

Accelerator Data Foundation: How It All Fits Together

Ronny Billen

Pascal Le Roux, Maciej Peryt, Chris Roderick, Zory Zaharieva



CERN, Beams Department
Controls Group
Data Management Section

The 12th International Conference on Accelerators and
Large Experimental Physics Controls Systems
October 12-16, 2009
Kobe International Conference Center
Kobe, Japan

Outline

- ✦ Introduction
- ✦ A Vision, a Strategy and some Tactics
- ✦ Accelerator Data Management Domains
- ✦ Data Federation
- ✦ Covering the CERN Accelerator Complex
- ✦ Human Resources
- ✦ Conclusions



Introduction

Two major events can be considered as turning points in data management in CERN's Accelerator Sector:

1 Purchase of a commercial RDBMS in 1983



- ⇒ Aimed to address *complex technical* aspects of LEP
 - Project planning, cabling, documents, magnet data,...
- ⇒ Since then, many successful *database driven* systems were implemented, but in a dispersed way
 - PS Controls, LEP Alarms,...

2 Reunification of “Accelerators & Beams” activities in 2003

- ⇒ Single groups for *Operation, Controls* and *Equipment* for the complete CERN accelerator complex
- ⇒ Unification of *accelerator data management* was proposed...and accepted by the hierarchy

The Vision

★ Data Management Team in the Controls Group

- ⇒ Dedicated team of 8-10 database software engineers
- ⇒ Senior members having also accelerator domain knowledge
- ⇒ Junior members proficiently up-to-date in database development
- ⇒ Ambitious technical and human objectives for the team

★ Need for a clear vision

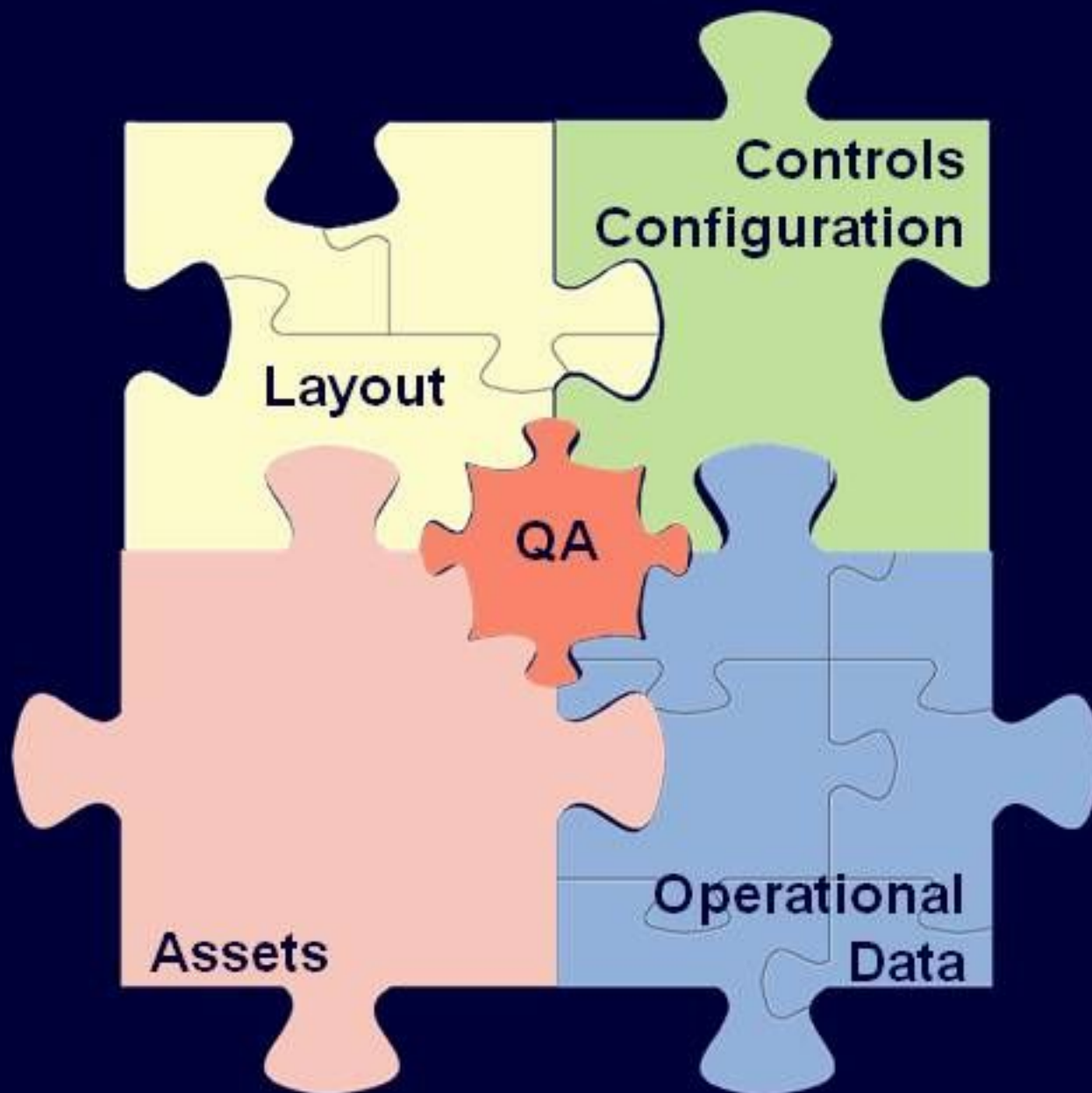
- ⇒ Highest importance attributed to LHC
 - huge complexity, but starting from a relatively clean sheet
- ⇒ *Rationalize, improve* and *federate* the existing data on the older accelerators
- ⇒ Break up the vast domain into manageable areas
 - Typically a senior and junior team member in each area

