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US-CMS User Facilities Subproject

SUMMARY

This document describes the "User Facilities" subproject of the US-CMS Software and Computing Project. The User Facilities subproject will provide the enabling infrastructure to permit US-CMS collaborators to fully participate in the physics program of CMS at the LHC, while at their home institutions as well as at CERN. This enabling infrastructure will consist of the software and hardware needed to access and analyze data as well as collaborative tools and videoconferencing to support a worldwide collaboration. Distributed computing for US-CMS will be in the form of computing centers, with the central US center (or Tier 1) located at Fermilab supporting smaller University-based Tier 2 centers.

Fermilab was selected by CMS to be the US based Tier 1 computing center because it has an excellent infrastructure (central facilities, networking, support staff) and experience in supporting a widely spread user community. Most importantly, Run II of CDF and DØ is the closest we shall come to the running conditions of future hadron collider experiments (such as the LHC) ahead of turn-on. The problems of large data volumes and CPU-intensive computing will provide Fermilab with unmatched experience in these areas, as will (indeed as has already) the challenge of converting high energy physics software from a Fortran environment to C++. The regional center will serve software, data and analysis needs of US-CMS institutions as well as support Tier 2 US-CMS regional centers. The scale of the regional center is similar to either the CDF or DØ Run II computing projects, namely $8.2M for hardware (spent mainly over the years 2003-2005). We estimate that of order 35 FTE's within Fermilab's Computing Division (CD) will be necessary for User Facility-related tasks by 2005.

PREAMBLE

This document describes the "User Facilities" subproject of the US-CMS Software and Computing Project. The mission of the User Facilities subproject is to provide the **enabling infrastructure to permit US-CMS collaborators to fully participate in the physics program of CMS from their home sites.** This enabling infrastructure will consist of the software and hardware needed to access, analyze and understand CMS data. The major cost and personnel-requirements driver for the subproject is a centralized facility in the form of a Regional Center for US-CMS at Fermilab.

Regional Centers are an essential part of the network-distributed Computing Models of the LHC experiments. An effective Computing Model balances proximity to the site where the raw data is stored and first processed (CERN) against proximity to the physicists doing the analysis in each world region. For the US it is particularly important that access to the relevant portions of the data is provided within the US, mitigating the dependence on a relatively expensive transatlantic network link of limited bandwidth. A joint project of all the LHC experiments, MONARC (Models Of Network Analysis at Regional Centers) [3], is being carried out with the goal of understanding how analysis will be carried out in such an environment, and defining the necessary scope of the Regional Centers. CMS and US-CMS are participating fully and leading this joint project, and are active in shaping its work[1]. MONARC has defined several levels ("Tiers") of Regional Center, and concluded that the first level "Tier 1" Center should have roughly 20% of the capacity of CERN for a single experiment. Because the amount of computing required outside of the Tier 0 center (CERN) is strongly tied to the amount of computing supported by the T0 center, computing for LHC is being reviewed by an international panel of experts with a goal of defining the scope of the T0 and T1 Regional Centers based on the total amount of computing required for each of the LHC experiments. The size of the T1 Regional Center at Fermilab will be defined during this process.

In addition to raw computing hardware and software, other amenities at Fermilab are needed to enable US-CMS physicists. Videoconferencing, desktop support and office space are clearly necessary; Fermilab also plans a training office and to host a remote control room for CMS. Physicists are normally most efficient when encouraged to interact freely and we must design the user facility with the aim of encouraging physicists to hold informal discussions.

Fermilab is a major CMS collaborator in its own right. Our physicists have leading responsibilities in the hadron calorimeter, muon and trigger systems, as well as overall project management responsibility for the US-CMS construction project. These subsystems require computing resources for detector design, physics simulation, analysis of test beam data, and storage and dissemination of technical information. Fermilab physicists will take leading roles in writing the reconstruction software for these subsystems, together with US-CMS physicists at many universities, and this will provide a natural path toward full participation in the physics analysis of data from CMS.

In this document we first outline the Work Breakdown Structure (WBS) for the User Facilities Subproject and then give a more detailed description of the items.

[1] H.Newman (Caltech) is the Spokesman of MONARC, and Joel Butler (FNAL) is Chair of the Architectures Working Group.

WBS STRUCTURE

1 User Facilities SubProject of the US-CMS Software and Computing Project

1.1 Tier 1 Regional Center at FNAL

This item covers the capital equipment and ongoing operational requirements of the Tier 1 Regional Center. Hardware will be acquired over a three year period from 2004 to 2006 (in order to spread the cost over several fiscal years, to provide some reduced capacity capability before 2006 for mock data challenges and test beam analysis, and to provide greater time for full system integration). Consistent with these aims, the hardware will be acquired as late as possible to allow maximally effective purchasing. There will also be ongoing expenses for the required hardware support to ensure full availability of the services and systems provided. Software systems do not share the falling prices expected of hardware, and in some cases have longer lead times for development, and so software system expenses here will start in earlier years.

1.1.1 Development and Test systems

These systems support software and hardware development and testing of both system and application software. These systems will be subsets of the full system and will be used by experts in each piece to develop and test software and hardware.

1.1.1.1 Modular Test Stands

These are single purpose test stands for specific parts of the offline system.

1.1.1.1.1 Offline Storage

This item refers to a hardware test stand to test or evaluate new tapes, tape drive or other kind of archival media, or software.

1.1.1.1.2 Online Storage

This item refers to a hardware test stand to test or evaluate new disks or software.

1.1.1.1.3 Data Distribution Servers

This is a hardware test stand to test data distribution software.

1.1.1.1.4 Software Build Machine

These are build machines for software. Typically Linux software builds can be done on individual desktops, however for a build machine for SUN (the other CMS supported platform) or in the event the Linux machines must be configured in a special way we may need a dedicated build machine.

1.1.1.2 Integration Test Stand

This is a small scale full system used for such items as system upgrade tests and new software testing before full deployment on the production systems. One or two fully integrated test stands will be needed and they should be as identical as possible (though on a much smaller scale) to the production systems.

1.1.2 Simulation and Reconstruction systems

The simulation systems support large scale production of simulated events, including event generation and full detector simulation. This is an activity that will almost entirely be carried out at Regional Centers and local CMS institutions. This is an extremely CPU intensive application, and will usually make use of inexpensive commodity computers with limited I/O performance.

The reconstruction systems support the reconstruction of both data and simulated events. Primary reconstruction of data will take place at CERN in quasi real time, but the regional center will perform primary reconstruction of simulated data, and secondary reconstruction (with improved algorithms or calibrations) of samples of events, on both a scheduled and on-demand basis. Special reconstruction of calibration data samples of interest to US subdetector groups will also be carried out here. This is again a CPU intensive application and will use inexpensive commodity computers.

These systems are lumped together in this WBS because they are well suited to large farms of commodity computing with little or totally scheduled I/O needs. Fermilab has a lot of experience in doing these systems for Run 2.

1.1.3 Analysis Systems

These systems provide the computing hardware needed for data analysis, the primary function of the regional center. Traditionally Fermilab has used UNIX SMP (shared memory multi processor) machines are used for this function because these systems must support large numbers of simultaneous users, provide a single system image no matter what physical hardware the user is logged on to that day, and provide high bandwidth input/output and network connections. Because of the huge projected difference in cost, and availability risks, as much use as possible will be made of inexpensive commodity computers.

1.1.4 Data Access and Distribution Servers

These systems provide the computing, disk caching and network facilities required to provide access to the event data stored in databases, and to supply this data over the network to both local and remote users.

1.1.5 Calibration and Non-Event Database Servers

These systems provide the computing, disk caching and network facilities required to provide access to the non-event data stored in databases, and to supply this data over the network to both local and remote users. The amount of non-event and calibration data is much smaller than the amount of event data, thus the requirements of CPU and I/O on these systems is much smaller than those in 1.2.4. Any additional software or hardware interfacing needed to read the slow control or geometry databases and serve them to the reconstruction and analysis processes is covered in this item.

1.1.6 Data Storage Systems

These systems provide the hierarchical data storage for event data, calibration data, and non-event data necessary for physics analysis. They will include on-line disk, secondary robotic tape storage and import/export facilities to move data into and out of the various levels of the data storage hierarchy.

1.1.6.1 Tape Data Storage System

This item covers the provision of elements of a data storage system for CMS production with a total capacity of about 3 Petabytes by 2005. The planning assumption is that major data access servers at FNAL will be able to sink data at the requisite rates, that a buffering/caching system within the storage systems will be needed for offsite and miscellaneous computing at FNAL. Identification of the hardware sufficient for procurement is an item in section 1.7.

It is assumed that every second year, we accept a density/speed increase for the tape drive fleet. Estimating assumptions: there is backwards read-compatibility of the tape drives, and the improvement is installed incrementally. All work to procure and modify the storage system in a way that handles the increased data rates.

1.1.6.1.1 Procurement and installation

This item includes initial procurement and installation., initial configuration, problem resolution involving experts, "burning in the vendor and vendor services) and installation of storage system application for the Library and Tape Drives, computers serving as tape servers and host machines and the native-to-storage-systems cache machines.

1.1.6.1.2 Storage System Interface Development:

This covers the software necessary to archive and retrieve data and databases in a mass storage system within the CMS experiment. The planning assumption relies on the completion of a successful prototype, so only incremental and maintenance development is necessary.

This item includes the maintenance and incremental improvements to the interface to the CMS Objectivity or other database systems to storage system.

1.1.6.1.3 Archive Administration Operation and Maintenance

1.1.6.1.3.1 Equipment Maintenance

Maintain tape libraries and attendant computers at the component level and liaison with filed engineers, vendors etc.

1.1.6.1.3.2 Tape Maintenance

Maintain the tape plant. Investigate drive and media problems, recover media, and manage media, the archive computers and archive application software.

1.1.6.1.3.3 Media Upgrades

This item covers floor space and footprint management with the assumption that every 4th year we migrate all low density data onto new media (i.e. migrate all data older than 4 years which are still required). Also retire any equipment rendered obsolescent. We assume we need 0.5 FTE every 4th year which averages out to 0.125 FTE every year during the operations phase.

1.1.6.1.3.4 Updates

Configure, (receiving the products of Software Maintenance) install and update the archive software in all respects coping with change. Test changes in a way appropriate for production.

1.1.6.1.3.5 Routine Administration

This item covers the day to day administration of the archive application such as creating groups, adjusting authorizations, resolving problems, and attending CMS meetings.

