Preliminary
LHC@FNAL Requirements

Document 165

Edited by
Erik Gottschalk, Elvin Harms, Shuichi Kunori, Michael Lamm, Mike Lamont, Kaori Maeshima, Patricia McBride, Elliott McCrory, Suzanne Panacek, Jean Slaughter

Executive Summary

LHC@FNAL is an operations centre to be located at Fermilab. The purpose of this centre is to help members of the Large Hadron Collider (LHC) community in North America contribute their expertise to LHC activities at CERN, and to assist CERN with the commissioning and operation of the LHC accelerator and experiments. While there are no technical reasons that would prevent participation in multiple LHC experiments, the current plan is to be involved with the CMS experiment, for which Fermilab is the host institution in the U.S.

As an operations centre, LHC@FNAL has three primary functions. First, it is a place that provides access to information in a manner that is similar to what is available in control rooms at CERN, and it is place where members of the LHC community can participate remotely in CMS and LHC activities. LHC@FNAL provides a location with hardware and software that is similar, if not identical, to what is available at CERN. For instance, one can imagine that it will be equipped with accelerator consoles that are identical to consoles at the CERN Control Centre (CCC), albeit without the functionality to control or operate accelerator components. Furthermore, LHC@FNAL will have safeguards in place to satisfy CERN safety, as well as CERN computing and networking security standards.

The second function of LHC@FNAL is to serve as a communications conduit between CERN and members of the LHC community located in North America. The need for communication is expected to be bi-directional. On the one hand, LHC@FNAL can respond to requests from CERN to locate US-CMS or LHC experts and establish a communications link between these experts and CERN. On the other hand, LHC@FNAL can respond to requests from experts who need access to information that is inaccessible to individuals at home or their home institution. For example, access to some information may require special access privileges or specialized software, or may require verbal communication with someone working at a control room at CERN. LHC@FNAL can provide access to this information, and can relay information to the CCC and CMS control rooms using established communications channels.

The third function of LHC@FNAL is outreach. With accelerator and experiment consoles that replicate systems at CERN and shift operators actively engaged in LHC activities, visitors to Fermilab will be able to see firsthand how research is progressing at the LHC. Visitors will be able to see current LHC activities, and will be able to see how future international projects in particle physics can benefit from active participation in projects at remote locations.

LHC@FNAL is expected to contribute to a wide range of activities as the LHC is readied for operations. For CMS there are test beam activities, the Cosmic Challenge, detector commissioning, and operations. For LHC, activities include hardware commissioning for U.S. deliverables, LHC beam commissioning, and post-commissioning activities. Post-

commissioning activities include remote participation in LHC machine studies, support of U.S. provided deliverables, and work on luminosity upgrades. The following list shows the types of activities that we envision for LHC@FNAL:

- Participate in CMS and LHC shifts
- Participate in CMS and LHC data monitoring and analysis
- Develop and test new monitoring capabilities
- Provide access to data, data summaries, and analysis results
- Provide training in preparation for shift activities at CERN
- Assist in establishing communications between accelerator and detector experts in North America and CERN

An important aspect of LHC@FNAL is that accelerator and detector experts will be in close proximity to each other while participating in activities at CERN. The advantage of this arrangement is an economy of scale. Individuals working together on LHC and CMS activities can use the same resources in their work while sharing their insights on the commissioning and operation of the LHC accelerator and CMS experiment.

In this document we define the requirements for LHC@FNAL. It is important to note that these are not requirements for LHC, or for CMS. However, to develop requirements for LHC@FNAL we had to make assumptions on how accelerator and detector experts in North America will interact with CERN and CMS staff. These assumptions are presented in Section 2 of this document. In general, there are two types of requirements: those that address physical aspects of an operations centre, and those that pertain to agreements and policies that need to be addressed by CERN, Fermilab, CMS, and LARP management.

Requirements are presented in four sections. The first section (Section 3.1) lists LHC@FNAL requirements that pertain exclusively to CMS, and the second section (Section 3.2) lists requirements for LHC. Requirements that are common to CMS and LHC are in the third section (Section 3.3), and requirements that are derived from constraints such as safety, security, and software development constraints are in the fourth section (Section 3.4). The requirements address general capabilities; access to LHC and CMS data, meetings and other types of information; software and software development; the LHC@FNAL operational environment; and computing, networking, software development, security and safety constraints.

This is a preliminary requirements document that will be submitted to Fermilab's Director by the end of July, 2005. Some of the requirements in this document are incomplete, and are labeled as such in this document. Incomplete requirements need further work to determine, for example, the amount of space that is needed for LHC@FNAL and specifications for computing and networking equipment.

The final version of this requirements document is to be completed by the end of calendar year 2005, along with a resource loaded schedule for the construction of LHC@FNAL. To complete this work we will need to learn more about LHC and CMS control systems, CERN computing and networking security, and visit a variety of operations centers and control rooms. An important source of information is our past experience with CMS test beam activities, and our current involvement in LHC and CMS. For example, for CMS we are establishing a room with capabilities for remote participation in the upcoming Cosmic Challenge. For LHC we are learning about access to software repositories and software applications. This work on LHC and CMS contributes to our experience with remote participation, and provides a basis for cost and schedule estimates as we begin work on a resource loaded schedule. The goal is to begin the implementation phase of LHC@FNAL at the beginning of calendar year 2006.

