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TOWARDS A COMMON MONITORING SYSTEM FOR THE ACCELERATOR AND TECHNICAL CONTROL ROOMS AT CERN

G. Arduini, C. Arimatea, M. Batz, J.M. Carron de la Morinais,
D. Manglunki, K. Priestnall, G. Robin, M. Ruetten, P. Sollander

CERN, Geneva Switzerland

Abstract

The communication and coordination between the CERN accelerator and technical control rooms will be a critical issue for an efficient operation of the LHC and its injectors, which are expected to provide also beams for fixed target experiments, for detector component tests and for other activities including machine development. Early detection of faults in the accelerator and technical infrastructure (electricity, cooling, etc.) and their possible consequences on operation are useful not only to prevent major breakdowns but also to recover from them and to reschedule efficiently machine operation to satisfy the overall beam time requests from the different and concurrent users. To meet these requirements a method to define and provide common monitoring tools for all the actors involved in machine operation has been established. This method has been applied to the SPS accelerator and is being implemented in the PS complex and in the SPS experimental areas.

1 INTRODUCTION

At present the operation of CERN's accelerators and of its technical infrastructure is performed by different teams working in three different control rooms with different monitoring and control systems:

- the Meyrin Control Room (MCR - CERN Meyrin site - Switzerland) [1]: operating the LINAC, PS Booster and PS (SPS injectors) and of several experimental facilities (ISOLDE, East Hall, nToF, Antiproton Decelerator),
- the Preveessin Control Room (PCR - CERN Preveessin site - France) [2]: operating the SPS (and formerly of LEP) and in the future the Large Hadron Collider (LHC),
- the Technical Control Room (TCR - CERN Meyrin site - Switzerland) [3]: operating CERN's technical infrastructure comprising electricity, cooling, ventilation etc. that all accelerators and experiments depend on.

The technical infrastructure of the LHC is expected to have a more serious impact on its operation as compared to present and past accelerators, including LEP [4]. The prevention and management of major breakdowns becomes more important to increase the accelerator's efficiency by the reduction of restart times. Therefore the activities and responsibilities of the different actors (MCR, PCR, TCR, stand-by services, etc.) contributing to the overall accelerator system operation have to be defined, and a common and homogenous method has to be established to monitor the status of the equipment needed for a given mode of accelerator operation. Due to the different work methods and the geographical distance between the control rooms this homogenisation is of particular importance.

This approach has been applied to the SPS machine and its technical infrastructure to tune the method and to establish a set of recommendations for its implementation and maintenance in view of an extension to other accelerators or experiments, as e.g. CPS, LHC, experimental areas and LHC experiments.

2 MONITORING SYSTEM ENGINEERING

A key element and the starting point for the monitoring and the restart of an accelerator after breakdowns is the definition of a set of modes of accelerator operation (operation scenarios) matching the beam time requests from different and concurrent users (fixed target experiments, detector component designers, accelerator physics experts). The main purpose of such a schematisation is to establish a set of common objectives to restart an accelerator that all the actors focus on. These operation scenarios also provide basic criteria to estimate the impact of a failure on the users and to redefine priorities and schedules in a transparent form.

Figure 1 shows the concept of the engineering method. On the basis of Accelerator Operation Scenarios (e.g. beam acceleration, beam extraction) the application of the Monitoring Engineering results in Operation Oriented System Documentation, which is in turn implemented in Task Oriented Monitoring Diagrams and Tools. The documentation is extracted from the system and process documentation of the concerned accelerator and its technical infrastructure and is optimised for operation in close collaboration with equipment specialists. It shall become part of the regular system documentation. The monitoring information that is needed to integrate all this in the remote supervision systems is defined and becomes part of the system specification.

