CHAPTER 13

MONITORING AND OPERATION OF GENERAL SERVICES

13.1 INTRODUCTION

The availability of the LHC technical infrastructure (general services) has an important impact on LHC operation. Most accelerator components rely on it either directly, or indirectly, both during LHC beam operation and during shutdown. Therefore the technical infrastructure monitoring and operation has to be guaranteed 24 hours a day and 365 days per year, especially for the correct functioning of the LHC safety systems. In this context the general services consist of the following systems located on the surface or underground installations as well as in the LHC experiments:

- Electrical distribution systems
- Cooling and ventilation
- Fire, gas, oxygen deficiency detection and evacuation systems
- Access safety system.

This chapter describes the concept of the monitoring and operation of the general services for the LHC. It focuses on 24 hour operation, maintenance activities and the operation from the control room. In addition the technical infrastructure monitoring (TIM) control system and the computer aided maintenance management system (CAMMS – MP5) are described.

13. 2 MAINTENANCE & OPERATION

13.2.1 General Services Maintenance

The general services operation is shared amongst a number of equipment groups. The operation of theses different systems depends on control systems which are, themselves, considered to be part of the LHC technical infrastructure. Figure 13.1 shows the main general services systems.

Table 13.1: General Services Systems

General Services Systems	Description
Safety systems	Fire, gas, oxygen deficiency detection and evacuation systems, access safety
Cooling and ventilation	Pumping stations, fluid distribution networks, cooling water, air-conditioning, ventilation, heating, reject water
Electrical distribution	Electricity high, medium, low tension, normal and secured supplies, emergency stops
Communication, control and monitoring infrastructure	Control hardware, front ends, servers for TS general service equipment only

Operation activities can be categorised as follows:

- System/accelerator start-up,
- Full/partial shutdown for maintenance,
- Normal/steady state operation,
- Breakdown and emergency scenarios.

Start-up and shutdown periods are used for preventive maintenance, process optimisation and upgrades. These activities are planned and co-ordinated by the equipment groups in close collaboration with the users. The control room has only a support role for the teams in the field.

The entire general services' equipment is itemised in a Computer Aided Maintenance Management System (CAMMS – MP5), see Sec. 13.4. This is used to plan ahead preventive equipment maintenance during the entire equipment lifecycle. MP5 is also used for extensive fault and breakdown reporting to improve process availability and reliability.

The operation and maintenance of the technical infrastructure relies to a considerable extent on industrial support contracts. These contracts ensure the maintenance and repair interventions both during normal working hours and out of working hours (stand-by service). CERN staff is available to provide assistance to the contract personnel, in particular during breakdowns when the competence of the stand-by service may be insufficient. Tab. 13.2 summarises the intervention teams and their obligations.

Table 13.2: Intervention Teams and Obligations

System	Industrial Support Contract	Time Limit	Contract Coverage	CERN Staff
Fire, gas, oxygen detection and evacuation systems	Schrack – Soteb	2 hours	24 h/365 d	First person found basis
Access control and safety radiation zones	None	None	accelerator run	CERN stand-by service
Site access control	GTD-Cégélec	4 hours	24 h/365 d	First person found basis
Cooling and Ventilation	ENDEL	30 minutes	24 h/365 d	First person found basis
Electrical Distribution	E065/ST	30 minutes to be on-site 15 minutes diagnostic	24 h/365 d	First person found basis
Diesel generators	E072/ST	360	24 h/365 d	First person found basis

13.2.2 Technical Control Room (TCR) Operation

Introduction

The TCR is a CERN-wide 24 hour service that is available for any technical related monitoring and operation task that fits its workload and skills profile. The TCR is manned with two operators on shift all year round. They have a higher technical diploma in domains such as electricity, cooling and ventilation, process control, mechanics or computing. Depending on the shift roster additional operators may be available during CERN opening hours, to reinforce the team on duty, e.g. during breakdowns.

The state of the systems under control in the TCR is monitored continuously by the monitoring and control systems. Each equipment group provides this information using their proprietary system and the information relevant to the TCR work is transmitted remotely to the control room using TIM, see Sec. 13.3. The TCR services can be split into two main categories:

- As a site facility call centre (Service 72201)
- For technical infrastructure, monitoring and operation.