1. Introduction

LHC@FNAL is an operations centre to be located at Fermilab. The purpose of this centre is to help members of the Large Hadron Collider (LHC) community in North America contribute their expertise to LHC activities at CERN, and to assist CERN with the commissioning and operation of the LHC accelerator and experiments. While there are no technical reasons that would prevent participation in multiple LHC experiments, the current plan is to be involved with the CMS experiment, for which Fermilab is the host institution in the U.S.

This document defines the requirements for LHC@FNAL. Requirements were developed by meeting with stakeholders to discuss activities that can be carried out at remote locations to support efforts at CERN. Activities that are envisioned for LHC@FNAL are the following:

- Participate in CMS shifts during commissioning and operations
- Participate in LHC hardware and beam commissioning and operations
- Monitor data quality for CMS
- Monitor data for LHC accelerator components
- Analyze the monitoring data for CMS and LHC
- Develop monitoring capabilities for CMS in collaboration with the LHC Physics Center
- Develop software for the LHC
- Provide access to monitoring data and analysis results
- Provide a training facility for US-CMS and North American LHC collaborators who will travel to CERN to participate in shift activities
- Provide support to North American LHC collaborators after they return from CERN
- Provide a rapid response “call center” to get experts located in North America connected to CERN

Several functions have been identified for LHC@FNAL. The first function is to provide a location that has the hardware and software necessary to participate in LHC accelerator and CMS detector activities, as well as access to the corresponding systems at CERN. One can imagine that LHC@FNAL will have accelerator consoles that are identical to the consoles located at the CCC, albeit without the functionality to control or operate accelerator components. For example, having duplicate hardware and software will be an important aspect of training North American LHC collaborators who will travel to CERN to participate in hardware or beam commissioning.

The second function is as a communications conduit between CERN and members of the LHC community in North America. With this capability LHC@FNAL functions as a *communications hub* by serving as an extension of the CERN Control Centre (CCC), where all CERN accelerator activities are coordinated; and as an extension of the main CMS Control Room, the primary site for operating the CMS experiment. Activities at the CCC include machine development, LHC hardware and beam commissioning, and operation of LHC cryogenics. Activities at the CMS Control Room are focused on CMS detector operations. As a communications hub, LHC@FNAL can serve as a point-of-contact for individuals involved in LHC accelerator or

CMS detector activities. For example, university researchers can get firsthand information about the operational status of CMS and the LHC, including detailed status of accelerator and detector subsystems.

A third function is outreach. By having hardware and software that replicates what is available in control rooms at CERN and by having members of the LHC community actively engaged in activities centered at CERN, visitors to Fermilab (either real or virtual) will be able to see firsthand how research in particle physics is progressing at the LHC. With this capability LHC@FNAL can highlight current LHC activities while demonstrating how future international projects in particle physics can benefit from active participation in projects at remote locations.

This requirements document includes several sections. Section 2 describes assumptions that we have made during the process of developing requirements for LHC@FNAL. Requirements are presented in Section 3. This section consists of four subsections: requirements that are specific to the CMS experiment (Section 3.1); requirements specific to the LHC accelerator (Section 3.2); requirements that involve both CMS and LHC (Section 3.3); and requirements that are derived from constraints such as safety, security, and software development constraints (Section 3.4). The appendix includes a section on **actors**. Actors represent the types of users involved with LHC@FNAL. The appendix also includes a section on **scenarios** that we used to extract requirements for LHC@FNAL.

2. Assumptions

Considerable effort has gone into planning for the LHC accelerator complex and the CMS experiment. Nevertheless, plans for commissioning and operations have not been completed as we develop scenarios and extract requirements for LHC@FNAL. Therefore, we have made assumptions about CMS and LHC to highlight external factors that influence LHC@FNAL activities.

Assumptions are subdivided into three categories: assumptions that are specific to CMS, assumptions for LHC, and assumptions that apply equally to CMS and LHC (referred to as "CMS/LHC assumptions").

Assumptions for CMS:

- The CMS Collaboration will have a shift schedule, a run plan, and a protocol that defines the roles and responsibilities of shift personnel. We assume that a shift leader is responsible for CMS shift activities.
- LHC@FNAL will have shift operators who will be able to assist US-CMS collaborators with CMS activities during commissioning and operations.
- LHC@FNAL will participate in CMS shifts. Neither the duration nor the frequency of the LHC@FNAL shifts has been determined.
- The CMS Collaboration will have a protocol for access to the CMS control system (PVSS), and a policy for how access to the control system will vary depending on the physical location of an individual user.

- The CMS Collaboration will have a policy that defines how DAQ resources are allocated. This includes allocation of DAQ resources to various detector groups for calibration and testing.
- The CMS Collaboration will have a protocol that defines how on-demand video conferencing will be used in CMS control rooms and LHC@FNAL.
- The CMS Collaboration will provide web access to electronic logbook and monitoring information to collaborators worldwide.
- The CMS Collaboration will maintain a *call tree* that lists on-call experts worldwide for each CMS subsystem during commissioning and operations.

