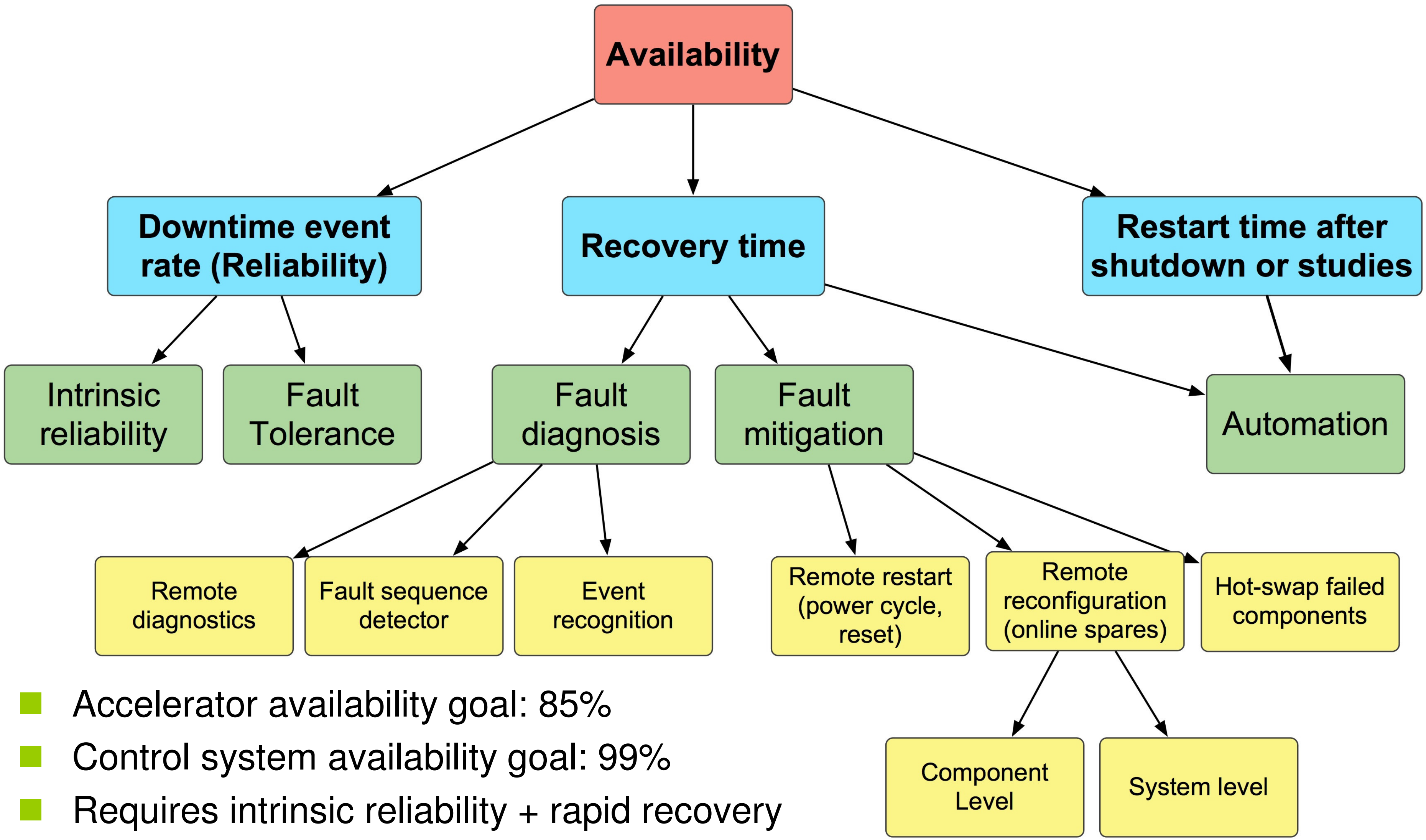
- ***1000+ front-end crates ⇒ 99.999% per crate.***
- ***Cannot afford a long period of identifying & fixing problems once machine operations begin.***

'Best effort' approach may not be sufficient

⇓

Investigate High Availability techniques.

Accelerator Availability



- Accelerator availability goal: 85%
- Control system availability goal: 99%
- Requires intrinsic reliability + rapid recovery