The following steps characterise the Engineering Monitoring that have been identified to match above-mentioned objective. They are applied in parallel to the technical infrastructure and to the accelerator components:

- Individuation of the actors (control room operators, stand-by services, equipment experts etc.) and their roles and responsibilities
- Individuation of all main systems/processes (e.g. vacuum, magnets, beam instrumentation) of an accelerator or experiment essential to their functioning

- Individuation of the technical infrastructure (e.g. electricity, cooling), on which the accelerator and experiment systems depend
- Individuation of the sub-systems/processes of the technical infrastructure (e.g. cooling towers, demineralised water production and distribution)
- Identification of the inter-dependencies between systems, processes and sub-processes and the correlation of their functions integrating the technical infrastructure and accelerator systems on a single representation
- Construction of the ideal restart sequence based on the inter-dependencies and correlation in the form of diagrams
- Identification of the critical paths for each operation scenario
- Integration of the results in the monitoring systems of each actor
- Standardisation of system names and abbreviations

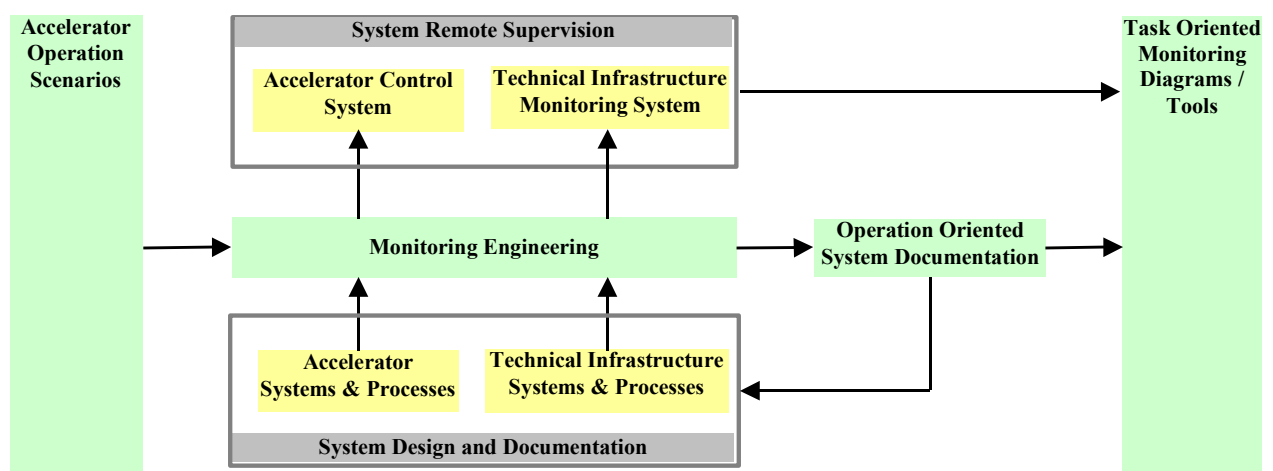


Figure 1 Concept of the engineering method and its implications

The output of this method is a set of diagrams representing the systems and their correlation, as well as the sequence and the logic of the accelerator restart and its technical infrastructure. Those diagrams are identical for all actors and shall be implemented in the form of Human Computer Interfaces (HCI). They assist the control room operator in the correct and rapid assessment of equipment faults and their implications for the user. They help as well to find the best restart strategy based on process dependencies (critical paths), process functions and nominal operation values and limits (e.g. trip temperatures of magnets). With this, priorities for the interventions of stand-by services and experts are established to respond to the accelerator's operation scenarios. The diagrams also increase the understanding and collaboration between the different control rooms and equipment groups by creating a common language.

This approach could also be used to evaluate the impact of preventive maintenance on a piece of equipment and provide additional input for scheduling machine exploitation. Furthermore, it can help to assess the impact of an equipment fault, which is in a warning state (degraded operation). The reduction of the down time can be achieved by implementing an early detection system of deteriorations of operating parameters of equipment in the critical path (e.g. an increase in the temperature of the demineralised water of the main magnets could trigger a warning so that the main power converters can be stopped before the trip level is reached).



