Distributed Control System Development by Distributed Developers

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Diamond Light Source

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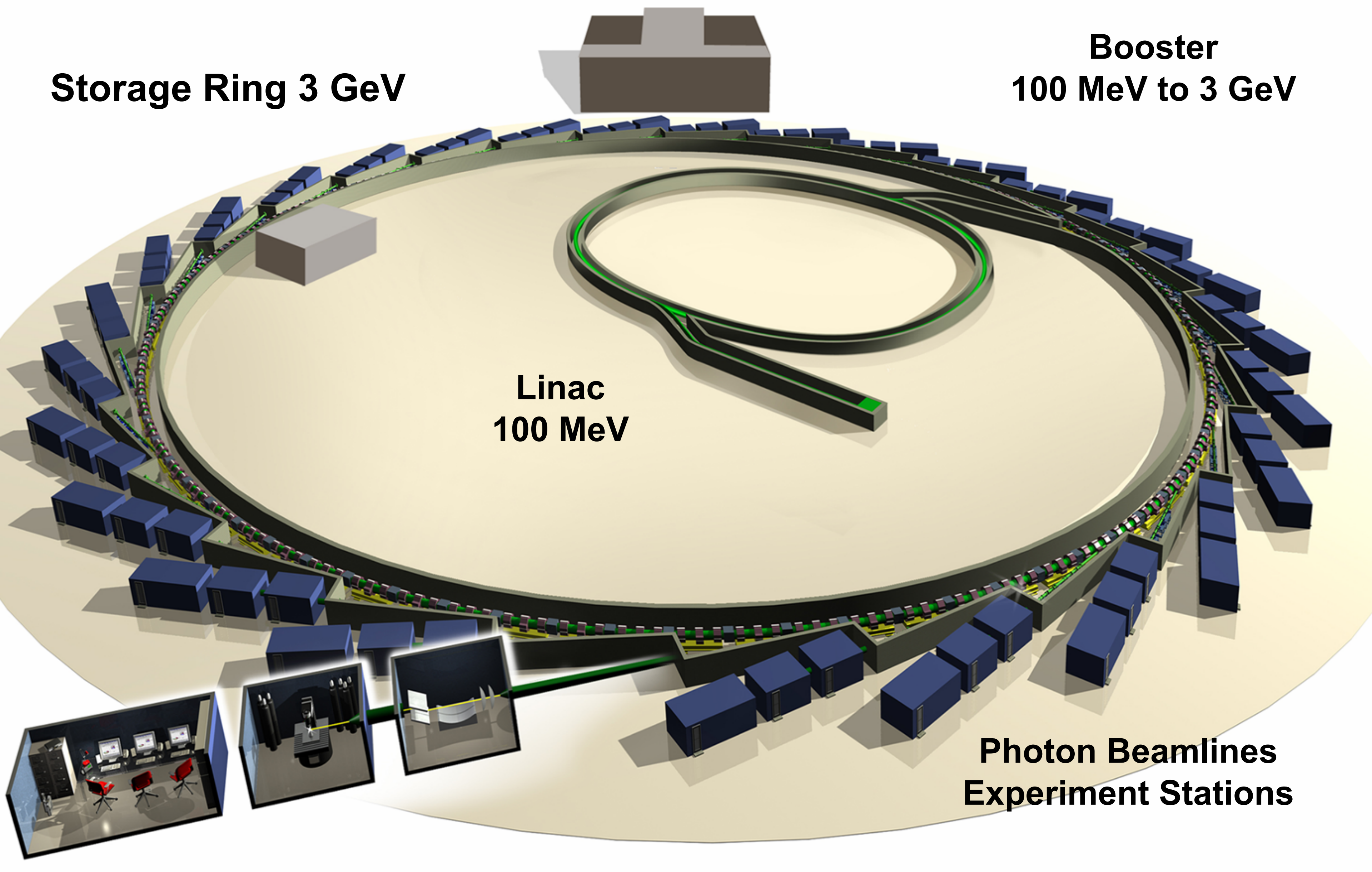
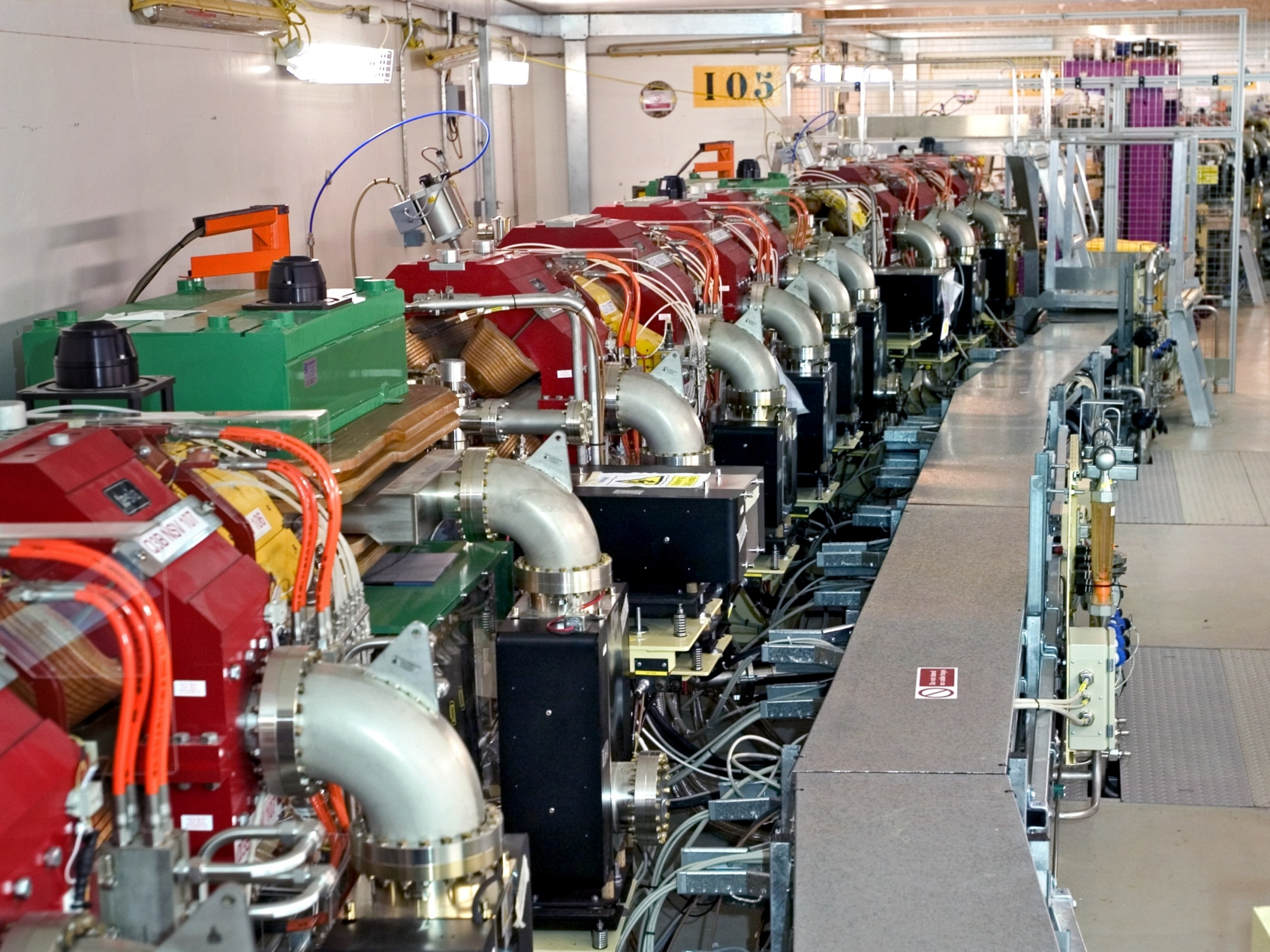
Diamond Light Source