Assumptions for LHC:

- Individuals working in a Field Control Room (FCR) in the LHC tunnel will have access to telephone communications with international calling capabilities.
- Individuals working at the CERN Control Centre (CCC) will have access to telephone communications with international calling capabilities.
- Personnel from North America will be at CERN to coordinate activities between the CCC and LHC@FNAL.
- The degree to which LHC@FNAL users have access to the LHC control system will be determined by LHC management.
- The LHC will have a shift schedule and a protocol that defines the roles and responsibilities of CCC shift personnel.
- The LHC will have a protocol that defines how machine commissioning and development activities are scheduled and carried out.

Assumptions for CMS/LHC:

- LHC@FNAL will comply with all CERN and Fermilab safety and security standards.

3. Requirements

The purpose of LHC@FNAL is to facilitate communication and help members of the LHC community in North America contribute their expertise to CMS and LHC activities. We expect that the requirements for LHC@FNAL will be satisfied without requiring significant resources from CERN. We will continue to rely on members of the CERN staff as consultants on matters such as layout of the CCC and CMS control rooms, CERN computing and network security, as well as CERN safety standards. The support that we have received so far from CERN staff members has been very helpful and has had a significant impact on the development of the requirements presented in this document.

The requirements in this document are organized into four sections. Sections 3.1 and 3.2 address requirements that we have identified for CMS and LHC, respectively. The requirements were developed independently by two subgroups in our committee, the detector subgroup and accelerator subgroup. Section 3.3 lists combined requirements for CMS and LHC. It addresses requirements that are common to both, such as general features of LHC@FNAL and the operational environment in which both CMS and LHC participants will work. Section 3.4 addresses constraints, such as safety, security, and software development constraints; and like the preceding section applies to both CMS and LHC.

In the first two sections (requirements for CMS and LHC), the subsections are organized in *progressive chronological* order. For CMS there are two subsections ordered chronologically: commissioning and operations. For LHC there are three subsections: hardware commissioning, beam commissioning, and post-commissioning activities. The progressive ordering means that each subsection introduces additional requirements as one advances from commissioning to operations. This means that someone who is only interested in LHC hardware commissioning, for example, can read about LHC requirements in the first subsection in Section 3.2, and then skip ahead to the requirements that are common to both CMS and LHC in the last two sections. Someone who is interested in requirements for LHC beam studies should read all of the requirements in Section 3.2 before moving on to the last two sections. One of the main reasons for organizing requirements in chronological order is that the schedule for LHC@FNAL will be influenced by requirements that must be satisfied early in the schedule to support CMS and LHC commissioning activities, compared to ones that can be addressed at a later time.

The numbering scheme that we use to identify individual requirements is derived from the organization of requirements into the four sections. The requirement number is of the form $n - m$, where n identifies the section number and m identifies the requirement in a particular section. This means that

- n = 1 for CMS requirements
- n = 2 for LHC requirements
- n = 3 for CMS/LHC combined requirements
- n = 4 for constraints

Individual requirements are presented in the form of a table as follows:

n – m. Requirement Name	Reference	Status
The requirement.		

The table includes the *requirement number*, followed by a *requirement name*. A *reference*, if included in the table, refers to one or more scenarios that provide supporting information for the requirement (see Appendix A2 for a list of scenarios). *Status* is used to indicate if a requirement is "incomplete" and needs additional information. The remainder of the table includes the text for the requirement.

3.1. CMS Experiment Requirements

Requirements that are exclusively CMS requirements are listed in this section, while CMS/LHC combined requirements are listed in Section 3.3 and constraints in Section 3.4. Two important requirements (*CMS Confidentiality* and *CMS Activities and Space*) are listed at the beginning of this section. The remainder of the section is subdivided into two subsections that list requirements for commissioning and operations. Requirements for commissioning (Subsection 3.1.1) must be satisfied early in the LHC@FNAL schedule to support commissioning of the CMS detector. Additional requirements for operations (Subsection 3.1.2) can be satisfied at a later time to support CMS operations.

LHC@FNAL will need to accommodate a diverse set of activities and serve the distributed community of the US-CMS Collaboration. Experts from various detector groups will want to participate in commissioning and operations, either through organized shifts or in debugging detector problems. While it is expected that CMS users of LHC@FNAL will come to the centre for shifts, on-call experts could be located at many remote locations. Support for these experts will be one of the important functions of the centre. The shift operator can assure that critical online information reaches the expert when required.

1 – 1. CMS Confidentiality		
Data, results, conclusions, and problem reports for CMS shall be kept confidential by all LHC@FNAL users according to CMS collaboration guidelines.		

1 – 2. CMS Activities and Space		
LHC@FNAL shall have the space that is needed to accommodate diverse US-CMS activities during commissioning and operations. These activities include, but are not limited to: • Commissioning and operations activities for various detector groups • Data quality monitoring (online and offline) • Support for experts located at other US-CMS institutes • US-CMS computing operations (optional) • Training for US-CMS shift operators and detector experts		

3.1.1. Requirements for CMS Commissioning

Requirements for CMS commissioning support commissioning of the CMS detector. The primary focus of these requirements is on access to information and communications. For LHC@FNAL users to be active remote participants in CMS commissioning, there is a need to be as involved as possible in commissioning meetings, and to have access to numerous means of communication to exchange information with CMS collaborators at CERN and US-CMS institutes.

