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REDESIGN AND UPGRADE OF THE LHC ACCESS CONTROL SYSTEM

T. Hakulinen, S. Di Luca, G. Godineau, R. Nunes, G. Smith, CERN, Geneva, Switzerland

Abstract

The old LHC Access Control System (LACS) was based on a single access control solution, which integrated software and hardware into one monolithic application encompassing all the different subsystems (access control, video surveillance, interphones, biometry, equipment control, safety elements). Both the hardware and software were approaching end-of-life by the vendor before the CERN Long Shutdown 2 (LS2). The new design is based on a distributed approach, where the different subsystems are integrated in a flexible manner with well-defined interfaces, which will permit much easier single subsystem management, upgrades, and even full replacements if necessary. From the system point of view, the focus is on the advantages that this redesign brings to system operation, testing, and management. Procedurally the interest is in the overall management of a very complex in-place upgrade of a system, where the new implementation needed to coexist with the old during its constant simultaneous solicitation over the LS2.

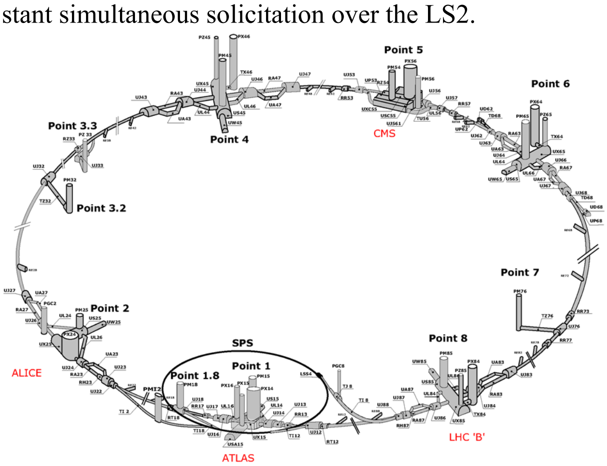

Figure 1: The LHC underground areas (not to scale).

MOTIVATION AND SYSTEM DESIGN

The LHC Personnel Protection System (PPS) consists of two components, the LHC Access Control System (LACS) and the LHC Access Safety System (LASS). The LACS manages user access to the LHC underground areas (Fig. 1) by enforcing strict conditions on user identification, authorization, authentication, and accounting. Operators can set the access modes of individual zones from fairly relaxed "General", to more stringent "Restricted" requiring a personal safety token for each user, and up to "Closed" forbidding all access to a zone. Users access a zone via a Personnel Access Device (PAD), which enforces unicity of passage and biometric authentication. Material is passed through a Material Access Device (MAD), where automated personnel detection ensures that only material and no persons can pass into the zone unaccounted. A double LHC access point is shown in Fig. 2.

Figure 2: LHC access point with MAD and two PADs.

The LASS manages the safety conditions of all zones by monitoring various "Elements Important for Safety" (EIS), which include access doors and beam safety elements, as well as radio frequency (RF) equipment, power converters, safety tokens, and statuses of the upstream injector chain (injection from the SPS via the TI2 and TI8 tunnels). The LASS will allow passing the machine into access or beam modes according to the detected conditions, and interlocks the machine if these conditions are not met.

While functionally separate systems, the LACS and the LASS operate in unison to guarantee the safety and availability of the LHC to the users. Most access devices (access points, sector doors) in the LHC involve both systems and changes to one often also affect the other.

The original LACS was implemented for the initial LHC project and commissioned in 2008 [1, 2]. The LACS was based on a single monolithic access control application, Evolynx by Cegelec, which, in addition to all usual access control functions, managed biometric authentication, PAD and MAD automation, inter-sector door automation, interphones, and video surveillance. The Evolynx product was at end-of-life and a comprehensive upgrade of both software and hardware was required. This upgrade comprised a full redesign of the control architecture of the various LACS subsystems:

- New access control software and hardware: A commercial access control application NEDAP was selected for managing the access authorizations per user and access zone. The same application is already used at CERN in the PS access control system and the CERN site access control system, and it is also used in the new SPS access control system [3].
- New operator interface: The focus was on the main access operator functions, in particular performance and ease of use for everyday operations, while still offering a detailed view of the entire system when necessary (Fig. 3).