HA requires different considerations

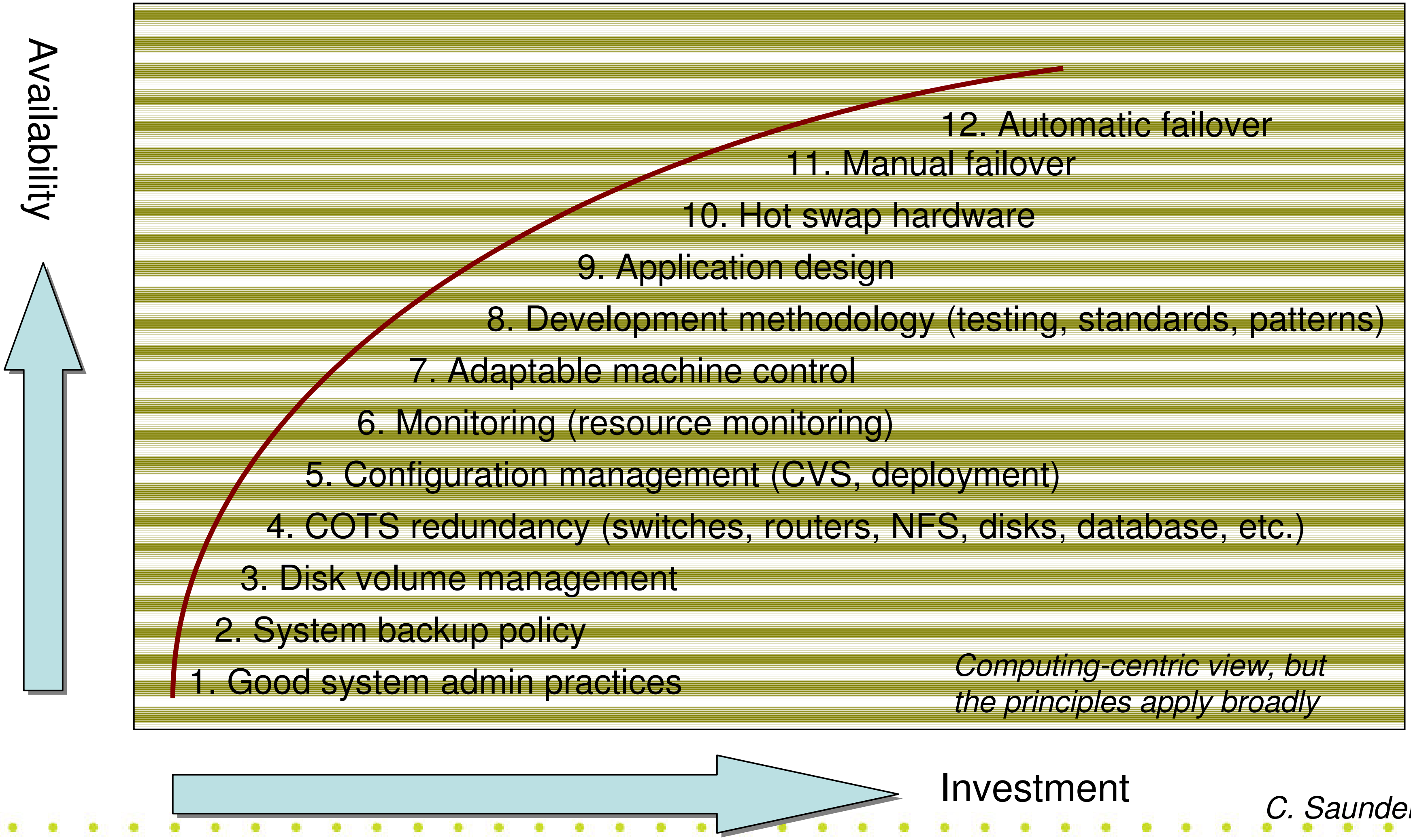
- ***Apply techniques not typically used on an accelerator***
  - Development culture must be different.
  - Cannot build ad-hoc with in-situ testing.
  - Build modeling, simulation, testing, and monitoring into hardware and software methodology up front.

- ***Hardware availability***
  - Instrumentation electronics to servers and disks.
  - Redundancy where feasible, otherwise adapt in software.
  - Modeling and simulation

- ***Software availability***
  - Equally important.
  - Software has many more internal states – difficult to predict.
  - Modeling and simulation needed here for networking and software.
  - Robustness, exception handling.

