Distributed Control System Development by Distributed Developers

Mark Heron Head of Controls Group Diamond Light Source

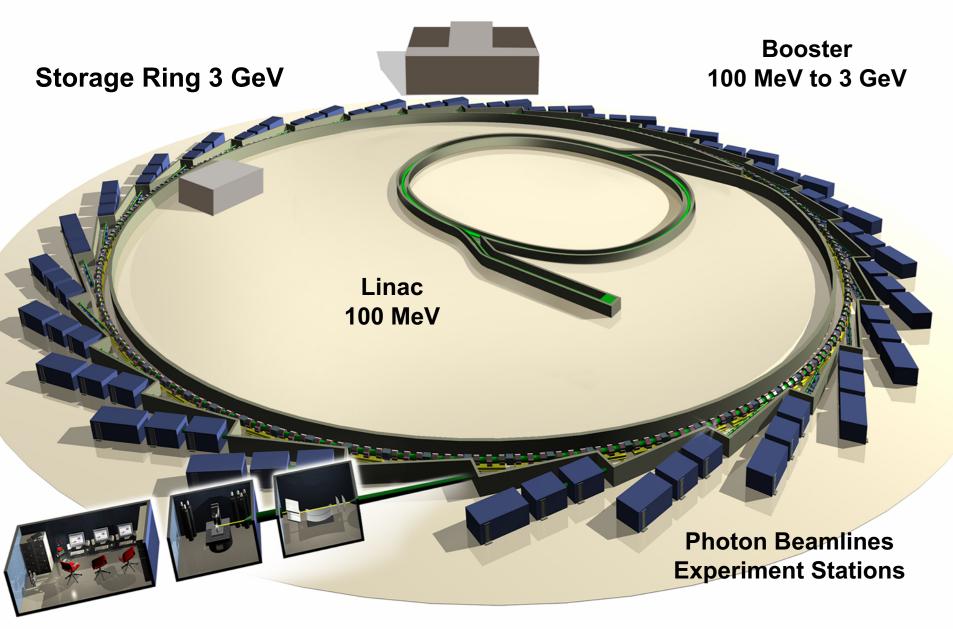


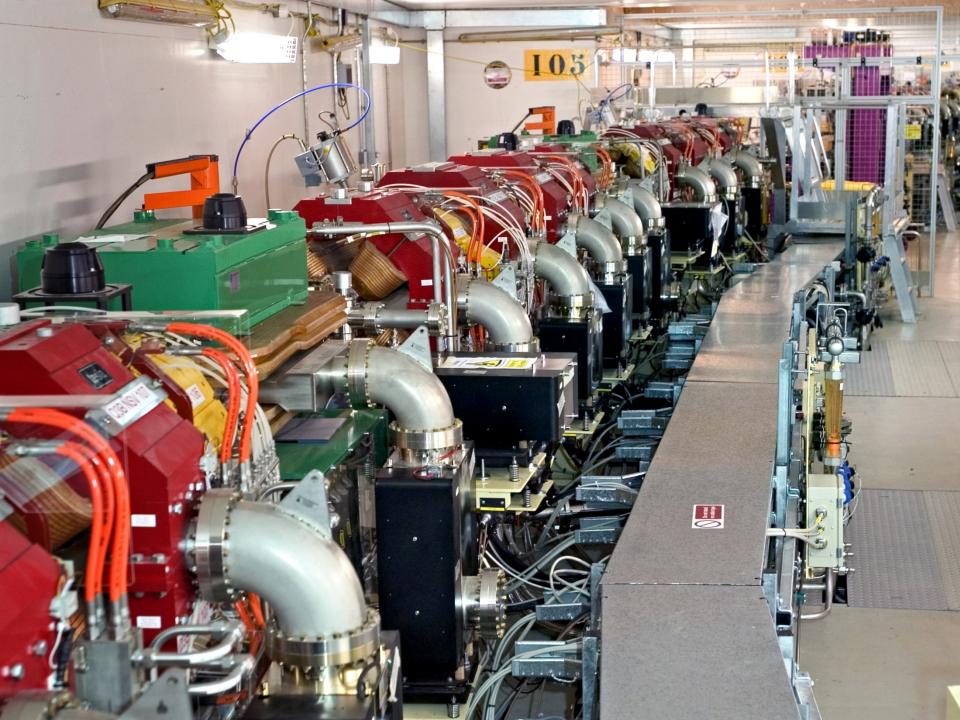
Content

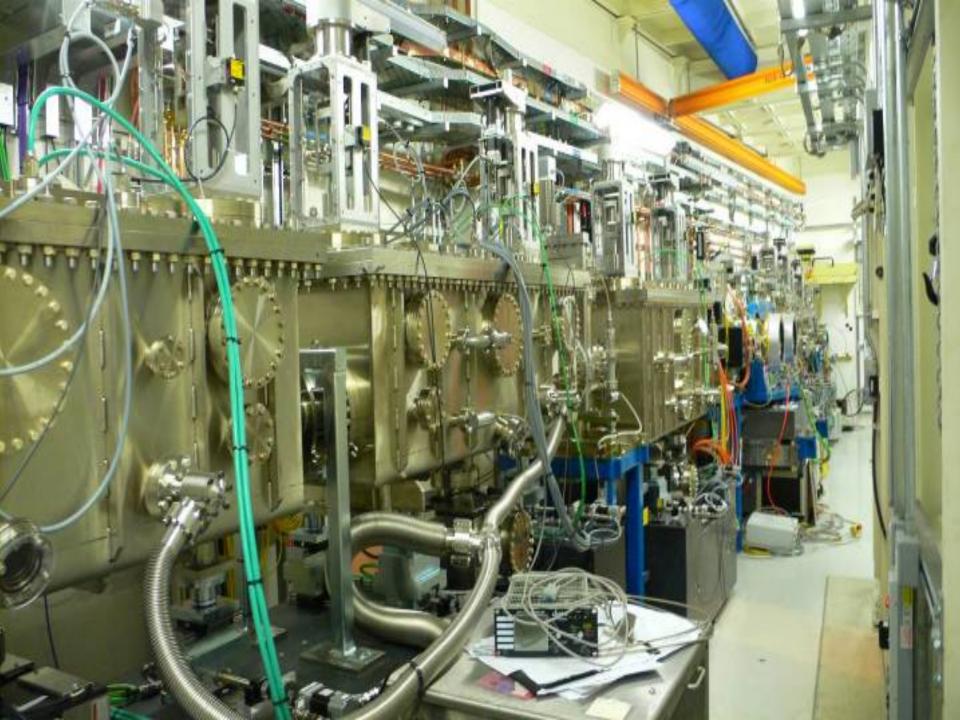
- 1. Introduce Diamond Light Source
- 2. Turnkey and In Kind Contribution Relevant to Distributed Control Systems
- 3. Some Misconceptions
- 4. Delivering Turnkey Control Systems for Diamond
- 5. Communication Challenge
- 6. Licensing, Toolkits, and Modern Development Tools
- 7. Lessons Learnt from Diamond
- 8. Conclusions



Diamond Light Source







Diamond Construction Schedule

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Phase 1		_				2											
102 Macromolecular Crystallography			_														
103 Macromolecular Crystallography			_		_												
104 Macromolecular Crystallography			_														
106 Nanoscience																	
115 Extreme Conditions																	
I16 Materials and Magnetism			_														
118 Microfocus Spectroscopy			_														
Phase II		-				_		_		-	_						
I22 Non-Crystalline Diffraction												Г	-				
B16 Test Beamline					_								Op	erat	tion	al	
I11 High Resolution Power Diffraction													-				
I24 Microfocus MX													Op	τιΜ	isat	ion	
119 Small Molecule Diffraction													Ca		ucti		