3.1.1.1. Access and Communications

1 – 3. CMS Meetings		
LHC@FNAL shall have video conferencing capabilities that allow convenient access by CMS collaborators to participate in relevant meetings of the CMS collaboration.		

1 – 4. CMS Tools for Remote Participation		
LHC@FNAL shall have the tools and facilities needed for remote participation in CMS commissioning activities at CERN.		

1 – 5. CMS Communications Channels for Commissioning		
LHC@FNAL shall have the capability to simultaneously communicate with multiple CMS control rooms (located at CERN or in remote locations) and CMS collaborators involved in commissioning activities.		

1 – 6. CMS Video/Audio Communications		
CMS shift personnel shall have access to on-demand video conferencing capabilities between control rooms, and multi-channel audio conferencing that can accommodate shift personnel in control rooms as well as detector experts with telephone access.		

1 – 7. CMS Video/Audio Access		
On-demand video/audio conferencing shall be secured (for example, by password protection) such that video/audio conferences are only accessible to CMS collaborators or LHC@FNAL users.		

1 – 8. CMS Video/Audio Monitoring		
LHC@FNAL shall have access to monitoring that can be provided by video/audio hardware. Video images shall be accompanied by location, date and time information.		

1 – 9. CMS Control System Access	280, 286	
LHC@FNAL shall have access to the CMS control system (PVSS). The degree to which CMS shift operators who are at LHC@FNAL have access to the CMS control system shall be established by CMS management and the CMS commissioning coordinator.		

3.1.2. Requirements for CMS Operations

Requirements for CMS operations include all of the requirements presented in Section 3.1, including the requirements that are introduced here. The first subsection introduces requirements for access to information and communications, access to calibration and alignment data, access to DAQ resources, and the ability to request changes to the CMS run plan. The second subsection addresses software development.

3.1.2.1. Access and Communications

1 – 10. CMS Monitoring Data Access	280	

LHC@FNAL shall have access to network-accessible monitoring data that is available in the main CMS Control Room. This shall include, but not be limited to:

- Data quality monitoring (DQM) information
- Databases for CMS subsystems
- Monitoring information provided by the CMS control system
- LHC beam conditions and data logged by the LHC control system

1 – 11. CMS Calibration and Alignment Data		
LHC@FNAL shall have access to standard data used for detector calibration and alignment, and the history of the data.		

1 – 12. CMS Run Plan Requests	286	
LHC@FNAL shall be able to submit requests to include special runs (such as calibration runs) in the CMS run plan and be notified of the status of these requests.		

1 – 13. CMS DAQ Resources		
LHC@FNAL shall be able to submit requests to use DAQ resources for CMS subsystem calibration and testing.		

3.1.2.2. Software and Software Development

Several different types of software will be in use at LHC@FNAL, and the requirements depend on the type of software that is being considered. In this section we refer to “CMS experiment software,” which is defined to be project-wide software that is developed for and used by CMS.

See Section 3.4.3 for a description of other types of software, and constraints on software development.

1 – 14. CMS Software Maintenance		
All CMS experiment software that is used for LHC@FNAL shall be maintained at the correct version.		

1 – 15. CMS Development Environment		
LHC@FNAL shall have the software development environment that is needed to develop CMS experiment software.		

3.2. LHC Accelerator Requirements

Requirements that are exclusively LHC requirements are presented in this section, while CMS/LHC combined requirements are presented in Section 3.3 and constraints in Section 3.4. After presenting three important requirements (*LHC Confidentiality*, *Enforcement of LHC Confidentiality*, and *LHC Space*) at the beginning of this section, the remainder of the section is subdivided into three subsections that present requirements for hardware commissioning, beam commissioning, and post-commissioning activities. Requirements for hardware commissioning (Subsection 3.2.1) must be satisfied early in the schedule for LHC@FNAL to support installation and commissioning of LHC accelerator components. Additional requirements for beam commissioning (Subsection 3.2.2) and post-commissioning activities (Subsection 3.2.3) can be satisfied at a later time.

2 – 1. LHC Confidentiality		
Data, results, conclusions, and problem reports for hardware commissioning, as well as commissioning and operating the LHC shall be kept confidential by all LHC@FNAL users. Only CERN has the authority to release this information to an outside party. Mailing lists and web pages will be protected with passwords and logins.		

2 – 2. Enforcement of LHC Confidentiality		
Fermilab management and LARP management shall be responsible for enforcing the LHC confidentiality agreement.		

2 – 3. LHC Space		
LHC@FNAL shall have the space to accommodate designated activities, particularly during LHC hardware commissioning, beam commissioning, operations, and beam studies. As a minimum, there will be sufficient space for two CCC-type consoles and ancillary equipment.		