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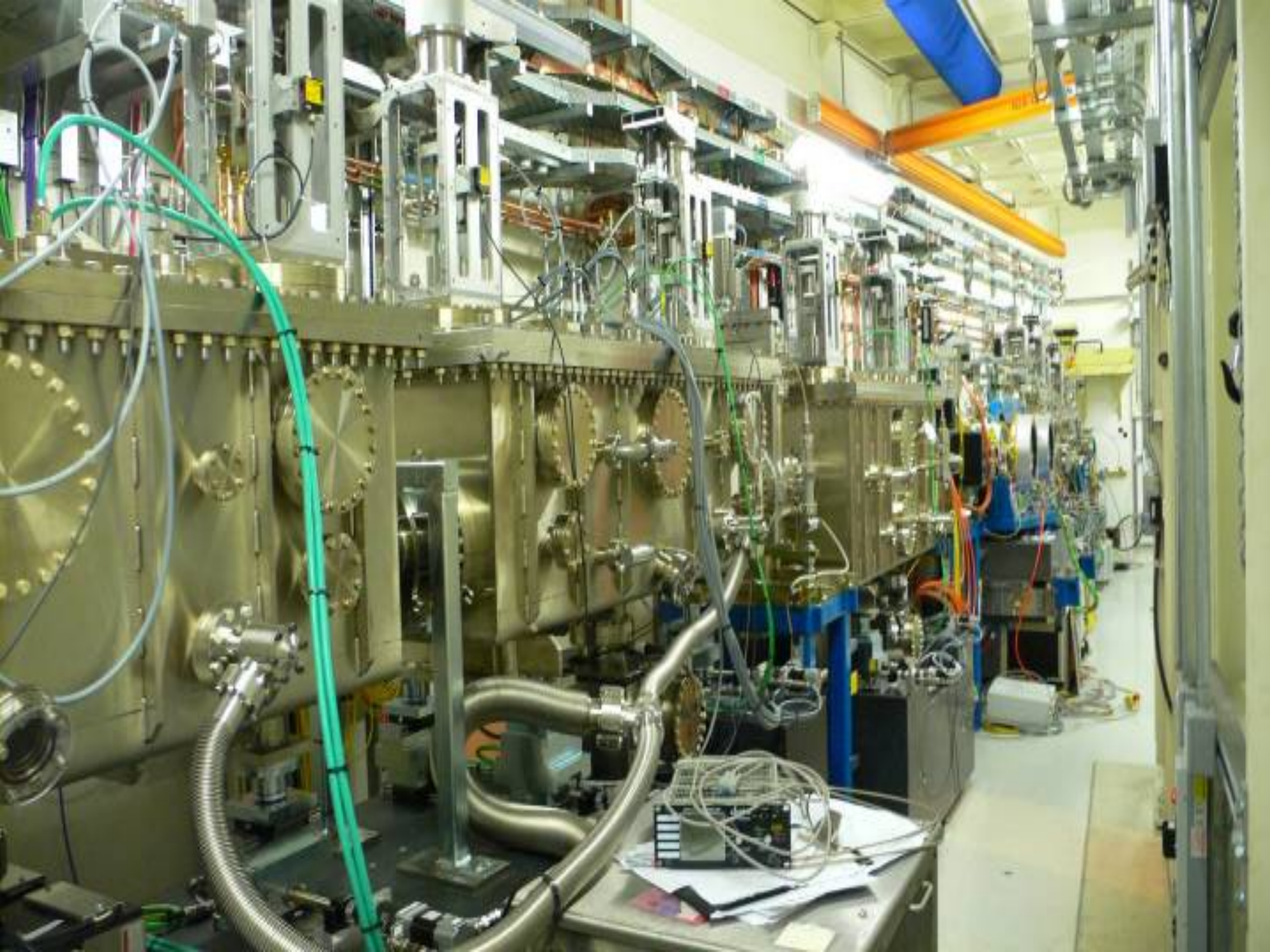
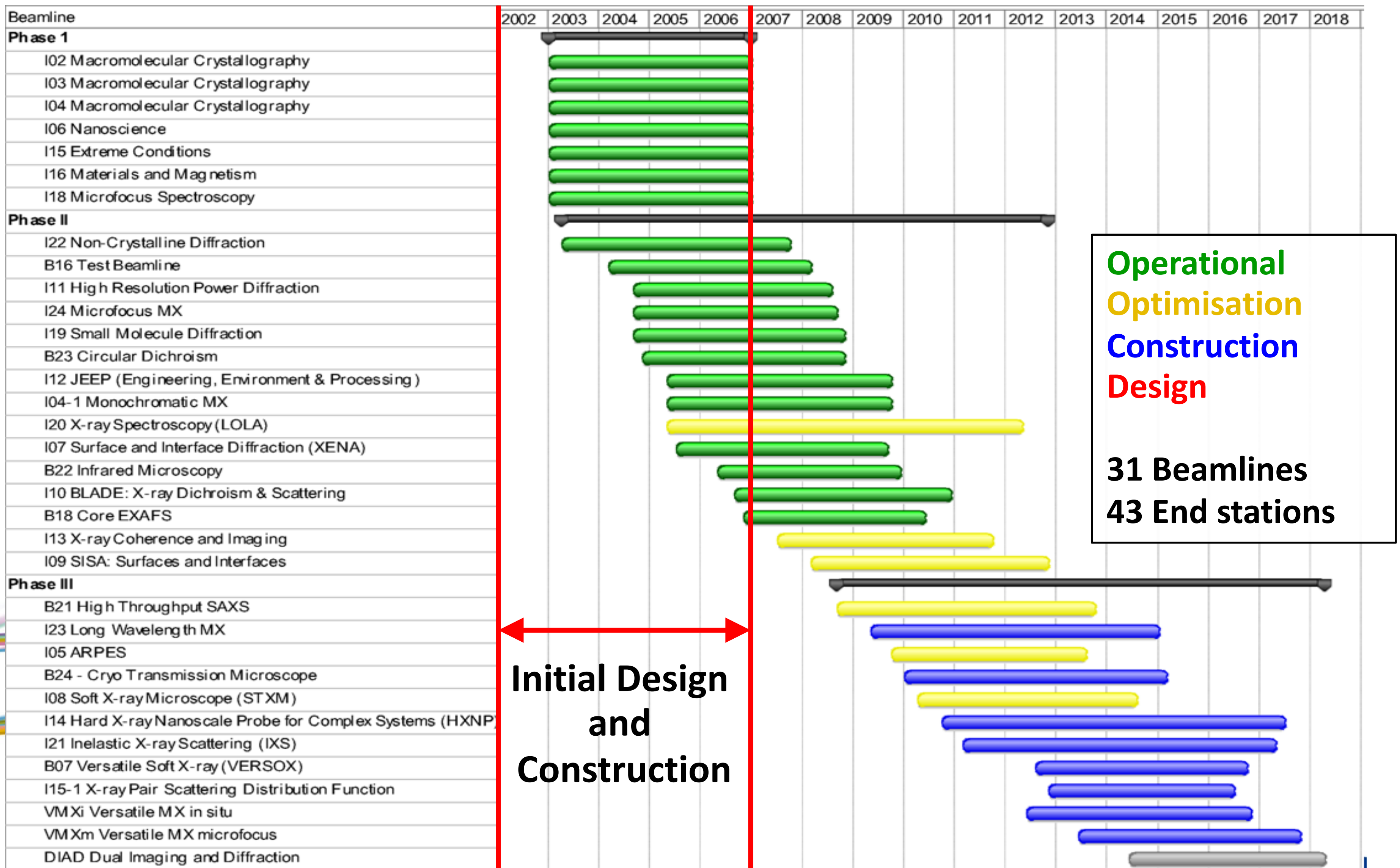