1.1.6.1.3.6 Operations Documentation

This item covers the documentation and instructions for the operators in order to support the data storage and archiving for 24x7 operations. This includes who to page under what circumstances, how to re-instantiate archived tapes, etc.

1.1.6.1.3.6.1 Develop initial methods
1.1.6.1.3.6.2 Maintain methods

1.1.7 Data import/export

The Tier 1 Center will interchange data with the Tier 0 center and five Tier 2 Centers. (In addition, it may interchange data with other institutions having data of interest. For planning purposes, we take this miscellaneous interchange as

one additional unit of interchange. A unit of effort for planning purposes is 1/8 of an FTE, or about 250 hours, before deductions for vacation, sick time and IEDA. Divided by 7, and allowing for vacation, sick time, IEDA, the planning unit would give about 24 hours/year of effective working time devoted to each peer institution.

1.1.7.1 Tape import/export

Given specifications for tape volume interchange, provide the capability to read and write tape in the specified formats and provide any other required mechanisms provide to implement production interchanges by tape. Define the work of actually interchanging data. For planning purposes we anticipating exporting and importing 500 TB/year by tape.

We assume there are three types of tape and drives in order to account for variations between the generating and receiving locations. We further assume that each year one type of drive will be replaced with another. Our experience is that tape interchange fails if one party will not put substantial effort to accommodate the working methods of the other. We assume the Tier 1 Center will have to accommodate variety amongst the Tier 2 Centers.

1.1.7.1.1 Facility Planning

We assume this takes 1/8 FTE for the initial planning.

1.1.7.1.2 Procurement Installation &configuration

1.1.7.1.2.1 Tape Technology

This item includes an initial installation of three tape technologies (1/8 FTE, one time) and a yearly replacement of one tape technology (1/8 FTE).

1.1.7.1.2.2 Tape Import/export method planning

Develop any software and procedures required to effect interchange: with the Tier 0 Center and the five Tier 2 centers: read and write tapes, handle them in an automated way.

1.1.7.1.2.2.1 Initial development

We estimate it takes ¼ FTE to initially develop the plan for tape import/export.

1.1.7.1.2.2.2 Maintenance

This item covers maintenance of the system.

1.1.7.1.3 Tape Import/export operations

Actually ingest and export data, transfer files, generate and check meta-data, verify the data transferred as expected. 25 tapes/week , dealing with peers in 6 different locations. One hour/tape: (1/2 FTE)

1.1.7.2 Network import/export

Provide the ability to transfer files for production activities at the requisite data rates and data volumes, between tier 0, tier 2 and other sources of data. Provide transfer mechanisms consistent with the respective organizations' computer security plan and otherwise coordinating with the remote site. Plan capacity and measure performance. Actually realize the needed transfers. Resolve any problems. Estimate : 20 TB per year.

1.1.7.2.1 Planning

This item covers planning and hardware evaluations of network import/export systems

1.1.7.2.2 Interface Software

This item covers software for network import/export. Interface the CMS archive facility at FNAL to five Tier 2 centers and the Tier 0 center.

1.1.7.2.3 Ingest/Export production

This item covers effecting transfers and resolving any problems. Actually ingest and export data, transfer files, generate and check meta-data, verify the data transferred as expected. Coordinate with remote sites. (1/4 FTE)

1.1.8 Data and Physics Analysis Software

This system deploys and maintains tools and environments for analyzing and visualizing the event and non-event data. A major component of this system will be the tools selected as overall CMS standards, LHC++ and other such packages. Sufficient of these systems must be easily and effectively usable and accessible to the Regional Center users and US physicists. These tools must be available on the typical inexpensive commodity desktop. These systems may require extension to support analysis of the data using multiple complementary tools.

1.2 System and User Support

These services and software provide the fundamental infrastructure for the support and use of the Regional Center Facilities. Because we are supporting physicists doing software development, detector design and test beam work during the R&D phase, system and user support services are necessary during all phases of the project. In addition to supporting physicists during the R&D phase, they provide for the efficient and effective use of the Regional Center facilities by the US CMS physicists, Tier II regional centers, and by worldwide CMS collaborators. In each case the expenses are a mixture of commercial software acquisition and licensing costs, and personnel costs for software development and ongoing support and maintenance.

1.2.1 Documentation

Software to support preparation, access to, management of, and distribution of documentation, both of software systems and of CMS hardware and detector systems. Automatic generation of documentation from the code repository is already being used for Run II. Local system and software documentation and distribution is included in here.

This item includes supporting the CMS documentation standards and toolkit and providing a librarian to organize and catalog the documentation available. Copies of the documentation set may be distributed as paper, web copies or CD/DVD copies.

1.2.2 Collaborative Tools

The key goal of facilitating physics research by CMS collaborators independent of their geographic location requires development, widespread deployment and systematic support of new tools to facilitate collaboration at a distance. This includes relatively conventional areas such as distributed code management systems and ordinary videoconferencing, to more radical approaches such as extended virtual and tele-presence products and innovative distant sharing of physics analysis. Work is ongoing in these areas, and further R&D is needed.

The UF subproject focuses on the deployment and general support in the US for these tools. Initial and ongoing R&D is being undertaken at Caltech in collaboration with CERN on remote collaboration systems as part of the CAS subproject. There is also substantial R&D underway at Fermilab focused on Run II, which we intend to exploit for CMS.

This item includes video conferencing, web servers and scheduling tools for meetings, etc.

1.2.3 Software Development Environment

Development and installation of the infrastructure which allows US-CMS collaborators to develop software within the CMS framework for execution on compliant CMS facilities. It is presumed that the usual mode of operation for a researcher will be to develop code on his/her desktop with locally resident tools, to coordinate this code with the larger pool of collaboration software, to run test jobs against a cached reference set of data for later submission on a processing facility appropriate to the job. The communication between the desktop and services systems should be as transparent as possible.

This item includes support for CMS code management and code distribution tools, code verification software and standard code development tools.

1.2.4 System Administration, Monitoring and Problem Resolution Software

Tools to allow system administration (account creation and deletion, disk quota and allocation, system software installation and update, etc) for the very large number of individual systems required at the regional center, and to allow monitoring and problem detection of the systems and automated and efficient response.

1.2.5 User Help Desk

Personnel and tools to allow for efficient consulting and help services at the regional center, providing for needs of both local and remote users. This includes development, integration, deployment and maintenance of a problem tracking tool and the CMS share of staffing the helpdesk.

1.2.6 Training Office

A training facility will be required for both end user training in the system and software aspects of US-CMS and also for the staff which will be required to manage and support the US-CMS computing infrastructure. Staff will need to develop training documents. As much of the training as possible should be available "online" due to the distributed nature of the collaboration. An on site training facility with a hands-on lab should also be available for those training needs which are better suited to a live presentation. Video conferencing capability in this facility would be an added benefit. A training lab is in the process of being augmented/deployed at FERMI and some of this work can be leveraged for CMS needs. Work has already started in developing training documents/classes for users and will start soon for training staff. This item also includes costs associated with maintaining a training facility and keeping the class material up to date.

1.2.6.1 User Training

1.2.6.1.1 Coding classes and instruction

One of the roles of the Regional Center will also be to provide training for US-CMS collaborators. We have already initiated training courses at Fermilab in the use of the C++ programming language, based on the successful courses already widely used by CDF and DØ, as well as Object Oriented Analysis and Design. This item covers such training as C++, Java, software design and documentation, and the software development process for large projects.

1.2.6.1.2 CMS Software Tutorials and Workshops

This item covers tutorials on the use of CMS software and computing systems as well as software workshops for experts.

Training will take the form of packages for self education as well as formal training classes, and will provide for both local and remote users. Remote collaborative systems being developed will include support for multi-site interactive training classes, using packet videoconferencing and associated tools.

1.2.6.2 Training support staff

This item covers specialized training for the UF support staff.

1.2.7 Support for Tier 2 Centers

This item covers support in the design, implementation, installation and operations phase for Tier 2 Centers including systems consulting and software installation support and consulting. Support starts during the Tier 2 prototype stage.

1.2.8 Computer Security

This item covers safe guarding the US-CMS compute facility from unauthorized access. The primary goal is to provide an easily accessible online facility for local and remote use while still providing network and computer security to prevent unauthorized access. Unauthorized access is not needed to to any classified work but instead to protect the compute resources from "internet vandals". The securing of the systems can be accomplished in many ways but requires that a couple of major "weak" points in computing systems be fortified.

1.2.8.1 Password Security

First we must try to ensure that user passwords are secure. Work in this area is already in progress at FERMI within the Strong Authentication Project. The primary goal of this project is to eliminate clear text passwords within the FERMI “strengthened realm”. This is being accomplished via the use of kerberos encryption mechanisms. US-CMS systems can leverage the work done to date on SA and become part of the strengthened realm. This is not a zero effort task. Additional work on SA may need to be done to develop tools and enhancements to the system required to support the widely distributed nature of CMS computing.

1.2.8.2 Operating System Security

The second aspect of computer security which must be addressed involves security holes in operating systems or other pieces of software. While FERMI has no direct control over these, systems can be put in place to minimize the risk of them by ensuring that all systems are update to date with vendor recommended security patches. This mechanism must be as automated as possible due to the large numbers of compute systems which will be required for CMS. FERMI already has such a mechanism in place for the Linux OS. Comparable mechanisms need to be developed for other CMS supported OS's (e.g. Solaris).

1.2.8.3 Access Auditing

Much can be done beyond the two previous steps to help fortify the security of computing systems. Systems can be configured to allow (or disallow) access to various services. Additional configuration can be made to audit access to the systems. There are various software components involved in these steps which either need to be purchased or maintained because they are freeware. In addition effort needs to be spent to maintain the optimal configuration and to review the audit reports.

1.3 Operations and Infrastructure

1.3.1 Software license maintenance

This item covers software license maintenance for both the central systems and for desktops. Although CMS specific licenses come through CERN, compiler, software development tools, operating systems, etc. all have related licenses that must be maintained and tracked. The amount of effort is taken from Run 2 experience at Fermilab.

1.3.1.1 Software license tracking (central systems)

This covers software license tracking for central systems for the T1 RC as well as the R&D systems and the systems used for the construction project.

1.3.1.2 Software license tracking (PCs/desktops)

This item covers software license tracking for desktops and non-farm use PC's.

1.3.2 Systems Operation

This item covers stable system operations.

1.3.2.1 Data center operations

This item covers the routine data center operations to support data distribution and archive/retrieval. FTE estimates come from Run 2 experience.

1.3.2.1.1 Operate data center

This item covers routine data center operations.