B23 Circular Dichroism			Ċ										COI	istr	ucu	ion	
I12 JEEP (Engineering, Environment & Processing)													Πο	sign			
I04-1 Monochromatic MX													DC.	SIGI			
I20 X-ray Spectroscopy (LOLA)											-						
107 Surface and Interface Diffraction (XENA)																	
B22 Infrared Microscopy								<u> </u>					31	Bea	ımli	nes	
110 BLADE: X-ray Dichroism & Scattering								-						L .			
B18 Core EXAFS					(43	End	l sta	ntio	ns
I13 X-ray Coherence and Imaging								-				L		_		_	
109 SISA: Surfaces and Interfaces																	
Phase III													-	-	-	_	-
B21 High Throughput SAXS								-									
I23 Long Waveleng th MX	_ ┣━		_														
105 ARPES								6		1	1						
B24 - Cryo Transmission Microscope	l In	itial	De	sia	'n									⇒			
I08 Soft X-ray Microscope (STXM)		i ci ai		-9.6	,,,						1			Т			
I14 Hard X-ray Nanoscale Probe for Complex Systems (H	XNP;	a	nd								1			_	-		
I21 Inelastic X-ray Scattering (IXS)															1		
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B07 Versatile Soft X-ray (VERSOX)		-113									(5		
B07 Versatile Soft X-ray (VERSOX) I15-1 X-ray Pair Scattering Distribution Function								1		1						1	
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115-1 X-ray Pair Scattering Distribution Function	_											C			$ \geq $		