Not just redundancy…

…but also sound design principles, methodology, QA



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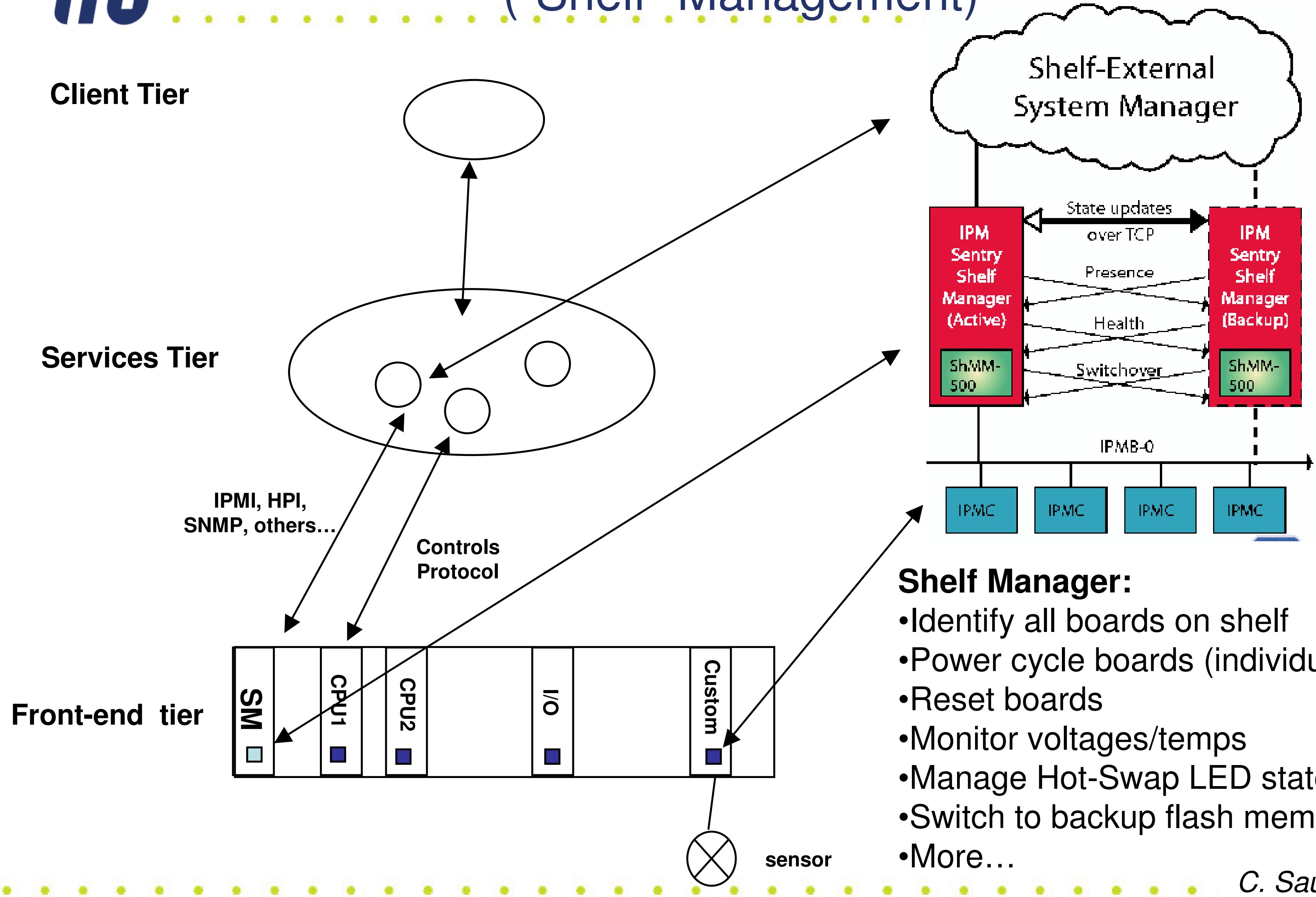
Resource management

- ***Online database containing information about every component in the system***
  - Cable plant, physical locations, electrical power, etc
  - Hardware, software, firmware, revisions, “DIP switch” settings,…
  - Physics model, engineering model.
- ***Validate equipment installation***
- ***Extensive monitoring and diagnostics to detect and recover from failures.***

Fault detection and remediation
("Shelf" Management)



Shelf Manager:

- Identify all boards on shelf
- Power cycle boards (individually)
- Reset boards
- Monitor voltages/temps
- Manage Hot-Swap LED state
- Switch to backup flash mem bank
- More…