1.3.2.1.2 Shipping tapes offsite

This item covers effort to ship tapes offsite and receive tapes from offsite.

1.3.2.1.3 Tape copy facility operations

This item covers effort to operate the tape copy facility.

1.3.3 Infrastructure support

This item covers effort to support the computing infrastructure for central systems as well as for offices.

1.3.3.1 Power support
1.3.3.2 Space planning
1.3.3.3 Offices
1.3.3.4 Computer floor

1.4 Tier 2 Regional Center(s)

The US-CMS computing plan calls for building "Tier 2" computing centers at several universities to provide additional support to US-CMS physicists. The motivation for these centers, as well as their functionality and hardware, software and personnel requirements, is discussed here.

The motivation for Tier 2 centers stems from CMS' commitment to meet its analysis requirements through a *highly distributed* data analysis infrastructure [4], an infrastructure that has been broadly adopted by all four LHC experiments. This infrastructure is distributed both for technical reasons (e.g., to place computational and data resources near to demand) and for strategic motives (e.g., to leverage existing expertise and technology investments). The worldwide computing resources are distributed as a hierarchy consisting of five levels, or "Tiers", where Tier 0 is the central facility at CERN; Tier 1 consists of the large national centers (e.g., Fermilab in the US); Tier 2 is a set of centers each covering one region of a large country such as the US or a smaller country; Tier 3 is composed of workgroup servers at universities and institutes; and Tier 4 contains the (thousands of) individual desktops and other access devices. The hierarchy follows a design strategy in which the size of a facility in a particular Tier is dictated by the Tier's average storage, computing and networking capabilities.

Each Tier 2 site will contain 20-25% of the computational capacity of the Fermilab Tier 1 center; so five centers would have approximately the same combined CPU capacity as the Tier 1 facility. Only five Tier 2 sites are being considered at this time, though nothing in principle restricts the total number. It is expected that Tier 2 sites will be sited in

different regions of the US, and located at universities which have significant existing computing infrastructure and good connectivity to regional networks. Thus sites can minimize costs by leveraging existing facilities and support personnel, as well as bringing in additional resources.

Several external projects are conducting R&D and developing prototypes in order to unite all CMS computing facilities from Tier 0 to Tier 4 in a global "computational data grid" that can be accessed from any institution. These projects, all of which involve physicists collaborating with computer scientists, address the general problem of large-scale distributed computation on massive datasets and not CMS' specific needs. The first is the Particle Physics Data Grid (PPDG) [5, funded by DOE from 1999–2001 and led by high-energy physicists, is attempting to develop a network and middleware infrastructure capable of supporting data analysis and data flow patterns common to many particle physics experiments. A major problem they are attacking is high-speed database replication between remote sites. The second activity is the EU DataGrid Project [6, funded for 2000–2003 by the European Union, will build a research testbed linking several large European laboratories. They will test scheduling and data management algorithms in this distributed environment and will run large demonstration experiments from high-energy physics, earth observation science and biology. Finally, the GriPhyN (Grid Physics Network) Project [7, funded by the NSF from 2000–2005, is conducting fundamental R&D on all aspects of large-scale data grids applied to four physics and astronomy experiments: ATLAS, CMS, LIGO and the Sloan Digital Sky Survey (SDSS). Its major deliverable will be a *Virtual Data Toolkit* to be used by the four physics experiments and other projects. GriPhyN incorporates computing leaders from the four experiments in its management structure, and has a direct liaison to the CMS Level 1 Computing Manager. Furthermore, to ensure its relevance, GriPhyN has made a commitment (by working with US-CMS leaders) to incorporate CMS-related computing milestones, schedules and deliverables into the GriPhyN management plan [8].

At this time, US-CMS has adopted a set of principles to differentiate Tier 2 computing activities in this subproject from those of the CAS subproject and external projects such as the ones described above. These principles are, (1) items and activities related to the normal functioning of the Tier 2 center are covered in this subproject (e.g., acquisition, installation and commissioning, hardware and software maintenance, developing management scripts, user support); (2) items and activities related to testing and deploying grid software tools are covered in this subproject; (3) efforts involved in researching and developing grid tools are considered to be external to the project or covered in a limited way in the Core Application Software (CAS) subproject; and (4) items and activities connected to the incorporation of grid tools into CMS core software are considered to belong to the CAS subproject. These categories are not straightforward to distinguish in all cases, but the separation should be valid most of the time.

The deployment of Tier 2 centers will have prototype and implementation phases, timed to occur simultaneously with those of the Tier 1 facility. The prototype phase FY2000–FY2003 will see the initial deployment and operation of small centers, one just before FY2001, one in FY2001 and one in FY2002. Prototype Tier 2 centers are needed to perform simulations, test hardware, networking, software and operations and to assist in activities that test and evaluate the data grid hierarchy. "Fully-equipped" Tier 2 centers will be deployed starting in FY2004, the same year as the Tier 1 center at Fermilab. Two will be deployed in FY2004, two in FY2005 and one in FY2006, the first year of LHC operations. Each Tier 2 center will have a Level 3 manager who will be responsible for ensuring that the milestones and deliverables applicable to that site are met on schedule. Centers are listed separately as they will ramp up at different times.

Tier 2 centers have several general responsibilities: (1) simulations (including reconstruction of simulated events), (2) user analysis, and (3) testing and other services in support of distributed analysis and the CMS data grid [4, 7]. The CPU and disk capacities reflect the fact that almost all simulations are performed on Tier 2 equipment and each center has a share of 20% of US physicists for analysis. Simulation and analysis require varying degrees of Tier 2 personnel involvement, particularly at peak times, to handle hardware and software problems, redistribute or reconfigure resources, coordinate with Tier 1 and other Tier 2 personnel, and help users. Heavy use of Tier 2 facilities for physics simulation is expected to occur during the run-up to the CMS Physics TDR in 2003.

1.4.1 Tier 2 Center #1

This task covers all items and activities needed for the first Tier 2 Center during its prototype and implementation phases. (For simplicity, we assume that the prototype center will become a fully implemented center in 2004. This is not guaranteed, as the US-CMS collaboration determines the location of all Tier 2 centers, but it simplifies the presentation of the WBS.) This center started a prototype phase in October 2000 and is located at the Caltech Center

for Advanced Computing Research (CACR) and the San Diego Supercomputer Center (SDSC). The center hardware was purchased from FY2000 funds, not listed here.

1.4.1.1 Tier 2 Design

This task covers the R&D needed to design this prototype center.

1.4.1.2 Tier 2 Equipment

This task includes all items and activities related to the equipment for this prototype center.

1.4.1.2.1 Hardware Procurement & Installation

This task covers the purchase and installation of the equipment.

1.4.1.2.2 Hardware Commissioning

It is expected that the heterogeneous hardware configuration (dual CPU boxes, data server, disks, LAN switches, power supplies, cooling and cabling) will require a commissioning phase to ensure smooth operation. Testing and reconfiguration of hardware will take place during this phase.

1.4.1.2.3 Hardware Support and Maintenance

This task covers all efforts related to the long-term maintenance of the equipment following the commissioning phase. Included are replacement or repair of damaged equipment, testing, bringing hardware online or offline as needed, kicking broken equipment across the room, routine inspections and operating system updates.

1.4.1.3 General Software

This task covers items and activities associated with non-grid related software.

1.4.1.3.1 General Software Testing

This task covers items and activities associated with non-grid related software testing.

1.4.1.3.2 General Software Deployment and Maintenance

This task covers items and activities associated with non-grid related software deployment and maintenance.

1.4.1.4 Grid Software

This task covers items and activities associated with the distributed analysis infrastructure for this prototype center. The distributed analysis infrastructure will be developed largely through integration of toolkits and methods developed by the data grid projects described previously, but will also benefit from several subtasks within the CAS subproject that are described in more detail in ref. [4]. These are

- **Distributed task scheduling**: Develop tools to schedule jobs at multiple geographic locations.
- **Distributed database management**: Develop tools to control the replication and synchronization of object databases at remote sites. Improve database performance and monitoring.
- **Load balancing**: Develop algorithms and tools to balance resources at a single site and eventually at multiple locations.
- **Distributed production tools**: Develop tools to aid CMS current production work on existing computing facilities, including those shared with non-CMS users and different computing architectures and configurations.
- **System simulation**: Simulate the performance of a computational grid with many users and jobs. The simulation uses tools developed by the MONARC project.

The integration of all these activities impacts the UF subproject because of the need to run "grid level" tests and monitoring activities at Tier 1 and Tier 2 sites. These latter activities normally will require the involvement of Tier 2 personnel at several sites and sometimes will reduce the availability of hardware for physics analysis and simulations (some tests can be conducted on real physics jobs, but in general some equipment will be set aside).

Because of the separately defined timelines of grid activities inside and outside the project we choose for now to avoid undue complexity in the WBS by aggregating all grid related personnel requirements for now into a single WBS level.

1.4.1.4.1 Grid Software Deployment

This task covers all items and activities related to the deployment of grid software and other software developed in support of Tier 2 operations.

1.4.1.4.2 Grid Software Testing

This task covers testing of grid software developed outside the project and other software developed in support of Tier 2 operations.

1.4.1.4.3 Grid Software Support and Maintenance

This task covers all items and activities related to maintaining grid software and other software developed in support of Tier 2 operations. Possible activities include installing and testing new software releases, monitoring of performance of existing software, evaluating and comparing software, and developing tools to automate or simplify software maintenance.

1.4.1.5 Physics Simulation Support

Physics simulation requires Tier 2 personnel involvement, particularly at peak times, to move data to and from the Tier 2 facility, handle hardware and software problems, redistribute or reconfigure resources, coordinate with Tier 1 and other Tier 2 personnel, and help users. The degree and kind of support will evolve as grid tools become are deployed and T1-T2, T2-T2 and T2-T3 interactions become more commonplace.

1.4.1.6 User Analysis Support

User analysis requires Tier 2 personnel involvement to handle hardware and software problems, redistribute or reconfigure resources, coordinate with Tier 1 and other Tier 2 personnel, and help users. The degree and kind of support will evolve as grid tools are deployed and T1-T2, T2-T2 and T2-T3 interactions become more commonplace.

This task includes all items and activities related to integrating the computing facilities with that of the Tier 1 center in support of a distributed computing system.

1.4.1.7 System Documentation

Documentation of Tier 2 hardware and software is needed by the physicists and staff at this center (particularly as support personnel and students are hired), by other Tier 2 sites that will be coming online later and by physicists at other CMS institutions that will be using Tier 2 services.

