cosylab
CONTROL SYSTEM LABORATORY

OUR PASSION:
To deliver high quality and be respected for that

Control System for New Large Experiments

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PCaPAC 2010, Saskatoon, Canada

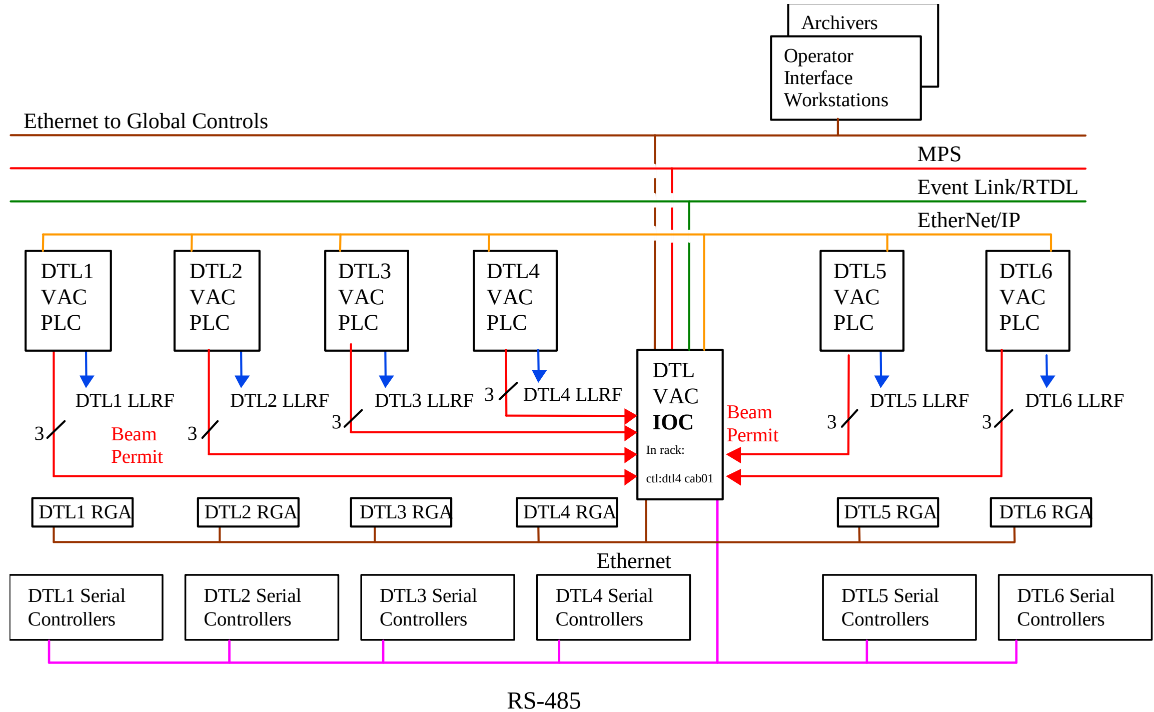
the best people make cosylab

Thank you for organizing this workshop

PCaPAC 2008 Group Photo

Change in Control System Development

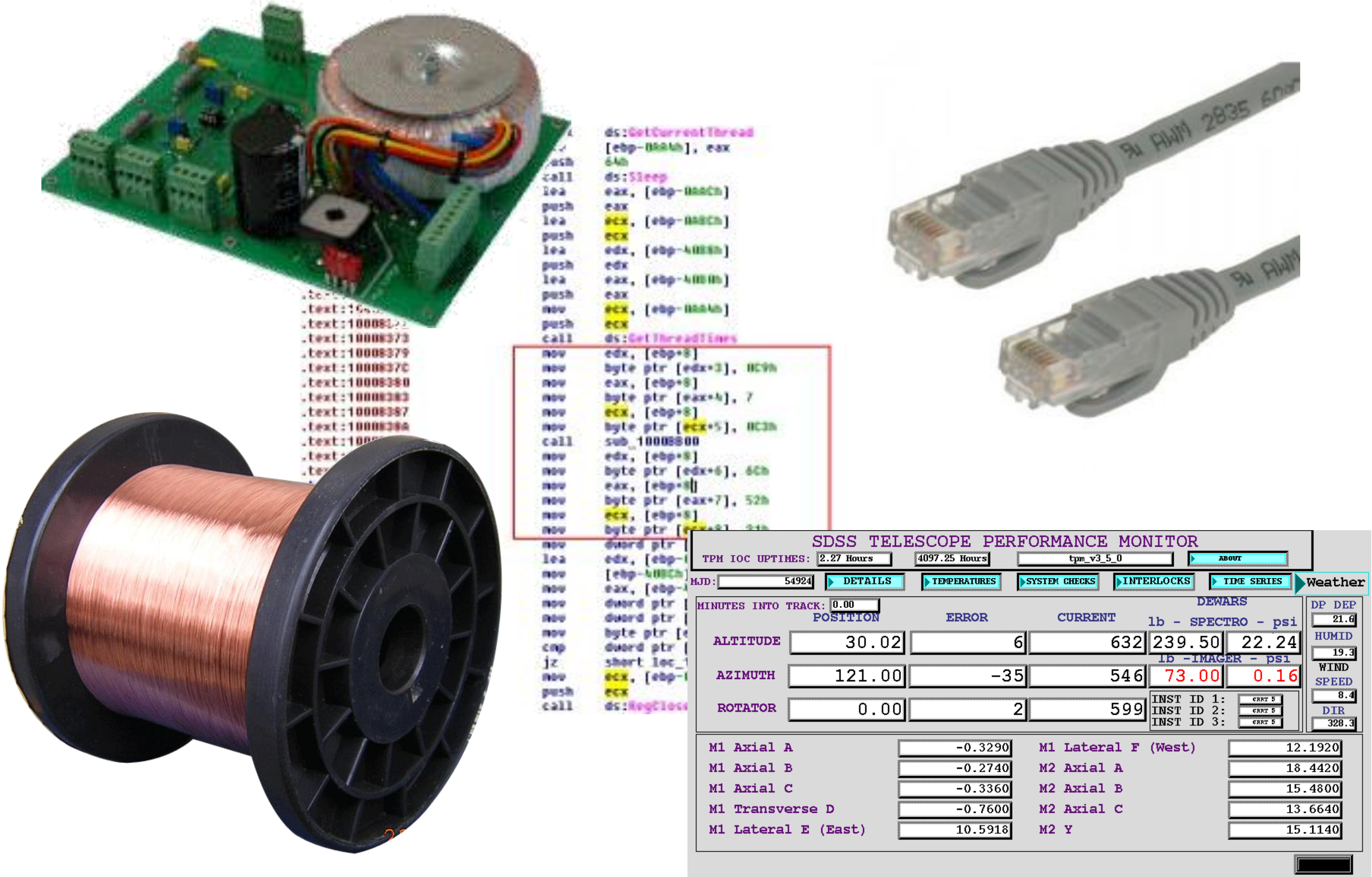
1980s



Today

What has changed?

