FERMI NATIONAL ACCELERATOR LABORATORY
P.O. BOX 500, BATAVIA, ILLINOIS 60510

THE TEVATRON 1 PROJECT MANAGEMENT PLAN

REVISION II
SEPTEMBER 1983

REVISION III

November 1985

OPERATED BY UNIVERSITIES RESEARCH ASSOCIATION, INC.
FOR THE UNITED STATES DEPARTMENT OF ENERGY

Submission and Approval

The Tevatron I Project Management Plan provides the baselines and controls that Fermilab and the Department of Energy will follow to meet the Tevatron I technical, cost, and schedule goals. The Tevatron I project provides for the conversion of the Energy Saver to a storage ring of approximately 1000 GeV and for a source of antiprotons for colliding beams. This plan will be reviewed and updated as required. Revisions will be made by agreement among the participants.

DOE

William A. Wallenmeyer, Acting
Associate Director for
High Energy and Nuclear Physics,
Office of Energy Research

William A. Wallenmeyer
Director, Division of High Energy
Physics
Office of High Energy and Nuclear
Physics
Tevatron I Program Manager

Hilary J. Rauch
Manager, Chicago Operations Office

Andrew E. Mravca
Manager, Batavia Area Office
DOE Tevatron I Project Manager

Fermilab

Leon Lederman, Director

John Peoples, Jr.
Project Manager

TABLE OF CONTENTS

I. Introduction

A. Historical Background 1
B. The Tevatron I Project 1
C. Plan of this Document 2

II. Project Objectives and Performance Criteria

A. Project Objectives 3

1. Technical Objectives 3
2. Project Cost Objectives 3
3. Schedule 4

III. Management Organization and Responsibilities and Project Functional Support Requirements

A. Introduction 5
B. Major Participants 5

1. DOE 5

a. DOE Headquarters (HQ) 5
b. Batavia Area Office (BAO) 5
c. Chicago Operations Office (CH) 6

2. Fermilab 6

a. General 6
b. Project Manager 6
c. Project Organization 6
d. Laboratory Support 7

C. Responsibilities 8

1. DOE 8

a. Headquarters 8
b. Batavia Area Field Office 9

2. Fermilab 10

a. General 10
b. Project Manager 10
c. Construction Manager 11

IV. Work Breakdown Structure

A. Work Breakdown Structure Dictionary 12
B. Work Breakdown Structure Element Definition 13

V. Work Plan

A. General Description of Work 21

1. Required Research and Development Effort 21
2. Plant Work to be Accomplished; Construct. Effort 21

B. Methods to Accomplish the Work 21

1. Accelerator Systems and Engineering Design 21

a. Accelerator Systems Design 22
b. Engineering Design of Conventional Facilities 22
c. Engineering Design of Special Facilities ... 22

2. Construction and Fabrication 22

a. Conventional Facilities 22
b. Special Facilities 23

3. Procurement Plan 23

a. General 23
b. Conventional Facilities 23
c. Special Facilities 23
d. Small Business Plan 24

4. Inspection and Acceptance 24

a. Conventional Facilities 24
b. Special Facilities 24
c. Overall Facilities 24

5. Quality Assurance 24

C. Technical Criteria 25

1. Conventional Facilities 25
2. Special Facilities 25

D. Codes, Standards, and Specifications 25

1. Davis-Bacon Determinations 25
2. Safety and Health 25
3. Equal Employment Opportunity (EEO) 26

VI. Schedule and Logic Diagram 27

VII. Cost Estimate

A. Cost Breakdown by WBS 28
B. Cost Plan 31

VIII. Performance Criteria 34

IX. Organization 37

A. General 37
B. DOE Participants 37

1. Headquarters 37
2. Field-Batavia Area Office 38

X. Project Management Controls Systems

A. Principles of Project Control 40
B. Project Control Documents 40
C. Fermilab Project Control Documents 41
D. Project Management Systems 41

1. General Documents 41
2. Financial Control System 42
3. Schedule Control System 43
4. Technical Control System 44

a. Design Report 44
b. Technical Review 44
c. Project Control Meeting 44
d. Project Advisory Group 44