★ Communicate, communicate, communicate



The Puzzle

Breaking up the data domain into several pieces



★ Advantages

- ⇒ Logical break-down
- ⇒ Organized
- ⇒ Manageable

★ Inconveniences

- ⇒ Integration not considered at the outset

★ Therefore

- ⇒ Emphasize common understanding and good communication between developers
- ⇒ Federation work began in 2007

Strategy

✦ Development work

- ⇒ Major effort: requirements gathering, analysis and development work
- ⇒ Legacy DB showed lack of *Quality Assurance* at DB and data levels
 - ↳ Introduced *integrity constraints* and *naming conventions*

✦ Technology

- ⇒ Use of Oracle technology stack (huge in-house expertise)
- ⇒ Use of Java, J2EE, JDBC deployed in *3-tier architecture*
- ⇒ *On-line* usage of database services for accelerator control

✦ Responsibilities

- ⇒ Acceptance of competence shift with *clear limits of responsibilities*
 - ① DM team developers
 - ② Application developers
 - ③ Data owners
 - ④ DB infrastructure service

Some Tactics

★ The important aspects to make the strategy successful

- ⇒ Involve end-users right from the start, throughout the design and development process
- ⇒ Communicate constantly on scheduled interventions and their anticipated impact
- ⇒ Iterate rapidly based on end-user feedback
- ⇒ Provide adequate environments for development, unit testing, system testing and production
- ⇒ Push data ownership to the experts, assist and guide the usage of the data maintenance interfaces



Layout Data



Icalepcs'07
RPPA03



1 Machine Layout

- ⇒ Accelerator design, magnetic model, beam optics by machine physicists
- ⇒ Mechanical installation & integration work; establishing the as-built model

