DØ Upgrade (E823)
Project Management Plan

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1. INTRODUCTION

This document describes the Project Management Plan that the participants will follow to meet the technical, cost and schedule objectives of the DØ Upgrade project.

1.1 Historical Background

The DØ detector was built during the period 1985 - 1992; commissioned in early 1992, and operated until early 1996. Data from this run have resulted in the discovery of the top quark; precision measurements of the electroweak gauge boson parameters; extension of the understanding of the strong force through parton jets, electroweak bosons, and bottom quarks; and increased the reach in the search for new particles. For the past five years, the DØ Collaboration has been developing plans for upgrades to the detector systems which will provide a productive, pre-eminent physics program in concert with the improvements to the Tevatron Collider.

1.2 The DØ Upgrade Project

The objectives of the DØ Upgrade Project are to modify the detector to be able to operate at the improved Tevatron Collider. The Collider will provide interactions at ten times the previous maximum rate, and will reduce the time between beam bunch crossings by a factor of over 25. Many detector modifications are dictated by these changes. The DØ Upgrade seeks to extend the understanding of fundamental particles already gained in the previous run, retaining its focus upon high transverse momentum processes and the search for very massive new particles.

These factors lead to several new detection systems in the DØ upgrade, replacing those that are rendered inoperable in the new environment:

- A new central tracking system within the existing calorimeter system comprised of (a) a silicon microstrip tracking detector; (b) scintillating fiber tracking detector; (c) a superconducting solenoidal magnet; and (d) a set of sampling preshower detectors;
- New coordinate measuring muon detectors and event selection detectors in the region of small angles with respect to the beams;
- New event selection electronics to enable operation at the higher event rates.

Upgrades to other detectors are planned, necessitated by the accelerator modifications:

- Upgrade of the calorimeter front-end electronics;
- Upgrade of the muon detector front-end electronics;
- Improvement of the data acquisition and event collection systems.

Documents relevant to the definition of the scope of E823 (DØ Upgrade) are:

- DØ Upgrade Proposal, Oct. 18, 1990
- E823 R&D and Optimization Progress Report, Jan. 1991 (DØ Note 1322)
- E823: Step 1 and Beyond, May 20, 1992 (DØ Note 1426)
- E823: Magnetic Tracking, Oct. 12, 1993 (DØ Note 1933)
- Final Report of the DØ Detector Upgrade Cost, Schedule, and Management Review (Directors Review), Feb. 14, 1995

- The DØ Upgrade - The Detector and Its Physics, July 30,1996. (Fermilab-PUB-96-357-E)

More detailed technical design documents have been prepared for the individual subsystems.

Preliminary cost estimates were developed in Spring 1991, and an initial Work Breakdown Structure was established for the project at that time. The WBS was revised in 1995-6 as the sub-systems were better defined. A new bottoms-up cost estimate was prepared in January 1995 and accepted by the Laboratory. The baseline cost estimate for the full project was established in May 1996.

1.3 Plan of this Document

This document describes the DØ Upgrade Project management system used to facilitate achievement of the project goals. The system provides for coordinated management of technical sub-systems, cost control for the full project, and control structures adequate to monitor cost, schedule, and resources.

The subsequent sections describe the project objectives and performance criteria, project management, the work plan, the work breakdown structure, the schedule, the cost estimate and cost plan, work authorization and project control, the reporting and review structures, and description of specific work plans for all sub-projects.

2. PROJECT OBJECTIVES AND PERFORMANCE CRITERIA

2.1 Technical Objectives

The DØ Upgrade Detector seeks to study the fundamental particles participating in the strong and unified electroweak interactions, and to search for new particles indicative of new interactions. Particular focii include the study of the newly discovered top quark, the W and Z boson carriers of the weak force, the properties of hadrons containing the bottom quark, and the character of the strong force in new regimes. These physics objectives require that characteristic objects be detected and identified at all angles outside 15 degrees with respect to the beam, and that the energies of the objects be well determined. The primary objects of interest are electrons, muons, bottom quark particles, and quark/gluon jets, with neutrinos and other non-interacting particles inferred from the measurements.

The DØ Detector must operate successfully in the Tevatron Collider at instantaneous luminosity of 2×10^{32} cm^{-2} sec^{-1} with bunch crossing times as small as 132 nsec. Tolerance of all systems for accumulated luminosity of 2 fb^{-1} is required. The detector must be capable of selecting collision events of interest, in real-time, from the 10 million collisions per second in the Collider. Detector systems must be sufficiently reliable to assure overall efficiencies of operation of 90%.

Subsystem requirements follow from these general objectives:

- The tracking system must record the trajectories of charged particles from the collision with greater than 95% efficiency in the presence of the magnetic field. Spatial accuracy must be sufficient to detect the separation of the decays of long-lived particles from the primary interaction vertex. The tracking detectors must provide signals of high momentum electrons and muons for use in event selection.
- The calorimeter system, based on the existing uranium-liquid argon detectors, must give measures of the energies of charged and neutral particles with minimum noise contributions arising from the high particle fluxes, and in the presence of the ambient magnetic fields.
- The muon system must be capable of selecting events containing high momentum muons, and of measurement of their trajectories for angles above 15 degrees with respect to the beams. The detectors must be adequately shielded to minimize the extraneous noise from particles associated with radiation from the beam elements and beam-beam collisions.
- The event selection and data acquisition systems must be capable of selecting events of physics interest with no more than 15% dead time for the experiment. The recording rate of interesting events to permanent media and subsequent analysis should be 10 - 20 per second.
- The experiment control systems and data logging systems must be capable of adequate real-time monitoring of the detector systems and the data quality to permit the overall efficiency goals to be met.

2.2 Cost Objectives

The project estimated costs are summarized below

Category		**Costs** (FY95 k$)	**Costs** (Escalated k$)
Equipment *	M&S	36,608	38,665
	SWF	8,499	8,681
	G&A	7,256	7,958
Total U.S. Equipment		52,364	55,304
Solenoid , Beam Pipe, Shielding (AIP funds)		5,313	5,168
Total AIP Funding		5,313	5,168
Operating	SWF	11,461	12,541
	G&A	4,584	5,016
Total U.S. Operating		16,045	17,557
Total U.S. Detector Cost		73,722	78,030
Non-U.S. Costs (Equipment)**		2,983	3,287
Total Detector Cost		76,704	81,317

*Equipment funds provided by the U. S. Department of Energy to Fermilab for this project include contingency, but do not include associated R&D costs nor additional U. S. funding from the DoE and the National Science Foundation supporting DØ collaborating institutions.

**Financial support for this project is provided in part by India and Russia. This estimate for non-U. S. contributions does not include substantial in-kind labor contributions, nor funds contributed for experiment operating expenses.

Cost details are provided in Chapters 7 and 10 of this document.

2.3 Project Schedule Objectives

Primary schedule objectives for the project include:

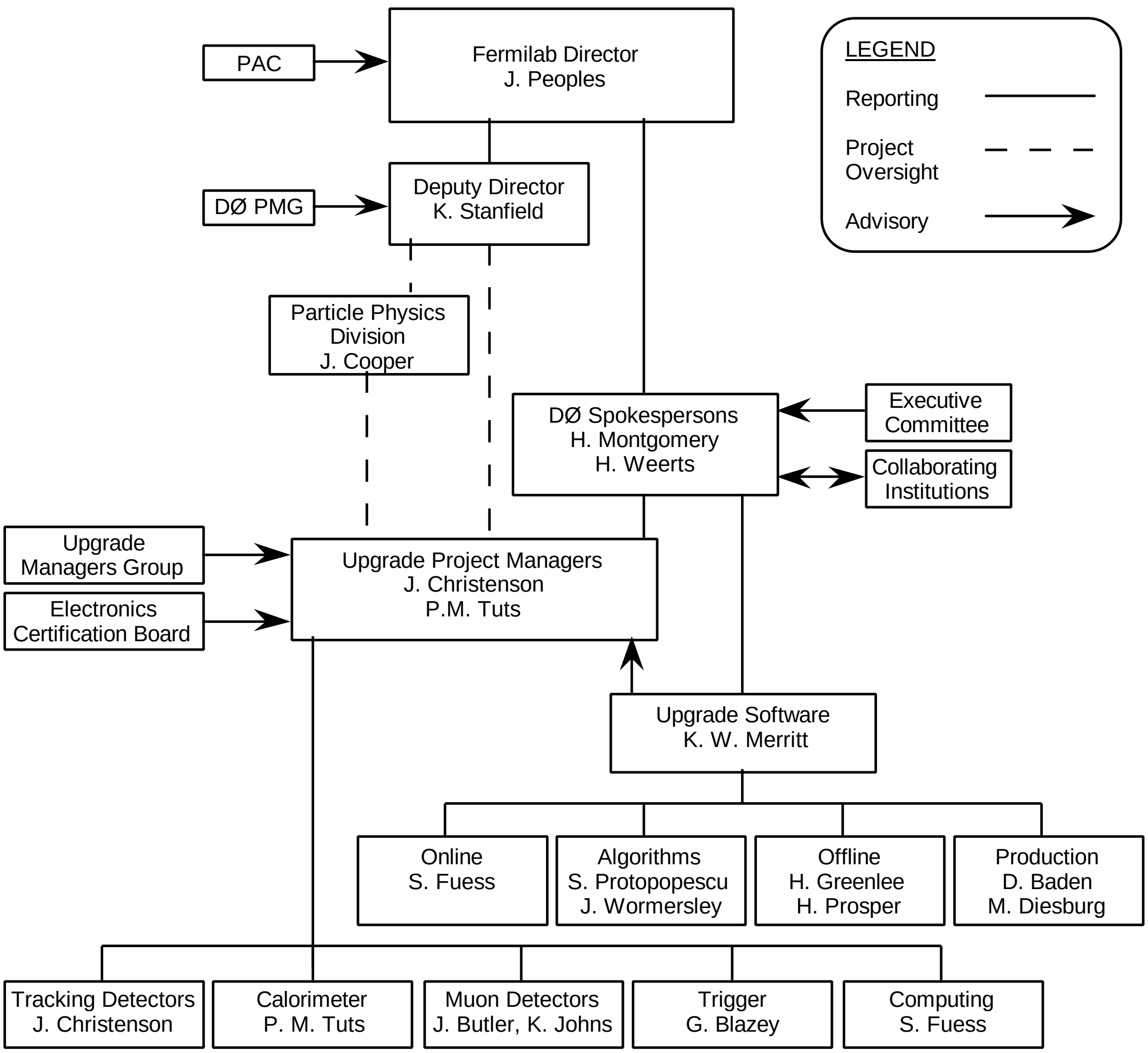
1	Start Project Design	1-Jul-90
2	Full Stage 1 Approval Obtained	1-May-96
3	Solenoid Installed and Tested	28-Apr-98
4	Tracker Installed in Solenoid	22-Jul-99
5	Detector Rolled In and Hooked Up	29-Nov-99

Details of the project schedule may be found in Chapter 6.

3. PROJECT MANAGEMENT, ORGANIZATION AND RESPONSIBILITIES

3.1 Overview

The DØ Upgrade Project is primarily funded by the DoE and managed through Fermilab. It is carried out in collaboration with universities and laboratories in the US and other countries. Its goal is to upgrade and improve the existing DØ detector to exploit the properties of the Tevatron after the Main Injector begins to operate. The project is to be managed to a predetermined scope, cost and schedule. The responsibilities for managing the project are represented in the organization chart below and are described in the following sections of this chapter.



DØ Upgrade Project Organization

3.2 Department of Energy

The Department has established the need for the DØ Upgrade Project by considering and responding to advice from its advisory panel, HEPAP, and to Fermilab requests in field task proposals, and by participating in peer review processes for the Fermilab program including the annual DoE laboratory-wide review and the Fermilab Physics Advisory Committee meetings. The Department of Energy provides the majority of funding for the DØ Upgrade Project. These funds are provided through the Fermilab annual financial plan by contract modification. The Division of High Energy Physics provides annual program guidance to the laboratory as well as annual guidance on the funding profile for the project. The Department excercises oversight of the project by:

- conducting semi-annual reviews of the project;
- participating in regularly scheduled Project Management Group (PMG)meetings;
- overseeing operations and fabrication activities;
- monitoring project progress via quarterly progress reports; and
- monitoring milestones/performance measures.

3.3 The Fermilab Director

The Fermilab Director is responsible to the Universities Research Association and the Department of Energy for the successful completion of the DØ Upgrade Project and only he is authorized to commit funds appropriated for Laboratory use. The Director approves the scope of the upgrade project with advice from the Fermilab Physics Advisory Committee (PAC) in response to proposals from the DØ Collaboration. Decisions regarding the scope of the upgrade are made in a two stage process. Stage I approval is given to endorse the scientific merit of the proposal when sufficient information is known regarding technical designs so that costs and schedules can be estimated. Resources can then be allocated so that a project management plan can be developed, detailed technical designs can be prepared, and cost estimates and resource loaded schedules can be made. In addition, a financial plan identifying the necessary funding resources must be prepared. Upon the successful completion of these plans Stage II approval is granted by the Director upon advice of the PAC. Approval for the project may proceed in parts, subsystem by subsystem. Construction of a subsystem normally begins after Stage II approval has been granted for that subsystem but may proceed earlier with the Director's approval.

The Director approves the sub-project Technical Design Reports (TDR), the Project Management Plan, the cost estimate, the schedule, the financial plan for the project and changes of scope to the project.

3.4 Deputy Director

The Director has delegated certain responsibilities and authority to the Deputy Director. The Deputy Director is responsible for management oversight of the project. Oversight of the project will be implemented in part through reviews including the Project Management Group (below) and/or Director’s Reviews. Along with routine interactions with project management, these reviews will identify actions and initiatives to be undertaken to achieve the goals of the project including allocation of financial and human resources. Progress will also be monitored through presentations to and discussions with the PAC.

To implement the work plan for the upgrade project, Memoranda of Understanding are executed with collaborating institutions. The Deputy Director approves all Institutional Memoranda of Understanding (MoU). He is responsible for providing a funding profile consistent with

Laboratory funding after consultation and guidance from the DoE program office. The Deputy Director advises the Director on his approval of the Technical Design Reports, the Project Management Plan (PMP), the cost estimate, the schedule, and the financial plan and concurs with these approvals.

3.5 Fermilab Particle Physics Division Head

The Fermilab Director and Deputy Director have delegated certain responsibilities and authorities to the Fermilab Particle Physics Division (PPD) Head. The PPD Head is responsible for portions of project management and oversight as the line manager for financial resources, human resources, technical resources, space resources, and ES&H issues for this project. The Project Managers report to the Deputy Director directly and through the Head of the PPD.

The PPD Head and his/her deputies are members of the Project Management Group. The PPD Head advises the Deputy Director on approval of Memoranda of Understanding relevant to PPD resources and concurs in these approvals. The PPD Head advises the Director and Deputy Director on approval of the PMP and the Cost/Schedule Plan (CSP) and concurs with these approvals.

On advice from the Director, the PPD Head allocates yearly budgets to the DØ Upgrade Project. These project funds are then administered by the Project Managers within the context of PPD procedures and policies and with the aid of the PPD budget office.

The PPD is the primary source of Fermilab manpower and technical resources for the project. The PPD Head and his/her designees make long term assignments of PPD people directly to the project in consultation with the Project Managers and in accordance with the CSP. The Project Managers then utilize these people to achieve the project goals, reporting changes in assignments to the PPD Head. The PPD Head maintains line management responsibility for these PPD employees and the Project Managers are part of the line management chain.

The PPD also provides support to the project through PPD technical resource groups. This is done in accordance with the CSP via specific work plans or Memoranda of Understanding. The PPD Head maintains direct line management responsibility for such PPD resources.

Since the Particle Physics Division is the primary source for providing the Fermilab labor needed to achieve the project schedule goals, labor shortfalls must be reported in a timely fashion. The PPD head or designee will advise the Project Managers and Deputy Director and report to the DØ PMG when insufficient labor is available for a given month to meet the levels indicated in the CSP. In this event, the Project manager will conduct a schedule impact study and submit a schedule variance as appropriate to the Deputy Director as required by the project controls.

3.6 DØ Spokespersons

The DØ Spokespersons provide the means of contact between the DØ Collaboration and the Laboratory. They speak for the Collaboration and represent the Collaboration in interactions with the Laboratory. The DØ Spokespersons are responsible for all aspects of the DØ Experiment, including the operation of the current detector, the analysis of data and production of physics results, and the improvement of the detector defined by the approved scope of the DØ Upgrade Project (E823). The Spokespersons are appointed by the Collaboration. In doing so, the Collaboration consults with the Director and he concurs in the selection.

3.7 DØ Upgrade Project Managers

The DØ Upgrade Project Managers are jointly responsible for all aspects of the DØ Upgrade Project. The Project Managers are designated by the Spokespersons with the concurrence of the Laboratory Director. They are appointed by the Director to manage the project to the approved scope, cost and schedule. A non-Fermilab collaborator may be appointed as a Project Manager after receiving a Guest Scientist appointment at the Laboratory. The Project Managers are responsible for developing and coordinating support for the project from various organizations including the DØ Project, other units within the Laboratory, and institutions in the Collaboration. This support includes engineering and design, procurement and fabrication, administration, financing and scheduling.

The Project Managers have the responsibility to complete the DØ Upgrade Project on schedule, on budget and within the agreed upon scope by managing the resources of the Collaboration and the Laboratory. They have fiscal authority over Fermilab funds allocated to the project and are responsible for monitoring expenditures of US and non-US funds. They track and report deviations from baseline schedules and costs as specified in the Project Management Plan. The Project Managers report to the Deputy Director directly and through the Head of the Particle Physics Division on all matters concerning the Upgrade Project related to managing the project to the approved scope, cost and schedule. They report to the Deputy Director on all matters which have the potential to result in commitments of the Laboratory or the Universities Research Association.

The Spokespersons, representing the Collaboration, seek approval for all scope changes having a significant impact on the physics capability of the upgraded detector by making scientific proposals to the Director. The Director may seek the advice of the Physics Advisory Committee when considering these proposals. The Director approves all such scope changes, those that increase the scope as well as those that reduce it. The Project Managers report to the Spokespersons on all technical and scientific issues of the Upgrade Project. The Project Managers may identify the need for out-of-scope changes as they arise. When there is a need for a change having a significant impact on the physics capability of the detector they report to the Spokespersons and also identify the need to the Director through the PMG. Other changes follow the change control procedures below.

The Project Managers are responsible for the Project Management Plan and for updating it as necessary with the approval of the signatories to this document.

The Project Managers are responsible for organizing presentations at reviews and status reports on the Upgrade Project as needed to respond to the Director and funding agencies. They have the authority to speak for the Collaboration on technical questions raised in these processes.

The Project Managers are responsible for the completion and approval of Technical Design Reports for each system.

3.8 DØ Upgrade Sub-Project Managers

All WBS Level 2 and Level 3 sub-projects are managed by individuals appointed by the Project Managers, with the concurrence of the Spokespersons. The Sub-Project Managers manage and direct their sub-projects and report to the Project Managers. They are directly responsible for generating and maintaining the cost-estimate, schedule, and resource requirements for their sub-projects. They are responsible for meeting the goals of their sub-project within the accepted baseline cost and schedule.

3.9 DØ Collaborator Responsibilities

The responsibilities of DØ Collaborators are specified in comprehensive Memoranda of Understanding. The MoU details the work that the Collaborator has agreed to do for the Upgrade Project, and includes a list of the personnel involved, a budget for the current Fiscal Year, and significant milestones. These agreements are updated as appropriate, typically through Addenda to specify the budget for the next Fiscal Year. They are approved by the DØ Contact Person and appropriate responsible parties for the collaborating institution and by the Project Managers, the DØ Spokespersons, the Particle Physics Division Head and the Deputy Director. The Project Managers have responsibility for coordinating all Collaboration-wide resources via these MoU's and they have authority to negotiate with all institutions for allocation of these resources. These MoU's are components of the Work Plan for the project and, as such, are considered part of the PMP.

3.10 Advisory Functions

DØ Executive Committee

At the discretion of the Spokespersons, major decisions of the DØ Collaboration, especially those of an organizational, institutional, or broad scientific nature, are discussed with the DØ Executive Committee. The Committee advises the Spokespersons. Each of the collaborating institutions (including the Fermilab DØ Project) is represented. The DØ Project Managers participate in the deliberations of this body.

DØ Upgrade Managers Group

The DØ Upgrade Managers Group is comprised of the Project Managers, the Sub-Project Managers, and others as the need arises. This group serves as a forum for discussion of technical and management issues in the project and is advisory to the Project Managers. It also provides a convenient mechanism for the dissemination of information.

DØ Project Management Group (PMG)

The Deputy Director will chair a Project Management Group which will meet as required to monitor the progress of the project. The meetings will be attended by those who have responsibility for the Upgrade Project and by those who have authority to redirect resources within the Laboratory and the Collaboration. The PMG will also serve as the Change Control Board for the project.

4. WORK PLAN

4.1 General Description of Work

This project provides for the upgrade of the DØ detector, as outlined in Section 1.2. A description of the work that needs to be done in each system may be found in Chapter 10, and detailed plans are contained in the corresponding Technical Design Reports. A brief description of the general work required to build the upgraded detector follows:

Tracking System

A new tracking system immersed in a 2 Tesla magnetic field will be installed at the center of the experiment in the Central Calorimeter. The superconducting solenoid will be built to specifications by a commercial vendor and shipped to Fermilab for installation. The cryogenic helium system will be designed and fabricated by Fermilab personnel and integrated with the existing Tevatron helium system. The silicon vertex detector will be fabricated from detectors manufactured commercially, tested by university collaborators, and assembled into detector modules at Fermilab at the Particle Physics Division Silicon Detector Facility. The scintillating-fiber tracker will be designed and built at Fermilab, in a facility especially setup for this purpose. The Visible Light Photon Counters (VLPCs) will be developed jointly with Boeing North American (BNA). BNA will supply all VLPC devices, while the assembly of the final cassettes will be bid competitively or done at Fermilab. The readout electronics will be designed by DØ personnel and the fabrication will be carried out by commercial suppliers.

The Central Preshower detector will be developed by university collaborators, but will be engineered and designed by Fermilab personnel. The detector modules will be built by the university group and shipped to Fermilab for installation. The detector will be assembled around the solenoid magnet prior to installing the magnet in the Central Calorimeter bore. The Forward Preshower detectors will be designed and built by a collaborating institution.

Calorimeter System

The large hermetic calorimeter detectors will be used in the upgrade without modification. However, the front-end electronic system will be upgraded within the existing infrastructure. The new circuits will be designed by DØ collaborators but will be produced commercially. Testing and commissioning will be done by physicists and technicians from the DØ project. The collaborators responsible for the original detector will rebuild the Intercryostat Detector to operate in the new magnetic field.

Muon System

Components of the major muon detector systems for the upgrade will be prototyped and built at collaborating institutions before being shipped to Fermilab for installation in the experiment. Due to the intricacy of the physical environment in which the detectors must be mounted, mounting and support structures will be designed and built at Fermilab. Commissioning of the completed system will be done by physicists in the muon upgrade group. The replacement front-end electronics will be designed and prototyped at Fermilab and at various collaborating institutions, but the bulk of it will be assembled commercially.

Trigger System

The Trigger Frameworks (control system for the trigger) will be designed and built by a university collaborator, with commercial assembly of duplicate boards. The Level 1 trigger systems are closely coupled to their detector systems. The fiber tracker/preshower trigger electronics will reside on the boards atop the VLPC cassettes with the front-end electronics and will be designed and developed by those responsible for the tracking electronics. On the other hand, the muon Level 1 system will be developed entirely by university groups concentrating solely on that system. The calorimeter Level 1 trigger will be based on the original (Run I) system, with suitable buffers added for shorter bunch crossing times. As elsewhere, commercial resources will be used wherever possible in the fabrication of the electronics.

Online Computing

The online computing system is comprised of all computer equipment and software required to operate, monitor and control the experiment. It includes sub-systems to control the trigger system and frameworks, manage event flow to tape and monitoring queues, control front-end electronics, handle alarms and monitoring information from all components of the experiment, and monitor the quality of the data taken. The hardware will be assembled from commercial equipment, and, where possible, procurements will be deferred to the latter stages of the project to obtain optimal capability for a given price. System software and some application software packages will be purchased from commercial suppliers. The specialized software to run this particular online system and to perform the special and unique tasks required will be developed by members of the Collaboration.

4.2 R&D Program

The Research and Development associated with the project started in 1991 when the initial upgrade proposal was submitted. Early work was devoted to defining overall directions for the detector systems and careful assessment of 'state-of-the-art' technologies. As the shape of the upgrade plan came into view, R&D was focused more sharply on specific implementations of the detectors. The fiber tracker with VLPC readout represented a new technology and required substantial R&D. The silicon vertex detector will be the largest such system built to date and poses substantial engineering and assembly challenges. Extensive tests and simulations are necessary to identify viable approaches to these detectors.

As the design of these systems is finalized and Technical Design Reports are submitted, the R&D effort will subside.

4.3 Methods to Accomplish Work

Design and Engineering

The performance specifications for the DØ Upgrade Project, described in Chapter 2, have been established by proposals from the DØ Collaboration to the Laboratory. The Director, with advice from the PAC, approved the proposals in part or in full.

As the design of a subsystem approaches completion, a Technical Design Report is submitted to the Project Managers that details the specific approach to be followed in building the system. At this stage, no major questions should remain unresolved. The Project Managers commission a review by members of the Collaboration and outside experts to ensure that the plan for building the system is sufficiently sound and complete to ensure that the performance will meet the upgrade goals. A written report is submitted by the review panel to the Project Managers, expressing any questions or concerns and recommending a course of action. The proponents are asked to respond to the review report, and the Project Managers, with the concurrence of the Spokespersons, approve the system for fabrication. This action represents the final approval required before actual production of the system begins.

Construction and Fabrication

Fabrication of components and subsystems will be done in-house using Fermilab facilities, by outside vendors working under subcontract to the Laboratory, and by DØ collaborators at their home institutions. The specific plans for building each subsystem are delineated in Chapter 10, and the responsibilities of each participating institution are further described in a Memorandum of Understanding.

In general, the work done by Fermilab will be for the larger and more complex systems requiring extensive engineering and design support and significant assembly effort. Further, those aspects of the work that require intimate knowledge of the physical DØ experiment will most likely be based at Fermilab. An example of this is the development of support structures for muon detectors built at collaborating institutions.

Procurement Plan

The components of the DØ Upgrade will be acquired in a manner consistent with DoE and general Fermilab guidelines. Whenever possible, fixed price competitive procurement practices will be followed. Purchase requisitions will be processed by the Fermilab procurements group after appropriate approval.

Inspection and Acceptance

The Project Managers will be responsible for assuring that the appropriate procedures are in place at the sub-project level to ensure that components and assemblies are inspected sufficiently to assure that they meet the technical specifications. The sub-project managers are responsible for devising appropriate inspections. Acceptance of components and systems will be done by those directly responsible for them. When appropriate, inspection visits will be made to vendor shops and industrial firms fabricating or preparing components for the project.

4.4 System Tests and Commissioning

Once components are assembled and integrated into a subsystem, 'system tests' will be performed. These tests will involve the activation, debugging and tune-up of the full subsystem. Though such tests pertain to the system under study alone, they may require other subsystems to be operational to enable the tests. Examples of system tests include the silicon tracker readout system, the VLPC cryo system, the solenoid magnet tests, operation and readout of the forward muon tracking system, and operation of the new trigger frameworks. The forward muon tracking system test will require an operational trigger framework and data acquisition system.

Commissioning consists of the process of integrating working subsystems into an operational experiment, and is obviously the final stage of preparation for actual data-taking. Here for the first time, one will confront interactions and potential conflicts between distinct detector, trigger and readout systems. The commissioning process is expected to evolve gradually, as subsystems are assembled and system tests performed. Finally, full operation of the upgraded detector in the Assembly Hall will begin, triggering the apparatus on cosmic ray muons that pass through the entire apparatus. Such testing was invaluable in preparing DØ for its first Collider run in 1992.

4.5 Quality Assurance Program

Quality Assurance is an integral part of the design, fabrication and construction of the DØ Upgrade. Special attention is paid to items that are most critical to the schedule and performance requirements of the Project. All work performed at Fermilab will draw on the guidelines and criteria set out in the Fermilab Quality Assurance Program(FQAP). These include:

- management criteria related to organizational structure, responsibilities, planning, scheduling, and cost control;
- training and qualifications of personnel;
- quality improvement;
- documentation and records;
- work processes;
- engineering and design;
- procurement;

- inspection and acceptance testing;
- assessment.

The application of these criteria to individual sub-projects is described in Chapter 10.

4.6 Environment, Safety, and Health Analysis and Compliance

The design, construction, commissioning, operation, and de-commissioning of all DØ Upgrade systems will be done in compliance with the standards in the Fermilab ES&H Manual, and all applicable ES&H standards in the Laboratory's "Work Smart Standards" set.

The Particle Physics Division has established a DØ Upgrade ES&H Review Committee. The committee is composed of experts in mechanical engineering, electrical engineering, fire protection, and cryogenics/ODH who are independent of the DØ Upgrade Project. They are free to draw on other experts as the need arises. Their charge is to review certain Upgrade detector components and associated support equipment to ensure that adequate analyses and documentation exists to demonstrate compliance with ES&H requirements. They are to conduct reviews at appropriate points in the design process and again prior to initial operation of systems. They will prepare reports to the Head of the Particle Physics Division that summarize the compliance status of each reviewed system and make recommendations for correcting any deficiencies or approving initial operations.

The existing DØ Detector was designated a Low Hazard Radiological Facility and the Safety Envelope was approved in " Memo to Dr. J. Peoples from Andrew E. Mravca, Subject: APPROVAL OF THE FERMILAB D-ZERO DETECTOR SAFETY ENVELOPE received on Nov. 8, 1994, following submission of a Safety Assessment Document (SAD). The DØ Upgrade Project does not influence that determination.

In compliance with the Fermilab ES&H Manual, the Directorate, through the ES&H Section will determine the need for an update or addendum to the DØ SAD.

The introduction of the solenoid magnet as part of the DØ Upgrade was reviewed for NEPA compliance. The CH NEPA Tracking No. was FERMI114. A memorandum was received by Dr. Stefanski of Fermilab from Andrew E. Mravca of DoE on May 13, 1994 with the signed CH 560 Environmental Evaluation Notification Form, granting a categorical exclusion and stating that no further NEPA review was required.

5. WORK BREAKDOWN STRUCTURE

All work required for successful completion of the DØ Upgrade Project is organized into a Work Breakdown Structure (WBS). The WBS contains a complete definition of the scope of the project and forms the basis for planning, execution, and control of the DØ Upgrade Project. Specifically, the WBS provides the framework for the following activities:

1. Budgeting: Each element of the WBS is assigned a budgeted cost (BC). The budgeted cost of the project can be seen at any level since the costs of all lower WBS levels are rolled up to the higher levels.
2. Cost Estimating: The WBS supports a systematic approach to preparation of the cost estimate for the project. The WBS structure is extended to a level sufficient to allow the definition of individual components for which a cost can be reasonably estimated. The BC and the cost estimate are equal for the lowest level in each branch of the WBS.
3. Scheduling: The WBS also supports a systematic approach to preparation of the project schedule. The WBS is associated with tasks in the project schedule.
4. Support Requirements: The WBS, in conjunction with the associated schedule and cost estimates, provides the framework for projecting funding and manpower requirements over the life of the project.
5. Configuration Control: The detailed scope of the project is specified within the WBS. Impacts of proposed changes to the scope are readily evaluated within the WBS framework.
6. Performance Measurement: The WBS supports the monitoring, control, and reporting of cost and schedule performance.

5.1 Organization of the WBS

The Work Breakdown Structure at Level 1 was defined by the Fermilab Director in March, 1991. It consists of four broad categories: DØ Upgrade Detector, Detector R&D, AIP Project and Project Support.

Each of the major systems that comprise the Upgrade Project are represented at WBS Level 2: Tracking Detectors, Calorimeter, Muon Detectors, Trigger, and Computing. These comprehensive categories are further divided into individual distinct sub-systems, each with their own Sub-Project Manager(s). The Project Cost Estimate and Schedule are organized in this manner.

To facilitate tracking costs, budget codes have been assigned to all items at WBS level 4.

5.2 Work Breakdown Structure through Level 3

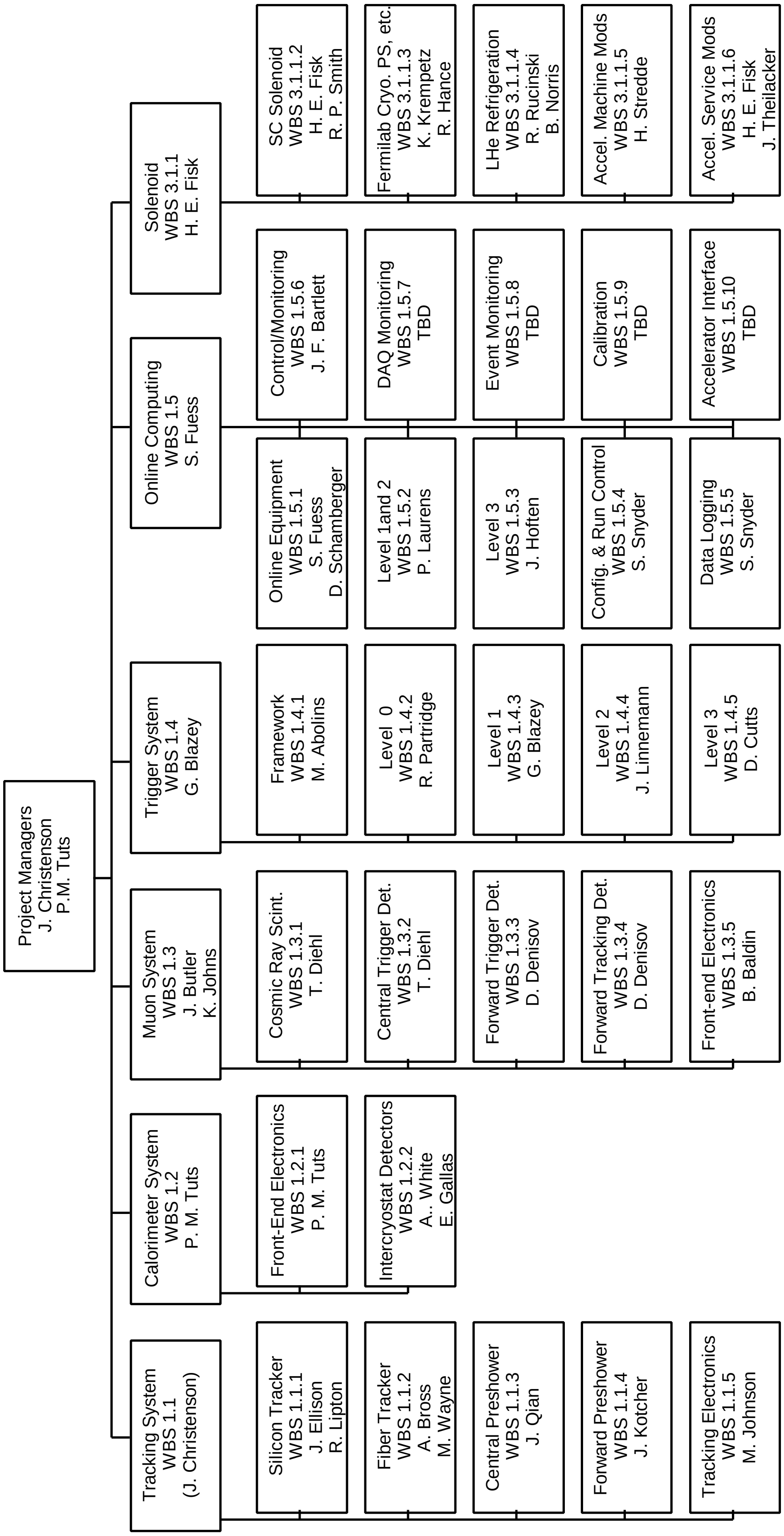
1 DØ Upgrade Detector
- 1.1 Tracking Detectors
  - 1.1.1 Silicon Tracker
  - 1.1.2 Fiber Tracker
  - 1.1.3 Central Preshower Detector
  - 1.1.4 Forward Preshower Detector
  - 1.1.5 Tracking Electronics
- 1.2 Calorimeter
  - 1.2.1 Front-end Electronics
  - 1.2.2 Intercryostat Detectors
- 1.3 Muon Detectors
  - 1.3.1 Cosmic Ray Scintillator
  - 1.3.2 Central Trigger Detectors
  - 1.3.3 Forward Trigger Detectors
  - 1.3.4 Forward Tracking Detectors
  - 1.3.5 Front-end Electronics
- 1.4 Trigger
  - 1.4.1 Framework
  - 1.4.2 Level Ø
  - 1.4.3 Level 1
  - 1.4.4 Level 2
  - 1.4.5 Level 3
- 1.5 Online Computing
  - 1.5.1 Online Equipment
  - 1.5.2 Level 1 and 2
  - 1.5.3 Level 3
  - 1.5.4 Configuration and Run Control
  - 1.5.5 Data Logging
  - 1.5.6 Control/Monitoring
  - 1.5.7 DAQ Monitoring
  - 1.5.8 Event Monitoring
  - 1.5.9 Calibration
  - 1.5.10 Accelerator Interface

2 Detector R&D

3 AIP Project
- 3.1 Solenoid
  - 3.1.1 Solenoid
    - 3.1.1.1 Management/EDIA
    - 3.1.1.2 Superconducting Solenoid
    - 3.1.1.3 Fermilab Cryo, PS, etc.
    - 3.1.1.4 LHe Refrigeration System
    - 3.1.1.5 Accelerator Machine Modifications
    - 3.1.1.6 Accelerator Services Modifications

4 Project Support
- 4.1 Project Management
- 4.2 Fermilab Technical Support

An organization chart based on the WBS, denoting the Level 3 Sub-project Managers, is shown on the following page.



WBS Structure and Managers at Level 3

5.3 WBS Dictionary

1 DØ Upgrade Detector

This Level 1 element consists of all those components of the actual upgrade of the DØ detector, its trigger and data acquisition system, and the associated online computing system necessary to process the data.

1.1 Tracking Detectors

A substantial effort in the DØ Upgrade is aimed at providing a tracking system for charged particles which is radiation-hard and can operate up to the highest Collider luminosities expected with the Main Injector. The construction and installation of all tracking components are contained in this level 2 element.

1.1.1 Silicon Tracker

One of the most powerful developments in tracking technology has been the advent of silicon microstrip detectors. This level 3 element covers the design, procurement and construction of a sophisticated silicon tracking system situated immediately outside the beam pipe that provides high-precision tracking and vertex determination. This element includes the silicon tracker electronics from the SVX II readout chip to the Port Card. All other electronics are covered in 1.1.5.

1.1.2 Fiber Tracker

In order to recognize and trigger on individual tracks in the high multiplicity events at the Collider, and to measure their momenta accurately, the radial space between the small silicon detector and the solenoid magnet will be instrumented with several cylinders of high-resolution tracking detectors. This element covers the design, procurement and construction of the fiber tracker consisting of scintillating fiber ribbons, support cylinders, and solid-state Visible Light Photon Counter (VLPC) readout devices. It also includes the cost of VLPC's for 1.1.3 and 1.1.4. All other electronics for this element is covered in 1.1.5.

1.1.3 Central Preshower Detector

Electrons are likely to begin showering in the material of the solenoid coil, and the onset of this shower, its relationship to a track, and its spatial characteristics can be used to distinguish it from a hadron. By installing a scintillation detector with good spatial resolution between the solenoid coil and the Central Calorimeter in the central region of the detector, the electron identification capabilities of the experiment will be considerably enhanced. This element covers the design, procurement and construction of a preshower detector composed of scintillator strips with wavelength shifting fiber readout by VLPC's. The VLPC's for this element are covered in 1.1.2, and the electronics for this element in 1.1.5.

1.1.4 Forward Preshower Detector

This element serves the same purpose as 1.1.3, except that it covers the forward regions in front of the End Calorimeters. The design of this system uses the same technology as that in 1.1.3. This element covers the design, procurement and construction of preshower detectors consisting of scintillator strips with wavelength shifting fiber readout by VLPC's. The VLPC readout for this element is covered in 1.1.2, and the electronics are covered in 1.1.5.

1.1.5 Tracking Electronics

This element covers the design, procurement, and construction for all the higher level front-end readout electronics for all tracking systems, 1.1.1, 1.1.2, 1.1.3, and 1.1.4. It covers all the electronics beyond the port cards for 1.1.1, all the electronics to readout the VLPC's for 1.1.2, 1.1.3, and 1.1.4. In addition, because of the tight integration of the readout and trigger electronics for all systems with VLPC readout it includes the trigger electronics for 1.1.2, 1.1.3, and 1.1.4.

1.2 Calorimeter

The DØ uranium-liquid argon calorimeter system is well-suited to the high radiation environment of the Tevatron Collider. The short inter-bunch times at the upgraded Collider necessitate a modification of the front-end electronics, both preamplifiers and shaping circuits (BLS). In addition, the scintillation counters and the readout of the Intercryostat Detector will be modified.

1.2.1 Front-end Electronics

The shorter bunch spacings of Run II will require the replacement of all 50,000 calorimeter preamps. In order to reduce the pile-up `noise' contribution to acceptable levels, the effective shaping time of the preamp-BLS system will be shortened. The new preamp will have lower electronic noise and will drive a terminated line to the BLS. The new preamplifier is designed to fit in the existing mechanical infrastructure of motherboards and crates. Better matched cables from the feedthrough port on the cryostat to the preamp input will be used to reduce unwanted reflections. This element covers the design, procurement, and construction of all calorimeter preamplifiers, shapers, analog delay chips, calibration pulser, power supplies and support electronics.

1.2.2 Intercryostat Detectors

The gaps between the Central and End Calorimeters result in some degradation of the energy resolution of the calorimeter in these overlap regions. The sensitivity is recovered with a set of scintillation counters mounted in the space between the calorimeter cryostats. In the upgraded experiment, the detectors must operate in the solenoid magnetic field. This element covers design, procurement and construction of the scintillator modules and the readout phototubes located in a region of reduced magnetic field, as well as the front-end electronics.

1.3 Muon Detectors

One of the major features of the upgraded DØ detector is the extensive muon system providing continuous coverage to within 15 degrees of the beam. The central trigger detectors, new forward trigger and tracking detectors and new front-end electronics are included in this item. The cosmic scintillation shield will be extended to cover the entire detector.

1.3.1 Cosmic Ray Scintillator

The cosmic ray scintillator shield provides a precision timing signal to allow the reduction of cosmic ray backgrounds in the detector. This element covers the design, procurement and construction of the scintillator detectors using fiber and phototube readout. It includes all the front-end electronics for this system.

1.3.2 Central Trigger Detectors

To trigger on low momentum muons that have not passed through the iron toroid material requires the addition of scintillation counters on the inner layer of the muon system, segmented in azimuth to match the geometry of the fiber trigger. This will allow efficient track triggers for muons that passed through the calorimeter. This element covers the design, procurement, and construction of scintillator modules with wavelength shifter readout and phototubes. It includes the electronics up to the phototube bases. The rest of the readout electronics is covered in 1.3.5.

1.3.3 Forward Trigger Detectors

In the forward portions of the muon system, accidental triggers dominate at high luminosity. Scintillator trigger detectors with a tile geometry and phototube readout, when combined with extensive shielding near the beam pipe will reduce the occupancy to manageable levels. This element covers the design, procurement and construction of the scintillator modules, the phototubes, and phototube bases. The rest of the electronics is covered in 1.3.5.

1.3.4 Forward Tracking Detectors

The present forward chambers will not survive the future accelerator running conditions. These chambers will be replaced by a mini-drift-tube system able to withstand the high radiation environment, and to handle the reduced bunch spacing time because of lower drift times. This element covers the design, procurement and construction of a mini-drift chamber system. All the front-end electronics for this element is covered in 1.3.5.

1.3.5 Front-end Electronics

The reduced minimum bunch crossing time requires the replacement of all front-end electronics. The addition of new trigger and tracking elements for the muon system requires additional front-end electronics. All muon systems will share a common design based on fast digitization followed by digital delays to accommodate trigger formation times. This element includes the design, procurement and assembly of all common muon readout electronics except for 1.3.1. The phototube base electronics is covered in the appropriate detector elements 1.3.2, 1.3.3 and 1.3.4.

1.4 Trigger

The DØ detector has a multi-level trigger system. As the luminosity increases several improvements at all levels will need to be made. In addition, some of the new detectors offer opportunities for highly effective new trigger capability. All upgrade trigger systems except Level 1 triggers for the fiber tracker and preshower detectors are included here.