“Ancient history” – build everything yourself



Small markets→ unique solutions

Today, we do not start from scratch

- Start by picking the control system package of your choice

TANGO

TINE

PVSS by ETM

EPICS

LabVIEW

FESA

DOOCS The Distributed Object Oriented Control System TESLA

And pick your favorite platform

Embedded With RTEMS www.rtems.com

VxWorks® WIND RIVER

SOLARIS

Mac

Standard packages and solutions available

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High level applications and machine physics

XAL

Relational DataBases

IRMIS

ORACLE

Timing systems

Beam Position Monitors

Machine protection systems

… but we have to deliver faster and with lower budget

- Typically reduced from 10% to 5% of a machine budget
- Limitation on the man-power, need to manage risks
- Only can be achieved with standard, well-tested components AND by focusing on development processes

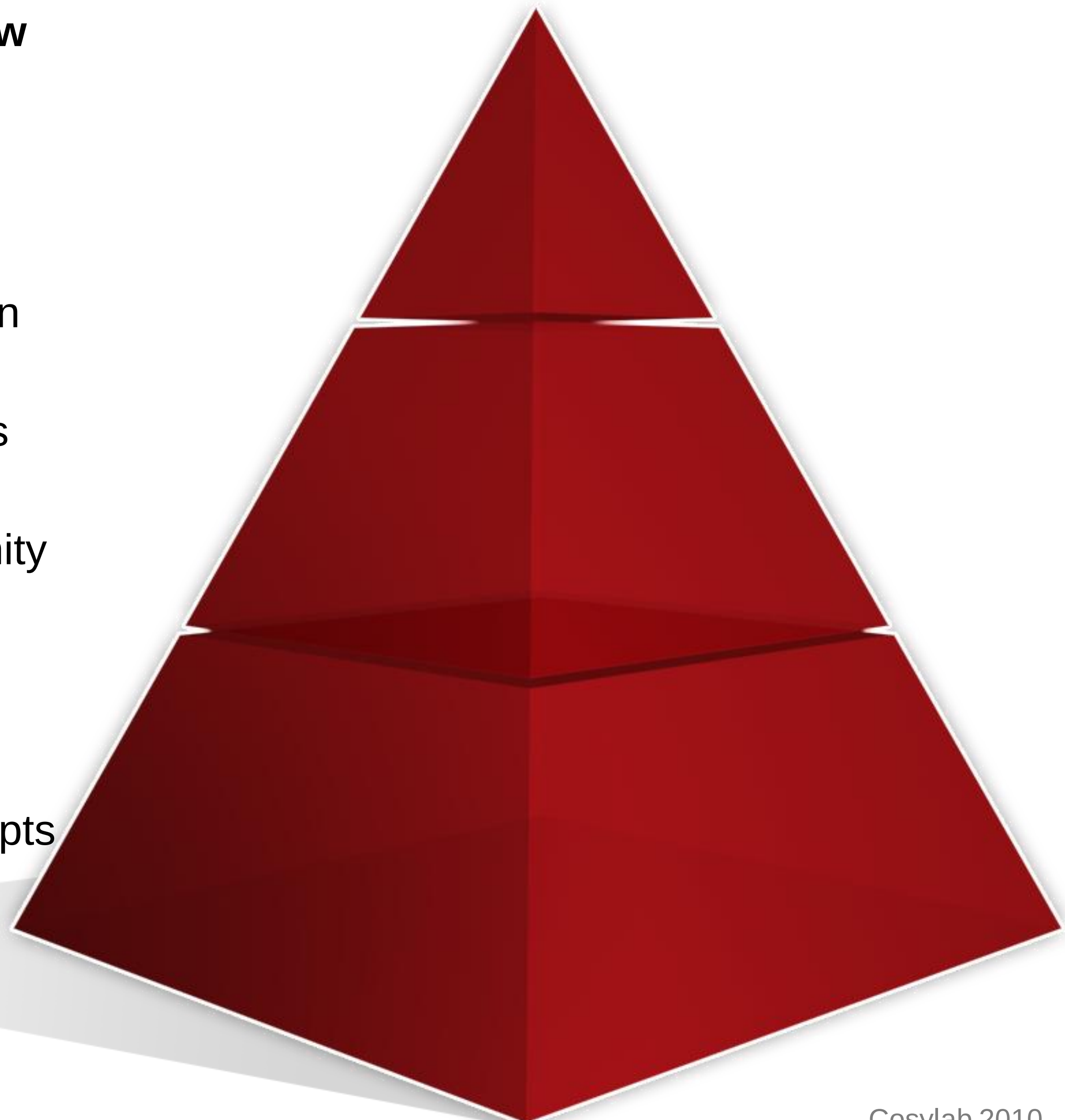
Standardization and Integration

- Control systems are built from off-the-shelf components, which are getting increasing more complex

- Complex systems require more integration time
  - Study requirements and technologies
  - Understand interfaces
  - Making choices early in the project
  - Test plans
  - Prototypes
  - Plan B

Integration makes the system work

- **Integration know-how**
  - Understand accelerator / integration
  - Best practices
- Hw/Sw implementation
  - FPGAs for geeks
  - Coding buzzwords
  - network
  - COTS or community support
- Specific domain knowledge
  - understand concepts



In every project there are also unsolved issues

- Complex new machines have new use cases
  - Hard Real-time feedback
  - Machine Protection System
  - Timing System
- Examples will show efforts towards standardization of new development

Hard Real-Time Feedback Systems

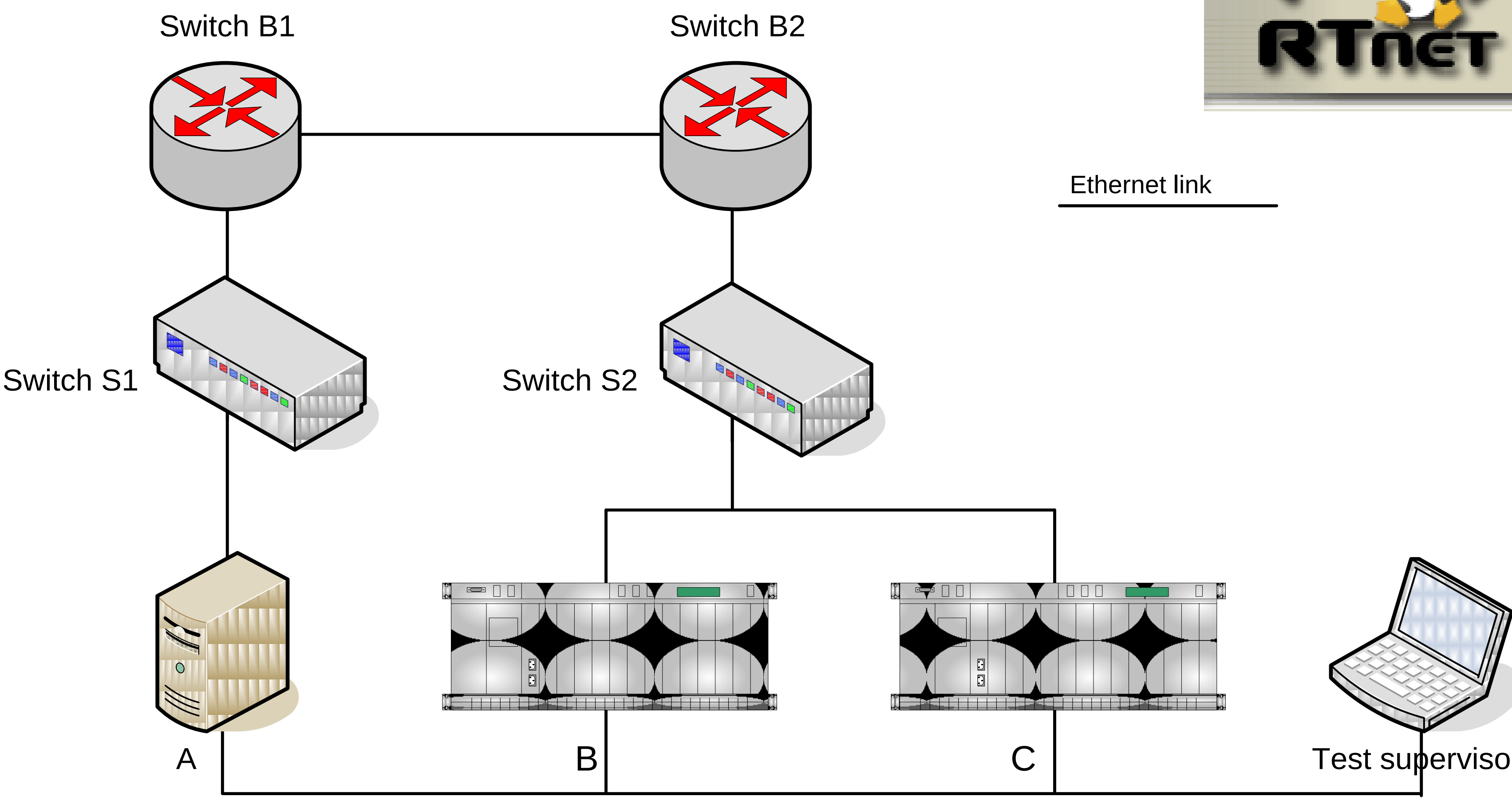
- Existing feedback solutions
  - Proprietary Reflective Memory
  - Custom Fast Orbit Feedback solutions