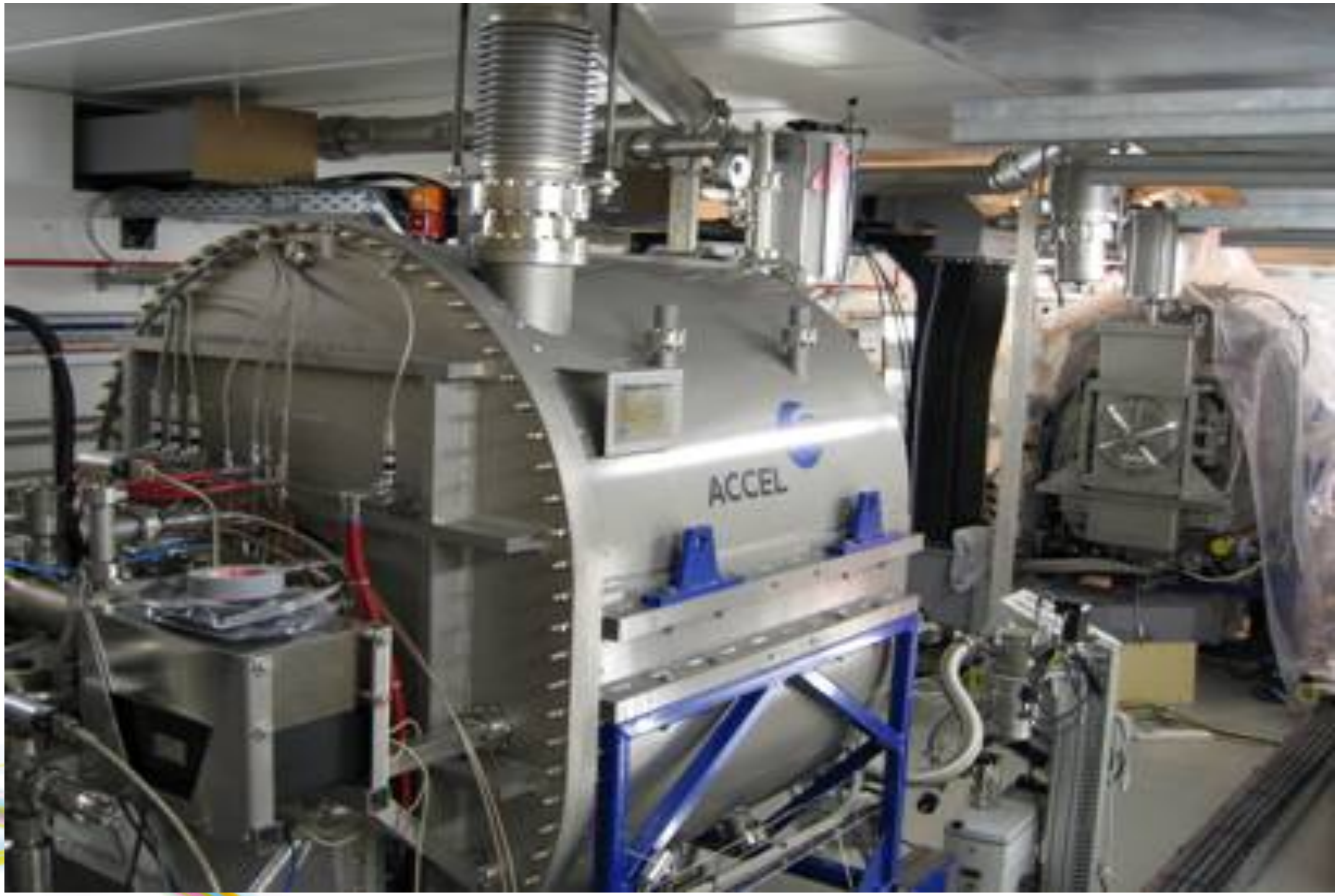
Diamond Construction Schedule



Diamond Light Source Construction

- Diamond Light Source Ltd, was funded to construct the facility in 3 phases.
- No In-kind contribution!!!
- Project plan included a number of turnkey systems, complete with distributed control systems.
  - Electron Linac, Booster RF, Storage Ring Superconducting Cavities, LLRF, RF Amplifier, Girder Alignment, Permanent Magnet Insertion Devices, Superconducting Multi Pole Wiggler, Beamline Optics, Beamline Monochromators, Beamline Diffractometers.
- Driven by limited resource and limited time.

Superconducting RF Cavity



Superconducting RF cavity complete with PLC, and EPICS IOCs as a turnkey solution.

Overall Project Objective

- To bring many pieces, from different suppliers, together and integrate according to an overall design.
- Complete integration, with controls, provides for the most time effect solution.
- Not at the expense of future maintenance or operational costs.
  - Not to have to re-engineer.