3.2.1. Requirements to Participate in LHC Hardware Commissioning

Requirements for LHC hardware commissioning are presented in this section. The primary focus is on access to information and communications, specifically communications with personnel in a CERN Field Control Room (FCR) since initial hardware commissioning will occur exclusively in this venue. During hardware commissioning LHC@FNAL users will be active, remote participants to help commission U.S.-provided deliverables and assist with diagnostics. This implies a need to be as involved as possible in commissioning meetings, and to have access to numerous means of communication to be able to exchange information with people who are engaged in commissioning activities at CERN.

3.2.1.1. Access and Communications

2 – 4. LHC Hardware Commissioning Data Access	126	
LHC@FNAL shall have read access to hardware commissioning data. This shall include, but not be limited to: • Quench data • Slow-monitoring data such as thermometry and liquid level gauges		

2 – 5. LHC Hardware Commissioning Logbook	126	
LHC@FNAL shall have access to the hardware commissioning logbook.		

2 – 6. FCR Shift Personnel	126	
LHC@FNAL personnel shall know who is on shift at the FCR, and they shall know the roles and responsibilities of the FCR shift personnel.		

2 – 7. LHC Hardware Commissioning Timescale	126	
The timescale for hardware commissioning aspects of LHC@FNAL shall match the LHC schedule for hardware commissioning. Full implementation shall be completed by June 2006.		

2 – 8. LHC Daily Schedule Meetings	138, 213	
LHC@FNAL shall have access to information and decisions from daily LHC schedule meetings at CERN. Ideally, this will include active participation by representatives of North American interests.		

3.2.2. Requirements to Participate in Beam Commissioning

Requirements for LHC beam commissioning are presented in this section. Compared to requirements in the previous section on hardware commissioning, the following requirements focus on duplicating some of the functionality that is available at the CERN Control Centre (CCC), such as access to information that is available to someone working at the CCC. Just as the CCC is expected to come on-line during the later stages of hardware commissioning for a sector test (ie. before beam commissioning begins), we expect to satisfy requirements presented here before the official start of LHC beam commissioning. Furthermore, software development (see Section 3.2.2.2) is also expected to begin well before LHC beam commissioning so that necessary tools can be tested in advance of the sector test.

3.2.2.1. Access and Communications

2 – 9. LHC Data Access	128, 138, 178	

LHC@FNAL shall have appropriate access to LHC accelerator data. This shall include, but not be limited to:

- Logged machine data
- Machine parameter changes "published" by CERN
- Logged fault data
- Online measurement repository
- Timely data from non-LARP instruments
- All data from LARP-supplied instruments, including (but not limited to):
  - scope traces from LARP instrument
  - read access to low level processor parameters and system information

2 – 10. LHC Configuration Access	178	

LHC@FNAL shall have access to LHC optics, errors, and transfer functions. An agreement between CERN and Fermilab ensures that LHC@FNAL has the required access to the appropriate repositories. LHC@FNAL shall also have access to pre-defined measurement data structures, storage and access methods.

2 – 11. CCC Communications Channels	120	Incomplete

LHC@FNAL shall have the capability for multiple (**minimum number?**) communications channels that can be used simultaneously.

2 – 12. LHC Shift Personnel	128, 213	

LHC@FNAL personnel shall know who is on shift at the CCC, and they shall know the roles and responsibilities of the CCC shift personnel.

3.2.2.2. Software and Software Development

Several different types of software will be in use at LHC@FNAL, and the requirements depend on the type of software that is being considered. In this section we refer to "LHC accelerator software," which is defined to be project-wide software that is developed for the LHC. See Section 3.4.3 for a description of other types of software, and constraints on software development.

2 – 13. CCC Software	120, 178	
LHC@FNAL shall have the same LHC accelerator software installed as the CCC.		

2 – 14. CCC Software Maintenance	120	
LHC@FNAL shall be administered such that LHC accelerator software is current and maintained at the same version as the CCC.		

2 – 15. CCC Console Layout	120	
The layout for displays on LHC@FNAL consoles shall mirror the displays on CCC consoles.		

2 – 16. LHC Development Environment	120, 178	
LHC@FNAL shall have the software development environment that is needed to develop LHC accelerator software.		

2 – 17. LHC Data for Testing	120	
LHC@FNAL shall have access to data necessary for testing LHC accelerator software.		

3.2.3. Requirements to Participate in Post-Commissioning LHC Activities

Requirements for participating in post-commissioning LHC activities are *additional* requirements besides the ones listed in previous sections. These activities are expected to include, but are not limited to, remote participation in LHC beam studies, support of U.S.-provided deliverables, and work on LHC luminosity upgrades

2 – 18. Beam Study Proposals	128	
LHC@FNAL personnel shall be able to submit beam-study proposals to LHC management and be notified of their status.		

2 – 19. Beam Study Protocols	128	
The protocol that defines how beam studies at the LHC are carried out shall include LHC@FNAL personnel, and shall include the following: • Methodology for making beam measurements • Methodology for ensuring the validity of measurement data • Ways to insure timely, accurate and complete communication before, during, and after each beam study		

3.3. CMS/LHC Combined Requirements

Requirements that involve both the CMS experiment and the LHC accelerator are presented in this section, which addresses general capabilities and features. There are two subsections. The first (Subsection 3.3.1) presents capabilities that are common to CMS and LHC, and the second (Subsection 3.3.2) presents requirements for the operational environment in which both CMS and LHC participants will work.