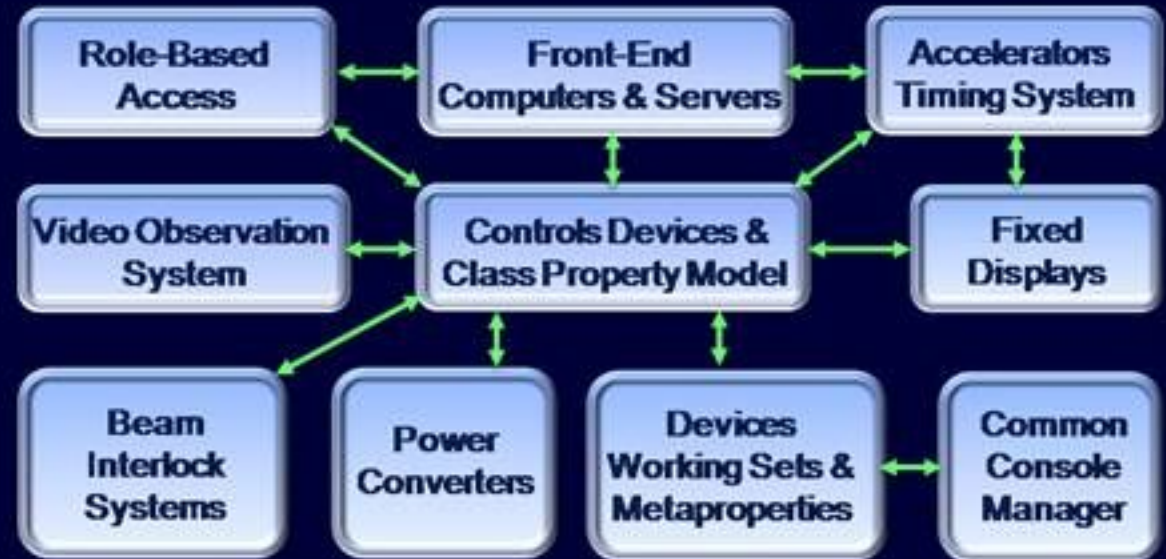
2 Controls Electronics Layout

- ⇒ Racks, crates, modules, fieldbus connections
- ⇒ 9,000+ racks for LHC
- ⇒ Essential during installation
- ⇒ Starting point for automatic *configuration* of front-end computers

3 Electrical Circuits Layout

- ⇒ Description of electrical objects in powering circuits
- ⇒ Relationship between power converters, current leads, bus bars, magnets, ...
- ⇒ Exploited in *operational data* domain

Controls Configuration



TUA004

Control system topology

- ⇒ From front-end computers to control room consoles
- ⇒ 65,000+ controls devices
- ⇒ 5 device-property models
- ⇒ Rejuvenated legacy DB

Interactive interfaces and APIs

- ⇒ 200+ re-developed Oracle ADF interfaces (Java-based forms)
- ⇒ 150+ Oracle APEX reports
- ⇒ Java APIs for control room apps
- ⇒ Pro*C APIs are being replaced