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Distributed Control System Development

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.

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Distributed Control System Development



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.





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Turnkey and In-Kind Contribution

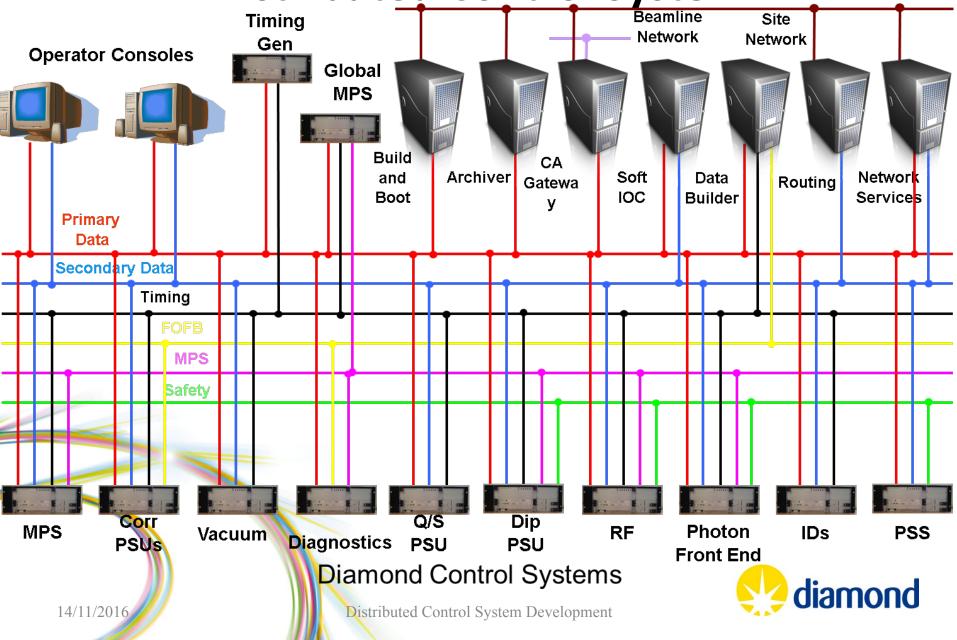
Issues	Turn Key Contracts	In Kind Contribution
Subsystem comes with its own local control system	V	V
Subsystems control system will be interfaced to the global control system	V	V
Physical interfaces to other systems	\checkmark	V
Functional interfaces to other systems	\checkmark	V
After commissioning, host organisation will responsibility for hardware and software	V	V
Financial incentives on supplier to adhere to project standards	٧	
14/11/2016 Distributed Control System Dev	velopment	

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



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

Appendix XXXX

Control system requirements for integration and compatibility with the DIAMOND distributed control system.

Introduction The DLS project has selected the EPICS control system tool kit for the distributed control system for the Diamend accolerates beamlines and convertional facilities. All control system must be based on this standard to enable cost effective and seamless integration with the rest of the DLS control system.

The second secon

The EPICS Model EPICS embodies the standard client server model, for a distributed control sy If the user consoles receive and processes information from servers that are the source of information and in the general case interface to the equipment being controlled.

The physical realisation of EPICS servers on DLS will be multiple embedded VME systems, running the VxWorks real-time operating system. The client side of EPICS on DLS will be realised on Linux based PCs.