E. Change Control Procedures 44
1. Principles 44

XI. Information and Reporting 46

A. Progress Reports 46
B. Technical Reports 46
C. Drawings and Specifications 46
D. Project Meetings 47

Appendices

A. Construction Project Data Sheet
B. Tevatron I Work Schedule Key Milestones (Level 2)
C. Project Responsibility Matrix
D. Tevatron I Master Schedule (Level 3)
E. Tevatron I Milestone Chart
F. Reporting Requirements Checklist

I. INTRODUCTION

This document describes the Project Management Plan that the participants will follow to meet the technical, cost, and schedule objectives of the Tevatron I project. The project will be constructed at the Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois. Fermilab is a Department of Energy (DOE) laboratory operated under Contract DE-AC02-76-CHO-3000 by the Universities Research Association, Inc. (URA). The major project participants are Fermilab, the Division of High Energy and Nuclear Physics (HENP) of DOE, the Batavia Area Office (BAO) of DOE, and the Chicago Operations Office (CH) of DOE. These organizations will work together as a team to accomplish the Tevatron I Project.

A. HISTORICAL BACKGROUND

The construction of Fermilab was authorized by the Congress in 1968 for the purpose of carrying out basic research directed at discovering and explaining the fundamental nature of matter. As part of the initial authorization, a 400-GeV proton synchrotron, the Main Ring, and associated experimental facilities were built at the laboratory site in Batavia and brought into operation in 1972. Between 1972 and the present, more than 300 elementary particle physics experiments have been done at Fermilab, primarily by physicists from American, European and Canadian laboratories. By 1978, protons had been accelerated to a maximum energy of 500 GeV in the Main Ring. The high cost of electrical power at 500 GeV made it uneconomical to operate the experimental program at that energy.

In 1979, following the successful demonstration at Fermilab that superconducting magnets could be built with the field quality necessary for a high-energy synchrotron, the Energy Saver project was begun. The goal of this project was the construction of a 500-GeV proton synchrotron with superconducting magnets. These magnets use considerably less electric power than conventional magnets like those of the Main Ring, thereby making a 500-GeV experimental program economical. The Main Ring and its injector will not be abandoned, but will be used as the injector for the Superconducting Ring.

B. THE TEVATRON I PROJECT

The objectives of the Tevatron I project described here are the conversion of the Energy Saver to a storage ring, the extension of its energy to approximately 1000 GeV or 1 TeV, and the creation of a source of antiprotons. Antiprotons will be injected into the Energy Saver in the direction of circulation opposite to the usual proton direction. Additions to the Energy Saver, will make it possible to form counterrotating beams of protons and antiprotons in the Energy Saver. These beams will be accelerated simultaneously to approximately 1 TeV, then held at that energy by using the Energy Saver as a storage ring. When the beams collide the center-of-mass energy will be nearly 2 TeV the highest energy available in any accelerator now in operation or under construction. The study of the reaction products of these extraordinarily energetic collisions is the

programmatic objective for which the Tevatron I facility is being constructed.

C. PLAN OF THIS DOCUMENT

This document presents the technical, cost, and schedule objectives of the Tevatron I project in detail, names the participants in the project, describes their roles and relation to each other, and presents the plan that the participants will follow to achieve the objectives. This plan has been prepared following the guidelines outlined in DOE 5700.4, Department of Energy Project Management System.

II. PROJECT OBJECTIVES AND PERFORMANCE CRITERIA

In this chapter we give the project technical objectives, the cost objectives, and the key schedule milestones, as set forth in the Construction Project Data Sheet (Appendix A).

A. PROJECT OBJECTIVES

1. Technical Objectives

The technical objective of the Tevatron I project is to provide the means to carry out physics experiments in a new energy range. The quantitative objectives needed are:

a. Antiproton Source

- Collection time — 5 hours or less
- Collection rate — 4×10^{10}/hour

b. Superconducting Storage Ring

- Peak Energy (protons and antiprotons) — 800-1000 GeV
- Peak luminosity 10^{30} cm^{-2} sec^{-1}

c. Experimental Areas

- Experimental Areas at B0 and D0

2. Project Cost Objectives

The project costs can be divided into construction, R&D in support of the project, and other project-related costs. The sum of these is the Total Project Cost (TPC).