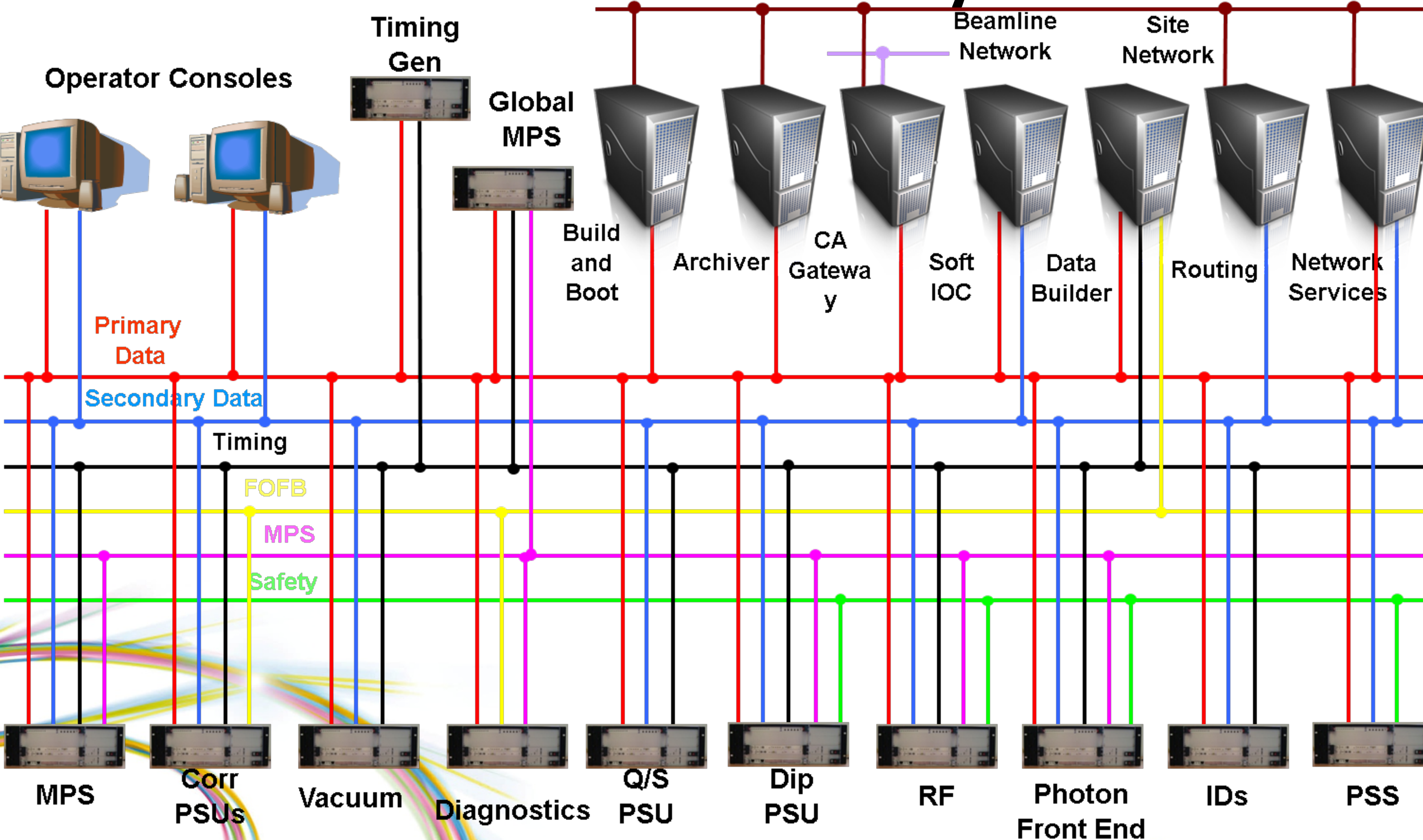
Turnkey and In-Kind Contribution

Issues	Turn Key Contracts	In Kind Contribution
Subsystem comes with its own local control system	√	√
Subsystems control system will be interfaced to the global control system	√	√
Physical interfaces to other systems	√	√
Functional interfaces to other systems	√	√
After commissioning, host organisation will responsibility for hardware and software	√	√
Financial incentives on supplier to adhere to project standards	√	

Some Misconceptions

- All I need to say is ….
- "My control system is/uses …."
  - EPICS or TANGO or SCADA
  - CORBA or ZMQ or HTTP or ….
  - Sockets or TCP or UDP
- "My control system uses …."
  - XXXXXX brand of PLC
  - Industrial Standards
  - RS232
  - Serial signals
  - Digital and Analog IO

Distributed Control System



Diamond Control Systems

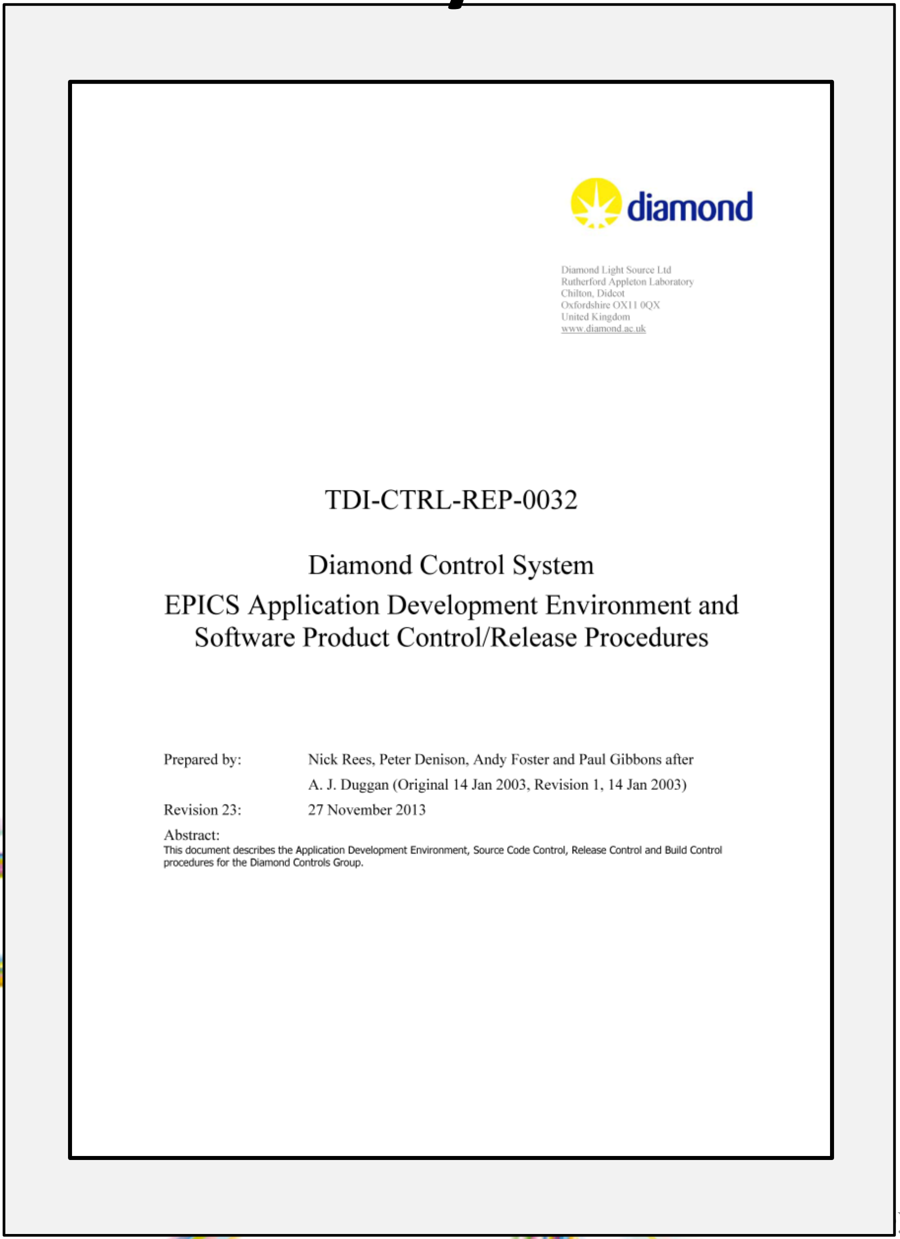
Planning for Turnkey Contracts at Diamond

- Set out to identified ***potential*** suppliers for technical subsystems.
  - Research Instruments, Thales Broadcast, CryoElectra, Micromech Systems, Budker Institute of Nuclear Physics, Oxford Danfysik, FMB, CosyLab, Observatory Sciences, and IDT.
- Prior to call for tender invited ***potential*** suppliers for discussions on what would be included in the call for tenders.
- To make them aware that we would specify control systems requirements as part of tenders.
- Prior to placing calls for tender we offered training in controls standards and tools.
- Making ***potential*** suppliers aware and helping them.

Control Systems Requirements in Call for Tender

- Call for tenders included controls requirements as an Annex.
- Defined requirements for hardware and software.
  - Referenced Control System development standards.
- Defined what would be provide by DLS in support of the contract.