1.4.1 Framework

The trigger is controlled and coordinated by the trigger frameworks. To increase the bandwidth for the with the post-Main Injector running, the trigger frameworks must be replaced. This element covers the design, procurement and construction of new trigger frameworks that communicate with the Level 1 and Level 2 triggers.

1.4.2 Level Ø

The current Level Ø scintillator system will not work in the magnetic field of the new solenoid. Further, the detectors must be redesigned to fit in the tight space with the forward preshower detector. This system will also serve as luminosity monitor for the experiment. This element covers the design, procurement and construction of the scintillator modules and field insensitive readout.

1.4.3 Level 1

The front-end systems provide fast information to the calorimeter Level 1 trigger system and the muon Level 1 trigger system. The present Level 1 calorimeter trigger system can be re-used with the addition of more buffering, but the muon Level 1 trigger system must be replaced. This element covers the design, procurement and construction of the Level 1 muon trigger, and the Level 1 calorimeter trigger modifications.

1.4.4 Level 2

The Level 2 trigger system must reduce the trigger rate out of Level 1 by about an order of magnitude. It is able to do this by refining the measurements used at this level, and combining the information from different detector systems or including information from a system that cannot provide a Level 1 trigger. An example is a fiber/preshower trigger matched with a calorimeter cluster. This element covers the design, procurement, and construction of the calorimeter, muon, and trigger preprocessors, and the global processor responsible for producing the Level 2 trigger.

1.4.5 Level 3

A cluster of forty-eight VAX processors has been used to make relatively complete analyses of the data to decide whether or not to write an event on tape. At higher luminosity, the need for higher bandwidth and more sophisticated algorithms will demand enhancement of this system. This element covers the procurement of faster processors, and the design, procurement and construction of electronics to provide modest bandwidth improvements.

1.5 Online Computing

All upgrades and expansion of online computing systems that support data acquisition are contained in this element. Offline computing is not covered in this document.

1.5.1 Online Equipment

The monitoring of the performance of the detector elements to ensure the quality of the data being taken is of the highest importance. A powerful and comprehensive online computing system is employed to configure and control all operations of the experiment, including triggering, data acquisition, event monitoring, and services that support the experiment. As the luminosity rises, the capabilities of such a system must improve correspondingly. This element covers the procurement of all computing elements beyond the Level 3 data acquisition system up to and including the equipment for recording the data for further offline processing.

2 Detector R&D

This Level 1 element consists of all the R&D needed to develop the detectors which form the components of the DØ Upgrade.

3 AIP Project

The optimal performance of the tracking system will depend on the solenoid magnet, the beryllium beam pipe and the shielding. This level 1 cost element covers the AIP project for the solenoid magnet, the muon shielding and the beam pipe.

3.1.1 Solenoid

In the upgraded DØ detector, charged particle momenta will be determined by measuring track bending in a solenoidal magnetic field of 2 Tesla. This element covers the procurement of the magnet, its services, refrigeration system, field measurement, and installation.

3.1.1.1 Management/EDIA

Management, Engineering and Design for Magnet, Cryo Systems, and Service Building modifications as well as inspection of the work done.

3.1.1.2 Superconducting Solenoid

This item covers the procurement of the magnet coil itself, suspended in a liquid helium cryostat, from a commercial vendor.

3.1.1.3 Fermilab Cryo, PS, etc.

This item covers a collection of services for the magnet, including installation, power supply, controls, and instrumentation for the magnet, vacuum systems, and liquid and gaseous helium distribution.

3.1.1.4 LHe Refrigeration System

This item includes the liquid helium refrigeration system (storage dewar, cold box, expansion devices, compressor system, and associated cryogenic controls).

3.1.1.5 Accelerator Machine Modifications

This item includes measurement of the field and the subsequent deployment of any correction magnets necessary for accelerator operations. It also includes the addition of shielding around the beam pipe which will provide radiation shielding to extend the lifetime of the muon tracking chambers, and reduce the backgrounds in the trigger detectors. This covers the design and construction of the shielding system and its supports. This element also covers all items required to construct, support, and install a replacement beam pipe which will be required to accommodate the new silicon tracking system.

3.1.1.6 Accelerator Services Modifications

This item includes the enlargement of the Accelerator LHe Cryo Service Building at DØ, and the addition of two large compressors to provide high pressure He gas for the DØ refrigeration system and auxiliary services: power, water, controls.

4 Project Support

Support of Fermilab DØ personnel with Upgrade Equipment funds.

4.1 Project Management

All activities related to managing the DØ Upgrade Project.

4.2 Fermilab Technical Support

Salary support of DØ personnel directly involved in the Upgrade Project.

6. SCHEDULE

A comprehensive schedule of work to design, construct, assemble and commission the DØ Upgrade is maintained to facilitate management of the project. It is comprised of detailed schedules for the development of each sub-system in the project and includes the resources (cost, manpower) required for each step. Based on these details, an overview of the project is fashioned, complete with cost and manpower needs as a function of time, and a series of milestones spread throughout the project.

6.1 Schedule Methodology

The schedule is assembled using Microsoft Project. It consists of a ‘master schedule’ that depicts the fabrication of each sub-system (or sub-project) and their ultimate installation and commissioning. The detailed schedule for the construction of each sub-system is contained in a distinct sub-project file that is linked to the master schedule. This architecture provides a convenient means for rolling-up or hiding detail when desired. Sub-project Managers are responsible for the generation and maintenance of the schedules for their sub-systems. These sub-project schedules can be updated independently, without affecting other sub-project schedules.

The schedule is built of tasks of various durations and milestones that are linked to describe the flow and interdependency of the work. For each task, the manpower required to do it is specified. Separate allocations of mechanical and electrical engineers, designer/drafters and technicians, as well as physicists are made, both for Fermilab and non-Fermilab personnel. Thus, profiles in time of various work groups are readily obtained to aid in the establishment of manpower requirements and the allocation of personnel as the project evolves. By entering the average weekly SWF cost of each type of manpower, labor cost profiles are extracted for each work group as well as the total labor cost for each sub-project and for the entire Upgrade Project.

The M&S funds needed for each task are down-loaded from the Cost Estimate. Cost plans for each sub-project and for the full project are easily derived. By adjusting the schedule to yield an overall cost plan that matches the profile of funds available from the Laboratory and other sources and a manpower plan that can be supported by the Laboratory, a consistent and viable work plan is established that represents the baseline schedule.

The scheduling program identifies the critical path (or paths) to completion of the project. This feature calls attention to those tasks that have no ‘float’ or slack that must be carefully monitored to prevent delay. Knowledge of the critical path facilitates changes to optimize the work and to hasten completion.

6.2 Schedule Baseline

The ‘baseline’ schedule that is consistent with the available funding and manpower resources, has been assembled. The schedule is monitored in great detail by the Sub-project Managers and the Project Managers. A comprehensive set of milestones scattered throughout the duration of each sub-project are monitored by the Sub-project Managers. A subset of these are monitored by the Project Managers, and a further subset are held by the Director and the DoE. These “Director’s Milestones” are shown in the table below. DoE milestones are indicated in boldface type.

No.	Director's Milestones	Date
1	**M1-Solenoid Delivered to Fermilab**	**15-May-97**
2	M2-VLPC Production 50% Complete	5-Aug-97
3	M2-Central Preshower Module Fabrication Complete	29-Aug-97
4	M2-Muon Forward Trigger Counter Assembly 10% Complete	22-Sep-97
5	M2-Central Preshower Installed on Solenoid	20-Oct-97
6	M2-Muon Forward Tracker MDT Assembly 10% Complete	19-Nov-97
7	M2-Forward Preshower Module Fabrication Begun	16-Feb-98
8	**M1-Solenoid Installed and Tested**	**28-Apr-98**
9	M2-Calorimeter Preamp System Test Complete	27-Jul-98
10	M2-First Silicon Tracker Barrel/Disk Module Complete	28-Jul-98
11	M2-Fiber Tracker Assembly Begun	31-Jul-98
12	M2-Muon Electronics Preproduction Testing Complete	5-Oct-98
13	M2-Calorimeter BLS Assembly Complete	6-Jan-99
14	M2-ICD Arrives at Fermilab	12-Mar-99
15	**M1-Central Silicon Complete**	**26-Mar-99**
16	M2-Fiber Tracker Assembly Complete	23-Jun-99
17	M2-Tracker Installed in Solenoid	22-Jul-99
18	M2-Muon End Toroids Installed on Platform	25-Aug-99
19	**M1-Ready To Roll In**	**1-Oct-99**
20	**M1-Detector Rolled-in and Hooked Up**	**29-Nov-99**

6.3 Manpower Requirements

Manpower profiles are extracted from the schedule for the various categories of personnel mentioned earlier. The results are displayed in the table below listing the average number of people (FTE's) in various technical job categories to support the plan. (F) denotes Fermilab manpower, (U) denotes non-Fermilab manpower.

Position	FY96	FY97	FY98	FY99	FY00	Total
Designer (F)	4.1	11.3	1.7			17.0
Electrical Engineer (F)	6.5	8.7	5.0	1.9	0.1	22.3
Electrical Technician (F)	3.5	7.6	15.1	8.5	0.1	34.7
Mechanical Engineer (F)	4.5	8.0	5.6	1.8	0.0	19.9
Mechanical Technician (F)	6.8	25.4	47.7	24.7	1.3	105.9
Computer Professional (F)		3.6	5.6	5.7	0.6	15.4
Sub-Total (F)	25.4	64.6	80.7	42.6	2.0	215.3
Designer (U)	0.2	1.7	0.0			1.9
Electrical Engineer (U)	6.3	11.5	10.7	4.4	0.1	33.1
Electrical Technician (U)	1.7	7.8	5.9	4.7	0.0	20.1
Mechanical Engineer (U)	1.1	2.2	2.1	0.8		6.2
Mechanical Technician (U)	3.0	20.5	41.7	8.2		73.4
Sub-Total (U)	12.4	43.6	60.3	18.2	0.1	134.6
Total (F+U)	37.7	108.2	141.0	60.8	2.2	349.9

7. COST ESTIMATE

7.1 Costing Methodology

The cost estimate presented here covers all Materials & Services and those Salaries, Wages and Fringe Benefits budgeted to capital funds for the DØ Upgrade Project for WBS level numbers 1, 3, and 4.

7.1.1 Cost Spreadsheet

A full cost spreadsheet has been compiled using Microsoft Excel, based on the input from the WBS level 3 Sub-project Managers. The costs are estimated at the lowest available WBS level where there is a sufficient level of detail to provide reliable cost estimates and risk-based contingency analyses. The spreadsheet is organized to provide a "rollup" of costs for all lower-lying WBS elements. For cost items that display a rollup cost, the percentage contingency displayed is the calculated contingency based on the rollup of the cost and contingency. The percentage contingency is calculated as Contingency/Cost*100. In this manner, the Project Managers are able to review the costs at any level of detail. The cost estimates provided by the Sub-project Managers are reviewed by the Project Managers in consultation with any technical experts that are deemed necessary to evaluate the cost estimates. The costs are given in FY95 dollars.

7.1.2 Contingency Estimation

The contingency is estimated by the WBS level 3 Sub-project Managers at the lowest available WBS level. It is based on detailed estimates of designs where available, and on the experience of the Sub-project Managers and the engineering staff directly involved with the subsystem where a conceptual design exists. Guidelines for the estimation of the contingency have been provided, but may be overridden by the Sub-project Managers in exceptional cases. The general guidelines for the contingency estimation are:

- 0% on items that have been completed.
- about 5% on items that have been ordered, but not delivered (this accommodates change orders, delivery costs, etc.)
- about 10-15% on items that can be readily estimated based on quotes for a detailed design
- about 20-30% on items for which a detailed conceptual design exists, but which may vary due to scope changes such as channel count
- about 50% on items for which there does not yet exist a detailed conceptual design, but which is an item required for the DØ Upgrade project

7.1.3 Cost Change Tracking

Changes to the cost estimate are made in accordance with the Project Control System described in Chapter 8. Records of all approved changes to WBS items are kept to maintain a cost change history for all items.

7.2 Cost Summary

The summary of all Equipment M&S, AIP, Project Support costs and Operating SWF, is presented in the following table in FY95 k$. The full detailed cost estimate for each subsystem is presented in Chapter 10.

WBS	ITEM	DETECTOR			
	FULL	M&S	Contingency		Total
1	D0 UPGRADE DETECTOR	k$	%	k$	k$
1.1	***TRACKING DETECTORS***				
1.1.1	SILICON TRACKER	4,952	16	786	5,739
1.1.2	FIBER TRACKER	7,377	22	1,601	8,978
1.1.3	CENTRAL PRESHOWER DETECTOR	355	17	62	417
1.1.4	FORWARD PRESHOWER DETECTOR	440	18	80	520
1.1.5	TRACKING ELECTRONICS	2,289	14	324	2,613
1.1	TOTAL TRACKING DETECTORS	15,413	19	2,853	18,267
1.2	***CALORIMETER***				
1.2.1	FRONT-END ELECTRONICS	4,055	9	379	4,434
1.2.2	INTERCRYOSTAT DETECTOR	301	13	40	342
1.2	TOTAL CALORIMETRY	4,356	10	419	4,776
1.3	***MUON DETECTORS***				
1.3.1	COSMIC RAY SCINTILLATOR	1,056	0	0	1,056
1.3.2	CENTRAL TRIGGER DETECTORS	981	10	99	1,081
1.3.3	FORWARD TRIGGER DETECTOR	1,709	15	262	1,971
1.3.4	FORWARD TRACKING DETECTOR	1,158	18	206	1,364
1.3.5	FRONT-END ELECTRONICS	3,624	12	443	4,067
1.3	TOTAL MUON DETECTION	8,528	12	1,010	9,539
1.4	***TRIGGER***				
1.4.1	FRAMEWORK	1,337	19	257	1,595
1.4.2	LEVEL 0	134	18	25	158
1.4.3	LEVEL 1	1,289	15	197	1,486
1.4.4	LEVEL 2	1,818	20	356	2,174
1.4.5	LEVEL 3	739	17	129	868
1.4	TOTAL TRIGGER	5,317	18	964	6,281
1.5	***ONLINE COMPUTING***				
1.5.1	ONLINE EQUIPMENT	605	19	117	722
1.5	TOTAL COMPUTING	605	19	117	722
	TOTAL D0 UPGRADE PROJECT	34,221	16	5,363	39,584
3.1.1	SOLENOID AIP	5,041	5	272	5,313
4	**PROJECT SUPPORT**				
4.1	***PROJECT MANAGEMENT***	1,391	13	182	1,573
4.2	***FERMILAB TECHNICAL SUPPORT***	5,541	25	1,385	6,926
	TOTAL PROJECT SUPPORT	6,932	23	1,567	8,499
	Equipment G&A				7,256
	Operating G&A				4,584
	OPERATING SWF FY97-00	9,169	25	2,292	11,461

7.3 Cost Plan

The cost plan summary for FY96-00, based on the detailed schedule, is shown in the table below in FY95 k$, with contingency included.

Category		Previous	FY98	FY99	FY00	Total
Equipment *	M&S	20,142	9,618	5,779	1,070	36,608
	SWF	6,039	1,576	775	109	8,499
	G&A	2,031	2,495	1,566	1,165	7,256
Total U.S. Equipment		28,212	13,688	8,120	2,344	52,364
Solenoid , Beam Pipe, Shielding (AIP funds)		5,313				5,313
Total AIP Funding		5,313				5,313
Operating	SWF	3,990	3,934	2,627	910	11,461
	G&A	1,596	1,574	1,051	364	4,584
Total U.S. Operating		5,586	5,508	3,678	1,274	16,045
Total U.S. Detector Cost		39,111	19,196	11,798	3,618	73,722
Non-U.S. Costs (Equipment)**		675	1,012	711	583	2,983
Total Detector Cost		39,786	20,208	12,509	4,201	76,705

8. WORK AUTHORIZATION, CONTINGENCY MANAGEMENT AND PROJECT CONTROL

8.1 Introduction

This chapter summarizes the management systems that the DØ Upgrade Project will use to monitor the cost and schedule performance and the technical accomplishments of the Project. The significant interfaces that exist among the various management systems are noted in the individual narrative descriptions below. Although these systems are described separately they are mutually supportive and will be employed in an integrated manner in order to achieve the project objectives. As conditions change during the evolution of the project, the management systems will be modified appropriately so as to remain responsive to the needs for project control and reporting. Consequently, while the policy and objectives of each management system will remain fixed, the methods, techniques, and procedures that will be employed by the DØ Upgrade Project may change as conditions dictate, over the life of the project.

The Work Authorization and Contingency Management System and the Project Control System described in this chapter defines the management and control procedures required by the Laboratory.

8.2 Guidelines and Policies

The Contingency Management System and the Project Control System employed by the DØ Upgrade Project will be consistent with the Fermilab "Project Control System Guidelines", dated May 1, 1994.

The following policies are applicable for the DØ Upgrade :

- All Project work is organized in accordance with the WBS.
- Formal (and informal) reviews by experts are used to establish baseline specifications and designs.
- Established cost, schedule, and technical baselines are used for measuring project performance. Technical baselines are maintained in the Technical Design Reports describing the current design implementation for each system included in the scope of the Upgrade Project.
- Changes to the approved cost, schedule and technical baselines proceed via a Change Request process described below.
- A project management system which features performance measurement based on cost accounting and scheduling is used to control the project and to provide forecast and feedback information to management.
- The decision making apparatus includes regular meetings among the DØ Upgrade Project Managers and the Sub-project Managers. These meetings help to identify and resolve interface issues within the project.
- Quality assurance, safety analysis and review, and environmental assessment are integral parts of the Work Authorization and Project Control.

8.3 Work Authorization and Contingency Management

Funds will be made available by the Director to the DØ Upgrade Project on an annual basis following the receipt of the Initial Financial Plan from DoE. These funds will correspond to a financial plan and a funding profile to project completion as determined by the Director. The funding profile will include contingency in each year of the project.

Work packages will be established by the Fermilab Budget Office following the WBS structure through level 4. The accumulation of M&S costs in these accounts will be initiated through purchase requisitions originating with the engineering and scientific staff assigned to the various sub-systems. Signature authority levels will be provided to the Fermilab Business Services Section by the DØ Upgrade Project Managers to assure that only authorized work is initiated.

At any time, the project contingency is the difference between the project Total Estimated Cost (TEC) and the Estimate at Completion (EAC). The Project Managers will hold the contingency and allocate it subject to the Project Control System described below.

The principles of contingency management that the DØ Upgrade Project will follow are as follows:

- The cost estimate for each sub-system will include contingency funds based on an assessment by the preparer of uncertainties and risks associated with the budgeted cost;
- The actual expenditure of contingency will be reflected in a new EAC to be updated every six months;
- The Deputy Director will approve all Change Requests that will require utilization of contingency, subject to the thresholds levels below;
- All changes will be tracked with approved Change Requests and a record of all Change Requests will be maintained by the DØ Upgrade Project;
- Each fiscal year, the Project Managers will assign the contingency available in that year within the following guidelines:

  The Project Managers may adjust the estimated cost of any WBS level 2 sub-project by as much as $100K, as long as the Project TEC is not exceeded. If the change exceeds $100K, the Change Request must be approved by the Deputy Director;

  The use of contingency above the amount budgeted for the year requires that a Change Request be approved by the Deputy Director.

- All changes from baseline cost shall be traceable.

8.4 Project Control System

The Project Control System includes the three categories listed below:

- BASELINE DEVELOPMENT: This includes management actions necessary to define project scope and responsibilities, establish baselines, and plan the project.
- PROJECT PERFORMANCE: This includes management actions after work commences that are necessary to monitor project status, report and analyze performance, and manage risk.
- CHANGE MANAGEMENT: This includes management actions necessary to ensure adequate control of project baselines, including the performance measurement baseline.

1. BASELINE DEVELOPMENT

The material necessary to describe baseline development adequately has already been covered in this PMP and will not be repeated here.

2. PROJECT PERFORMANCE MEASUREMENT

Project performance aspects of the Project Control System consists of the following:

a. Funds Management

The detailed obligation plan for each WBS item is derived from the baseline schedule for the project that is funded at a rate consistent with the profile of funds from the Laboratory and other sources. This top-down obligation plan is adjusted by Project Management as appropriate to reflect changes in the Laboratory funding profile.

b. Accounting

A record of all M&S obligations associated with individual WBS elements is maintained in the DØ Upgrade Project financial system for tracking purposes. Each obligation is identified with the corresponding lowest-level WBS number(s), thereby enabling comparison of obligations with the Cost Estimate at any level. In this way, the usage of contingency is monitored item by item. Monthly tracking reports are produced that show all purchasing activity in each sub-project, itemized by WBS number. For each item, as well as roll-ups to higher levels, the cost estimate, current-year allocation, year-to-date and project-to-date obligations and balances are displayed.

All Upgrade M&S transactions are also associated with Fermilab work packages at WBS level 4. The Fermilab financial system is used to track and account for all obligations and subsequent costs at level 4 and above. Monthly accounting reports depict obligation and cost details and summaries for all work packages or WBS categories at and above level 4. The cost of labor in each WBS level 2 category in the Upgrade Project is captured by reporting the fraction of effort of each individual involved in the work and transferring the salary cost to the corresponding budget code.

The financial system accommodates the allocation of direct costs collected from a single point to multiple control accounts. This is accomplished through split coding. The split codes are tracked through the work packages in question and are reflected in the monthly reports.

c. Performance Measurement and Analysis

The principle functions of performance measurement and analysis are to identify, quantify, analyze and rectify significant deviation from the plan as early as possible.

Schedule Variance

At the end of each month, the detailed schedule for each sub-project is examined for variances from the baseline schedule. This is accomplished by updating the 'actual' schedule on the basis of work performed in the period, and comparing the actual schedule to the baseline schedule. An extensive set of milestones for each sub-project is also monitored.

Changes that have a significant impact on the project, either by delaying completion or by affecting the cost or manpower plan of the project, are identified for further analysis. A plan to rectify the problem is developed that may include:

- alteration of the schedule to optimize the work and reduce the delay,
- allocation of additional resources (funds or manpower) to shorten the time required to perform given tasks.

Any change that would alter the schedule, cost or personnel resources of work to be performed is subject to the controls described below.

Cost Variance

In approving a purchase requisition, the WBS level 3 manager will compare the proposed obligation with the balances remaining for that item and its parents at higher levels. If the obligation does not exceed the estimated cost, the manager may approve the requisition directly. However, if the obligation would require use of contingency on that item or at a higher level, the manager must formulate a plan to fund the item and attach the details to the requisition for approval by the Project Manager. In this fashion, use of contingency is approved prior to incurring the obligation. Cost variances that exceed the established thresholds are formally reported as provided below.

Each month, obligation performance is determined by comparing obligations to date with budgeted or allocated costs to date as indicated by the obligation-loaded schedule.

Resource Variance

On a monthly basis, the available funds and manpower resources are compared with those required in the schedule to identify shortfalls that could lead to schedule and/or cost variances. Any such variances will be brought to the attention of the DØ PMG.

3. CHANGE MANAGEMENT

Change Management aspects of the Project Control System consist of the following:

Out-of-Scope Changes

An Out-of-Scope Change is a proposed change to the scope of the Laboratory-approved DØ Upgrade Project that would alter the physics capabilities of the detector in a major way or introduce a new detector system. The ‘scope’ of the project includes the design, construction and installation of the collection of systems or improvements to systems that have been granted Stage I approval by the Director. The scope of the project is defined by the proposal document which includes content equivalent to a Conceptual Design Report. Each individual system or an improvement to a system has an impact on the physics capability of the DØ Upgrade Project as a whole. This physics capability is also defined in the proposal. The scope of the project as an aggregate determines the physics capabilities of the upgraded detector.

Any Out-of-Scope change must be initiated by a formal proposal by the Spokespersons to the Director for consideration. In response to such a proposal, the Director may seek the advice of the Fermilab Physics Advisory Committee, the DØ PMG and/or a Director's Review. Such a proposal may be granted Stage I approval, deferred for further clarification of the physics potential, technique, cost and/or schedule, or it may be rejected.

In-Scope Changes

Any change to the DØ Upgrade Project that does not alter the scope of the Project as defined above does not require a new proposal to be submitted to the Laboratory. Although the scope of the project is not affected, changes resulting in cost variations, changes of personnel assignments or schedule impact are considered In-Scope Changes.

In-Scope Changes must have the approval of the DØ Upgrade Project Managers. In-Scope Changes that result in cost variations or changes in the EAC for any WBS level 2 system greater than $100K must be initiated by a Change Request to the DØ PMG. Such Requests require the approval of the Deputy Director.

In-Scope Changes that result in changes to any milestones held by the Director of more than one month must be initiated by a Change Request submitted for consideration by the DØ PMG and approval by the Deputy Director. The response to such a Change Request may be to initiate a plan to reallocate resources to recover the schedule, a plan to stage or descope the detector or a plan to revise the project schedule objectives.

In-Scope Changes that result in an increase of the cost of personnel resources by more than 10% for any WBS level 2 system must be reported to the DØ PMG.

The following in-scope changes require the approval of DoE Headquarters:

- Any increase to the Total U.S. DoE Equipment Cost; or
- Any delay greater than six months in a Level 1 milestone.

The DØ PMG will function as the Change Control Board for the project. Each Change Request will be reviewed by the DØ Project Managers. Subject to the above discussion, the Change Request will be forwarded to the DØ PMG for approval by the Deputy Director. The DØ Project Managers will maintain current records of all Change Requests and their disposition.

The following table summarizes the change control thresholdsresponsibilities:

DØ Upgrade Project Change Control Thresholds

	DoE Headquarters	**FNAL Director/Deputy Director**	**DØ Upgrade Project Management**
Technical		Changes that affect ES&H requirements or impact accelerator systems. Out-of-scope changes to upgrade physics capabilities.	Changes that do not affect ES&H requirements and do not change the upgrade project scope.
Cost	Any increase to the Total U.S. DoE Equipment Cost.	Any increase in the EAC greater than $100K for a WBS Level 2 system.	Any change in the EAC less than $100K for a WBS Level 2 system.
Schedule	Any delay of a DoE milestone by more than six months.	Any change that results in the delay of a Director's milestone by more than one month.	Any change that results in the delay of an Upgrade Project Manager's milestone by more than one month.
Personnel		Any increase in personnel costs of more than 10% for a WBS Level 2 system.	Any change in personnel costs less than 10% for a WBS Level 2 system.

9. REPORTING AND REVIEW

9.1 Progress Reports

The DØ Upgrade Project provides reports on a regular basis to cognizant management. The objective of the reporting is to provide for the collection and integration of essential technical, cost, schedule and performance data into reports to aid in the monitoring and management of the Project.

Level 3 Monthly Reports
All WBS Level 3 Managers submit informal written reports to the Project Managers detailing specific progress on the pertinent sub-systems. These reports summarize activities of the previous month, describe activities planned for the upcoming month, and include comments and concerns.

Quarterly Reports
These reports to the Particle Physics Division Head and the Directorate outline progress, problems, budget and schedule status, including comparisons of projected status versus actual status. These reports are submitted to the DoE by the Directorate.

9.2 Technical Design Reports

A comprehensive Technical Design Report is written for each sub-system when the design of the system is sufficiently advanced that all significant issues and concerns have been resolved. This report is not a detailed engineering design, but a thorough discussion of all salient features of the detector or system and a rationale for key features and techniques. The report describes the plan for building the sub-system and the resources required. These reports, upon review and approval, become the technical baseline for the sub-systems.

9.3 Meetings and Reviews

DØ Project Management Group (PMG)
Meeting convened by the Deputy Director to monitor the progress of the project, as described in Section 3.10.

DØ Upgrade Management Group
Meeting of Sub-Project Managers described in Section 3.10.

Electronics Certification Board
A group of electronics engineers and physicists knowledgeable and involved in electronics, chaired by one of the Project Managers, that meets as needed to review and coordinate electronic designs for the various detector and trigger systems. This group recommends approval of design plans to the Project Managers. It sets standards for all electronics in the project and develops specifications, protocols and rules for sub-systems to assure compatibility.

General Upgrade Meetings
Eight meetings each year, synchronized with Collaboration meetings held four times per year, for presentation of status reports, discussion of current issues and dissemination of news and information. These meetings are of general interest to anyone involved in the Upgrade and serve to integrate diverse activities and provide an opportunity for physicists to criticize work in areas other than their own in this large project.

Sub-Project Meetings

Meetings called by Sub-Project Managers, typically bi-weekly, to discuss status, progress, and issues directly related to the pertinent sub-project, as well as its coupling to other parts of the Upgrade. It is here that the consensus of the experts is developed. Possible departures from schedule and cost, and their mitigation, are discussed in these meetings.

10. SPECIFIC SUB-PROJECT WORK PLANS

10.1 Solenoid Magnet

The D0 Upgrade Solenoid is Accelerator Improvement Project 39-FA-94-6301 under directive BAF-94-2, 5/12/94. Details can be found in the Project Management Plan for that project. The solenoid is WBS 3.1.1.

Schedule Milestones

The milestones for the Solenoid AIP project are given in the table below. Completed milestones are marked with an asterisk.

Level 4 Sub-Project	Milestone	Date
Magnet	Contract Issued*	Jan-95
	Design review*	Apr-96
	Start Coil Winding*	Apr-96
	Finsh Coil*	Jul-96
	Cryostat/CD End*	Feb-97
	Toshiba Magnet Test*	Mar-97
	Arrival at Fermilab	15-May-97
	Installed	28-Apr-98
Cryo/PS/H2O/He	Cryo Design Complete*	Dec-95
	HX Installed*	Jan-96
	Tran. Lines/ Piping*	Mar-97
	Expanders/U-Tubes	Apr-97
	Cryo System Tests	May-97
	Bus Work Complete	Dec-97
	PS/QP Installed	Dec-97
Refrigeration System	Compressors/Hi Press.*	Jun-96
	Instrumentation/Controls*	Dec-96
Accel. Machine Mods.	Beam Tube Procured	Mar-98
	Beam Tube Installed	Nov-98
	Shielding Designed	Jul-97
	Shielding Pre-Assembly	Jan-98
Accel. Service Mods.	Cryo Building Plans*	Mar-95
	Contract Issued*	Apr-95
	Building Mods Complete	Feb-96

Manpower Plan

The manpower plan for the Solenoid Magnet sub-project is given in the following table. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	Solenoid					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Designer (F)	1.5	0.9				2.4
Electrical Engineer (F)	0.5	0.8	0.2	0.1		1.6
Electrical Technician (F)	0.6	0.7				1.2
Mechanical Engineer (F)	2.8	2.2	1.1	0.1		6.1
Mechanical Technician (F)	4.2	4.1	2.4			10.8
Total	9.6	8.6	3.7	0.1		22.1

Cost Estimate

The cost estimate for the Solenoid AIP (in k$) is shown in the table below.

WBS 3.1.1	**Title**	**Cost Est. FY96**	**Obligated Sep-96**	**Cost to Complete**
3.1.1.1	Management/EDIA	282	99	45
3.1.1.2	Solenoid Procurement	2,400	2,018	298
3.1.1.3	Cryo,PS,Vac,He Dist.	650	293	377
3.1.1.4	LHe Refrig.	450	439	29
3.1.1.5	Accel. Machine Mods	616	0	531
3.1.1.6	Accel. Service Mods	770	767	0
	Totals	**5,168**	**3,616**	**1,280**
	Obligated+Cost to Complete			4,896
	Contingency on C to C			272
	Total (Oblig+C to C+Cont)			**5,168**
	Cont % on C to C			21.25%

10.2 Silicon Tracker

Objectives and Performance Criteria

Objectives of the silicon tracking system include:

- Providing very high resolution measurements of particle tracks in the region near the beam pipe;
- Providing track reconstruction to η=3;
- Providing point resolution of 10 µm;
- Alignment to 25 µm;
- Strip position known to better than 5 µm;
- Maximum silicon temperature less than 15 degrees C;
- Wafers from the manufacturer required to have > 99.5% good channels;
- > 98.5% working channels after construction;
- A readout system that functions at 53 MHz;
- Detectors and associated readout must be radiation hard to ~ 1 Mrad.

A detailed description of the design and performance objectives for the detector is contained in the DØ Silicon Tracker Design Report, DØ note 2169.

Components

Major Components of the silicon tracker are:

- Six barrel/disk detector assemblies;
- Two central end disk assemblies;
- Four outer H-disk assemblies;
- Carbon fiber support assembly.

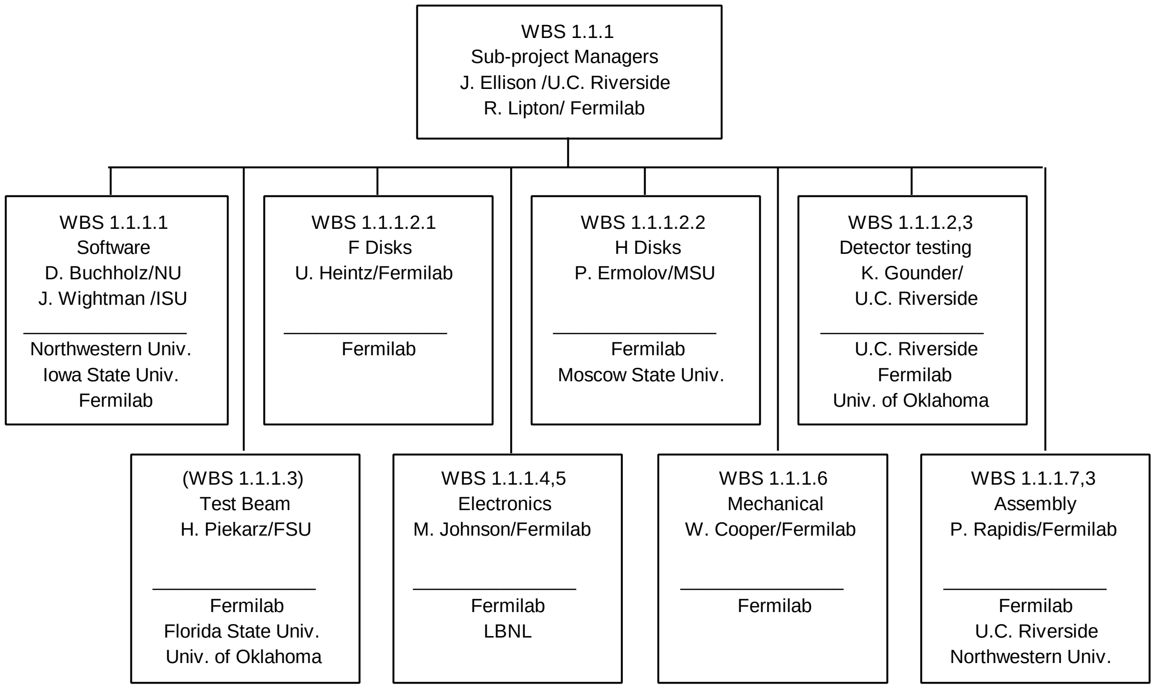
The detector consists of ~800,000 channels of readout and ~1500 individual detectors.

Management, Organization, and Responsibilities

The institutions currently participating in the Silicon Tracker sub-project are Fermilab, LBNL, U. C. Riverside, U. C. Irvine, Florida State University, Northwestern University, University of Oklahoma, Moscow State University, and Iowa State University. Sub-system managers are Ronald Lipton (Fermilab) and John Ellison (U. C. Riverside). There are a number of subgroups charged with development, construction, and testing various elements of the tracker. The subgroup organization and leadership is shown on the accompanying chart.

Engineering and equipment intensive work such as mechanical design and detector construction is centered at Fermilab. Work on detector design, acceptance testing, and software is centered at universities. Work is coordinated through weekly Fermilab group meetings, monthly full group meetings, and extensive electronic communication. Weekly meetings are often transmitted over the Internet as a videoconference, and meeting minutes and announcements are distributed on the "DØ News" network. The group also maintains a World Wide Web page which contains current system drawings, detector inventory lists, and testing results.

Silicon Tracker Sub-project Organization



<u>Work Plan</u>

Engineering/Design

Most engineering is provided by Fermilab and managed in the mechanical or readout subgroups. Most mechanical engineering is provided by the Fermilab Mechanical Support and DØ Upgrade technical teams of the Particle Physics Division. This engineering is shared with the CDF SVX II effort. Major areas of mechanical engineering effort are: 1) detector module design and thermal modeling 2) barrel module design 3) installation fixturing 4) overall support structure. Design and prototype work proceeds from the simpler, single-sided barrel ladders, to the more complex double-sided barrel and disk modules.

Electrical engineering for the SVX II chip is provided by the Fermilab Electrical Support technical team and LBNL. Engineering for the readout is provided by Fermilab and LBNL. Collaboration physicists provide silicon detector design simulations. Major areas of electrical engineering include: 1) SVX II chip 2) readout support multichip module 3) cabling 4) readout electronics. The SVX II chip is designed at FNAL/LBNL and is fabricated by industry. A fixed-target test beam run provides full system tests of detectors and readout electronics.

Procurement

Major procurement items are 1) silicon detectors, 2) electronics, 3) support structures. Vendors are selected through competitive bids. Prototype tests are required for all major items. Silicon detectors are custom devices that require close collaboration with the manufacturer. DØ engineers and physicists provide specifications to vendors for delivery schedules and performance characteristics of the detectors. Mask patterns are specified by sub-project personnel. Performance specifications are included in the vendor selection process. Final design decisions involve interaction between engineers and physicists and the vendor. DØ personnel work with the vendors to ensure that detectors have adequate radiation damage characteristics. SVX II chips are produced by a rad-hard silicon foundry. Layouts are submitted and prototypes produced before final production. The size of the final order is determined by the yields measured in the prototype lot. Orders for the bulkheads include full design drawings, with the very tight tolerances for detector alignment provided by Fermilab engineers and physicists.

Inspection

All components are inspected on arrival to ensure that specifications are met. Each detector module has a traveler which includes information on each stage of inspection and testing. Laboratories for detector inspection are equipped at U. C. Riverside, the University of Oklahoma, and Fermilab. Inspections include alpha source determination of depletion voltage, current-voltage characteristic determination, capacitor tests and visual inspection. Results are stored in a central database at Fermilab. A fraction of detectors is tested at each location to ensure consistency. Inspection of SVX II chips is performed using an automatic probe station at LBNL. All bulkheads and ladder pieces are inspected upon arrival at Fermilab using coordinate measuring machines located in the silicon detector facility (SciDet) at Lab D. Go/No Go fixtures and testing gauges will be used for critical features.

Construction/Fabrication

Both DØ and CDF silicon trackers are constructed in the Fermilab silicon detector facility (SciDet). The facility provides infrastructure, including wirebonding, test equipment, and coordinate measuring machines. The facility also provides technician support. Construction operations are supervised by a DØ lead technician and DØ physicists. Construction stages include: 1) readout module fabrication 2) ladder/wedge module fabrication 3) assembly of ladder/wedge modules into barrels/disks 4) installation of the barrel/disk modules into the support structure 5) installation of the tracker into the DØ experiment.

Testing/Commissioning

Each module is tested extensively. The most important performance test uses an infrared laser system to scan through the detectors, inducing a particle-like pulse on each channel. This test gives us information on gain, pedestal, crosstalk, and noise. It locates, and permits repair of, bad channels. Results of all tests are recorded on the module travelers. There is a 1-2 week burn-in for each ladder/disk module. Detector modules are tested for functionality at each stage of construction. Barrel modules are operated and burned in as they are installed in the support half-cylinder.

The commissioning effort also includes precise measurements of all detector components. Ladder fiducials are measured as they are fabricated. As modules are installed in the barrel, locations are measured with respect to barrel fiducials. Barrel locations are measured and adjusted with respect to the support cylinder. The final alignment uses tracks from interactions and cosmic rays after installation into the fiber tracker and solenoid magnet.

Schedule Milestones

The milestones for the Silicon Tracker sub-project are given in the table below. M1, M2, and M3 identify milestones held by the DoE, the Fermilab Directorate, and the Upgrade Project managers, respectively.

ID	Sub-Project Milestones-Silicon Tracker	Date
125	M3-Silicon Tracker Ladder Production Begun	13-Aug-97
161	Start Production Of H Wedges	8-Sep-97
105	F Disk Test Assembly	18-Sep-97
131	Complete First Barrel	5-Dec-97
145	M3-Silicon Tracker F Wedge Production Begun	2-Jan-98
165	M3-First Silicon Tracker H Disk Assembled	1-Apr-98
133	M2-First Silicon Tracker Barrel/Disk Module Complete	28-Jul-98
134	Complete 4 Barrels	2-Sep-98
167	Finish H Wedges	4-Sep-98
150	Finish F Wedges	29-Sep-98
168	M3-Silicon Tracker H Disks Complete	2-Nov-98
152	M3-Silicon Tracker F Disks Complete	7-Jan-99
135	M3-All Silicon Tracker Barrels Complete	11-Feb-99
206	Install Barrels/F Disks In Support And Test	26-Mar-99
48	M1-Central Silicon Complete	26-Mar-99
208	H-Disks Ready	21-Jun-99

Manpower Plan

The manpower plan for the Silicon Tracker sub-project is given in the table below. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	Silicon Tracker					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Designer (F)		1.3	1.1			2.4
Electrical Engineer (F)	0.9	1.1	0.2			2.1
Electrical Technician (F)	0.3	0.8	1.5			2.6
Mechanical Engineer (F)	0.2	1.1	2.2	0.4		3.9
Mechanical Technician (F)	0.8	3.1	12.7	2.7	0.1	19.5
Sub-Total (F)	2.2	7.4	17.8	3.1	0.1	30.6
Electrical Engineer (U)	0.1					0.1
Electrical Technician (U)	0.0	0.1				0.1
Mechanical Engineer (U)	0.2					0.2
Mechanical Technician (U)	1.2	3.2	4.7			9.0
Sub-Total (U)	1.5	3.3	4.7			9.5
Total	3.7	10.6	22.5	3.1	0.1	40.1

Cost Estimate

The cost estimate for the silicon tracker is shown in the accompanying table. In most cases 20% spares are included. Contingency is based on the status of the purchase according to the criteria described in section 7.1.2.