- Synchronous Databus Network (SDN) Evaluation for ITER
  - Requirements (1 kHz cycle, 40 kB data, 10 usec jitter)
  - Market research
  - Demonstrator
  - Recommendation

  - We decided to look at Gigabit Ethernet.

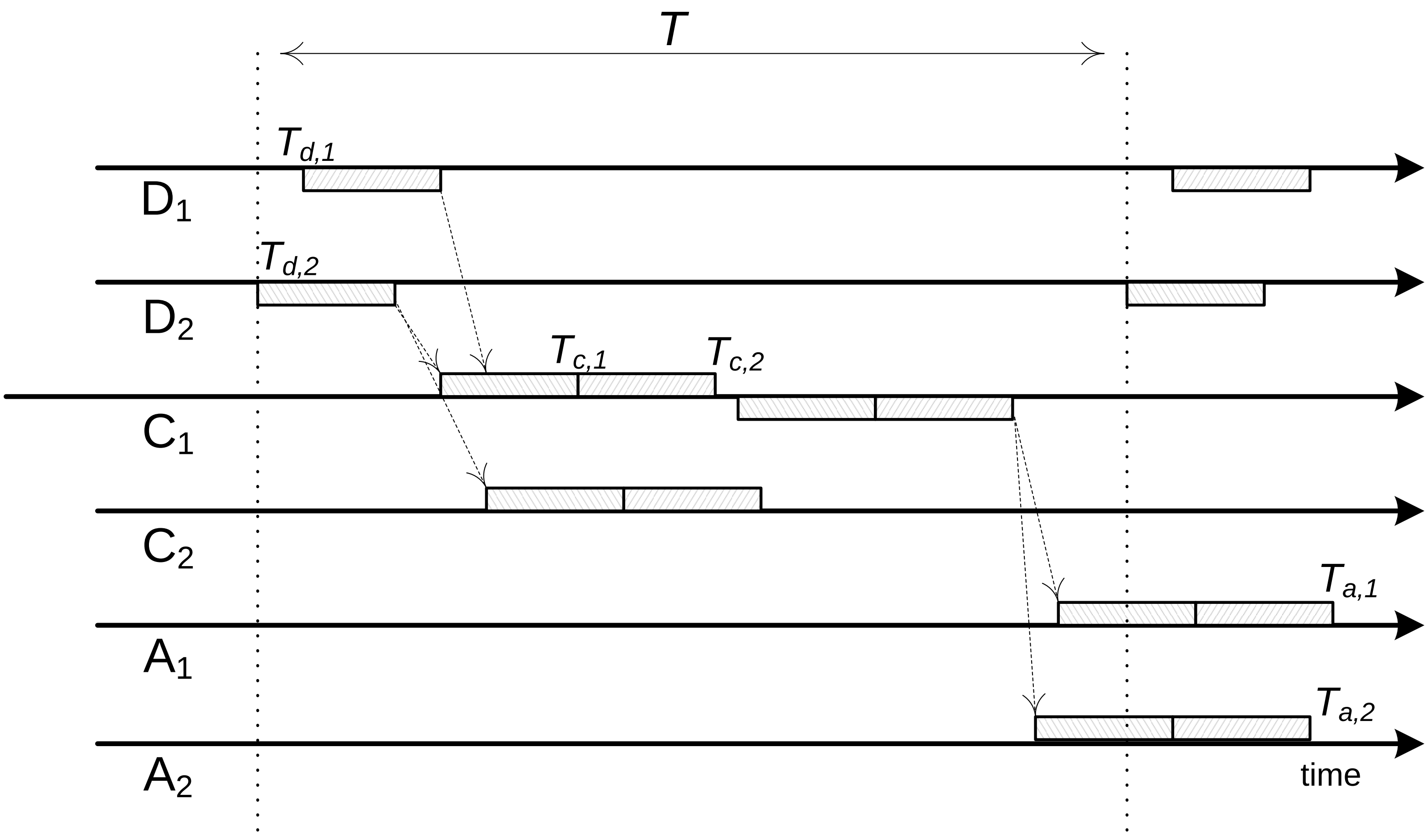
ITER SDN – Gigabit Ethernet Evaluation

- Test stand