Control System Standards and Processes



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TDI-CTRL-REP-0032

Diamond Control System
EPICS Application Development Environment and
Software Product Control/Release Procedures

Prepared by: Nick Rees, Peter Denison, Andy Foster and Paul Gibbons after A. J. Duggan (Original 14 Jan 2003, Revision 1, 14 Jan 2003)

Revision 23: 27 November 2013

Abstract:
This document describes the Application Development Environment, Source Code Control, Release Control and Build Control procedures for the Diamond Controls Group.

- Series of control systems development standards.
  - Application Development Environment, defines how controls EPICS software is developed.
  - Naming of PVs.
  - Naming of IO Modules.
  - GUI Standards.
  - Electrical
- Used by in-house developers.

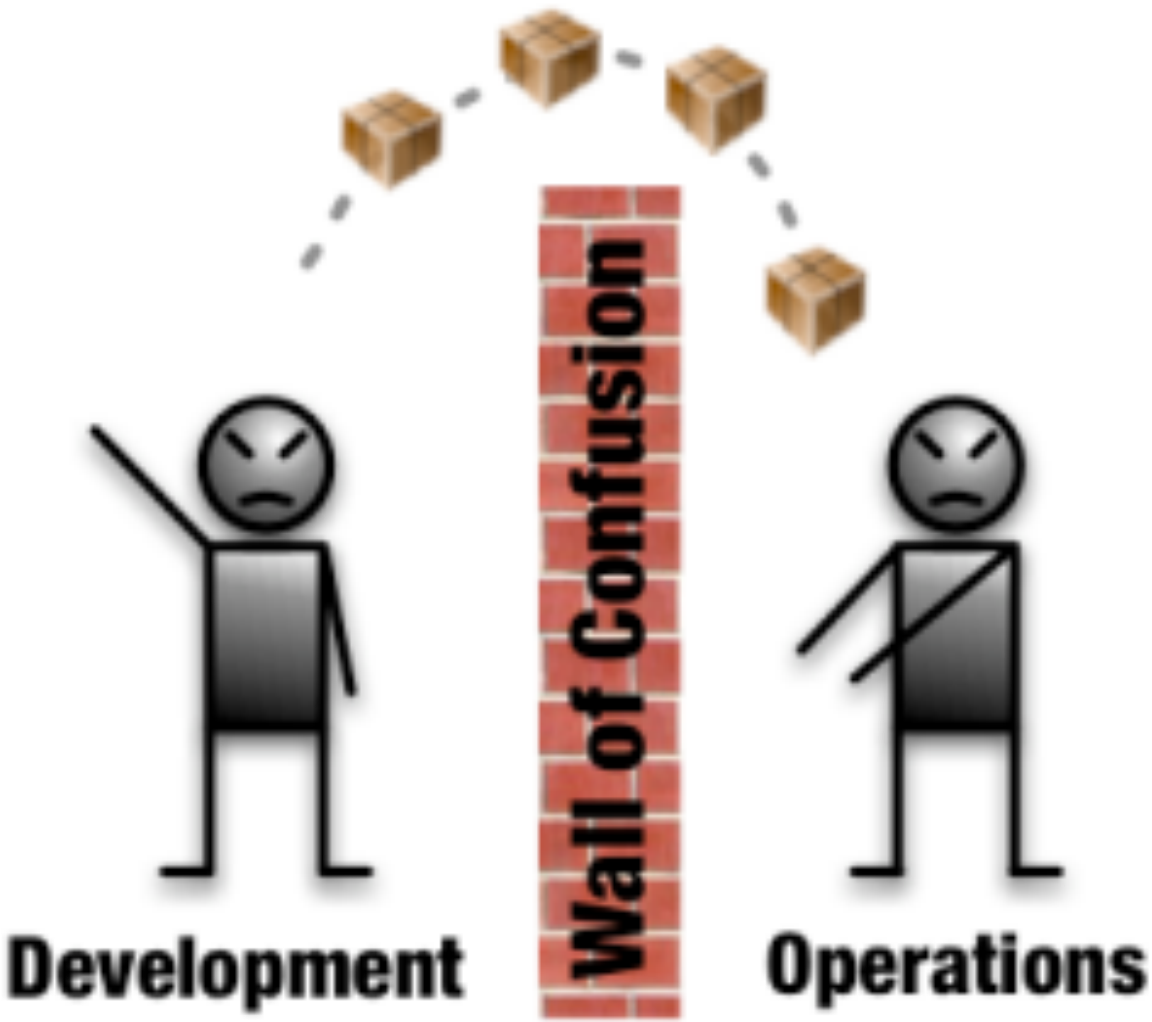
ITER Standards

Folder 1:

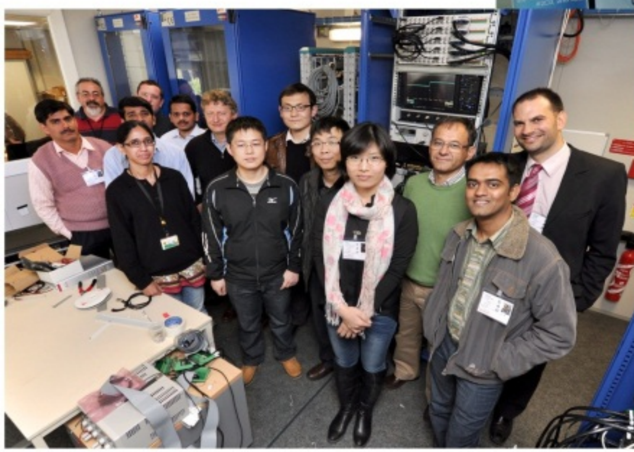
1. **Plant Control Design Handbook (PCDH)** **v7.0 (2013) - The core document which collects all requirements**
2. **Plant System I&C Architecture** v2.5 *- updated Nov 2014*
3. **CODAC Core System Overview** v5.3 *- updated Jun 2016*
4. **The CODAC - Plant System Interface** v2.1 (2013)
5. **Signal and plant system I&C Variable Naming Convention** v8.1 (2013)
6. **Self-description Data Documentation and Guidelines** v2.1 (2011)
7. **Methodology for Plant System I&C specifications** v6.2 (2013)
8. **Plant system I&C Integration plan** v4.6 (2013)
9. **SEQA-45 - Software Engineering and Quality Assurance for CODAC** v3.2 *- updated Dec 2013*
10. **PLC Software Engineering Handbook** v1.4 (2013)
11. **Philosophy of ITER Alarm System Management** v2.1 (2013)
12. **HMI Style Guide and Toolkit** v3.7 *- updated Jun 2016*
13. **Outline Guide to ITER PON Archiving** v1.1 (2013)
14. **Guidelines for PSOS SM management by COS SM** v2.5 (2013)
15. **Guidelines for diagnostic data structure and plant system status information** v2.1 (2013)
16. **Management of Local Interlock Functions** v5.0 *- updated Apr 2015*
17. **Plant Control Design Handbook for Nuclear control systems (PCDH-N)** v4.1 *- updated Sep 2016*
18. **CWS case study specifications** v3.4 (2013)
19. **ITER CODAC Abbreviations and Acronyms** v3.0 (2013)
20. **ITER CODAC Glossary** v1.2 (2011)

- Plant Control Design Handbook and supporting documents defines methodology, standards, specifications and interfaces applicable to all ITER plant systems with instrumentation and controls.
- Applicable to all procurement with instrumentation and controls.
- All major project reviews are required to show compliance.