3 IMPLEMENTATION

The implementation of the HCI's is done in the form of task-oriented tools, which integrate the more detailed process monitoring tools into a global structure and become the standard tool for operation,

see Figure 2. In general only the “Process Equipment Level” and the “Alarm Displays” are considered and implemented for operation, i.e. the “Process Synoptic Diagrams” and “Process Analysis Programs”. The engineering method adds another three levels to the synoptic process diagrams and the operator uses them in parallel with the alarm facilities:

- a. The “General States Overview” enables the operator to evaluate the availability of systems necessary for the functioning of the entire accelerator and the technical infrastructure directly connected to the latter at a glance. It shows all systems and all locations together, see Figure 3.
- b. With the “Accelerator Functionality Level” the operator can assess system states quickly, verify the correctness of the standard restart procedure and establish alternative procedures, if the situation requires it at the time of a breakdown. One of these diagrams is necessary per operation scenario, representing the details of the accelerator equipment and the general states of the technical infrastructure on one single diagram, see Figure 4.
- c. The “Detailed Technical Infrastructure Monitoring Diagram” serves the same purpose but concerns the details of the complex technical infrastructure. It shows the systems and sub-systems required by the machine in detail, see Figure 5.
- d. On the “Process Equipment Level” specific diagnosis programs for the accelerator and technical infrastructure are available. Those correspond to today’s operation tools and allow the analysis of the processes in detail and remote equipment control.