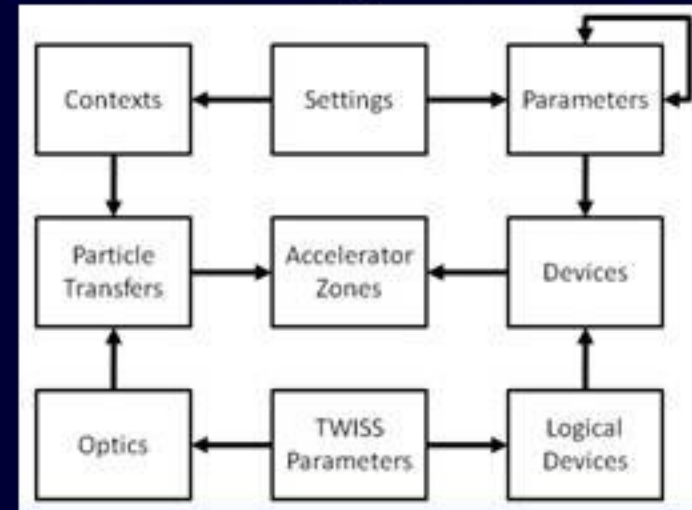
THP108

Operational Data



1 Settings

⇒ Parameter space for LSA



WEP006

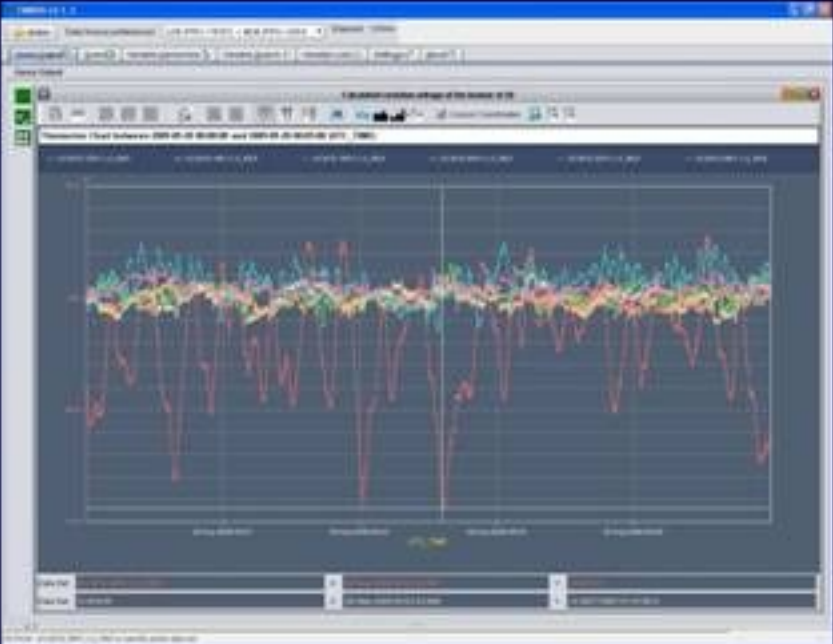
2 Measurements & Logging

⇒ Store time-series data, keep on-line

⇒ Beam and equipment measurements

WEP005

Time	Severity	Category	Message	Description
19:09	2	CMW_ALARM	SFS_2PACT_BA2	Alarm state not known
19:09	2	CMW_ALARM	SMA_507_08001	Alarm state not known
19:09	2	CMW_ALARM	SMA_507_08002	Alarm state not known
19:09	1	COMPUTER	RFS0F2	Moving or misbehaving process - At least 2sec pr...
19:09	1	COMPUTER	EPV_845_8LMHC	Out space or disk usage problem - Pk with Supra...
19:09	1	COMPUTER	ES_CLR_T07	Contact lost
19:09	1	COMPUTER	KAD0A3	Contact lost
19:09	2	SP_5P5_BEAMC	BECAPT_2P02	Measurement time-out
19:09	2	Twiss	TDX_CV1_BA3_CT005	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT006	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT007	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT008	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT009	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT010	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT011	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT012	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT013	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT014	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT015	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT016	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT017	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT018	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT019	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT020	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT021	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT022	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT023	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT024	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT025	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT026	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT027	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT028	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT029	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT030	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT031	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT032	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT033	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT034	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT035	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT036	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT037	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT038	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT039	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT040	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT041	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT042	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT043	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT044	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT045	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT046	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT047	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT048	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT049	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT050	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT051	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT052	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT053	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT054	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT055	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT056	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT057	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT058	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT059	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT060	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT061	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT062	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT063	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT064	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT065	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT066	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT067	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT068	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT069	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT070	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT071	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT072	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT073	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT074	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT075	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT076	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT077	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT078	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT079	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT080	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT081	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT082	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT083	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT084	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT085	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT086	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT087	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT088	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT089	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT090	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT091	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT092	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT093	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT094	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT095	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT096	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT097	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT098	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT099	Bus Error
19:09	2	Twiss	TDX_CV1_BA3_CT100	Bus Error



3 Alarms - LASER

⇒ Capture, store, notify anomalies

Assets Data



Physical components

- ⇒ CERN-centralized **asset management**
- ⇒ CERN-wide **part identifier**
- ⇒ Commercial system enriched with home-made interfaces
- ⇒ Keep track of complete **lifecycle** of the asset

TUB004

Quality Assurance



★ Fitting the pieces of the puzzle

⇒ QA starting point: identification of objects

↳ Equipment code catalogues as official references

⇒ Supporting QA tools

↳ Including a Naming database

★ Basis for Data Federation

⇒ Imposed naming conventions

⇒ Clear procedures, standards and instructions to be followed by all

CERN
CH-1211 Geneva 23
Switzerland



the
Large
Hadron
Collider
project

LHC Project Document No.
LHC-PM-QA-001.00 rev 1.0

CERN Div./Group or Supplier/Contractor Document No.