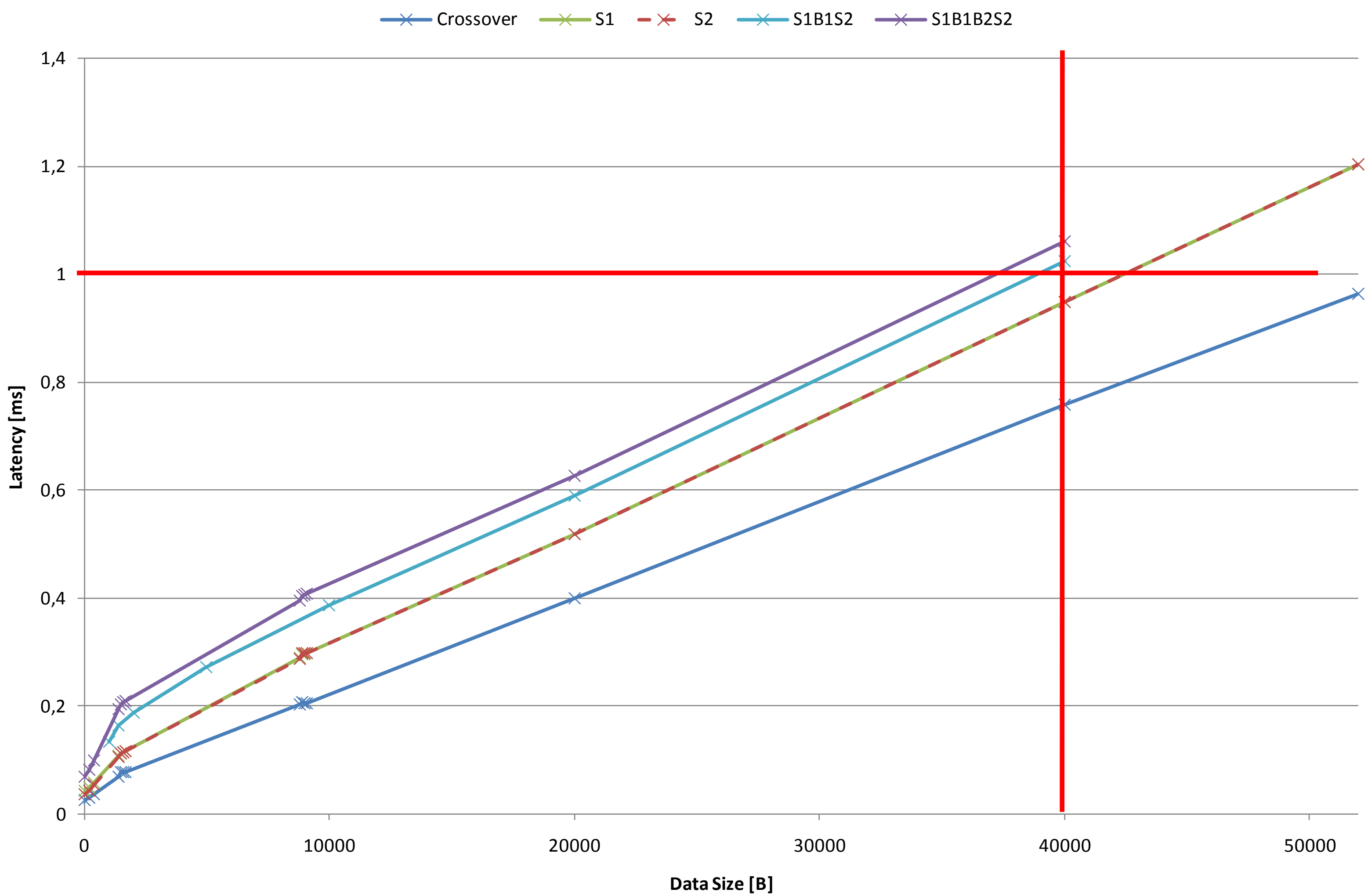
ITER SDN – Gigabit Ethernet Evaluation

- Test scenario

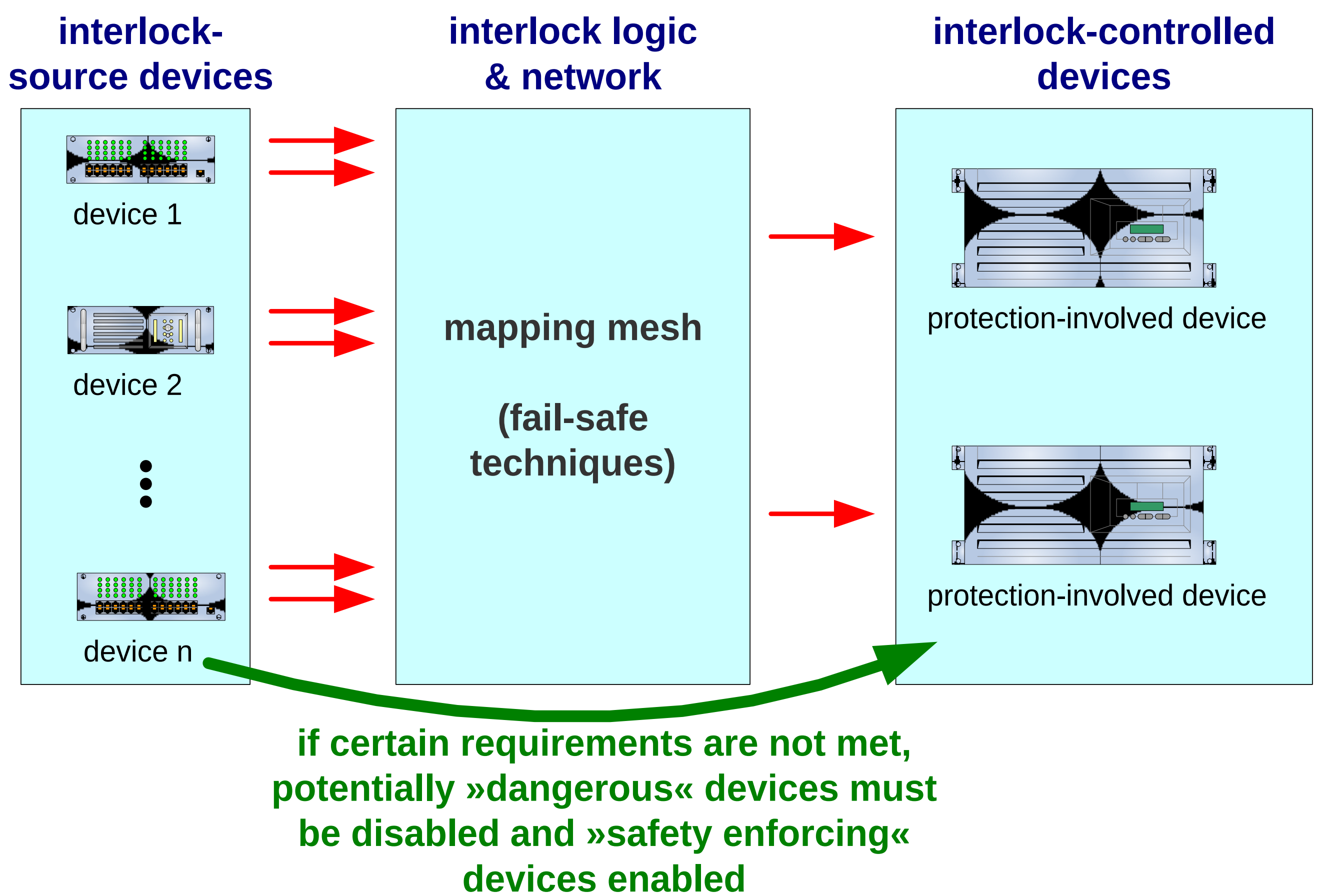


SDN – Gigabit Ethernet Evaluation

- Result: Cycles of 2 kHz and more are achieved with data sizes common in accelerators
- Not good for ITER requirements today, but will be soon



