USING THE LHC CONTROL SYSTEM – 2016 RETROSPECTIVE AND SHORT TERM PLANS

G.Crockford CERN, Geneva, Switzerland

Abstract

The paper will discuss the LHC control system performance during 2016 operation. It aims to answer the following questions: In retrospect, which controls facilities, if any, were missing and what could be improved? How did we perform on follow-up of requests from Evian 2015? Human errors committed while interacting with the control system are discussed and suggestions made for possible mitigation measures. Looking forward to EYETS (the extended year end technical stop), the planned control system changes and their impact will be presented.

INTRODUCTION

The LHC Control System was very stable in 2016. During five full years of operation with beam, the LHC suite of applications, fixed displays and feedbacks have evolved and matured to a high level of efficiency and reliability. All critical problems were cured in a very reactive manner (e.g. Early in the year some problems of slowness when re-generating setting for beam-processes were temporarily mitigated by increasing the database cache size). Nevertheless, some ideas and requests for improvements remain which will be discussed in the following sections.

PRIORITIES SET AT EVIAN 2015

An OP perspective on LHC controls was presented at Evian 2015 [1]. This paper established a list of the top five priorities of software improvements. These priorities were later re-evaluated in follow-up discussions [2].

Top five priorities

The following priorities were established following discussions within BE-OP-LHC.

- Improved filling diagnostics.
- Improve integration of QPS, PIC, EquipState.
- Improve automation of sequencer and scripting.
- Know the state (of the machine) at a given time.
- Improve window management on consoles.
-

SOFTWARE DEVELOPMENTS 2016

This is a non-exhaustive overview of some key new software developments used for the first time during the 2016 run.

Improved filling diagnostics

At the top of the list, following a discussion of application software priorities, was a need for improved filling diagnostics. Much time was lost in previous years diagnosing injection problems between the SPS and LHC. To improve this situation an application was developed with a generic architecture in mind. The analysis framework can be reused in other applications. A beta version of this application was available for tests towards the end of the 2016 physics run.

Figure 1: Analysis framework

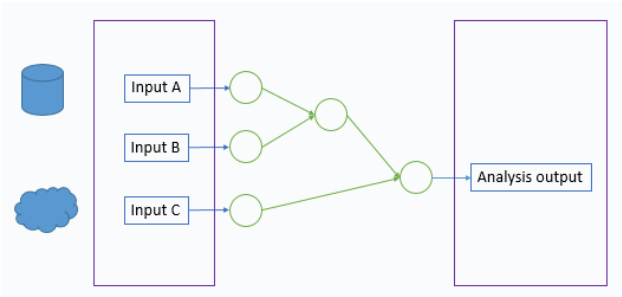
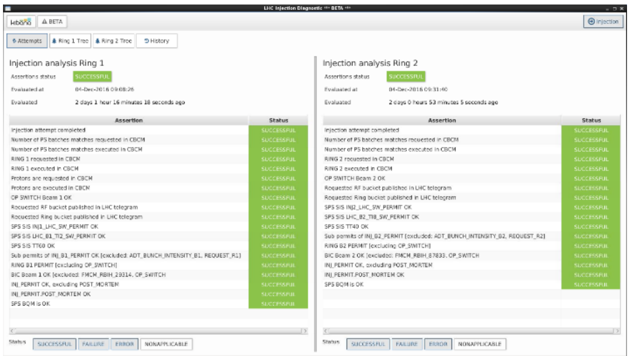


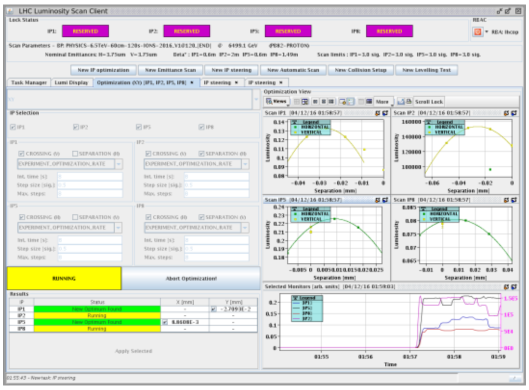
Figure 2: Injection diagnostic GUI



Luminosity Scan Client and Server

This application (and its underlying server) is a replacement for the previous luminosity scan application. A central server provides a reservation system for the interaction points, thus removing the possibility of conflicting trims. Introduced at the beginning of the 2016 run and heavily used throughout the year, this application improved efficiency for routine optimisation of collisions and emittance scans (IP5), as well as facilities for automated Van Der Meer scans.

