RT controls Working Session

Members of working session :

	Previous Activity	Present Activity
L. Bottura LHC/MTA	Applied superconductivity for fusion	LHC magnetic field measurements
O. Brunig SL-AP	HERA beam physics	LHC beam physics
A. Burns (chair) SL-BI	SPS-LEP BI software	SPS-LHC Q, Q', local orbit, . . . measurement (and feedback)
A. Butterworth SL-LRF	LEP RF control software	In addition, LEP EIC during runs
J.J. Gras SL-BI	SPS-LEP BI software	SPS-LEP BI software
M. Jonker SL-CO	SPS-LEP EIC + high level timing	SL PCR application software
Q. King SL-PO	Control system at "JET"	LHC PC digital control
P. Ribeiro SL-CO	Front-end software	Front-end control

What do we mean by "Real Time" ?

A real time system has **deterministic** behaviour; but does not necessarily have to be fast. In the case of the LHC we want a **bounded response time** for repetition rates ~ 1 Hz (max. 10 Hz for some systems)

Why do we need this for the LHC ?

Because of non-reproducibility of magnet field errors, demanding beam parameter limits and a very low tolerance of the machine to beam losses.

The large beam losses common during HERA commissioning are unacceptable for the LHC. (e.g. during snap-back, with a 80% correction of the (non-reproducible) sextupole error in the main dipoles**, the chromaticity goes out of tolerance in ~ 1 sec**. [LHC Report 221, April 2000])

Is real time control exotic ?

NO ! Widely available industrial standards and products available today, such as ATM, WorldFIP, LynxOS, PowerPC, would satisfy the presently known requirements for RT Control, at a reasonable cost. (e.g. full ATM system for LHC : ~ 2 MSF)

Relevant ongoing (or recently completed) activities :

- **Digital control for all LHC power converters** (following RECCS WG specification : LHC Project Note 183; String 2 installation Q3 2000 Ł validation of control design using WorldFIP 2.5 Mb/s fieldbus and PowerPC/LynxOS gateway) [SL/PO/CC]

- **Specification of standards for BPM/BL crates** (BI group pushing for decision this year on H/W & S/W standards for ~250 tunnel crates). Subsidiary major issue is use or not of optical fibers to equipment crates. [SL/BI-SL/CO ad hoc WG]

- **ATM prototyping** (Lab ATM set-up with VME/PowerPC CPUs running LynxOS; completion of ATM infrastructure in around SPS; SPS Q-loop project) [SL/CO/FE]

- RECCS-II WG (published **"Requirements for real time correction of decay and snapback in the LHC superconducting magnets"**, LHC Project Note 221)

- **LHC Communications Infrastructure WG** (started May 1999, reports to LHC TCC, Interim Report being finalised, technical specification for purchasing process needed for **autumn 2000**, installation as part of general services Oct. 2001 – Dec. 2002).

- **"Reflections on RT knobs and RT control"** [unpublished, M. Jonker].

Establishing requirements :

As a first step, the following services requiring RT control are identified:

- Closed loop control of orbit (global and local), tune (& chromaticity ?)
- Magnetic multipole correction feed-forward
- RT knobs and associated displays
- References for certain regulation loops ?

Not yet decided : Centralisation of beam loss data (for beam abort)

Excluded are numerous local regulation loops (e.g. PC current regulation, cryogenics temperature regulation, RF phase and synchronisation loops,transverse feedback, . . .)

and the systems involved in providing these services :

- Power converters (for correction elements)
- Beam instrumentation (orbit, tune, chromaticity ?, beam-loss ??)
- Magnetic reference system (includes reference magnet measurements in SM18)
- RF (transmission of reference to radial loop, if there is one)
- RT Applications
- RT Network

Establishing requirements (contd.) :

- Clarify any possible overlap with **Interlock System**. Most inputs hardwired to this system, but what about BL ? Also how will post-mortem trigger be transmitted (has to go also to systems that do not provide input to abort controllers) ?