WBS	**1.1.1**	**SILICON TRACKER**						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.1.1	**SILICON TRACKER**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.1.1.1	***Engineering & Design***				277,000	9	25,950	302,950
1.1.1.1.1	SVX II engineering	m. yr	1.00	105,000	105,000	15	15,750	120,750
1.1.1.1.2	MOSIS submission	Subm	0.50	24,000	12,000	5	600	12,600
1.1.1.1.3	UTMC submission	Subm	1.00	128,000	128,000	5	6,400	134,400
1.1.1.1.4	HDI engineering	m. yr	1	0	0	15	0	0
1.1.1.1.5	Test readout system	syst	4	8,000	32,000	10	3,200	35,200
1.1.1.2	***Disks***				1,118,420	15	167,405	1,285,825
1.1.1.2.1	F disk				632,700	9	57,975	690,675
1.1.1.2.1.1	F wedge detectors	ea	144	2,220	319,680	5	15,984	335,664
1.1.1.2.1.2	F wedge berylium	ea	144	300	43,200	25	10,800	54,000
1.1.1.2.1.3	Probe testing	ea	144	100	14,400	25	3,600	18,000
1.1.1.2.1.4	F disk fixtures	lot	1	15,000	15,000	25	3,750	18,750
1.1.1.2.1.5	F wedge fabrication	ea	144	150	21,600	25	5,400	27,000
1.1.1.2.1.6	F Disk Support	disk	12	12,500	150,000	10	15,000	165,000
1.1.1.2.1.7	F wedge det. spares	ea	31	2,220	68,820	5	3,441	72,261
1.1.1.2.2	H disk				378,800	23	87,200	466,000
1.1.1.2.2.1	H wedge detectors	ea	384	600	230,400	25	57,600	288,000
1.1.1.2.2.2	Probe testing	ea	384	25	9,600	25	2,400	12,000
1.1.1.2.2.3	H wedge substrate	ea	192	200	38,400	25	9,600	48,000
1.1.1.2.2.4	H disk fixtures	lot	1	12,000	12,000	25	3,000	15,000
1.1.1.2.2.5	H wedge fabrication	ea	384	100	38,400	25	9,600	48,000
1.1.1.2.2.6	H Disk Support	disk	4	12,500	50,000	10	5,000	55,000
1.1.1.2.3	Spares	0.20			106,920	21	22,230	129,150
1.1.1.3	***Barrels***				2,111,300	11	240,045	2,351,345
1.1.1.3.1	Layer 1 (innermost)				169,428	17	28,631	198,059
1.1.1.3.1.1	Double sided	ea	84	1,200	100,800	25	25,200	126,000
1.1.1.3.1.2	Single sided	ea	84	817	68,628	5	3,431	72,059
1.1.1.3.2	Layer 2 (double sided)	ea	168	1,567	263,256	5	13,163	276,419
1.1.1.3.3	Layer 3				338,856	17	57,263	396,119
1.1.1.3.3.1	Double sided	ea	168	1,200	201,600	25	50,400	252,000
1.1.1.3.3.2	Single sided	ea	168	817	137,256	5	6,863	144,119
1.1.1.3.4	Layer 4 (double sided)	ea	336	1,567	526,512	5	26,326	552,838
1.1.1.3.5	Spares Layer 1,3	ea	96	1,009	96,816	5	4,841	101,657
1.1.1.3.6	Spares Layer 2,4	ea	96	1,567	150,432	5	7,522	157,954
1.1.1.3.7	Probe testing	ea	1200	50	60,000	25	15,000	75,000

WBS	**1.1.1**	**SILICON TRACKER**						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.1.1	**SILICON TRACKER**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.1.1.3.8	Berylium substrates	ladder	600	300	180,000	25	45,000	225,000
1.1.1.3.9	Fixtures	lot	1	25,000	25,000	25	6,250	31,250
1.1.1.3.10	Barrel assembly fixtures	lot	2	7,500	15,000	25	3,750	18,750
1.1.1.3.11	Ladder fabrication	ladder	600	150	90,000	25	22,500	112,500
1.1.1.3.12	Bulkheads	brl	7	28,000	196,000	5	9,800	205,800
1.1.1.4	***Readout IC's***		7164		537,569	25	134,392	671,961
1.1.1.4.1	F disk	IC	2304	59	136,224	25	34,056	170,280
1.1.1.4.2	H disk	IC	1152	59	68,112	25	17,028	85,140
1.1.1.4.3	Layer 1	IC	396	59	23,414	25	5,853	29,267
1.1.1.4.4	Layer 2	IC	840	59	49,665	25	12,416	62,081
1.1.1.4.5	Layer 3	IC	792	59	46,827	25	11,707	58,534
1.1.1.4.6	Layer 4	IC	1680	59	99,330	25	24,833	124,163
1.1.1.4.7	Chip testing	IC	7164	10	71,640	25	17,910	89,550
1.1.1.4.8	Spares	0.10			42,357	25	10,589	52,946
1.1.1.5	***Readout System (Detector to Port Card)***				798,160	24	193,528	991,688
1.1.1.5.1	Disk HDI	pc	480	350	168,000	25	42,000	210,000
1.1.1.5.2	Barrel HDI	pc	504	350	176,400	25	44,100	220,500
1.1.1.5.3	HDI assembly and test	pc	984	75	73,800	25	18,450	92,250
1.1.1.5.4	IBM cables	pc	984	125	123,000	25	30,750	153,750
1.1.1.5.5	Port Card Cables	pc	246	200	49,200	25	12,300	61,500
1.1.1.5.6	Transition Card	pc	36	800	28,800	25	7,200	36,000
1.1.1.5.7	Bias Voltage System	pc	984	100	98,400	20	19,680	118,080
1.1.1.5.8	Interface board	pc	10	800	8,000	20	1,600	9,600
1.1.1.5.9	Spares	0.10			72,560	25	17,448	90,008
1.1.1.6	***Mechanical Support, Services***				85,000	25	21,250	106,250
1.1.1.6.1	Half-cylinder	ea	1	15,000	15,000	25	3,750	18,750
1.1.1.6.2	Installation fixtures	lot	1	10,000	10,000	25	2,500	12,500
1.1.1.6.3	Cooling system	lot	1	20,000	20,000	25	5,000	25,000
1.1.1.6.4	Air system	lot	1	15,000	15,000	25	3,750	18,750
1.1.1.6.5	Monitoring system	lot	1	25,000	25,000	25	6,250	31,250
1.1.1.7	***Detector Assembly, Installation***				25,000	14	3,500	28,500
1.1.1.7.1	Silicon install fixturing	pc	1	10,000	10,000	20	2,000	12,000
1.1.1.7.2	Silicon Supports	pc	4	2,500	10,000	10	1,000	11,000
1.1.1.7.3	Installation services	pc	1	5,000	5,000	10	500	5,500
1.1.1	TOTAL SILICON TRACKER				4,952,449	16	786,070	5,738,519

10.3 Central Fiber Tracker

Objectives and Performance Criteria

Objectives of the central fiber tracker include:

- Serve as the outer tracking system for the DØ upgrade;
- Provide complete tracking coverage up to $\eta = \pm 1.7$;
- Provide Level 1 track triggering for electrons and muons;
- Locate individual fibers to an accuracy of 25 μm in the r-ϕ direction;
- Mean number of detected photoelectrons per fiber must exceed 2.5 for a minimum ionizing particle;
- Doublet layer efficiencies of better than 99%;
- VLPCs delivered from the manufacturer must have no dead channels.

Components

Major Components of the fiber tracker are:

- Eight concentric support cylinders occupying the radial space from 20 to 50 cm;
- Eight cylinders of axial fiber doublet layers and either u or v stereo angle doublet layers;
- Clear fiber waveguides of about 8 to 11meters length;
- Visible Light Photon Counter (VLPC) readout system.

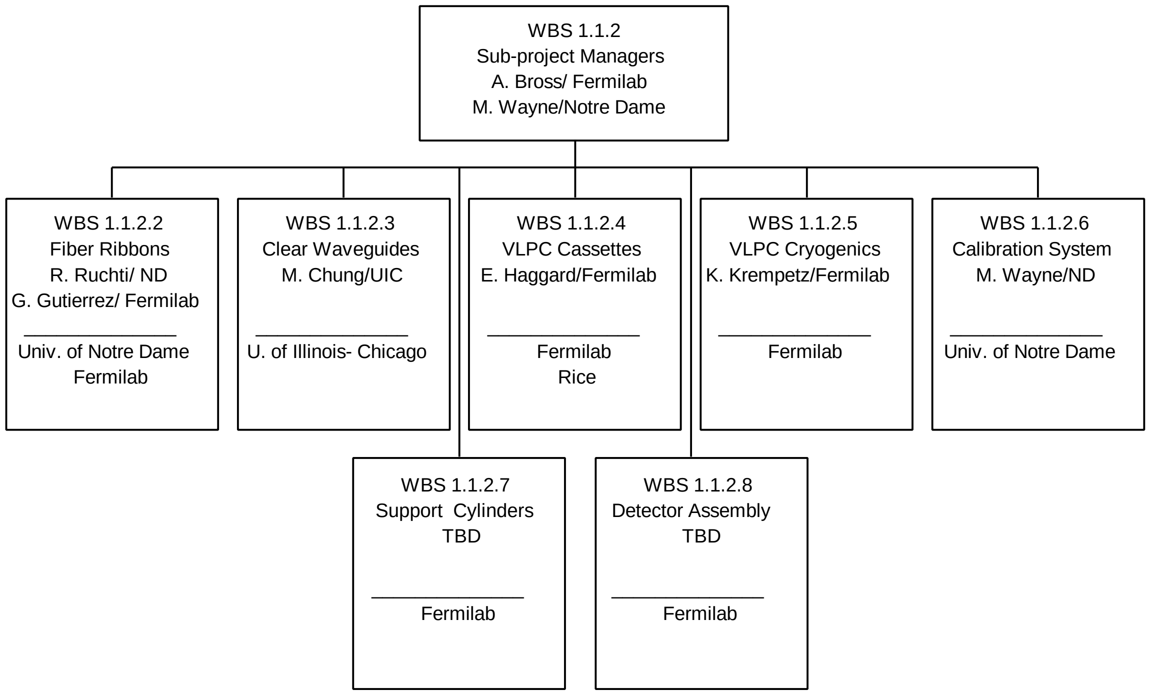
The detector contains approximately 77,000 fibers and associated readout.

Management, Organization and Responsibilities

Institutions participating in the Central Fiber Tracker project are Fermilab, Korea University, Kyungsung University, University of Illinois at Chicago, University of Notre Dame, Purdue University, Rice University, University of Rochester and Seoul National University. Sub-project managers are Alan Bross (Fermilab) and Mitchell Wayne (Notre Dame). Engineering and the mechanical design of the detector is based at Fermilab. The bulk of the detector construction takes place at Fermilab, but some detector components such as the clear waveguide fiber bundles and calibration system are fabricated at universities. Quality control, testing and software development are shared between the universities and Fermilab. The organization of the subgroups in charge of the key elements of the fiber tracker effort is shown in the accompanying chart.

The fiber tracker group meets bi-weekly at Fermilab to discuss and coordinate the work effort on the project. Minutes of the meetings are posted on the “DØ News” network. Meetings concentrating on mechanical design and engineering are held on a weekly basis. The fiber tracking group maintains a World Wide Web page.

Central Fiber Tracker Subproject Organization



Work Plan

Engineering/Design

A major part of the engineering effort is provided by Fermilab, with some engineering design work coming from the university groups. Mechanical engineering support for the actual detector is provided by the Particle Physics Division at Fermilab.

Major areas of the mechanical engineering include: 1) Cylinders and support structures, with engineering provided by Fermilab; 2) Scintillating fiber ribbon fabrication, with engineering provided by Fermilab; 3) Clear waveguide bundle fabrication, with engineering provided by UIC; 4) Optical connector fabrication, with engineering provided by Fermilab; 5) VLPC cassette design and fabrication, with engineering provided by Fermilab and Boeing North American (BNA); 6) VLPC cryostat design and fabrication, with engineering provided by Fermilab; Prototypes of fiber ribbons, waveguide bundles and optical connectors are built and tested. A prototype VLPC cassette, containing 1,024 channels, enables testing of the cassette at operational temperature.

Major areas of the electrical engineering include: 1) VLPC cassette design, with engineering provided by Fermilab and BNA; 2) Readout and trigger electronics, with engineering provided by Fermilab and U. C. Davis; 3) Temperature control electronics, with engineering provided by Rochester; 4) Calibration system electronics, with engineering provided by Notre Dame.

Procurement

Major procurement items for the fiber tracker are: 1) Scintillating and clear waveguide fiber; 2) VLPCs; 3) Parts (mandrels, support pieces, etc.) for cylinder fabrication; 4) Flex circuits and assorted component parts for the VLPC cassettes. The fiber has been purchased from Kuraray Corporation of Japan. The VLPCs are purchased from BNA. The fiber tracking group provides specifications for delivery schedules and performance characteristics of the VLPC, and the group works closely with BNA to guarantee that these specifications are met.

Inspection

Careful inspection of both procured and fabricated detector components is an important task for the fiber tracking group. All procured components are inspected upon arrival to ensure that specifications have been met. Inspection and quality control of the scintillating fiber are performed at Notre Dame before the fiber is fabricated into ribbons. Inspection and quality control of the clear waveguide fiber are performed at UIC before the fiber is fabricated into waveguide bundles. Each support cylinder is measured carefully to ensure that all dimensions are within tolerance. Each wafer of VLPC die undergoes visual inspection at BNA before individual arrays are diced. VLPC die with identified stacking faults and/or metallization problems are removed from the sample. The remaining die undergo operation screening at liquid helium temperature (7 ^{o}K). Each optical connector is inspected for fabrication errors. This includes the connectors which mate the scintillating to clear fibers at the detector and the two types of optical connector utilized in the VLPC cassette. The flex circuits utilized in the VLPC cassettes are tested for continuity and shorts.

Construction/Fabrication

The fabrication of most major components of the fiber tracker is shared between Fermilab, BNA and the university groups. The construction of the actual detector is based at Fermilab. The major areas of construction are: 1) Fabrication of scintillating fiber ribbons, carried out at Fermilab; 2) Fabrication of clear waveguide bundles, carried out at UI Chicago; 3) Connector fabrication, carried out at Fermilab; 4) Construction of support cylinders, carried out at Fermilab; 5) Ribbon mounting on the support cylinders, carried out at Fermilab; 6) Installation of the completed tracker in DØ; 7) Fabrication of the VLPC cassettes, carried out at Fermilab or BNA; 8) Construction of the VLPC cryostat, carried out at Fermilab.

A facility for fiber ribbon fabrication is located in the DØ assembly building. A facility for waveguide bundle construction is located at UI Chicago. A facility in Lab 3 at Femilab is being prepared for ribbon mounting and full detector construction.

Testing/Commissioning

Every fiber of each scintillating fiber ribbon is tested for light output, and the fiber-to-fiber registration of each ribbon is measured carefully. All of the clear waveguide bundles, plus connectors, are tested for uniformity of light transmission, fiber-by-fiber. The testing of the VLPC readout is particularly comprehensive. Every 8-channel VLPC array is tested to remove any with channels out of specification. If necessary, cassettes are built up with VLPC arrays showing similar performance characteristics. After fabrication, the VLPC cassettes are tested and any cassette with non-functioning channels is reworked. The calibration system is inaccessible during the run, so it is critical that the system be thoroughly tested and built with as much redundancy as possible.

The completed detector is commissioned at DØ. The calibration system enables some system-level debugging, and cosmic rays provide measurements of light yields, efficiencies and alignment.

<u>Schedule Milestones</u>

The milestones for the Central Fiber Tracker sub-project are given in the tables below. M1, M2, and M3 identify milestones held by the DoE, the Fermilab Directorate, and the Upgrade Project managers, respectively.

ID	**Sub-Project Milestones-Central Fiber Tracker**	**Date**
7	M3-Fiber Tracker TDR Submitted	15-Apr-97
6	Engineering Design Complete	6-Jun-97
13	Connector Designed	26-Jun-97
39	Final Ribbon Design	23-Jul-97
27	Final Cylinder Engineering Design	25-Jul-97
48	Finalize Mounting Procedures	2-Sep-97

ID	Sub-Project Milestones-Central Fiber Tracker	Date
33	Tracker Supports Design Complete	22-Sep-97
59	Waveguide Facility Ready	6-Oct-97
42	M3-Fiber Tracker Ribbon Fabrication Begun	18-Dec-97
67	Final System Designed	23-Jan-98
61	M3-Fiber Tracker Waveguide Production Begun	28-Jan-98
52	M3-Fiber Tracker Ribbon Mounting Begun	11-Mar-98
43	M3-Fiber Tracker Ribbon Fabrication 50% Complete	24-Jun-98
72	M2-Fiber Tracker Assembly Begun	31-Jul-98
62	Waveguide Production 50% Complete	2-Oct-98
53	M3-Fiber Tracker Ribbon Mounting 50% Complete	9-Oct-98
73	M2-Fiber Tracker Assembly Complete	23-Jun-99

ID	Milestones- VLPC Cassettes	Date
6	HISTE V Characterization Complete	24-Oct-96
10	Notice To Proceed For Full HISTE VI Production	7-Mar-97
25	Procedures Finalized	15-Mar-97
21	Ready For 1st Article Assembly	20-Mar-97
82	M3-Test VLPC Cryostat Ready	9-Apr-97
30	M3-Ready For 1st VLPC Cassette Test	2-May-97
88	Begin 1st Cyrostat Fabrication	7-Jul-97
55	M2-VLPC Production 50% Complete	5-Aug-97
51	Cassette Production Readiness Review	24-Sep-97
63	Factory Ready	26-Nov-97
67	Module Production Begun	15-Dec-97
93	M3-1st VLPC Cryostat Installed	20-Jan-98
71	M3-VLPC Cassette Assembly Begun	17-Apr-98
75	Ready For Production Cassette Testing	12-Jun-98
56	M3-VLPC Production Complete	26-Jun-98
97	M3-VLPC Cryo System Operational	16-Jul-98
72	M3-VLPC Cassette Assembly 50% Complete	13-Oct-98
73	M3-VLPC Cassette Assembly Complete	22-Apr-99

Manpower Plan

The manpower plan for the Central Fiber Tracker sub-project is given in the table below. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	Fiber Tracker					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Designer (F)	1.4	3.4	0.1			4.9
Electrical Technician (F)	0.2	0.2	0.9	1.1		2.5
Mechanical Engineer (F)	1.1	3.0	2.0	1.2		7.4
Mechanical Technician (F)	0.7	6.9	12.4	8.3		28.4
Sub-Total (F)	3.5	13.5	15.5	10.6		43.1
Electrical Technician (U)	0.6					0.6
Mechanical Engineer (U)	0.3	0.1	0.7	0.8		1.9
Mechanical Technician (U)		0.7	2.8	2.3		5.8

Sub-Total (U)	0.9	0.8	3.6	3.0	8.3
Total	4.4	14.3	19.1	13.6	51.4

Cost Estimate

The cost estimate for the Central Fiber Tracker is shown in the accompanying table. Spares and contingency costs have been determined on a per-item basis. The average contingency for the entire project is 22%, and is dominated by the contingency on the VLPC cassette production.

WBS	1.1.2	FIBER TRACKER						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.1.2	**FIBER TRACKER**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.1.2.1	***Engineering & Design***				0	0	0	0
1.1.2.2	***Scintillating Fiber Ribbons***				585,000	17	102,000	687,000
1.1.2.2.1	Scintillating fibers	K ea	95	2,100	199,500	10	19,950	219,450
1.1.2.2.2	Ribbons	ea	360	50	18,000	10	1,800	19,800
1.1.2.2.3	Connectors	ea	360	50	18,000	10	1,800	19,800
1.1.2.2.4	Aluminization	K ea	95	100	9,500	10	950	10,450
1.1.2.2.5	Ribbon Machine/molds	ea	4	10,000	40,000	25	10,000	50,000
1.1.2.2.6	Ribbon QC test box	ea	1	50,000	50,000	10	5,000	55,000
1.1.2.2.7	Ribbon laying & fixturing				250,000	25	62,500	312,500
1.1.2.2.7.1	Ribbon laying fixturing	lot	1	50,000	50,000	25	12,500	62,500
1.1.2.2.7.2	Ribbon Mounting Facility	lot	1	200,000	200,000	25	50,000	250,000
1.1.2.3	***Clear Waveguides***				812,800	10	81,280	894,080
1.1.2.3.1	Clear fiber	K ea	90	5,700	513,000	10	51,300	564,300
1.1.2.3.2	Connectors A	ea	360	50	18,000	10	1,800	19,800
1.1.2.3.3	Connectors B	ea	2880	10	28,800	10	2,880	31,680
1.1.2.3.4	Sheathing	ea	360	50	18,000	10	1,800	19,800
1.1.2.3.5	Factory setup	lot	1	30,000	30,000	10	3,000	33,000
1.1.2.3.6	Test/QC system	lot	1	25,000	25,000	10	2,500	27,500
1.1.2.3.7	Fabrication/testing	lot	1	180,000	180,000	10	18,000	198,000
1.1.2.4	***Visible Light Photon Counter (VLPC) Cassette***				5,040,000	24	1,210,000	6,250,000
1.1.2.4.1	Production cassettes	K ea	100	50,000	5,000,000	24	1,200,000	6,200,000
1.1.2.4.2	Auxillary Test stand	ea	1	40,000	40,000	25	10,000	50,000
1.1.2.5	***Visible Light Photon Counter (VLPC) Cryogenics***				342,000	21	70,200	412,200
1.1.2.5.1	Test Cryostat	ea	1	50,000	50,000	25	12,500	62,500
1.1.2.5.2	Final cryo system	ea	2	100,000	200,000	20	40,000	240,000
1.1.2.5.3	Helium distribution system	lot	1	50,000	50,000	15	7,500	57,500
1.1.2.5.4	Cryostat installation	lot	1	2,000	2,000	10	200	2,200
1.1.2.5.5	Temperature Controller	lot	1	40,000	40,000	25	10,000	50,000
1.1.2.6	***Calibration System***				207,000	20	41,400	248,400
1.1.2.6.1	LED bar for fiber illumination	ea	1	25,000	25,000	20	5,000	30,000
1.1.2.6.2	Connectors	lot	1	30,000	30,000	20	6,000	36,000
1.1.2.6.3	Drive Electronics				50,000	20	10,000	60,000
1.1.2.6.3.1	Driver chips	lot	1	4,000	4,000	20	800	4,800

WBS	**1.1.2**	**FIBER TRACKER**						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.1.2	**FIBER TRACKER**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.1.2.6.3.2	Receiver chips	lot	1	4,000	4,000	20	800	4,800
1.1.2.6.3.3	DACs	lot	1	4,000	4,000	20	800	4,800
1.1.2.6.3.4	Passive components	lot	1	8,000	8,000	20	1,600	9,600
1.1.2.6.3.5	Circuit boards	lot	1	20,000	20,000	20	4,000	24,000
1.1.2.6.3.6	Board assembly	lot	1	10,000	10,000	20	2,000	12,000
1.1.2.6.4	Pulsing Electronics	lot	1	5,000	5,000	20	1,000	6,000
1.1.2.6.5	Cabling, connectors	lot	1	5,000	5,000	20	1,000	6,000
1.1.2.6.6	Power supplies	lot	1	2,000	2,000	20	400	2,400
1.1.2.6.7	Computer control (VME interface)	lot	1	10,000	10,000	20	2,000	12,000
1.1.2.6.8	Data storage (disks)	lot	1	10,000	10,000	20	2,000	12,000
1.1.2.6.9	Design/fabrication/testing	lot	1	70,000	70,000	20	14,000	84,000
1.1.2.7	***Mechanical Support, Services***				365,000	25	91,250	456,250
1.1.2.7.1	Support cylinders	ea	8	40,000	320,000	25	80,000	400,000
1.1.2.7.2	Cylinder Supports	ea	4	7,500	30,000	25	7,500	37,500
1.1.2.7.3	External Supports	ea	1	5,000	5,000	25	1,250	6,250
1.1.2.7.4	Purge gas system	ea	1	10,000	10,000	25	2,500	12,500
1.1.2.8	***Detector Assembly***				25,000	20	5,000	30,000
1.1.2.8.1	Waveguide install fixturing	lot	1	10,000	10,000	20	2,000	12,000
1.1.2.8.2	Survey fixturing	ea	4	2,500	10,000	20	2,000	12,000
1.1.2.8.3	Tracker installation fixtures	lot	1	5,000	5,000	20	1,000	6,000
1.1.2	TOTAL FIBER TRACKER				7,376,800	22	1,601,130	8,977,930

10.4 Central Preshower Detector

Objectives and Performance Criteria

Objectives of the central preshower system include:

- Provide discrimination between hadrons and electrons in the central rapidity region;
- Reduce the Level 1 electron trigger rate by a factor 3 to 5;
- Aid off-line electron identification;
- Cover a pseudorapidity range of -1.2 to 1.2;
- Strip-to-strip alignment better than 50 µm.

A detailed description of the design and expected performance can be found in the design report of the central preshower detector.

Components

The preshower is a scintillator/fiber based detector directly outside the solenoid and inside the central calorimeter. Major components of the central preshower are:

- A lead radiator;
- Three layers (axial, u and v) of finely segmented triangular scintillating strips with wavelength-shifting fiber readout;
- Clear fiber waveguides;
- Visible light photon detectors and SVX II readout.

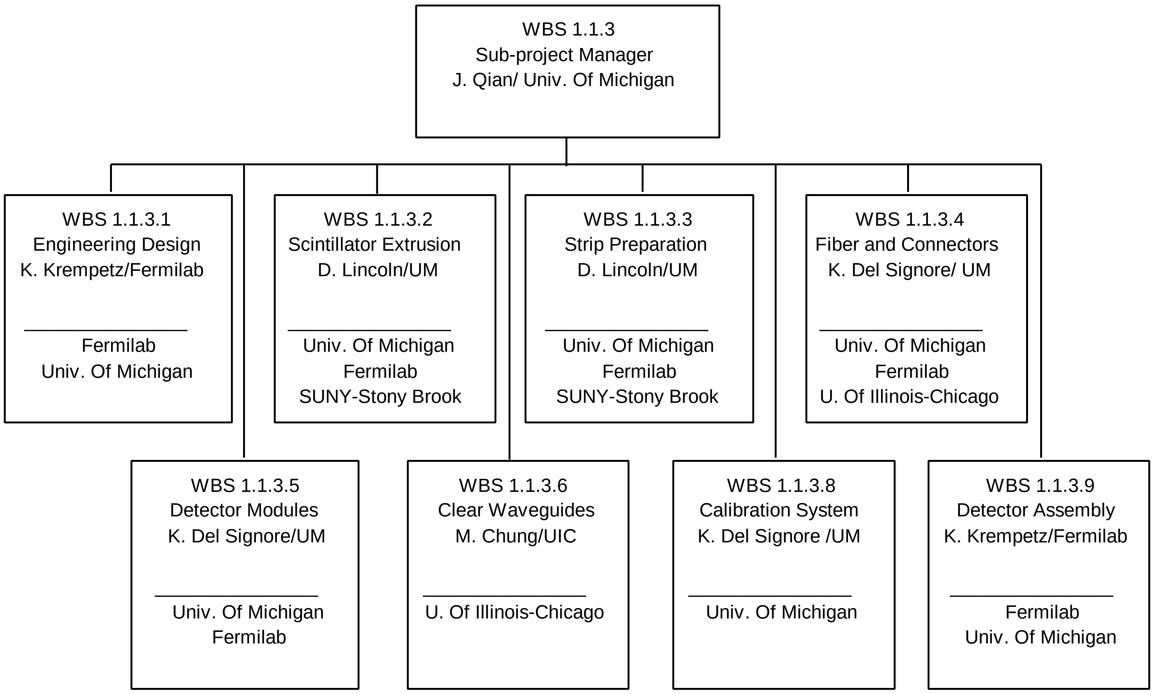
The total channel count is 7,680 for VLPC and 15,360 for electronics.

Management, Organization, and Responsibilities

The institutions working on the central preshower project are Fermilab, University of Illinois at Chicago, University of Michigan, and SUNY at Stony Brook. Jianming Qian of the University of Michigan serves as the sub-project manager. The organization of the central pre-shower sub-project is shown in the accompanying chart.

Engineering design and equipment-intensive work such as strip wrapping and fiber polishing are centered at Fermilab. The detector construction, connector development, on-line and off-line software are done at the universities. The University of Michigan assumes the overall responsibility for the detector which includes the project management, prototype work, procurements, construction and testing, installation, commissioning, maintenance and software development. The UIC group is responsible for the development of preshower connectors and the construction of clear fiber bundles. Development of the specific preshower chip is done at Fermilab in conjunction with the development of the fiber electronics. Stony Brook assists in detector assembly, testing and operation of the detector. Within the central preshower group, the work is coordinated through extensive electronic communications and monthly group meetings.

Central Preshower Sub-project Organization



Work Plan

Engineering Design

The mechanical design of the detector is done at Fermilab by mechanical engineers. The major issues are modularity, strongback material, lead installation, supporting and mounting fixtures. The design benefits greatly from the experience gained through the construction of a small-scale prototype module.

The design of the preshower-specific readout chip is done by the physicists and electrical engineers at Fermilab. The design calls for a bilinear readout to expand the dynamic range of the SVX II chip. It is realized by a precursor chip sandwiched between VLPC and SVX II chip. The chip consists of a fast trigger pickoff and a one-to-two signal splitter.

Procurement

The major items are: 1) scintillating strips, 2) wavelength-shifting fibers and 3) strongback materials. Scintillating strips are made through extrusion. Production strip extrusions are based on the results of the extrusion prototype run. Double-clad wavelength-shifting fibers are ordered from industry (Kuraray). Orders for the strongback materials are based on the final detector design and the prototyping of a full-scale module.

Detector Construction

The scintillating strips are wrapped with aluminized mylar using the wrapping machine in IB3 at Fermilab. These techniques are based on a small prototype module produced with this system. The wrapped strips are formed into helical shapes for the stereo layers using an oven at Fermilab. The fibers are inspected and polished at Fermilab.

The module assembly is done at the University of Michigan on special assembly tables. Every channel of the assembled module is tested using a radioactive source and a multianode phototube readout.

Sixteen-channel fiber-to-fiber connectors are made by injection molding at UIC. Five hundred pairs of connector bodies are made from black ABS plastic. After a sample test, they are assembled in the module assemblies and in the clear fiber lightguide bundles.

Installation

The installation of the preshower detector is a two-step process. First, the detector is installed on the solenoid before the solenoid is moved into the bore of the central calorimeter in the summer of 1997. The installation is done module by module. Each module is supported at both ends. Once installed each channel is tested using the built-in LED system. The test is sufficient to detect any damage during the installation. In this case, the damaged module is replaced by a spare module. The second step involves connecting clear-fiber bundles to the detector and to the VLPC.

The commissioning of the preshower detector includes detailed characterizations of each channel with VLPC readout using LEDs and trigger integration with the fiber tracker. Relative positions of each module with respect to other subdetectors are determined.

Schedule Milestones

The schedule for the preshower detector is dictated by that of the solenoid. The limited space between the solenoid and the calorimeter implies that the preshower detector will have to be installed on the solenoid before it can be moved into the calorimeter bore. The milestones for the Central Pre-Shower Detector sub-project are given in the table below. M1, M2, and M3 identify milestones held by the DoE, the Fermilab Directorate, and the Upgrade Project managers, respectively.

ID	Milestones-Central Preshower Detector	Date
4	Design Report	15-Jan-96
5	TDR Review	6-Apr-96
14	Scintillating Strips Ready	3-Sep-96
19	Fibers Ready	1-Oct-96
37	M3-First Central Preshower Module Complete	7-May-97
24	Fiber/Connector Assembly Complete	5-Jun-97
39	M2-Central Preshower Module Fabrication Complete	29-Aug-97
45	Calibration System Ready	17-Dec-97

Manpower Plan

The manpower plan for the Central Preshower Detector sub-project is given in the table below. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	Central Preshower					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Designer (F)	0.5	0.6				1.1
Mechanical Engineer (F)	0.1	0.2	0.0			0.3
Mechanical Technician (F)	0.3	0.9	0.1			1.2
Sub-Total (F)	0.9	1.6	0.1			2.6
Mechanical Engineer (U)	0.1					0.1
Mechanical Technician (U)	0.1	1.0				1.2
Sub-Total (U)	0.3	1.0				1.3
Total	1.2	2.7	0.1			3.9

<u>Cost Estimate</u>

The cost estimate for the central preshower detector is shown in the accompanying table. Where appropriate (e.g. scintillators, fibers, connectors), we include 15-20% spares. Contingency is typically 10-20% and is assigned based on the criteria in section 7.1.2.

WBS	1.1.3	CENTRAL PRESHOWER DETECTOR						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.1.3	**CENTRAL PRESHOWER DETECTOR**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.1.3.1	***Engineering & Design***				0		0	0
1.1.3.1.1	Mechanical Support							0
1.1.3.1.2	Signal Electronics							0
1.1.3.2	***Scintillator Extrusion***				42,800	14	5,880	48,680
1.1.3.2.1	Polystyrene	lb	1000	10	10,000	20	2,000	12,000
1.1.3.2.2	Fluor	lot	1	3,000	3,000	20	600	3,600
1.1.3.2.3	Compounding	lot	1	3,000	3,000	20	600	3,600
1.1.3.2.4	Die	ea	2	5,600	11,200	10	1,120	12,320
1.1.3.2.5	Extrusion Service	lot	1	15,600	15,600	10	1,560	17,160
1.1.3.3	***Strip Preparation***				19,000	20	3,800	22,800
1.1.3.3.1	Wrapping	hr	500	30	15,000	20	3,000	18,000
1.1.3.3.2	Mylar	lot	1	2,000	2,000	20	400	2,400
1.1.3.3.3	Supplies	lot	1	2,000	2,000	20	400	2,400
1.1.3.4	***Fiber & Connectors***				53,200	14	7,474	60,674
1.1.3.4.1	WLS Fiber	km	18	1,370	24,660	10	2,466	27,126
1.1.3.4.2	Silvering	lot	1	5,000	5,000	10	500	5,500
1.1.3.4.3	Connectors (WLS fiber side)	ea	580	13	7,540	20	1,508	9,048
1.1.3.4.4	Fiber/connector assembly	lot	1	3,000	3,000	20	600	3,600
1.1.3.4.5	Fiber/connector polishing	lot	1	3,000	3,000	20	600	3,600
1.1.3.4.6	Fiberguide material	lot	1	1,000	1,000	20	200	1,200
1.1.3.4.7	Fiberguide machining	hr	200	30	6,000	20	1,200	7,200
1.1.3.4.8	Shipping & handling	lot	1	1,000	1,000	20	200	1,200
1.1.3.4.9	Supplies	lot	1	2,000	2,000	10	200	2,200
1.1.3.5	***Detector Modules***				107,280	18	19,728	127,008
1.1.3.5.1	Strongback material/skin	ea	60	500	30,000	20	6,000	36,000
1.1.3.5.2	Mounting fixtures	lot	1	5,000	5,000	20	1,000	6,000
1.1.3.5.3	Slumping press and shape formation	lot	1	8,000	8,000	20	1,600	9,600
1.1.3.5.4	Assembly tables and setups	lot	1	8,000	8,000	20	1,600	9,600
1.1.3.5.5	Alignment jigs and tools	lot	1	4,000	4,000	20	800	4,800
1.1.3.5.6	Vacuum bagging system	ea	1	4,000	4,000	20	800	4,800
1.1.3.5.7	Glue and syringes	lot	1	5,000	5,000	20	1,000	6,000
1.1.3.5.8	Detector assembly	hr	2160	8	17,280	10	1,728	19,008
1.1.3.5.9	Quality control/monitoring	lot	1	10,000	10,000	20	2,000	12,000
1.1.3.5.10	Storage & shipping fixture	lot	1	6,000	6,000	20	1,200	7,200
1.1.3.5.11	Assembly supplies	lot	1	5,000	5,000	20	1,000	6,000
1.1.3.5.12	Shipping & handling	lot	1	5,000	5,000	20	1,000	6,000

WBS	1.1.3	CENTRAL PRESHOWER DETECTOR						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.1.3	**CENTRAL PRESHOWER DETECTOR**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.1.3.6	***Clear Waveguides***				81,920	20	16,384	98,304
1.1.3.6.1	Clear Waveguide	km	85	800	68,000	20	13,600	81,600
1.1.3.6.2	Connectors (detector side)	ea	580	13	7,540	20	1,508	9,048
1.1.3.6.3	Connector Boots	ea	580	11	6,380	20	1,276	7,656
1.1.3.7	***VLPC Cassettes (in WBS1.1.2.4)***							
1.1.3.8	***Calibration System***				32,040	18	5,608	37,648
1.1.3.8.1	Blue LED System	ea	580	35	20,300	20	4,060	24,360
1.1.3.8.2	Light bar (material/machining)	ea	580	3	1,740	20	348	2,088
1.1.3.8.3	Temperature monitor system	ea	1	2,000	2,000	20	400	2,400
1.1.3.8.4	Mounting/tooling fixture	lot	1	3,000	3,000	10	300	3,300
1.1.3.8.5	Controller	lot	1	5,000	5,000	10	500	5,500
1.1.3.9	***Detector Assembly***				19,000		2,850	21,850
1.1.3.9.1	Mounting/alignment tooling	lot	1	6,000	6,000	15	900	6,900
1.1.3.9.2	Lead rework/install	lot	1	10,000	10,000	15	1,500	11,500
1.1.3.9.3	Air gap spacer	lot	1	3,000	3,000	15	450	3,450
1.1.3	TOTAL CENTRAL PRESHOWER DETECTOR				355,240	17	61,724	416,964

10.5 Forward Preshower Detector

Objectives and Performance Criteria

The Forward Preshower Detector (FPS) is designed to

- Enhance discrimination between hadrons and electrons in the forward rapidity region;
- Provide enhanced rejection to allow triggers on forward electrons ($1.4<|\eta|<2.5$);
- Provide a factor of ~ 2-4 in Level 1 rejection, and an additional factor of ~2-4 in Level 2 rejection;
- Detect minimum ionizing tracks in the layers closest to the interaction point;
- Detect particle showers in the layers downstream of the absorber.

Details of the physics motivation, triggering studies, and detector design can be found in the DØ Upgrade report, DØ Note 2894 (or FERMILAB-FN-641).

Components

Major components of the forward preshower are:

- Two active layers of scintillator (a u and a v layer);
- A lead absorber;
- Two active layers of scintillator (u,v) downstream of the lead;
- Clear fiber waveguides;
- Visible light photon counters and SVX II readout.

The scintillators are triangular extrusions with embedded wavelength shifting fibers. The detector will consist of a total of 16,000 channels of readout.

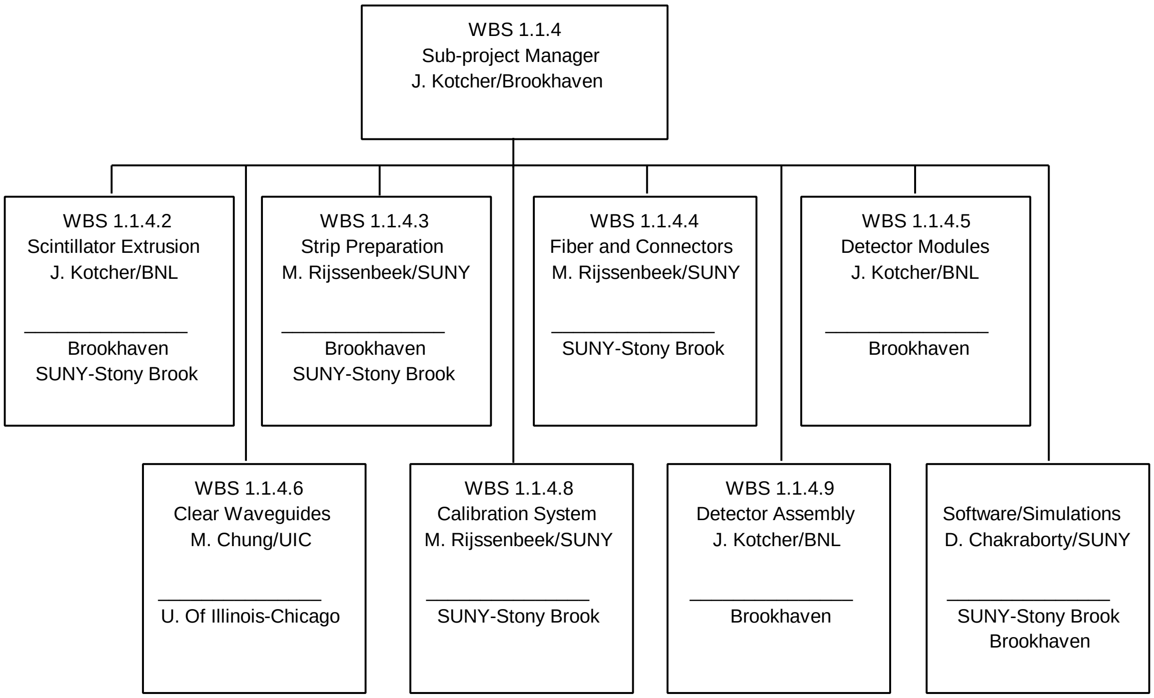
Management, Organization, and Responsibilities

The institutions involved with developing the initial engineering design of the FPS are Fermilab, Brookhaven National Laboratory, University of Texas at Arlington, State University of New York at Stony Brook, and Florida State University. The sub-project manager is J. Kotcher (BNL). The remaining engineering and design work and module/detector construction will take place at Brookhaven. The detector will be shipped to FNAL for installation in the final DØ detector upon completion.

Detector support issues, module construction and alignment, installation concerns, detector readout and commissioning, and overall project management will be centered at Brookhaven. SUNY Stony Brook is collaborating on various aspects of the detector, including wavelength-shifting and clear fiber preparation and routing, offline software, trigger algorithm development, and detector simulations. As in the case of the CPS, the University of Illinois at Chicago is developing and providing preshower WLS/clear fiber connectors and the clear fiber bundles. Brookhaven and Stony Brook will contribute to the connector design and testing.

A test of four prototype FPS modules will take place in Spring, 1997 in the Fermilab fixed-target beam line, with BNL and SUNY Stony Brook providing the manpower and expertise. Cryogenic, electronics, and beam line support for the test will be provided by Fermilab. Topics studied will include measurement of electron and pion response, shower cluster size, position accuracy, calibration needs, influence of upstream material on FPS performance, module boundary effects, magnetic field effects, and data-to-Monte Carlo comparisons.

Forward Preshower Sub-project Organization



Work Plan

Engineering and Design

The design and engineering work for the FPS is done at Brookhaven. The first design addresses many of the primary considerations relevant to detector construction and installation logistics, such as an overall construction scheme, a means of mounting the FPS to the end cryostats, fiber routing pathways, module and detector construction and materials, and module support structures and mounting brackets.

The choice of the same technology for the FPS as that used in the CPS greatly simplifies the FPS design and R&D. The scintillator extrusion technique, fiber bundling, connector design, scintillator wrapping, detector readout, and the calibration system are examples of detector techniques and subsystems that are based, at varying levels, on CPS research and development.

Procurement

The major items are: 1) scintillating strips; 2) wavelength-shifting fibers; and 3) heating/molding fixtures and other assembly hardware. Scintillating strips are made through extrusion. Production strip extrusions are based on the results of the extrusion prototype run. Double-clad wavelength-shifting fibers are ordered from industry (Kuraray). Orders for the assembly fixtures are based on the final detector design and full-scale module prototypes that are being constructed for a beam test at Fermilab in the spring of 1997.

Detector Construction

One FPS detector is mounted on the inner face of each of the end calorimeters. The shape of the detector conforms with the curvature of the EC cryostat heads. The detector support structures are molded to conform to the shape of the EC cryostat heads during construction. Eight aluminum ribs are mounted radially on the surface of the support layer. The ribs provide structural support for the detector, and hold the detector modules in place.

The modules are made of nested triangular scintillator strips that are held together with epoxy and supported with epoxied fiberglass skins for additional support. The scintillator triangles are each pre-wrapped with aluminized mylar for optical isolation. The modules are produced with excess scintillator around the module boundary, and cut to size after the fact using a water-jet cutting technique. The modules are constructed independently, and are sandwiched between layers of aluminum skins, which provide the mounting surface and structural support for the active volume of the detector. The scintillator strips are oriented perpendicular to the edge of each module. The shaping of the strips to accommodate the appropriate bending radius is facilitated by a heat-molding process. The inter-strip alignment is maintained by a precisely machined assembly jig. Heat molding of the scintillator and epoxy curing of the module heads are done on aluminum domes that have been machined to the radius of the EC cryostat heads. In order to facilitate the curing and molding processes, the entire assembly is vacuum bagged.

The amount of material upstream of the FPS in the region $1.4 < |\eta| < 1.65$ dictates that the (early) mip layer subtend the pseudorapidity range $1.65 < |\eta| < 2.5$. The outer, or showering, layers subtend the full range ($1.4 < |\eta| < 2.5$). The detector consists of a (smaller) inner layer, and a (larger) outer one directly bolted to the cryostat head via support brackets welded to the face of the end calorimeter cryostats. The larger (smaller) modules comprising each layer will each contain 300 (200) channels. There are a total of 16 modules of each type on each side, making a total of 64 modules.

After construction, the modules are electrically tested and inserted between the support ribs into the pre-assembled detector support layer. The modules are re-tested after insertion, to ensure no damage was suffered during the process. Each successive module is inserted and tested, until the entire layer is assembled. There are four such layers in each final FPS.

The development of prototypes for the beam test has given us the opportunity to develop a detailed module construction scheme. We have developed precision jigs for maintaining scintillator spacing during assembly, settled on an appropriate module cutting technique, and determined the materials and methods by which the scintillator will be heat-molded to the desired radius (i.e., that of the end calorimeter cryostat). Two of the four prototype modules have been constructed thus far, and the scintillator strip alignment accuracy is well within our design goals. The WLS fiber lengths and routing scheme is being determined at Stony Brook, with initial fiber preparation (polishing, silvering of ends) having been done at Fermilab.

A Technical Design Report, incorporating all of the relevant information gleaned from test beam preparation and studies, Monte Carlo simulations, and other sources, will be completed in July, 1997.

Installation

Installation logistics may demand that the FPS be installed while the detector is in the Collision Hall. The modular design of the FPS facilitates a sectional approach to installation.

<u>Schedule Milestones</u>

The milestones for the Forward Pre-Shower Detector sub-project are given in the table below. M1, M2, and M3 identify milestones held by the DoE, the Fermilab Directorate, and the Upgrade Project managers, respectively.