EPICS Dutabase The functionality of the EPICS control system is primarily defined in the process database within the IOC. The database consists of a number of records, and there use the record support layer to perform the processing necessary to access 0.0, perform data conversion, alarm checklars, measurements. Records can be linked togdher to perform nore complex necessing.

EPICS Sequencer For complex sequencing of equipment then finite state machines can be used to asyment the functionality of the EPICS database. The Sequence allows the implementation and control of (noise or move) finite state machines on the IOC. The state machines are created using State Notation Language (SNL).

EPICS Device/Drivers Device and driver support provides the mechanism for integrating new interface bushesen under EPICS. These are C modules written to EPICS specifications.

Stable of TPUS Gaves and Crast suppression official modules along with documentation on their mess coll be suppied for preferred redown. Physical power for words official and official stability of the suppression of the supervision of stability to almost an entry of the supervision of the supervision of stability of the supervision o

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the IO to the rear of the crate where SCSI 2 type cable can be used to connect the IO to DIN rul mounded interface modules. The detailed interface specifications will be provided an commenciment of contants. Unknewn possible the vendor will only use this hadware. Where this is not possible DIS must approve any third party hardware before it is incorporated in the interface. Use of PLCs

Use of PLCs should ONLY be used for low level interlocking which is not suitable to be realised in the IOC. Each input output and logic state of the plc must be monitored by the IOC, either through direct connection or serial link. If PLC's are to be used within the design, then only the following.

AB Micro Logix Low end application Siemens \$7/300 or \$7/400 High end application

Control System Layout The system is to be physically arranged to be compatible with the Diamond building layout, with the cortexif rack, containing all instrumentation equipment located in a Control & Imstrumentation Awa (CLA). The equipment to control will be located in the Accelerator Ring tunnel 40m from the rack, in the CLA.

Nevelopment System n order to fulfil the contract and to maintain standardisation of equipment DLS will upply and EPICS development system providing: ty and EPICS development system providing: A software development environment, consisting of a Linux based computer, pre-installed with EPICS and a suite of DLS approved development tools and

WxWorks operating system, board support package and licences for the issued

hardware. VME64x IOC crates, standard IOC hardware, Processor, and required

erface modules, itial training with the supplied equipment and software. It relevant DLS documentation and conventions re-mistent interface with the DLS control system.

EPICS development system includes a set of applications for design and degment of system components. The EPICS database will be designed and figured using the VisuaIICST offlower package. This candida database to be great by placing records on a form, defining limits and providing interconnects thically. The Extensible Display Manager (EDM) is the preferred tool for centing thised spectral infections.

Ication Development Eavironment software created by the vendor is to comply with the DL5 file structure and ion Centrol Regoinsy structure defined in the document "CTRL-XX-project ment Centrol System EFRCS Application Development Environment and ware Product Centrol Release Proceedence." The fits structure and Version Centrol software Tracture definitions and configuration will be supplied with the dopment server at contract communication. No other fits increation or software

- 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.



Distributed Control System Development

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Control System Standards and Processes



Diamond Light Source Ltd Rutherford Appleton Laboratory Chilton, Didcot Oxfordshire OX11 0QX United Kingdom www.diamond.ac.uk

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)

27 November 2013

Revision 23:

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

ystem Development

• 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



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

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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.

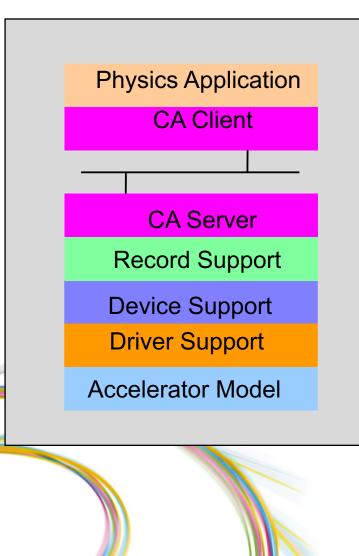


Other Physical Interfaces

- 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.