1.4.2 Tier 2 Center #2

This item covers the effort needed for the second Tier 2 Center. This center will come online in FY2001 as a prototype center. For the time being, the WBS tasks are the same as that of the first Tier 2 center.

1.4.3 Tier 2 Center #3

This item covers the effort needed for the third Tier 2 Center. This center will come online in FY2002 as a prototype center. For the time being, the WBS tasks are the same as that of the first Tier 2 center.

1.4.4 Tier 2 Center #4

This item covers the effort needed for the fourth Tier 2 Center. This center will come online in FY2005 as a full Tier 2 center. For the time being, the WBS tasks are the same as that of the first Tier 2 center.

1.4.5 Tier 2 Center #5

This item covers the effort needed for the fifth Tier 2 Center. This center will come online in FY2006 as a full Tier 2 center. For the time being, the WBS tasks are the same as that of the first Tier 2 center.

1.5 Networking

1.5.1 On-site network infrastructure

This item covers the design, procurement, implementation and operation of the network infrastructure and services necessary to support the US-CMS User Facilities located at Fermilab. Dedicated, high performance network infrastructure will be required to support the Fermilab-based CMS central computing resources, including analysis systems, data management & access systems, and data storage systems. Network support for CMS desktop computing systems will also be necessary. Network services will need to be provided in an ongoing basis. The general approach will be to provide network resources & services designed to meet the specific requirements of the US-CMS User Facilities, but consistent with overall network architecture & operation of the Fermilab local network.

1.5.1.1 Network design

The design component of section 1.6.1 will involve the evaluation, proto-typing, and selection of networking technologies for the Fermilab-based US-CMS computing resources. Cost/performance trade-offs will be assessed, and factored into technology selections. The architectural design selected will be consistent with and easily integrated into the overall Fermilab local network architecture. Network technology & hardware choices will be reviewed on an ongoing basis to ensure that network requirements for US-CMS User Facilities continue to be met.

1.5.1.2 Network equipment procurement and implementation

The implementation component of section 1.6.1 will involve the procurement and installation of the network infrastructure for the Fermilab-based US-CMS systems. Verification of design performance expectations will be performed. Network hardware will upgraded or replaced as necessary to keep the local CMS network infrastructure capable of meeting the needs of the systems it is designed to support.

1.5.1.3 Operational network support

The operational component of section 1.6.1 will involve the day-to-day support and ongoing maintenance of local network infrastructure dedicated to US-CMS systems. Network services necessary for the operation of US-CMS systems will be provided, with dedicated servers deployed where necessary. Operational support for the US-CMS local network will be integrated into the overall Fermilab local network, to the extent practicable, in order to provide maximum coverage at minimum cost.

1.5.2 Off-site network support

This item covers the support necessary to provide off-site network access for Fermilab-based US-CMS User Facilities. Fermilab-based US-CMS systems will have wide area network access requirements that extend beyond the site's general off-site access facilities. As a CMS Tier 1 Regional Center, Fermilab will require a high bandwidth, highly reliable access path to CERN. Similarly, Fermilab will need to offer similar high bandwidth, high reliability access paths for US-CMS Tier 2 Regional Centers. The high bandwidth, high performance network paths to CERN and the US Tier-2 sites will rely on the backbone services of the major US research networks, particularly ESnet and the Internet-2 networks. While design & operation of these networks is outside the scope of this project proposal, robust &

reliable access paths between the local Fermilab network infrastructure and those networks will be necessary. In addition, network services associated with Data Grids used by US-CMS User Facilities will be needed.

1.5.2.1 CERN connectivity

US-CERN networking is assumed to utilize the trans-Atlantic network facilities provided for LHC and other major DOE/NSF's high energy physics programs. Fermilab's ESnet connection is expected to serve as the wide-area access path to the CERN trans-Atlantic facilities. However, CMS may require additional bandwidth beyond the capacity of Fermilab's ESnet link (currently an OC3, but expected to be an OC12 in 12-18 months). Additionally, some form of guaranteed bandwidth between Fermilab and CERN may be required, and an alternate access path between Fermilab and the CERN trans-Atlantic facilities may be needed. Fermilab's off-site access facilities will be engineered and upgraded to meet the bandwidth, performance, and redundancy needs for the movement of CMS data between Fermilab and CERN. The operational support of the upgraded off-site network facilities will be integrated into the overall Fermilab wide area network support effort.

1.5.2.2 US-CMS collaboration connectivity

Network access between Fermilab and US-CMS Tier-2 Regional Centers is assumed to be via the Internet-2 networks. Fermilab's ESnet link is expected to provide the default access path to the Internet-2 networks as well. Higher bandwidth, guaranteed bandwidth, or alternate access to the Internet-2 network infrastructure may be needed to provide the performance and robustness required between Fermilab and the Tier-2 Centers. The operational support of the upgraded off-site network facilities will be integrated into the general Fermilab wide area network support effort.

1.5.2.3 Data grid network services

The US-CMS collaboration is expected to incorporate data grid services to optimize the movement of data between collaborating CMS sites. Data grid services are in very early stages of development, and not clearly defined at this time. A component of data grid services will include network services, such as Quality-of-Service mechanisms. The design, proto-typing, implementation, and operational support of the network services necessary for the deployment and use of data grid services are included in this item.

1.5.3 Network security

This item covers the design, implementation, and operation of network security services and mechanisms necessary for secure operation of the US-CMS systems at Fermilab. Two components are identified. One is the network-level security devices and mechanisms needed to protect on-site CMS systems from vulnerabilities associated with general internet connectivity. The other is collaboration-wide security services and mechanisms that will be deployed across the CMS collaboration, including at Fermilab, to facilitate secure collaboration-wide operation. The latter services and mechanisms will likely be associated with the data grid services deployed by the collaboration.

1.5.3.1 On-site network security

Network-level protection devices, such as firewalls and intrusion detection systems, will be put in place at Fermilab to protect local US-CMS systems. To the extent practicable, network-level security protection for local CMS systems will be incorporated into the site's existing network security infrastructure. Operational support for network protection devices dedicated to local CMS systems will be integrated into Fermilab's general network security support effort.

1.5.3.2 Collaborative-wide network security

The network security services and mechanisms identified by the collaboration for the movement of data between Fermilab and other CMS sites will be implemented and supported. The design, proto-typing, implementation, and operational support of the security services, such as authentication and access control mechanisms, necessary for the deployment and use of data grid services for CMS are included in this item.

1.5.4 Network performance monitoring

This item covers network monitoring, performance, and troubleshooting support effort required for the efficient operation of the network infrastructure supporting CMS systems at Fermilab. Two components are identified. One is monitoring and optimization of network performance across the local CMS network infrastructure at Fermilab. The other is monitoring and network performance optimization of CMS data movement between Fermilab and other CMS collaboration sites. To the extent practicable, local and wide area network performance monitoring will be part of the overall Fermilab network performance troubleshooting and optimization support effort.

1.5.4.1 On-site network performance monitoring & troubleshooting

Network performance & troubleshooting tools will be procured and developed to assist in optimizing local network use by CMS computing systems located at Fermilab. Software products and tools will be procured or developed to quantify and display the performance characteristics of the local CMS network infrastructure. Local network performance analysis and troubleshooting will be provided. LAN analyzers, packet capture probes, and related hardware tools will be procured to assist with investigation of local CMS network performance problems.

1.5.4.2 Off-site network performance monitoring & troubleshooting

Network performance & troubleshooting tools will be needed to assist in detecting and diagnosing wide area network performance problems between Fermilab and CERN, as well as between Fermilab and the US-CMS Tier-2 Centers. The wide area network infrastructure used for CMS collaboration will be operated & supported by network service providers, such as ESnet, Abilene, etc. Those service providers will monitoring the status and function of their network infrastructure. However, end-to-end performance monitoring & troubleshooting between Fermilab and CERN, as well as between Fermilab and the Tier-2 Centers will be necessary. Tools to facilitate that monitoring & troubleshooting will be developed. The wide area performance tool kit will be based, to the extent practicable, on specifications for monitoring and instrumentation tools for the data grid services deployed within the collaboration.

1.6 Computing and Software R&D

This item covers both hardware and software R&D activities of the User Facilities Subproject up to and including commissioning of the initial prototype regional center in 2002. These include activities carried out primarily at the site if the Tier 1 Regional Center (FNAL), as well as R&D efforts at other institutes important to the design and operation of the Regional Center itself and the overall distributed data access and analysis architecture. There is some overlap of these activities with the Core Applications Software subproject, especially in the software development and testing area. In general this subproject concentrates on those aspects related to deployment, operations and support, while the AS subproject concentrates on software design and development, preparation of software releases, and end user interface aspects.

1.6.1 Distributed Data and Computing Test Beds

A key concept in the CMS computing plan is the use of interconnected centers located throughout the world to perform CMS reconstruction and analysis. The MONARC (Models Of Network Analysis at Regional Centers) R&D project [3], a common project endorsed and monitored by the LCB (LHC Computing Board) is actively engaged in studying this issue. US-CMS has assumed an important leadership role in MONARC, and a number of US CMS scientists are collaborating on this project.

Hardware will be needed to perform tests of MONARC concepts and to measure performance. These tests will provide important inputs to the actual design of regional centers and their interconnections, and to the proposed strategies to be used for distributed data analysis. This WBS item provides the funding for MONARC associated test-bed systems that will be used to measure fundamental parameters of distributed data analysis using various databases (as input for modeling activities described below), and to create small scale distributed data analysis test-bed systems as described in the MONARC project execution plan. The test-bed systems at FNAL will interact with other systems in the US and in Europe over wide area networks, with an emphasis on the next generation networks that will soon become available in the US.

1.6.1.1 Hardware Testbed system design

This item covers the design, in coordination with T0 and T2 centers where appropriate, of the hardware testbed.

1.6.1.2 Hardware Testbed system

This item covers procurement, installation and commissioning of the hardware testbed. This item includes procurement, installation and commissioning of the system.

1.6.1.3 Distributed Data Management software

Because CMS computing depends heavily on distributed data and data management, the T1 center will have to develop and maintain the tools needed for this. Most of the development is expected to occur in the CAS project or in other computing projects such as PPDG and GriPhyN, however an item is in here for any additional development needed for use in the T1 specific architecture. This item also includes maintenance of the software which ends after the fully functional regional center and moves to item 1.2.4.

1.6.1.4 Distributed Data Access software

This item develops (as necessary), deploys and maintains software at the T1 center necessary for distributed data access.

1.6.1.5 Monitoring Tools

This item covers the development (as necessary) and maintenance of monitoring tools for the Prototype RC and for computing R&D.