ID	**Milestones-Forward Preshower Detector**	**Date**
4	M3-Forward Preshower TDR Submitted	27-Jul-97
6	Design Complete	2-Oct-97
28	Scintillator Procurement Complete	2-Jan-98
37	M2-Forward Preshower Module Fabrication Begun	16-Feb-98

23	Begin Connector Assembly	2-Mar-98
40	1st Module Complete	1-May-98
24	Connector Assemblies Complete	22-Jun-98
41	M3-Forward Preshower Modules 50% Complete	6-Nov-98
51	M3-1st Forward Preshower Detector Complete	3-Feb-99
42	Module Fabrication Complete	12-Mar-99
78	M3-Forward Preshower-North Installed/Hooked Up	30-Apr-99
53	M3-2nd Forward Preshower Detector Complete	8-Jun-99

Manpower Plan

The manpower plan for the Forward Preshower Detector sub-project is given in the table below. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	Forward Preshower					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Mechanical Technician (F)		0.6		0.5		1.0
Sub-Total (F)		0.6		0.5		1.0
Designer (U)	0.1	1.1	0.0			1.1
Electrical Technician (U)			0.0			0.0
Mechanical Engineer (U)	0.0	0.5	0.3			0.9
Mechanical Technician (U)		0.3	3.5	1.1		5.0
Sub-Total (U)	0.1	1.9	3.9	1.1		7.0
Total	0.1	2.5	3.9	1.6		8.0

Cost Estimate

The cost estimate for the forward preshower detector is given in the accompanying table. The costs for the FPS are based on a detailed analysis of the CPS cost estimates. Modifications to the CPS estimates were made in order to account for differences in design between the two detectors. Where applicable, we typically include 10% spares. Contingency is typically 10-20% and is assigned based on the criteria in section 7.1.2.

WBS 1.1.4 FORWARD PRESHOWER DETECTOR

WBS	ITEM	MATERIALS & SERVICES (M&S)				CONTINGENCY		
1.1.4	FORWARD PRESHOWER DETECTOR	Unit	#	Unit Cost	M&S TOTAL	%	Cost	TOTAL Cost
1.1.4.1	***Engineering & Design***				0		0	0
1.1.4.1.1	Engineering design	m-yr	0.0	120,000	0	20	0	0
1.1.4.2	***Scintillator Extrusion***				23,500	20	4,700	28,200
1.1.4.2.1	Polystyrene	lb	350	10	3,500	20	700	4,200
1.1.4.2.2	Fluor	lot	1	1,000	1,000	20	200	1,200
1.1.4.2.3	Compounding	lot	1	1,000	1,000	20	200	1,200
1.1.4.2.4	Die	ea	1	6,000	6,000	20	1,200	7,200
1.1.4.2.5	Extrusion	day	10	1,200	12,000	20	2,400	14,400
1.1.4.3	***Strip Preparation***				13,000	20	2,600	15,600
1.1.4.3.1	Wrapping	hr	300	30	9,000	20	1,800	10,800
1.1.4.3.2	Mylar	lot	1	2,000	2,000	20	400	2,400
1.1.4.3.3	Supplies	lot	1	2,000	2,000	20	400	2,400
1.1.4.4	***Fiber & Connectors***	ch			44,725	18	8,245	52,970
1.1.4.4.1	WLS Fiber	km	12.5	1,370	17,125	20	3,425	20,550
1.1.4.4.2	Polishing jig	ea	1	1,000	1,000	10	100	1,100
1.1.4.4.3	Silvering	lot	1	2,000	2,000	10	200	2,200
1.1.4.4.4	Connectors	ea	1200	13	15,600	20	3,120	18,720
1.1.4.4.5	Fabrication/testing	hr	400	10	4,000	10	400	4,400
1.1.4.4.6	Connector supplies/hardware	lot	1	5,000	5,000	20	1,000	6,000
1.1.4.5	***Detector Module Assembly***				78,000	20	15,600	93,600
1.1.4.5.1	Heating/molding fixture	ea	2	20,000	40,000	20	8,000	48,000
1.1.4.5.2	Strongback material	lot	1	5,000	5,000	20	1,000	6,000
1.1.4.5.3	Epoxy	lot	1	3,000	3,000	20	600	3,600
1.1.4.5.4	Vacuum bagging setup	lot	1	5,000	5,000	20	1,000	6,000
1.1.4.5.5	Assembly supplies	lot	1	5,000	5,000	20	1,000	6,000
1.1.4.5.6	Tooling	lot	1	20,000	20,000	20	4,000	24,000
1.1.4.6	***Clear Waveguides***				187,200	20	37,440	224,640
1.1.4.6.1	Clear Waveguide	km	210	800	168,000	20	33,600	201,600
1.1.4.6.2	Connectors	ea	1200	16	19,200	20	3,840	23,040
1.1.4.7	***VLPC Cassettes (in WBS1.1.2.4)***							
1.1.4.8	***Calibration System***				55,600	10	5,560	61,160

WBS	1.1.4	FORWARD PRESHOWER DETECTOR						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.1.4	**FORWARD PRESHOWER DETECTOR**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.1.4.8.1	Blue LED System	ea	1200	35	42,000	10	4,200	46,200
1.1.4.8.2	Light bar (material/machining)	ea	1200	3	3,600	10	360	3,960
1.1.4.8.3	Controller	lot	1	5,000	5,000	10	500	5,500
1.1.4.8.4	Mounting/tooling fixture	lot	1	3,000	3,000	10	300	3,300
1.1.4.8.5	Temperature control system	ea	1	2,000	2,000	10	200	2,200
1.1.4.9	***Detector Assembly***				38,000		5,700	43,700
1.1.4.9.1	Mounting/alignment tooling	lot	1	10,000	10,000	15	1,500	11,500
1.1.4.9.2	Lead rework/install	lot	1	10,000	10,000	15	1,500	11,500
1.1.4.9.3	Storage and Shipping Fixture	lot	1	6,000	6,000	15	900	6,900
1.1.4.9.4	Assembly Supplies	lot	1	6,000	6,000	15	900	6,900
1.1.4.9.5	Shipping & Handling	lot	1	6,000	6,000	15	900	6,900
1.1.4	TOTAL FORWARD PRESHOWER DETECTOR				440,025	18	79,845	519,870

10.6 Tracking Electronics

Objectives and Performance Criteria

Objectives of the tracking electronics system include:

- Readout at 53 MHz;
- Less than 5% deadtime;
- Readout boards must keep up with the SVX II chip which has a mean readout time of 7 μ sec;
- Provide inputs to various trigger systems;
- <1 board failure per week.

A detailed specification of part of the system can be found in DØ note 2169.

Components

Components of the tracking electronics include:

- On-detector electronics;
- Readout control;
- VME readout buffer;
- Level 1 tracking trigger;
- Interconnects to the trigger manager system;
- Interconnects to the monitoring and control system;
- Crates and power supplies.

There are approximately 350 boards in this system with a total of 5 board designs.

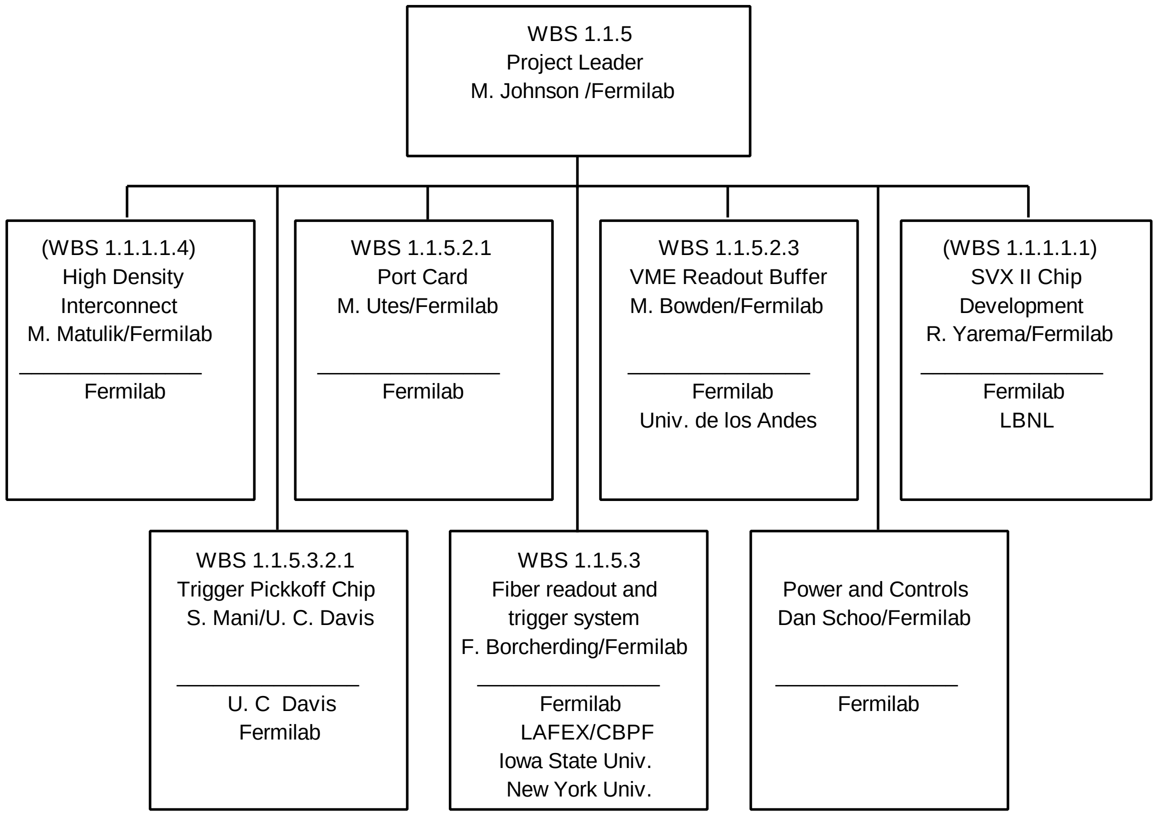
Management, Organization and Responsibilities

The institutions involved in this design are U. C., Davis, Fermilab, Iowa State University, LAFEX/CBPF from Rio de Janeiro, Brazil, Lawrence Berkeley National Laboratory and New York University. The sub-project manager is Marvin Johnson. Adept Design of San Diego CA is providing the design for one of the chips. The project is centered at Fermilab. System testing and integration are done at Fermilab.

The accompanying chart shows the principal design projects and the responsible person. The specifications for the designs are jointly developed by the sub-project managers and the physicists who are building the detectors. Prototypes are built to test the feasibility of various ideas. After this stage, the specifications are modified as required, signed off by the relevant detector group leaders and the final design is started. From this point on, all changes require formal engineering change orders. One design (the VME Readout Buffer) is a joint design with CDF so design changes require the consent of both experiments.

Design progress is monitored by the sub-project manager. Detailed design specifications are internally reviewed before board layout commences. These reports are distributed to all interested parties for comments.

Tracking Electronics Sub-project Organization



<u>Work Plan</u>

Engineering Design.
Almost all of the engineering design is done at Fermilab. Presently there are 9 engineers/designers working on this project at Fermilab (including 1 person from LAFEX/CBPF and 1 from the University de los Andes). The only outside engineering effort is from Adept IC Design Inc. Prototypes of all components of a system are built and tested with detector components on the bench and in test beams. System performance is extensively checked against the required specifications. The performance is also documented in DØ notes and DØ engineering notes.

After final designs are complete, some fraction - typically a few per cent- of the boards are built in a ‘pre production’ run. A fraction of the entire system is run in a test beam. If problems are found, the boards are modified as required. After a successful test beam run, final procurement starts.

Procurement.
The radiation-hard SVX chip is the only device that is not a standard electronics device. A vendor is identified for this. Several prototype versions are required before the design is certified. All the other parts can be built by a number of vendors and are selected by competitive bidding.

Testing and Commissioning.
The SVX II chips are tested by LBNL on custom designed probe stations. The other chip is much less complex so a simple test fixture will be adequate.

All boards will be bed-of-nails tested and burned in at the vendor. Iowa State provides additional system testing before the boards are installed in the detector. Support for system testing is provided both by Iowa State and the Fermilab engineering team.

Schedule Milestones

The milestones for the Tracking Electronics sub-project are given in the tables below. M1, M2, and M3 identify milestones held by the DoE, the Fermilab Directorate, and the Upgrade Project managers, respectively.

ID	Milestones-Tracking Electronics	Date
4	SVXII Rad Hard Chips Available	1-Oct-96
12	M3-Tracking Electronics System Test Begins	7-Mar-97
16	Order Placed for Port Cards	26-Aug-97
18	Order Placed for VRB Cards	26-Aug-97
20	Order Placed for Controller Cards	1-Oct-97
27	M3-Full Production of Port/VRB Cards Begun	22-Oct-97
35	First Readout Crate Installed & Working	26-Feb-98
29	Full Production of Controller Card Begun	2-Apr-98

ID	Milestones-Fiber Electronics	Date
4	SVXII Rad Hard Chips Available	1-Oct-96
15	M3-Fiber Tracker Stereo Board Test Complete	3-Jun-97
7	M3-Fiber Trigger Pickoff Chips Ordered	25-Jun-97
9	Multichip Modules Ordered	19-Sep-97
26	Trigger Board Prototype Complete	9-Jan-98
19	M3-Fiber Tracker Stereo Boards Ordered	26-May-98
21	Stereo Boards Ready	8-Jan-99
31	M3-Fiber Trigger Trigger Boards Ordered	15-Feb-99
37	First Crate Operational	19-Feb-99
33	Trigger Boards Ready	15-Sep-99

Manpower Plan

The manpower plan for the Tracking Electronics sub-project is given in the table below. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	Tracking Electronics					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Electrical Engineer (F)	3.0	0.9	1.2	0.8	0.1	6.1
Electrical Technician (F)	1.1	0.1	1.1			2.3
Sub-Total (F)	4.1	1.0	2.4	0.8	0.1	8.4
Electrical Engineer (U)	0.6	0.7	1.3	1.0	0.1	3.8
Electrical Technician (U)			1.6	0.6		2.1
Sub-Total (U)	0.6	0.7	2.8	1.6	0.1	5.9
Total	4.7	1.8	5.2	2.4	0.2	14.3

Cost Estimate

The cost estimate for the tracking electronics is shown in the accompanying table. The cost includes 10% spares with the exception of the custom chips which have at least 30% spares depending on the final chip yield. The average contingency is 14%, and is assigned based on the criteria in Section 7.1.2.

WBS	1.1.5	TRACKING ELECTRONICS						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.1.5	**TRACKING ELECTRONICS**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.1.5.1	***Engineering & Design***				0	25	0	0
1.1.5.2	***Si Readout System***				1,101,250	10	107,225	1,208,475
1.1.5.2.1	Port Card System				400,520	10	41,452	441,972
1.1.5.2.1.1	Port Cards	pc	84	4,180	351,120	10	35,112	386,232
1.1.5.2.1.2	Backplanes	pc	24	600	14,400	10	1,440	15,840
1.1.5.2.1.3	Power Supplies	watts	5000	3	15,000	10	1,500	16,500
1.1.5.2.1.4	Controller Card	ea	8	2,000	16,000	20	3,200	19,200
1.1.5.2.1.5	Rack Prep	ea	4	1,000	4,000	5	200	4,200
1.1.5.2.2	Fiber optic system				55,000	5	2,750	57,750
1.1.5.2.2.1	Fiber cables	ea	500	110	55,000	5	2,750	57,750
1.1.5.2.3	VRB System				645,730	10	63,023	708,753
1.1.5.2.3.1	VRB Cards	ea	125	3,876	484,500	10	48,450	532,950
1.1.5.2.3.2	J3 Backplanes	ea	15	600	9,000	20	1,800	10,800
1.1.5.2.3.3	VRB Controller	ea	15	1,882	28,230	10	2,823	31,053
1.1.5.2.3.4	Rack Prep & Crates	ea	7	7,000	49,000	5	2,450	51,450
1.1.5.2.3.5	Diagnostic Computer	ea	15	3,000	45,000	10	4,500	49,500
1.1.5.2.3.6	VRB Test tooling	lot	1	30,000	30,000	10	3,000	33,000
1.1.5.3	***Fiber/Preshower Readout System***				1,187,336	18	216,838	1,404,174
1.1.5.3.1	Trigger Card				494,672	19	95,912	590,584
1.1.5.3.1.1	SVX II chip	ea	704	59	41,624	25	10,406	52,030
1.1.5.3.1.2	Front End Chip	ea	2816	20	56,320	20	11,264	67,584
1.1.5.3.1.3	Field programmable Gate Arrays	ea	352	300	105,600	20	21,120	126,720
1.1.5.3.1.4	Multi chip module	ea	704	200	140,800	20	28,160	168,960
1.1.5.3.1.5	Cynapse Connectors	ea	704	22	15,488	20	3,098	18,586
1.1.5.3.1.6	PC Board	ea	88	350	30,800	20	6,160	36,960
1.1.5.3.1.7	Miscellaneous Chips	ea	88	200	17,600	20	3,520	21,120
1.1.5.3.1.8	Port Card	ea	8	4,180	33,440	10	3,344	36,784
1.1.5.3.1.9	Assembly	ea	88	300	26,400	20	5,280	31,680
1.1.5.3.1.10	Power supply	watt	4400	4	17,600	10	1,760	19,360
1.1.5.3.1.11	Backplanes	ea	15	600	9,000	20	1,800	10,800
1.1.5.3.2	Tooling				148,000	20	29,600	177,600
1.1.5.3.2.1	Front end chip development	lot	1	65,000	65,000	20	13,000	78,000
1.1.5.3.2.2	Pulser system	lot	1	20,000	20,000	20	4,000	24,000
1.1.5.3.2.3	Synapse connector mold	lot	1	14,000	14,000	20	2,800	16,800
1.1.5.3.2.4	SVX packaging	lot	1	49,000	49,000	20	9,800	58,800
1.1.5.3.3	Stereo Card				235,952	18	42,848	278,800
1.1.5.3.3.1	SVX II chip	ea	704	59	41,624	25	10,406	52,030
1.1.5.3.3.2	Multi chip module	ea	704	50	35,200	20	7,040	42,240

WBS	1.1.5	TRACKING ELECTRONICS						
WBS	ITEM	MATERIALS & SERVICES (M&S)				CONTINGENCY		
1.1.5	TRACKING ELECTRONICS	Unit	#	Unit Cost	M&S TOTAL	%	Cost	TOTAL Cost
1.1.5.3.3.3	Cynapse Connectors	ea	704	22	15,488	20	3,098	18,586
1.1.5.3.3.4	PC Board	ea	88	350	30,800	20	6,160	36,960
1.1.5.3.3.5	Miscellaneous Chips	ea	88	200	17,600	15	2,640	20,240
1.1.5.3.3.6	Port Card	ea	8	4,180	33,440	10	3,344	36,784
1.1.5.3.3.7	Assembly	ea	88	300	26,400	20	5,280	31,680
1.1.5.3.3.8	Bias supply	ea	88	100	8,800	15	1,320	10,120
1.1.5.3.3.9	Power supply	watt	4400	4	17,600	10	1,760	19,360
1.1.5.3.3.10	Backplanes	ea	15	600	9,000	20	1,800	10,800
1.1.5.3.4	Fiber Optic system				13,200	5	660	13,860
1.1.5.3.4.1	Fiber optic cables	ea	120	110	13,200	5	660	13,860
1.1.5.3.5	VRB System				105,988	10	10,619	116,607
1.1.5.3.5.1	VRB Cards	ea	24	3,876	93,024	10	9,302	102,326
1.1.5.3.5.2	J3 Backplanes	ea	2	600	1,200	20	240	1,440
1.1.5.3.5.3	VRB Controller	ea	2	1,882	3,764	10	376	4,140
1.1.5.3.5.4	Rack Prep	ea	2	1,000	2,000	5	100	2,100
1.1.5.3.5.5	Diagnostic Computer	ea	2	3,000	6,000	10	600	6,600
1.1.5.3.6	FPS Readout/Trigger				189,524	20	37,200	226,724
1.1.5.3.6.1	SVX II chip	ea	288	59	17,028	25	4,257	21,285
1.1.5.3.6.2	Front End Chip	ea	1152	25	28,800	20	5,760	34,560
1.1.5.3.6.3	Field programmable Gate Arrays	ea	72	200	14,400	20	2,880	17,280
1.1.5.3.6.4	Multi chip module	ea	288	200	57,600	20	11,520	69,120
1.1.5.3.6.5	Cynapse Connectors	ea	288	22	6,336	20	1,267	7,603
1.1.5.3.6.6	PC Board	ea	36	350	12,600	20	2,520	15,120
1.1.5.3.6.7	Miscellaneous Chips	ea	36	400	14,400	20	2,880	17,280
1.1.5.3.6.8	Port Card	ea	2	4,180	8,360	10	836	9,196
1.1.5.3.6.9	Assembly	ea	36	300	10,800	20	2,160	12,960
1.1.5.3.6.10	Power supply	watt	1800	4	7,200	10	720	7,920
1.1.5.3.6.11	Backplanes	ea	12	1,000	12,000	20	2,400	14,400
1.1.5	TOTAL TRACKING ELECTRONICS				2,288,586	14	324,063	2,612,649

10.7 Calorimeter Front End Electronics

Objectives and Performance Criteria

The objectives of the new calorimeter front-end electronics system are to provide:

- Storage of the analog signal for about 4 μsec until a trigger can be formed;
- Operation at 132 nsec minimum bunch spacing;
- Trigger signals for use by the Calorimeter L1 trigger system;
- To re-use as much of the existing infrastructure as possible;
- Similar noise performance at high luminosity to what we presently achieve;
- Minimal signal pile-up.

Components

Major components of the calorimeter front end include:

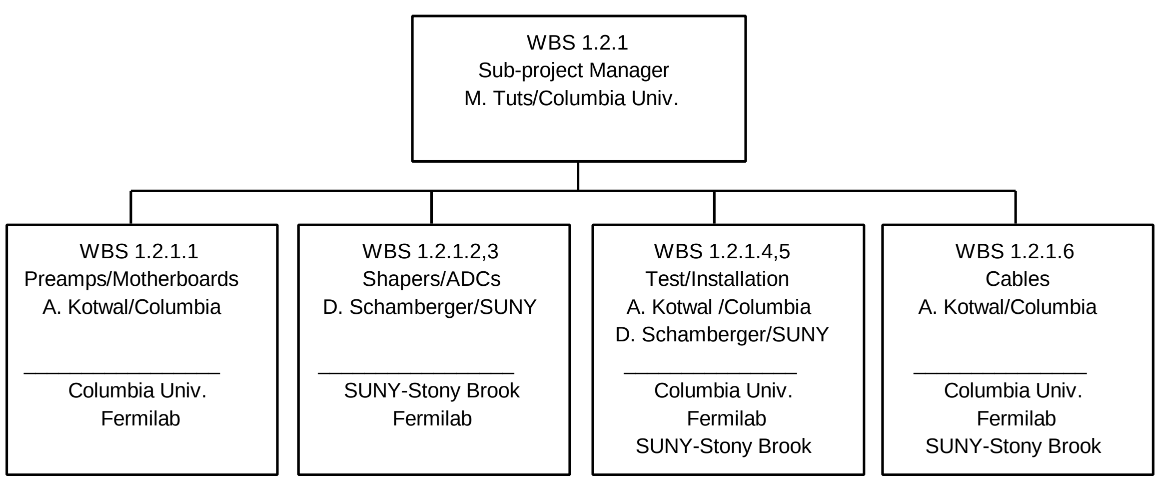
- Replacement of all 110 Ω twisted pair cables with 30 Ω cables;
- Low noise front-end preamplifier hybrids;
- New preamplifier motherboards;
- New BLS boards with faster shaping circuitry and analog delay circuitry;
- Switched capacitor arrays (SCA) for analog storage;
- A new calibration system;
- A new timing system.

There are a total of 60,000 calorimeter channels to be replaced.

Management, Organization, and Responsibilities

The institutions participating in the Calorimeter Front-End Electronics sub-project are Columbia University, Fermilab, and the State University of New York at Stony Brook. The sub-project manager is Michael Tuts (Columbia University). The primary responsibility for the preamplifier system rests with Columbia University, and the primary responsibility for the BLS system rests with SUNY at Stony Brook. Fermilab contributes to both those efforts with engineering support for the testing of preamplifiers, low voltage power supply design, and SCA testing. The sub-group organization and leadership is shown in the accompanying chart. Work is coordinated by weekly meetings held at Fermilab, and extensive electronic communication. A World Wide Web page for the calorimeter front-end electronics is under construction.

Calorimeter Electronics Sub-project Organization



Work Plan

Engineering/Design

Since this project re-uses a major portion of the mechanical infrastructure, minimal mechanical engineering resources are needed. These needs are addressed by the DØ Mechanical support group.

The dominant engineering design effort is electrical. The principal tasks are the design of: (1) a new preamplifier and preamplifier motherboard; (2) the BLS and BLS motherboard; (3) the custom ASIC SCA chip; (4) new power supplies; (5) a timing system; and (6) a calibration system. The responsibilities for these first four design tasks are assigned according to the institutional responsibilities described in previous sections. The SCA is designed by LBNL engineering according to specifications provided by DØ. Engineering support is provided by the collaborating institutions.

Procurement

The procurement of the cables and the preamp motherboards are placed through the Fermilab purchasing office, based on specifications provided by the responsible physicist or engineer, according to the standard Fermilab purchasing practices. Other system components are placed by individual university groups, in accordance with memoranda of understanding (MOU) between Fermilab/DØ and the DØ University Group. This category of procurement covers the assembly of preamplifier motherboards (as described in the Columbia University MOU), and the procurement of the BLS system (as described in the SUNY Stony Brook MOU). Others are procured through Fermilab.

Inspection

The inspection of the elements of the calorimeter front-end electronics system is made at various stages during the production. The assembly of the cables (cutting to length, attachment of connectors, labeling) is done at the vendor, with weekly inspections by a member of the Fermilab DØ staff. The University groups responsible for other individual electronics systems take responsibility to inspect the materials received from vendors and assemblers. Any systems that do not meet specifications will be returned to the vendor/assembler for repair or replacement. Test jigs are provided to vendors where appropriate to assure that the systems meet specifications.

Construction/Fabrication

The majority of the electronics construction and fabrication takes place at the vendor. The remaining construction items consist of loading the preamplifier and BLS hybrids on their respective motherboards, the removal of the present feedthrough to preamplifier cables and installation of the new cable bundles, and the removal of the present power supplies and the installation of the new power supplies. There is also some construction required for the replacement of one of the three BLS crate backplanes with a new backplane. These construction tasks are carried out by the DØ technical support staff and physicists, under the supervision of a senior physicist or engineer directly involved in the project.

Testing/Commissioning

The individual preamplifier and BLS hybrids are received at Fermilab after having undergone simple functional testing. Upon receipt, the individual hybrids are loaded on the appropriate motherboards for a module test in a small test station. This verifies the operation of a single loaded motherboard. These loaded motherboards are then placed in a large scale test jig for burn-in. After successfully undergoing a burn-in test, the loaded motherboards are installed in their final locations. Once installed, there is a quadrant test of 5,000 channels to verify the noise performance and check for any bad channels. Once this test is completed the electronics is ready for use. When all 60,000 channels have been installed, the full calorimeter electronics system is powered up and run with cosmic rays. Pedestal and pulser calibrations are made, and the stability of the complete system is monitored to check for stability over time.

Schedule Milestones

The milestones for the Calorimeter Front End Electronics sub-project are given in the table below. M1, M2, and M3 identify milestones held by the DoE, the Fermilab Directorate, and the Upgrade Project managers, respectively.

ID	Milestones-Calorimeter Electronics	Date
149	Feedthrough to Preamp Cabling Finished	3-Oct-96
33	Preamp Motherboard Design Complete	24-Feb-97
10	Preamp Design Finalized	28-Feb-97
65	SCA Preproduction Evaluation Complete	27-Mar-97
3	M3-Calorimeter Electronics TDR Submitted	1-Apr-97
46	Preamp PS Design Finalized	25-Apr-97
39	Preamp Motherboard Production Begun	18-Jun-97
77	Shaper Hybrid Design and Test Complete	28-Jul-97
22	M3-Calorimeter Preamp Production Begun	2-Oct-97
85	Buffer Control & Trigger Sum Design and Test Complete	21-Oct-97
109	M3-Calorimeter BLS PS Prototype Built/Tested	18-Dec-97
119	Calibration System Design Complete	27-Feb-98
99	BLS Motherboard Design and Test Complete	4-Mar-98
128	Timing & Control System Design Complete	22-Apr-98
139	ADC Controller Design Complete	20-May-98
81	Shaper Hybrid Construction Complete	17-Jul-98
55	M2-Calorimeter Preamp System Test Complete	27-Jul-98
153	Begin Preamp Installation	28-Jul-98
155	M3-Calorimeter CC,ECN Preamp Installation Complete	17-Dec-98
103	M2-Calorimeter BLS Assembly Complete	6-Jan-99
158	M3-CC, ECN Calorimeter System Checked Out	28-Apr-99
163	Checkout of Calorimeter Electronics Complete	11-Oct-99

Manpower Plan

The manpower plan for the Calorimeter Front-End Electronics sub-project is given in the accompanying table. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	Calorimeter Electronics					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Electrical Engineer (F)	0.0	0.5	0.7	0.5	0.0	1.7
Electrical Technician (F)	0.6	0.6	2.4	2.2	0.0	5.7
Mechanical Technician (F)				0.2		0.2
Sub-Total (F)	0.6	1.1	3.1	2.8	0.0	7.6
Electrical Engineer (U)	0.4	1.4	1.7	0.4		3.9
Electrical Technician (U)			0.1			0.1
Sub-Total (U)	0.4	1.4	1.8	0.4		4.0
Total	1.0	2.5	4.9	3.2	0.0	11.7

Cost Estimate

The cost estimate for the front-end calorimeter system is shown in the accompanying table. The spares for this system are about 10%, and are reflected in the total parts count for each of the systems. The average contingency is 9% and is assigned based on the criteria in section 7.1.2.

WBS 1.2.1 FRONT-END ELECTRONICS

WBS 1.2.1	ITEM FRONT-END ELECTRONICS	MATERIALS & SERVICES (M&S) Unit	# 	Unit Cost	M&S TOTAL	CONTINGENCY %	Cost	TOTAL Cost
1.2.1.1	***Preamp System***		60,000		909,090	9	84,474	993,564
1.2.1.1.1	Preamp Engineering & Design	lot	1	20,000	20,000	10	2,000	22,000
1.2.1.1.2	Preamp Hybrids	ea	60,000	8	579,420	9	54,012	633,432
1.2.1.1.2.1	Parts				233,220	8	19,812	253,032
1.2.1.1.2.1.1	Transistors	lot	1	84,240	84,240	5	4,212	88,452
1.2.1.1.2.1.2	Capacitors				86,880	18	15,600	102,480
1.2.1.1.2.1.2.1	Tantalum (2.2uF)	ea	240,000	0.20	48,000	20	9,600	57,600
1.2.1.1.2.1.2.2	Bypass (.1uF, Z5U)	ea	480,000	0.019	8,880	0	0	8,880
1.2.1.1.2.1.2.3	Precision	ea	600,000	0.050	30,000	20	6,000	36,000
1.2.1.1.2.1.3	Connectors	ea	60,000	1.04	62,100	0	0	62,100
1.2.1.1.2.2	Assembly (ceramic, resistors)	ea	60,000	5.60	336,000	10	33,600	369,600
1.2.1.1.2.3	Test Station				10,200	6	600	10,800
1.2.1.1.2.3.1	DAQ	ea	1	6,200	6,200	0	0	6,200
1.2.1.1.2.3.2	Test Jig	ea	4	1,000	4,000	15	600	4,600
1.2.1.1.3	Preamp Motherboards				248,650	7	16,258	264,908
1.2.1.1.3.1	NRE setup	lot	1	790	790	5	40	830
1.2.1.1.3.2	PC boards	ea	1,260	76	95,760	5	4,788	100,548
1.2.1.1.3.3	Assembly	ea	1,260	20	25,200	5	1,260	26,460
1.2.1.1.3.4	Parts				114,300	6	7,020	121,320
1.2.1.1.3.4.1	Connectors	ea	60,000	1.29	77,400	0	0	77,400
1.2.1.1.3.4.2	Precision resistors	ea	60,000	0.30	18,000	25	4,500	22,500
1.2.1.1.3.4.3	Fuses, diode, resistor	ea	1,260	5	6,300	20	1,260	7,560
1.2.1.1.3.4.4	DIN connector	ea	2,520	5	12,600	10	1,260	13,860
1.2.1.1.3.5	Testing	ea	1,260	10	12,600	25	3,150	15,750
1.2.1.1.4	Preamp Power Supplies				61,020	20	12,204	73,224
1.2.1.1.4.1	Main Power transformers	ea	30	800	24,000	20	4,800	28,800
1.2.1.1.4.2	Chassis	ea	30	150	4,500	20	900	5,400
1.2.1.1.4.3	Control Power	ea	30	120	3,600	20	720	4,320
1.2.1.1.4.4	Heatsink	ea	30	117	3,510	20	702	4,212
1.2.1.1.4.5	Solid State Relay	ea	30	113	3,390	20	678	4,068
1.2.1.1.4.6	Schottky Rectifiers	ea	30	103	3,090	20	618	3,708
1.2.1.1.4.7	Output Connectors	ea	30	70	2,100	20	420	2,520
1.2.1.1.4.8	Circuit Breaker	ea	30	64	1,920	20	384	2,304
1.2.1.1.4.9	Power Transistors	ea	30	157	4,710	20	942	5,652
1.2.1.1.4.10	Parts/PC boards	ea	30	220	6,600	20	1,320	7,920
1.2.1.1.4.11	Mechanical rework	ea	30	120	3,600	20	720	4,320
1.2.1.2	***BLS System***				2,347,342	11	250,512	2,597,854
1.2.1.2.1	BLS Engineering & Design	lot	1	10,000	10,000	20	2,000	12,000
1.2.1.2.2	BLS Switched Capacitor Arrays				551,101	13	70,129	621,229
1.2.1.2.2.1	SCA die				404,650	9	36,610	441,260
1.2.1.2.2.1.1	Prototype 10 wafers	lot	1	27,000	27,000	2	540	27,540

WBS	1.2.1	FRONT-END ELECTRONICS						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.2.1	**FRONT-END ELECTRONICS**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.2.1.2.2.1.2	Production wafers	wafer	391	880	343,750	10	34,375	378,125
1.2.1.2.2.1.3	Photoplate generation	lot	1	33,900	33,900	5	1,695	35,595
1.2.1.2.2.2	Die packaging	die	50,000	1.25	62,500	25	15,625	78,125
1.2.1.2.2.3	Tester Setup	m.mo	2	5,517	11,034	30	3,310	14,344
1.2.1.2.2.4	Testing	m.mo	26	2,800	72,917	20	14,583	87,500
1.2.1.2.3	Shaper Hybrid		60,000		828,581	9	71,758	900,339
1.2.1.2.3.1	Sallen-Key	ea	60,000	2.48	148,800	20	14,880	163,680
1.2.1.2.3.1.1	Transistors	ea	480,000	0.15	72,000	10	7,200	79,200
1.2.1.2.3.1.2	Tantallum Caps (2.2uF)	ea	240,000	0.20	48,000	10	4,800	52,800
1.2.1.2.3.1.3	Ceramic Caps (Z5U)	ea	480,000	0.02	9,600	10	960	10,560
1.2.1.2.3.1.4	Precision Caps (NPO)	ea	240,000	0.08	19,200	10	1,920	21,120
1.2.1.2.3.2	x1/x8 amp	ea	60,000	4.18	250,800	6	13,980	264,780
1.2.1.2.3.2.1	HFA1135	ea	120,000	1.85	222,000	5	11,100	233,100
1.2.1.2.3.2.2	Tantallum Caps (2.2uF)	ea	120,000	0.20	24,000	10	2,400	26,400
1.2.1.2.3.2.3	Ceramic Caps (Z5U)	ea	240,000	0.02	4,800	10	480	5,280
1.2.1.2.3.3	Trigger pickoff		60,000	0.35	21,000	10	2,100	23,100
1.2.1.2.3.3.1	Transistors	ea	60,000	0.15	9,000	10	900	9,900
1.2.1.2.3.3.2	Ceramic Caps (Z5U)	ea	120,000	0.02	2,400	10	240	2,640
1.2.1.2.3.3.3	Precision Caps (NPO)	ea	120,000	0.08	9,600	10	960	10,560
1.2.1.2.3.4	Ceramic Chip (with resistors)	ea	60,000	6.75	405,000	10	40,500	445,500
1.2.1.2.3.5	Male Pins	kea	1,080	2.76	2,981	10	298	3,279
1.2.1.2.4	Analog Buffer Daughter Board		5,000	80.88	404,405	7	29,220	433,625
1.2.1.2.4.1	Daughter Board (10 layer)	ea	5,000	12	60,000	20	12,000	72,000
1.2.1.2.4.2	Connectors & Sockets				65,550	5	3,278	68,828
1.2.1.2.4.2.1	25 pair	ea	10,000	1.08	10,780	5	539	11,319
1.2.1.2.4.2.2	20 pair	ea	10,000	0.95	9,470	5	474	9,944
1.2.1.2.4.2.3	17 pair	ea	10,000	0.81	8,050	5	403	8,453
1.2.1.2.4.2.4	PLCC 68 pin sockets	ea	25,000	1.49	37,250	5	1,863	39,113
1.2.1.2.4.3	Capacitors				21,600	5	1,080	22,680
1.2.1.2.4.3.1	Tantallum Caps (10uF)	ea	15,000	0.28	4,200	5	210	4,410
1.2.1.2.4.3.2	0.1uF Ceramic Caps (Z5U)	ea	350,000	0.02	7,000	5	350	7,350
1.2.1.2.4.3.3	Precision Caps (NPO)	ea	120,000	0.07	8,400	5	420	8,820
1.2.1.2.4.3.4	0.22uF Ceramic Caps (Z5U)	ea	20,000	0.10	2,000	5	100	2,100
1.2.1.2.4.4	Resistors				63,555	5	3,178	66,733
1.2.1.2.4.4.1	Precision Resistor (0.1%)	ea	240,000	0.25	60,000	5	3,000	63,000
1.2.1.2.4.4.2	Regular Resistors (1%)	ea	45,000	0.02	675	5	34	709
1.2.1.2.4.4.3	Low Precision Resistors (5%)	ea	240,000	0.01	2,880	5	144	3,024
1.2.1.2.4.5	LM311M comparator	ea	60,000	0.30	18,000	5	900	18,900
1.2.1.2.4.6	HFA1135 Op-Amp	ea	60,000	1.85	111,000	5	5,550	116,550
1.2.1.2.4.7	Cmos 4053 switch	ea	40,000	0.45	18,000	5	900	18,900
1.2.1.2.4.8	Cmos 4174 registor	ea	10,000	0.50	5,000	5	250	5,250
1.2.1.2.4.9	Cmos 4519 MUX	ea	15,000	0.48	7,200	5	360	7,560
1.2.1.2.4.10	TL074X2 Op-Amp	ea	15,000	2.30	34,500	5	1,725	36,225
1.2.1.2.5	S/H & Output Buffer		60,000	1.00	59,747	11	6,387	66,134
1.2.1.2.5.1	TL074X2 Op-Amp	ea	7,500	2.30	17,250	5	863	18,113
1.2.1.2.5.2	Capacitors				4,500	5	225	4,725
1.2.1.2.5.2.1	0.1uF Ceramic Caps (Z5U)	ea	15,000	0.02	300	5	15	315

WBS	1.2.1	FRONT-END ELECTRONICS						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.2.1	**FRONT-END ELECTRONICS**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.2.1.2.5.2.2	Precision Caps (NPO)	ea	60,000	0.07	4,200	5	210	4,410
1.2.1.2.5.3	Cmos 4066 switch	ea	30,000	0.50	15,000	5	750	15,750
1.2.1.2.5.4	Ceramic Chip (with resistors)	ea	7,500	3	22,500	20	4,500	27,000
1.2.1.2.5.5	Male Pins	1000's	180	2.76	497	10	50	546
1.2.1.2.6	BLS Boards		1,250	251	313,410	11	34,998	348,408
1.2.1.2.6.1	Connectors		1,250	74.73	93,410	7	6,998	100,408
1.2.1.2.6.1.1	96 pin DIN	ea	1,250	3	3,750	10	375	4,125
1.2.1.2.6.1.2	64 pin DIN	ea	2,500	2	5,000	10	500	5,500
1.2.1.2.6.1.3	Board mount Socket Pins	1000's	1,080	35.00	37,800	10	3,780	41,580
1.2.1.2.6.1.4	25 pair Header	ea	10,000	1.79	17,850	5	893	18,743
1.2.1.2.6.1.5	20 pair Header	ea	10,000	1.57	15,680	5	784	16,464
1.2.1.2.6.1.6	17 pair Header	ea	10,000	1.33	13,330	5	667	13,997
1.2.1.2.6.2	Control & Drivers	ea	1,250	4	5,000	20	1,000	6,000
1.2.1.2.6.3	Trigger sum driver	ea	3,750	4	15,000	30	4,500	19,500
1.2.1.2.6.4	SCA Power conditioning	ea	1,250	10	12,500	30	3,750	16,250
1.2.1.2.6.5	Motherboards	bd	1,250	150	187,500	10	18,750	206,250
1.2.1.2.7	Backplanes	ea	78	250	19,531	20	3,906	23,438
1.2.1.2.8	BLS Power Supplies				43,380	20	8,676	52,056
1.2.1.2.8.1	Main Power transformers	ea	36	800	28,800	20	5,760	34,560
1.2.1.2.8.2	Chassis	ea	36	25	900	20	180	1,080
1.2.1.2.8.3	Control Panel	ea	36	120	4,320	20	864	5,184
1.2.1.2.8.4	Power Transistors	ea	36	65	2,340	20	468	2,808
1.2.1.2.8.5	Parts/PC boards	ea	36	75	2,700	20	540	3,240
1.2.1.2.8.6	Mechanical rework	ea	36	120	4,320	20	864	5,184
1.2.1.2.9	BLS Crate Controllers	ea	78	1,500	117,188	20	23,438	140,625
1.2.1.3	***ADC Controllers***	ea	20	1,000	20,000	25	5,000	25,000
1.2.1.4	***Timing System***				170,500	20	34,100	204,600
1.2.1.4.1	Central Crate Cards (MCH3)	ea	30	2,750	82,500	20	16,500	99,000
1.2.1.4.2	Signal Fanout Cards	ea	16	2,500	40,000	20	8,000	48,000
1.2.1.4.3	Signal Fanout Crates	ea	2	3,500	7,000	20	1,400	8,400
1.2.1.4.4	Signal Fanout Power Supplies	ea	2	3,000	6,000	20	1,200	7,200
1.2.1.4.5	Coax Cabling (MCH3 to Quadrants)	lot	1	35,000	35,000	20	7,000	42,000
1.2.1.5	***Calibration System***				32,499	14	4,700	37,199
1.2.1.5.1	Pulser box		20		22,499	12	2,700	25,199
1.2.1.5.1.1	Printed circuit boards				9,000	15	1,350	10,350
1.2.1.5.1.1.1	SCR pulser PCB	ea	20	100	2,000	15	300	2,300
1.2.1.5.1.1.2	Assemble pulser PCB	ea	20	50	1,000	15	150	1,150
1.2.1.5.1.1.3	DAC PCB	ea	20	100	2,000	15	300	2,300
1.2.1.5.1.1.4	Assemble DAC PCB	ea	20	50	1,000	15	150	1,150
1.2.1.5.1.1.5	Pulser logic PCB	ea	20	100	2,000	15	300	2,300
1.2.1.5.1.1.6	Assemble pulser logic PCB	ea	20	50	1,000	15	150	1,150
1.2.1.5.1.2	Pulser rack mount box	ea	20	163	3,260	10	326	3,586
1.2.1.5.1.3	Parts				10,239	10	1,024	11,263
1.2.1.5.1.3.1	Switches and LED's				325	10	32	357

WBS	1.2.1	FRONT-END ELECTRONICS						
WBS	ITEM	MATERIALS & SERVICES (M&S)				CONTINGENCY		
1.2.1	FRONT-END ELECTRONICS	Unit	#	Unit Cost	M&S TOTAL	%	Cost	TOTAL Cost
1.2.1.5.1.3.1.1	Push button switch	ea	40	6.38	255	10	26	281
1.2.1.5.1.3.1.2	Yellow LED	ea	40	0.35	14	10	1	15
1.2.1.5.1.3.1.3	Green LED	ea	60	0.69	41	10	4	46
1.2.1.5.1.3.1.4	Red LED	ea	40	0.35	14	10	1	15
1.2.1.5.1.3.2	Resistors				203	10	20	223
1.2.1.5.1.3.2.1	20k 5W	ea	20	1.00	20	10	2	22
1.2.1.5.1.3.2.2	10k 10W	ea	20	2.06	41	10	4	45
1.2.1.5.1.3.2.3	13k 5W	ea	40	1.00	40	10	4	44
1.2.1.5.1.3.2.4	68ohm 2W	ea	100	0.81	81	10	8	89
1.2.1.5.1.3.2.5	51 ohm	ea	100	0.02	2	10	0	2
1.2.1.5.1.3.2.6	200 ohm	ea	100	0.02	2	10	0	2
1.2.1.5.1.3.2.7	270 ohm	ea	100	0.02	2	10	0	2
1.2.1.5.1.3.2.8	330 ohm	ea	100	0.02	2	10	0	2
1.2.1.5.1.3.2.9	1k	ea	100	0.02	2	10	0	2
1.2.1.5.1.3.2.10	4.7k	ea	100	0.02	2	10	0	2
1.2.1.5.1.3.2.11	10k	ea	100	0.02	2	10	0	2
1.2.1.5.1.3.2.12	1M	ea	100	0.02	2	10	0	2
1.2.1.5.1.3.2.13	2.7 ohm 1/2W	ea	100	0.03	3	10	0	3
1.2.1.5.1.3.3	Capacitors				802	10	80	882
1.2.1.5.1.3.3.1	40uF 400V	ea	40	3.35	134	10	13	147
1.2.1.5.1.3.3.2	.01uF 3kV	ea	40	0.97	39	10	4	43
1.2.1.5.1.3.3.3	1uF	ea	60	0.91	55	10	5	60
1.2.1.5.1.3.3.4	.1uF	ea	220	1.68	370	10	37	407
1.2.1.5.1.3.3.5	2.2uF	ea	140	0.75	105	10	11	116
1.2.1.5.1.3.3.6	680 pF	ea	40	1.00	40	10	4	44
1.2.1.5.1.3.3.7	560 pF	ea	60	1.00	60	10	6	66
1.2.1.5.1.3.4	Semiconductors				3,116	10	312	3,428
1.2.1.5.1.3.4.1	IN3048	ea	40	0.05	2	10	0	2
1.2.1.5.1.3.4.2	Zener	ea	20	0.10	2	10	0	2
1.2.1.5.1.3.4.3	GA201A	ea	60	40.00	2,400	10	240	2,640
1.2.1.5.1.3.4.4	IRF721	ea	20	6.00	120	10	12	132
1.2.1.5.1.3.4.5	MUR840	ea	20	1.60	32	10	3	35
1.2.1.5.1.3.4.6	3483 Op amp	ea	20	2.75	55	10	6	61
1.2.1.5.1.3.4.7	1N5711	ea	40	0.30	12	10	1	13
1.2.1.5.1.3.4.8	1N914	ea	60	0.16	10	10	1	11
1.2.1.5.1.3.4.9	1N4005	ea	80	0.06	5	10	0	5
1.2.1.5.1.3.4.10	2N2369	ea	60	0.52	31	10	3	34
1.2.1.5.1.3.4.11	74LS193	ea	60	0.47	28	10	3	31
1.2.1.5.1.3.4.12	74LS14	ea	20	0.33	7	10	1	7
1.2.1.5.1.3.4.13	74LS123	ea	40	0.56	22	10	2	25
1.2.1.5.1.3.4.14	74LS74	ea	20	0.32	6	10	1	7
1.2.1.5.1.3.4.15	74128	ea	20	0.78	16	10	2	17
1.2.1.5.1.3.4.16	74LS540	ea	80	0.89	71	10	7	78
1.2.1.5.1.3.4.17	DAC-80	ea	20	14.85	297	10	30	327
1.2.1.5.1.3.5	Connectors				1,916	10	192	2,108
1.2.1.5.1.3.5.1	BNC ITT 4578	ea	140	9.32	1,305	10	130	1,435
1.2.1.5.1.3.5.2	BNC ITT 4578	ea	60	9.32	559	10	56	615

WBS	1.2.1	FRONT-END ELECTRONICS						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.2.1	**FRONT-END ELECTRONICS**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.2.1.5.1.3.5.3	50 pin	ea	20	2.62	52	10	5	58
1.2.1.5.1.3.6	Power supply, etc				3,878	10	388	4,265
1.2.1.5.1.3.6.1	Triple power supply	ea	20	161.92	3,238	10	324	3,562
1.2.1.5.1.3.6.2	Transformers	ea	60	10.00	600	10	60	660
1.2.1.5.1.3.6.3	100k pot	ea	20	1.48	30	10	3	33
1.2.1.5.1.3.6.4	8 pin DIP switch	ea	20	0.48	10	10	1	11
1.2.1.5.2	Switch box				10,000		2,000	12,000
1.2.1.5.2.1	Printed circuit boards	ea	20	100	2,000	20	400	2,400
1.2.1.5.2.2	Switch rack mount box	ea	20	150	3,000	20	600	3,600
1.2.1.5.2.3	Parts	ea	20	250	5,000	20	1,000	6,000
1.2.1.6	***Cables Feedthrough-Preamp***	ea	2,400	240	576,000	0	0	576,000
1.2.1	FRONT-END ELECTRONICS				4,055,431	9	378,785	4,434,217

10.8 Calorimeter Intercryostat Detector

Objectives and Performance Criteria

The objectives of the ICD detector are:

- To provide improved energy resolution in the intermediate region of the calorimeter system, $1.1 < |\eta| < 1.4$;
- To correct for the dead material introduced by the solenoid.