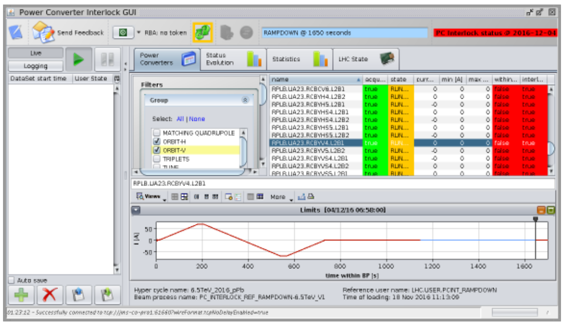
Figure 3: Luminosity Scan Client



Power Converter Interlock GUI

This application maintains a survey of power converter currents in tolerance at a given time in a beam process. It is linked to the Software Interlock System. The most recent improvement on this system provides an interlock on Quadrupole currents, to ensure that the phase advance between the beam dump kicker and tertiary collimators at the experiments is respected. The GUI display also provides a means to monitor the time remaining in a transitory beam process, such as the ramp or squeeze.

Figure 4: Power converter interlock GUI



To improve the robustness of this facility, there remains a requirement for an improved state machine to be able to follow the state of the machine at a given time (rather than relying upon time elapsed following the broadcast of a timing event, as is currently the case).

Chromaticity and Tune Estimate

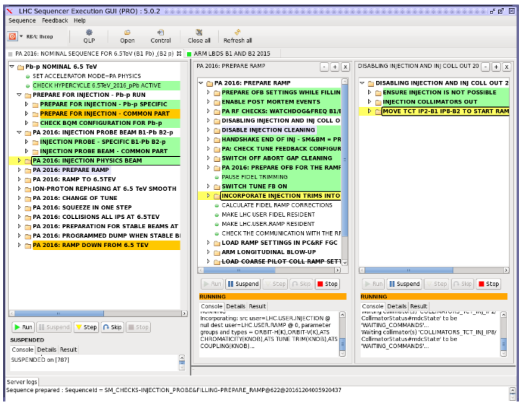
Measurements and corrections of Tune and Chromaticity are frequently performed in routine LHC beam operation. A new application was introduced in 2015, and further developed in 2016, to make carrying out these routine measurements and trims more fast and convenient.

Figure 5: Tune and Chromaticity estimate

Sequencer Multi-Tasking

The Sequencer was very heavily used in 2016 and proved to be robust and reliable. For stability and to focus on other priorities it was agreed to freeze further developments on the Sequencer in 2016. The current version of the sequencer provides the possibility to manually pull out sequences for parallel execution. This requires some inside knowledge as to what tasks can be executed in parallel, and may vary depending on the working practices of individuals. A systematic time saving could be achieved if the parallel execution of sequences could be automated. However due care should be taken to ensure that the operator remains fully aware of the sequences being executed. Figure 6 shows the example of the sequence to prepare the ramp. The task to remove injection protection collimators takes a few minutes and can be executed in parallel.

Figure 6: Sequencer, Prepare Ramp



Window Management on Consoles

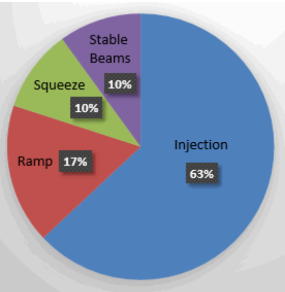
To improve configuration and management of the upper tier of fixed display screens in the LHC island of the CCC, start-up scripts were implemented to define the application displays and their window positioning, to be executed upon re-start or reboot.