It is estimated that on average the workload is shared equally between these categories and depending on the operation mode the workload varies considerably. Tab. 13.3 summarises the TCR services related to the general services.

Table 13.3: TCR Services for LHC General Services

TCR Service	Description
General services monitoring	24 hours, 365 days
On-site & remote interventions	Mainly outside normal working hours
Co-ordination and follow-up of troubleshooting activities	Comprising control rooms of water and electricity suppliers (SIG, EDF)
Optimise restart after breakdowns	See chap. 13.2.3
Incident analysis and reporting	Anytime
Energy monitoring	24 hours, 365 days

Site Facility Call Centre

The site facility call centre registers and dispatches faults in CERN's technical site facilities, such as office buildings, restaurants etc. This activity is provided in collaboration with the Facilities Management Group (FM) and its industrial support contractor. In addition, any request for repair or technical assistance that is not part of standard procedures and contracts, is processed in the TCR to provide a pragmatic solution with minimum delay.

The workload of this service varies considerably and can be in conflict with the workload necessary for the LHC general services operation, due to the available TCR resources. Once LHC exploitation has started, priorities and resources will be reviewed.

Technical Infrastructure Monitoring and Operation

The remote monitoring and operation of CERN's technical infrastructure and in particular of the LHC general services, is centralised in the TCR. This makes the TCR a main actor during normal operation and breakdown of the general services, where it is in charge of the co-ordination of intervening teams of the TS equipment groups. In addition, during normal operation one of the two TCR operators on shift carries out first-line on-site repair interventions. These interventions are a rapid way to achieve a first fault diagnosis and so improve the setting-up of the appropriate compensatory measures, in many cases allowing fault recovery without the intervention of a specialist or stand-by service [1]. These interventions are, in general, not possible during breakdowns because the workload requires a minimum of two operators in the control room. This is due to the fact that several thousand fault signals have to be handled and co-ordination and communication between the intervening teams has to be managed.

As a consequence of an alarm or any other notification of a malfunction, the TCR makes an impact and cause analysis before triggering the appropriate corrective intervention. Operator help systems and procedures are established to assure reliable situation assessment. Fast and effective interventions are important to reduce LHC downtime and keep the necessary level of safety.

All interventions related to general services' equipment are traced using MP5. It is also used to generate work orders for CERN staff or the related industrial service contractor. During normal working hours the team responsible receives the work orders directly via MP5 and takes it in charge automatically. Out of normal working hours the stand-by services are called in by the TCR operator manually. Control room operations not related to a particular installation or equipment are documented in an electronic logbook.

Other TCR Services

In addition to the general services monitoring and operation, the 24 hour monitoring of some systems that are part of the accelerator infrastructure has been delegated to the TCR, e.g. the SPS beam vacuum. This is motivated by the qualification of the TCR operators, which is well adapted to these tasks and to the fact that the accelerator control rooms are only manned during beam operation. For LHC exploitation it is proposed to delegate similar tasks to the TCR. Some additional areas under discussion are shown in Tab. 13.4.

Table.13.4: Future TCR Services Related to Accelerator Infrastructure and Future Services

TCR Services Today	**Description**
SPS beam vacuum monitoring	Pumps, pressure, controls
Cryogenic installations: backup calling	Backup for automatic alarm messaging system
Monitoring of communication, control and monitoring infrastructure	E.g. controls network, vacuum servers
Future TCR Services	**Description**
513 control room operation	Transfer of computer centre operation team to TCR
LHC experiment system monitoring	During the shutdown when experiment operation is not available, during the run to be defined
Vacuum	Extension to include PS, LHC & QRL considered

With the integration of the TCR in the new CERN Common Control Centre (CCC), the service structure of the TCR has to be reviewed. This will be a way to create synergies and more flexibility with the operation teams that carry out tasks requiring similar qualifications and operator skills. Appropriate structures need to be set-up to handle management differences arising from the difference between industry-like, round-the-clock operation of the TCR as opposed to the accelerator operation. By adapting man power and workload profiles, the TCR can evolve its services quickly and flexibly to future needs of the LHC.