Further details may be found in D0 Note 2281, titled ``Proposal to Upgrade the Intermediate and Forward Regions of the D0 Calorimeter."

Components

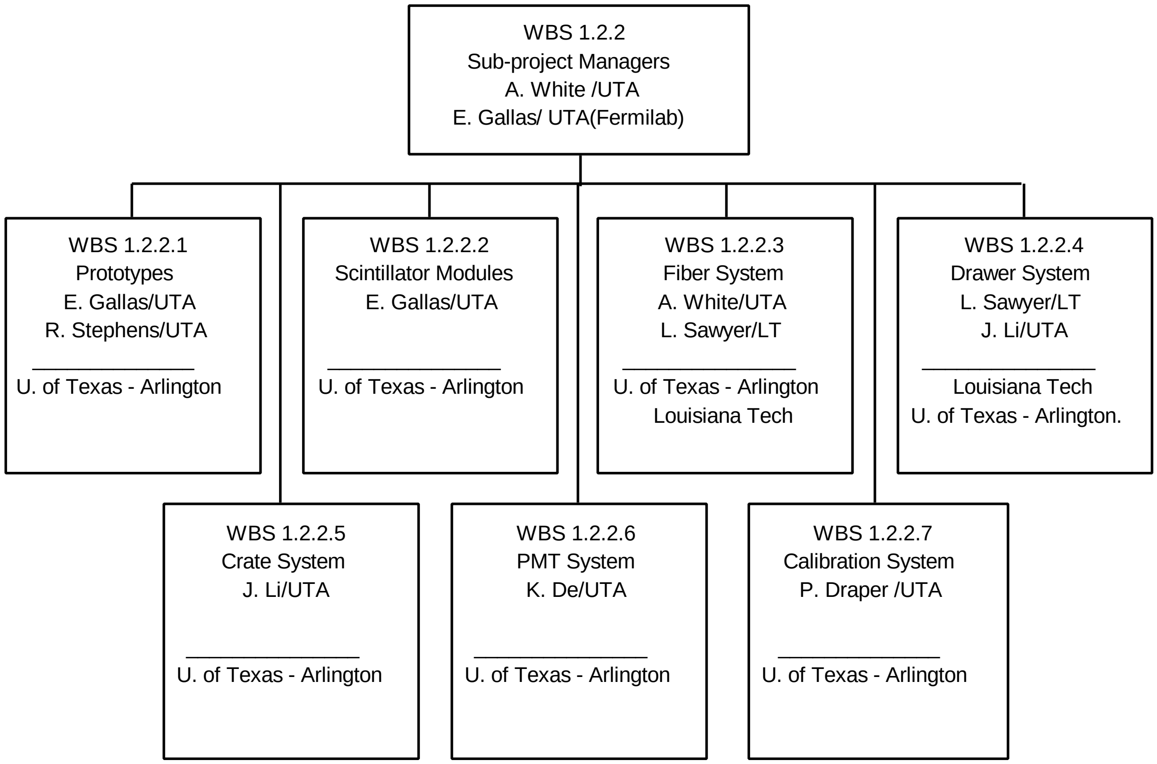
- Scintillator tiles;
- Phototubes and readout assemblies;
- Electronics and calibration system.

Management, Organization, and Responsibilities

The University of Texas at Arlington and Louisiana Tech are responsible for the design, construction and installation of the Run II ICD. Sub-project managers are Andrew White and Elizabeth Gallas from UTA. The majority of the ICD work takes place at UTA and Louisiana Tech, with the following exceptions: scintillator machining is done at Fermilab in the Lab. 8 facilities; engineering help with the installation of the ICD and the support for the crate containing the phototubes and electronics on the end cryostats is provided by Fermilab. The organization of the ICD sub-project is shown in the accompanying chart.

UTA provides fully constructed ICD modules, fiber cables and the drawer/readout system to Fermilab. Andrew White is stationed at UTA and Elizabeth Gallas is stationed at Fermilab. Work is coordinated through weekly meetings at UTA with telephone hookup to Fermilab.

Calorimeter Intercryostat Detector Sub-project Organization



Work Plan

Engineering/Design

The engineering design of the drawer system is performed at UTA. Due to the close integration necessary with other sub-systems, mechanical engineering for the overall support structures of the ICD is provided by Fermilab. Engineering for the readout is provided by UTA, except for the upgrade of the preamplifier which is handled by the calorimeter electronics upgrade group.

Electrical engineering work on the mother boards follows the mechanical design. Design and fabrication of the preamps are the responsibility of the calorimeter electronics group.

Procurement

Major procurement items are 1) scintillators 2) fibers and 3) drawers. Orders are placed after successful testing of the prototype.

Inspection

Due to the small number of channels in the ICD (384), most components will be hand manufactured and assembled. We utilize students at UTA for assembly tasks. Quality assurance will be an important component of ICD construction. There are tests at every stage of production. Cosmic ray test stands are available at UTA and Fermilab for light yield tests. A fiber tester is located at UTA. Electronic boards are individually tested with digital oscilloscopes and the data recorded. An automated PMT tester is used for testing the 400+ tubes. Uniformity tests use an ultraviolet laser. Calibration is performed using a laser or LED system.

Construction/Fabrication

Scintillators are machined into supertiles at Fermilab. After cosmic ray testing, supertiles are shipped to UTA. Fibers are spliced, tested, connectorized and polished at UTA. Ribbon cables are manufactured and connectorized. Students assemble and test the ICD boxes. The drawers are machined locally. Electronics boards are assembled by sub-contractors. The final drawer system is assembled and tested at UTA before shipment to Fermilab for installation.

Testing/Commissioning

All ICD modules and readout drawers are tested at UTA before shipment to Fermilab. They are cosmic ray tested at Fermilab on the bench. After installation, they are cosmic ray tested and commissioned with the rest of the calorimeter.

Schedule Milestones

The milestones for the Calorimeter Intercryostat Detector sub-project are given in the table below. M1, M2, and M3 identify milestones held by the DoE, the Fermilab Directorate, and the Upgrade Project managers, respectively.

ID	Milestones-Intercryostat Detector	Date
10	M3-ICD TDR Submitted	1-Apr-97
19	First Prototype Tested	28-Apr-97
26	M3-ICD Full Prototype Tested	2-Oct-97
60	Start Drawer Fabrication	30-Oct-97
35	Start Tile Module Fabrication	13-Nov-97
64	Begin Testing Boards	6-Apr-98
42	M3-20% ICD Tile Modules Tested	23-Apr-98
67	20% Readout Tested	10-Jun-98
49	25% Cables/Connectors Tested	9-Jul-98
56	Fiber Backplane Ready	23-Sep-98
68	Drawers Ready	26-Oct-98
40	Tile Modules Assembled	4-Nov-98
50	Fiber Cables Completed	13-Nov-98
43	M3-ICD Tile Modules Ready	15-Jan-99
79	ICD Crate Ready	26-Feb-99
82	M2-ICD Arrives At Fermilab	12-Mar-99
69	M3-Intercryostat Detector-North Installed/Hooked Up	26-Mar-99

Manpower Plan

The manpower plan for the Intercryostat Detector sub-project is given in the table below. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	Intercryostat Detector					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Electrical Engineer (F)			0.0			0.0
Mechanical Technician (F)	0.0	0.1	0.4	0.1		0.6
Sub-Total (F)	0.0	0.1	0.5	0.1		0.7
Electrical Engineer (U)		0.1				0.1
Mechanical Engineer (U)	0.4	0.3				0.7
Mechanical Technician (U)	0.3	1.1	2.1	0.4		3.8
Sub-Total (U)	0.6	1.5	2.1	0.4		4.6
Total	0.7	1.6	2.5	0.5		5.2

Cost Estimate

The cost estimate for the ICD is shown in the accompanying table. In most cases we include 10% spares. Contingency is typically 10% to 20% and is assigned based on the criteria in section 7.1.2.

WBS 1.2.2 INTERCRYOSTAT DETECTOR

WBS	ITEM	MATERIALS & SERVICES (M&S)				CONTINGENCY		
1.2.2	INTERCRYOSTAT DETECTOR	Unit	#	Unit Cost	M&S TOTAL	%	Cost	TOTAL Cost
1.2.2.1	***Engineering and design***				5,000	10	500	5,500
1.2.2.1.1	Second Protoype	lot	1	5,000	5,000	10	500	5,500
1.2.2.2	***Scintillator Modules***				68,632	14	9,440	78,072
1.2.2.2.1	Module design	lot	1	4,641	4,641	0	0	4,641
1.2.2.2.2	Scintillator	sheet	40	682	27,280	25	6,820	34,100
1.2.2.2.3	WLS Fiber	m	225	2.23	502	20	100	602
1.2.2.2.4	Clear Fiber	m	300	1.87	561	20	112	673
1.2.2.2.5	Fiber Splicer	ea	1	8,641	8,641	10	864	9,505
1.2.2.2.6	Fiber Tester	ea	1	4,438	4,438	10	444	4,882
1.2.2.2.7	Connectors	ea	114	23.42	2,670	10	267	2,937
1.2.2.2.8	Other Supplies	lot	1	1,000	1,000	10	100	1,100
1.2.2.2.9	Module Assembly	ea	38	304.69	11,578	0	0	11,578
1.2.2.2.10	Cosmic Ray Testing				7,322	10	732	8,054
1.2.2.2.10.1	CR Teststands	ea	2	2,117	4,234	10	423	4,657
1.2.2.2.10.2	CR Testing	module	38	81.25	3,088	10	309	3,396
1.2.2.3	***Fiber System***				53,211	11	5,605	58,815
1.2.2.3.1	Fiber System Design	lot	1	4,641	4,641	10	464	5,105
1.2.2.3.2	Fiber Ribbons				30,539	11	3,250	33,789
1.2.2.3.2.1	Fiber	m	1260	1.56	1,966	20	393	2,359
1.2.2.3.2.2	Ribbon Construction	ea	114	140	15,960	10	1,596	17,556
1.2.2.3.2.3	Connectors	ea	228	24.62	5,613	10	561	6,175
1.2.2.3.2.4	Connector Polisher	ea	1	7,000	7,000	10	700	7,700
1.2.2.3.3	Fiber Backplane				18,031	10	1,890	19,921
1.2.2.3.3.1	Fibers	m	1600	1.56	2,496	20	499	2,995
1.2.2.3.3.2	Cookies	ea	434	5.58	2,422	10	242	2,664
1.2.2.3.3.3	Connectors	ea	114	92	10,488	10	1,049	11,537
1.2.2.3.3.4	Fiber Routing	ea	4	406.25	1,625	0	0	1,625
1.2.2.3.3.5	Enclosures	ea	4	250	1,000	10	100	1,100
1.2.2.4	***Drawer System***				67,683	16	10,859	78,542
1.2.2.4.1	Drawer Design	ea	1	4,331	4,331	10	433	4,764
1.2.2.4.2	Drawers	ea	76	410	31,160	20	6,232	37,392
1.2.2.4.3	Connectors	ea	76	15	1,140	10	114	1,254
1.2.2.4.4	Electronics Design	lot	1	4,641	4,641	10	464	5,105
1.2.2.4.5	Motherboards	ea	76	121	9,168	20	1,834	11,001
1.2.2.4.6	HV Bases	ea	184	10	1,840	10	184	2,024
1.2.2.4.7	Electronics Testing	ch	434	10	4,408	10	441	4,849
1.2.2.4.8	Drawer Assembly	ea	76	137	10,420	10	1,042	11,462
1.2.2.4.9	Temperature Sensors	ea	19	30	576	20	115	691

WBS	1.2.2	INTERCRYOSTAT DETECTOR						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.2.2	**INTERCRYOSTAT DETECTOR**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.2.2.5	***Crate System***				30,124	15	4,544	34,667
1.2.2.5.1	Crate Design	ea	1	4,331	4,331	10	433	4,764
1.2.2.5.2	Crates	ea	4	1,580	6,320	10	632	6,952
1.2.2.5.3	Steel Blocks	ea	4	1,040	4,160	10	416	4,576
1.2.2.5.4	Pulser/LVPS Boards	ea	4	1,764	7,056	20	1,411	8,468
1.2.2.5.5	Cooling System	ea	4	2,064	8,256	20	1,651	9,908
1.2.2.6	***PMT System***				35,950	10	3,595	39,545
1.2.2.6.1	PMT Holders	ea	434	46	19,964	10	1,996	21,960
1.2.2.6.2	PMT sockets	ea	434	5	2,170	10	217	2,387
1.2.2.6.3	PMT testing				13,816	10	1,382	15,197
1.2.2.6.3.1	PMT Teststand	lot	1	5,000	5,000	10	500	5,500
1.2.2.6.3.2	PMT Testing	ea	434	20.31	8,816	10	882	9,697
1.2.2.7	***Calibration System***				16,094	16	2,609	18,703
1.2.2.7.1	Laser Calibration Design	lot	1	6,094	6,094	10	609	6,703
1.2.2.7.2	Hardware	lot	1	10,000	10,000	20	2,000	12,000
1.2.2.8	***Cabling***				11,235	17	1,943	13,178
1.2.2.8.1	Pulser Cables	ea	152	20	3,040	20	608	3,648
1.2.2.8.2	LVPS Cables	ea	76	25	1,900	20	380	2,280
1.2.2.8.3	HVPS Cables	ea	217	15	3,255	20	651	3,906
1.2.2.8.4	Signal Cables	ea	152	20	3,040	10	304	3,344
1.2.2.9	***Shipping***	lot	1	5,000	5,000	10	500	5,500
1.2.2.10	***Installation***				3,670	10	367	4,036
1.2.2.10.1	Support Design	ea	1	1,547	1,547	10	155	1,702
1.2.2.10.2	Install Boxes & Drawers	ea	38	56	2,123	10	212	2,335
1.2.2.11	***Commissioning***	lot	1	4,875	4,875	10	488	5,363
1.2.2	TOTAL INTERCRYOSTAT DETECTOR				301,473	13	40,448	341,922

10.9 Muon Central Trigger Detectors

Objectives and Performance Criteria

Objectives of the Muon Central Trigger Detectors include:

- Identifying and triggering on interactions containing one or more high-p_t muons and two or more low-p_t muons;
- Providing a soft muon tag for b-jet identification;
- Measuring the muon momentum and charge independent of the central fiber tracker;
- Sending sufficient information to the Level 1 muon trigger to enable an unprescaled high p_t muon trigger at a luminosity of $2x10^{32}$ cm^{-2} sec^{-1};
- A WAMUS PDT momentum resolution of $d(1/p)/(1/p)=sqrt[0.18^2+(0.003p)^2]$
- Providing CMSC-A scintillator time resolution of 4 nsec at the trigger level and 1.5 nsec after muon reconstruction;
- Providing detection efficiency > 98%.

Detailed descriptions of the designs of the detectors are available in DØ Notes 2780, 2894 and references therein.

Components

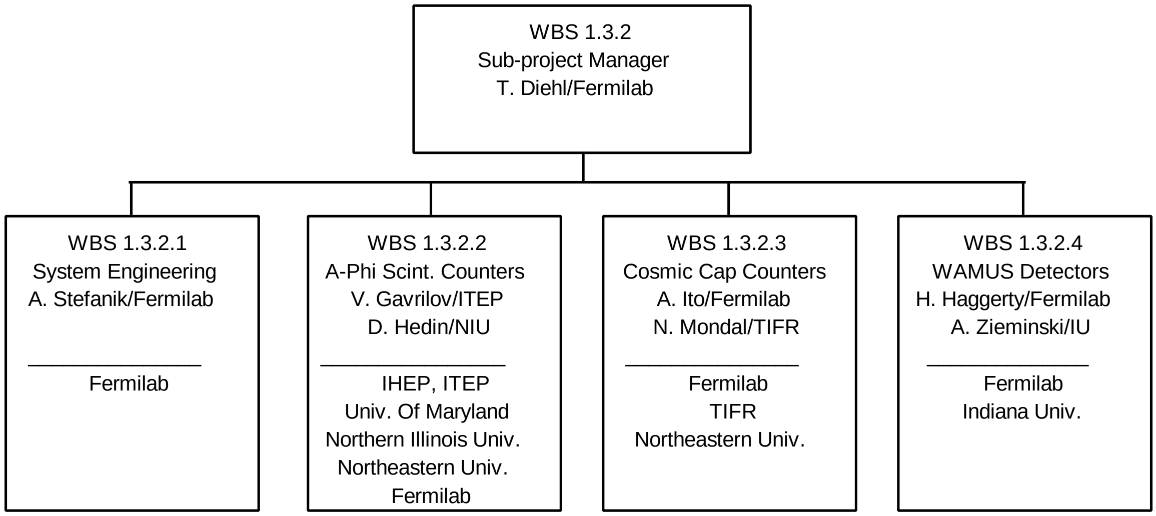
Major Components of the Muon Central Trigger Detectors are:

- Three layers of large-cell drift chambers (WAMUS PDTs);
- A layer of scintillation counters between the calorimeter and first layer of WAMUS;
- A layer of scintillation counters (cosmic cap) outside the last layer of WAMUS.

Management, Organization, and Responsibilities

The institutions participating in the Muon Central Trigger Detector project are Fermilab, University of Indiana, Institute for High Energy Physics (IHEP), Institute for Theoretical and Experimental Physics (ITEP), University of Maryland, Northeastern University, Northern Illinois University, and the Tata Institute for Fundamental Research (TIFR). The sub-project manager is Thomas Diehl (Fermilab). There are a number of subgroups charged with development, construction, and testing various elements of the detectors. The subgroup organization and leadership is shown on the accompanying chart. Engineering and equipment-intensive work such as mechanical design and final detector assembly and mounting is centered at Fermilab. Counter construction and detector testing occurs at TIFR, ITEP, and NIU. Work is coordinated during weekly Fermilab group meetings, monthly group meetings, and extensive electronic communication. Detailed minutes of the weekly meetings and announcements are transmitted on the Internet and via “DØ News”. The group also maintains a World Wide Web page which contains information and documentation of the project.

Muon Central Trigger Detectors Sub-project Organization



Work Plan

Engineering/Design

WAMUS PDTs and 75% of the outer layer of scintillation counters were an integral part of the DØ detector during Run I. Therefore, the new components of the detector require only a moderate level of engineering for successful design. Most of this engineering is provided by Fermilab and managed in the detector subgroups. The mechanical engineering and design is provided via the DØ Project. Physicists provide the initial detector design simulations and specifications. The areas of greatest mechanical engineering effort are the design of the CMSC-A counters and case, and the installation of these counters in the limited space available.

Procurement

Major procurement items are 1) plastic scintillator, 2) wave-shifter fiber and, 3) photomultiplier tubes. Vendors are selected based on competitive bidding and technical ability.

Inspection

All components are inspected on arrival to ensure that specifications are met. Each detector module has a traveler which includes information on each stage of inspection and testing. Scintillation counters are built and tested at TIFR, ITEP, and Fermilab/NIU. For the scintillation counters, the inspection includes tests of light-yield, uniformity, and time resolution. Results are stored in the travelers. Initial testing of the photomultiplier tubes and bases takes place at MELZ and IHEP, respectively. Final checks are performed at Fermilab. Results of all tests are stored in the travelers and in databases.

Construction/Fabrication

For the new scintillation counters, construction stages include: 1) scintillator grooving, 2) fiber cutting and initial counter assembly, and 3) final counter assembly. The scintillator grooving occurs primarily at Fermilab, with contributions from TIFR and ITEP. Construction operations are supervised by DØ physicists.

Testing/Commissioning

Once the detectors are installed they will be carefully commissioned. We have experience operating the Run I WAMUS system as well as 75% of the outer layer of scintillation counters. However, both systems will have new electronics which must be commissioned for Run II. We will ensure that the monitoring and support systems, including high-voltage, gas flow and pressure, low-voltage power for the electronics, and communications, are functioning within specifications. We also will ensure that the electronics operates properly and that the detectors correctly identify cosmic ray muons. We will use pulsers to calibrate the electronics and verify that it is operating. Lastly, we will cross-check the system by detecting and monitoring the muons produced by the collisions.

Schedule Milestones

The milestones for the Muon Central Trigger Detectors sub-project are given in the table below. M1, M2, and M3 identify milestones held by the DoE, the Fermilab Directorate, and the Upgrade Project managers, respectively.

ID	Milestones-Muon Central Detectors	Date
17	Design Work Finished	27-Feb-97
3	M3-Muon Central Detector TDR Submitted	24-Mar-97
55	M3-First Muon CFA Counter Assembled	23-May-97
93	M3-Deck PDT's Modified	10-Jun-97
122	Shield Design Finalized	23-Jul-97
9	CFB Counters at Fermilab	7-Aug-97
57	Muon CFA Assembly 10% Complete	3-Sep-97
116	M3- Muon Cosmic Calibration System Complete	6-Nov-97
33	Assembly & Test At TIFR Complete	4-Dec-97
125	Shielding Fabricated	4-Feb-98
62	M3-Muon CFA Assembly 50% Complete	16-Apr-98
99	PDT HV Testing Complete	19-May-98
64	Assembly & Test Complete	3-Nov-98
107	M3-10% of Muon PDTs Commissioned	6-Nov-98
80	10% of CFA Commissioned	1-Dec-98
82	M3-Muon CFA Installation Complete	9-Mar-99
84	CFA Commissioning Complete	10-Sep-99
110	PDT Commissioning Complete	16-Sep-99

Manpower Plan

The manpower plan for the Muon Central Trigger Detectors sub-project is given in the table below. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	Muon Central Detectors					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Designer (F)	0.3	1.6				1.9
Electrical Technician (F)			0.3			0.3
Mechanical Engineer (F)	0.0	0.2	0.0			0.2
Mechanical Technician (F)	0.1	5.1	5.4	3.8		14.4
Sub-Total (F)	0.4	6.9	5.8	3.8		16.9
Mechanical Technician (U)	1.4	3.1	2.3	0.1		6.9
Sub-Total (U)	1.4	3.1	2.3	0.1		6.9
Total	1.8	10.0	8.1	3.9		23.8

Cost Estimate

The cost estimate for the Muon Central Trigger Detectors is shown in the accompanying table. In most cases we include 10% spares for scintillation counters and 10% spares for associated electronics. Contingency is typically 10% and is assigned based on the criteria in section 7.1.2.

WBS 1.3.2 CENTRAL TRIGGER DETECTORS

WBS	ITEM	MATERIALS & SERVICES (M&S)				CONTINGENCY		
1.3.2	CENTRAL TRIGGER DETECTORS	Unit	#	Unit Cost	M&S TOTAL	%	Cost	TOTAL Cost
1.3.2.1	*Engineering design*				0	25	0	0
1.3.2.2	*A-phi Counters*				532,352	9	48,410	580,761
1.3.2.2.1	Purchase scintillator (cut &polish, .5")	sq-ft	2080	65	135,200	2	2,704	137,904
1.3.2.2.2	Machining Scintillator	ea	693	30	20,790	10	2,079	22,869
1.3.2.2.3	Waveshifter Fiber G2	km	50	500	25,000	15	3,750	28,750
1.3.2.2.4	Phototubes (1" 115M)	ea	693	50	34,650	2	693	35,343
1.3.2.2.5	Phototube bases (assembled)	ea	693	25	17,325	10	1,733	19,058
1.3.2.2.6	Magnetic shields	ea	658	40	26,334	20	5,267	31,601
1.3.2.2.7	Counter Case	ea	693	75	51,975	10	5,198	57,173
1.3.2.2.8	HV Fanout box 1	ea	43	1,203	51,729	10	5,173	56,902
1.3.2.2.9	HV Fanout box 2	ea	43	924	39,732	10	3,973	43,705
1.3.2.2.10	Scintillator frame and support	ea	8	3,500	28,000	20	5,600	33,600
1.3.2.2.11	Calibration system	ea	693	30	20,790	20	4,158	24,948
1.3.2.2.12	HV cable	ea	693	31.70	21,968	10	2,197	24,165
1.3.2.2.13	Signal cable	ea	693	11.34	7,859	10	786	8,644
1.3.2.2.14	Glues/bits/tapes	lot	1	5,000	5,000	10	500	5,500
1.3.2.2.15	Polyethylene Shields	ea	2	16,000	32,000	10	3,200	35,200
1.3.2.2.16	Polyethylene Shield Mounting Frames	ea	2	2,000	4,000	10	400	4,400
1.3.2.2.17	Assembly at ITEP	lot	1	10,000	10,000	10	1,000	11,000
1.3.2.3	*Cosmic Cap and Bottom Counters*				280,987	9	26,656	307,643
1.3.2.3.1	Scintillator	sq-ft	885	65	57,525	10	5,753	63,278
1.3.2.3.2	Scintillator machining	ea	88	40	3,520	10	352	3,872
1.3.2.3.3	Scintillating machining jig	ea	1	25,000	25,000	0	0	25,000
1.3.2.3.4	Scintillating fiber (Bicron 91A)	km	75	500	37,500	10	3,750	41,250
1.3.2.3.5	Phototubes (1" 115M)	ea	176	50	8,800	10	880	9,680
1.3.2.3.6	Phototube bases (assembled)	ea	176	25	4,400	10	440	4,840
1.3.2.3.7	Magnetic shields	ea	167	40	6,688	20	1,338	8,026
1.3.2.3.8	Counter frame and case	ea	134	115	15,410	10	1,541	16,951
1.3.2.3.9	HV Fanout box 1	ea	18	1,203	21,654	10	2,165	23,819
1.3.2.3.10	HV Fanout box 2	ea	12	924	11,088	10	1,109	12,197
1.3.2.3.11	HV cable	ea	268	31.70	8,496	10	850	9,345
1.3.2.3.12	Signal cable	ea	796	11.34	9,027	10	903	9,929
1.3.2.3.13	Calibration System	ea	796	30	23,880	20	4,776	28,656
1.3.2.3.14	Glues/bits/tapes	lot	1	5,000	5,000	10	500	5,500
1.3.2.3.15	Counter Assembly at TIFR	lot	1	20,000	20,000	0	0	20,000
1.3.2.3.16	Shipping Counters from TIFR	lot	1	15,000	15,000	10	1,500	16,500
1.3.2.3.17	Shipping Counters to TIFR	lot	1	8,000	8,000	10	800	8,800
1.3.2.4	*Cable, Power Supplies*				168,148	15	24,405	192,553

WBS	**1.3.2**	**CENTRAL TRIGGER DETECTORS**						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.3.2	**CENTRAL TRIGGER DETECTORS**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.3.2.4.1	Reterminate Astro cables				17,098	20	3,420	20,518
1.3.2.4.1.1	Connector	lot	1	5,328	5,328	20	1,066	6,394
1.3.2.4.1.2	Additional Astro cable	lot	1	7,770	7,770	20	1,554	9,324
1.3.2.4.1.3	Cable termination	lot	1	3,000	3,000	20	600	3,600
1.3.2.4.1.4	Tooling	lot	1	1,000	1,000	20	200	1,200
1.3.2.4.2	New Signal Cable	lot	1	40,000	40,000	20	8,000	48,000
1.3.2.4.3	Modify Electronics Mounts	ea	94	200	18,800	20	3,760	22,560
1.3.2.4.4	Data/1553 cables/connectors	lot	4	10,000	40,000	10	4,000	44,000
1.3.2.4.5	Refurbish LVPS	ea	110	275	30,250	10	3,025	33,275
1.3.2.4.6	New 3/5V LV PS	ea	220	100	22,000	10	2,200	24,200
1.3.2	TOTAL CENTRAL TRIGGER DETECTORS				981,487	10	99,470	1,080,957

10.10 Muon Forward Trigger Detectors

Objectives and Performance Criteria

The objectives of the Muon Trigger System include:

- Identifying and triggering on interactions containing one or more high p_t muons and two or more low p_t muons;
- Providing detection efficiency of > 98%;
- Sending sufficient information to the Level 1 muon trigger to enable an unprescaled high p_t muon trigger at a luminosity of $2x10^{32}$ cm^{-2} sec^{-1};
- Providing time resolution of 4 nsec at the trigger level and 1.5 nsec after muon reconstruction;
- Working in magnetic fields up to 400 Gauss.

A detailed description of the design and performance objectives for the detector is contained in the DØ Muon System Upgrade Proposal, DØ note 2780.

Components

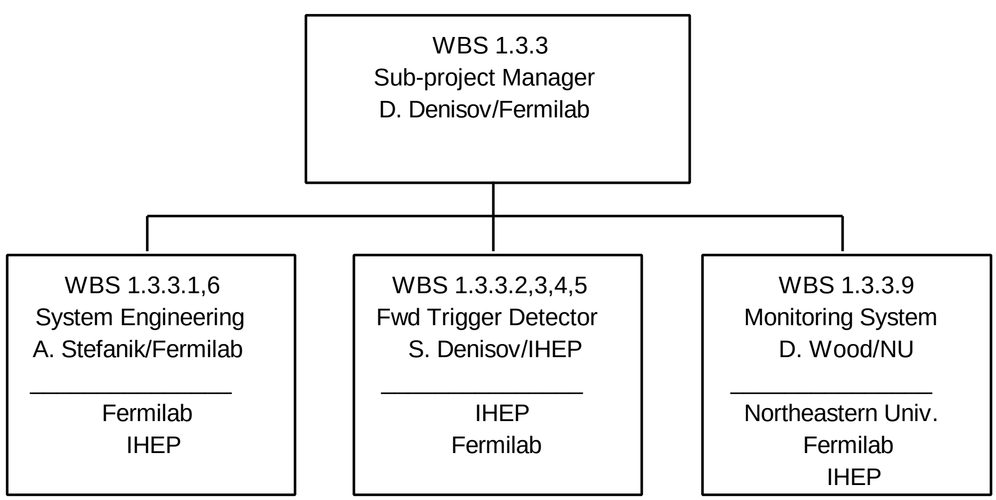
The major components are three planes of pixel scintillation counters located on each end of the DØ detector. There are a total of 4838 counters. Each counter uses one phototube and one phototube base.

Management, Organization, and Responsibilities

The institutions participating in the Forward Muon Trigger Detector project are the Institute for High Energy Physics (IHEP), Fermilab, and Northeastern University. The sub-project manager is Dmitri Denisov of Fermilab. The organization is shown on the accompanying chart.

The counter design, production, and testing is performed at IHEP. Engineering of the support structures, installation, and commissioning is performed at Fermilab. Work is coordinated by the forward muon system sub-project manager through weekly muon upgrade meetings and extensive electronic communications. Meeting minutes are distributed via the "DØ News" network and filed at Fermilab. The group also supports a WWW page with up-to-date information on system parameters and design status.

Muon Forward Trigger Detectors Sub-project Organization



Work Plan

Engineering/Design

The forward trigger counters are designed and produced at IHEP. The counter sizes range from 10 x 15 cm^2 to 80 x 120 cm^2. The design and production of the octant assembly and octant support structures are the responsibility of Fermilab engineers. The critical design issues are minimization of dead regions and access to the photomultiplier tubes (PMTs) and bases..

Major areas of electrical engineering include: 1) design of bases for photomultipliers and 2) digitization and readout electronics. The former is performed at IHEP which also produces the bases. The latter is the responsibility of Fermilab engineers and is covered in the muon electronics section.

Procurement

Major procurement items are 1) scintillator 2) wavelength shifter 3) phototubes 4) bases (IHEP) 5) magnetic shields (IHEP) 6) cables and connectors. In most cases we have estimates from vendors of final costs.

Inspection

Inspection is a major part of the scintillation counter production effort. All components are inspected upon arrival before their final assembly. All phototubes are inspected at the factory by a IHEP representative before shipment to Fermilab. Special databases are created in order to keep track of each detector element's production and test status.

There are two major test laboratories. One is at IHEP where counters are tested after assembly before their shipment to Fermilab. A second one is at Fermilab where final assemblies are extensively tested.

The major tests of individual counters include noise studies, muon detection efficiency (using radioactive sources and cosmic ray muons), time resolution and uniformity. The operating voltage for each phototube is determined and stored in a central database maintained at Fermilab.

Construction/Fabrication

Construction stages include: 1) scintillator machining 2) wavelength shifter preparation 3) magnetic shield and base production 4) counter assembly 5) shipment of the counters to Fermilab 6) construction of mechanical supports 7) installation of counters into octant supports 8) installation of octants into the detector.

Items 1 through 5 are done at IHEP by IHEP technicians and physicists. Items 6 through 8 are done at Fermilab by IHEP and Fermilab groups.

Testing/Commissioning

Batches of MELZ phototubes, IHEP PMT bases, and Bicron scintillator and wavelength shifter are tested to ensure that they satisfy the performance criteria. IHEP and Fermilab have performed extensive tests of forward trigger counter prototypes. Forward trigger counters received from IHEP are tested briefly with a radioactive source before being installed into octants. A prototype octant will be assembled to test and evaluate the structural design. Once an octant has been assembled, more extensive tests using cosmic rays will be performed. These tests will continue once octants are assembled onto the detector supports

All detector sub-systems (high voltage, front-end electronics, on-line software, etc.) will be tested before operation and we will use the startup period for the final adjustment of parameters.

Schedule Milestones

The milestones for the Muon Forward Trigger Detectors sub-project are given in the table below. M1, M2, and M3 identify milestones held by the DoE, the Fermilab Directorate, and the Upgrade Project managers, respectively.

ID	Milestones- Muon Forward Trigger Detectors	Date
3	M3-Muon Forward Trigger Detector TDR Submitted	1-Apr-97
39	Safety Review	9-May-97
24	Begin Counter Assembly	16-Jun-97
25	M2-Forward Trigger Counter Assembly 10% Complete	22-Sep-97
44	Prototype Octant Assembled	11-Feb-98
26	Assembly Of 50% Of Counters Complete	25-Mar-98
49	M3-Muon Forward Trigger Detector Octant Assembly Begun	21-May-98
64	M3-Muon Forward Trigger Detector A-Layer Planes Installed	17-Nov-98
69	B-Layer North Plane Installed	6-Jan-99
30	M3-All Muon Forward Trigger Detector Modules at Fermilab	10-Feb-99
74	M3-Muon Forward Trigger Detector C-Layer Planes Ready	20-May-99
52	All Octants Assembled	17-Jun-99
80	B-Layer South Plane Installed	4-Oct-99
82	Pixel Commissioning Complete	2-Nov-99

Manpower Plan

The manpower plan for the Muon Forward Trigger Detectors sub-project is given in the table below. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	Muon Forward Trigger Detectors					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Designer (F)	0.2	2.1	0.3			2.5
Electrical Engineer (F)		0.3				0.3
Electrical Technician (F)			1.2	0.9	0.0	2.0
Mechanical Engineer (F)	0.1	0.8	0.1	0.1		1.0
Mechanical Technician (F)		1.4	2.5	4.5	0.0	8.5
Sub-Total (F)	0.3	4.6	4.1	5.5	0.0	14.4
Designer (U)		0.3				0.3
Electrical Engineer (U)		0.1	0.4	0.0	0.0	0.6
Electrical Technician (U)		3.3	0.9	1.0	0.0	5.2
Mechanical Engineer (U)		0.5				0.5
Mechanical Technician (U)		9.9	14.5	1.7		26.1
Sub-Total (U)		14.1	15.8	2.7	0.0	32.7
Total	0.3	18.7	19.8	8.2	0.0	47.0

Cost Estimate

The cost estimate for the forward muon trigger counters is shown in the accompanying table. We include 20% spares for complex detector elements (phototubes, for example) and 5% for simple parts (soft steel magnetic shields, for example). Contingency is assigned based on the criteria of section 7.1.2 and is typically 15%.

WBS 1.3.3 FORWARD TRIGGER DETECTOR

WBS	ITEM	MATERIALS & SERVICES (M&S)				CONTINGENCY		
1.3.3	FORWARD TRIGGER DETECTOR	Unit	#	Unit Cost	M&S TOTAL	%	Cost	TOTAL Cost
1.3.3.1	***Engineering design***				0	25	0	0
1.3.3.2	***Scintillator***	m2	525	750	393,750	10	39,375	433,125
1.3.3.3	***Wave-shifter Bars***	ea	9677	7.50	72,576	20	14,515	87,091
1.3.3.4	***Phototube System***				556,416	13	74,995	631,411
1.3.3.4.1	Phototubes (1", Meltz)	ea	4838	50	241,920	10	24,192	266,112
1.3.3.4.2	Phototube Bases				120,960	10	12,096	133,056
1.3.3.4.2.1	Socket	ea	4838	5.50	26,611	10	2,661	29,272
1.3.3.4.2.2	High Voltage Connector	ea	4838	3	14,515	10	1,452	15,967
1.3.3.4.2.3	Signal BNC Connector	ea	4838	3.50	16,934	10	1,693	18,628
1.3.3.4.2.4	Resistors	ea	4838	13	62,899	10	6,290	69,189
1.3.3.4.3	Magnetic Shields				193,536	20	38,707	232,243
1.3.3.4.3.1	Soft Steel Shield	ea	4838	25	120,960	20	24,192	145,152
1.3.3.4.3.2	Mu-metal Shield	ea	4838	10	48,384	20	9,677	58,061
1.3.3.4.3.3	Assembly Parts	ea	9677	2.50	24,192	20	4,838	29,030
1.3.3.5	***Counter Packaging***				145,960	20	29,192	175,152
1.3.3.5.1	Light Tight Counter Package	ea	4838	25	120,960	20	24,192	145,152
1.3.3.5.2	Wrapping Materials	lot	1	15,000	15,000	20	3,000	18,000
1.3.3.5.3	Support Frames	lot	1	10,000	10,000	20	2,000	12,000
1.3.3.6	***Mechanical Supports***				192,000	20	38,400	230,400
1.3.3.6.1	Major Support Structures	ea	48	1,100	52,800	20	10,560	63,360
1.3.3.6.2	Octants for Counter Installation	ea	48	2,900	139,200	20	27,840	167,040
1.3.3.7	***Signal Cables***				54,867	10	5,487	60,354
1.3.3.7.1	Coax RG58 Cables	ea	4838	4.75	22,982	10	2,298	25,281
1.3.3.7.2	BNC Connectors	ea	4838	2.63	12,725	10	1,272	13,997
1.3.3.7.3	Lemo Connectors	ea	4838	3.96	19,160	10	1,916	21,076
1.3.3.8	***High Voltage System***				118,528	20	23,706	142,234
1.3.3.8.1	Coax RG58 Cable	ea	4838	4.75	22,982	20	4,596	27,579
1.3.3.8.2	SHV Connectors	ea	9677	4.19	40,546	20	8,109	48,655
1.3.3.8.3	HV Fanout Box	ea	48	1,000	48,000	20	9,600	57,600
1.3.3.8.4	Other Parts	lot	1	7,000	7,000	20	1,400	8,400
1.3.3.9	***Monitoring System***				145,142	20	29,028	174,171

WBS	**1.3.3**	**FORWARD TRIGGER DETECTOR**						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.3.3	**FORWARD TRIGGER DETECTOR**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.3.3.9.1	Light Pulsers	ea	48	1,915	91,920	20	18,384	110,304
1.3.3.9.2	Clear Fiber Light Guides	ea	4838	7.50	36,288	20	7,258	43,546
1.3.3.9.3	Optical Connectors	ea	4838	3.50	16,934	20	3,387	20,321
1.3.3.10	***Testing & Shipping***				30,000	23	7,000	37,000
1.3.3.10.1	Test Fixtures	lot	1	10,000	10,000	20	2,000	12,000
1.3.3.10.2	Shipping	lot	1	20,000	20,000	25	5,000	25,000
1.3.3	TOTAL FORWARD TRIGGER DETECTOR				1,709,240	15	261,698	1,970,938

10.11 Muon Forward Tracking Detectors

Objectives and Performance Criteria

Objectives for the Forward Muon Tracking Detectors include:

- Identifying and triggering on interactions containing one or more high-p_t muons and two or more low-p_t muons;
- Measuring the muon momentum and charge independent of the central fiber tracker;
- Providing momentum resolution of $d(1/p)/(1/p)=sqrt[0.19^2 + (0.002p)^2]$;
- Providing detection efficiency of > 95%;
- Sending sufficient information to the Level 1 muon trigger to enable an unprescaled high p_t muon trigger at a luminosity of $2x10^{32}$ cm^{-2} sec^{-1}.