EDMS Document No.
107132

Date: 1999-09-09

LHC Quality Assurance Plan

Foreword

The LHC Project represents an unprecedented challenge for CERN in several respects: the purpose of it is to build a world-class hadron collider making use of the most advanced techniques in several fields such as superconducting magnets, cryogenics, vacuum, powering, etc. The LHC is intrinsically complex as the different systems that make it interact with each other and require careful definitions of their mutual interfaces. Also and contrary to the former accelerators built at CERN, maintenance and machine consolidation after running in will almost be impossible in the long continuous cold parts of the LHC.

In addition to technical constraints, some systems and components will be entirely under the responsibility of external Institutes and Collaborations and will be supplied ready for installation. Finally, the construction phase extends over a rather long period, in a context of constant annual budget and of declining human resources.

One way for taking up this challenge is to implement a Total Quality Management System, based on defect prevention and continuous process improvement. To this end, I have asked Paul Faucher, Head of Technical Coordination and Planning in the LHC Project Team, to act as my deputy for Quality Assurance and to prepare a Quality Assurance Plan in collaboration with all interested parties. A QAP Working Group, chaired by M. Mottier was then set up with members coming from project management and hardware groups.

I am glad to introduce the resulting Quality Assurance Plan, which defines the overall structure for quality activities and responsibilities for LHC and contains all related procedures and standards. The QAP has been made available on the Web for some time, procedures and standards being added when they were introduced. However, it has been found essential to distribute a paper copy of the QAP to each project engineer not only for easy reference, but mainly to make project engineers realise that the QAP is now put into force.

It is part of the professional duties of each project person to ensure that material, components and assemblies of their systems are fully compliant with all applicable requirements of the QAP and that the procedures described herein are implemented in an effective manner. The management is ultimately responsible for Quality, by ensuring that each project individual is made responsible for the quality of the work he is performing, from the design stage to the final installation through the whole construction process.

Quality is essential to make the LHC a great success.

Lyndon Evans
Director,
LHC Project Leader

Data Federation

★ The perfect solution for data integration...

⇒ Unique identifier (i.e. primary key) for each object throughout all data domains

★ ...was not put in place, so...

⇒ How do we solve this problem?

★ Exchange of keys between the domains

⇒ Object Identifiers are truly **unchangeable** primary keys

- **Not the object name!** It may change over time

⇒ Several implementations on a case-by-case basis

- Database views, materialized views
- Use of 'grant select' or database links
- PL/SQL code for more complex data propagation
- Execution on manual, semi-automatic or automatic basis

★ Best illustrated by example



Assets Installed in Layout Slots

LAYOUT DATABASE

Advanced Search: Functional Positions | Interfaces | Systems | Electrical | Classifications | Utilities

LHC MACHINE BY SECTOR (STUDY)

- 512
 - L59R1
 - DSR1
 - ARC12
 - ARC12
 - 12R1
 - LBARA.12R1**
 - QCBL.12R1
 - HCDOA.12R1.B1
 - HCDOA.12R1.B2
 - QBAA.A12R1
 - GVVCA.A12R1
 - GDMA.A12R1
 - GDMA.A12R1
 - GDVA.A12R1
 - HQB.A12R1.E
 - GDHB.A12R1
 - GDMA.B12R1
 - GDVA.B12R1
 - HQBC.A12R1.M
 - MA.A12R1
 - QHEW.A12R1.LH821
 - QTES.A12R1.TT821
 - MA.A12R1
 - VSSB.A12R1.B
 - VSSB.A12R1.R
 - GVVCT.A12R1
 - GDMA.A12R1
 - GDMA.C12R1
 - GDMA.D12R1
 - GDMA.A12R1