1.6.1.5.1 Data Access Monitoring

This item covers development , deployment and maintenance of software needed to monitor data access and use patterns during the R&D phase.

1.6.1.5.2 Systems Monitoring (CPU/MEM/ETC)

This item covers monitoring of the hardware systems including CPU usage, memory usage and other systems level parameters. These parameters can be compared against the MONARC simulations in order to validate the design for the T1 RC.

1.6.2 R&D in Commodity Computing for T1/T2 Computing

This item covers R&D in using cheap(er) hardware for the central T1/T2 centers. Much of this effort will be in coordination with CERN as the T0 center. This item continues into the operations phase because tracking technology and deploying test systems to try new hardware will be an ongoing activity in order to keep the central systems up to date.

We assume the basic building blocks are CPU intensive farms, with low I/O requirements such as those used in Run 2, data intensive farms for analysis to replace the expensive SMP boxes used in Run 2 and data servers with large amount of disk to test data distribution with large database AMS.

1.6.2.1 Technology Tracking

This item covers tracking technology and watching the market for faster, better, and cheaper ways of supplying computing for CMS.

1.6.2.2 Technology Investigation and Deployment

This item covers test and evaluation systems deployment.

1.6.2.2.1 Data Intensive Computing
This item covers the procurement, installation and commissioning of Linux machines to be used for data analysis. They have a strong I/O component . The system infrastructure software is also included.

1.6.2.2.2 CPU Intensive Computing
This item covers the procurement, installation and commissioning of farm-like Linux machines. The system infrastructure software is also included, although we don't expect to have to develop special software since these types of farms are already deployed at Fermilab. Most of the effort is in software maintenance.

1.6.2.2.3 Data Access and Distribution Servers
This item covers the procurement, installation and commissioning of servers and disks needed to distribute the event data. We assume the software (e.g. AMS servers) will be developed elsewhere in CMS, however deployment and maintenance is included here.

1.6.3 Prototype Fully Functional Center

It is expected that the hardware for the initial regional center operation (which will start at initial data taking in 2005) will be acquired over a three year period, as described above. However, it is necessary to assemble a lower capacity but fully functional regional center at an earlier date to provide proof of concept at an early enough date to allow design modifications in potential problem areas. CMS has a milestone for such prototyping of regional center operation in 2002. This WBS item covers the hardware required for these initial tests.

1.6.4 Computing Systems simulation software

As described above, the MONARC project is studying the parameters of distributed data analysis architectures with full participation by US-CMS physicists. One important component of this study is to model and simulate the CMS analysis process, including a full complement of (modeled) regional and local centers. This item covers the installation, support and use of prototype software, including a selected set of analysis and database applications, in production-prototype systems to test the MONARC concepts and measure key parameters that govern the performance of the distributed systems.

This complements, and must be coordinated with, the efforts to understand and characterize the physics analysis process, and to develop, run and analyze simulations of these systems, which are described in the CAS subproject document.

1.6.5 System Administration
This item covers routine system administration for the test and development systems.

1.7 CMS Detector Construction Phase Computing

Some of the computing power needed during the construction phase can be supplied by leveraging the use of shared FNAL computing resources. There will be a need for some dedicated CMS systems, including support for test beams, data handling and analysis, certain compute intensive simulation projects, and software development and distribution servers. These systems have a modest scope compared to the eventual production systems. The main characteristic of these systems is the substantial re-use of computing methods in use at FNAL rather than the final methods developed for production use while the experiment is under construction. Effort is reserved for coping with fluid specifications for data interchange because of similar considerations at the Tier 0 and Tier 2 sites.

The type of work necessary to provide for Construction Phase computing includes: work to configure the facilities to be useable in the CMS environment; work to modify, extend and configure CMS software to use the existing facilities.; Incremental work involved in operating and maintaining shared facilities, including lifetime upgrades; providing input to the design of the final system; Specification and construction of a modest, dedicated to CMS computing facility.

1.7.1 CMS Computing Facility

This item covers the procurement, installation, commissioning and maintenance of any additional dedicated CMS computing needed for the construction phase activity. The FTE estimate is very low as we assume most of the effort will be leveraged from the central computing systems for the Computing Facility.

1.7.2 Data Storage System

This item covers the provision of elements of a data storage system from parts of the Fermilab data storage infrastructure

1.7.2.1 Procurement of extra capacity

This item covers the procurement of extra tape drives and media needed to support the CMS experiment during the construction phase.

1.7.2.2 Extra administration

This item covers any extra administration needed for the CMS data storage system.

1.7.2.3 Software Interface

This covers software necessary to archive and retrieve data and databases in a mass storage system within the CMS experiment.

1.7.2.4 Export data to final system

This item covers the export of any data needed to the final Tier 1 center as it comes on line.

1.7.3 Network based file interchange

Provide the ability to transfer files for production activities at the requisite data rates and data volumes, between Tier 0, Tier 2 and other sources of data. Provide transfer mechanisms consistent with the respective organizations' computer security plan and otherwise coordinating with the remote site. Plan capacity and measure performance. Actually realize the needed transfers. Resolve any problems. For planning purposes, we estimate the need to transfer 20 TB per year during the construction phase.

1.7.3.1 Planning
1.7.3.2 Software

This item covers the deployment and development (as necessary) of software needed to transfer data to/from remote sites and to monitor the performance.

1.7.3.3 Production

This item covers actually realizing the needed transfers and problem resolution. For planning purposes, we estimate the need to transfer 20 TB per year during the construction phase. We will measure the performance during this stage as well.

1.7.4 Tape import/export

Provide the ability to read and write tape formats acceptable to the institutions mentioned below, and provide methods to implement data production interchanges by tape. We estimate about 100 tapes/year for the construction phase.

1.7.4.1 Planning/coordination

This item covers the planning for the system and coordination with T0 and (prototype) T2 centers.

1.7.4.2 Procurement

For planning purposes we are assuming two distinct tape technologies + automation.

1.7.4.3 Software

Develop any software required to effect interchange: read and write tapes, handle them in an automated way

1.7.4.4 Production

Identify operational procedures for data interchange and actually ingest and export data, transfer files, generate and check meta-data, verify the data transferred as expected.

Provide tapes, tape drives, tape libraries and attendant computers required for tape interchange with Tier 0 center

1.7.5 System Administration

This item covers routine system administration for CMS systems during the construction phase.

1.8 Support for FNAL based computing

This item covers both hardware and software activities of the User Facilities Subproject up to and including commissioning of the initial prototype regional center in 2002. These include activities carried out primarily at the site if the Tier 1 Regional Center (FNAL), as well as R&D efforts at other institutes important to the design and operation of the Regional Center itself and the overall distributed data access and analysis architecture. There is some overlap of these activities with the Applications Software subproject, especially in the software development and testing area. In general this subproject concentrates on those aspects related to deployment, operations and support, while the AS subproject concentrates on software design and development, preparation of software releases, and end user interface aspects.

1.8.1 Desktop Systems

These systems provide desktop computing resources to local users and visitors at the regional center. The assumption is that we will be supporting 100 desktop systems by the year 2006. Support numbers come from Run 2 experience.

1.8.1.1 Installation

1.8.1.1.1 System specification and design

This item covers the specification of both desktop and server machines to form a homogeneous set of heterogeneous machines.

1.8.1.1.2 Host server systems

This item covers the host server systems, assuming 1 server class machine for every 20 desktops.

1.8.1.1.3 Backup systems

This item covers a backup system for the user areas on the desktops.

1.8.1.1.3.1 Tape technology selection
1.8.1.1.3.2 Robot specification and selection
1.8.1.1.3.3 Installation and setup

1.8.1.2 Support

This item covers desktop OS installation and updates and CMS/FNAL product installation and updates. Hardware repair for desktops is assumed to be outsourced (i.e. D1).

1.8.1.3 User data storage and archiving

This item covers the system specification, design, installation and deployment for a backup system for user data storage and archiving.

1.8.2 Remote Control Room

This item covers the hardware and software needed to run a remote control room at Fermilab.

FTE Profile

The following tables show the FTE estimates for each WBS item.

	2001	2002	2003	2004	2005	2006	2007
1.1.1 Development and Test systems	**0**	**0**	**0**	**2.5**	**1.75**	**1.75**	**2.5**
1.1.1.1 Modular Test Stands	0	0	0	0.5	0	0	0.5
1.1.1.1.1 Offline Storage	0	0	0	0.125	0	0	0.125
1.1.1.1.2 Online Storage	0	0	0	0.125	0	0	0.125
1.1.1.1.3 Data Distribution Server	0	0	0	0.125	0	0	0.125
1.1.1.1.4 Software Build Machine	0	0	0	0.125	0	0	0.125
1.1.1.2 Integration Test Stand	0	0	0	2	1.75	1.75	2
1.1.1.2.1 Hardware	0	0	0	0.75	0	0	0.25
1.1.1.2.1.1 Hardware System Design	0	0	0	0.125	0	0	0.25
1.1.1.2.1.2 Integration Test Stand Hardware	0	0	0	0.625	0	0	0
1.1.1.2.1.2.1 Procurement	0	0	0	0.125	0	0	0
1.1.1.2.1.2.2 Installation & Commissioning	0	0	0	0.5	0	0	0
1.1.1.2.2 Software Deployment and Integration	0	0	0	1.25	1.75	1.75	1.75
1.1.1.2.2.1 Distributed Data Management (SW)	0	0	0	0.25	0.5	0.5	0.5
1.1.1.2.2.1.1 Software Deployment & Devel.	0	0	0	0.25	0.25	0.25	0.25
1.1.1.2.2.1.2 Maintenance	0	0	0	0	0.25	0.25	0.25
1.1.1.2.2.2 Distributed Data Access (SW)	0	0	0	0.25	0.5	0.5	0.5
1.1.1.2.2.2.1 Software Development	0	0	0	0.25	0.25	0	0
1.1.1.2.2.2.2 Maintenance	0	0	0	0	0.25	0.5	0.5
1.1.1.2.2.3 Monitoring Tools	0	0	0	0.75	0.75	0.75	0.75
1.1.1.2.2.3.1 Data Access Monitoring	0	0	0	0.25	0	0	0
1.1.1.2.2.3.1.1 Maintenance	0	0	0	0	0.25	0.25	0.25
1.1.1.2.2.3.2 Network Monitoring	0	0	0	0.25	0	0	0
1.1.1.2.2.3.2.1 Maintenance	0	0	0	0	0.25	0.25	0.25
1.1.1.2.2.3.3 Systems Monitoring	0	0	0	0.25	0	0	0
1.1.1.2.2.3.3.1 Maintenance	0	0	0	0	0.25	0.25	0.25