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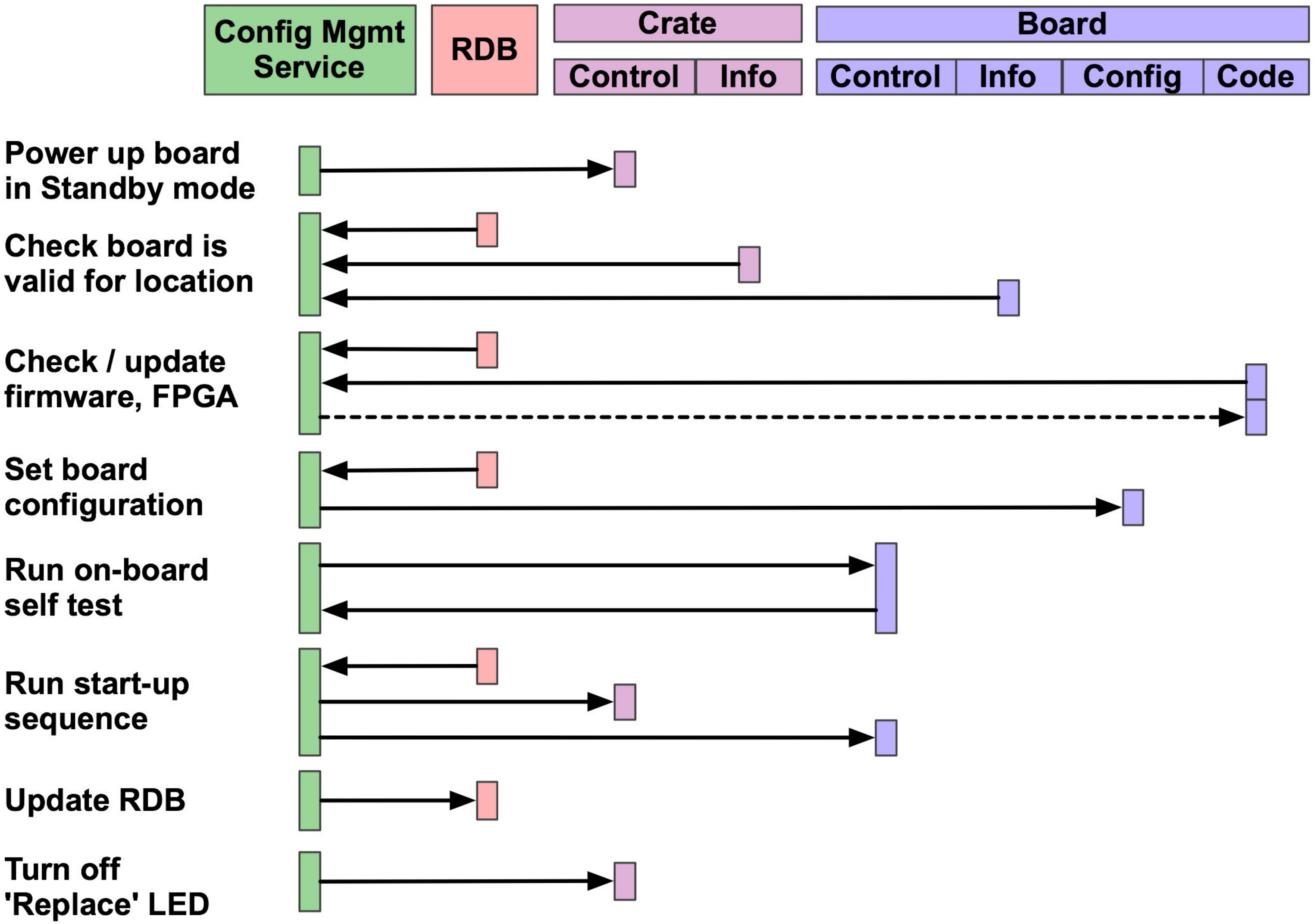
Resource management
Example: replacing circuit board



Front-end electronics requirements

- ***HA-specific requirements***
  - Intelligent Platform Management
  - Remote power on/off and reset/initialize for individual boards.
  - Highly improved diagnostics capabilities in all electronics subsystems.
  - Support redundancy: processors, comms links, power supplies,…
  - Hot-swappable components: circuit boards, fans, power supplies, …
- ***Platform basic requirements***
  - Standard modular architecture
  - Broad industry support of core components
  - Wide range of COTS modules + support custom instrumentation.
  - ‘High performance’ + cost-effective.

If not VME or VXI, then what…?

- ***Candidate standards include ATCA, uTCA, VME64x, VXS, VPX, other VITA standards…***

- ***Of systems available today, ATCA offers the best representative feature set***
  – Represents best practices of decades of telecom platform development.
  – Increasing evidence of commercial products for controls applications.
  – Growing interest in the Controls and DAQ community.
  – Being evaluated by several labs. Strong candidate for XFEL.

- ***Two flavors***
  – ATCA: Full-featured, large form-factor
  – uTCA: Reduced feature-set, smaller form-factor, lower cost.

- ***For ILC Controls, allows R&D on high availability techniques.***

Engineering Design R&D Phase

- ***Main focus of R&D efforts are on high availability***
  - Gain experience with high availability tools & techniques to be able to make value-based judgments of cost versus benefit.
- ***Four broad categories***
  - Control system failure mode analysis
  - High-availability electronics platforms (ATCA)
  - High-availability integrated control systems
    - Conflict avoidance & failover, model-based resource monitoring.
  - Controls as a tool for implementing system-level HA
    - Fault detection methods, failure modes & effects

RDR model to EDR design

- ***Technical equipment / Area System specific…***
  - Better information on device counts, types, locations
  - Data rates, etc
  - Tunnel/alcove space utilization
  - Cable and relay rack layout cost optimization.