Documents Are Not Enough

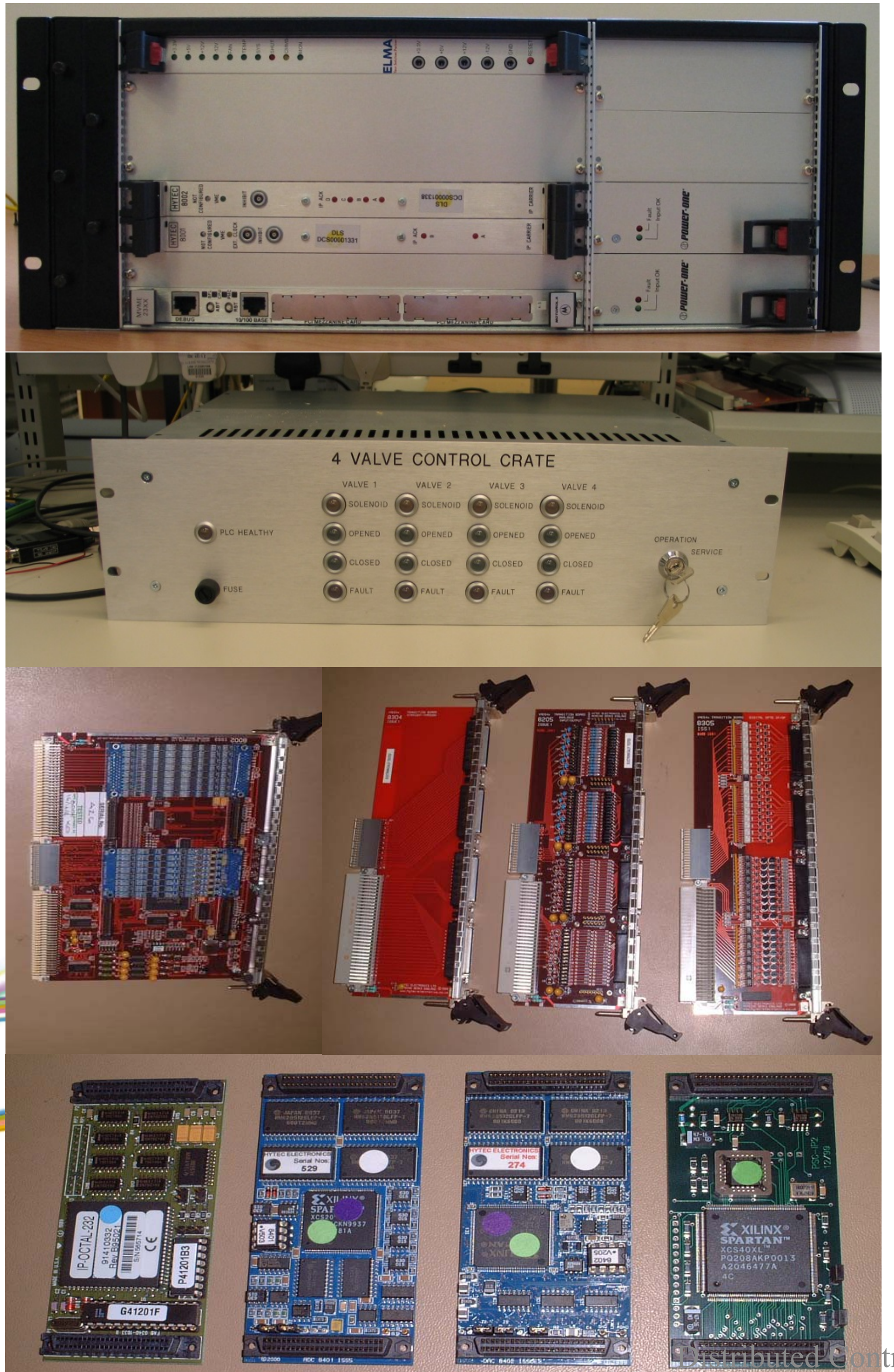


Support and Monitor Progress



Courtesy ITER

- Standards, and specifications are not enough.
- Training, Advice, Technical support, Bug tracking, Software Updates, Change control – ongoing.
- Understand and measure progress.



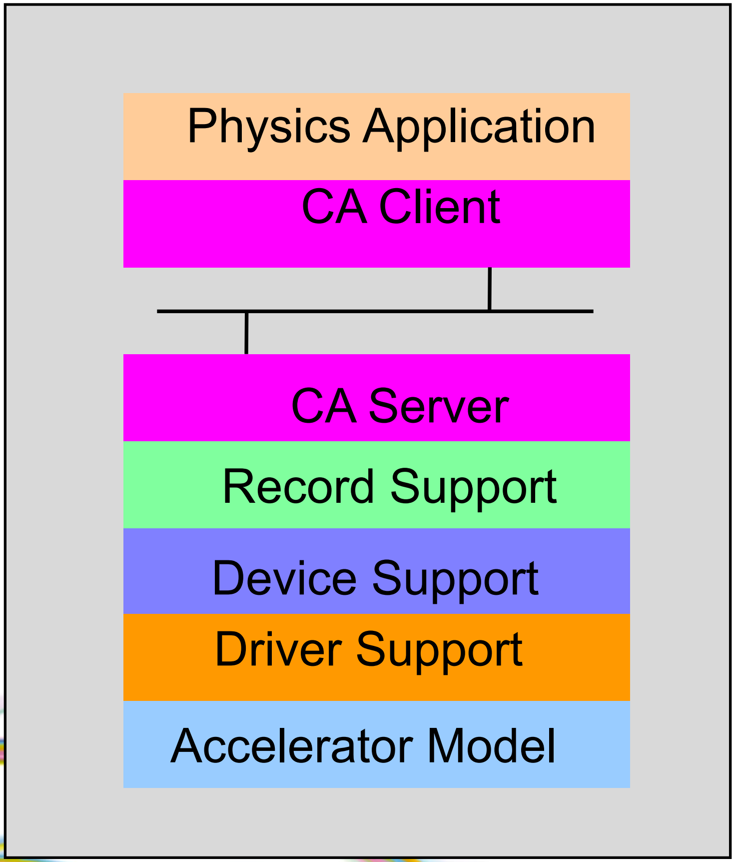
Hardware

- From a cost and time point of view, it is advantageous for a supplier to use hardware they are familiar with and have existing designs.
- Free issued standard hardware.
  - PC, VME Crate, IO modules, PLC, etc.
- PC loaded with Diamond development environment.

Other Physical Interfaces

- Potentially other physical interfaces to overall control systems, beyond supervisor control system network.
  - Secondary monitoring network interface.
  - Machine Protection System.
  - Personnel Safety System.
    - Will be part of the overall Safety System.
  - Low latency / real-time interface.
    - Feedback or archiving.
  - Timing and Synchronisation.
  - Subsystem to subsystem interfaces.
- These need to be defined by project standards.
  - More project specific.
  - So suppliers may be less familiar with them.
- Tools need to be provided to support the subsystem developer in development and testing.