	2001	2002	2003	2004	2005	2006	2007
1.1.2 Simulation & Reconstruction systems	**0**	**0**	**0**	**1.75**	**3.125**	**4**	**2.75**
1.1.2.1 Hardware	0	0	0	1	1.75	2.25	1.25
1.1.2.1.1 Procurement	0	0	0	0.25	0.25	0.25	0.25
1.1.2.1.2 Installation & Commissioning	0	0	0	0.5	1	1.5	0.5
1.1.2.1.3 Hardware Maintenance	0	0	0	0.25	0.5	0.5	0.5
1.1.2.2 Software	0	0	0	0.5	0.75	0.75	0.5
1.1.2.2.1 Deployment & Development	0	0	0	0.25	0.5	0.5	0.25
1.1.2.2.2 Software Maintenance	0	0	0	0.25	0.25	0.25	0.25
1.1.2.3 System Administration	0	0	0	0.25	0.625	1	1
1.1.3 Analysis Systems	**0**	**0**	**0**	**2.25**	**5.5**	**9**	**7.75**
1.1.3.1 Hardware	0	0	0	0.875	2	3.5	2.5
1.1.3.1.1 Procurement	0	0	0	0.25	0.5	0.5	0.5
1.1.3.1.2 Installation & Commissioning	0	0	0	0.5	1	2	1
1.1.3.1.3 Hardware Maintenance	0	0	0	0.125	0.5	1	1
1.1.3.2 Software	0	0	0	0.375	1	1.25	1
1.1.3.2.1 Deployment & Development	0	0	0	0.375	0.5	0.75	0.5
1.1.3.2.2 Software Maintenance	0	0	0	0	0.5	0.5	0.5
1.1.3.3 System Administration	0	0	0	1	2.5	4.25	4.25
1.1.4 Data Access and Distribution Servers	**0**	**0**	**0**	**1**	**1.25**	**1.25**	**1.25**
1.1.4.1 Hardware	0	0	0	0.5	0.5	0.5	0.5
1.1.4.1.1 Procurement	0	0	0	0.125	0.125	0.125	0.125
1.1.4.1.2 Installation & Commissioning	0	0	0	0.25	0.125	0.125	0.125
1.1.4.1.3 Hardware Maintenance	0	0	0	0.125	0.25	0.25	0.25
1.1.4.2 Software	0	0	0	0.5	0.75	0.75	0.75
1.1.4.2.1 Local Software	0	0	0	0.25	0.25	0.25	0.25
1.1.4.2.1.1 Deployment & Development	0	0	0	0.25	0.125	0.125	0.125
1.1.4.2.1.2 Software Maintenance	0	0	0	0	0.125	0.125	0.125
1.1.4.2.2 GRID Software	0	0	0	0.25	0.5	0.5	0.5
1.1.4.2.2.1 Deployment & Development	0	0	0	0.25	0.25	0.25	0.25
1.1.4.2.2.2 SoftwareMaintenance	0	0	0	0	0.25	0.25	0.25

	2001	2002	2003	2004	2005	2006	2007
1.1.5 Calibration and Non-Event Database Servers	**0**	**0**	**0**	**0.625**	**0.75**	**0.75**	**0.75**
1.1.5.1 Hardware	0	0	0	0.25	0.25	0.25	0.25
1.1.5.2 Software	0	0	0	0.25	0.25	0.25	0.25
1.1.5.3 System Administration	0	0	0	0.125	0.25	0.25	0.25
1.1.6 Data Storage Systems	0	0	0	2	2.375	1.375	1
1.1.6.1 Tape Data Storage System	0	0	0	2	2.375	1.375	1
1.1.6.1.1 Procurement and installation	0	0	0	1	1	0.5	0
1.1.6.1.2 Storage System Interface Development:	0	0	0	0.25	0.25	0.25	0.25
1.1.6.1.3 Archive Administration O & M	0	0	0	0.75	1.125	0.625	0.75
1.1.6.1.3.1 Ewuipment Maintenance	0	0	0	0.125	0.125	0.125	0.125
1.1.6.1.3.2 Tape Maintenance	0	0	0	0.125	0.125	0.125	0.125
1.1.6.1.3.3 Media Upgrades	0	0	0	0	0	0	0.125
1.1.6.1.3.4 Software and Configuration Updates	0	0	0	0.125	0.125	0.125	0.125
1.1.6.1.3.5 Routine Administration	0	0	0	0.125	0.125	0.125	0.125
1.1.6.1.3.6 Operations Documentation	0	0	0	0.25	0.625	0.125	0.125
1.1.6.1.3.6.1 Develop initial methods	0	0	0	0.25	0.5	0	0
1.1.6.1.3.6.2 Maintain methods	0	0	0	0	0.125	0.125	0.125
1.1.7 Data import/export	**0**	**0**	**0**	**1.625**	**1.25**	**1.25**	**1.25**
1.1.7.1 Tape import/export	0	0	0	0.875	0.75	0.75	0.75
1.1.7.1.1 Facility Planning	0	0	0	0.125	0	0	0
1.1.7.1.2 Procurement, Installation & Conf.	0	0	0	0.5	0.25	0.25	0.25
1.1.7.1.2.1 Tape Technology	0	0	0	0.25	0.125	0.125	0.125
1.1.7.1.2.2 Tape Import/export method planning	0	0	0	0.25	0.125	0.125	0.125
1.1.7.1.2.2.1 Initial development	0	0	0	0.25	0	0	0
1.1.7.1.2.2.2 Maintenance	0	0	0	0	0.125	0.125	0.125
1.1.7.1.3 Tape Import/export operations	0	0	0	0.25	0.5	0.5	0.5
1.1.7.2 Network Import/export	0	0	0	0.75	0.5	0.5	0.5
1.1.7.2.1 Planning	0	0	0	0.25	0.125	0.125	0.125
1.1.7.2.2 Interface Software	0	0	0	0.25	0.125	0.125	0.125
1.1.7.2.3 Ingest/Export production	0	0	0	0.25	0.25	0.25	0.25
1.1.8 Data and Physics Analysis Software	**0**	**0**	**0**	**0.875**	**1**	**1**	**1**
1.1.8.1 Deployment	0	0	0	0.5	0.5	0.25	0.25
1.1.8.2 Maintenance	0	0	0	0	0.125	0.125	0.125
1.1.8.3 Licenses	0	0	0	0.125	0.125	0.125	0.125
1.1.8.4 User Support	0	0	0	0.25	0.25	0.5	0.5

	2001	2002	2003	2004	2005	2006	2007
1.2 System and User Support	**1.3125**	**2.25**	**3**	**3.125**	**5**	**4.5**	**4.5**
1.2.1 Documentation	0.125	0.25	0.5	0.5	1	1	1
1.2.2 Collaborative Tools	0.125	0.125	0.25	0.25	1	1	1
1.2.3 Development Environment	0.125	0.25	0.5	0.5	1	1	1
1.2.4 Administration, Monitoring + Problem Resol	0.1875	0.625	0.5	0.5	0.5	0.25	0.25
1.2.4.1 User administration tools	0.0625	0.125	0.125	0.125	0.125	0.05	0.05
1.2.4.2 Resource allocation and tracking tools	0.0625	0.25	0.125	0.125	0.125	0.1	0.1
1.2.4.3 Resource/process monitoring tools	0.0625	0.25	0.25	0.25	0.25	0.1	0.1
1.2.5 User Help Desk	0.125	0.25	0.25	0.25	0.375	0.25	0.25
1.2.5.1 Problem tracking tool	0.0625	0.2	0.2	0.2	0.25	0.125	0.125
1.2.5.2 Staffing of helpdesk	0.0625	0.05	0.05	0.05	0.125	0.125	0.125
1.2.6 Training Office	0.25	0.25	0.25	0.25	0.25	0.25	0.25
1.2.6.1 User Training	0.125	0.125	0.125	0.125	0.125	0.125	0.125
1.2.6.2 Training support staff	0.125	0.125	0.125	0.125	0.125	0.125	0.125
1.2.7 Support for Tier 2 Centers	0.25	0.25	0.25	0.375	0.375	0.25	0.25
1.2.7.1 Software Installations	0.125	0.125	0.125	0.25	0.25	0.125	0.125
1.2.7.2 Systems Consulting	0.125	0.125	0.125	0.125	0.125	0.125	0.125
1.2.8 Computer Security	0.125	0.25	0.5	0.5	0.5	0.5	0.5
1.2.8.1 Password Security	0.0625	0.125	0.25	0.25	0.25	0.25	0.25
1.2.8.2 Operating System Security	0.0625	0.125	0.125	0.125	0.125	0.125	0.125
1.2.8.3 Access Auditing	0	0	0.125	0.125	0.125	0.125	0.125
1.3 Operations and Infrastructure	**0.625**	**1.25**	**1.25**	**2**	**2.75**	**4.75**	**5.25**
1.3.1 Software license maintenance	0.125	0.25	0.25	0.5	0.75	1.25	1.25
1.3.1.1 Software license tracking (central systen	0.125	0.125	0.125	0.25	0.25	0.25	0.25
1.3.1.2 Software license tracking (PCs/desktops	0	0.125	0.125	0.25	0.5	1	1
1.3.2 Systems Operation	0.25	0.5	0.5	1	1.5	3	3.75
1.3.2.1 Data center operations	0.125	0.25	0.25	0.5	0.75	1	1.5
1.3.2.1.1 Operate data center	0.125	0.25	0.25	0.5	0.75	0.75	1
1.3.2.1.2 Shipping tapes offsite	0	0	0	0	0	0.25	0.25
1.3.2.1.3 Tapecopy facility operations	0	0	0	0	0	1	1
1.3.3 Infrastructure support	0.25	0.5	0.5	0.5	0.5	0.5	0.25
1.3.3.1 Power support	0.125	0.25	0.25	0.25	0.125	0.25	0.125
1.3.3.2 Space planning	0.125	0.25	0.25	0.25	0.375	0.25	0.125