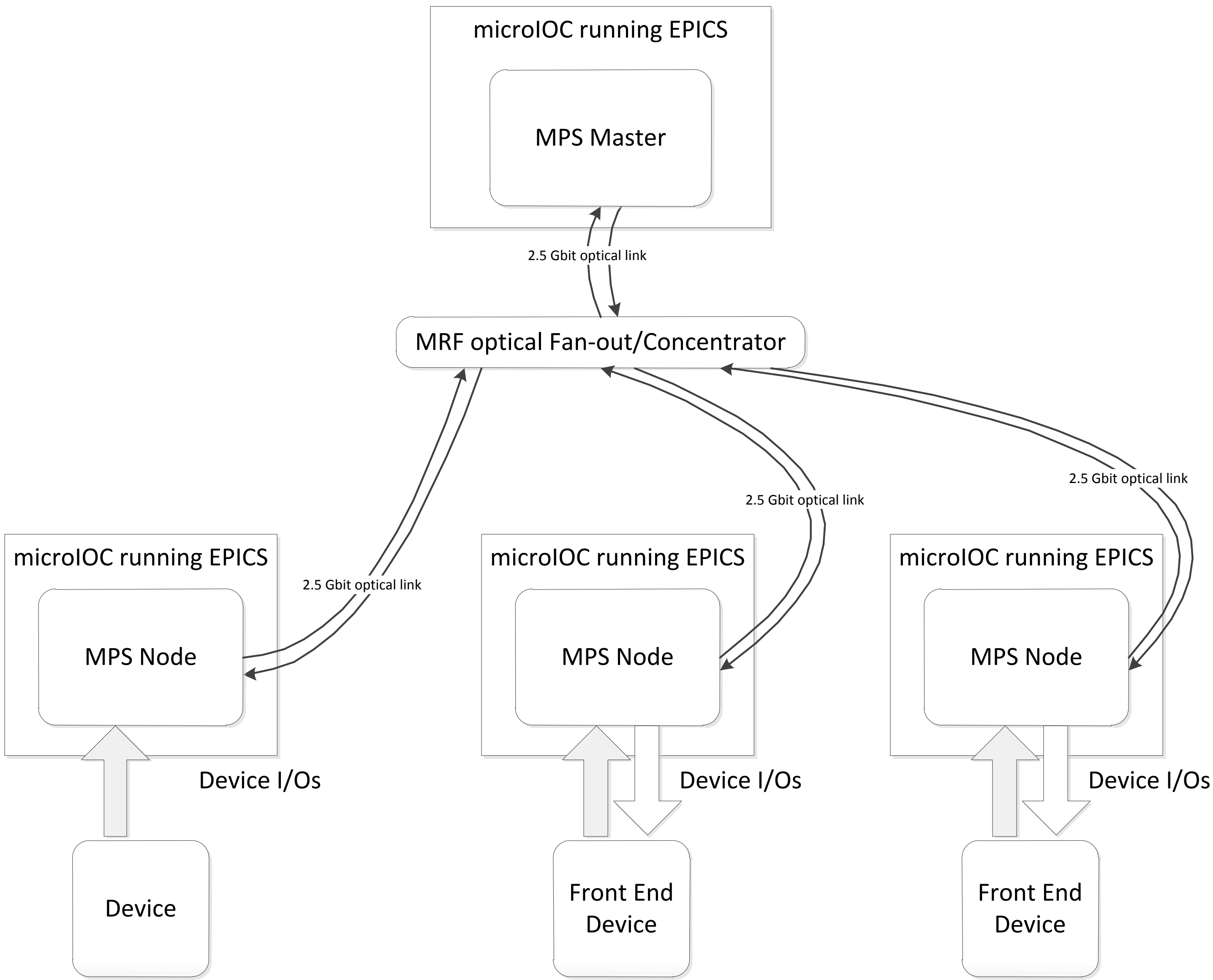
Machine Protection and Interlocks Concept



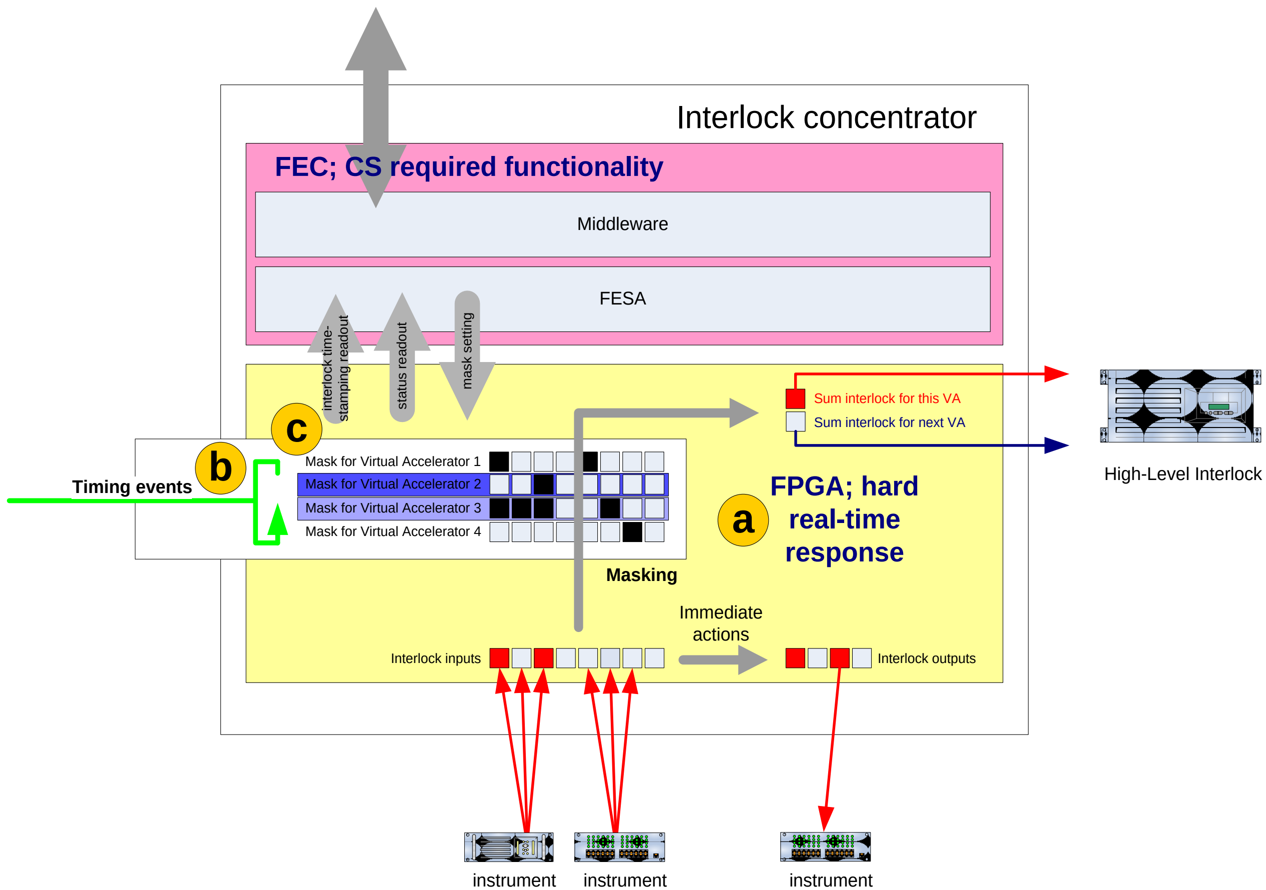
User Requirements from FAIR, SNS, FRIB, ESS

- Monitor device operation and provide **fast** feedback in case of faults
  - Inputs for fault signals
  - Outputs for driving Front End Devices
  - **Reconfigurable I/O matrix (support different common use-cases)**
- Flexibly adapt to machine mode of operation
  - **Bypass certain fault signals or treshold levels**
  - Integration with Control and Timing System ensures real-time adaptation
  - Automatic recovery is able to restore beam
- **Perform operation diagnostics and postmortem analisys**
  - High resolution **logging** of fault signal changes
  - **Timeline** for postmortem dump can be reconstructed
  - Oversee machine and system health
  - Machine health can be monitored by Control System
  - Local displays for troubleshooting and status