HUMAN ERROR AND CONTROLS

Different studies focus on the interplay of humans with complex systems and the resulting system failure modes [3]. The general conclusion is that human variability is a force that can be relied upon, and therefore should be harnessed. This is particularly true in a control room environment involving shift work, 24 hours a day, as well as an often busy working environment with many incoming phone calls and visitors to the control room. Therefore when an instance of human error occurs, rather than blame the individual, it should be seen as an opportunity to analyse why the control system defences did not catch the error. An analysis was made of instances of human error in LHC operations in 2016. Machine protection defences against these incidents proved to be very robust, and in all instances errors were caught with clean protection dumps of the beam. However downtime incurred due to human error could be improved.

There were 52 events classified as “operational mistake” in 2016, distributed over different operational phases, as illustrated in Figure 6.
A protection dump at injection may have a small impact on downtime. However, the further along the operational phases in preparing beams for physics, the greater the impact.

Figure 6: Distribution of Operational Mistakes



Human Error Examples

The following is a non-exhaustive list of instances of human error, showing the most common mistakes.

- Errors while overriding the Safe Beam Flag (SBF) with Setup beam. Unintentionally forcing SBF to false. Errors with masks and hidden interlocks. Intensity over allowed threshold with respect to energy.
- Incorrect sequence execution. For example, switching on the ALICE Dipole instead of the Solenoid.
- Errors in MD setup and recovery from MD. E.g. loading coarse collimator settings without BETS-TCDQ mask set.
- Preparing a Hypercycle change with circulating beam, resulting in changes to Safe Beam Parameters.

Human Error and EquipState

A frequently occurring task in LHC beam operations in 2016 was the recovery from power converter faults. This process requires an interplay between three separate applications. Equip State, the QPS Circuit Synoptic and the PIC controller (see list of prioities from Evian 2015 [1]) During this process of re-arming and resetting, there is, amongst others, a non-negligible risk of switching off the power converters in a complete sector by mistake, as EquipState has no requirement to confirm global execute commands. In such cases the impact on downtime can be one extra precycle taking 40 minutes.

Human Error Defences

While human error can never be completely eradicated, attempts can be made to catch commonly occurring errors before they provoke a protection beam dump or have other impact on machine downtime. Mitigation measures were already added to the Sequencer and Software Interlock System in reaction to some operational mistakes. The following are some more suggestions based on the errors experienced in 2016.

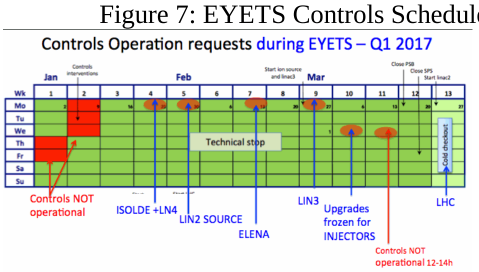
- Confirmation of critical or global execute commands. Popup confirmation should be used where (and only where) there is a risk of errors.
- Improved checks from state machine or sequencer when Safe Beam Flag is overridden should be implemented.
- Working in pairs as a team can often help prevent mistakes and is highly recommended. This is especially important outside normal working hours, during the night or during special modes of operation which break from the normal routine.

PLANS FOR EYETS

Plans for the Extended Year End Technical Stop are outlined as follows [4].

- Controls maintenance from 5th to 13th January. CO services will not be available during this period.
- Development on core controls services to be frozen by 8th March 2017.
- All application software will have to be ported to the CBNG build tool. Training is required for application software developers and will be given in due time.