	2001	2002	2003	2004	2005	2006	2007
1.4 Tier 2 Regional Centers	**2.5**	**3.5**	**4**	**5**	**6.5**	**7.5**	**7.5**
1.4.1 Tier 2 Center 1	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
1.4.1.1 T2 Design	0.25	0	0	0	0	0	0
1.4.1.2 T2 Equipment	0.5	0.5	0.5	0.625	0.625	0.625	0.625
1.4.1.2.1 Hardware Procurement & Installa	0.25	0	0	0.125	0.125	0.125	0.125
1.4.1.2.2 Commissioning	0.25	0.25	0.25	0.25	0.25	0.25	0.25
1.4.1.2.3 Hardware Maintenance	0	0.25	0.25	0.25	0.25	0.25	0.25
1.4.1.3 T2 Software Infrastructure Framework	0.5	0.375	0.5	0.5	0.5	0.5	0.5
1.4.1.3.1 Installation and Deployment	0.5	0.25	0.25	0.25	0.25	0.25	0.25
1.4.1.5 System Documentation	0.125	0.125	0.125	0.125	0.125	0.125	0.125
1.4.2 Tier 2 Center 2	**1**	**1**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
1.4.2.1 T2 Design	0.125	0	0	0	0	0	0
1.4.2.1 T2 Design	0	0.125	0	0	0	0	0
1.4.2.2 T2 Equipment	0	0.5	0.375	0.375	0.5	0.625	0.625
1.4.2.2.1 Hardware Procurement & Installa	0	0.25	0.125	0.125	0	0.125	0.125
1.4.2.2.2 Commissioning	0	0.25	0.25	0.25	0.25	0.25	0.25
1.4.2.2.3 Hardware Maintenance	0	0	0	0	0.25	0.25	0.25
1.4.2.3 T2 Software Infrastructure Framework	0	0.25	0.375	0.375	0.5	0.5	0.5
1.4.2.3.1 Installation and Deployment	0	0.25	0.25	0.25	0.25	0.25	0.25
1.4.2.3.2 Maintenance	0	0	0.125	0.125	0.25	0.25	0.25
1.4.2.4 Integration with T1/T2	0	0.125	0.125	0.125	0.375	0.25	0.25
1.4.2.5 System Documentation	0	0	0.125	0.125	0.125	0.125	0.125
1.4.2 Tier 2 Center 4	**0**	**0**	**0**	**1**	**1**	**1.5**	**1.5**
1.4.2.1 T2 Design	0	0	0	0.125	0	0	0
1.4.2.2 T2 Equipment	0	0	0	0.5	0.375	0.5	0.625
1.4.2.2.1 Hardware Procurement & Installa	0	0	0	0.25	0.125	0	0.125
1.4.2.2.2 Commissioning	0	0	0	0.25	0.25	0.25	0.25
1.4.2.2.3 Hardware Maintenance	0	0	0	0	0	0.25	0.25
1.4.2.3 T2 Software Infrastructure Framework	0	0	0	0.25	0.375	0.5	0.5
1.4.2.3.1 Installation and Deployment	0	0	0	0.25	0.25	0.25	0.25
1.4.2.3.2 Maintenance	0	0	0	0	0.125	0.25	0.25
1.4.2.4 Integration with T1/T2	0	0	0	0.125	0.125	0.375	0.25
1.4.2.5 System Documentation	0	0	0	0	0.125	0.125	0.125
1.4.2 Tier 2 Center 5	**0**	**0**	**0**	**0**	**1**	**1.5**	**1.5**
1.4.2.1 T2 Design	0	0	0	0	0.125	0	0
1.4.2.2 T2 Equipment	0	0	0	0	0.5	0.5	0.625
1.4.2.2.1 Hardware Procurement & Installa	0	0	0	0	0.25	0	0.125
1.4.2.2.2 Commissioning	0	0	0	0	0.25	0.25	0.25
1.4.2.2.3 Hardware Maintenance	0	0	0	0	0	0.25	0.25
1.4.2.3 T2 Software Infrastructure Framework	0	0	0	0	0.25	0.5	0.5
1.4.2.3.1 Installation and Deployment	0	0	0	0	0.25	0.25	0.25
1.4.2.3.2 Maintenance	0	0	0	0	0	0.25	0.25
1.4.2.4 Integration with T1/T2	0	0	0	0	0.125	0.375	0.25
1.4.2.5 System Documentation	0	0	0	0	0	0.125	0.125

	2001	2002	2003	2004	2005	2006	2007
1.5 Networking	**0.5**	**1**	**2**	**2.5**	**3**	**3**	**3**
1.5.1 Onsite network infrastructure	0.5	0.75	1	1	1	1	1
1.5.1.1 Network design	0.125	0.25	0.5	0.5	0.25	0.25	0.25
1.5.1.2 Procurement and implementation	0.125	0.25	0.25	0.25	0.5	0.25	0.25
1.5.1.3 Operational network support	0.25	0.25	0.25	0.25	0.25	0.5	0.5
1.5.2 Offsite network support	0	0.125	0.25	0.5	0.5	0.5	0.5
1.5.2.1 CERN connectivity	0	0	0.125	0.125	0.125	0.125	0.125
1.5.2.2 US-CMS connectivity	0	0.125	0.125	0.125	0.125	0.125	0.125
1.5.2.3 Data grid network services	0	0	0	0.25	0.25	0.25	0.25
1.5.3 Network security	0	0.125	0.25	0.5	0.75	0.75	0.75
1.5.3.1 Onsite network security	0	0.125	0.25	0.25	0.25	0.25	0.25
1.5.3.2 Offsite network security	0	0	0	0.25	0.5	0.5	0.5
1.5.4 Network performance monitoring	0	0	0.5	0.5	0.75	0.75	0.75
1.5.4.1 Onsite mon. and troubleshooting	0	0	0.25	0.25	0.25	0.25	0.25
1.5.4.2 Offsite mon. and troubleshooting	0	0	0.25	0.25	0.5	0.5	0.5

	2001	2002	2003	2004	2005	2006	2007
1.6 Computing and Software R&D							
1.6.1 Distributed Data and Computing Test Beds	**0.5**	**0.5**	**0.5**	**0.375**	**0**	**0**	**0**
1.6.1.1 Hardware Testbed system design	0.0625	0.0625	0.0625	0	0	0	0
1.6.1.2 Hardware Testbed system	0.125	0.125	0.125	0	0	0	0
1.6.1.2.1 Procurement	0.0625	0.0625	0.0625	0	0	0	0
1.6.1.2.2 Installation & Commissioning	0.0625	0.0625	0.0625	0	0	0	0
1.6.1.3 Distributed Data Management (SW)	0.125	0.125	0.125	0.125	0	0	0
1.6.1.3.1 Software Development	0.125	0.125	0.0625	0	0	0	0
1.6.1.3.2 Maintenance	0	0	0.0625	0.125	0	0	0
1.6.1.4 Distributed Data Access (SW)	0.0625	0.0625	0.0625	0.125	0	0	0
1.6.1.4.1 Software Development	0.0625	0.0625	0	0	0	0	0
1.6.1.4.2 Maintenance	0	0	0.0625	0.125	0	0	0
1.6.1.5 Monitoring Tools	0.125	0.125	0.125	0.125	0	0	0
1.6.1.5.1 Data Access Monitoring	0.125	0.125	0.25	0.125	0	0	0
1.6.1.5.2 Systems Monitoring	0.125	0.125	0.25	0.125	0	0	0
1.6.2 R&D in Computing Hardware for T1/T2	**1.4375**	**2**	**1.625**	**0.25**	**0.25**	**0.25**	**0.25**
1.6.2.1 Technology Tracking and Testing	0.25	0.25	0.25	0.25	0.25	0.25	0.25
1.6.2.2 Technology Investigation and Deployment	1.1875	1.75	1.375	0	0	0	0
1.6.2.2.1 Data Intensive Computing	0.5	0.625	0.625	0	0	0	0
1.6.2.2.1.1 Procurement & Installation	0.0625	0.125	0.125	0	0	0	0
1.6.2.2.1.2 Commissioning	0.0625	0.125	0.125	0	0	0	0
1.6.2.2.1.3 System Infrastructure Software	0.375	0.375	0.375	0	0	0	0
1.6.2.2.1.3.1 Interactive Cluster Software	0.125	0.125	0.25	0	0	0	0
1.6.2.2.1.3.1.1 Software Deployment	0.125	0.125	0.25	0	0	0	0
1.6.2.2.1.3.1.2 Maintenance	0	0	0	0	0	0	0
1.6.2.2.1.3.2 Batch Cluster Software	0.125	0.125	0.0625	0	0	0	0
1.6.2.2.1.3.2.1 Software Deployment	0.125	0.125	0.125	0	0	0	0
1.6.2.2.1.3.2.2 Maintenance	0	0	0	0	0	0	0
1.6.2.2.1.3.3 System Monitoring Software	0.125	0.125	0.0625	0	0	0	0
1.6.2.2.1.3.3.1 Software Deployment	0.125	0.125	0.125	0	0	0	0
1.6.2.2.1.3.3.2 Software Maintenance	0	0	0	0	0	0	0
1.6.2.2.2 CPU Intensive Computing	0.3125	0.625	0.5	0	0	0	0
1.6.2.2.2.1 Procurement,Installation & Commis	0.0625	0.125	0.125	0	0	0	0
1.6.2.2.2.2 Systems Infrastructure Software	0.25	0.5	0.375	0	0	0	0
1.6.2.2.2.2.1 Batch Cluster Software Maint	0.0625	0.125	0.0625	0	0	0	0
1.6.2.2.2.2.2 Aut. Job Handling Framework	0.0625	0.125	0.0625	0	0	0	0
1.6.2.2.2.2.3 System Monitoring Software Ma	0.0625	0.125	0.125	0	0	0	0
1.6.2.2.2.2.4 CMS software environment	0.0625	0.125	0.125	0	0	0	0
1.6.2.2.3 Data Access and Distribution Servers	0.375	0.5	0.25	0	0	0	0
1.6.2.2.3.1 Procurement & Installation	0.0625	0.125	0.0625	0	0	0	0
1.6.2.2.3.2 Commissioning	0.0625	0.125	0.0625	0	0	0	0
1.6.2.2.3.3 System Infrastructure Software	0.25	0.25	0.125	0	0	0	0
1.6.2.2.3.3.1 Software Deployment	0.25	0.25	0.125	0	0	0	0
1.6.2.2.3.3.2 Software Maintenance	0	0	0.125	0.125	0	0	0