Star topology



Machine Protection and Interlocks
Concentrator/Master

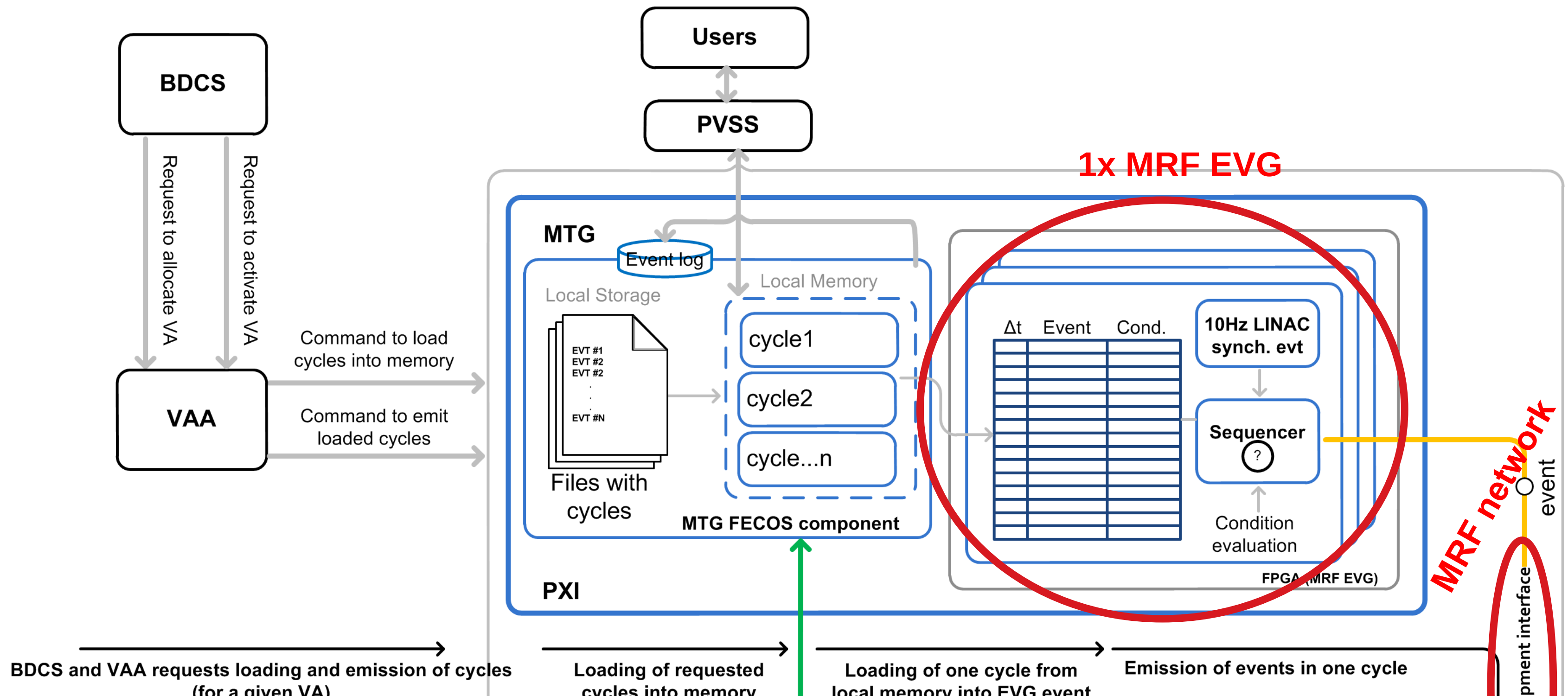


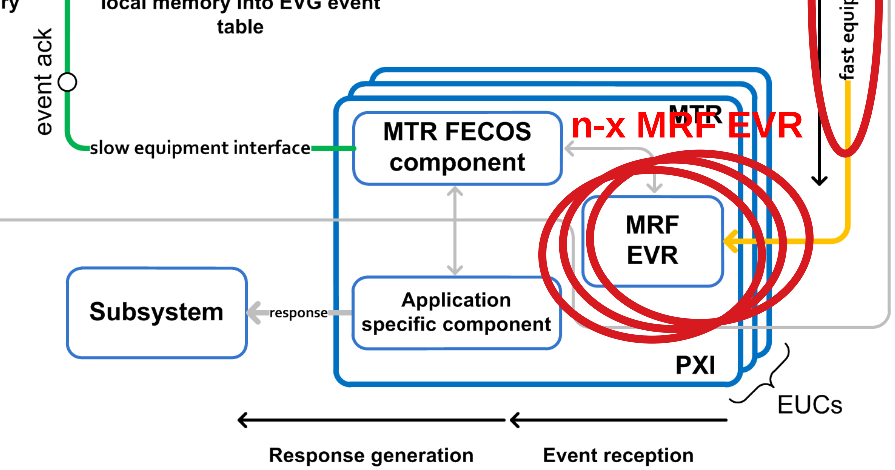
Interlock concentrator schematic overview

Response times

- Calculated response times
- System parameters
  - 60 nodes (MPS Nodes) → 9 1-to-8 Fan-Out/Concentrators in two levels
  - 32 inputs per node
  - 1 km of fiber cable between MPS Master and each MPS Node
- Postmortem log resolution: 8 ns
- Local response: ~ 290 ns
- Global response: ~ 11 µs (10.2 µs of this is fiber delay)

Example: MedAustron timing integration





- REDNET = real-time event and data network
- requirement analysis,
- architecture design
- development, testing…
  - FPGA
  - LV (complete development framework)…

International projects are organizationally more complex

- Dave Gurd: “Building an accelerator at six geographically dispersed sites is quite mad, but politically expedient” (thanks Todd!)
- In-kind contributions
- 100s of developers
- Different culture of developers