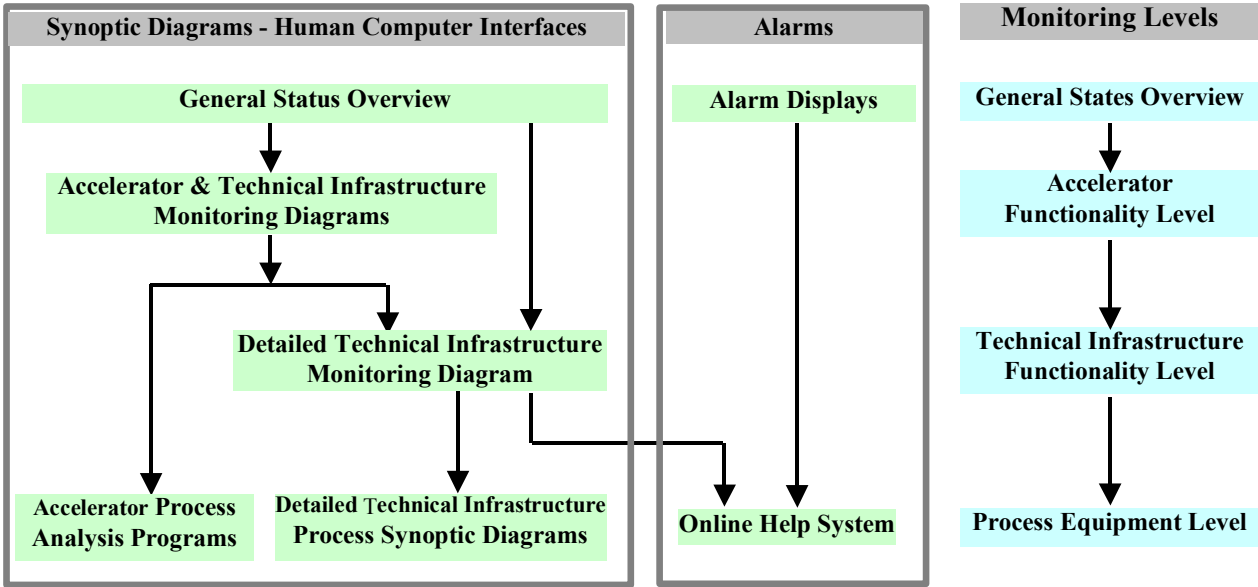


Figure 2 Context of the task-oriented monitoring tools

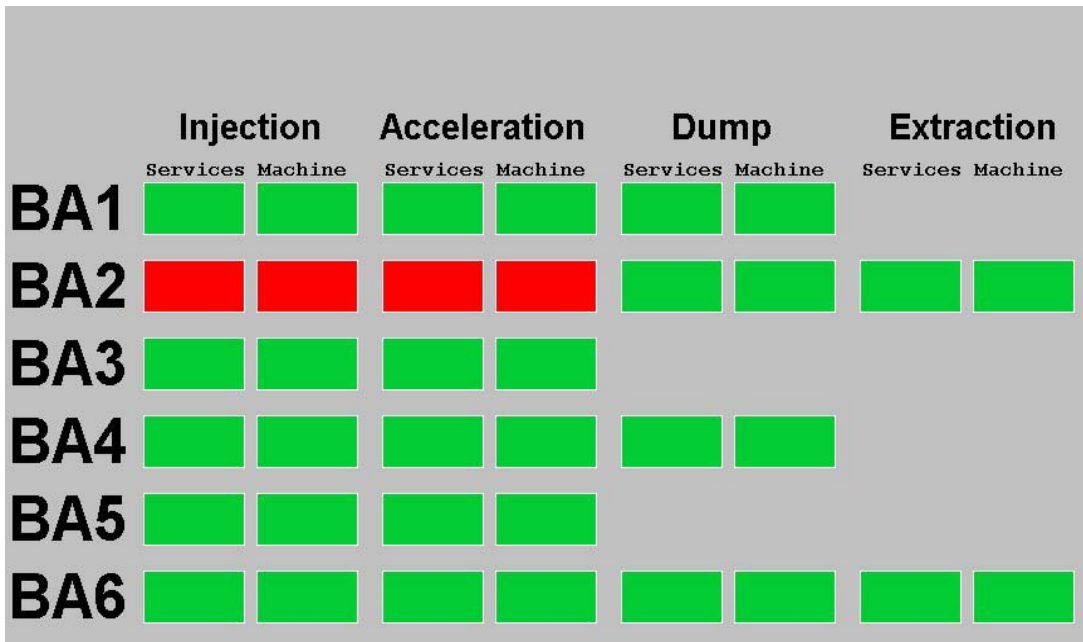


Figure 3 Example of the General states Overview for the SPS

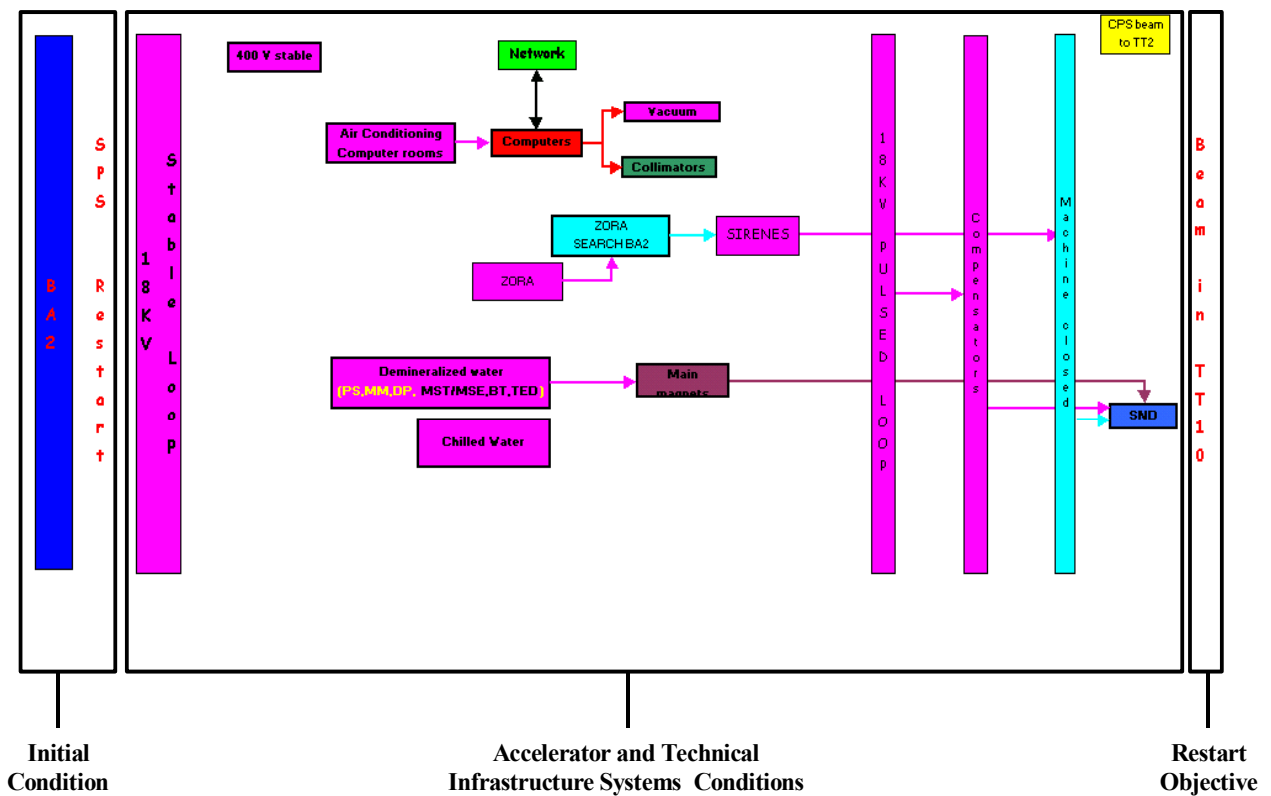


Figure 4 Example of an Accelerator and Technical Infrastructure Monitoring Diagram

The restart diagrams will be integrated in the monitoring system of each actor. For a correct animation of the human computer interfaces the details (monitoring tags) of each systems and sub-systems have to be identified and structured in a logic that determines the fault states, or summary states that define the state of availability of the systems, see Figure 6.