IDENTIFICATION		
Machine	LHC Ring	
Type	LBARA (Type ID : 101624: Quality Assurance ...)	
Description	Arc Dipole, Type A Cryo-Assembly, Arcs on the Right, Cryo-Magnet Extremity Type A	
Official Name	LBARA.12R1 ID:102122 Link to MTF Slot	
Expert Name		
Vacuum Name	LBARA.78.12R1	
Beam	This slot is on both beams (B1, Blue : B2, Red) [E]	
Equipment (MTF PART ID)	HCLBARA000-IN001352 Link to MTF Equipment	
Classification		
Related Electrical object		
Log		

DIMENSIONS		
Length	15.55 m	
Width	0 m	
Height	0 m	

LOCALISATION		
Location	LHC HALF-CELL - 12R1 (CIVIL WORK : R18)	
S Start	440.2807 m (440	
S End	455.9407 m (455	
U Start	0 m	
U End	0 m	
V Start	0 m	
V End	0 m	

MTF
Equipment Management Folder

Actions: Show NCR Report

Assembly Tree

- Arc Dipole LBARA
 - Cryo Dipole LBARA
 - Cold Mass MBAR
 - Cryostat Assembly
 - Assembled beam screen - R
 - MB upstream
 - MB upstream (V1)
 - Flexible K-long (v1)
 - Flexible K-long
 - Long Sleeve

Top Assembly Folder : Main Info

Top Assembly Identifier: **HCLBARA000-IN001352**

Other Identifier: None

Description: Arc Dipole LBARA

Asset identifiers are imported

Main	
Actions	View summary
Physical	
Manufacturer	
Project Engineer	
Status	Manufacturing
Other Identifier	
Parent Equipment	
Parent Slot	LBARA.12R1
Location	R18
State	Good
MRC	MTF1
Design	
Item in ABS	LBARA Arc Dipole Variant (ver.0)
Audit	
Created on	2005-11-16 by DIPCOOR
Last modified on	2007-03-22