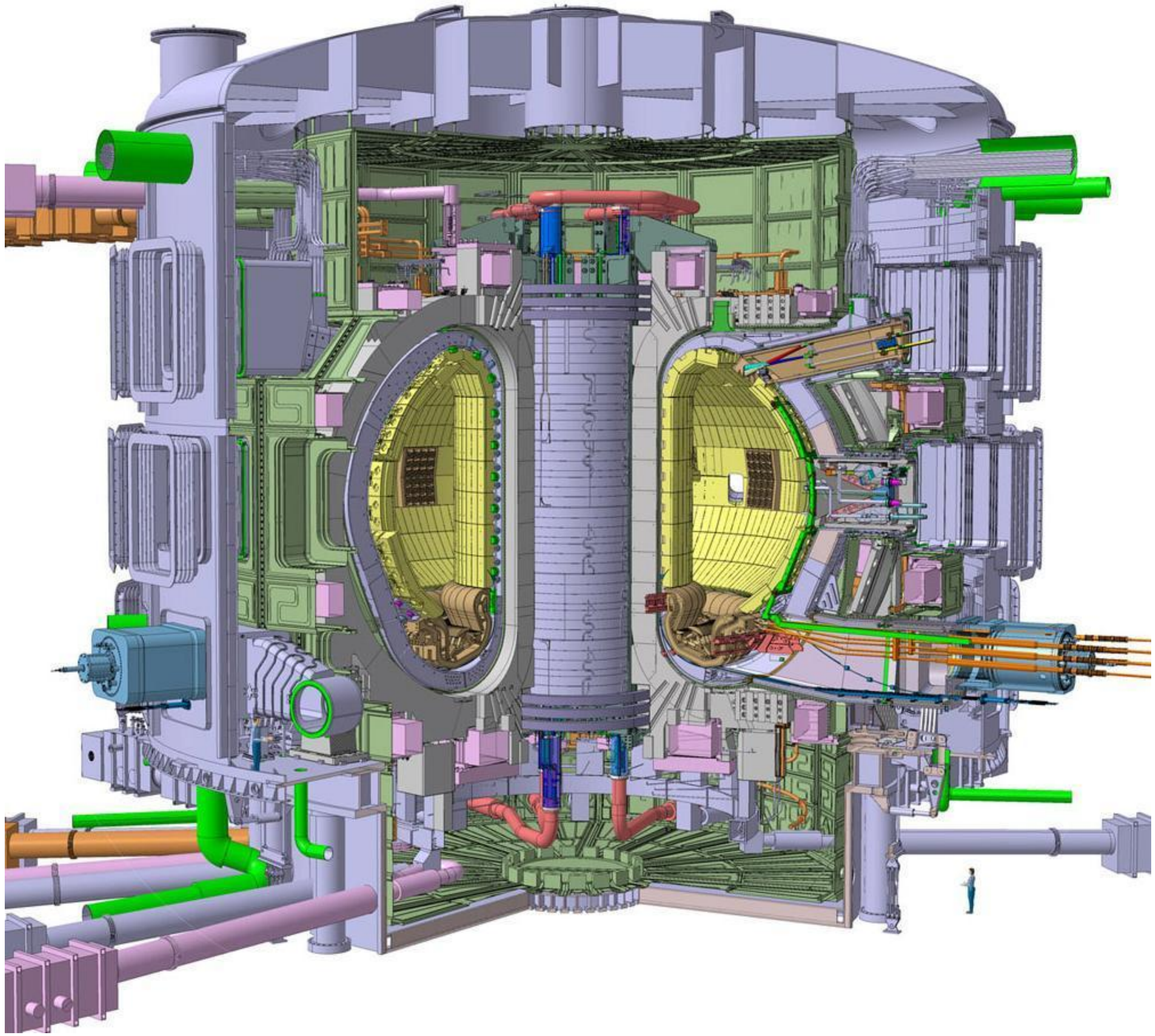
FAIR

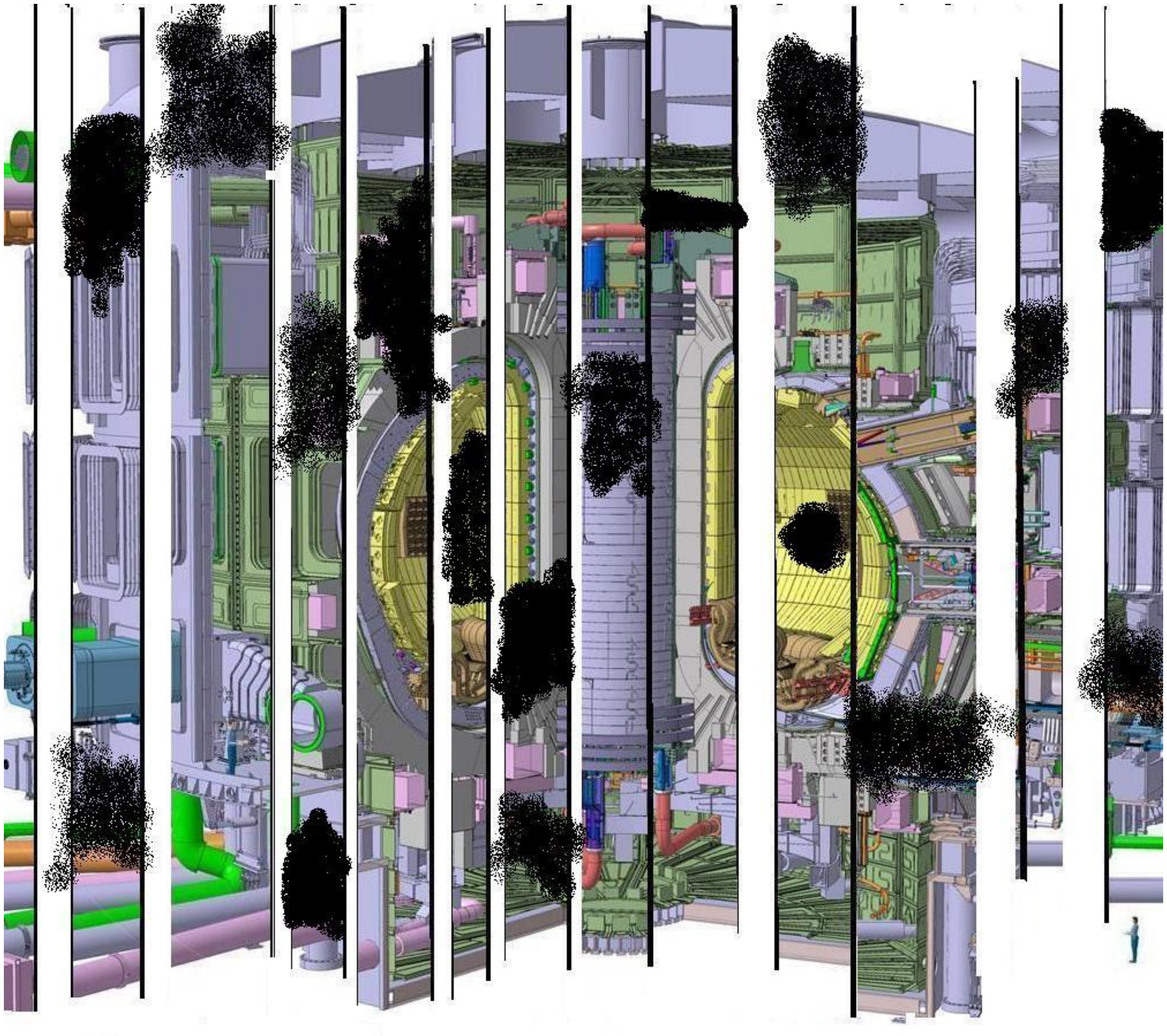
EUROPEAN SPALLATION SOURCE

iter

the way to new energy

china eu india japan korea russia usa

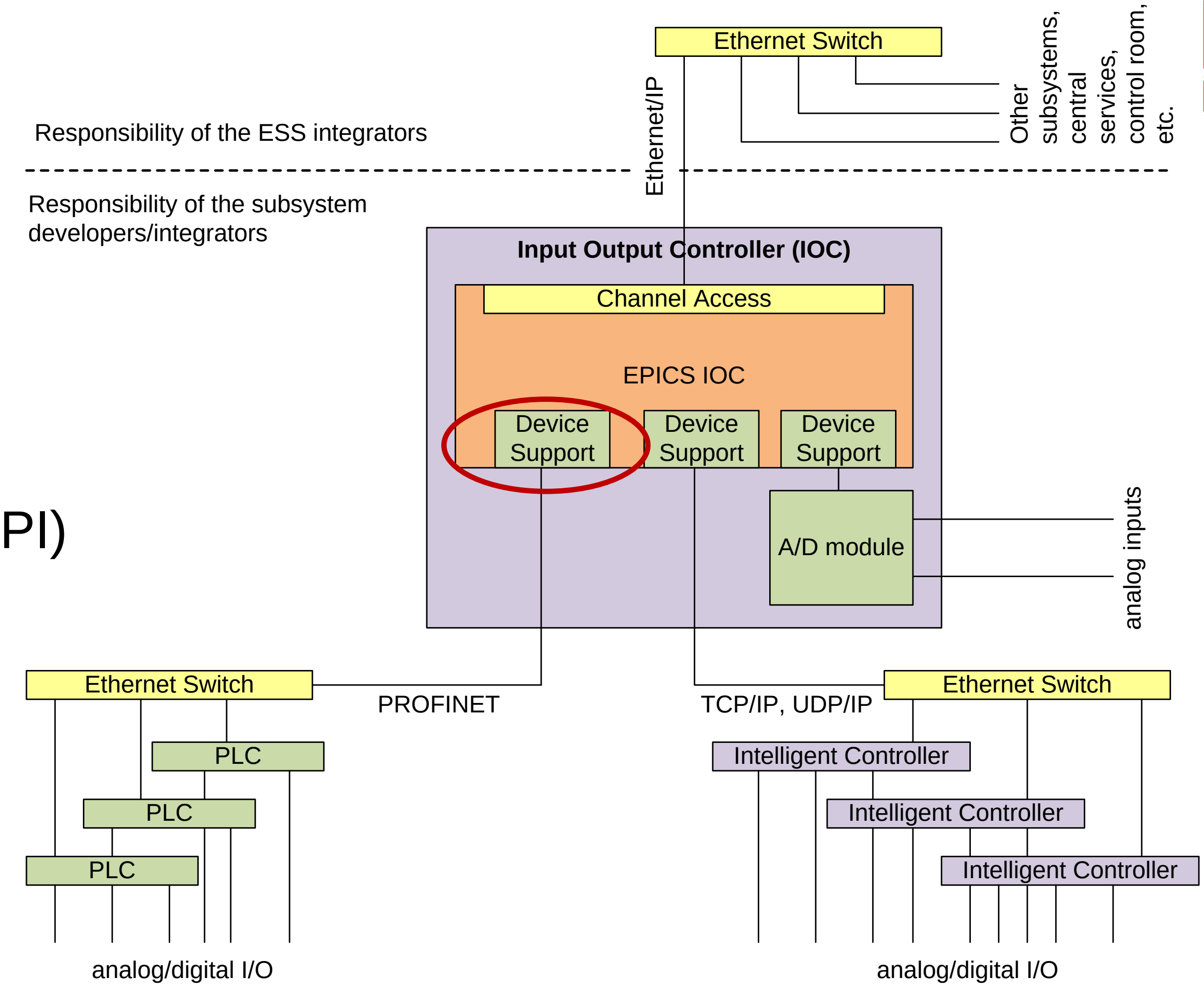




Example: ITER Plant Control Design Handbook & Core System

- Topics covered by the PCDH:
  - Project life-cycle including roles and QA
  - Architecture
  - Naming conventions
  - Software specifications
  - Hardware specifications
- ITER IO provides CODAC Core system, the uniform software package for the development of the plant systems instrumentation & control (I&C) supporting the PCDH standards.

ESS Control Box



- Control Box
  - Hardware
  - Software (IOC, OPI)
  - Procedures

- Benefits
  - Encourage consistency between sub-systems
    - including target and experimental stations,
  - Enable factory acceptance testing of subsystems through control system,
  - Validate technology decisions,
  - Minimize throw-away hardware and software development

Role of Control System

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- **Relatively low technical risk**

- **Higher organizational risk**
  - Collaboration of partner institutions
  - Control system comes late in the project
  - Integrates with most of other subsystems

- Control Systems are an **engineering** discipline like all the others, but with an even more complicated cycle

  - Write specifications
  - Architecture
  - Design
  - Prototyping – **fun part**
  - Test procedures
  - Implementation (coding)
  - Documentation
  - Testing
  - Debugging
  - Acceptance

- Iterative development (evolution through upgrade phases)
- Advancement of technologies

What is Really Important in a Control System?