13.2.3 Major Breakdowns

General

In the context of the restarting of accelerators and experiments after major breakdowns, such as a major power outage, the impact analysis becomes a complex task. To achieve a quick recovery of beam or experiment operation additional aid for the analysis and decision making processes in the control rooms and for field operators and equipment groups has to be provided.

This aid must be based on the optimal restart sequences as seen from the accelerator operations point of view. These sequences are different for different operation scenarios and have to take into account the LHC injectors, too. Operation scenarios might be SPS proton beam for fixed target physics or SPS proton beam for LHC injection. These restart sequences are established and validated by operation teams and the equipment groups of ST and AB divisions. In consequence, the progress of the restart activities is made available and transparent to all the operation teams involved (control rooms, CERN equipment specialists, stand-by services and contractors). During major breakdowns the control rooms co-ordinate all interventions and activities following these sequences. Moreover, re-scheduling becomes possible taking into consideration the availability of accelerators for concurrent modes of operation.

Tools

Prototypes of monitoring applications based on the above-mentioned principles are available for the PS complex and the SPS. Status and fault information of the accelerator equipment and the related general services are synthesised in one single application available to all control rooms, named GTPM [2][3]. Their usage resulted in considerable progress in co-ordination and restart time reduction. As a side effect these applications are an excellent tool for operator training. Operation teams, general services and LHC equipment groups, as well as the associated control and monitoring teams will have to collaborate to achieve the extension of this concept to the LHC.

Event Reports

Faults in the general services resulting in an interruption of accelerator or experiment exploitation are documented in Major Event Report [4]. This report contains a detailed analysis of the event, its causes and consequences. All the involved parties contribute to this analysis, including the accelerator and experiment control rooms. Improvement issues, either technical or organisational, are identified and proactive measures are taken to reduce fault impacts and recovery time [5].

13. 3 TECHNICAL INFRASTRUCTURE MONITORING (TIM)

13.3.1 Introduction

The monitoring of the general services from the TCR will be made through the Technical Infrastructure Monitoring (TIM) system [6-8]. This system will replace the present TCR data acquisition and transmission system: the Technical Data Server (TDS). The TIM system has to be fully operational 24 hours per day, 365 days per year. In order to facilitate control room operation as much as possible it integrates data from various heterogeneous data sources of the general services and the LHC and its injectors.

It provides a homogeneous monitoring environment to the TCR following design standards, see Sec. 13.3.3. The accelerator control rooms use human computer interfaces of the TIM system such as the restart applications after breakdowns (GTPM) and specific process applications for fault assessment, which still need to be specified.

The TIM system has to provide the following functionalities:

- Data acquisition from approximately 100 different data sources,
- Human computer interfaces in the form of process monitoring applications,
- Data logging system and trending utility,
- Alarm Display,
- Alarm notification through automatic telephone calls using the Alarm Notification System (ANS).

For cost and efficiency reasons some of these elements will be developed as common tools for use by all the control room operators. The implementation of the complete operational TIM system will be ready for the LHC start up in 2007. However, most of the components have to be used earlier in test environments such as the QRL commissioning and thus have to be ready before 2007. The aim is to have a partial TIM system implementation as of 2004. The final system is planned to be implemented in 3 phases:

- Replacement of the existing human computer interfaces,
- Integration of common tools such as alarm screens and data logging utilities,
- Replacement of the existing TCR data acquisition and transmission system by the TIM system.

13.3.2 Architecture

The TIM system is based on industrial hardware such as Siemens PLC's and HP or Sun server machines for the operational platforms, however, it will also use standard off-the-shelf hardware for test and development environments. This has the advantage of ensuring support for the operational platform and low cost for test and development platforms.

Standard software packages will be used wherever possible. It is planned to use Linux (Red Hat Advanced Server version) for the servers and Windows (standard CERN configuration) for the operator consoles. This gives access to the complete CERN office infrastructure in parallel to the monitoring tools. Existing UNIX or OSF/Motif applications can be run using X-terminal emulation software such as Exceed during the transition from the present system to the TIM system.