3.3.1. General Capabilities

3 – 1. LHC@FNAL Safeguards		
LHC@FNAL shall have safeguards such that actions do not interfere with or jeopardize the quality of data recorded by CMS, and do not interfere with or jeopardize LHC operations.		

3 – 2. LHC@FNAL Hardware and Software Consistency		
To minimize the impact on CERN resources, LHC@FNAL shall maximize consistency in hardware and software with CERN and obtain software licenses as needed.		

3 – 3. LHC@FNAL Consoles	120, 138, 213	
LHC@FNAL shall have the same or equivalent consoles installed as the CCC.		

3 – 4. LHC@FNAL Communications	120, 126, 128, 138, 178, 213, 280	
Several types of reliable communications shall exist between LHC@FNAL and CMS control rooms, LHC Field Control Rooms, CERN Control Centre, and CMS and LHC collaborators worldwide. The types of communications shall include, but not be limited to: • Telephone (wired and wireless) • On-demand video conferencing • On-demand screen sharing • Simple, prompt electronic messaging with audio alerts (for example, “instant messaging” • E-mail • Electronic logbook		

3 – 5. LHC@FNAL Shifts	126, 213	
LHC@FNAL shall be staffed as conditions require. The shift schedule (showing shift personnel, time on shift, and contact information), shall be posted so that it can be accessed by CMS and LHC personnel.		

3 – 6. LHC@FNAL Record of Shift Schedule		
The LHC@FNAL shift schedule shall be archived and published on-line so that it can be accessed by CMS and LHC personnel.		

3 – 7. LHC@FNAL Directory		
LHC@FNAL shall maintain a directory of LHC@FNAL users and their contact information for CMS and LHC personnel.		

3 – 8. LHC@FNAL Web Page		
LHC@FNAL shall maintain a web page with information that includes, but is not limited to: • LHC@FNAL operational status • LHC@FNAL shift schedule • LHC@FNAL directory		

3 – 9. LHC@FNAL Lifespan and Effectiveness Reviews	138	
LHC@FNAL shall remain in operation for as long as there are US-CMS and US/LARP commitments that depend on its existence. LHC@FNAL shall be reviewed for effectiveness by its major stakeholders one year after it begins operation, after each stage of commissioning activities has been concluded, and periodically thereafter as determined by those stakeholders.		

3.3.2. Operational Environment

Several different areas are needed to accommodate the diverse activities that are expected to be carried out at LHC@FNAL. One of the unique features is the close proximity of people working on the LHC accelerator and the CMS experiment. LHC@FNAL requires space for personnel working on CMS and space for LHC personnel, where someone can work undisturbed on one without interference from activities devoted to the other. We refer to this as the *shift area*. A *common area* is needed where CMS and LHC personnel can work together, and a *working area* provides necessary space for LHC@FNAL users who are not actively engaged in shift activities but need access to capabilities provided by LHC@FNAL. If LHC@FNAL is to achieve its goal as an outreach tool, it will need to be constructed such that its primary activities can be carried out, with minimal disruption, while those activities are viewed by interested onlookers.

3 – 10. LHC@FNAL Shift Area	213	
Space for LHC@FNAL shall include a shift area with CCC and CMS consoles and access to communications for shift personnel as required by **3 – 4**.		

3 – 11. LHC@FNAL Common Area		
Space for LHC@FNAL shall accommodate a common area where CMS and LHC personnel can communicate with each other while actively engaged in remote activities at CERN.		

3 – 12. LHC@FNAL Display Sharing		
To facilitate communication between CMS and LHC, LHC@FNAL consoles shall have the capability of displaying both CMS and LHC data.		

3 – 13. LHC@FNAL Working Area		
Space for LHC@FNAL shall include a working area for LHC@FNAL users who are not actively engaged in shift activities. The working area shall provide telephones and internet connectivity.		

3 – 14. LHC@FNAL Social Area	213	
Space for LHC@FNAL shall include a social area with a kitchen facility.		

3 – 15. LHC@FNAL Outreach	213	
LHC@FNAL shall be constructed such that activities can be viewed from the outside without undo disturbance of its users.		

3 – 16. LHC@FNAL Clocks	138	
LHC@FNAL shall have at least two clocks: one showing the local time at Fermilab, the second showing the time at CERN.		

3.4. Constraints

Global requirements that restrict the degree of freedom of LHC@FNAL capabilities are presented in this section. These *constraints* are restrictions for both the CMS experiment and the LHC accelerator and are therefore presented together. There are five subsections that include requirements for communications, computing and networking, software, security, and safety.

At this time (July 2005), many of the details regarding constraints have not been worked out, and therefore a large fraction of the requirements in this section are identified as "incomplete."

3.4.1. Communications Requirements

4 – 1. Communications		Incomplete
Reliable communications shall be available to LHC@FNAL users. Additional work is needed to determine specifications for communications.		

3.4.2. Computing and Networking Requirements

4 – 2. Computing		Incomplete
Computing resources shall be available to LHC@FNAL users. Additional work is needed to determine specifications for computing.		