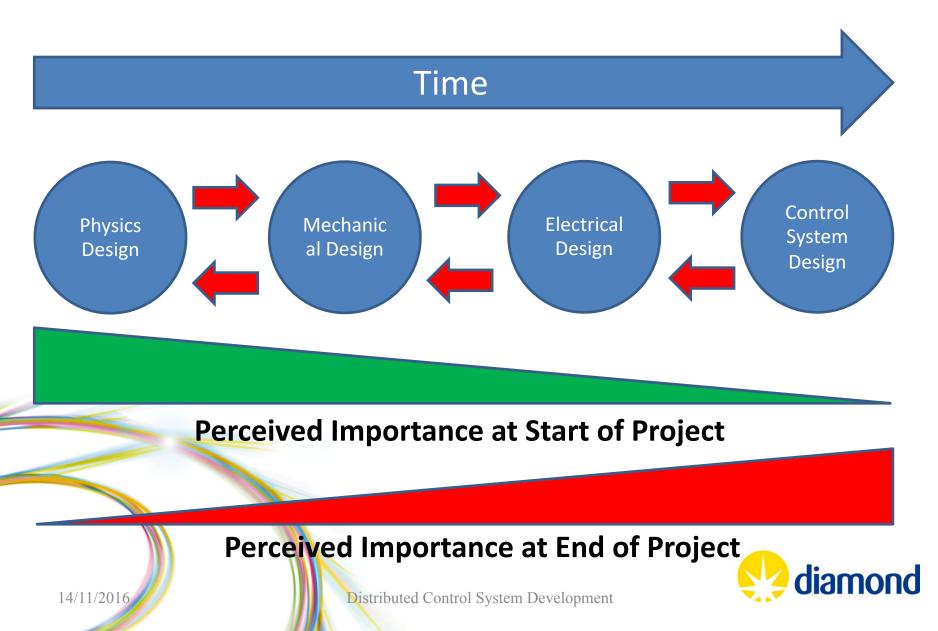
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Communication Challenge (1)

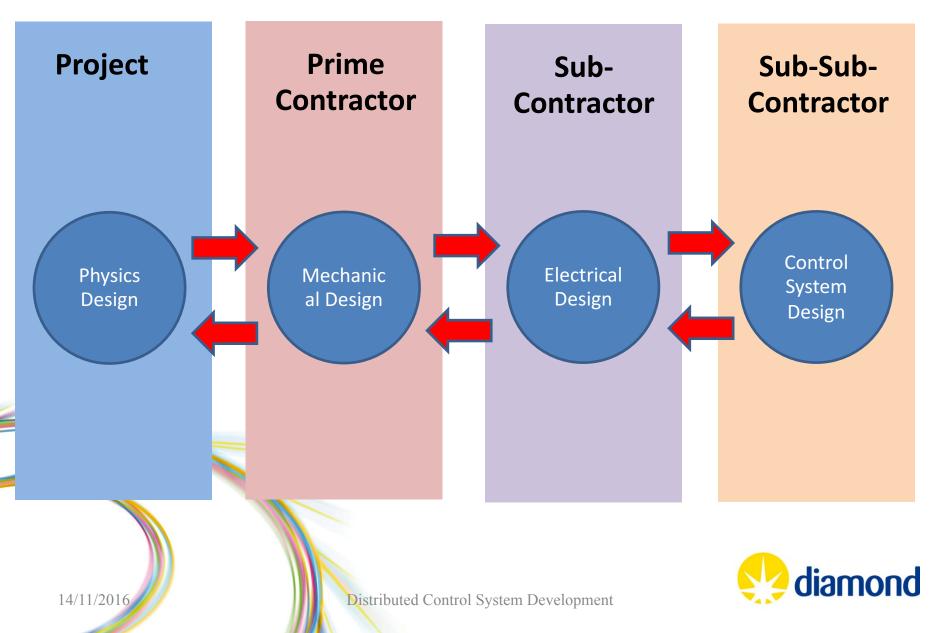
- Consider arbitrary subsystem, the development process follows stages:-
 - 1. Project/Facility
 - Physics Design, Project management.
 - 2. In-kind Partner
 - Technical design of subsystem, Project management.
 - 3. Primary Contractor
 - Mechanical, Project management.
 - 4. Sub-Contractor
 - Electrical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