- ***Refine model for standardization of front-end equipment requirements and interfaces.***

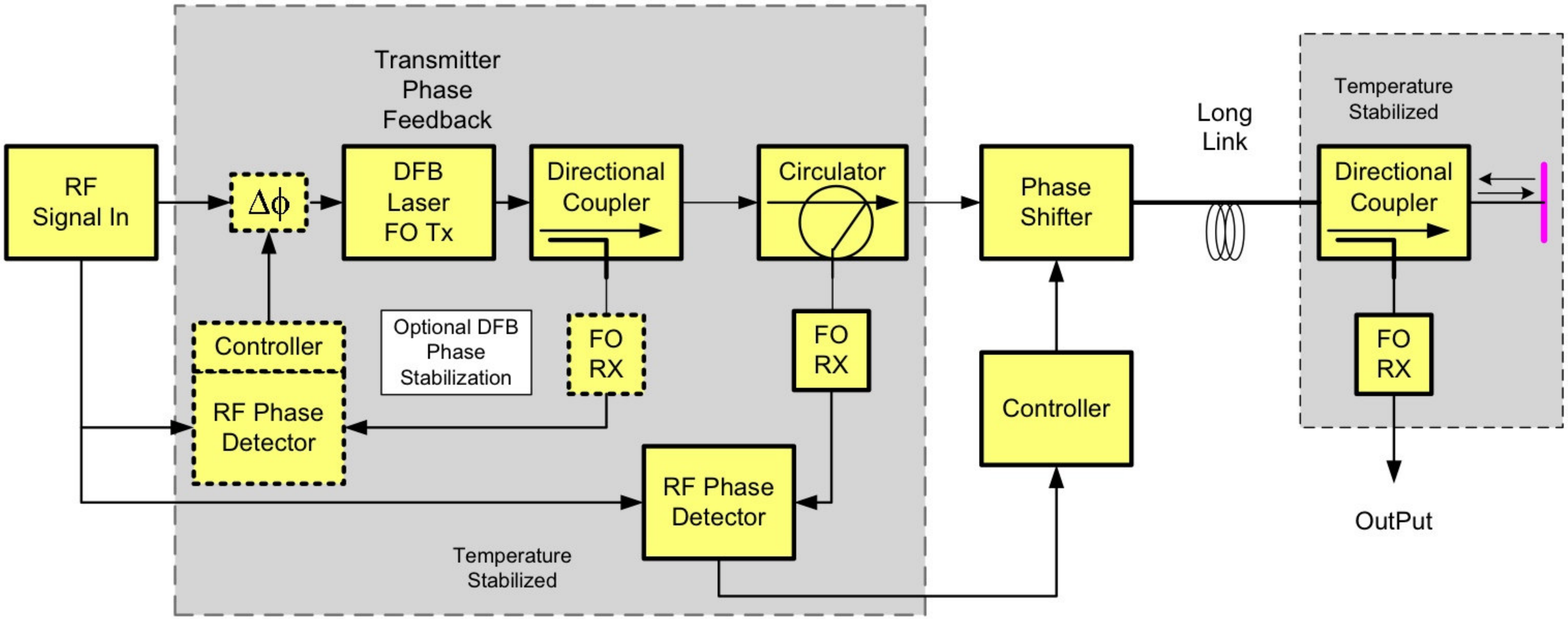
- ***Explore impact of different vendor models***
- ***Bottom up assessment of overall level of effort.***
- ***High Availability feature set and cost optimization.***
- ***High level control system functionality.***

Controls Work Packages

- ***Electronics Platform (ATCA is in here)***
- ***High availability***
- ***Controls system architecture***
- ***Engineering***
- ***Software Development***
- ***Configuration***
- ***Integration (includes interfaces with each accelerator area)***
- ***Timing and Synchronization***
- ***Project Management***
- ***Safety System***
- ***Automation***
- ***Operator Console Application***

-- backup slides --

Phase stabilized link



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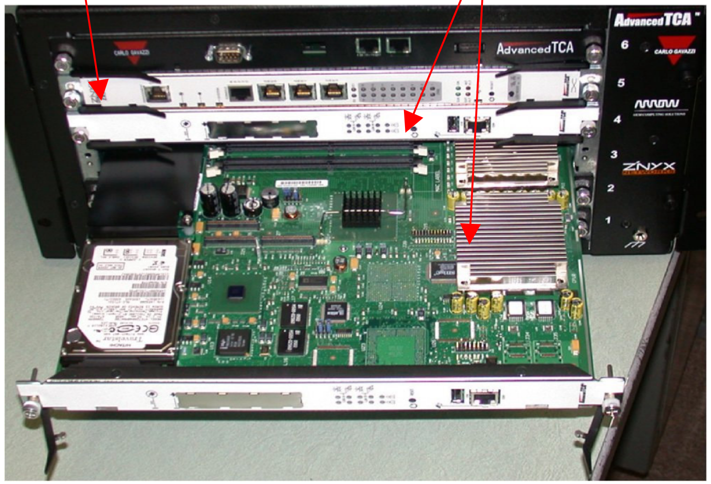
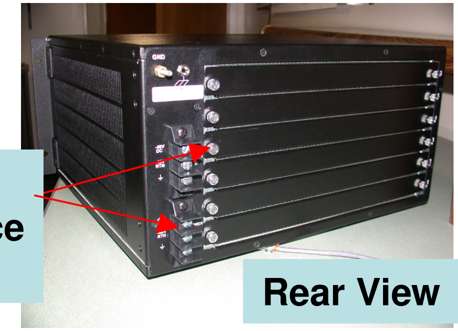
ATCA crates