A detailed description of the design and performance objectives for the detector is contained in the DØ Muon System Upgrade Proposal, DØ note 2780.

Components

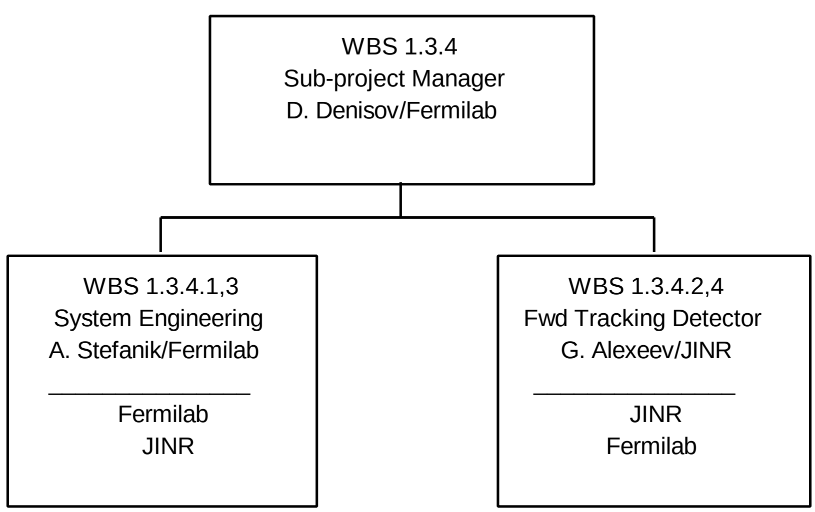
The major components are three planes of mini-drift tubes located on each end of the DØ detector. There are a total of 50,400 channels which are implemented as 6300 eight 1 cm x 1 cm cell modules.

Management, Organization, and Responsibilities

The institutions participating in the Forward Muon Tracking Detector project are JINR (Dubna) and Fermilab. The sub-project manager is Dmitri Denisov of Fermilab. The organization is shown on the accompanying chart. The mini-drift tube design, production, and testing is performed at JINR. Engineering of the support structures, installation and commissioning is performed at Fermilab.

Work is coordinated through weekly muon upgrade meetings and extensive electronic communication. Meeting agendas and minutes are distributed via the “DØ News” network and are filed at Fermilab. The group also supports a WWW page with up-to-date information on system parameters and design status.

Muon Forward Tracking Detector Sub-project Organization



Work Plan

Engineering/Design

The forward tracking detectors are designed and produced at JINR. The critical design issue is the fabrication of the eight cell mini-drift tube. The design and production of the octant assembly and octant support structures are the responsibility of Fermilab engineers. The critical design issues are alignment accuracy of the tubes and access to the amplifier-discriminator electronics.

Electrical engineering is used for the design and fabrication of amplifier/discriminator boards and digitization/readout electronics. Amplifier/discriminator boards are designed and produced at JINR. Digitization/readout electronics is designed and produced at Petersburg Nuclear Physics Institute (PNPI). These electronics are covered in the Muon Electronics Section.

Procurement

Major procurement items are: 1) MDT modules; 2) high voltage cables and connectors; 3) signal cables and connectors and; 4) octant assembly and support structures. Item 1 is produced at JINR. Apart from the MDT modules themselves, all system elements (cables, connectors, etc.) are very well known and identification of vendors is based on the best cost/performance ratio.

Inspection

Inspection is one of the major parts of the MDT modules production effort. All components are inspected upon arrival before MDT final assembly. Databases are used to keep track of each detector element's production and test status.

There are two major test laboratories. One at JINR where the MDT modules are fully tested after assembly and before shipping to Fermilab. Tests include gas leak checks, dark current measurements, and efficiency studies. A second test setup exists at Fermilab where MDTs assembled into octants are extensively tested using cosmic muons and radioactive sources. All high voltage and signal cables are checked before final installation using special test stands.

Construction/Fabrication

Construction stages include: 1) extrusion of MDT elements; 2) internal surface cleaning; 3) anode wire installation; 4) sealing of modules; 5) extensive tests of modules; 6) shipment of modules to FNAL; 7) manufacturing of support structures; 8) installation of MDT modules into octants; 9) installation of octants into the DØ detector. Items 1 through 6 are done at JINR by JINR technicians and physicists. Items 7 through 9 are done at Fermilab by JINR and Fermilab groups.

Testing/Commissioning

Extensive tests of prototype MDT modules have been carried out in the DØ collision hall, using Fermilab test beams and cosmic ray muons. MDT modules received from JINR will be tested for HV and gas integrity before being installed into octants. A prototype octant will be assembled to test and evaluate the structural design. Once an octant has been assembled, more extensive tests using cosmic ray muons and radioactive sources will be performed. These tests will continue once octants are assembled onto the detector supports.

All detector sub-systems (high voltage, front-end electronics, on-line software, etc.) will be exercised before Collider running and the startup period will be used for final adjustment of parameters.

Schedule Milestones

The milestones for the Muon Forward Tracking Detectors sub-project are given in the table below. M1, M2, and M3 identify milestones held by the DoE, the Fermilab Directorate, and the Upgrade Project managers, respectively.

ID	Milestones-Muon Forward Tracker	Date
3	M3-Muon Forward Tracker TDR Submitted	15-May-97
25	Safety Review	9-Jun-97
14	Full Scale Assembly Of MDT Started	3-Sep-97
17	M2-Muon Forward Tracker MDT Assembly 10% Complete	19-Nov-97
31	Prototype MDT Octant Assembled	11-Feb-98
18	M3-Muon Forward Tracker MDT Assembly 50% Complete	21-Apr-98
40	M3-Muon Forward Tracker Octant Assembly Begun	23-Apr-98
55	M3-Muon Forward Tracker A-Layer Planes Installed	20-Oct-98
20	M3-All Muon Forward Tracker MDT Modeules at Fermilab	9-Dec-98
60	B-Layer North Plane Installed	9-Dec-98
66	M3-Muon Forward Tracker C-Layer Planes Ready	6-May-99
47	All Octants Assembled	19-May-99
72	B-Layer South Plane Installed	20-Sep-99
74	MDT Commissioning Complete	12-Oct-99

Manpower Plan

The manpower plan for the Muon Forward Tracking Detectors sub-project is given in the table below. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	Muon Forward Tracking Detectors					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Designer (F)	0.2	1.4	0.2			1.8
Electrical Technician (F)			0.7	1.1		1.8
Mechanical Engineer (F)	0.1	0.7	0.2	0.1		1.0
Mechanical Technician (F)		0.7	7.4	4.2		12.4
Sub-Total (F)	0.3	2.8	8.5	5.4		16.9
Designer (U)	0.1	0.4				0.4
Electrical Engineer (U)			0.2	0.3		0.5
Electrical Technician (U)			0.5	0.9		1.4
Mechanical Engineer (U)	0.1	0.7	1.1	0.1		1.9
Mechanical Technician (U)	0.1	1.2	11.8	2.6		15.7
Sub-Total (U)	0.3	2.2	13.5	3.8		19.9
Total	0.6	5.0	22.0	9.2		36.8

Cost Estimate

The cost estimate for the forward muon tracking detectors is shown in the accompanying table. We include 20% spares for most of the detector elements. Contingency is assigned based on the criteria in section 7.1.2, and is typically 15-20%.

WBS 1.3.4 FORWARD TRACKING DETECTOR

WBS	ITEM	MATERIALS & SERVICES (M&S)				CONTINGENCY		
1.3.4	FORWARD TRACKING DETECTOR	Unit	#	Unit Cost	M&S TOTAL	%	Cost	TOTAL Cost
1.3.4.1	***Engineering design***				0	25	0	0
1.3.4.2	***Mini-Drift Tubes***				535,500	15	80,325	615,825
1.3.4.2.1	8-Cell Comb	ea	6300	25.50	160,650	15	24,098	184,748
1.3.4.2.2	Plastic Sleeve	ea	6300	6.84	43,092	15	6,464	49,556
1.3.4.2.3	Plastic Cover	ea	6300	3.30	20,790	15	3,119	23,909
1.3.4.2.4	End Cap	ea	12600	4.75	59,850	15	8,978	68,828
1.3.4.2.5	Wire Locks	ea	12600	3.45	43,470	15	6,521	49,991
1.3.4.2.6	Wire Supports	ea	25200	2.15	54,180	15	8,127	62,307
1.3.4.2.7	Gas Connectors	ea	12600	3.00	37,800	15	5,670	43,470
1.3.4.2.8	Anode Wire	km	151	140.00	21,168	15	3,175	24,343
1.3.4.2.9	High Voltage Connectors	ea	6300	6.50	40,950	15	6,143	47,093
1.3.4.2.10	Signal Connectors	ea	6300	8.50	53,550	15	8,033	61,583
1.3.4.3	***Mechanical Supports***				290,016	20	58,003	348,019
1.3.4.3.1	Main Support Structures	ea	48	1,100	52,800	20	10,560	63,360
1.3.4.3.2	Octants for Mini-Drift Tube Supports	ea	48	2,900	139,200	20	27,840	167,040
1.3.4.3.3	Polyethylene Spacers	ea	96	1,021	98,016	20	19,603	117,619
1.3.4.4	***Gas System***				50,640	20	10,128	60,768
1.3.4.4.1	Gas Lines	ea	96	95	9,120	20	1,824	10,944
1.3.4.4.2	Gas Connection/Monitoring Boxes	ea	48	240	11,520	20	2,304	13,824
1.3.4.4.3	Gas Monitoring Devices	ea	4	7,500	30,000	20	6,000	36,000
1.3.4.5	***Signal Cables***				94,469	20	18,894	113,362
1.3.4.5.1	Signal Flat Cables (ADB-MDC)	ea	1575	7.50	11,813	20	2,363	14,175
1.3.4.5.2	Connectors (ADB-MDC)	ea	1575	10.00	15,750	20	3,150	18,900
1.3.4.5.3	Signal Cables (MDT-ADB)	ea	6300	2.50	15,750	20	3,150	18,900
1.3.4.5.4	Connectors (MDT-ADB)	ea	6300	8.12	51,156	20	10,231	61,387
1.3.4.6	***High Voltage System***				157,437	20	31,487	188,924
1.3.4.6.1	HV Distribution Boards	ea	6300	10	63,000	20	12,600	75,600
1.3.4.6.2	HV Cables	ea	6300	5.25	33,075	20	6,615	39,690
1.3.4.6.3	Connectors	ea	12600	4.87	61,362	20	12,272	73,634
1.3.4.7	***Testing & Shipping***				30,000	23	7,000	37,000
1.3.4.7.1	Test Fixtures	lot	1	10,000	10,000	20	2,000	12,000
1.3.4.7.2	Shipping	lot	1	20,000	20,000	25	5,000	25,000
1.3.4	TOTAL FORWARD TRACKING DETECTOR				1,158,062	18	205,837	1,363,899

10.12 Muon Electronics

Objectives and Performance Criteria

Objectives of the muon electronics include:

- Discrimination and digitization of detector signals;
- Buffering, preprocessing and transfer of the digital data to Level 1, Level 2, and Level 3 trigger systems;
- Deadtimeless operation with 132 nsec bunch crossing time and 10 kHz Level 1 trigger rate;
- Minimal design complexity.

A general description of the muon electronics for Run II can be found in the article “DØ Upgrade Muon Electronics Design”, IEEE Trans. on Nucl. Science, Vol.42, No.4, August 1995, pp.736-742. Additional documentation can be found on the Muon Electronics WWW page.

Components

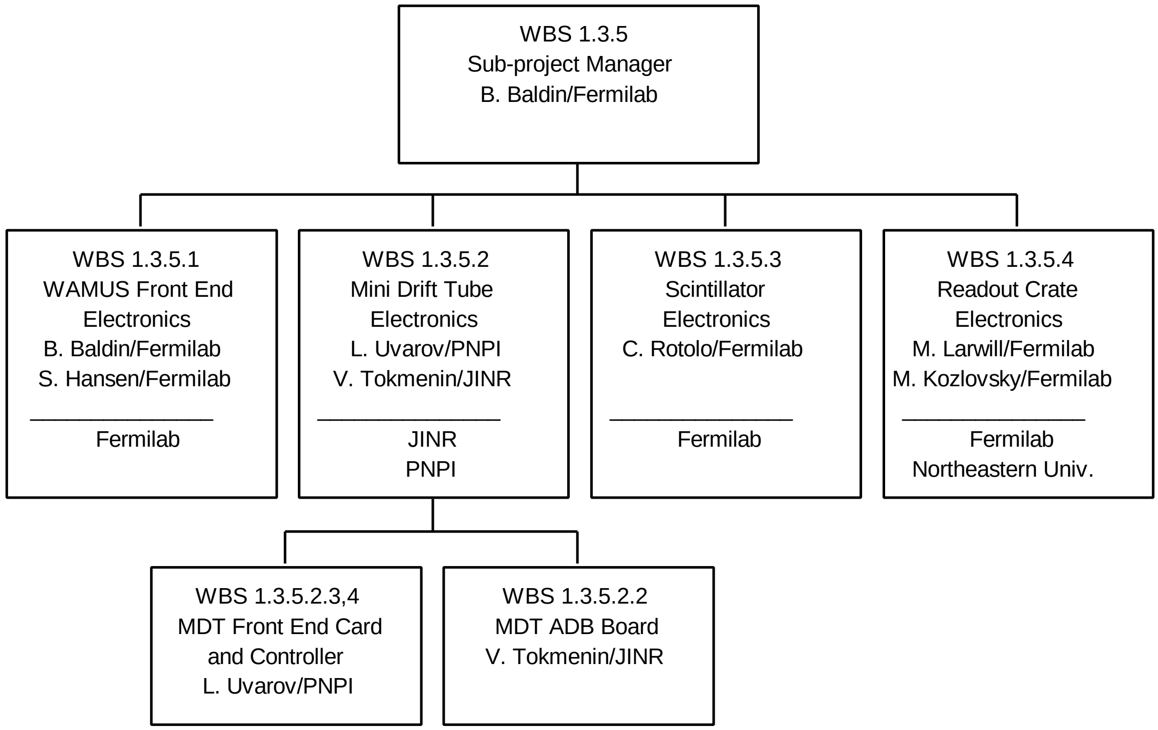
The major components for the muon system electronics include: 1) the front end boards and control boards for the Wide Angle Muon System (WAMUS); 2) Amplifier/discriminator boards, digitizer cards, and readout controllers for the Forward Angle Muon System (FAMUS) MDTs; 3) front end cards and readout controllers for WAMUS and FAMUS scintillators; 4) muon readout and fanout cards for readout and control of muon electronics; 5) VME microprocessors. The channel count for the WAMUS PDT electronics is approximately 9500. The channel count for the FAMUS FDT electronics is approximately 48,000. The channel count for the WAMUS and FAMUS scintillators is approximately 6000.

Management, Organization, and Responsibilities

The institutions currently participating in the Muon Electronics project are Fermilab, the Joint Institute for Nuclear Research (JINR), Northeastern University, and the Petersburg Nuclear Physics Institute (PNPI). The sub-project manager is Boris Baldin of Femilab. There are a number of subgroups charged with the design, fabrication, and testing of individual muon electronics cards or boards. The subgroup organization and leadership are shown on the accompanying chart.

The coordination of the design efforts is achieved by periodic muon electronics group meetings and reports of the results in muon upgrade meetings. Also, the initial R&D phase of the projects is done at Fermilab, which allows easy and fast communication between design engineers and creates a basis for continuation of the design work at home institutions. There are sections related to the electronics in the Muon Upgrade and Muon Electronics WWW pages. E-mail communications are very important and are used on an everyday basis.

Muon Front End Electronics Sub-project Organization



Work Plan

Engineering/Design

The conceptual design of all subsystems and initial R&D are done at Fermilab. The design and fabrication of the Amp/Disc boards for the mini-drift tubes are done at JINR. Design and prototype testing of the rest of the mini-drift tube electronics are done at PNPI. Production of all the muon electronics except Amp/Disc boards is done by US vendors since participating institutions cannot provide the proper level of SMD technology. All muon electronics subsystems are required to pass a design review by physicist and engineers. Testing and installation of the electronics are performed at Fermilab by visitors from participating institutions and Fermilab technical staff. The electronics design projects are:

- WAMUS HV Service Board
- WAMUS Delay/Jumper Board
- WAMUS Front End Board
- WAMUS Control Board
- Scintillator Digitizing Card
- Scintillator Control Card
- Mini-drift AD Board
- Mini-drift Digitizing Card
- Mini-drift Controller Card
- Muon Readout Card
- Muon Fanout Card
- Trigger Fanout Card

Cable plant refurbishing and new cable installation are done by the Fermilab technical staff. There is also a significant amount of work on software development, which is done by participating physicists.

Procurement

There are several procurement items related to this sub-project including components for various electronics modules, cables, and commercially available items like VME crates, power supplies and VME microprocessors. The analysis of the market is done during the preparation of the cost estimate and vendors for major part of the components are identified. A 10% channel subsystem test is used to confirm the system before final purchases.

Inspection

All electronics modules are tested using specially developed test stations at Fermilab. The tests include mechanical property checks, electrical property checks, and functional checks under software control. The Muon Group has accumulated expertise in remote software testing of electronics during Run I and is applying it toward the new electronics. Any deviation of parameters that may degrade electronics performance will be identified by the test station hardware and software systems.

Construction/Fabrication

There are two stages in fabrication of the muon electronics. The first is the fabrication, installation, and function verification of about 10% of the total electronics. Both tests with individual detectors and full system tests (readout) will be performed. The installation and testing is performed by Fermilab technical staff, and engineers and physicists from participating institutions. The second stage is the fabrication, installation and commissioning of the balance of the muon electronics.

Testing/Commissioning

After the 10% subsystem test, we will correct any problems found and begin fabrication, installation and commissioning of the full muon electronics system. This will be the most manpower intensive phase of the project and several months of continuous testing of the full system will be necessary to guarantee significant reliability during the run. The important part of these tests is the ability to simulate real collisions by cosmic ray muons. We will implement features in the hardware which allow effective use of the cosmic ray muons. Also, all electronics channels will be required to have appropriate test signals that allow simulation of real particles at any level.

Schedule Milestones

The milestones for the Muon Electronics sub-project are given in the table below. M1, M2, and M3 identify milestones held by the DoE, the Fermilab Directorate, and the Upgrade Project managers, respectively.

ID	Milestones-Muon Electronics	Date
3	M3-Muon Electronics TDR Submitted	1-Jun-97
18	FEB, CB Prototypes Complete	25-Jun-97
124	MRC, MFC Prototypes Complete	28-Aug-97
65	MDC, MDRC Prototypes Complete	10-Oct-97
88	SFE, SRC Prototypes Complete	18-Dec-97
89	M3-Muon Electronics Prototypes Complete	18-Dec-97
48	10% MDT ADB Fabricated	9-Feb-98
26	10% FEB, CB Electronics Fabricated	20-Apr-98
129	10% MRC, MFC Fabricated	26-May-98
51	MDT ADB Preproduction Testing Complete	2-Jun-98
70	10% MDC, MDRC Fabricated	9-Jun-98
102	10% SFE, SRC Fabricated	11-Jun-98
29	FEB, CB Preproduction Testing Complete	10-Sep-98
132	MRC, MFC Preproduction Testing Complete	17-Sep-98
73	MDC, MDRC Preproduction Testing Complete	1-Oct-98
105	SFE, SRC Preproduction Testing Complete	5-Oct-98
106	M2-Muon Electronics Preproduction Testing Complete	5-Oct-98
54	MDT ADB Fabrication Complete	19-Nov-98
135	MRC, MFC Production Complete	25-Jan-99
32	FEB, CB Production Complete	15-Feb-99
76	MDC, MDRC Fabrication Complete	8-Mar-99
109	SFE, SRC Fabrication Complete	10-Mar-99

Manpower Plan

The manpower plan for the Muon Electronics sub-project is given in the table below. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	Muon Electronics					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Electrical Engineer (F)	2.0	3.5	2.6	0.3	0.0	8.4
Electrical Technician (F)	0.7	4.5	6.6	2.8	0.0	14.6
Mechanical Technician (F)		0.9	2.9			3.8
Sub-Total (F)	2.7	8.9	12.0	3.2	0.0	26.8
Electrical Engineer (U)	2.2	2.3	0.6	0.1		5.1
Electrical Technician (U)	1.1	3.5	1.3	1.7	0.0	7.6
Sub-Total (U)	3.2	5.8	1.9	1.8	0.0	12.7
Total	6.0	14.6	13.9	5.0	0.1	39.5

Cost Estimate

The cost estimate for the muon electronics is shown in the accompanying table. In most cases 10% spares are included, except for the high volume mini-drift system, which includes 5% spares. Contingency is assumed to be 10% in most cases, following the criteria of section 7.1.2.

WBS 1.3.5 FRONT-END ELECTRONICS

WBS	ITEM	MATERIALS & SERVICES (M&S)				CONTINGENCY		
1.3.5	FRONT-END ELECTRONICS	Unit	#	Unit Cost	M&S TOTAL	%	Cost	TOTAL Cost
1.3.5.1	*WAMUS Front End Electronics*				909,201	11	96,365	1,005,566
1.3.5.1.1	Engineering design				0	20	0	0
1.3.5.1.2	Wamus Front-End boards (FEB)				676,802	10	64,746	741,548
1.3.5.1.2.1	Wire amplifier/discriminator parts				87,779	10	8,778	96,557
1.3.5.1.2.1.1	Diode (MMBD7000LT1)	ea	19008	0.14	2,661	10	266	2,927
1.3.5.1.2.1.2	Amplifier (UPC1669G)	ea	7603	1.97	14,978	10	1,498	16,476
1.3.5.1.2.1.3	Amplifier (HFA1105IR)	ea	7603	3.25	24,710	10	2,471	27,181
1.3.5.1.2.1.4	Discriminator (MAX913)	ea	7603	3.67	27,904	10	2,790	30,694
1.3.5.1.2.1.5	Connector (3M 34 pin)	ea	2376	4.32	10,264	10	1,026	11,291
1.3.5.1.2.1.6	SMD Resistor	ea	180576	0.016	2,889	10	289	3,178
1.3.5.1.2.1.7	SMD Capacitors	ea	38016	0.05	1,901	10	190	2,091
1.3.5.1.2.1.8	SMD Inductors	ea	9504	0.26	2,471	10	247	2,718
1.3.5.1.2.2	Pad amplifier/integrator parts		2614		56,406	11	6,033	62,439
1.3.5.1.2.2.1	Dual diode (MMBD7000LT1)	ea	5227	0.14	732	10	73	805
1.3.5.1.2.2.2	RF Transistor (NE85633)	ea	10454	0.47	4,914	10	491	5,405
1.3.5.1.2.2.3	RF Transistor (MMBR4957LT)	ea	5227	0.47	2,457	10	246	2,702
1.3.5.1.2.2.4	Gm amplifier (OPA660AU)	ea	5227	6.20	32,409	10	3,241	35,650
1.3.5.1.2.2.5	Dual OP amp (AD712)	ea	2614	1.50	3,920	20	784	4,704
1.3.5.1.2.2.6	SMD Resistors	ea	285120	0.012	3,421	10	342	3,764
1.3.5.1.2.2.7	SMD Capacitor	ea	171072	0.05	8,554	10	855	9,409
1.3.5.1.2.3	Wire Buffer & Digitizer parts				288,625	6	16,032	304,657
1.3.5.1.2.3.1	4 ch TDC (TMCTEG3)	ea	2376	54.00	128,304	0	0	128,304
1.3.5.1.2.3.2	FIFO (IDT220LB35)	ea	4752	12.80	60,826	10	6,083	66,908
1.3.5.1.2.3.3	Wire signal sep. (EPX740LC44)	ea	2376	20.00	47,520	10	4,752	52,272
1.3.5.1.2.3.4	Coarse Time Cntr. (CY7C335WC)	ea	297	15.00	4,455	10	446	4,901
1.3.5.1.2.3.5	L1 Controller (EPX740LC44)	ea	2376	20.00	47,520	10	4,752	52,272
1.3.5.1.2.4	Pad Digitizer & Buffer				101,595	10	10,160	111,755
1.3.5.1.2.4.1	ADC Mux (74HC4066)	ea	2614	0.81	2,117	10	212	2,329
1.3.5.1.2.4.2	Analog Buffer (AD818AR)	ea	2614	1.99	5,201	10	520	5,721
1.3.5.1.2.4.3	10bit Pipelined ADC (AD875JST)	ea	2614	9.45	24,699	10	2,470	27,168
1.3.5.1.2.4.4	ADC Mem. Buffer (IDT2205LB35)	ea	2614	12.80	33,454	10	3,345	36,799
1.3.5.1.2.4.5	ADC Evt FIFO (IDT2205LB35)	ea	1307	12.80	16,727	10	1,673	18,400
1.3.5.1.2.4.6	ADC Cntrl Logic (EPX740LC44-10)	ea	653	20.00	13,068	10	1,307	14,375
1.3.5.1.2.4.7	SMD Resistor	ea	171072	0.012	2,053	10	205	2,258
1.3.5.1.2.4.8	SMD Capacitors	ea	47520	0.09	4,277	10	428	4,704
1.3.5.1.2.5	Trigger Logic, timing & control parts				47,357	10	4,736	52,092
1.3.5.1.2.5.1	Op amp (OP279GS)	ea	594	1.95	1,158	10	116	1,274
1.3.5.1.2.5.2	Op Amp (LM285M)	ea	297	1.20	356	10	36	392
1.3.5.1.2.5.3	Discriminator (MAX763A)	ea	297	3.50	1,040	10	104	1,143
1.3.5.1.2.5.4	Op Amp (LM317D2T)	ea	297	1.00	297	10	30	327
1.3.5.1.2.5.5	CDC328A	ea	1782	5.48	9,765	10	977	10,742
1.3.5.1.2.5.6	Logic (74ACT11244DL)	ea	297	1.13	336	10	34	369

WBS	1.3.5	FRONT-END ELECTRONICS						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.3.5	**FRONT-END ELECTRONICS**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.3.5.1.2.5.7	Logic (74ACT16825DL)	ea	594	4.40	2,614	10	261	2,875
1.3.5.1.2.5.8	Logic (74ACT16373DL)	ea	594	3.50	2,079	10	208	2,287
1.3.5.1.2.5.9	DS90C031TM	ea	594	3.47	2,061	10	206	2,267
1.3.5.1.2.5.10	DS90C032TM	ea	297	3.47	1,031	10	103	1,134
1.3.5.1.2.5.11	Logic (74F38)	ea	297	0.65	193	10	19	212
1.3.5.1.2.5.12	PAL Logic (EPX740LC44)	ea	297	20.00	5,940	10	594	6,534
1.3.5.1.2.5.13	PAL Logic (EPX740LC68)	ea	297	21.15	6,282	10	628	6,910
1.3.5.1.2.5.14	Logic (74CBT16209DL)	ea	891	2.99	2,664	10	266	2,930
1.3.5.1.2.5.15	Logic (74FCT807CT SO)	ea	297	9.25	2,747	10	275	3,022
1.3.5.1.2.5.16	Logic (74GTL16612DL)	ea	594	7.78	4,621	10	462	5,083
1.3.5.1.2.5.17	Digital delay (CY7C335-66WI)	ea	297	14.05	4,173	10	417	4,590
1.3.5.1.2.6	Board Fabrication & assembly	ea	297	320.00	95,040	20	19,008	114,048
1.3.5.1.3	HV Service Card				98,423	14	13,741	112,164
1.3.5.1.3.1	Transformer (PE-8304)	ea	2436	4.80	11,695	10	1,170	12,865
1.3.5.1.3.2	HV Capacitor (1000pF,7.5kV)	ea	7776	0.75	5,832	10	583	6,415
1.3.5.1.3.3	HV Capacitor (10000pF,5kV)	ea	15552	2.40	37,325	10	3,732	41,057
1.3.5.1.3.4	SMD Resistors	ea	23328	0.04	933	10	93	1,026
1.3.5.1.3.5	Mechanical Parts	ea	2436	1.50	3,655	10	365	4,020
1.3.5.1.3.6	Board Fab. & assembly	ea	2436	16.00	38,984	20	7,797	46,780
1.3.5.1.4	Wire Signal Delay/Jumper Board				37,475	13	4,988	42,463
1.3.5.1.4.1	Analog Delay (DL3855)	ea	3960	3.25	12,870	10	1,287	14,157
1.3.5.1.4.2	HV Capacitor (1000pF,7.5kV)	ea	15840	0.75	11,880	10	1,188	13,068
1.3.5.1.4.3	SMD Resistors	ea	7920	0.04	317	10	32	348
1.3.5.1.4.4	Board Fab. & assembly	ea	1241	10.00	12,408	20	2,482	14,890
1.3.5.1.5	Wamus control boards (WCB)				88,501	13	11,290	99,791
1.3.5.1.5.1	Digital Signal Processor & Mem.	ea			17,164	12	2,130	19,294
1.3.5.1.5.1.1	DSP (ADSP-2181)	ea	103	50.00	5,170	10	517	5,687
1.3.5.1.5.1.2	DSP RAM (IDT 71256L-20Y)	ea	103	20.00	2,068	10	207	2,275
1.3.5.1.5.1.3	Boot EEPROM (AM29F010-120J)	ea	103	10.00	1,034	10	103	1,137
1.3.5.1.5.1.4	Address Decoder	ea	103	20.00	2,068	20	414	2,482
1.3.5.1.5.1.5	Crossing Counter Buff. (SN74ACT7805-15)	ea	103	26.00	2,688	10	269	2,957
1.3.5.1.5.1.6	L1 Logic PAL	ea	103	20.00	2,068	10	207	2,275
1.3.5.1.5.1.7	Buffer Memories	lot	103	20.00	2,068	20	414	2,482
1.3.5.1.5.2	Line Driver & Receiver	ea			8,056	10	806	8,861
1.3.5.1.5.2.1	DS90C031TM	ea	620	3.47	2,153	10	215	2,368
1.3.5.1.5.2.2	DS90C032TM	ea	310	3.47	1,076	10	108	1,184
1.3.5.1.5.2.3	Logic (74GTL16612DL)	ea	620	7.78	4,827	10	483	5,309
1.3.5.1.5.3	Serial Data Transmitter	ea			22,748	10	2,275	25,023
1.3.5.1.5.3.1	L1 Serial Transmitter (AMCC S2033)	ea	207	75.00	15,510	10	1,551	17,061
1.3.5.1.5.3.2	L2 Cyprus Hotlink Transmitter	ea	207	35.00	7,238	10	724	7,962
1.3.5.1.5.4	Other Parts	lot	103	117.00	12,098	15	1,815	13,912
1.3.5.1.5.5	Control Card Fabrication & Assembly	ea	103	275.00	28,435	15	4,265	32,700
1.3.5.1.6	Test fixtures	ea	8	1,000.00	8,000	20	1,600	9,600
1.3.5.2	***Mini-drift Chamber Electronics***				1,853,173	13	235,256	2,088,429
1.3.5.2.1	Engineering design				0	20	0	0
1.3.5.2.2	Amplifier/Discriminator Board				597,303	12	72,330	669,633

WBS 1.3.5 FRONT-END ELECTRONICS

WBS	ITEM	MATERIALS & SERVICES (M&S)				CONTINGENCY		
1.3.5	FRONT-END ELECTRONICS	Unit	#	Unit Cost	M&S TOTAL	%	Cost	TOTAL Cost
1.3.5.2.2.1	Amplifier Discriminator Parts				369,936	10	36,994	406,930
1.3.5.2.2.1.1	Diode (MMBD7000LT1)	ea	50400	0.14	7,056	10	706	7,762
1.3.5.2.2.1.2	Amplifier (UPC1669G)	ea	50400	1.97	99,288	10	9,929	109,217
1.3.5.2.2.1.3	Amplifier (HFA1105IR)	ea	50400	2.24	112,896	10	11,290	124,186
1.3.5.2.2.1.4	Discriminator (MAX903)	ea	50400	2.22	111,888	10	11,189	123,077
1.3.5.2.2.1.5	Surface Mount Devices	ea	1575	24.64	38,808	10	3,881	42,689
1.3.5.2.2.2	Connectors				50,967	10	5,097	56,064
1.3.5.2.2.2.1	High Density Connectors	ea	1575	15.00	23,625	10	2,363	25,988
1.3.5.2.2.2.2	Other Connectors	ea	6300	4.34	27,342	10	2,734	30,076
1.3.5.2.2.3	Other Parts	lot	1575	48.00	75,600	20	15,120	90,720
1.3.5.2.2.4	Board Fabrication & Assembly	ea	1575	64.00	100,800	15	15,120	115,920
1.3.5.2.3	Front-end Card				1,228,428	13	158,043	1,386,471
1.3.5.2.3.1	Latch/Buffer/FIFO				598,851	14	86,285	685,136
1.3.5.2.3.1.1	Input Discriminator (MAX902)	ea	26400	4.44	117,216	10	11,722	128,938
1.3.5.2.3.1.2	Input Latch/Register (CY7C381A)	ea	3300	16.00	52,800	10	5,280	58,080
1.3.5.2.3.1.3	L1 Logic (EPX740LC68)	ea	3300	21.15	69,795	10	6,980	76,775
1.3.5.2.3.1.4	Circular Buffer (74ACT7806)	ea	3300	16.00	52,800	10	5,280	58,080
1.3.5.2.3.1.5	L1 FIFO (IDT72205LB35)	ea	3300	12.80	42,240	10	4,224	46,464
1.3.5.2.3.1.6	Other Parts	lot	52800	5.00	264,000	20	52,800	316,800
1.3.5.2.3.2	Trigger Logic & Timing Control				329,934	10	32,993	362,927
1.3.5.2.3.2.1	Digital delay (CY7C335WC)	ea	1650	15.00	24,750	10	2,475	27,225
1.3.5.2.3.2.2	Trigger Control (EPX740LC44-10)	ea	13200	20.00	264,000	10	26,400	290,400
1.3.5.2.3.2.3	Centroid Logic (AT6002-2AC)	ea	1650	24.96	41,184	10	4,118	45,302
1.3.5.2.3.3	Connectors				90,750	13	11,825	102,575
1.3.5.2.3.3.1	Hi density Connectors	ea	1650	15.00	24,750	10	2,475	27,225
1.3.5.2.3.3.2	HF Connectors	ea	550	20.00	11,000	10	1,100	12,100
1.3.5.2.3.3.3	Sockets	ea	27500	2.00	55,000	15	8,250	63,250
1.3.5.2.3.4	Common Parts				87,893	10	8,789	96,682
1.3.5.2.3.4.1	CDC 329A	ea	2475	5.48	13,563	10	1,356	14,919
1.3.5.2.3.4.2	Logic (74ACT11244DL)	ea	275	1.13	311	10	31	342
1.3.5.2.3.4.3	PAL Logic (EPX740C44)	ea	275	20.00	5,500	10	550	6,050
1.3.5.2.3.4.4	PAL Logic (EPX740LC68)	ea	275	21.68	5,962	10	596	6,558
1.3.5.2.3.4.5	Logic (74CBT16209DL)	ea	550	2.99	1,645	10	164	1,809
1.3.5.2.3.4.6	Logic (74FCT807CT SO)	ea	275	9.45	2,599	10	260	2,859
1.3.5.2.3.4.7	Logic (74GTL16612DL)	ea	825	16.00	13,200	10	1,320	14,520
1.3.5.2.3.4.8	Digital Delay (CY7335-66WI)	ea	275	14.05	3,864	10	386	4,250
1.3.5.2.3.4.9	L1 Serial Transmitter (AMC CS2033)	ea	550	75.00	41,250	10	4,125	45,375
1.3.5.2.3.5	Board Fabrication & Assembly	ea	275	440.00	121,000	15	18,150	139,150
1.3.5.2.4	Mini-drift Controller Card				23,442	17	4,083	27,525
1.3.5.2.4.1	Digital Signal Processor & Mem.				4,582	12	569	5,150
1.3.5.2.4.1.1	DSP (ADSP-2181)	ea	28	50.00	1,380	10	138	1,518
1.3.5.2.4.1.2	DSP RAM (IDT 71256L-20Y)	ea	28	20.00	552	10	55	607
1.3.5.2.4.1.3	Boot EEPROM (AM29F010-120J)	ea	28	10.00	276	10	28	304
1.3.5.2.4.1.4	Address Decoder	ea	28	20.00	552	20	110	662
1.3.5.2.4.1.5	Crossing Counter Buff. (SN74ACT7805-15)	ea	28	26.00	718	10	72	789
1.3.5.2.4.1.6	L1 Logic PAL	ea	28	20.00	552	10	55	607
1.3.5.2.4.1.7	Buffer Memories	lot	28	20.00	552	20	110	662

WBS	1.3.5	FRONT-END ELECTRONICS						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.3.5	**FRONT-END ELECTRONICS**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.3.5.2.4.2	Line Drivers & Receivers				644	10	64	709
1.3.5.2.4.2.1	Logic (74GTL16612DL)	ea	83	7.78	644	10	64	709
1.3.5.2.4.3	Serial Data Transmitters & Logic				1,932	10	193	2,125
1.3.5.2.4.3.1	Cypress Hotlink Transmitters	ea	55	35.00	1,932	10	193	2,125
1.3.5.2.4.4	Other Parts	ea	28	240.00	6,624	20	1,325	7,949
1.3.5.2.4.5	Board Fabrication & Assembly	ea	28	350.00	9,660	20	1,932	11,592
1.3.5.2.5	Test fixtures	ea	4	1,000.00	4,000	20	800	4,800
1.3.5.3	***Scintillator Electronics***				431,974	10	44,874	476,847
1.3.5.3.1	Engineering design				0	20	0	0
1.3.5.3.2	Scintillator Front-End board (FEB)				400,984	10	39,027	440,011
1.3.5.3.2.1	Amplifier/discriminator parts				109,199	10	10,920	120,119
1.3.5.3.2.1.1	Diode (MMBD7000LT1)	ea	13108	0.14	1,835	10	184	2,019
1.3.5.3.2.1.2	Amplifier (UPC1669G)	ea	6554	1.97	12,911	10	1,291	14,202
1.3.5.3.2.1.3	Transformer (PE-8304)	ea	1638	4.80	7,865	10	786	8,651
1.3.5.3.2.1.4	Discriminator (MAX913)	ea	6554	3.67	24,052	10	2,405	26,458
1.3.5.3.2.1.5	SMD Resistor	ea	78646	0.016	1,258	10	126	1,384
1.3.5.3.2.1.6	SMD Capacitors	ea	45877	0.05	2,294	10	229	2,523
1.3.5.3.2.1.7	Double LEMO front panel conn.	ea	3277	18.00	58,984	10	5,898	64,883
1.3.5.3.2.2	Buffer & Digitizer parts				206,199	8	16,196	222,395
1.3.5.3.2.2.1	FIFO (IDT220LB35)	ea	3277	12.80	41,944	10	4,194	46,139
1.3.5.3.2.2.2	4ch TDC (TMCTEG)	ea	1638	54.00	88,476	5	4,424	92,900
1.3.5.3.2.2.3	Coarse Time Counter (CY7C335WC)	ea	137	15.00	2,048	10	205	2,253
1.3.5.3.2.2.4	L1 Controller (EPX740LC44)	ea	1638	20.00	32,769	10	3,277	36,046
1.3.5.3.2.2.5	Trigger Logic (EPX740LC44)	ea	1638	20.00	32,769	10	3,277	36,046
1.3.5.3.2.2.6	16ch DAC (AD8600)	ea	410	20.00	8,192	10	819	9,011
1.3.5.3.2.3	Trigger Logic, timing & control parts				33,019	12	4,026	37,044
1.3.5.3.2.3.1	CDC 328A	ea	819	5.48	4,489	10	449	4,938
1.3.5.3.2.3.2	Logic (74ACT11244DL)	ea	137	1.13	154	10	15	170
1.3.5.3.2.3.3	PAL Logic (EPX740C44)	ea	137	20.00	2,731	10	273	3,004
1.3.5.3.2.3.4	PAL Logic (EPX740LC68)	ea	137	21.68	2,960	10	296	3,256
1.3.5.3.2.3.5	Logic (74CBT16209DL)	ea	273	2.99	816	10	82	898
1.3.5.3.2.3.6	Logic (74FCT807CT SO)	ea	137	9.25	1,263	10	126	1,389
1.3.5.3.2.3.7	Other Parts	lot	137	53.00	7,236	20	1,447	8,684
1.3.5.3.2.3.8	Digital Delay (CY7335-66WI)	ea	137	14.05	1,918	10	192	2,110
1.3.5.3.2.3.9	L1 Serial Transmitter (AMC CS2033)	ea	137	75.00	10,240	10	1,024	11,264
1.3.5.3.2.3.10	Logic (74GTL16612DL)	ea	137	7.78	1,062	10	106	1,168
1.3.5.3.2.3.11	Logic (74ACT16825DL)	ea	137	1.08	147	10	15	162
1.3.5.3.2.4	Fabrication & Assembly	ea	137	385.00	52,567	15	7,885	60,452
1.3.5.3.3	Scintillator control board (SCB)				11,989	17	2,047	14,036
1.3.5.3.3.1	Digital Signal Processor & Mem.	ea			2,656	12	330	2,986
1.3.5.3.3.1.1	DSP (ADSP-2181)	ea	16	50.00	800	10	80	880
1.3.5.3.3.1.2	DSP RAM (IDT 71256L-20Y)	ea	16	20.00	320	10	32	352
1.3.5.3.3.1.3	Boot EEPROM (AM29F010-120J)	ea	16	10.00	160	10	16	176
1.3.5.3.3.1.4	Address Decoder	ea	16	20.00	320	20	64	384
1.3.5.3.3.1.5	Crossing Counter Buff. (SN74ACT7805-15)	ea	16	26.00	416	10	42	458
1.3.5.3.3.1.6	L1 Logic PAL	ea	16	20.00	320	10	32	352

WBS	1.3.5	FRONT-END ELECTRONICS						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.3.5	**FRONT-END ELECTRONICS**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.3.5.3.3.1.7	Buffer Memories	lot	16	20.00	320	20	64	384
1.3.5.3.3.2	Line Drivers & Receivers				373	10	37	411
1.3.5.3.3.2.1	74GTL16612DL	ea	48	7.78	373	10	37	411
1.3.5.3.3.3	Serial Data Transmitter (Cypress Hotlink)	ea	32	35.00	1,120	10	112	1,232
1.3.5.3.3.4	Other Parts	ea	16	240.00	3,840	20	768	4,608
1.3.5.3.3.5	Fabrication & Assembly	ea	16	250.00	4,000	20	800	4,800
1.3.5.3.4	Test fixtures	ea	4	1,000.00	4,000	20	800	4,800
1.3.5.3.5	Test Stands (PC…)	ea	3	5,000.00	15,000	20	3,000	18,000
1.3.5.4	***Crate Electronics***				429,850	15	66,331	496,181
1.3.5.4.1	Muon readout card (MRC)				78,960	17	13,442	92,402
1.3.5.4.1.1	Parts	ea	94	500	47,000	15	7,050	54,050
1.3.5.4.1.2	Board fabrication & Assembly	ea	94	340	31,960	20	6,392	38,352
1.3.5.4.2	Muon master fanout card				11,050	17	1,913	12,963
1.3.5.4.2.1	Parts	ea	17	350	5,950	15	893	6,843
1.3.5.4.2.2	Board fabrication & Assembly	ea	17	300	5,100	20	1,020	6,120
1.3.5.4.3	CPU Board (VSCB-20)				138,240	15	20,736	158,976
1.3.5.4.3.1	Board	ea	48	2,880	138,240	15	20,736	158,976
1.3.5.4.4	VME Crates	ea	40	5,040	201,600	15	30,240	231,840
1.3.5	TOTAL FRONT-END ELECTRONICS				3,624,197	12	442,825	4,067,023

10.13 Trigger Framework

OBJECTIVES AND PERFORMANCE CRITERIA

Objectives of the Trigger Framework include:

- Providing the logic for up to 128 Specific Triggers;
- Providing scalers necessary to monitor these Specific Triggers and the 128 Geographic Sections of the DAQ system;
- Providing the logic necessary to send the Level 1 Specific Triggers Fired Mask to the Level 2 Global Processor and to distribute the decisions from the Level 2 Global Processor to the Geographic Sections;
- Providing the scalers for monitoring the Level 2 Trigger operation;
- Minimizing the deadtime of the experiment;
- Providing, via the Trigger Control Computer, the interface for COOR to setup and control Level 1 and Level 2 triggering;
- Providing, via the Trigger Control Computer, monitoring information about the operation of the Level 1 and Level 2 triggers.