Figure 7: EYETS Controls Schedule



Work in the LSA Team

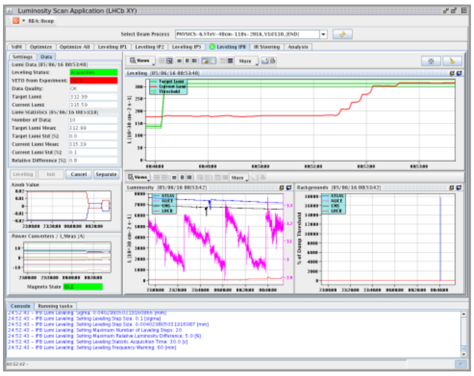
The main work plans within the LSA team is as follows.

- Introduction of Functions and Function List types in FESA3, CMW and FGCs.
- Better setting archiving, to properly resolve the slowness issues experienced with setting regeneration. Maintain reasonable limits on dataset cache size.
- Consolidation of LSA Suite. With a view to the eradication of individual applications.

Work in the OP Software Team

The main focus of the OP software team will be on further developments to the Luminosity Scan client and server, with a view to eradicating the old Luminosity Scan application (which was still required in 2016 for luminosity levelling in the separation plane). It will later be extended to include facilities for crossing-angle levelling and Beta* levelling.

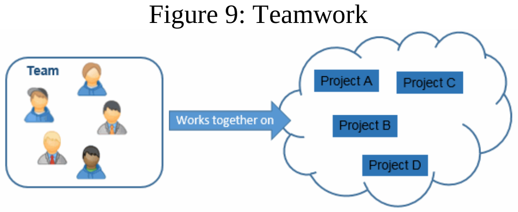
Figure 8: Luminosity Levelling (old application)



OP Software Teamwork Approach

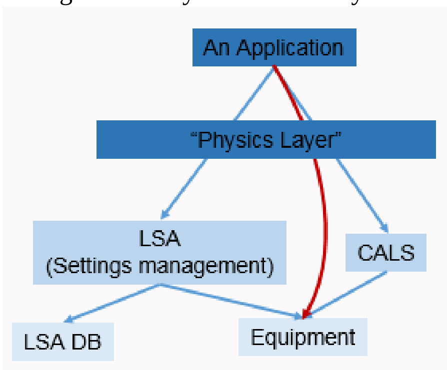
During 2016 it was decided to try a teamwork approach to software development within the LHC operations section. A group of five volunteers was formed. While being slow to get started using a new approach and working techniques, it was agreed that this approach will be of benefit in the long term. One significant issue faced by software developers is the ever increasing burden to maintain software following the author's departure from CERN. A teamwork approach to developing new software will alleviate this problem in the long term.

Figure 9: Teamwork



When developing new software, care is taken to maintain a layered control system, where the application client layer can remain thin and light, and tools from the underlying business layer can be easily reused by different applications.

Figure 10: Layered Control System



CONCLUSION

The LHC Control System has reached an excellent level of stability and efficiency in 2016. New tools are contributing to fast and efficient operation. The human factor should be kept in mind, and attempts made to analyse and catch errors before they have an impact on downtime. A teamwork approach to software development projects is the way forwards. There is much work in progress during EYETS 2017. Notably for CBNG build tool, consolidation of LSA suite and further developments to the luminosity scan facility.

ACKNOWLEDGMENTS

The author would like to thank the following for valuable discussions and contributions to this paper.

K. Fuchsberger, L. Ponce, M. Solfaroli, D. Jacquet, G. H. Hemelsoet, M. Hostettier, G. Papotti, J. Wenninger, M. Albert, R. Gorbonosov, M. Gourber-Pace, G. Kruk.

REFERENCES

[1] K.Fuchsberger "LHC Controls, and OP Perspective", Proceedings of the 2015 Evian Workshop on LHC Beam Operation, CERN-ACC-2015-376.

[2] K.Fuchsberger, "LHC OP Software Priorities 2016"

[3] S. Ganguly "Human error vs. Work place Management in modern Organizations", http://www.iracst.org/ijrmt/papers/vol1no12011/3vol1no1.pdf

[4] M.Gourber-Pace, "EYETS Schedule 2016-2017", https://wikis.cern.ch/display/SUWG/EYETS+2016-2017