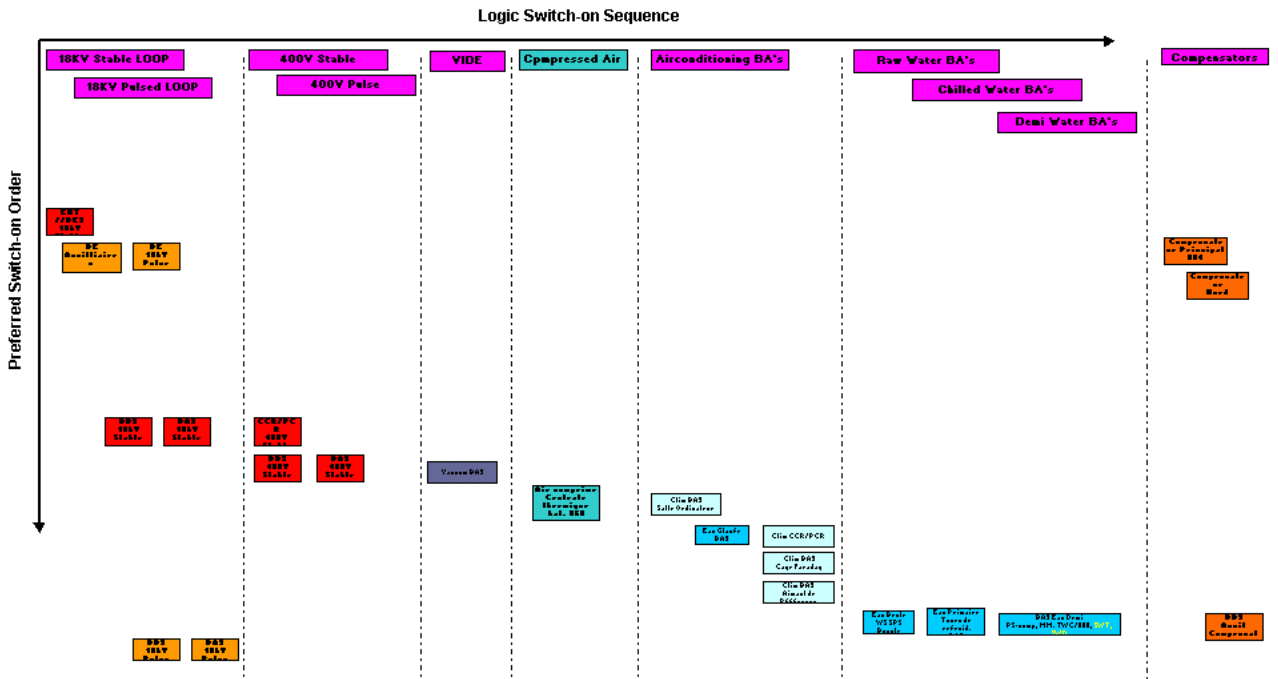


Figure 5 Example of a Detailed Technical Infrastructure Monitoring Diagram

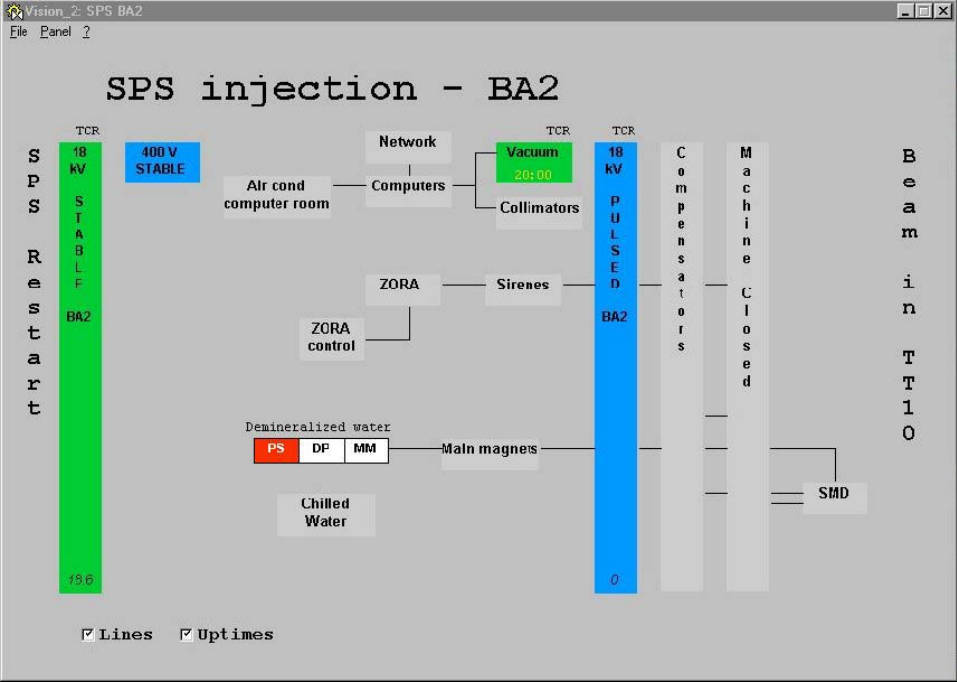


Figure 6 PVSS implementation of an Accelerator & Technical Infrastructure Monitoring Diagram

The Accelerator and Technical Infrastructure Monitoring Diagrams show systems, sub-systems and system correlation, the information on the availability of physics, the main system processes (accelerator and technical infrastructure), the state of the critical paths and the system dependencies. They contain the following information, Figure 4:

- The buildings that contain the accelerator and technical infrastructure,
- The preferred "geographical" switch-on order; i.e. the order of the technical buildings to restart,
- The logical switch-on sequence; i.e. the sequence, in which the systems must be restarted according to technical constraints and interaction,

- The attribution of systems to the different actors involved,
- Check-points that interrupt the restart process, if they are not available: including down-stream and up-stream accelerators.