Asset-to-Slot assignment done by the equipment owner via this interface



Slot identifiers are imported

Asset identifiers are imported

Asset-to-Slot assignment done by the equipment owner via this interface

Other Examples of Data Propagation

Beam loss monitoring electronics

⇒ Module data needed for beam interlocks

Commissioning sets of circuits

⇒ Electrical layout needed to drive settings

Configuring front-end computers

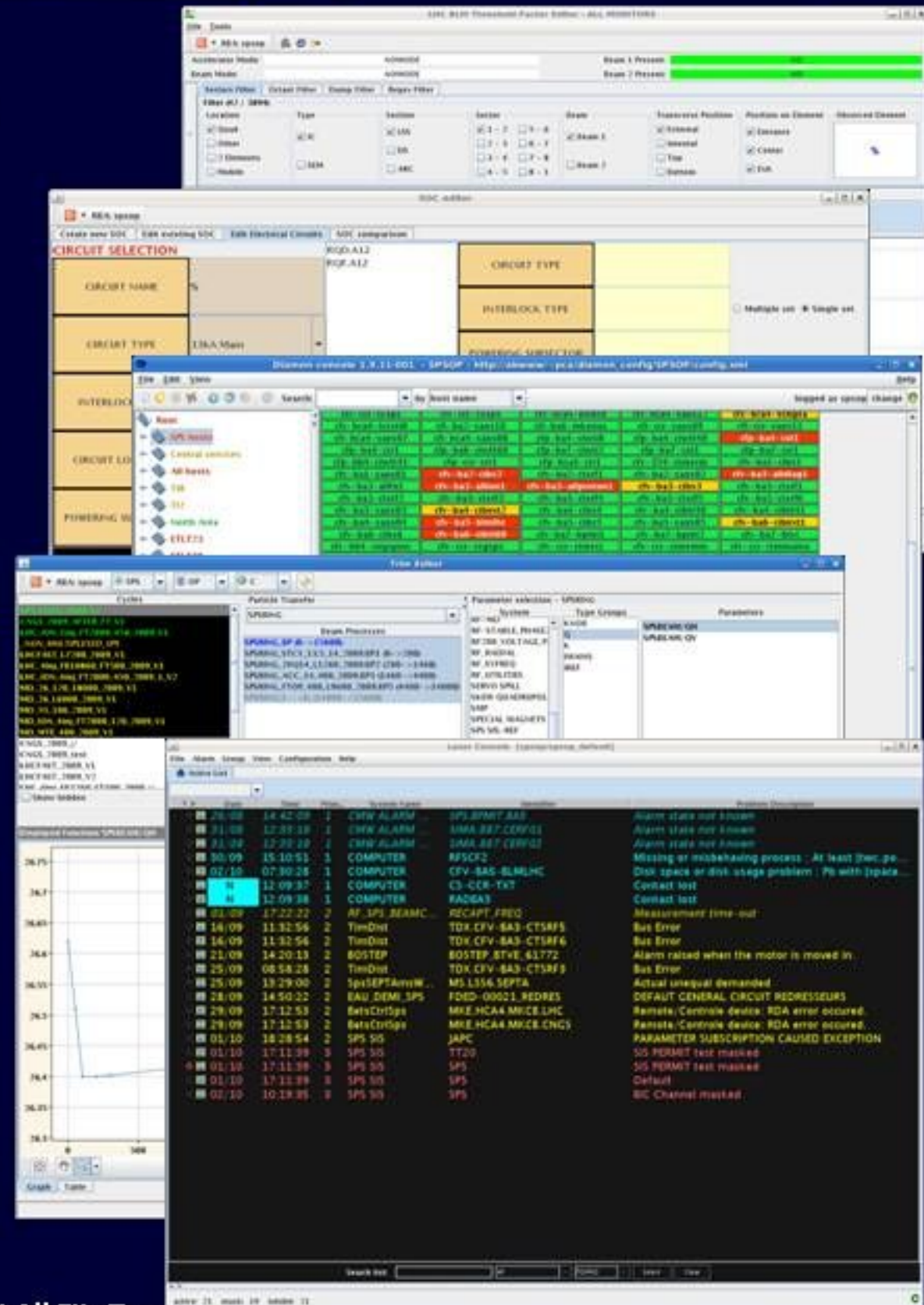
⇒ HW/SW configuration derived from layout data

Driving settings from SW devices

⇒ From device-property to Device-parameter

Generating alarm definitions

⇒ Based on controls configuration



Covering the CERN accelerator Complex

- ✦ **Architecture, design and implementation was set out with LHC in mind**
- ✦ **Retrofit to existing accelerators is in progress**
 - ⇒ Integrate the existing data into the current model
 - ⇒ Extend the model to cater for specifics of other accelerators
 - ⇒ High level controls and settings management of the PS-complex is the most difficult challenge
 - ⇒ Renovation project with convergence towards LHC has been launched

TUP019



Human Resources

- ★ The people are the most important assets in the process of *analysis, design, development and maintenance*
- ★ The core team of database engineers have to:
 - ⇒ Follow and use the **technology** effectively
 - ⇒ Acquire specific **domain knowledge**
 - ⇒ Show flexibility in adapting to the **changing user requirements**
 - ⇒ Impose **data access methods** to application developers
- ★ **Their responsibility is proportional to the database complexity**



	tables	constraints	code	volume
Layout	134	495	55,602	5.3 GB
Configuration	514	1,524	30,326	9.7 GB
Settings	281	1,392	9,026	14.6 GB
Logging	55	103	14,431	+17 TB
Alarms	207	191	24,915	62.8 GB

Conclusions

👉 What's the important message here?

- ⇒ Data management is an **organizational** issue
- ⇒ The accelerator domain is a **very wide area**
 - Legacy, in-house developments, commercial systems are part of our environment
- ⇒ Ensure **single source** of maintained, consistent data
 - Avoid confusion, doubt and errors
- ⇒ In case of data propagation
 - **Procedures** for **execution** and **verification** of the data synchronization are mandatory (i.e. Quality Assurance)

👉 **A database is only as good as the correctness of the data it contains**

👉 **Software comes and goes, data stays forever**

Questions?



R. Billen