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- Don’t worry:
  - modern computer technology allows any reasonable implementation of software and hardware to function properly

- So what is really important?
  - To define the development procedures
  - To make everyone agree on the interfaces (API) from the start
  - To have the naming convention ASAP
  - To get test plan and documentation **before** implementation starts
  - Especially important in very large international collaborations, such as ESS, ITER and FAIR.

Preempt creativity => **Apply the Control Box concept**

The use of the Control Box addresses most of the issues that are important for the CS from a project (and not technical) point of view - it allows the individual teams and also the project leadership to establish standards and processes early on in the project.

Conclusions

- Standardization is the key trend
- Integration is the biggest aspect of controls work today
- Organizational risks are increasing with complex projects, focus on development process
- In short, control system development is becoming more and more an engineering discipline and less like a science.

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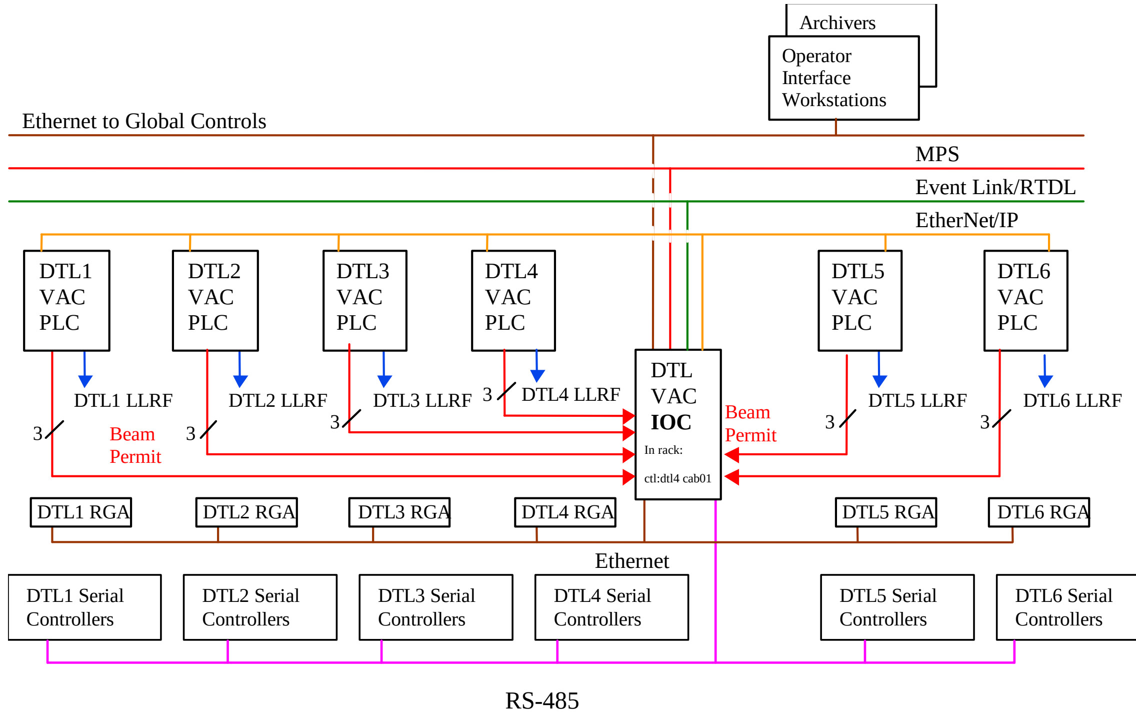
1980s



Today

Thank you!

BACKUP SLIDES

Example Of Interlock Rule For High Power Linac

- Figure: Examples of how beam losses integrated over the previous second may cause rate limiting: A. Pulses 1 through 4 are below threshold but pulse 5 exceeds threshold-3 and sets the beam to a zero rate. B. Pulses 6 through 9 integrate a loss that exceeds threshold-1, lowering the rate to 10 Hz. C. Pulses 12 through 14 integrate a loss that exceeds threshold-2, lowering the rate to 1 Hz.