Hardware Architecture

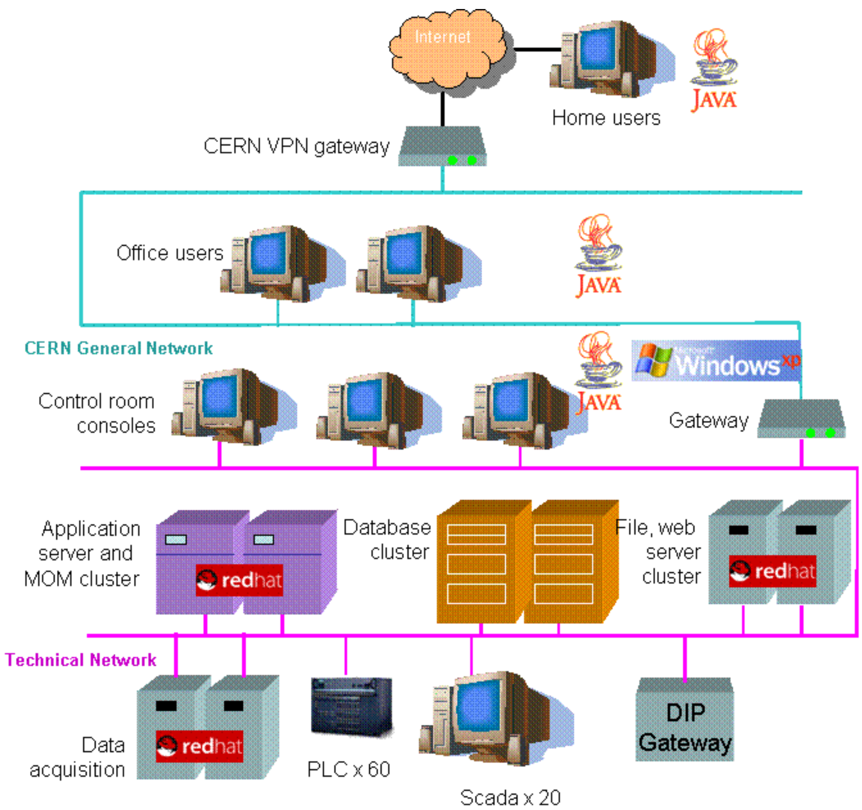

Figure 13.1: TIM Hardware Architecture

The monitoring system will rely on redundant hardware deployed in two separate locations for maximum safety and availability; one location being the current TCR building (212) and the other being the future CCC, see Tab. 13.5. The servers need air-conditioned rooms and uninterruptible power supplies. Fig. 13.1 shows the TIM hardware architecture in more detail:

Table 13.5: TI Hardware Locations

Hardware Purpose	Hardware Type	CCC	TCR - 212	IT - 513
Data Acquisition server	HP ProLiant	1	2	
Application server	HP ProLiant	1	1	
File server	HP ProLiant	1	1	
DB server off-line	Sun Solaris			1
DB server on-line	Sun Solaris	1	1	

Software Architecture

The TIM system will use component-based software architecture with standard data acquisition components, a middleware component and a set of user interface components, see fig. 13.3. Process information enters the TIM system through dedicated equipment drivers. There are two main categories of data: TS general services' equipment data and data from other domains (e.g. accelerator data, vacuum, cryogenics etc).

General services equipment is interfaced to the TIM through a PLC driver (Dsec) and the Standard Data Acquisition Library (Ddal). The Dsec is a Java application acquiring data from PLC's and updating the application server through the message oriented middleware (MOM) SonicMQ. The Ddal is also the ST-MA standard component to communicate with SCADA systems. The TIM system will provide a version of Ddal connecting to SonicMQ replacing the version now used to connect to the TDS. Thus existing applications need not be modified, only restarted using a new version of the library. This is a big advantage as most of these applications have been developed by contractors, which would make each modification time-consuming and costly.

The Oracle9i Application Server and the SonicMQ JMS-brokers will be used for the middleware, both for data acquisition and data distribution. The Oracle9i Application Server covers the business logic, persistence, configuration etc. The SonicMQ brokers handle data communication from data sources and to data clients. The data clients or user interface components connect to the middleware receiving current data and updates as they occur. Sec. 13.3.3 describes the human computer interface components in more detail.