	2001	2002	2003	2004	2005	2006	2007
1.6.3 Prototype Fully Functional Regional Center	**0.125**	**0.6875**	**1.75**	**0.25**	**0**	**0**	**0**
1.6.3.1 Prototype Regional Center Design	0.125	0.25	0.25	0	0	0	0
1.6.3.2 Prototype Regional Center	0	0.4375	1.5	0.25	0	0	0
1.6.3.2.1 Hardware Procurement & Installation	0	0.125	0.25	0	0	0	0
1.6.3.2.2 Commissioning	0	0.125	0.25	0	0	0	0
1.6.3.2.3 Software Infrastructure Framework	0	0.0625	0.25	0	0	0	0
1.6.3.2.3.1 Installation and Deployment	0	0.0625	0.25	0	0	0	0
1.6.3.2.3.2 Maintenance	0	0	0	0	0	0	0
1.6.3.2.4 Integration with Other Centers (T0/T2)	0	0.0625	0.5	0	0	0	0
1.6.3.2.5 System Documentation	0	0.0625	0.25	0.25	0	0	0
1.6.4 Simulation Software	0.5	0.5	0.5	0.375	0.375	0.375	0.375
1.6.4.1 Simulation Validation	0.25	0.25	0.25	0.125	0.125	0.125	0.125
1.6.4.2 Distributed Computing Model	0.125	0.125	0.125	0.125	0.125	0.125	0.125
1.6.4.3 Tier 1 Regional Center Simulations	0.125	0.125	0.125	0.125	0.125	0.125	0.125
1.6.5 System Administration	0.125	0.125	0.125	0.125			
1.7 Detector Construction Phase Computing	**2**	**1.875**	**1.875**	**0.25**	**0**	**0**	**0**
1.7.1 CMS Computing Facility	0.25	0.25	0.25	0	0	0	0
1.7.1.1 Procurement , Installation,Comm,Maint.	0.125	0.125	0.125	0	0	0	0
1.7.1.2 Software installation & maintenance	0.125	0.125	0.125	0	0	0	0
1.7.2 Data Storage System	0.375	0.375	0.375	0.25	0	0	0
1.7.2.1 Procurement of extra capacity	0.0625	0.0625	0.063	0	0	0	0
1.7.2.2 Extra administration	0.0625	0.0625	0.063	0	0	0	0
1.7.2.3 Software Interface	0.25	0.25	0.25	0	0	0	0
1.7.2.4 Export data to final system	0	0	0	0.25	0	0	0
1.7.3 Network based file interchange	0.375	0.375	0.375	0	0	0	0
1.7.3.1 Planning	0.125	0.125	0.125	0	0	0	0
1.7.3.2 Software	0.125	0.125	0.125	0	0	0	0
1.7.3.3 Production	0.125	0.125	0.125	0	0	0	0
1.7.4 Tape import/export	0.5	0.375	0.375	0	0	0	0
1.7.4.1 Planning/coordination	0.125	0.125	0.125	0	0	0	0
1.7.4.2 Procurement	0.125	0	0	0	0	0	0
1.7.4.3 Software	0.125	0.125	0.125	0	0	0	0
1.7.4.4 Production	0.125	0.125	0.125	0	0	0	0
1.7.5 System Administration	0.5	0.5	0.5				

	2001	2002	2003	2004	2005	2006	2007
1.8 Support for FNAL based computing	**0.375**	**1.375**	**1.375**	**2.375**	**2.25**	**2**	**2**
1.8.1 Desktop systems	0.375	1.375	0.625	1.625	1.5	1.5	1.5
1.8.1.1 Installation	0.25	0.625	0.25	0.5	0.25	0.375	0.375
1.8.1.1.1 System specifiation, design,installatio	0.125	0.25	0.125	0.125	0.125	0.125	0.125
1.8.1.1.2 Host server systems	0.125	0.25	0.125	0.125	0.125	0.125	0.125
1.8.1.1.3 Backup systems	0	0.125	0	0.25	0	0.125	0.125
1.8.1.1.3.1 System specification and selectio	0	0.0625	0	0.125	0	0	0
1.8.1.1.3.2 Installation and setup	0	0.0625	0	0.125	0	0.125	0.125
1.8.1.2 Support	0.125	0.25	0.25	1	1	1	1
1.8.1.3 User data storage and archiving	0	0.5	0.125	0.125	0.25	0.125	0.125
1.8.1.3.1 System specification and design	0	0.25	0	0	0	0	0
1.8.1.3.2 Installation,deployment,maintenance	0	0.25	0.125	0.125	0.25	0.125	0.125
1.8.2 Remote Control Room	0	0	0.75	0.75	0.75	0.5	0.5
1.8.2.1 Hardware	0	0	0.25	0.25	0.25	0.25	0.25
1.8.2.1.1 Procurement, Installation & Comm	0	0	0.25	0.25		0	0
1.8.2.1.2 Maintenance	0	0	0	0	0.25	0.25	0.25
1.8.2.2 Software	0	0	0.5	0.5	0.5	0.25	0.25
1.8.2.2.1 Deployment & Development	0	0	0.5	0.5	0.5	0	0
1.8.2.2.2 Maintenance	0	0	0	0	0	0.25	0.25

Below we list a summary of the User Facility Personnel requirements by WBS number.

	2001	2002	2003	2004	2005	2006	2007
1 User Facility Project	**10**	**15.0625**	**18**	**29.25**	**37.125**	**42.75**	**41.125**
1.1 Tier 1 Regional Center	0	0	0	12.625	17	20.375	18.25
1.2 System and User Support	1.3125	2.25	3	3.125	5	4.5	4.5
1.3 Operations and Infrastructure	0.625	1.25	1.25	2	2.75	4.75	5.25
1.4 Tier 2 Regional Centers	2.5	3.5	4	5	6.5	7.5	7.5
1.5 Networking	0.5	1	2	2.5	3	3	3
1.6 Computing and Software R&D	2.6875	3.8125	4.5	1.375	0.625	0.625	0.625
1.7 Detector Construction Phase Computing	2	1.875	1.875	0.25	0	0	0
1.8 Support for FNAL based computing	0.375	1.375	1.375	2.375	2.25	2	2

The Table shows the full number of staff who will be working on User Facilities tasks, excluding physicists, but including engineers, technicians, and support staff.

Table: Personnel Requirements for the User Facilities subproject, rolled up from the previous tables.

THE TIER 1 REGIONAL CENTER

We expect the Regional Center at Fermilab to be one of a handful (5), worldwide, Tier 1 CMS Regional Computing centers. The role of the regional center is twofold: the provision of computing resources (CPU, disk) at Fermilab, and

the serving of data, software, documentation, and communications to other US institutions participating in CMS and the experiment at CERN. A critical part of the latter role is to provide robust and high performance network connections between the US-CMS institutions and Fermilab and between Fermilab and CERN. The Regional Centers are not expected to provide CPU resources for first pass data reconstruction, but will support reprocessing of data. The Regional Center must provide high quality service, including 24 hours a day, seven days a week help facilities; essentially continuous access to data; and guaranteed data integrity. Remote users must have both interactive services and access to the data, and visitor facilities should also be provided for US-CMS collaborators who prefer to come to Fermilab to work. The Center's role will also include training collaborators in object oriented software and C++ (this has already begun at Fermilab), hosting US software and analysis meetings and workshops, and generally maintaining an environment conducive to productive participation in CMS. As often noted, this latter task involves the creation of a "critical mass" of physicists interested and experienced in the experiment who can solve a typical user's problems in getting started. The critical mass also attracts visitors and seminars, and provides a means of disseminating work within the collaboration.

We also intend to develop a remote control room for CMS at Fermilab. This will allow physicists at Fermilab to remotely monitor the experiment and to perform some (or even many) of the activities normally carried out by shift personnel without needing to be physically present at CERN. Such a system has already been demonstrated between KEK and Fermilab for CDF. The remote control room will be part of a system to remotely serve monitoring data to other sites throughout the US.

Funding of the Regional Center

The cost of the US-CMS Regional Center is comparable to either of the present CDF or DØ Run II computing projects, and the support level per physicist is similar (it will serve the US-CMS collaboration which is similar in size to the Tevatron experiments). Funding for this activity is not yet explicitly included in present Fermilab budget projections, and would be difficult within the projected Computing Division budget even if there were no new initiatives requiring significant resources over the next six years.

Management of the Regional Center

The Tier 1 Regional Center will be managed within the Fermilab Computing Division, and the management structure will be as described in the USCMS Software and Computing Project Management Plan. Necessary R&D, prototyping, establishment and operations of the Regional Center are all part of the WBS for the Computing and Software Project which was listed above. Given Fermilab's demonstrated experience with Run II, the establishment of the CMS regional center is clearly within our capabilities. We shall take special effort to incorporate the lessons learned during the Run II project into the planning for the center.

The Regional Center needs to be fully responsive to the needs of its constituencies. The management plan describes the points of contact with the US CMS and international CMS collaborations.

Schedule and CMS milestones

A timeline for the establishment of the Tier 1 regional center, together with some relevant CMS milestones, are listed below:

- 1999-2003: **R&D Phase**
- 2000: CMS Milestone: select regional centers [1]
- 2003: CMS milestone: "Turn on" a prototype functional center [1]
- 2004-2006 **Implementation Phase** (ramp up activities as Run II's resource needs reduce to operational level.)
- 2006: CMS milestone: Fully operational centers [1]
- 2007 on: Support of **CMS Operations Phase**

Cost and personnel required for support of the CMS Regional Center

The scope of the regional center is taken from the preliminary results of the Hoffman Review [Report not yet public] and is consistent with CMS estimates. The hardware costs are based on the CMS Computing Technical proposal, Run II experience, CMS estimates, and present Fermilab expenditures, and is detailed in a separate note.

It is difficult to gauge the personnel needs of the UF subproject since there is as yet no CMS Technical Design Report for Computing. As a first estimate the profile and FTE requirements have been based on our experience with the Run II computing and software projects [2], scaled appropriately. We will continue to refine these estimates as we increase our understanding of the needs of CMS, but we do not expect the final results to be significantly less than those shown.

REFERENCES

[1] CMS Computing Technical Proposal, December 1996, and reply to referees, April 1997. This schedule has recently been updated to reflect a more realistic LHC turn on schedule and taking into account funding profiles.

[2] M. Kasemann, private communication.

[3] MONARC Project Execution Plan, LCB 98-003, September 1998; http://www.cern.ch/MONARC/.

[4] CMS Distributed Data Management and Processing Software Project, http://home.fnal.gov/~bauerdic/uscms/scp/baserev_nov_2000/.

[5] Particle Physics Data Grid home page, http://www.cacr.caltech.edu/ppdg/.

[6] European Union DataGrid home page, http://grid.web.cern.ch/grid/.

[7] GriPhyN Project home page, http://www.griphyn.org/.

[8] The GriPhyN Management Plan (incomplete).