Functional Interface

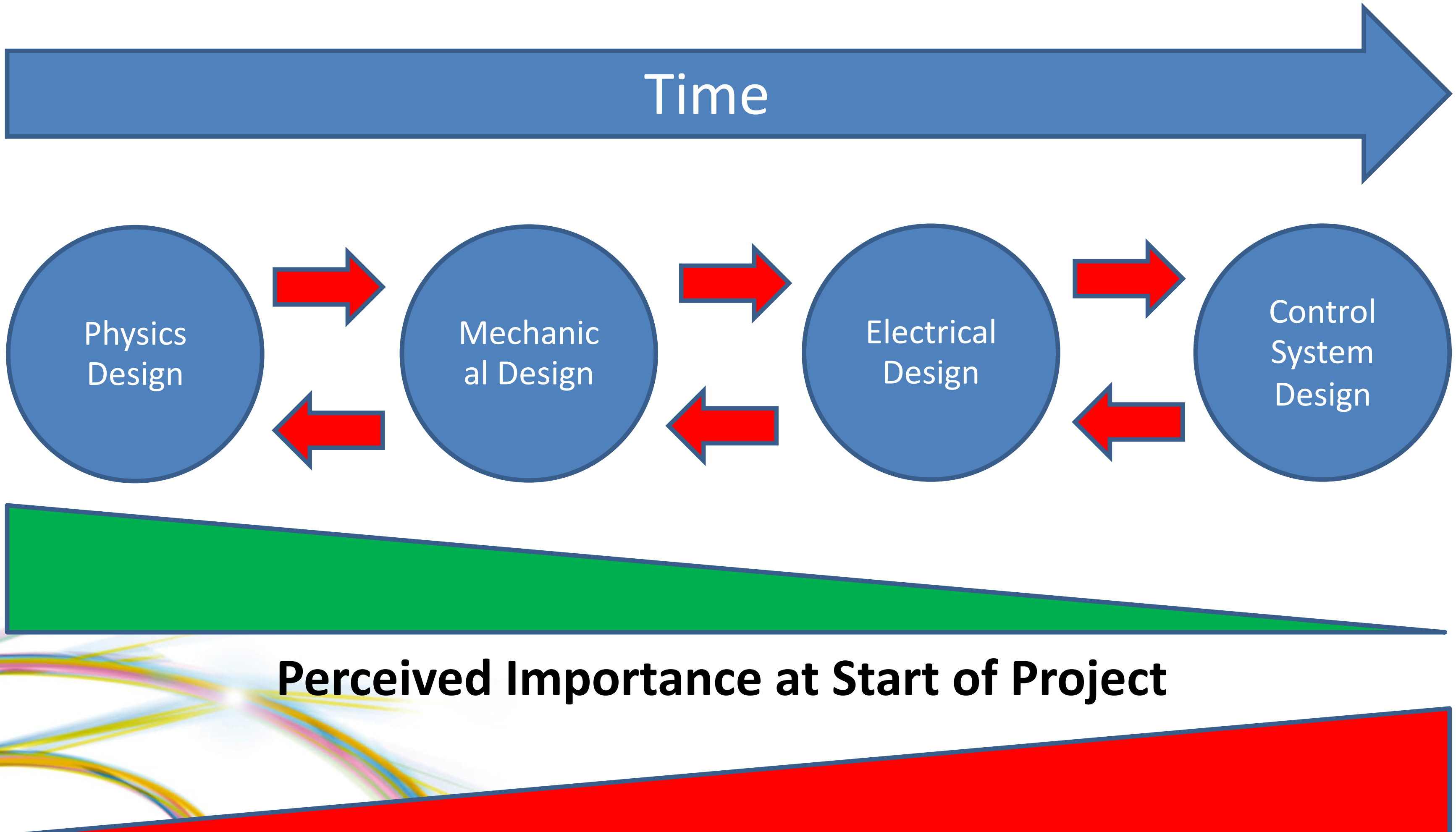


- Subsystem development provides standalone operation of the subsystem.
  - Operator panels, archiving, and alarms.
  - Provides functionality to operate the subsystem.
- Needs to be integrated into overall control system functionality
  - Machine-centric operations ie start plasma.
- Early integration is possible with a functional simulation to develop, test and debug against.

Communication Challenge (1)

- Consider arbitrary subsystem, the development process follows stages:-
  1. Project/Facility
     - Physics Design, Project management.
  2. In-kind Partner
     - Technical design of subsystem, Project management.
  3. Primary Contractor
     - Mechanical, Project management.
  4. Sub-Contractor
     - Electrical controls, Project management.
  5. Sub-Sub-Contractor
     - Controls software, Project management.

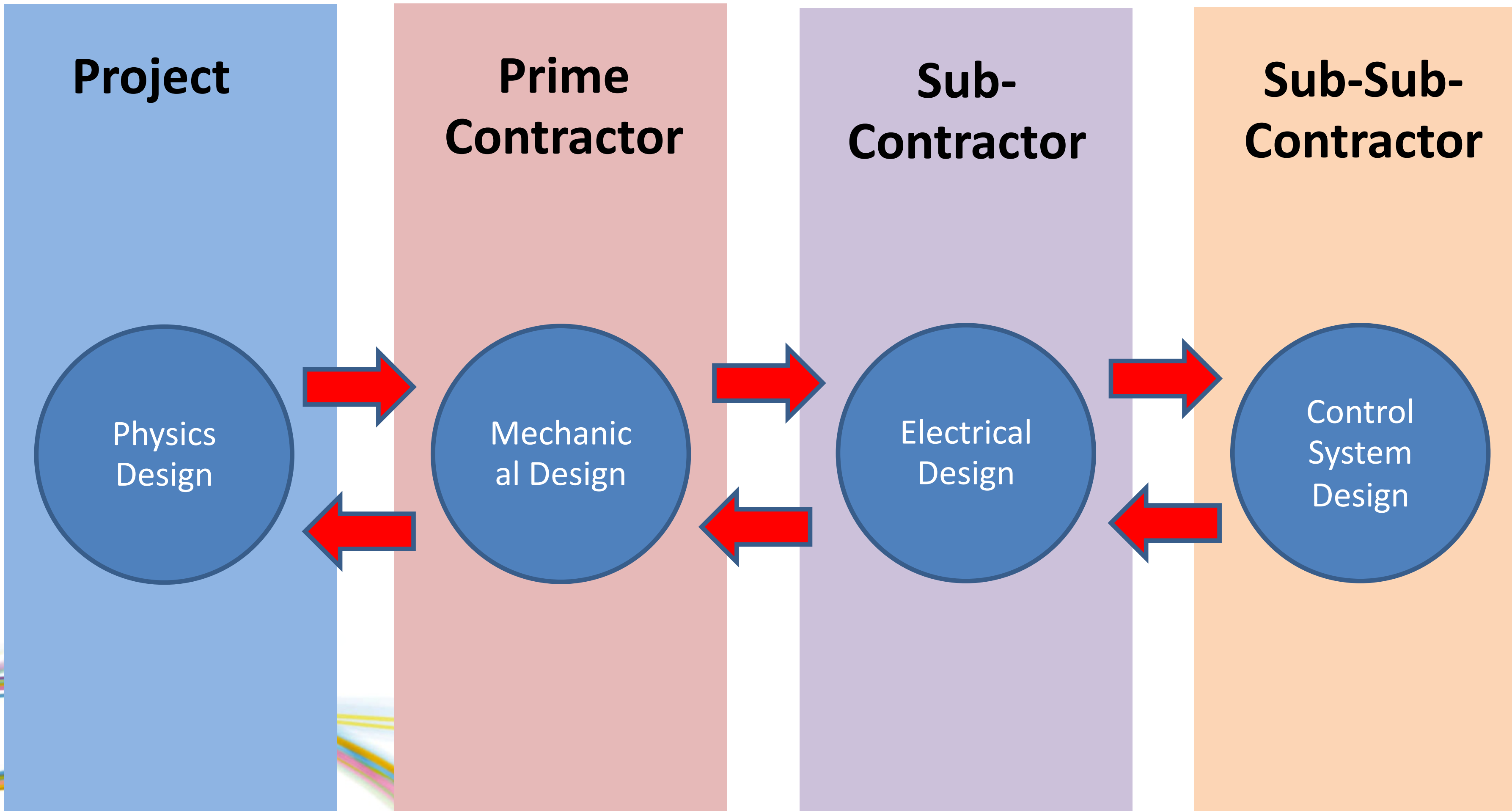
Communication Challenge (2)