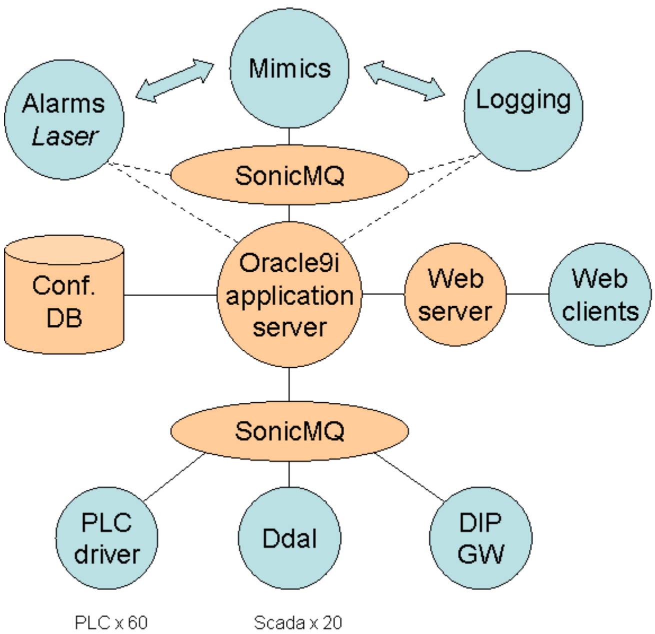

Figure 13.2: TIM Software Architecture

Data acquisition from non general services systems and data publication to external users will use the Data Interchange Protocol (DIP) gateway [9]. The DIP protocol is a standard protocol being implemented by the LHC Data Interchange Working Group (LDIWG), mandated by the CERN Controls Board to supply a protocol for inter-domain data exchange. A first version of the DIP is requested for the QRL tests in sector 7-8. The file servers host application files (human computer interfaces etc.) and the web server provides an operation portal for system administration.

Configuration

The TIM system will use an Oracle database for configuration and data persistence: the Technical Data Reference Database (TDrefDB). The data will be extracted by configuration tools for the configuration of the different layers and modules of the TIM system. This has the advantage of using a single data source and to achieve a coherent configuration for the complete monitoring chain. At the time of writing only TDS components are configured from the TdrefDB and for the TIM systems the configuration will also include the connected external components.

The reconfiguration or update of system parameters will be possible without stopping the operational system (online configuration). Similarly the configuration of one part of the system will not unduly perturb the proper functioning of another. The configuration tools must always be available and a complete reconfiguration of any operational part must be possible by any trained person (i.e. stand-by service or TCR operator). The operational operating system version and all software will be burned on a bootable CD to assure an identical environment in case of a system restart.

All software modules will be kept in the Software Configuration and Management System (SCaMS) and with this tool all installation and version changes can be traced.

Technical Network

TIM data clients access the application or file servers via the Technical Network. All applications and administrations tools will be available to specialists connected to the general CERN network. On-call specialists may connect to the system through the CERN VPN. The TIM system completely relies on the network availability but a network failure may stop the monitoring.

The new CERN technical network will be used to ensure high availability and reliable data transfer. It has to be verified that all critical network paths are either redundant or that uninterrupted service can be assured otherwise. Recent events have again shown that it is absolutely vital that network maintenance is carried out without interrupting the network. The necessary maintenance procedures must be established and approved.

13.3.3 Human Computer Interfaces

Process Diagrams

At the time of writing there are 32 monitoring applications, totalling some 700 process diagrams. These diagrams mainly concern the three domains: electricity, safety and cooling and ventilation.

The equipment groups responsible for these domains are currently implementing proprietary control systems in the form of SCADA systems. These include:

- The Electrical Network Supervisor (ENS) [10] for electrical distribution equipment
- PcVue for safety equipment (CSAM [11], RAMSES [12], LHC Access Control [13])
- Wizcon for cooling and ventilation.

These systems all offer remote access to their proprietary human computer interfaces. Wherever possible these applications will be used in the TCR, providing that they can be integrated with the other tools on the TCR operator consoles. Previously, these views were developed by the TCR and used by both the TCR and the equipment groups, re-using the SCADA tools will lower development costs and ease maintenance.