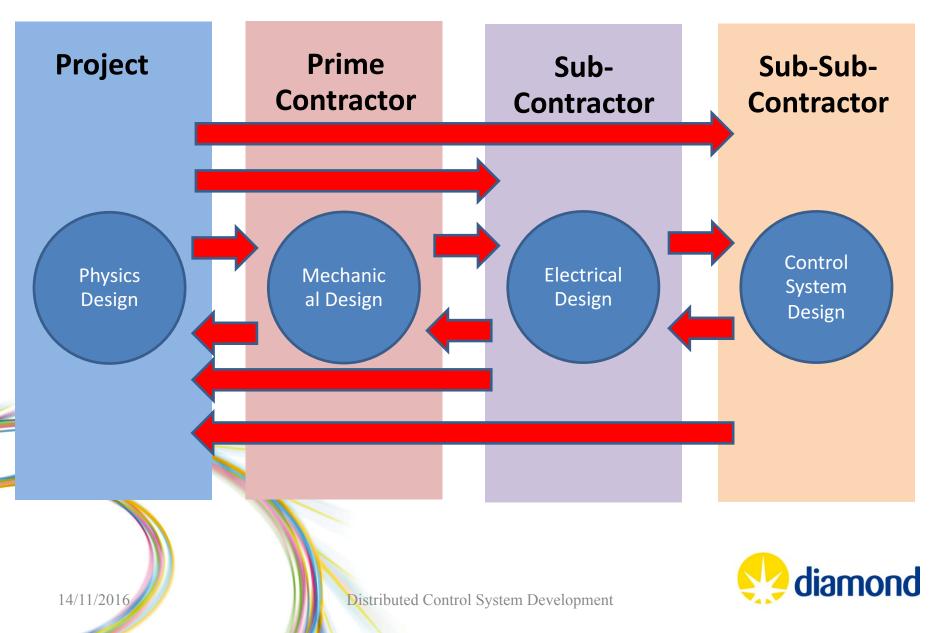
Communication Challenge (2)



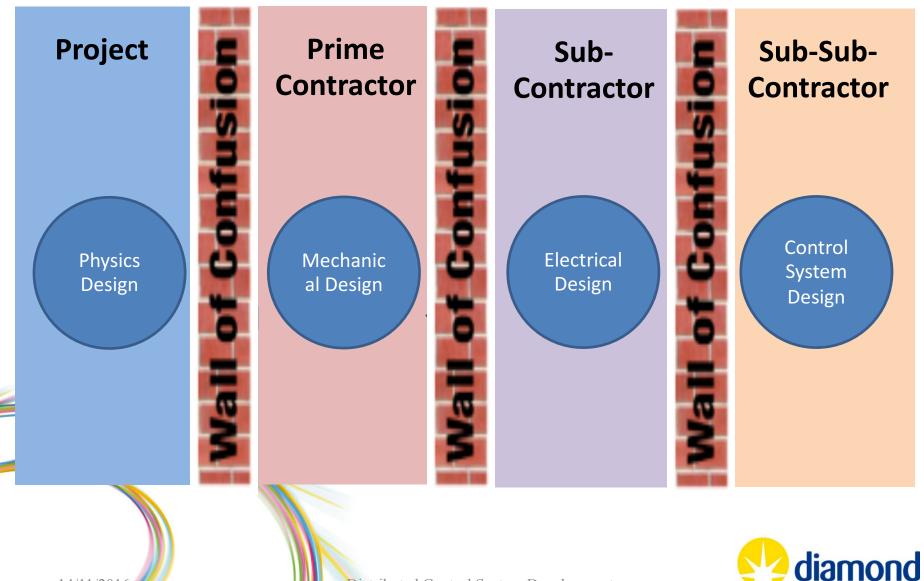
Communication Challenge (3)



Communication Challenge (4)



Communication Challenge (5)



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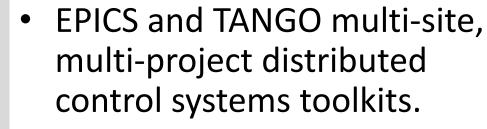
Software Licensing

- 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.



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Controls System Toolkit



- 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.



EPICS

TΔNG

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



Distributed Control System Development

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-toface 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.



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