A detailed functional description of the Trigger Framework and descriptions of its design and features are available in various D-Zero Notes and in other notes available on the DØ Web Server.

Components

Major components include:

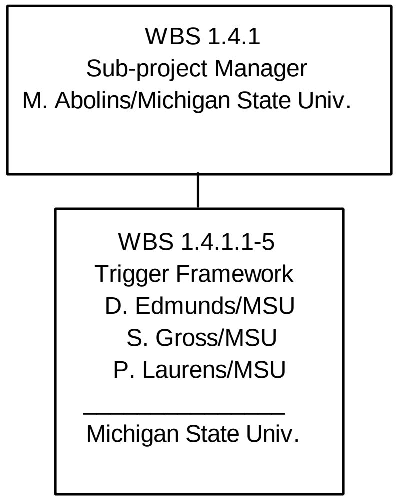
- Level 1 and Level 2 circuit boards;
- Crates and power supplies;
- Cables;
- Trigger Control Computer;
- Software.

Management, Organization, and Responsibilities

The initial description of the functions to be performed by the Trigger Framework and how the other components of the DØ Run II Trigger and DAQ Systems would connect to it are worked out in meetings of the Electronics Certification Board (ECB). The ECB is headed by Mike Tuts and includes representatives from all of the systems with which the Trigger Framework will interact.

The electronics design, construction, and software support for the Trigger Framework are being carried out at Michigan State University (MSU) by a group led by Maris Abolins. This group includes Dan Edmunds who is primarily responsible for the overall system design and its connections to the rest of the Trigger DAQ system, Steve Gross who is primarily responsible for the detailed electronics design, and Philippe Laurens who is primarily responsible for the software components of the Trigger Framework. This organization is shown in the accompanying chart. This group has weekly meetings to coordinate its work. Specifications and implementation of the software components of the Trigger Framework are coordinated in meetings of the Online software committee and by e-mail with the leaders of the online group.

Trigger Framework Sub-project Organization



<u>Work Plan</u>

Engineering/Design

Most of the detailed design work for the Trigger Framework involves electronics and software engineering. This work is carried out at MSU by individuals who have previously performed engineering work on similar projects including hardware and software that was used at DØ during Run I.

The major areas of electronics engineering include the design of the circuit boards and field programmable gate arrays that make up the Trigger Framework hardware. All of this work is accomplished on a CAD system using Mentor and Neo-CAD design packages.

The software engineering includes the design of the online control, monitoring, and server programs. The design of this software is strongly coupled to other parts of the online system and to the software standards used by DØ in Run II. Other software components include hardware exerciser and diagnostic programs which are not directly coupled to other parts of the DØ software system.

Procurement

The major procurement items for building the Trigger Framework are: 1) raw printed circuit board manufacturing; 2)the electronic components for the circuit boards; and 3) the assembly service to put together the circuit boards. Small procurement items include mechanical components for the circuit boards and card files and power supply, cooling, and cabling components. All of this procurement is handled by the Michigan State University Purchasing Department following mandatory procedures.

Inspection

Inspection takes place at both the raw printed circuit board level and at the finished circuit board level. The manufacturing, assembly, and inspections procedures used, meet the IPC standards of the Institute for Interconnect and Packaging. Travelers are kept for each circuit board and for other significant assemblies (backplanes, power supplies). These travelers become part of the inventory system that was started for the Run I trigger components that were built at MSU.

Construction/Fabrication

Construction of the Trigger Framework involves the assembly of the printed circuit boards and the assembly and cabling of the various components into the two racks that the Trigger

Framework will occupy. The circuit board assembly work is carried out at an external assembly service vendor. Assembly of the components into the racks takes place at MSU.

Testing/Commissioning

The fully assembled Trigger Framework undergoes extensive testing at MSU before being shipped to Fermilab. This testing uses diagnostic and exerciser programs to verify that the framework meets all of its design specifications. The advantage in completing the testing at MSU before the Framework is brought to Fermilab is that once it is installed at Fermilab it is difficult to take it offline without interfering with the work of other groups. The intent is to provide close to 100% availability once it is installed at Fermilab. Most of the commissioning work at Fermilab involves connecting the Framework to other components of the Run II Trigger and DAQ systems as they become available.

Schedule Milestones

The Level 1 Trigger Framework is needed early in the assembly of the Run II Trigger DAQ System for DØ. Early delivery and installation of the Level 2 Framework is necessary to allow exercising of all aspects of the Run II DAQ Front-Ends. The milestones for the Trigger Framework sub-project are given in the tables below. M1, M2, and M3 identify milestones held by the DoE, the Fermilab Directorate, and the Upgrade Project managers, respectively.

ID	**Milestones-Triggers**	**Date**
134	L2 Muon TDR Complete	25-Feb-97
6	Circuit Board Layout Finished	10-Apr-97
57	Global TDR Submitted	28-May-97
99	Cal TDR Submitted	28-May-97
249	Design L2 Simulation Framework	2-Jun-97
261	Tool Parameter Format Defined	30-Jun-97
13	L1 Framework Testing Underway	28-Jul-97
61	V1.0 Frame in non-VME Prototype	1-Aug-97
226	M3-Trigger Level 3 TDR Submitted	11-Aug-97
30	M3-Calorimeter Level 1 Trigger Readout Cards Modified	18-Sep-97
251	Implement L2 Simulation Frame	1-Oct-97
264	L2 Inputs Into L3 Defined	1-Oct-97
14	L1 Framework Delivered to Fermilab	11-Nov-97
16	L2 Framework Testing Underway	21-Jan-98
68	M3-Install Level 2 Trigger Operating System	9-Mar-98
234	M3-Trigger Level 3 System Test Complete	11-Mar-98
17	L2 Framework Delivered to Fermilab	18-Mar-98
138	Operate L2 Muon Parallel Processors in Test Crate	13-Apr-98
258	Preprocessor, Global Timing OK in Hdwe	1-May-98
268	Filter Tools Designed	29-May-98
257	L2 Algorithms in L2 Simulator	5-Jun-98
75	Global /Cal Preprocessor Communication at MSU	25-Aug-98
114	Global /Cal Preprocessor Communication at MSU	25-Aug-98
256	Integrate Sim's of Preprocessors, Global	29-Sep-98
149	L2 Muon Installation Complete	1-Oct-98
275	First Executable Complete	3-Dec-98
212	L3 Purchases 50% Complete	8-Jan-99
35	M3-Calorimeter Level 1 Trigger Commissioned	26-Feb-99
88	Online Tests with L2 Global	1-Apr-99
270	L1 and L2 Emulation and High Level Tools Complete	1-Apr-99

ID	Milestones-Triggers	Date
128	Commissioning Global/Calorimenter L2 Complete	14-Jun-99
90	M3-Trigger Level 2 Commissioned	18-Oct-99
239	L3 Installation Complete	20-Oct-99
218	L3 Purchases Complete	18-Nov-99

ID	Milestones-Muon Level 1 Trigger	Date
3	M3-Muon Level 1 Trigger TDR Submitted	1-May-97
112	MCEN and MCCM Design Review	1-May-97
130	MCEN, MCCM Prototypes Complete	11-Aug-97
42	MTCxx, MTCM, MTM Prototypes Complete	6-Oct-97
131	M3-Muon Level 1 Trigger Prototype Complete	6-Oct-97
118	10% MCEN, MCCM Complete	28-Jan-98
48	10% MTCxx, MTCM, MTM Complete	30-Jul-98
120	Preproduction Testing Complete	18-Sep-98
50	Preproduction Testing Complete	20-Nov-98
121	M3-Muon Level 1 Trigger Preproduction Testing Complete	20-Nov-98
53	MTCxx, MTCM, MTM Production Complete	2-Mar-99
124	MCEN, MCCM Production Complete	9-Mar-99

Manpower Plan

The manpower plan for the combined trigger sub-projects (Framework, Levels 1, 2, and 3) is given in the table below. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	General Trigger					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Electrical Engineer (F)		1.6	0.1	0.3		2.0
Electrical Technician (F)		0.5	0.3	0.5		1.3
Mechanical Technician (F)			1.4			1.4
Sub-Total (F)		2.1	1.8	0.8		4.6
Electrical Engineer (U)	3.0	6.8	6.5	2.6		19.0
Electrical Technician (U)		0.9	1.5	0.6		3.0
Sub-Total (U)	3.0	7.7	8.0	3.2		21.9
Total	3.0	9.8	9.8	4.0		26.6

Cost Estimate

The cost estimate for the Trigger Framework is shown in the accompanying table. In most cases we include 20% spares. Contingency is assigned based on the criteria in section 7.1.2 and is typically 20%.

WBS	1.4.1	FRAMEWORK						
WBS	ITEM	MATERIALS & SERVICES (M&S)				CONTINGENCY		
1.4.1	FRAMEWORK	Unit	#	Unit Cost	M&S TOTAL	%	Cost	TOTAL Cost
1.4.1.1	***Engineering and Design***	yr	2	130,000	260,000	20	52,000	312,000
1.4.1.2	***Framework L1***				673,230	19	130,382	803,612
1.4.1.2.1	Circuit boards				614,166	19	118,570	732,736
1.4.1.2.1.1	Timing Origination Module Board		20		18,280	20	3,656	21,936
1.4.1.2.1.1.1	Semiconductors				1,720	20	344	2,064
1.4.1.2.1.1.1.1	TTL IC's	ea	120	1	120	20	24	144
1.4.1.2.1.1.1.2	ECL IC's	ea	320	5	1,600	20	320	1,920
1.4.1.2.1.1.2	Connectors				1,700	20	340	2,040
1.4.1.2.1.1.2.1	96 pin DIN	ea	40	9	360	20	72	432
1.4.1.2.1.1.2.2	160 pin DIN	ea	60	13	780	20	156	936
1.4.1.2.1.1.2.3	34 pin 0.1x0.1	ea	40	4	160	20	32	192
1.4.1.2.1.1.2.4	LEMO	ea	80	5	400	20	80	480
1.4.1.2.1.1.3	Circuit board 400x400mm, 12 layer	ea	20	551	11,020	20	2,204	13,224
1.4.1.2.1.1.4	Electronic Parts (LED's, bypass caps)	lot	20	50	1,000	20	200	1,200
1.4.1.2.1.1.5	Mechanical Parts (front panel, stiffener)	lot	20	50	1,000	20	200	1,200
1.4.1.2.1.1.6	Assembly (1 side SMD+THD)	ea	20	92	1,840	20	368	2,208
1.4.1.2.1.2	Foundation Module Circuit Board		20		55,880	20	11,176	67,056
1.4.1.2.1.2.1	Semiconductors				21,660	20	4,332	25,992
1.4.1.2.1.2.1.1	FPGA's	ea	120	150	18,000	20	3,600	21,600
1.4.1.2.1.2.1.2	Converts TTl, ECL	ea	720	3	2,160	20	432	2,592
1.4.1.2.1.2.1.3	VME Interface	ea	20	25	500	20	100	600
1.4.1.2.1.2.1.4	Support PROM's timing fanout	ea	20	50	1,000	20	200	1,200
1.4.1.2.1.2.2	Connectors		0		1,520	20	304	1,824
1.4.1.2.1.2.2.1	160 pin DIN	ea	80	13	1,040	20	208	1,248
1.4.1.2.1.2.2.2	34 pin 0.1x0.1	ea	20	4	80	20	16	96
1.4.1.2.1.2.2.3	LEMO	ea	80	5	400	20	80	480
1.4.1.2.1.2.3	Fiber Interface	ea	20	750	15,000	20	3,000	18,000
1.4.1.2.1.2.4	Circuit board 400x400mm, 14 layer	ea	20	640	12,800	20	2,560	15,360
1.4.1.2.1.2.5	Electronic Parts (LED's, bypass caps)	lot	20	75	1,500	20	300	1,800
1.4.1.2.1.2.6	Mechanical Parts (front panel, stiffener)	lot	20	50	1,000	20	200	1,200
1.4.1.2.1.2.7	Assembly (1 side SMD+THD)	ea	20	120	2,400	20	480	2,880
1.4.1.2.1.3	Term Receiver Module Circuit Board		16		73,504	20	14,701	88,205
1.4.1.2.1.3.1	Semiconductors				46,128	20	9,226	55,354
1.4.1.2.1.3.1.1	FPGA's	ea	288	150	43,200	20	8,640	51,840
1.4.1.2.1.3.1.2	Converts TTl, ECL	ea	576	3	1,728	20	346	2,074
1.4.1.2.1.3.1.3	VME Interface	ea	16	25	400	20	80	480
1.4.1.2.1.3.1.4	Support PROM's timing fanout	ea	16	50	800	20	160	960
1.4.1.2.1.3.2	Connectors				1,216	20	243	1,459
1.4.1.2.1.3.2.1	160 pin DIN	ea	64	13	832	20	166	998
1.4.1.2.1.3.2.2	34 pin 0.1x0.1	ea	16	4	64	20	13	77

WBS	1.4.1			FRAMEWORK					
WBS	ITEM	MATERIALS & SERVICES (M&S)				CONTINGENCY		
1.4.1	FRAMEWORK	Unit	#	Unit Cost	M&S TOTAL	%	Cost	TOTAL Cost
1.4.1.2.1.3.2.3	LEMO	ea	64	5	320	20	64	384
1.4.1.2.1.3.3	Fiber Interface	ea	16	750	12,000	20	2,400	14,400
1.4.1.2.1.3.4	Circuit board 400x400mm, 14 layer	ea	16	640	10,240	20	2,048	12,288
1.4.1.2.1.3.5	Electronic Parts (LED's, bypass caps)	lot	16	75	1,200	20	240	1,440
1.4.1.2.1.3.6	Mechanical Parts (front panel, stiffener)	lot	16	50	800	20	160	960
1.4.1.2.1.3.7	Assembly (1 side SMD+THD)	ea	16	120	1,920	20	384	2,304
1.4.1.2.1.4	And-Or Network Module Circuit Board		14		53,816	20	10,763	64,579
1.4.1.2.1.4.1	Semiconductors				40,362	20	8,072	48,434
1.4.1.2.1.4.1.1	FPGA's	ea	252	150	37,800	20	7,560	45,360
1.4.1.2.1.4.1.2	Converts TTl, ECL	ea	504	3	1,512	20	302	1,814
1.4.1.2.1.4.1.3	VME Interface	ea	14	25	350	20	70	420
1.4.1.2.1.4.1.4	Support PROM's timing fanout	ea	14	50	700	20	140	840
1.4.1.2.1.4.2	Connectors				1,064	20	213	1,277
1.4.1.2.1.4.2.1	160 pin DIN	ea	56	13	728	20	146	874
1.4.1.2.1.4.2.2	34 pin 0.1x0.1	ea	14	4	56	20	11	67
1.4.1.2.1.4.2.3	LEMO	ea	56	5	280	20	56	336
1.4.1.2.1.4.3	Circuit board 400x400mm, 14 layer	ea	14	640	8,960	20	1,792	10,752
1.4.1.2.1.4.4	Electronic Parts (LED's, bypass caps)	lot	14	75	1,050	20	210	1,260
1.4.1.2.1.4.5	Mechanical Parts (front panel, stiffener)	lot	14	50	700	20	140	840
1.4.1.2.1.4.6	Assembly (1 side SMD+THD)	ea	14	120	1,680	20	336	2,016
1.4.1.2.1.5	Trigger Decision Module Board		24		110,256	20	22,051	132,307
1.4.1.2.1.5.1	Semiconductors				69,192	20	13,838	83,030
1.4.1.2.1.5.1.1	FPGA's	ea	432	150	64,800	20	12,960	77,760
1.4.1.2.1.5.1.2	Converts TTl, ECL	ea	864	3	2,592	20	518	3,110
1.4.1.2.1.5.1.3	VME Interface	ea	24	25	600	20	120	720
1.4.1.2.1.5.1.4	Support PROM's timing fanout	ea	24	50	1,200	20	240	1,440
1.4.1.2.1.5.2	Connectors				1,824	20	365	2,189
1.4.1.2.1.5.2.1	160 pin DIN	ea	96	13	1,248	20	250	1,498
1.4.1.2.1.5.2.2	34 pin 0.1x0.1	ea	24	4	96	20	19	115
1.4.1.2.1.5.2.3	LEMO	ea	96	5	480	20	96	576
1.4.1.2.1.5.3	Fiber Interface	ea	24	750	18,000	20	3,600	21,600
1.4.1.2.1.5.4	Circuit board 400x400mm, 14 layer	ea	24	640	15,360	20	3,072	18,432
1.4.1.2.1.5.5	Electronic Parts (LED's, bypass caps)	lot	24	75	1,800	20	360	2,160
1.4.1.2.1.5.6	Mechanical Parts (front panel, stiffener)	lot	24	50	1,200	20	240	1,440
1.4.1.2.1.5.7	Assembly (1 side SMD+THD)	ea	24	120	2,880	20	576	3,456
1.4.1.2.1.6	Framework Output Module Board		10		45,940	20	9,188	55,128
1.4.1.2.1.6.1	Semiconductors				28,830	20	5,766	34,596
1.4.1.2.1.6.1.1	FPGA's	ea	180	150	27,000	20	5,400	32,400
1.4.1.2.1.6.1.2	Converts TTl, ECL	ea	360	3	1,080	20	216	1,296
1.4.1.2.1.6.1.3	VME Interface	ea	10	25	250	20	50	300
1.4.1.2.1.6.1.4	Support PROM's timing fanout	ea	10	50	500	20	100	600
1.4.1.2.1.6.2	Connectors				760	20	152	912
1.4.1.2.1.6.2.1	160 pin DIN	ea	40	13	520	20	104	624
1.4.1.2.1.6.2.2	34 pin 0.1x0.1	ea	10	4	40	20	8	48
1.4.1.2.1.6.2.3	LEMO	ea	40	5	200	20	40	240
1.4.1.2.1.6.3	Fiber Interface	ea	10	750	7,500	20	1,500	9,000
1.4.1.2.1.6.4	Circuit board 400x400mm, 14 layer	ea	10	640	6,400	20	1,280	7,680

WBS 1.4.1 FRAMEWORK

WBS	ITEM	MATERIALS & SERVICES (M&S)				CONTINGENCY		
1.4.1	FRAMEWORK	Unit	#	Unit Cost	M&S TOTAL	%	Cost	TOTAL Cost
1.4.1.2.1.6.5	Electronic Parts (LED's, bypass caps)	lot	10	75	750	20	150	900
1.4.1.2.1.6.6	Mechanical Parts (front panel, stiffener)	lot	10	50	500	20	100	600
1.4.1.2.1.6.7	Assembly (1 side SMD+THD)	ea	10	120	1,200	20	240	1,440
1.4.1.2.1.7	Support Functions Type 1 Board		5		22,970	20	4,594	27,564
1.4.1.2.1.7.1	Semiconductors				14,415	20	2,883	17,298
1.4.1.2.1.7.1.1	FPGA's	ea	90	150	13,500	20	2,700	16,200
1.4.1.2.1.7.1.2	Converts TTl, ECL	ea	180	3	540	20	108	648
1.4.1.2.1.7.1.3	VME Interface	ea	5	25	125	20	25	150
1.4.1.2.1.7.1.4	Support PROM's timing fanout	ea	5	50	250	20	50	300
1.4.1.2.1.7.2	Connectors				380	20	76	456
1.4.1.2.1.7.2.1	160 pin DIN	ea	20	13	260	20	52	312
1.4.1.2.1.7.2.2	34 pin 0.1x0.1	ea	5	4	20	20	4	24
1.4.1.2.1.7.2.3	LEMO	ea	20	5	100	20	20	120
1.4.1.2.1.7.3	Fiber Interface	ea	5	750	3,750	20	750	4,500
1.4.1.2.1.7.4	Circuit board 400x400mm, 14 layer	ea	5	640	3,200	20	640	3,840
1.4.1.2.1.7.5	Electronic Parts (LED's, bypass caps)	lot	5	75	375	20	75	450
1.4.1.2.1.7.6	Mechanical Parts (front panel, stiffener)	lot	5	50	250	20	50	300
1.4.1.2.1.7.7	Assembly (1 side SMD+THD)	ea	5	120	600	20	120	720
1.4.1.2.1.8	Support Functions Type 2 Board		5		22,970	20	4,594	27,564
1.4.1.2.1.8.1	Semiconductors				14,415	20	2,883	17,298
1.4.1.2.1.8.1.1	FPGA's	ea	90	150	13,500	20	2,700	16,200
1.4.1.2.1.8.1.2	Converts TTl, ECL	ea	180	3	540	20	108	648
1.4.1.2.1.8.1.3	VME Interface	ea	5	25	125	20	25	150
1.4.1.2.1.8.1.4	Support PROM's timing fanout	ea	5	50	250	20	50	300
1.4.1.2.1.8.2	Connectors				380	20	76	456
1.4.1.2.1.8.2.1	160 pin DIN	ea	20	13	260	20	52	312
1.4.1.2.1.8.2.2	34 pin 0.1x0.1	ea	5	4	20	20	4	24
1.4.1.2.1.8.2.3	LEMO	ea	20	5	100	20	20	120
1.4.1.2.1.8.3	Fiber Interface	ea	5	750	3,750	20	750	4,500
1.4.1.2.1.8.4	Circuit board 400x400mm, 14 layer	ea	5	640	3,200	20	640	3,840
1.4.1.2.1.8.5	Electronic Parts (LED's, bypass caps)	lot	5	75	375	20	75	450
1.4.1.2.1.8.6	Mechanical Parts (front panel, stiffener)	lot	5	50	250	20	50	300
1.4.1.2.1.8.7	Assembly (1 side SMD+THD)	ea	5	120	600	20	120	720
1.4.1.2.1.9	Scaler Card Data Block Readout		11		50,534	20	10,107	60,641
1.4.1.2.1.9.1	Semiconductors				31,713	20	6,343	38,056
1.4.1.2.1.9.1.1	FPGA's	ea	198	150	29,700	20	5,940	35,640
1.4.1.2.1.9.1.2	Converts TTl, ECL	ea	396	3	1,188	20	238	1,426
1.4.1.2.1.9.1.3	VME Interface	ea	11	25	275	20	55	330
1.4.1.2.1.9.1.4	Support PROM's timing fanout	ea	11	50	550	20	110	660
1.4.1.2.1.9.2	Connectors				836	20	167	1,003
1.4.1.2.1.9.2.1	160 pin DIN	ea	44	13	572	20	114	686
1.4.1.2.1.9.2.2	34 pin 0.1x0.1	ea	11	4	44	20	9	53
1.4.1.2.1.9.2.3	LEMO	ea	44	5	220	20	44	264
1.4.1.2.1.9.3	Fiber Interface	ea	11	750	8,250	20	1,650	9,900
1.4.1.2.1.9.4	Circuit board 400x400mm, 14 layer	ea	11	640	7,040	20	1,408	8,448
1.4.1.2.1.9.5	Electronic Parts (LED's, bypass caps)	lot	11	75	825	20	165	990
1.4.1.2.1.9.6	Mechanical Parts (front panel, stiffener)	lot	11	50	550	20	110	660

WBS	1.4.1	FRAMEWORK						
WBS	ITEM	MATERIALS & SERVICES (M&S)				CONTINGENCY		
1.4.1	FRAMEWORK	Unit	#	Unit Cost	M&S TOTAL	%	Cost	TOTAL Cost
1.4.1.2.1.9.7	Assembly (1 side SMD+THD)	ea	11	120	1,320	20	264	1,584
1.4.1.2.1.10	Scaler Card Monitor Readout		24		92,256	20	18,451	110,707
1.4.1.2.1.10.1	Semiconductors				69,192	20	13,838	83,030
1.4.1.2.1.10.1.1	FPGA's	ea	432	150	64,800	20	12,960	77,760
1.4.1.2.1.10.1.2	Converts TTl, ECL	ea	864	3	2,592	20	518	3,110
1.4.1.2.1.10.1.3	VME Interface	ea	24	25	600	20	120	720
1.4.1.2.1.10.1.4	Support PROM's timing fanout	ea	24	50	1,200	20	240	1,440
1.4.1.2.1.10.2	Connectors				1,824	20	365	2,189
1.4.1.2.1.10.2.1	160 pin DIN	ea	96	13	1,248	20	250	1,498
1.4.1.2.1.10.2.2	34 pin 0.1x0.1	ea	24	4	96	20	19	115
1.4.1.2.1.10.2.3	LEMO	ea	96	5	480	20	96	576
1.4.1.2.1.10.3	Circuit board 400x400mm, 14 layer	ea	24	640	15,360	20	3,072	18,432
1.4.1.2.1.10.4	Electronic Parts (LED's, bypass caps)	lot	24	75	1,800	20	360	2,160
1.4.1.2.1.10.5	Mechanical Parts (front panel, stiffener)	lot	24	50	1,200	20	240	1,440
1.4.1.2.1.10.6	Assembly (1 side SMD+THD)	ea	24	120	2,880	20	576	3,456
1.4.1.2.1.11	Pass Through Boards		20		5,520	20	1,104	6,624
1.4.1.2.1.11.1	Connectors				1,420	20	284	1,704
1.4.1.2.1.11.1.1	160 pin DIN	ea	60	13	780	20	156	936
1.4.1.2.1.11.1.2	34 pin 0.1x0.1	ea	160	4	640	20	128	768
1.4.1.2.1.11.2	Circuit Board 14.4xx6", 5layer	ea	20	115	2,300	20	460	2,760
1.4.1.2.1.11.3	Electronic Parts (LED's, bypass caps)	lot	20	20	400	20	80	480
1.4.1.2.1.11.4	Mechanical Parts (front panel, stiffener)	lot	20	50	1,000	20	200	1,200
1.4.1.2.1.11.5	Assembly (1 side SMD+THD)	ea	20	20	400	20	80	480
1.4.1.2.1.12	Paddle Cards		80		9,840	20	1,968	11,808
1.4.1.2.1.12.1	Connectors				2,320	20	464	2,784
1.4.1.2.1.12.1.1	160 pin DIN	ea	80	13	1,040	20	208	1,248
1.4.1.2.1.12.1.2	34 pin 0.1x0.1	ea	320	4	1,280	20	256	1,536
1.4.1.2.1.12.2	Circuit Board 2.9"x5.1", 5 layer	ea	80	54	4,320	20	864	5,184
1.4.1.2.1.12.3	Electronic Parts (LED's, bypass caps)	lot	80	20	1,600	20	320	1,920
1.4.1.2.1.12.4	Assembly (1 side SMD+THD)	ea	80	20	1,600	20	320	1,920
1.4.1.2.1.13	VRB for Readout	ea	11	3,876	42,636	10	4,264	46,900
1.4.1.2.1.14	VRB Controler for Readout	ea	2	1,882	3,764	20	753	4,517
1.4.1.2.1.15	Vertical Interconnect Slave	ea	6	1,000	6,000	20	1,200	7,200
1.4.1.2.2	Crates				44,064	20	8,813	52,877
1.4.1.2.2.1	Card file Mech Parts (Schroff 9Ux460mm)	ea	6	500	3,000	20	600	3,600
1.4.1.2.2.2	J1 Backplane				3,888	20	778	4,666
1.4.1.2.2.2.1	J1 Backplane circuit board	ea	6	375	2,250	20	450	2,700
1.4.1.2.2.2.2	J1 Backplane Connectors	ea	126	13	1,638	20	328	1,966
1.4.1.2.2.3	J2-J3 backplanes				5,826	20	1,165	6,991
1.4.1.2.2.3.1	J2-J3 Backplane circuit board	ea	6	425	2,550	20	510	3,060
1.4.1.2.2.3.2	J2-J3 Backplane Connectors	ea	252	13	3,276	20	655	3,931
1.4.1.2.2.4	Crate power supplies				25,350	20	5,070	30,420
1.4.1.2.2.4.1	Power Supply Chassis	ea	6	300	1,800	20	360	2,160
1.4.1.2.2.4.2	Power Supply +3.3v	ea	6	1,850	11,100	20	2,220	13,320
1.4.1.2.2.4.3	Power Supply +5V, -2V, -4.5V	ea	6	1,975	11,850	20	2,370	14,220
1.4.1.2.2.4.4	Chassis AC Wiring Components	ea	6	100	600	20	120	720
1.4.1.2.2.5	Cooling Fans and Ducts	ea	6	1,000	6,000	20	1,200	7,200

WBS	**1.4.1**	**FRAMEWORK**						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.4.1	**FRAMEWORK**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.4.1.2.3	Cables				12,500	20	2,500	15,000
1.4.1.2.3.1	Interconnection cables	ea	100	25	2,500	20	500	3,000
1.4.1.2.3.2	Connection to TCC computer	ea	2	5,000	10,000	20	2,000	12,000
1.4.1.2.4	Installation				2,500	20	500	3,000
1.4.1.2.4.1	Mechanical prep	lot	1	2,500	2,500	20	500	3,000
1.4.1.3	***Framework L2***				201,803	19	38,423	240,226
1.4.1.4	***Foreign Scalers***				183,902	19	34,842	218,744
1.4.1.5	***Framework Support equipment***				18,500	10	1,850	20,350
1.4.1	TOTAL FRAMEWORK				1,337,435	19	257,497	1,594,932

10.14 Level Ø

Objectives and Performance Criteria

Objectives of the Level Ø system include:

- Measuring collider luminosity to 1 to 2% accuracy relative to CDF, and better than 5% absolute accuracy;
- Providing diagnostic information regarding accelerator performance;
- Providing large η trigger coverage for diffractive and rapidity gap triggers;
- High acceptance (98-99%) for non-diffractive inelastic collisions;
- Vertex position resolution $\leq$ 3 cm;
- Timing resolution $\leq$ 250 psec;
- Surviving radiation doses as high as 1 Mrad.

A description of the design and performance objectives for the detector is contained in the Level Ø Proposal, DØ note 2860.

Components

Major Level Ø components include:

- Scintillator;
- Phototubes and associated hardware;
- Readout electronics.

These make up the 64 fast scintillation counters that cover the region $2.6 < |\eta| < 4.5$.

Management, Organization, and Responsibilities

Brown University is responsible for the design, construction, and testing of the Level Ø hardware and software. The sub-project manager is Richard Partridge (Brown University).

Work Plan

Engineering/Design

Engineering and design are provided by the Brown University group. Engineering projects include the design of the electronics and mechanical design of the support structure. Design work also includes the final scintillation counter design.

Procurement

The only large procurement item is the photomultiplier tubes. Hammamatsu is the sole vendor of the fine-mesh photomultiplier tubes that are able to survive in the large magnetic fields present at their location in DØ.

Inspection

Careful inspection of the procured and fabricated detector components is performed by the Brown University group. All components are inspected on arrival to ensure that specifications are met. Each fabricated item, including scintillator tiles and electronic boards, is visually inspected by a member of the Brown University group to ensure good quality control.

Construction/Fabrication

Construction of the scintillator assemblies takes place in the Fermilab plastics shop using both Fermilab and Brown University personnel. Custom electronics required for the vertex position measurement are constructed in the Brown University high energy physics labs, which are staffed with experienced electronics technicians. Mechanical fixtures and support assemblies are constructed in the Brown University physics department machine shop. Assembly of the completed detector takes place at Fermilab under the direction of Brown University physicists.

Testing/Commissioning

Each photomultiplier tube is tested upon arrival. Scintillator assemblies undergo testing following each stage of fabrication. Custom electronics are tested at Brown following fabrication. Commissioning takes place after the luminosity monitor is mounted on the detector.

Schedule Milestones

The milestones for the Level Ø sub-project are given in the table below. M1, M2, and M3 identify milestones held by the DoE, the Fermilab Directorate, and the Upgrade Project managers, respectively.

ID	Milestones-Level Ø	Date
87	M3-Level Ø-North Installed/Hooked Up	14-May-99

Manpower Plan

The manpower plan for the Level Ø sub-project is given in the table below. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	Level 0					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Mechanical Technician (F)				0.04		0.04
Total (F)				0.04		0.04

Cost Estimate

The cost estimate for the Level Ø trigger elements is shown in the accompanying table. In most cases we include 10% spares. Contingency is based on the criteria in section 7.1.2 and averages to 18%.

WBS	**1.4.2**	**LEVEL 0**						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.4.2	**LEVEL 0**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.4.2.1	***Scintillator***	sheet	2	1,000	2,000	10	200	2,200
1.4.2.2	***PMT and Asssociated Hardware***	ea	50	1,500	75,000	20	15,000	90,000
1.4.2.3	***Mechanical Support & Enclosures***	lot	2	5,000	10,000	20	2,000	12,000
1.4.2.4	***Electronics***				46,600		7,360	53,960
1.4.2.4.1	Level 0 Electronics	lot	1	13,000	13,000	20	2,600	15,600
1.4.2.4.2	Accelerator Diagnostic DAQ	lot	1	12,000.00	12,000	20	2,400	14,400
1.4.2.4.3	Cables & Connectors	lot	1	2,000.00	2,000	20	400	2,400
1.4.2.4.4	Timing Discriminators	ea	14	1,400.00	19,600	10	1,960	21,560
1.4.2	TOTAL LEVEL 0				133,600	18	24,560	158,160

10.15 Level 1 Trigger

Objectives and Performance Criteria

Objectives of the Level 1 (L1) trigger include:

- The reduction of the inelastic trigger rate by a factor of 1000;
- The transfer of all decision information to the trigger framework, Level 2 trigger, and Level 3 trigger farm.

The performance criteria for the Level 1 trigger are:

- A maximum input rate of 5 MHz;
- Completion of trigger decisions within 4.2 μsec;
- An acceptance rate of 10 kHz.

Trigger decisions will be based on information from the central fiber tracker (CFT), central and forward preshower detectors (CPS, FPS), calorimeter, muon scintillator, and muon tracking detectors.

Components

The major components are:

- The CFT logic cards loaded with field programmable gate arrays (these cards include CPS logic);
- The FPS trigger logic;
- The muon MTC05 and MTC10 cards;
- The calorimeter sum and logic cards;
- Communication links between the detectors and trigger elements and the trigger elements and the framework.

The CFT, CPS, FPS and Muon trigger logic will be located in the collision hall. The calorimeter trigger will be housed in the movable counting house.

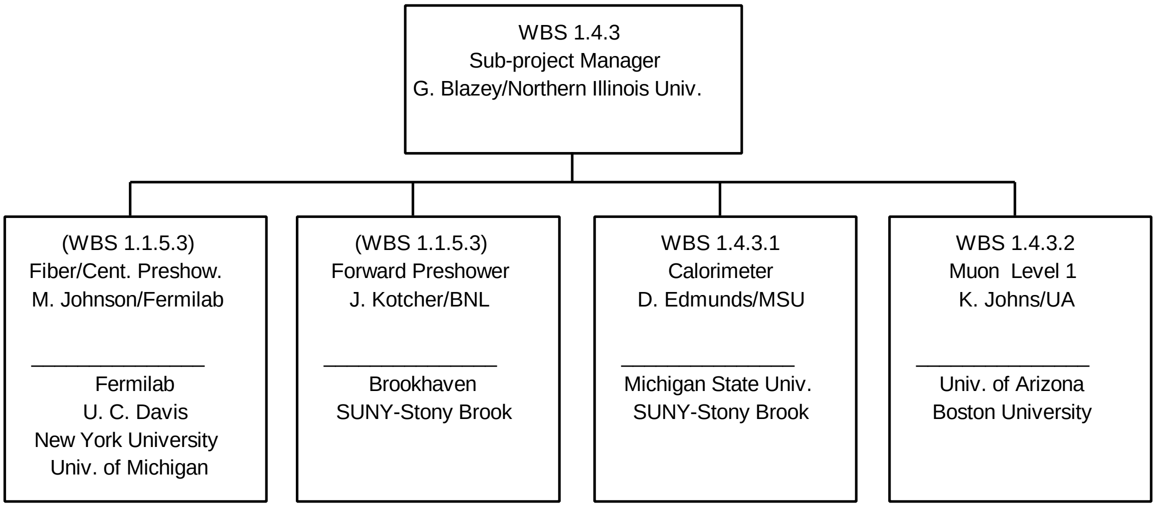
Management, Organization, and Responsibilities

The institutions contributing to the Level 1 Trigger project include Fermilab, U. C. Davis, New York University, University of Michigan, Brookhaven National Laboratory, Michigan State University, SUNY at Stony Brook, University of Arizona, Boston University, and Northern Illinois University

Most of the CFT and CPS trigger development and construction is performed at Fermilab. U. C. Davis is responsible for the interface electronics between the CFT and the readout/trigger electronics. The University of Michigan contributes to the CPS development. Brookhaven National Laboratory and SUNY at Stony Brook are responsible for the FPS Level 1 design and construction. The calorimeter trigger upgrade is the responsibility of the University of Michigan. The University of Arizona and Boston University are responsible for Level 1 muon electronics. Simulation of the various Level 1 detectors and their performance has been centered at Fermilab with extensive contributions from all other institutions.

The sub-project manager is Gerald C. Blazey (Northern Illinois University). The accompanying chart illustrates the Level 1 trigger organization. Work is coordinated by twice monthly upgrade trigger meetings and extensive electronic correspondence. The trigger group also maintains a World Wide Web page for rapid communications and as an archive.

Level 1 Trigger Sub-project Organization



Work Plan

Engineering/Design

The Level 1 trigger requires extensive electrical engineering of acquisition, control and logic circuits, electromechanical engineering of electrical interfaces and extended cable plants, and selection and construction of detector elements. Detector segmentation, coverage, and sensitivity specifications are determined through detailed simulations of particle interactions.

The electrical and mechanical design of the fiber tracker and central preshower trigger are led by Fermilab. The primary task is selection and programming of the gate arrays that formulate the trigger output. Fermilab will design the circuit boards containing the gate arrays. The forward preshower trigger electrical and mechanical design is centered at Brookhaven. Beam test of the prototype will occur at Fermilab. The calorimeter trigger, entirely retained from Run I, requires minor upgrades specified and to be completed at Michigan State. The design and construction of the Level 1 muon trigger elements are done primarily at the University of Arizona. Cable plants for all systems are designed at Fermilab.

Procurement

Most trigger components are standard or stock items. Vendors for large orders are selected through competitive bidding.

Inspection

All items are visually inspected upon receipt. No testing is required since components are completely tested during the testing and commissioning of trigger modules.

Construction/Fabrication

The various trigger cards will be fabricated and assembled by vendors. Vendors will be selected by competitive bidding.

Testing/Commissioning

The entire Level 1 system requires extensive debugging prior to the availability of particle interactions. The efficiency of each circuit element will be tested on the bench before assembly with pulse generators and logic analyzers. Individual circuit elements will be tested at Fermilab, U. C. Davis, Michigan State, University of Arizona, SUNY at Stony Brook, and Brookhaven National Laboratory. After assembly with the preshower and muon detectors, the triggers will be tested with radioactive sources.

Cosmic rays and particle interaction tracks will be utilized for the final trigger commissioning and integration at Fermilab. The efficiency and alignment of individual elements and the efficiency of combined trigger elements will be measured with these tracks. Minor online adjustments will be made to the trigger.

Schedule Milestones

The construction schedule for the trigger elements is tied quite closely to the assembly of the detector elements. The milestones for the Level 1 Trigger sub-project are given in the Trigger Framework section, Chapter 10.13.

Manpower Plan

The manpower plan for the Level 1 Trigger sub-project has been combined with the other trigger sub-project plans. The combined trigger plan is given in the manpower plan table in Section 10.13, Trigger Framework.

Cost Estimate

The cost estimate for Level 1 trigger elements is shown in the accompanying table. Costs are based on vendor estimates and include 10% spares, where appropriate. Contingency is assigned base on the criteria in section 7.1.2. and is typically 15%.