However, homogeneous operator interfaces have to be provided. One way of achieving this is by using web interfaces and hyperlinks and by respecting the TCR human computer interface conventions [14]. It is planned that at least 26 of the current 32 monitoring applications will be replaced by web access to SCADA systems.

The only exception will be the CSAM systems. The fire brigade Safety Control Room (SCR) will be equipped with the control system provided by the CSAM project. The TCR is the backup location for the SCR in case of SCR breakdown and will be equipped with the full SCADA solution for safety applications. Web interfaces are not sufficient and, in addition, technical alarms from the safety equipment (e.g. detector faults) will be transmitted to the TCR through the TIM system.

The TIM system will offer overview process diagrams, displaying systems from all these different data sources in a single application, such as the GTPM views. The TIM system also offers the possibility for operators to develop detailed views for equipment not monitored by the SCADA systems.

Data Logging

The data logging functionality is divided in two parts: data acquisition and data display. The data acquisition is currently made in an event driven way or by polling equipment periodically with special logging processes. In both cases the acquired data is written to an external Oracle logging database. Data display is performed by the "JavaGuils" client, a tool produced and used by both TS and AB departments. At present there are around 850 analogue measurements being logged and this number will increase in the future.

The LHC Logging Project [15] is setting up a new LHC data logging facility both for logging data to a database and retrieving data in a user interface. The TIM project will use identical facilities to allow cross-system correlation.

Alarms

Approximately 15 000 alarms are defined in the TDS and this number will significantly increase in the future as equipment will be supervised by the use of more detailed information. The TIM system aims for a common alarm display to be used by all services, such as the PCR, TCR, SCR and other control rooms. The LHC Alarm Service project (LASER) [16] is preparing the successor to the Central Alarm System (CAS). The TIM will use the LASER product as its main alarm screen. By doing this, the TCR will have access to any alarm through a single user interface, whether the alarm is generated by the TIM system or by a dedicated equipment control system, e.g. for the cryogenics.

13.3.4 Alarm Notification System (ANS)

The Alarm Notification System (ANS), was designed in 1998 to replace the obsolete Automatic Paging System, which had been used at CERN to automatically inform support personnel about alarm occurrences in systems under their responsibility. The ANS supports Short Message Service (SMS) paging to GSM displays and interactive voice notification. Users of the ANS are able to set their individual settings independently via a dedicated administration interface available on the NICE network.

SMS Paging to GSM

SMS is a service provided by the Swiss service provider. The ANS can send a user defined message to the SMS server when an alarm is received. The reception of a new message is indicated by an acoustic signal from the GSM. The message can be downloaded to the GSM display from the SMS server.

Interactive Voice Notification

Due to the necessity of immediate and reliable automatic notification, interactive voice notification was introduced. A user can define up to three phone numbers to be contacted in case of an alarm. These numbers are contacted by the ANS in a sequential order. The notification chain stops when a message has been acknowledged by the user. The ANS includes a speech synthesiser to handle voice communication.

Operational Environment

The ANS is an automatic extension of any monitoring system which will be updated in 2004 and will be integrated in the TIM system of redundant hardware deployment, see Fig. 13.3

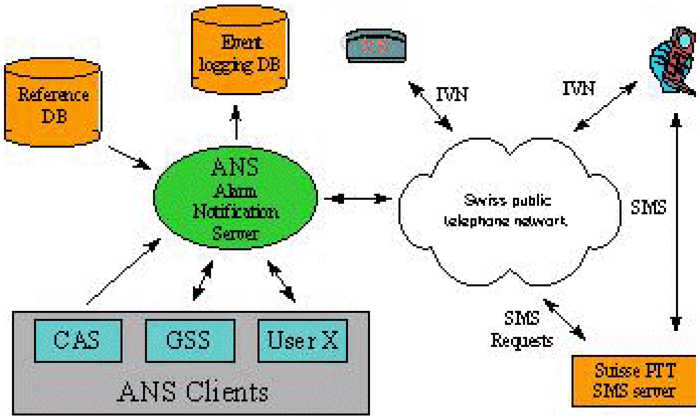

Figure 13.3: ANS Operational Environment

13.3.5 Monitoring and Control System Maintenance

In general, the control teams belonging to each specific equipment group handle first-line interventions for hardware, software and applications. They also act as a filter for additional support provided by the industrial support contract for controls (C168). This contract is only available during working hours, see Tab. 13.6. Outside normal working hours electrical (EL) and cooling and ventilation (CV) experts intervene, if available, on their own monitoring systems. Process control equipment of CV can partially be fixed by the process maintenance contract. Common support structures through service-level agreements with other CERN departments as well as common maintenance contracts for third-party products are used. TIM system providers and the system maintainers may be different depending on the type of hardware or software. The list of TIM products is shown in Tab. 13.7.