- Confirm or establish **quantitative specifications for processes & systems** concerned by RT control, e.g. required maximum response times and rates
- Some requirements already specified (e.g. from magnet snap-back, machine physics).

- Work through "**Use Cases" of operational scenarios** to identify may have been missed out (some already presented by M. Vanden Eynden at CO-OP Forum).

- Make recommendations on **functional architecture**.

Producing design

Sorry, no concrete ideas at this stage.

Validating design

Present **initial conceptual design** to users (confirm potential of design to satisfy requirements, allow users to adjust requirements)

Prototyping :

- **Lab set-ups** – good starting point
- **SPS** – may be of limited use due to lack of suitable client equipment
- **String 2** – could possibily be test-bed for parasitically simulating RT control loop with installation of 15 PCs
- **Sector test, spring 2004** – **has considerable potential** with a good pool of operational equipment (especially BPM/BL and PCs) **but no clear need for RT control**. Model-based feedforward correction will be needed to correct persistent current decay (no real-time reference magnet measurements available).
  Could also test RT control via IP/Ethernet.

Other issues requiring further study

- The consequences of request by W. Herr at LHC CO-OP Forum for **bunch-by-bunch measurements in collision** (bunch current and lifetime, beam size, luminosity, . .) for beam crossing control. (N.B. he did not request turn-by-turn rate)

- Implementation of **post-mortem trigger** and the possibility to freeze and read-out post-mortem buffers at other times. The first is part of the abort system, the second is not.

- Are there **special synchronisation requirements** for RT ? (e.g. RT trim input to PCs can be asynchronous since sampling rate will be ~10 times faster (100 Hz) than that in trim providers (orbit or tune feedback, RT knobs, . .))

1st Recommendation :

Soon after this workshop, **form a LHC-CP Working Group** to make a detailed study of RT control issues and establish initial requirements **by end of 2000.** (Most members of RT working session would be willing to participate)

The chair should be someone able to devote a substantial part of his time to this activity.

The WG should probably have some role during the subsequent phases.

The overlap with the LHC CIWG needs to be clarified, although it is assumed that the fibers installed will cover the RT communications requirements.

The WG will need to keep well informed on :

- the on-going definition phase of BPM/BL project
- the progress of the PC control project
- the proposed correction algorithms
- the real time network

2nd Recommendation :

Nominate a project leader for the Real Time Control system, as a LHC-CP "sub-project" (should be member of above WG -- and of SL/CO group ?)

The "Project Team" should define the boundaries and responsibilities, in concertation with the equipment groups involved.

3rd Recommendation :

Commit sufficient manpower resources early enough to have **most of the functionality of the control system ready for the sector test in spring 2004**. This includes high level applications, databases, timing, equipment access (middleware ?), and a **magnetic reference system.**

For the systems requiring RT control, **the choice of network protocol could be left open** (i.e. IP/Ethernet or ATM or . . .) since there will be no possibility of using closed loop feedback.

Could also test a limited RT network installation, before purchasing and installing for the rest of the machine.

Summary (1)

- **Even a "slow" machine like the LHC can benefit from Real Time controls – and at a reasonable cost and without using immature technologies.**

- **A Working Group should be formed (yes, yet another LHC WG) to complete the set of RT control requirements – to allow work to start on an initial conceptual design in early 2001.**

- **A project leader for RT Controls (as an LHC-CP sub-project) should be nominated this year, with a mandate acceptable to the equipment groups involved.**

Summary (2)

- **Target date for having a control system with full functionality (for the 1st LHC sector installed) should be early 2004. This should include the first version of a functioning magnetic reference system (LHC-MTA project).**

- **The remaining time until first beam in the complete LHC (late 2005 or early 2006) can be used to**
  - **improve what is deficient,**
  - **complete what is not ready,**
  - **commission newly installed equipment and their associated applications**
  - **install the chosen RT protocol, if this has not already been done.**

- **. . . then at the LHC startup we could hope to concentrate on the main challenge (commissioning the machine).**