In the case of a break down or during the start-up of the accelerator the operator restarts the processes beginning in the upper left corner and the accelerator is fully available when reaching the lower right corner and all the intermediate elements are available. Three different degrees of dependencies and time correlation can be distinguished:

- The correlated system cannot function, if the technical infrastructure is missing
- The correlated system can function during a limited period of time without the technical infrastructure system
- The correlated system is needed to assure the monitoring or control.

3.1 Tests and Maintenance

The efficiency of the monitoring tools and of the related procedures to re-establish or maintain beam conditions depends on the correctness of the information available on the systems and their correlation. Therefore an important effort both from operation and equipment groups must be devoted to maintain and manage the data related to the engineering method and the monitoring tools. A validation and maintenance procedure will have to be established and adequate time for tests will have to be provided during shutdown, cold checkout or setting-up with beam. Post-mortem analyses of the incidents shall systematically be carried out to find possible improvements of the monitoring tools. The following aspects should be covered by such an analysis:

- Completeness of systems and processes and their correlation necessary for the operation of the accelerator and the technical infrastructure,
- Synchronisation of the restart of the technical infrastructure and accelerator systems; i.e. to have the technical infrastructure ready on time to start an accelerator or experiment,
- Identification of potential sources of faults that would need an early detection system; e.g. unusual temperature increases that are still in the acceptable limits but risk exceeding them,
- Identification of (critical) systems that shall be secured against breakdowns; e.g. due to electrical perturbations,
- Completeness of monitoring information in the form of alarms, process diagrams etc.

4 PERSPECTIVES

Accelerator operation of the technical infrastructure has to be focused on maximising the overall availability of the accelerator by reducing the time to restart after a breakdown. To move to a common monitoring system for the accelerators and the technical infrastructure at CERN, seems to be crucial to achieve this goal by improving the collaboration and understanding between the different control rooms and other actors implied in accelerator and experiment operation.

The monitoring engineering described in this paper has been developed in collaboration with the PCR and MCR and its application to the SPS proved that it covers the above-mentioned requirements and objectives [6], [7]. The natural extension of this experience gathered on the SPS, are the SPS experimental areas, the PS complex and its experimental areas. Future facilities such as the LHC and CNGS will be operated concurrently with existing ones (e.g. the North and West SPS experimental areas, the PS East hall, the nToF facility, ISOLDE). Early diagnosis of an equipment failure and of its implications will be an important input to establish alternative operating scenarios and to re-schedule beam time distribution among the users that fit with the estimate recovery time.

The extension to the LHC is, however, challenging and the following considerations have to be taken into account to prepare TCR and accelerator operation in time:

- Little or no operational experience exists for the new facilities and the users and actors are not yet defined and no operation experience exists in particular as far as the correlation of the different technical systems is concerned
- The system documentation must be available early, containing process inputs, outputs, positioning, functionality to fulfil, it's purpose and the user
- The results of the monitoring engineering method and the needs described have to be integrated in the specifications of monitoring and control systems so that they are fully considered during development and contract execution
- The monitoring tools shall be available for the commissioning phase so that errors can be detected and corrected before the beginning of LHC operation.

5 CONCLUSION

An engineering method has been defined for the monitoring of the CERN accelerators, their experimental areas and their technical infrastructure systems. This method has been successfully applied to the SPS accelerator and a prototype of a Human Computer Interface is being implemented for testing during the next SPS start-up [5]. This tool will be available in the PCR and the TCR and, once defined the operational scenario, should make the restart procedure more transparent to all actors involved. This approach could also be used:

- To evaluate the impact of preventive maintenance on a piece of equipment,
- To provide additional input for scheduling machine exploitation and
- To train newly recruited operators and external contractors.

6 REFERENCES

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