Table 13.6: Intervention Teams and Obligations

System	Industrial Support Contract	Time Limit	Contract Coverage	CERN Staff
Monitoring TCR	C168/ST	4 hours	working hours	Voluntary unpaid CERN expert
Monitoring Cooling and Ventilation	C168/ST	4 hours	working hours	First person found basis
Monitoring Electrical Distribution	None	None	working hours	First person found basis

Table 13.7: TIM Products

Product	Description
Operating System	Linux (Red Hat Advanced Server)
	Windows 2000 (CERN standard version)
Application server	Oracle9i Application Server
JMS broker	SonicMQ 5.0
ILOG tools	JViews & JRules (under negotiation with IT, AB)
Drivers	TDS gateway (used during migration phase)
	DIP driver
	ISAP driver (DsecJMS)
	TIM-LASER interface
	TIM-Logging interface
Tools	Data configuration
	Supervision module for components and the TIM system itself
Hardware	HP ProLiant server machines
	Database servers (SUN Microsystems)
	Siemens PLCs
	Windows consoles (for control rooms)

13.4 COMPUTER AIDED MAINTENANCE MANAGEMENT SYSTEM (CAMMS)

Since 1999 CERN uses MP5, developed by DATASTREAM, to manage CERN equipment or assets. The MP5 software is widely used at CERN:

- For the management of manufacturing processes of LHC assets by the EST division
- And for Computer Aided Maintenance Management (CAMMS) for technical infrastructure assets.

Tab. 13.8 details the functionalities available at CERN. The current version of MP5 is running in the standard NICE environment with Oracle tools. The ST/MA & EST/ISS MP5 support teams currently prepare this tool for the LHC. A single database for CERN in multi organisation mode with a web interface will be put in place (D7i).

Table 13.8: MP5 Functionalities available at CERN

Module	Function
Base	Functions as the prerequisite for all other modules.
	Security & administrative controls
Asset Management	Identify, track, locate, and analyzes physical assets.
	Associates documents, permits, and other data with assets.
	Establish & control relationships between assets and the associated business processes.
Work Management	Control work orders for routine maintenance, response maintenance and periodic preventive maintenance.
	Store material and task lists in a library for easy reference and retrieval.
	Determine cause and effect relationships and provides a full range of diagnostic tests.
	Generate invoices for work performed on "third-party" assets.
	Expedite work order entry.
Project Management	Allow large projects to be sub-divided.
	Compute actual costs, committed costs, and planned costs of projects.
	Include individual budget setup and management for each project and allow linking of projects.
Inspection Management	Manage condition-based maintenance by defining inspection points.
	Execute inspection jobs, triggered by time frequency and/or meters based on previous inspection results
Materials Management	Streamline parts and materials management by constantly monitoring inventory online.
	Maximise an efficient quantity on hand of store room parts (EOQ Analysis).
	Allocate materials to work orders and automatically generate pick lists for materials.
	Identify items to be requisitioned based on existing stock, forecasts, and reservations.
	Classify parts based on their percentage of total inventory value (ABC Analysis).
	Individual inventory pricing methods
Purchasing Management	Compute the cost of services using either fixed prices or time and materials.
	Control purchase order and invoicing for stocked materials, direct materials, hired labour, and services.
	Register standard contracts and register blanket orders with vendors, along with financial agreements and conditions.
	Allow vendor rankings to facilitate the purchasing process.
	Monitor the progress of quotations for materials and services.
	Maintain a library of standard ISO clauses.
Budget Management	Automate the process of setting up budgets
	Provide a link between the financial, organisational and physical structures
	Calculate a variety of financial and performance indicators.
Reports	Allow users to select pre-defined reports to track the performance of assets.

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