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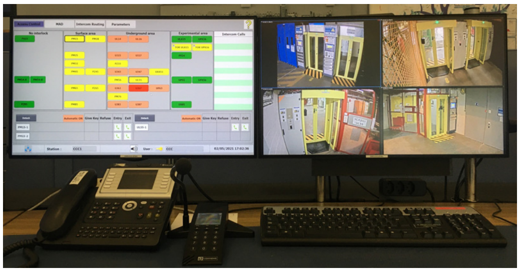

Figure 3: LACS operator interface. Access point controls are on the left and video feeds of the selected access points on the right.

- MAD replacement at 4 LHC access points to match the MAD dimensions with larger lifts installed by the LHC lift renovation project requiring supplementary civil engineering works and cabling adaptations.
- Access point and access door automation upgrade: 49 new instrumentation racks were equipped for the LHC access points (including the test platform and 2 future HL-LHC access points). Also, 18 sector door racks and 2 central control racks were refurbished. The entire supervision and control layer of the access points including PADs, MADs, and sector doors was re-implemented from scratch. The old control units of these devices were removed coupled with the associated cabling modifications as the PAD and MAD automation was centralized in the access point PLC.

The guiding principle in the design of the new LACS was to manage the various subsystems separately with a very light integration and clearly defined system interfaces. For each subsystem its specialized application would carry out its tasks with its own hardware, software, and native management utilities. In contrast to the deeply integrated monolithic philosophy of the old LACS, the new system will allow much easier subsystem management, upgrades, and even full replacement with minimum impact to the other subsystems.

The overall architecture is concentrated around a central PLC, which manages the interactions between the various, often complex, subsystems. As an example, the functional specification diagram of an LHC access point is shown in Fig. 4. The access point functionality is built around a standard Siemens 1500 series PLC for all automation functions as well as an off-the-shelf fanless embedded PC for user interface management.

While the LACS renovation was the more visible part to regular users, equally important modifications were carried out on the LASS. An ambitious package of consolidation and modification items was implemented including several safety, reliability, and availability enhancements. A new access point was added to LHC site 6, with a subsequent need to revise the LASS sectorization as well. Several smaller LASS modifications were also carried out on virtually all LHC sites. This included addition of 4 new sectors to LHC tunnel zones at sites 1 and 5, where they will serve as emergency evacuation paths for the new HL-LHC galleries.

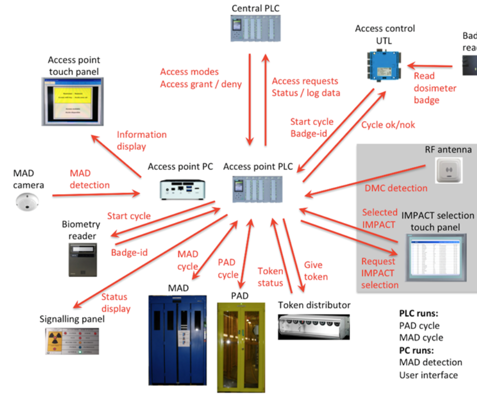

Figure 4: Functional specification diagram of the access point. The greyed-out part is a reservation for a future integration of an active dosimeter (DMC).

PLANNING AND EXECUTION

The project planning started several years before the LS2, which was scheduled for 2019-2020, and as the overall planning was known to be very tight, an optimized upgrade procedure was developed. Big upgrades to access systems can only be done during technical stops and therefore always coincide with intense solicitation of those systems. It was also necessary to keep the old system running in parallel with the new one during the upgrade. The main planning phases were:

- Full prototyping of the upgraded systems in the LHC access system off-line test bench during 2018.
- Installation of a new access point as a pilot at LHC site 6 late 2018 to debug the installation procedure.
- Upgrade of non-interlocked access points of the large LHC experiments (ATLAS, CMS, LHCb), which are not connected to the LASS. This makes installation easier and ideal for training the upgrade teams and optimizing installation sequencing.
- Planning of the general upgrade order in collaboration with the LS2 coordination and other stakeholders to maximize access point availability and to take advantage of other concurrent works like the LHC lift renovation project, which would condemn an entire pit access for several weeks and allow local surface access points to be upgraded in its shadow.
- Preparation and wide distribution of a set of precise compensatory measures for each individual upgrade to minimize access delays to other equipment groups.
- Organization of verification and validation testing for minimum nuisance and maximum transparency for other users. A detailed test protocol for each test was written and submitted for formal acceptance by the CERN LS2 Committee.