5-Slot Crate w/ Shelf Manager
Fabric Switch
Dual IOC Processors

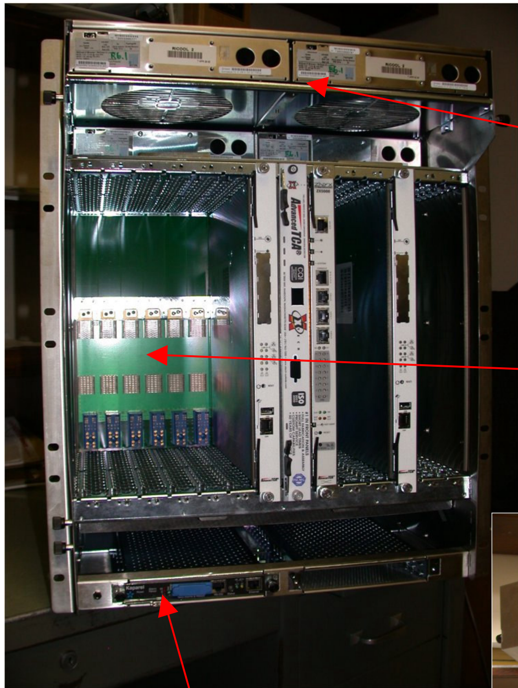


Dual 48VDC
Power Interface



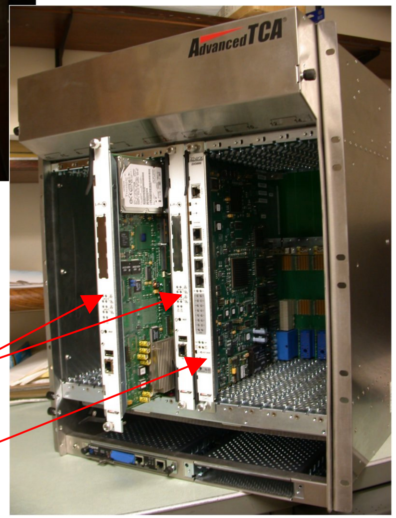
Rear View

4 Hot-Swappable Fans



16 Slot Dual Star Backplane

Shelf Manager



Dual IOC's
Fabric Switch

R. Larsen

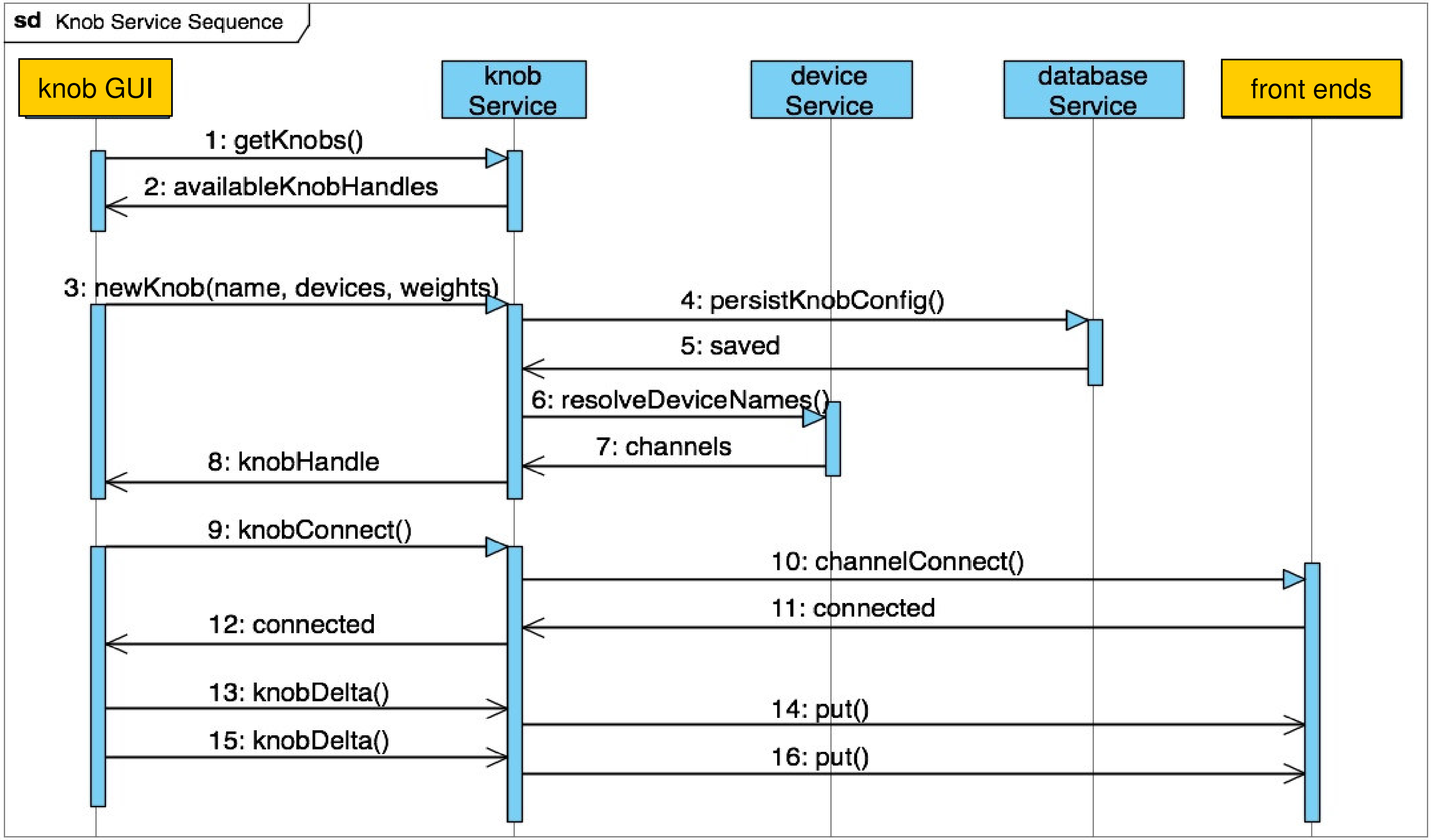
Services

- ***Some activities are not well suited to channel-oriented interfaces***
  - **Complex**
    - May require lots of parameters and a sequence of interactions