4 – 3. Reliable Networking		Incomplete
Reliable networking shall be available to LHC@FNAL users. Additional work is needed to determine specifications for networking.		

3.4.3. Software Requirements

Several different types of software will be in use at LHC@FNAL, and the software requirements depend on the type of software that is being considered. Requirements refer to four types of software:

- CMS experiment software – refers to project-wide software that is developed for and used by CMS
- LHC accelerator software – refers to project-wide software that is developed for the LHC accelerator

- LHC@FNAL software – refers to project-specific software that is developed explicitly for LHC@FNAL
- External software – other software used at LHC@FNAL. For example operating systems, code development software, video-conferencing software, and instant-messaging software.

LHC@FNAL software must be developed using standard software tools that allow version tracking, assist code reviews, encourage documentation, and help with maintainability. The software must be robust and stable. Software bugs that could interfere with LHC@FNAL operations must be eliminated.

4 – 4. Software compliance		
Software developed at the LHC@FNAL for CMS and LHC shall conform to rules and coding standards established by the CMS Collaboration and LHC Project, respectively.		

4 – 5. Software repository		
LHC@FNAL software shall reside in a software repository that must be used to keep track of different versions of the software during development.		

4 – 6. Version control		
The version numbers of LHC@FNAL software used to process data shall be managed in such a way that the particular version that was used to process data can always be identified and reproduced.		

4 – 7. Parameters database		
Shared parameters and constants defined by LHC@FNAL software shall reside in a database so that the particular values used to process data can always be identified.		

4 – 8. Software testing		
LHC@FNAL software shall include code for testing purposes as part of the development process, and must be used for testing the software after development has been completed.		

3.4.4. Security Requirements

4 – 9. Computing and Networking Security		Incomplete
LHC@FNAL shall have secure computing and networking. Additional work is needed to determine specifications for the level of security that is needed.		

4 – 10. LHC@FNAL Space Security		Incomplete
LHC@FNAL space shall be secured. Additional work is needed to determine level of security that is needed.		

3.4.5. Safety Requirements

4 – 11. General safety		
LHC@FNAL shall comply with all applicable CERN, CMS, and LHC safety standards.		

4 – 12. LHC@FNAL safety		
LHC@FNAL shall comply with all applicable Fermilab ES&H safety standards.		

Appendix

A1. Actors

Actors are the types of users involved with LHC@FNAL. In this section we list actors we who are engaged in CMS experiment and/or LHC accelerator activities.

A1.1. CMS Actors

We refer to three types of actors for CMS. The three types are CMS shift personnel, CMS subsystem and technical experts, and CMS computing experts.

CMS shift personnel are CMS collaborators participating in shifts at CERN and at remote sites. The actors are:

- CMS shift leader – The shift leader is responsible for CMS shift activities. At least initially, we expect the shift leader to be located at CERN.
- CMS communications coordinator – The communications coordinator is responsible for maintaining the *call tree* that lists on-call experts worldwide for each CMS subsystem during commissioning and operations. The communications coordinator may need to respond to phone calls requesting information on how to contact CMS control rooms, LHC@FNAL, or other remote sites associated with CMS.
- CMS monitoring shift coordinator – The monitoring shift coordinator works with the shift leader to establish shift schedules for monitoring shifts.
- CMS monitoring shift operator – The monitoring shift operator is responsible for monitoring (such as data-quality monitoring and control-system monitoring) during a shift.
- CMS shift operator – Shift operators perform CMS shift activities.
- CMS safety coordinator – The safety coordinator is responsible for general safety by ensuring compliance with CERN and CMS safety standards.

CMS *subsystem experts* are experts who are “on call” to solve problems in particular subsystems. Subsystem experts are likely to be located at CERN, but are also likely to be located in many other locations such as Fermilab, other remote sites, and at universities. All CMS subsystems (pixel, tracker, preshower, ECAL, HCAL, muon, trigger, DAQ, and DCS) are expected to have experts who can be called with questions or when problems arise. In addition to subsystem experts, there are *technical experts* for other systems in CMS. The actors are:

- CMS on-call expert (for a subsystem) – The on-call expert for a particular subsystem is the person who responds to problems that have been identified for the subsystem, or responds to questions regarding the subsystem.
- CMS super expert (for a subsystem) – The super expert for a particular subsystem is the person who is contacted when the on-call expert is unable to resolve a problem or answer

a question. This person is “protected” from receiving too many phone calls or e-mail messages by the on-call expert.

- CMS technical expert – The technical expert is responsible for a technical system such as software, electronics, magnet, cooling/ventilation, and power distribution. The technical expert is the on-call expert during CMS shifts.

CMS computing experts are technical experts who provide support for production computing, such as computing that is performed at the FNAL Tier 1 Center. The actors are:

- GRID operator at Fermilab
- CMS production operator at FNAL Tier 1 Center
- CMS production coordinator

A1.2. LHC Actors

LHC actors are subdivided into two categories based on location, either CERN or FNAL. This distinction is useful for accelerator scenarios, since these scenarios are tied more closely to CERN compared to scenarios that involve the CMS detector. Whether an LHC actor is located at CERN or at FNAL is not an indication of where they are employed. The actors may be engineers, physicists, hardware or software designers, and may be employed by universities, or laboratories other than CERN or FNAL.