The execution window including commissioning was two weeks for a single access point and three weeks for a double access point. With the additional LASS modifications, the overall duration of the upgrade project was foreseen to last from October 2018 to September 2020. However, restrictions related to the COVID-19 outbreak delayed the final installations until early 2021.

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VERIFICATION AND VALIDATION

Extensive testing of the upgraded installations has been carried out starting early 2020 to be finished in 2021 to ensure the perfect functioning of all new and modified parts of the system and to avoid any regression of existing functionalities. Several different types of tests were carried out during the installation:

- Cabling and point-to-point functionality. These tests involve terminal-to-terminal testing of electrical connectivity as well as sensor/actuator-to-PLC signal verification. These tests are transparent to users.
- Local automation and signal transmission. These tests are carried out to verify reaction of individual sensor/actuator actions on the human-machine interface and data logging. Again, these tests are mostly transparent.
- Site-wide functional verification. These tests require the access team to take exclusive control of each LHC site one by one for short periods of time to verify the effect of local actions on the Global Interlock (GI) function of the safety system. These tests require that the entire LHC be passed in beam mode, meaning that no access doors can be breached and the other LHC sites need to be seen as safe by the GI. This can be accomplished by applying a specific hardware configuration to make them appear safe, which allows them to remain accessible during tests. Since access is blocked to the LHC site being tested, careful planning was necessary in collaboration with the LHC coordination. Occasionally, co-activity had to be accepted in areas undergoing tests, but with careful briefing and communication, passage of other teams between zones could be coordinated to minimize disturbance to everyone. An important part of the testing protocol was the use of a Siemens simulation station connected to the safety system PLC, which allowed any missing safety elements (due to unfinished EIS upgrades by other groups, for example) to be seen as safe programmatically. This also allowed manipulation of the patrol armed conditions of sectors in the strictly controlled test mode, which is a very powerful feature and a real time-saver in the LHC, where some of the zones span kilometres and might take tens of minutes for humans to patrol between repeated tests tripping the armed status.
- Local functional validation. These are validation tests carried out by the CERN Departmental Safety Officers (DSO), who are responsible for the safety of the accelerators. Local tests are carried out to validate specific safety functions, such as the interlocks for RF conditioning, powering of the superconducting magnets, and injection lines from the SPS.
- Global functional verification. These tests are extended to the entire machine. The purpose of these tests is to verify that the GI reacts correctly and without any regression with all the LHC sites connected. A small subset of tests is carried out on each site. As these tests mainly involve verification of the global safety program, it is important to allow enough time between them and the final validation to be able to analyse and fix any possible issues. The global verification tests of the entire LHC before the closing of the machine again in 2021 still remain to be carried out.
- Global functional validation. This is the final validation test by the DSO of the entire LHC machine before beam permit. All simulations and other shortcuts are removed and the access control and safety systems will be tested in their nominal capacity according to the protocol defined by the DSO.

CONCLUSIONS

The LHC Access Control System upgrade and the associated safety system modifications went altogether very smoothly, which is largely due to the careful planning and flexibility of the entire project team and excellent collaboration with the LS2 coordination. Several lessons could be learned from the upgrade project:

- Future technical stops are likely to get more complex and busy with a growing number of equipment groups needing to access the underground areas concurrently. Therefore, early planning including all the stakeholders is essential.
- The project must be able to adapt planning to changing circumstances. Luckily, the exact order of access system modifications is rarely critical, unlike some of the other accelerator subsystems, which gives our teams flexibility in planning around them.
- It will be increasingly difficult to reserve entire sites and particularly the whole machine and major experiments for exclusive safety system tests. While some will eventually be necessary, most tests can be carried out with parts of the system simulated or strapped.
- Simulation of conditions of other sites as well as local access devices during the verification tests is an extremely powerful tool. However, its use needs to be formalized both technically and procedurally to ensure its proper use.
- Flexibility in the various phases of system tests needs to be built into the initial design of new access and safety systems projects to avoid complications in the future.

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