  - **Dynamic**
    - May be added and removed frequently during operations
    - May require dynamic allocation (network latency and/or cpu loading)

- ***Services allow rapid prototyping of high level apps through composition, while maintaining an impedance to changing the core functions.***

- ***Services***

Example: Knob Service Sequence



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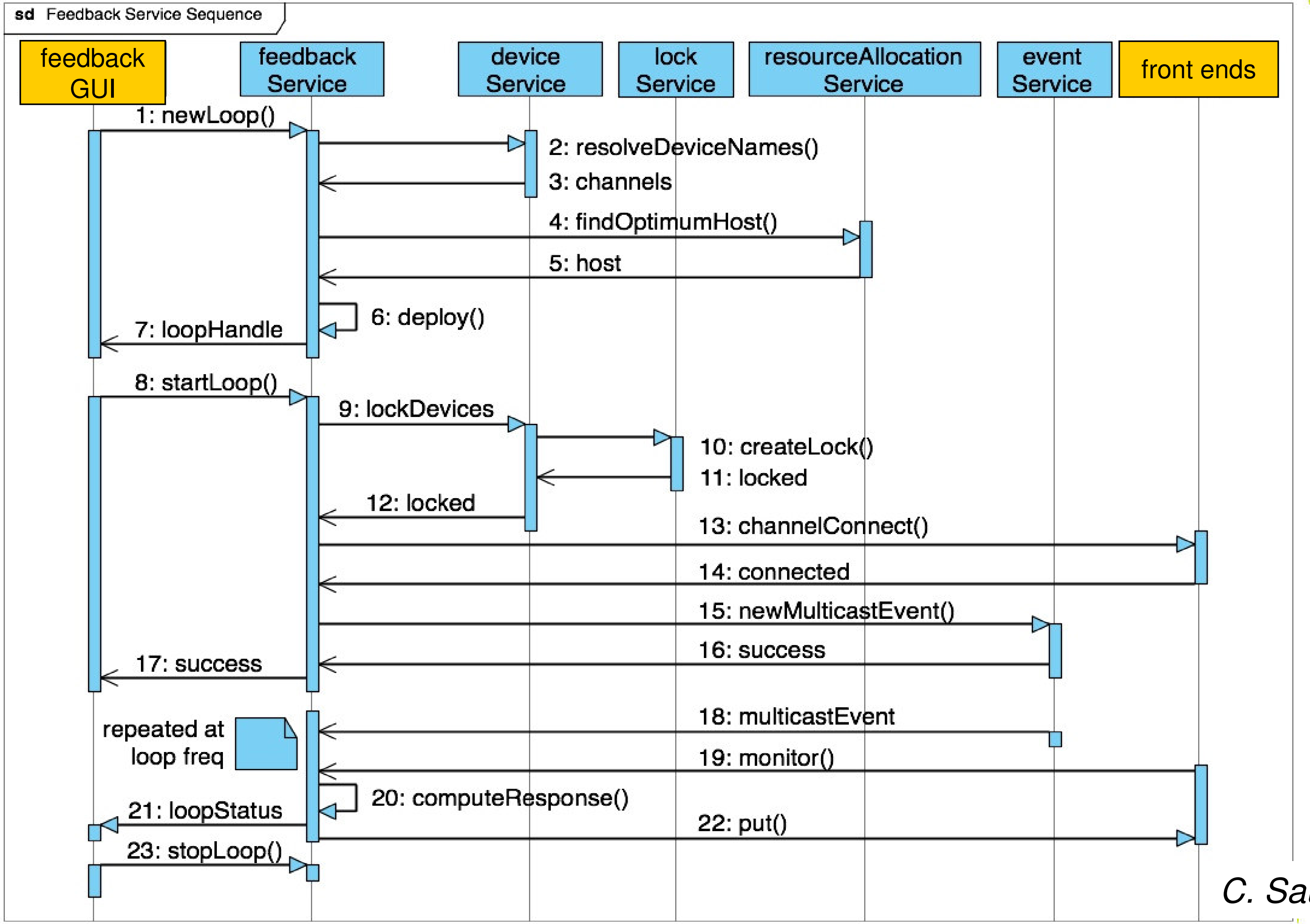
Example: Feedback Service Sequence