Actors located at CERN are the following:

- LHC expert at CERN
- LHC control-room expert at CERN
- LHC control-room operator at CERN
- LHC operations specialist at CERN
- Field control-room operator at CERN
- FNAL contact person at CERN (a person who resides at CERN for an extended period of time and communicates regularly with people at FNAL)

Actors located at FNAL:

- LHC expert at FNAL
- LHC control-room expert at FNAL (someone who is familiar with control-room hardware and software at CERN)

A1.3. CMS/LHC Actors

We refer to three types of CMS/LHC actors. The three types are LHC@FNAL users, management and support personnel.

LHC@FNAL users are:

- LHC@FNAL shift operators

- CMS experts
- LHC experts

Actors in management are:

- CERN Management
- FNAL Management
- CMS Management
- LPC Management
- LARP Management
- LHC@FNAL Administrator

Support personnel include the following:

- CERN network security
- FNAL network security
- FNAL site security
- FNAL audio/video expert
- FNAL computer support
- FNAL networking expert
- FNAL helpdesk

A2. Scenarios

Scenarios were developed for the purpose of extracting requirements for LHC@FNAL. The development of the scenarios was done by subdividing our committee into two subgroups, a detector and an accelerator subgroup, and developing scenarios independently for CMS and LHC.

Each scenario is arranged in the form of a table. The table includes a scenario number that corresponds to the document number in the document database[1] that was used to develop the scenarios. Scenario tables include the following information:

- Scenario number: an identification number (also the document database number)
- Author: name of the person (or people) who developed the scenario
- Date: the date when the scenario was first proposed
- Reviewers: the names of reviewers for the scenario

[1] http://docdb.fnal.gov/CMS-public/DocDB/DocumentDatabase

- Reviewed: the date when the scenario was reviewed
- Approved: the date when the reviewers approved the scenario
- Goal: a short, active verb phrase that describes the scenario
- Level: a categorization that defines a scenario as occurring at a high, medium, or low level based on the types of actions that are described. Examples of high, medium, and low level scenarios are:
    - High level: run a CMS shift at LHC@FNAL
    - Medium level: locate and contact a CMS system expert
    - Low level: find a CMS system expert in a directory
- Actors: the types of people involved in the scenario
- Trigger: a description of an event or activity that initiates the scenario
- Narrative: a description of the scenario that includes tasks in the order in which they occur
- Exceptions: alternatives that may come into play as unforeseen problems or events occur
- Comments: any comments that are relevant to the scenario

A2.1. CMS Experiment Scenarios

The following table lists the scenarios that were developed for the CMS experiment. The first column shows the scenario number (described in the previous section) that appears as a reference number in requirements tables (see Section 3 for a description of requirements tables). The second column shows the name of the scenario and a link to the scenario in our document database.

Scenario Number	Scenario Name and Link to Document Database
130	Run a “normal” CMS data-monitoring shift at FNAL http://docdb.fnal.gov/CMS-public/DocDB/ShowDocument?docid=130
280	CMS tracker scenario: unstable beam conditions http://docdb.fnal.gov/CMS-public/DocDB/ShowDocument?docid=280
286	CMS tracker scenario: tracker check-out during operations http://docdb.fnal.gov/CMS-public/DocDB/ShowDocument?docid=286
287	CMS tracker scenario: tracker commissioning and debugging shifts http://docdb.fnal.gov/CMS-public/DocDB/ShowDocument?docid=287
288	CMS HCAL scenario: LHC@FNAL participation in CMS commissioning activities http://docdb.fnal.gov/CMS-public/DocDB/ShowDocument?docid=288

289	CMS HCAL scenario: detector expert participation in CMS commissioning shifts http://docdb.fnal.gov/CMS-public/DocDB/ShowDocument?docid=289
290	CMS HCAL scenario: LHC@FNAL on-call during normal operations http://docdb.fnal.gov/CMS-public/DocDB/ShowDocument?docid=290

A2.2. LHC Accelerator Scenarios

The following table lists the scenarios that were developed for the LHC accelerator. The first column shows the scenario number (described Section A2) that appears as a reference number in requirements tables (see Section 3 for a description of requirements tables). The second column shows the name of the scenario and a link to the scenario in our document database.

Scenario Number	Scenario Name and Link to Document Database
120	Tool development at FNAL for LHC http://docdb.fnal.gov/CMS-public/DocDB/ShowDocument?docid=120
126	Magnet quench scenario http://docdb.fnal.gov/CMS-public/DocDB/ShowDocument?docid=126
128	LHC beam study http://docdb.fnal.gov/CMS-public/DocDB/ShowDocument?docid=128
138	Debugging the Schottky detector http://docdb.fnal.gov/CMS-public/DocDB/ShowDocument?docid=138
178	LHC beta beating analysis http://docdb.fnal.gov/CMS-public/DocDB/ShowDocument?docid=178
213	First beam in the LHC http://docdb.fnal.gov/CMS-public/DocDB/ShowDocument?docid=213