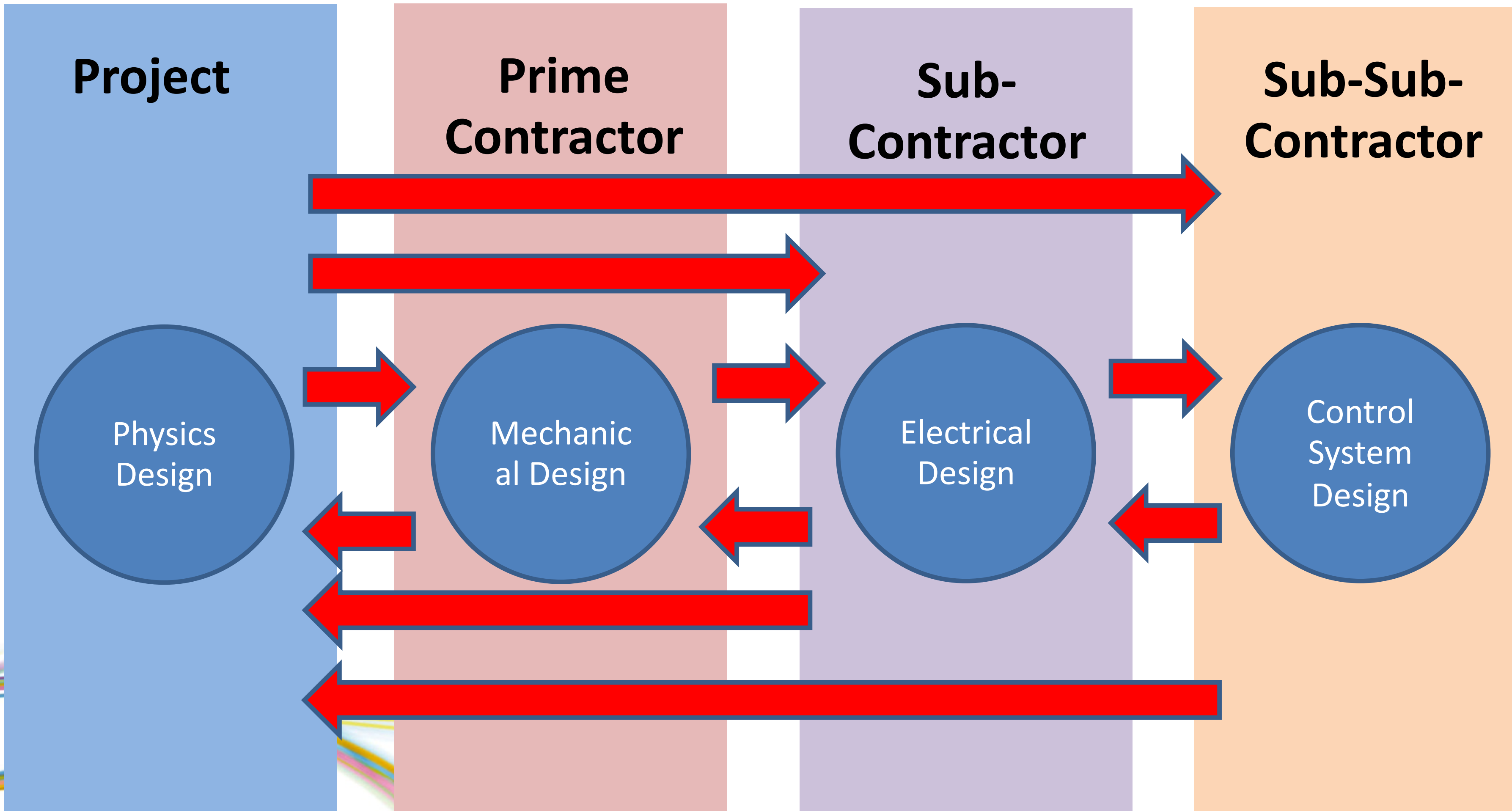
Perceived Importance at Start of Project

Perceived Importance at End of Project

Communication Challenge (3)



Communication Challenge (4)



Communication Challenge (5)

Project

Physics Design

Wall of Confusion

Prime Contractor

Mechanical Design

Wall of Confusion

Sub-Contractor

Electrical Design

Wall of Confusion

Sub-Sub-Contractor

Control System Design

Software Licensing

- Open Source software licenses.
  - Need to understand and operate within the scope of the license.
  - GPL, LGPL, BSD, EPICS, …..
  - Generally designed to enable freedom to work.
- Commercial software operates under supplier specific licenses.
  - Need to understand and operate within the scope of the license.
  - Can be restrictive.
  - Who is the software licensed to?
  - Is the license transferable?
  - Does the host have to buy a second copy?
- Within the accelerator community software tools largely use Open Source software.
  - Linux, Python, GCC, Git, EPICS, TANGO, ….
  - Freedom to work.

Controls System Toolkit

- EPICS and TANGO multi-site, multi-project distributed control systems toolkits.
- Support for EPICS and TANGO across many laboratories.
- Active collaborations.
- Adoption and support by industry of EPICS and TANGO.
- There are commercial control systems alternatives.
  - EPICS and TANGO are open source.

Modern Development Tools

- Distributed software developed is becoming the norm.
  - Enabled by Internet.
  - Makes turnkey and in-kind developments easier.
- Git is example of distributed version control system.
  - Github provides one way to manage this.
- There is now a vast range of cloud based services.
  - Software development.
  - Project management.
  - Team working.

Lessons Learned At Diamond

- It can be difficult to manage progress and quality of remote software development.
  - Software progress milestones and reviews MUST be written into contract/agreement.
  - Based on software in a version control repository.
- Used a model of a developer developing a system in-house and supporting an external organisation developing a turnkey system.
  - Worked well.
- When a system includes commercial software or software developed outside the established frame work. The supplier has to provide all source and a copy of development environment licenced to host project.
  - This gets around the problem of black boxes or the supplier used an old development environment which host can't support.
- Front ended version control system to simplify use and give consistency of use.
  - Diamond_Create_Module, Diamond_Check_In, Diamond_Tag, etc

Conclusions

- Development of control systems as part of turnkey or in-kind increasingly common.
- Important to have documented development processes to ensure consistency and quality.
- Needs to part of contract or agreement.
  - Not enough, there needs to be support and face-to-face contact.
- Use of an established control system tool kit and open source software helps.
- Use of the modern distributed development tools and processes helps.

Thank you.