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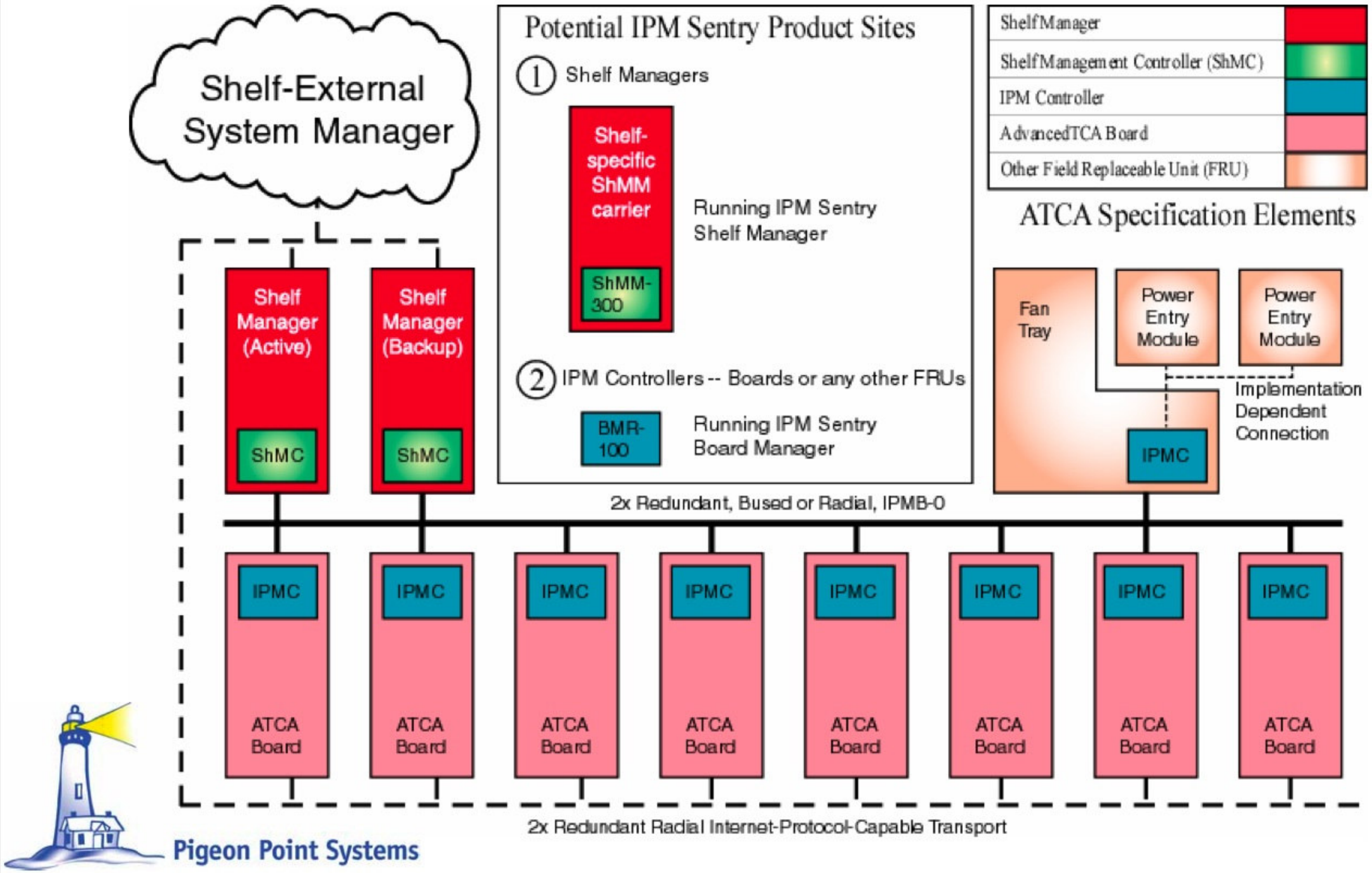
ATCA Shelf w/ Dedicated Shelf Management Controllers



Alcatel·Lucent