WBS	**1.4.3**	**LEVEL 1**						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.4.3	**LEVEL 1**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.4.3.1	***Calorimeter L1 Trigger***				272,390	16	44,689	317,079
1.4.3.1.1	Engineering & design	lot	1	130,000	130,000	15	19,500	149,500
1.4.3.1.2	CTMBD cards for L1 Cal trig	ea	35	1,700	59,500	20	11,900	71,400
1.4.3.1.3	VRB cards	ea	8	3,876	31,008	10	3,101	34,109
1.4.3.1.4	VRB Controller Card	ea	1	1,882	1,882	10	188	2,070
1.4.3.1.5	CTFE Modifications	ea	400	125	50,000	20	10,000	60,000
1.4.3.2	***Muon L1 Trigger***				1,016,454	15	152,468	1,168,922
1.4.3.2.1	Level 0.5 Card (MTC05)	ea	32	7,992.37	255,756	15	38,363	294,119
1.4.3.2.1.1	Serial (AMCC) daughter receiver Cards		512	114.82	58,788	15	8,818	67,606
1.4.3.2.1.1.1	Receiver Deserializer	ea	512	24	12,288	15	1,843	14,131
1.4.3.2.1.1.2	FPGA	ea	512	12.76	6,533	15	980	7,513
1.4.3.2.1.1.3	ECL receiver	ea	1024	6	6,144	15	922	7,066
1.4.3.2.1.1.4	30pin Connector	ea	512	3.10	1,587	15	238	1,825
1.4.3.2.1.1.5	3 pin Connector	ea	512	0.13	67	15	10	77
1.4.3.2.1.1.6	Coax Connector	ea	1024	2.54	2,601	15	390	2,991
1.4.3.2.1.1.7	Decoupling Capacitors	ea	12800	0.13	1,664	15	250	1,914
1.4.3.2.1.1.8	Tantalum Decoupling Capacitors	ea	1536	0.25	384	15	58	442
1.4.3.2.1.1.9	Ferrite Beads	ea	1536	0.34	522	15	78	601
1.4.3.2.1.1.10	Resistors	ea	6144	0.13	799	15	120	919
1.4.3.2.1.1.11	Connection Capacitors	ea	4608	0.13	599	15	90	689
1.4.3.2.1.1.12	Printed Circuit Fabrication	ea	512	20	10,240	15	1,536	11,776
1.4.3.2.1.1.13	Printed Circuit Aseembly	ea	512	30	15,360	15	2,304	17,664
1.4.3.2.1.2	Input FIFO for synchr.	ea	512	26	13,312	15	1,997	15,309
1.4.3.2.1.3	Output FIFOs	ea	544	26	14,144	15	2,122	16,266
1.4.3.2.1.4	Dual Port Memories	ea	128	54	6,912	15	1,037	7,949
1.4.3.2.1.5	Coax Connectors	ea	512	6	3,072	15	461	3,533
1.4.3.2.1.6	FPGA for trig logic	ea	192	500	96,000	15	14,400	110,400
1.4.3.2.1.7	FPGA for second lookup	ea	32	200	6,400	15	960	7,360
1.4.3.2.1.8	VME interface logic	ea	32	100	3,200	15	480	3,680
1.4.3.2.1.9	160 pin DIN Connector	ea	32	25	800	15	120	920
1.4.3.2.1.10	128 pin DIN Connectors	ea	32	20	640	15	96	736
1.4.3.2.1.11	Other parts	ea	32	100.0	3,200	15	480	3,680
1.4.3.2.1.12	RG58 Cable	ft	38400	0.30	11,520	15	1,728	13,248
1.4.3.2.1.13	RG58 Cable Connectors	ea	1024	7	7,168	15	1,075	8,243
1.4.3.2.1.14	Production Layout	ea	32	156.25	5,000	15	750	5,750
1.4.3.2.1.15	PCB Fabrication	ea	32	500	16,000	15	2,400	18,400
1.4.3.2.1.16	Cable Fanout Boxes	ea	64	150	9,600	15	1,440	11,040
1.4.3.2.2	Level 1 Card (MTC10)	ea	32	7,636	244,356	15	36,653	281,009
1.4.3.2.2.1	Serial (AMCC) daughter receiver Cards	ea	512	114.82	58,788	15	8,818	67,606
1.4.3.2.2.1.1	Receiver Deserializer	ea	512	24	12,288	15	1,843	14,131

WBS	1.4.3	LEVEL 1						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.4.3	**LEVEL 1**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.4.3.2.2.1.2	FPGA	ea	512	12.76	6,533	15	980	7,513
1.4.3.2.2.1.3	ECL receiver	ea	1024	6	6,144	15	922	7,066
1.4.3.2.2.1.4	30pin Connector	ea	512	3.10	1,587	15	238	1,825
1.4.3.2.2.1.5	3 pin Connector	ea	512	0.13	67	15	10	77
1.4.3.2.2.1.6	Coax Connector	ea	1024	2.54	2,601	15	390	2,991
1.4.3.2.2.1.7	Decoupling Capacitors	ea	12800	0.13	1,664	15	250	1,914
1.4.3.2.2.1.8	Tantalum Decoupling Capacitors	ea	1536	0.25	384	15	58	442
1.4.3.2.2.1.9	Ferrite Beads	ea	1536	0.34	522	15	78	601
1.4.3.2.2.1.10	Resistors	ea	6144	0.13	799	15	120	919
1.4.3.2.2.1.11	Connection Capacitors	ea	4608	0.13	599	15	90	689
1.4.3.2.2.1.12	Printed Circuit Fabrication	ea	512	20	10,240	15	1,536	11,776
1.4.3.2.2.1.13	Printed Circuit Aseembly	ea	512	30	15,360	15	2,304	17,664
1.4.3.2.2.2	Input FIFO for synchr.	ea	512	26	13,312	15	1,997	15,309
1.4.3.2.2.3	Output FIFOs	ea	544	26	14,144	15	2,122	16,266
1.4.3.2.2.4	Dual Port Memories	ea	128	54	6,912	15	1,037	7,949
1.4.3.2.2.5	Coax Connectors	ea	512	6	3,072	15	461	3,533
1.4.3.2.2.6	Flex FPGA for trig lookup	ea	192	500	96,000	15	14,400	110,400
1.4.3.2.2.7	FPGA for second lookup	ea	0	200	0	15	0	0
1.4.3.2.2.8	VME interface logic	ea	32	100	3,200	15	480	3,680
1.4.3.2.2.9	160 pin DIN Connector	ea	32	25	800	15	120	920
1.4.3.2.2.10	128 pin DIN Connectors	ea	32	20	640	15	96	736
1.4.3.2.2.11	Other parts	ea	32	100.0	3,200	15	480	3,680
1.4.3.2.2.12	RG58 Cable	ft	38400	0.30	11,520	15	1,728	13,248
1.4.3.2.2.13	RG58 Cable Connectors	ea	1024	7	7,168	15	1,075	8,243
1.4.3.2.2.14	Production Layout	ea	32	0.00	0	15	0	0
1.4.3.2.2.15	PCB Fabrication	ea	32	500	16,000	15	2,400	18,400
1.4.3.2.2.16	Cable Fanout Boxes	ea	64	150	9,600	15	1,440	11,040
1.4.3.2.3	Crate manager card (MTCM)	ea	8	2,744	21,955	15	3,293	25,248
1.4.3.2.3.1	Control Logic	ea	32	200	6,400	15	960	7,360
1.4.3.2.3.2	Trigger Logic	ea	8	200	1,600	15	240	1,840
1.4.3.2.3.3	VME interface logic	ea	8	100	800	15	120	920
1.4.3.2.3.4	Cypress Serial Links	ea	16	30	480	15	72	552
1.4.3.2.3.5	Serial Transmitter Daughter Card (AMCC)	ea	8	134.22	1,074	15	161	1,235
1.4.3.2.3.5.1	Transmitter Serializer	ea	8	19	154	15	23	177
1.4.3.2.3.5.2	FPGA	ea	8	36.96	296	15	44	340
1.4.3.2.3.5.3	ECL Driver	ea	16	6	96	15	14	110
1.4.3.2.3.5.4	30pin Connector	ea	8	3.10	25	15	4	29
1.4.3.2.3.5.5	3 pin Connector	ea	8	0.13	1	15	0	1
1.4.3.2.3.5.6	Coax Connector	ea	16	2.54	41	15	6	47
1.4.3.2.3.5.7	Decoupling Capacitors	ea	200	0.13	26	15	4	30
1.4.3.2.3.5.8	Tantalum Decoupling Capacitors	ea	24	0.25	6	15	1	7
1.4.3.2.3.5.9	Ferrite Beads	ea	24	0.34	8	15	1	9
1.4.3.2.3.5.10	Resistors	ea	96	0.13	12	15	2	14
1.4.3.2.3.5.11	Connection Capacitors	ea	72	0.13	9	15	1	11
1.4.3.2.3.5.12	Printed Circuit Fabrication	ea	8	20	160	15	24	184
1.4.3.2.3.5.13	Printed Circuit Aseembly	ea	8	30	240	15	36	276
1.4.3.2.3.6	Output FIFOs	ea	16	26	416	15	62	478

WBS	1.4.3	LEVEL 1							
WBS	ITEM	MATERIALS & SERVICES (M&S)				CONTINGENCY		
1.4.3	LEVEL 1	Unit	#	Unit Cost	M&S TOTAL	%	Cost	TOTAL Cost
1.4.3.2.3.7	Dual Port Memories	ea	32	54	1,728	15	259	1,987
1.4.3.2.3.8	Other Parts	ea	8	200	1,600	15	240	1,840
1.4.3.2.3.9	160 pin DIN Connector	ea	8	25	200	15	30	230
1.4.3.2.3.10	128 pin DIN Connector	ea	8	20	160	15	24	184
1.4.3.2.3.11	96 pin DIN Connector	ea	8	15	120	15	18	138
1.4.3.2.3.12	Cable to MTM Card	ft	80	0.30	24	15	4	28
1.4.3.2.3.13	Connectors for Cable to L2	ea	16	7	112	15	17	129
1.4.3.2.3.14	Connectors for Cable to MRC	ea	16	7	112	15	17	129
1.4.3.2.3.15	Connectors for Cable to Fanout	ea	16	10	160	15	24	184
1.4.3.2.3.16	Connectors for Cable to MTM	ea	16	7	112	15	17	129
1.4.3.2.3.17	PCB Fabrication	ea	8	500	4,000	15	600	4,600
1.4.3.2.3.18	Production Layout	ea	8	357.14	2,857	15	429	3,286
1.4.3.2.4	Muon Trigger Manager Card (MTM)		3	2,074	6,222	15	933	7,155
1.4.3.2.4.1	Control Logic	ea	3	200	600	15	90	690
1.4.3.2.4.2	Trigger Logic	ea	3	200	600	15	90	690
1.4.3.2.4.3	VME interface logic	ea	3	100	300	15	45	345
1.4.3.2.4.4	Serial Receiver Daughter Card (AMCC)	ea	3	114.82	344	15	52	396
1.4.3.2.4.4.1	Receiver Deserializer	ea	3	24	72	15	11	83
1.4.3.2.4.4.2	FPGA	ea	3	12.76	38	15	6	44
1.4.3.2.4.4.3	ECL receiver	ea	6	6	36	15	5	41
1.4.3.2.4.4.4	30pin Connector	ea	3	3.10	9	15	1	11
1.4.3.2.4.4.5	3 pin Connector	ea	3	0.13	0	15	0	0
1.4.3.2.4.4.6	Coax Connector	ea	6	2.54	15	15	2	18
1.4.3.2.4.4.7	Decoupling Capacitors	ea	75	0.13	10	15	1	11
1.4.3.2.4.4.8	Tantalum Decoupling Capacitors	ea	9	0.25	2	15	0	3
1.4.3.2.4.4.9	Ferrite Beads	ea	9	0.34	3	15	0	4
1.4.3.2.4.4.10	Resistors	ea	36	0.13	5	15	1	5
1.4.3.2.4.4.11	Connection Capacitors	ea	27	0.13	4	15	1	4
1.4.3.2.4.4.12	Printed Circuit Fabrication	ea	3	20	60	15	9	69
1.4.3.2.4.4.13	Printed Circuit Aseembly	ea	3	30	90	15	14	104
1.4.3.2.4.5	Output FIFOs	ea	6	26	156	15	23	179
1.4.3.2.4.6	Dual Port Memories	ea	12	54	648	15	97	745
1.4.3.2.4.7	Other Parts	ea	3	200	600	15	90	690
1.4.3.2.4.8	160 pin DIN Connector	ea	3	25	75	15	11	86
1.4.3.2.4.9	128 pin DIN Connector	ea	3	20	60	15	9	69
1.4.3.2.4.10	96 pin DIN Connector	ea	3	15	45	15	7	52
1.4.3.2.4.11	Cable to Framework	ft	600	0.30	180	15	27	207
1.4.3.2.4.12	Connectors for Cable to Framework	ea	6	7	42	15	6	48
1.4.3.2.4.13	PCB Fabrication	ea	3	500	1,500	15	225	1,725
1.4.3.2.4.14	Production Layout	ea	3	357.14	1,071	15	161	1,232
1.4.3.2.5	Mini-drift Centroid Finder Card (MCEN)		58	6,260	363,076	15	54,461	417,537
1.4.3.2.5.1	Serial Transmitter Daughter Card (AMCC)	ea	232	134.22	31,139	15	4,671	35,810
1.4.3.2.5.1.1	Transmitter Serializer	ea	232	19.20	4,454	15	668	5,123
1.4.3.2.5.1.2	FPGA	ea	232	36.96	8,575	15	1,286	9,861
1.4.3.2.5.1.3	ECL Driver	ea	464	6	2,784	15	418	3,202
1.4.3.2.5.1.4	30pin Connector	ea	232	3.10	719	15	108	827
1.4.3.2.5.1.5	3 pin Connector	ea	232	0.13	30	15	5	35

WBS	1.4.3	LEVEL 1						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.4.3	**LEVEL 1**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.4.3.2.5.1.6	Coax Connector	ea	464	2.54	1,179	15	177	1,355
1.4.3.2.5.1.7	Decoupling Capacitors	ea	5800	0.13	754	15	113	867
1.4.3.2.5.1.8	Tantalum Decoupling Capacitors	ea	696	0.25	174	15	26	200
1.4.3.2.5.1.9	Ferrite Beads	ea	696	0.34	237	15	35	272
1.4.3.2.5.1.10	Resistors	ea	2784	0.13	362	15	54	416
1.4.3.2.5.1.11	Connection Capacitors	ea	2088	0.13	271	15	41	312
1.4.3.2.5.1.12	Printed Circuit Fabrication	ea	232	20	4,640	15	696	5,336
1.4.3.2.5.1.13	Printed Circuit Aseembly	ea	232	30	6,960	15	1,044	8,004
1.4.3.2.5.2	Serial Receiver Daughter Card (AMCC)	ea	696	114.82	79,915	15	11,987	91,902
1.4.3.2.5.2.1	Receiver Deserializer	ea	696	24	16,704	15	2,506	19,210
1.4.3.2.5.2.2	FPGA	ea	696	12.76	8,881	15	1,332	10,213
1.4.3.2.5.2.3	ECL receiver	ea	1392	6	8,352	15	1,253	9,605
1.4.3.2.5.2.4	30pin Connector	ea	696	3.10	2,158	15	324	2,481
1.4.3.2.5.2.5	3 pin Connector	ea	696	0.13	90	15	14	104
1.4.3.2.5.2.6	Coax Connector	ea	1392	2.54	3,536	15	530	4,066
1.4.3.2.5.2.7	Decoupling Capacitors	ea	17400	0.13	2,262	15	339	2,601
1.4.3.2.5.2.8	Tantalum Decoupling Capacitors	ea	2088	0.25	522	15	78	600
1.4.3.2.5.2.9	Ferrite Beads	ea	2088	0.34	710	15	106	816
1.4.3.2.5.2.10	Resistors	ea	8352	0.13	1,086	15	163	1,249
1.4.3.2.5.2.11	Connection Capacitors	ea	6264	0.13	814	15	122	936
1.4.3.2.5.2.12	Printed Circuit Fabrication	ea	696	20	13,920	15	2,088	16,008
1.4.3.2.5.2.13	Printed Circuit Aseembly	ea	696	30	20,880	15	3,132	24,012
1.4.3.2.5.3	Input FIFO's for synchronization	ea	928	26	24,128	15	3,619	27,747
1.4.3.2.5.4	Output FIFO's	ea	986	26	25,636	15	3,845	29,481
1.4.3.2.5.5	Dual Port Memories	ea	232	54	12,528	15	1,879	14,407
1.4.3.2.5.6	Input EPLD	ea	928	6	5,568	15	835	6,403
1.4.3.2.5.7	FPGA for trig logic	ea	232	500	116,000	15	17,400	133,400
1.4.3.2.5.8	FPGA for second lookup	ea	0	200	0	15	0	0
1.4.3.2.5.9	VME interface logic	ea	58	100	5,800	15	870	6,670
1.4.3.2.5.10	160 pin DIN Connector	ea	58	25	1,450	15	218	1,668
1.4.3.2.5.11	128 pin DIN Connectors	ea	58	20	1,160	15	174	1,334
1.4.3.2.5.12	Other parts	ea	58	100.0	5,800	15	870	6,670
1.4.3.2.5.13	RG58 Cable	ft	23200	0.30	6,960	15	1,044	8,004
1.4.3.2.5.14	RG58 Cable Connectors	ea	1856	7	12,992	15	1,949	14,941
1.4.3.2.5.15	Production Layout	ea	58	86.21	5,000	15	750	5,750
1.4.3.2.5.16	PCB Fabrication	ea	58	500	29,000	15	4,350	33,350
1.4.3.2.6	Mini-drfit Chamber Crate Manager (MCEN Crate Manager)		7	2,607	18,250	15	2,738	20,988
1.4.3.2.6.1	Control Logic	ea	28	200	5,600	15	840	6,440
1.4.3.2.6.2	Trigger Logic	ea	7	200	1,400	15	210	1,610
1.4.3.2.6.3	VME interface logic	ea	7	100	700	15	105	805
1.4.3.2.6.4	Cypress Serial Links	ea	14	30	420	15	63	483
1.4.3.2.6.5	Ouput FIFO's	ea	14	26	364	15	55	419
1.4.3.2.6.6	Dual Port Memories	ea	28	54	1,512	15	227	1,739
1.4.3.2.6.7	Other parts	ea	7	200	1,400	15	210	1,610
1.4.3.2.6.8	160 pin DIN Connector	ea	7	25	175	15	26	201
1.4.3.2.6.9	128 pin DIN Connectors	ea	7	20	140	15	21	161
1.4.3.2.6.10	96 pin DIN Connectors	ea	7	15	105	15	16	121

WBS	1.4.3	LEVEL 1						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.4.3	**LEVEL 1**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.4.3.2.6.11	Connectors for Cable to L2	ea	14	7	98	15	15	113
1.4.3.2.6.12	Connectors for Cable to MRC	ea	14	7	98	15	15	113
1.4.3.2.6.13	Connectors for Cable to Fanout	ea	14	10	140	15	21	161
1.4.3.2.6.14	Connectors for Cable to MTM	ea	14	7	98	15	15	113
1.4.3.2.6.15	PCB Fabrication	ea	7	500	3,500	15	525	4,025
1.4.3.2.6.16	Production Layout	ea	7	357.14	2,500	15	375	2,875
1.4.3.2.7	Muon Trigger VME Crates		12	8,903	106,840	15	16,026	122,866
1.4.3.2.7.1	VME Crate Hardware	lot	12	500	6,000	15	900	6,900
1.4.3.2.7.2	Backplane Layout	ea	12	133	1,600	15	240	1,840
1.4.3.2.7.3	Backplane PCB Fabrication	ea	12	500	6,000	15	900	6,900
1.4.3.2.7.4	Backplane Assembly	ea	12	120	1,440	15	216	1,656
1.4.3.2.7.5	Backplane Parts	lot	12	50	600	15	90	690
1.4.3.2.7.6	Backplane Connectors	ea	480	20	9,600	15	1,440	11,040
1.4.3.2.7.7	Microprocessor (68k)	ea	12	3,000	36,000	15	5,400	41,400
1.4.3.2.7.8	Power Supplies	ea	12	3,000	36,000	15	5,400	41,400
1.4.3.2.7.9	Cooling	lot	12	500	6,000	15	900	6,900
1.4.3.2.7.10	Other Hardware	lot	12	100	1,200	15	180	1,380
1.4.3.2.7.11	Cabling	lot	12	100	1,200	15	180	1,380
1.4.3.2.7.12	Mechanical Shop Time	lot	12	100	1,200	15	180	1,380
1.4.3	TOTAL L1 TRIGGER				1,288,844	15	197,157	1,486,001

10.16 Level 2 Trigger

Objectives and Performance Criteria

Objectives of the Level 2 trigger include:

- To combine detector information;
- To reduce the Level 2 output bandwidth of 10 kHz to 1 kHz;
- To introduce less than a few percent of deadtime into the DAQ system;
- Decision time less than 100 μsec.

A detailed description of the performance criteria and requirements is presented in DØ notes 2746 and 2894. A list of notes and drawings is also maintained on a World Wide Web page for the Level 2 trigger.

Components

Major components of the Level 2 trigger include:

- Level 2 Calorimeter preprocessor;
- Muon Preprocessor;
- Tracking preprocessor;
- Level 2 global stage;
- Software.

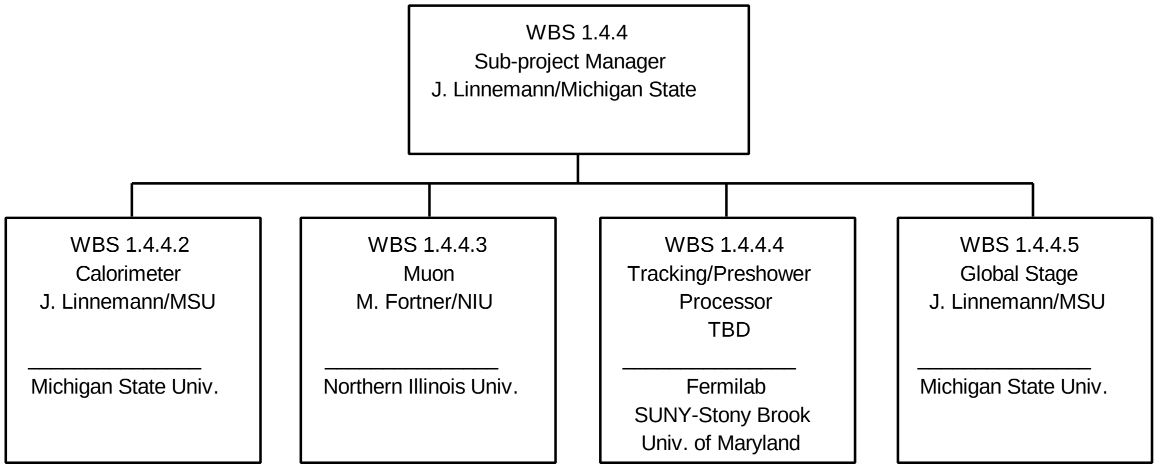
Level 2 has preprocessors for every detector subsystem which collect and prepare condensed data to be sent to a global Level 2 processor. The global processor receives the data from all detectors (about 1 Kbytes/event) and determines which required triggers this event passed or not based on this information. This information is passed on to the Level 2 framework, which in turn decides whether to accept or reject the event and communicates this information back to the rest of the DAQ system, which is holding this event in its buffers. If the event passes, it is handed to the Level 3 trigger stage.

Management, Organization and Responsibilities

The institutions within DØ contributing to the design and simulations of the Level 2 system are: Michigan State University., Northern Illinois University, Iowa State University, Fermilab, and U. C. Davis. The sub-project manager is J. Linnemann (Michigan State). The division of responsibilities is as follows: the Level 2 framework, calorimeter preprocessors and global processors are done by MSU, the muon preprocessors are the responsibility of NIU, the tracking part is worked on by Fermilab and U. C. Davis, and Iowa State supplies timing simulations of the system.

There are weekly meetings at MSU and biweekly meetings at Fermilab, where the progress is reported in the framework of the trigger meeting. Transparencies of meetings are made available as DØ notes and minutes of meetings are distributed via e-mail distribution lists. Major decisions are either documented in DØ notes or on the World Wide Web Level 2 trigger page.

Level 2 Trigger Sub-project Organization



Work Plan

Engineering/Design

The engineering efforts are mostly in the design/selection of the preprocessors and the institutions responsible for this have been listed above. The implementation of the Level 2 system in the DØ DAQ system requires a number of timing studies of the system to determine its behavior within the boundary conditions of the overall system. These will be done by physicists.

Procurement

The major components to be procured are a) the calorimeter preprocessor; 2) the muon preprocessor; 3) the tracking preprocessor; 4) the global stage processor; and 5) software. Specifications on bandwidth and input source requirements for the systems are provided by DØ physicists and engineers. Preprocessors for the muon and tracking systems will be DSPs which are readily available from industry. The calorimeter and global stage processors will be identical RISC processors based on a modified version of a commercially available RISC-based motherboard family. This is a joint development effort with CDF/University of Michigan, which has similar bandwidth and input requirements. Associated electronics and components for the Level 2 trigger system will be procured from commercial vendors, in conjunction with related procurements for the Trigger Framework and Calorimeter Front End Electronics sub-projects. Software will be written by project physicists and purchased commercially."

Inspection

Since most of these components are either custom electronics or processors, we expect no direct inspection, but will immediately go to testing and commissioning.

Construction/Fabrication

The Level 2 framework, which provides communication of all the components within the Level 2 system and to the rest of the DAQ system, will be built at MSU. The muon system will be done at NIU and the tracking preprocessors at Fermilab. The calorimeter and global processors will be done by MSU and UoM. There is also a large amount of software to be written, namely the algorithms which are creating/processing the information in either preprocessors or global processors. A large fraction of this will be done by MSU and Fermilab physicists and engineers, with the help of other institutions.

Testing/Commissioning

Algorithms that will run at Level 2 rely heavily on our experience from Run I and even use experimental data to test and time them. Once the first hardware for each subsystem is available it will be bench tested for timing performance. The commissioning of the system will not take place until it is installed in the DØ DAQ system with all other components. This will be during the time when the whole DAQ is being commissioned.

Schedule Milestones

Because of the rapid developments in the speed and capabilities of electronics, we delay the final purchase of the system as long as long possible. However we have to decide on certain aspects and possible vendors earlier, so that algorithms and code can be written and ported to the final system, with only minor modifications. The milestones for the Level 2 Trigger sub-project are given in the Trigger Framework section, Chapter 10.13.

Manpower Plan

The manpower plan for the Level 2 Trigger sub-project has been combined with the other trigger sub-project plans. The combined trigger plan is given in the manpower plan table in Section 10.13, Trigger Framework.

Cost Estimate

The cost estimate for the Level 2 trigger elements is shown in the accompanying table. Contingency is assigned base on the criteria in section 7.1.2. and is typically 20%.

WBS 1.4.4	LEVEL 2							
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.4.4	**LEVEL 2**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.4.4.1	***L1.5 Calorimeter Electron Trigger***				261,000	0	0	261,000
1.4.4.1.1	L1 Interface	lot	1	100,000	100,000	0	0	100,000
1.4.4.1.2	DSP System	lot	1	100,000	100,000	0	0	100,000
1.4.4.1.3	Software Development	lot	1	61,000	61,000	0	0	61,000
1.4.4.2	***L2 Calorimeter Preprocessor***				340,700	20	68140	408,840
1.4.4.2.1	Engineering & Design	m. yr.	1	50,000	50,000	20	10000	60,000
1.4.4.2.2	Data Transport from L1 to L2	lot	1	155,000	155,000	20	31000	186,000
1.4.4.2.3	Processor Boards	ea	3	17,500	52,500	20	10500	63,000
1.4.4.2.4	VME Physics Crate	ea	1.5	4,000	6,000	20	1200	7,200
1.4.4.2.5	Custom Backplane	ea	1.5	1,000	1,500	20	300	1,800
1.4.4.2.6	Data Source Drive Cards	ea	12.5	1,000	12,500	20	2500	15,000
1.4.4.2.7	Development system				42,500	20	8500	51,000
1.4.4.2.7.1	Processor Boards (1st generation)	lot	1	17,500	17,500	20	3500	21,000
1.4.4.2.7.2	Processor Boards (2nd generation)	ea	1	17,500	17,500	20	3500	21,000
1.4.4.2.7.3	Crates	ea	1	4,000	4,000	20	800	4,800
1.4.4.2.7.4	Custom Backplane	ea	1.0	1,000	1,000	20	200	1,200
1.4.4.2.7.5	Data Source Drive Cards	ea	2.5	1,000	2,500	20	500	3,000
1.4.4.2.8	Commuications with Framework	ea	2.0	2,000	4,000	20	800	4,800
1.4.4.2.9	Readout to L3	ea	1.0	14,700	14,700	20	2940	17,640
1.4.4.2.10	L2 Status Register	ea	2.0	1,000	2,000	20	400	2,400
1.4.4.3	***Muon Preprocessor***				389,000	24	94750	483,750
1.4.4.3.1	Engineering & Design	m. yr.	1	50,000	50,000	20	10000	60,000
1.4.4.3.2	CNAPS development system	lot	1	20,000	20,000	25	5000	25,000
1.4.4.3.3	CNAPS-128	ea	15	18,000	270,000	25	67500	337,500
1.4.4.3.4	SLIC	ea	15	2,000	30,000	25	7500	37,500
1.4.4.3.5	Processor Controllers	ea	2	3,000	6,000	25	1500	7,500
1.4.4.3.6	Interface Controllers	ea	2	2,000	4,000	25	1000	5,000
1.4.4.3.7	Crates	ea	3	3,000	9,000	25	2250	11,250
1.4.4.4	***Tracking Preprocessors***				587,000	24	142000	729,000
1.4.4.4.1	CFT Preprocessor				239,500	24	57400	296,900
1.4.4.4.1.1	Engineering & Design	m.yr.	0.75	50,000	37,500	20	7500	45,000
1.4.4.4.1.2	Crates	ea	6	2,000	12,000	20	2400	14,400
1.4.4.4.1.3	Interface Controller	ea	3	5,000	15,000	25	3750	18,750
1.4.4.4.1.4	Serial Interace	ea	24	2,000	48,000	25	12000	60,000
1.4.4.4.1.5	Processor Controller	ea	3	5,000	15,000	25	3750	18,750
1.4.4.4.1.6	Processors	ea	14	8,000	112,000	25	28000	140,000
1.4.4.4.2	Preshower Preprocessor				347,500	24	84600	432,100
1.4.4.4.2.1	Engineering & Design	lot	0.75	50,000	37,500	20	7500	45,000
1.4.4.4.2.2	Crates	ea	4	2,000	8,000	20	1600	9,600

WBS	**1.4.4**	**LEVEL 2**						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.4.4	**LEVEL 2**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.4.4.4.2.3	Interface Controller	ea	3	5,000	15,000	25	3750	18,750
1.4.4.4.2.4	Serial Interace	ea	20	2,000	40,000	25	10000	50,000
1.4.4.4.2.5	Processor Controller	lot	3	5,000	15,000	25	3750	18,750
1.4.4.4.2.6	Processors	lot	29	8,000	232,000	25	58000	290,000
1.4.4.5	***L2 Global Stage***				240,700	21	51140	291,840
1.4.4.5.1	Engineering & Design	m. yr.	1.00	50,000	50,000	20	10000	60,000
1.4.4.5.2	Data Transport from Preprocessors to L2 Global	lot	1	60,000	60,000	25	15000	75,000
1.4.4.5.3	Processor Boards	ea	3	17,500	52,500	20	10500	63,000
1.4.4.5.4	VME Physics Crate	ea	1.5	4,000	6,000	20	1200	7,200
1.4.4.5.5	Custom Backplane	ea	1.5	1,000	1,500	20	300	1,800
1.4.4.5.6	Data Source Drive Cards	ea	7.5	1,000	7,500	20	1500	9,000
1.4.4.5.7	Development system				42,500	20	8500	51,000
1.4.4.5.7.1	Processor Boards (1st generation)	lot	1	17,500	17,500	20	3500	21,000
1.4.4.5.7.2	Processor Boards (2nd generation)	ea	1	17,500	17,500	20	3500	21,000
1.4.4.5.7.3	Crates	ea	1	4,000	4,000	20	800	4,800
1.4.4.5.7.4	Custom Backplane	ea	1.0	1,000	1,000	20	200	1,200
1.4.4.5.7.5	Data Source Drive Cards	ea	2.5	1,000	2,500	20	500	3,000
1.4.4.5.8	Commuications with Framework	ea	2.0	2,000	4,000	20	800	4,800
1.4.4.5.9	Readout to L3	ea	1.0	14,700	14,700	20	2940	17,640
1.4.4.5.10	L2 Status Register	ea	2.0	1,000	2,000	20	400	2,400
1.4.4	TOTAL L2 TRIGGER				1,818,400	20	356,030	2,174,430

10.17 Level 3 Trigger

Objectives and Performance Criteria

Objectives of the Level 3 Trigger system include:

- Providing the hardware and software framework for software-based event triggering;
- Providing data paths and associated modules which carry the raw data blocks to the processors and to the online system;
- Accepting an input rate of at least 1 kHz;
- Having the capability for upgrading to input rates of 10 kHz or higher;
- Having an output rate from Level 3 of at least 20 Hz, with capability for rates in the range of 100 to 200 Hz.

Components

Major components of the Level 3 trigger include:

- Buffer boards in the crates where the DØ Detector data is digitized;
- Data readout and control systems;
- A farm of high performance processors;
- Associated software.

The Level 3 design conforms to the existing architecture in which there is a direct transfer of all the digitized data for an event from buffer modules in the digitizer crates to multiported memories associated with a Level 3 processor system. Additionally the Level 3 Trigger incorporates essentially all the existing custom modules on hand, and particularly the buffer memory modules in the VME digitizer crates and the muliported memories in each of the processor nodes. The Level 3 Trigger represents an upgrade to the existing system in three particular areas : 1) a speed upgrade to the VME buffer memory boards, added to 40% of the modules during Run 1, is completed on all boards; 2) all processor systems will be replaced; and 3) the readout/control system is upgraded to improve occupancy of the data paths and hence readout capability and flexibility.

Management, Organization, and Responsibilities

Brown University carries the responsibility for the design, development and testing, and installation of the Level 3 Trigger. D. Cutts (Brown University) is the Level 3 Trigger sub-project manager. The Level 3 Trigger sub-system is an upgraded version of the existing high level trigger system currently in place at DØ, for which Brown University carried similar responsibility.

The Level 3 Trigger provides the data acquisition link bringing data from the front end digitizing crates to the online system, and as such is critical to the operation or testing of the detector. Brown University has responsibility for ensuring that this existing and evolving system will remain available for data collection while its upgrade is underway. This requirement influences the Work Plan described below.

In addition to hardware components of the Level 3 Trigger, Brown is responsible for associated software, involving both the data acquisition and the filter framework. The data acquisition software consists of operational control, monitoring and diagnostic routines. In addition Brown provides the packages related to the handling of the data blocks in the Level 3 processors within a framework permitting efficient use of filter algorithms.

The effort on the Level 3 Trigger is carried out in close coordination with the development of other trigger systems, through frequent presentations, notes and Web postings. Additionally, we stay in close contact with M. Tuts and the Electronic Certification Board which he heads, with D. Schamberger who has oversight responsibility for overall data acquisition, and G. Blazey who coordinates all Run II trigger systems. For the software components we coordinate our efforts with DØ Run II software managers.

Work Plan

Engineering/Design

A significant amount of engineering and design effort is involved with the Level 3 Trigger development. Brown University coordinates this work. In each of the areas being upgraded from the present high level trigger system there are some related engineering/design issues. The continuation of the partially completed upgrade of the VME buffer memory boards requires a redesign of the daughter card because a component used earlier is no longer available. Likewise, the readout/control system upgrade involves the design of a few new modules; and the adapter linking the multiported memories to the processors represents a modification to the existing design. This engineering/design work builds on existing designs which have proved highly successful in the present system.

As part of the design cycle, Brown University is upgrading its existing small scale version of the DØ data acquisition/ high level trigger system. Prototype and test versions of the new designs for Level 3 modules are studied at Brown, and only incorporated into the evolving Level 3 at DØ when the data collection will not be impaired. As part of these tests Brown works on the required associated software.

Procurement

The specific procurement items (described above) generally represent upgrades to an existing system based on custom high performance modules. A major item is the specific commercial processor to be used in the Level 3; we will delay procurement of the quantity of these items until 1998 but examine candidate processors as part of the development and testing of the other portions of the upgrade to Level 3. The readout/control system evolves from tests at Brown through full procurement.

Inspection

Brown University tests versions of all components in its small scale Level 3 development system, providing a thorough testing of all final components as part of the installation process at DØ. At each stage component modules which do not perform as required will be modified, repaired or replaced. Software associated with operation, monitoring and diagnostics of these items will be developed and debugged in parallel.

Construction/Fabrication

Brown University will modify its existing DØ trigger/data acquisition development setup to construct a small scale replica of the Level 3 trigger at Brown. This system is important for Brown’s responsibility for the development and certification process. Brown is also responsible for the upgrade at DØ of the existing high level trigger/data acquisition system into the Level 3 Trigger, in an evolutionary sequence which does not impact the need for uninterrupted data acquisition capability from the DØ Detector

Testing/Commissioning

As described above, Brown University is responsible for testing and commissioning the Level 3 Trigger. The testing is centered at Brown, for tests involved in the development cycle associated with both prototype modules needed for the upgrade and with associated control, monitoring and diagnostic software development. Commissioning new components of the Level 3 Trigger at DØ follows completion of this work at Brown, and will be done incrementally as described above. This seamless commissioning involves advance testing at Brown of the associated software required for the operation, monitoring and diagnostics of the new Level 3 Trigger components, and subsequent commissioning of this software at DØ in conjunction with the hardware.

Schedule Milestones

The milestones for the Level 3 Trigger sub-project are given in the Trigger Framework section, Chapter 10.13.

Manpower Plan

The manpower plan for the Level 3 Trigger sub-project has been combined with the other trigger sub-project plans. The combined trigger plan is given in the manpower plan table in Section 10.13, Trigger Framework.

Cost Estimate

The cost estimate for the Level 3 trigger elements is shown in the accompanying table. These costs are based on vendor estimates. Contingency is assigned base on the criteria in section 7.1.2. and is typically 10-20%.

WBS	1.4.5	LEVEL 3						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.4.5	**LEVEL 3**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.4.5.1	***Engineering & Design***	m. yr.	3.0	50,000	150,000	10	15,000	165,000
1.4.5.2	***Bandwidth Expansion***				39,000	10	3,900	42,900
1.4.5.2.1	VBD upgrade VME readout	ea	60	400	24,000	10	2,400	26,400
1.4.5.2.2	High Speed Output upgrade	ea	1	15,000	15,000	10	1,500	16,500
1.4.5.3	***Level 3 Nodes***				332,800	20	66,560	399,360
1.4.5.3.1	Processor Upgrade	ea	48	5,000	240,000	20	48,000	288,000
1.4.5.3.2	Processor Bus Adapter	ea	48	1,500	72,000	20	14,400	86,400
1.4.5.3.3	L3 Rack Upgrades	ea	9	1,200	10,800	20	2,160	12,960
1.4.5.3.4	L3 Supervisor and Inerfaces	ea	1	10,000	10,000	20	2,000	12,000
1.4.5.4	***Readout control***				217,000	20	43,400	260,400
1.4.5.4.1	Collector Cards and Fiber	ea	8	6,000	48,000	20	9,600	57,600
1.4.5.4.2	Distributor Controllers	ea	12	8,000	96,000	20	19,200	115,200
1.4.5.4.3	Event Tag Generator, Interfaces	ea	1	10,000	10,000	20	2,000	12,000
1.4.5.4.4	Multiport Memory Daughter Cards	ea	96	500	48,000	20	9,600	57,600
1.4.5.4.5	Monitoring and Diagnostic Systems	ea	1	15,000	15,000	20	3,000	18,000
1.4.5	TOTAL L3 TRIGGER				738,800	17	128,860	867,660

10.18 Online Computing

Objectives and Performance Criteria

The DØ Online Computing system will be upgraded for operation of the DØ detector during Run II of the Tevatron collider. Objectives include:

- Collection of data at 20 Hz with 250 Kbytes/event;
- DAQ bandwidth of 5 Mbytes/sec;
- Short-term DAQ burst capacity of 25 Mbytes/sec;
- Greater than 99% up-time level of reliability.

Components

The DAQ system consists of:

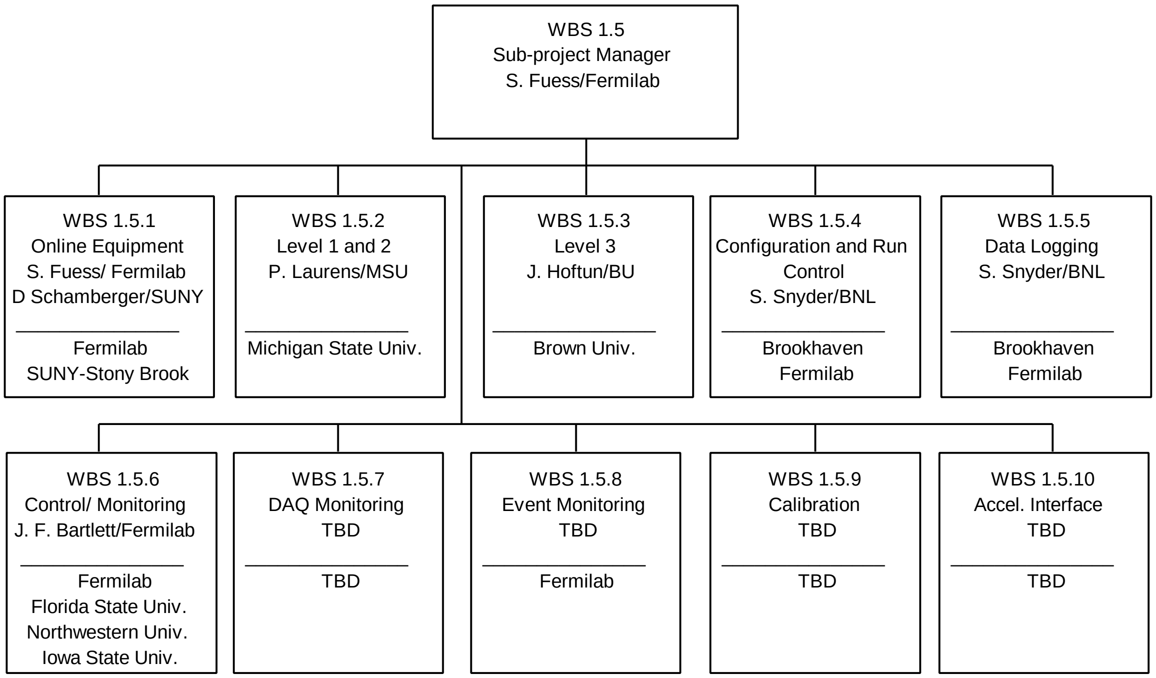
- DAQ nodes for data collection;
- Logging, control and monitoring nodes;
- Front ends with close connection to detector elements;
- Associated software.

Management, Organization, and Responsibilities

The institutions with significant participation in the development of the Online computing system are Fermilab, Brookhaven National Laboratory, Brown University, Michigan State University, Northwestern University, Iowa State University, and State University of New York at Stony Brook. There are also software contributions from members of groups associated with the detector elements and with monitoring of the event data stream. The Online Computing sub-project manager is S. Fuess (FNAL). The Online Software effort is also a sub-project within the entire DØ Run II software development effort. This software sub-project is also headed by S. Fuess, with the Run II software project headed by W. Merritt (FNAL). There are several subgroups charged with the production of various software elements. The sub-project organization and leadership is shown in the accompanying chart.

A list of tasks for Online Computing exists and is partially complete in the assignment of institutions and personnel to the tasks. The maintenance and further development of this task list, along with the scheduling and resource requirements, is the responsibility of the Online computing managers. The Online Computing group meets weekly at Fermilab, with videoconferencing capability as needed. Reference material and notes from these meetings are distributed on World Wide Web pages.

Online Computing Sub-project Organization



Work Plan

Engineering / Design

The design of the Run II Online computing system closely follows that successfully used in the Run I system. Hardware modifications are necessary to accommodate the higher bandwidth requirements. Software modifications are needed to accommodate the new detector elements as well as to conform to the operating systems and programming environments of the chosen hardware solution. The computing hardware architecture is determined by the members of the contributing groups along with expert consultation from the Fermilab Computing Division. Software is developed for the Online system as part of the more general DØ Run II Software development program. Guidelines and recommendations for software design are established. The Online software benefits from the tools and methods under development for the Offline effort.

Procurement

The computing hardware for the Online system will be purchased late in the Run II upgrade period in order to take advantage of technical improvements and lower costs. The exact items to be purchased depend upon the results of deliberations on the architecture of the Online system, but it is expected that the system will consist of workstations (and perhaps PCs) connected by a standard high-speed network.

Design and Coding

The design of the Online system closely follows that employed in Run I. Details of both the hardware architecture and software components will be determined in the early phase of the project. The first phase of software coding for the Online system will consist of the construction of common tools to be employed across many tasks. For example, the task-to-task communication procedures will be common to all components. The software for the various system components will then be developed in parallel.

Testing/Commissioning

The schedule for the Online system has several milestones at which various levels of functionality exist. The initial stage is for specifications and tool development. This is followed by a period of development of individual components, which are tested individually and then merged into a complete system. The complete data path is constructed, with final coordinated operation of all of the components.

Schedule Milestones

The milestones for the Online Computing sub-project are given in the table below. M1, M2, and M3 identify milestones held by the DoE, the Fermilab Directorate, and the Upgrade Project managers, respectively.

ID	Milestones- Online Computing	Date
18	Test Beam Phase 1 Operational	8-Apr-97
19	Test Beam Phase 2 Operational	2-Jun-97
46	COOR Phase 1 Available	27-Jun-97
65	Data Distributor Operational	3-Jul-97
50	TAKER Available	30-Jul-97
54	M3-Online Level 1 Readout Available	1-Oct-97
20	Test Beam Phase 3 Completed	10-Dec-97
47	COOR Phase 2 Available	20-Jan-98
48	M3-Online Run Control System Operational	20-Jan-98
62	M3-Online Data Logger Operational	23-Jul-98
26	M3-EPICS Control System Operational	6-Aug-98
41	M3-Online Alarm System Operational	16-Sep-98
35	Clock Server Available	6-Nov-98
31	High Voltage Phase 1 Available	2-Feb-99
37	M3-Online Parameter Page Available	23-Feb-99
39	C&M Logger Available	23-Feb-99
58	M3-Online Level 3 Readout Available	1-Mar-99
24	M3-Online Database Populated	20-Apr-99
55	L2 Readout Available	1-Jun-99
33	High Voltage Phase 2 Available	5-Nov-99
28	COMM_TKR Operational	30-Nov-99

Manpower Plan

The manpower plan for the Online Computing sub-project is given in the accompanying table. (F) denotes Fermilab manpower and (U) denotes non-Fermilab manpower. Units are in FTEs.

	Online Computing					
Position	**FY96**	**FY97**	**FY98**	**FY99**	**FY00**	**Total**
Computer Professional (F)		3.6	5.6	5.7	0.6	15.4
Total (F)		3.6	5.6	5.7	0.6	15.4

Cost Estimate

The cost estimate for the Online computing hardware is shown in the accompanying table. These costs are based on vendor estimates. Contingency is assigned based on the criteria in section 7.1.2 and averages to 19%.

WBS	1.5.1	ONLINE EQUIPMENT						
WBS	**ITEM**	**MATERIALS & SERVICES (M&S)**				**CONTINGENCY**		
1.5.1	**ONLINE EQUIPMENT**	**Unit**	**#**	**Unit Cost**	**M&S TOTAL**	**%**	**Cost**	**TOTAL Cost**
1.5.1.1	***Workstations***				260,000	18	46,000	306,000
1.5.1.1.1	DAQ Workstations (CPU,mem,netwk,IO,soft)	ea	4	35,000	140,000	20	28,000	168,000
1.5.1.1.2	Monitoring Workstations	ea	6	20,000	120,000	15	18,000	138,000
1.5.1.2	***Network (switch,bridge,router)***	lot	1	80,000	80,000	25	20,000	100,000
1.5.1.3	***Disk/tape Peripherals***				90,000	25	22,500	112,500
1.5.1.3.1	Disk	Gb	60	500	30,000	15	4,500	34,500
1.5.1.3.2	Tape	ea	12	5,000	60,000	30	18,000	78,000
1.5.1.4	***Printers/Monitors***	lot	1	75,000	75,000	5	3,750	78,750
1.5.1.5	***Software***	lot	1	100,000	100,000	25	25,000	125,000
1.5.1	TOTAL ONLINE EQUIPMENT				605,000	19	117,250	722,250