The project cost objectives have been revised in the 1986 Construction Project Data Sheets (Appendix A) and constitute the revised baseline estimate dated 10/84. These are given in the Table below:

Total Project Cost for Tevatron I
(in thousands of dollars)

Total Estimated Cost (TEC) (Construction Line Item)	$ 84,000
R&D in Support of the Project	48,163*
Other Project-Related Costs	2,341*
Total Project Cost (TPC)	$134,504

*No Contingency Allowance

Estimated costs are given at Level 3 of the Work Breakdown Structure in Chapter 7 of this plan.

3. Schedule

Schedule objectives for the project are embodied in the Key Milestones, which are as follows:

No.	Milestone	Date
1	Start Project Design	October 1, 1980
2	Start Accelerator Systems Fabrication[1]	April 1, 1981
3	Start Experimental Facilities Construction[2]	June 15, 1982
4	Start Antiproton Source Conventional Construction[3]	April 15, 1983
5	Complete Antiproton Target Hall and Transport Enclosure[4]	July 1, 1984
6	Complete Installation of Antiproton Beam Transport[5]	Feb. 1, 1985
7	Complete Installation of Debuncher & Accumulator Components (exclusive of cooling)[6]	March 1, 1985
8	Complete Accumulator Retrofit	Feb. 1, 1986
9	Complete Debuncher Stochastic Cooling Systems	Feb. 1, 1986
10	Complete Antiproton Source Commissioning	March 1, 1986
11	Complete Accelerator Systems Commissioning	March 1, 1986
12	Complete Experimental Facilities Const.	April 1, 1987
13	Initiate Colliding Beam Experiments	September 1, 1986
14	Complete Tevatron I Project	September 30, 1987

[1] Fabrication started April 6, 1981
[2] Construction started June 14, 1982
[3] Construction started August 16, 1983
[4] Completed February 14, 1985 after a delay in the accelerator shutdown in 1984.
[5] Completed July 7, 1985
[6] Completed June 6, 1985

Feb 1980 39,500
FY'81 budget request.

1982 Data Sheet 49 M5

III. MANAGEMENT ORGANIZATION AND RESPONSIBILITIES AND PROJECT FUNCTIONAL SUPPORT REQUIREMENTS

A. INTRODUCTION

This chapter describes the organizations participating in the Tevatron I project and their relation to each other in the management of the project.

The Fermi National Accelerator Laboratory is responsible for accomplishment of the Tevatron I project in accordance with the provisions of prime contract DE-AC02-76-CH03000 between the Department of Energy (DOE) and the Universities Research Association, Inc. (URA).

DOE is responsible for the project management to ensure that Fermilab meets the technical objectives within the scheduled time and cost. Primary DOE field responsibility for the project rests with the Batavia Area Office (BAO) of the Chicago Operations Office (CH). The responsibility matrix for the project is given in Appendix C.

B. MAJOR PARTICIPANTS

1. DOE

a. DOE Headquarters (HQ). The following Headquarters organizations play significant roles in discharging DOE's responsibilities. They are related as shown in the organization of Figure 3-1.

1. Office of Energy Research (A.W. Trivelpiece)
2. Office of High Energy and Nuclear Physics (W.A. Wallenmeyer, Acting)
3. Division of High Energy Physics (W.A. Wallenmeyer)

The Division of High Energy Physics is a part of the office of High Energy and Nuclear Physics, which is in turn a part of the Office of Energy Research. Responsibility for the Tevatron I project has been vested in the Division of High Energy Physics, which has established the project objectives and will monitor its progress. The Director of High Energy Physics, William A. Wallenmeyer, is designated as the HQ program manager for Tevatron I. He provides programmatic direction and technical overview of all project activities. He is also responsible for coordinating communications with other HQ offices.

b. Batavia Area Office (BAO). The manager of BAO is the Tevatron I project manager for DOE. He will maintain communication and provide management advice to CH and the DOE HQ Program Office. He will resolve any conflicts that may occur.

PROJECT ORGANIZATION/RESPONSIBILITIES

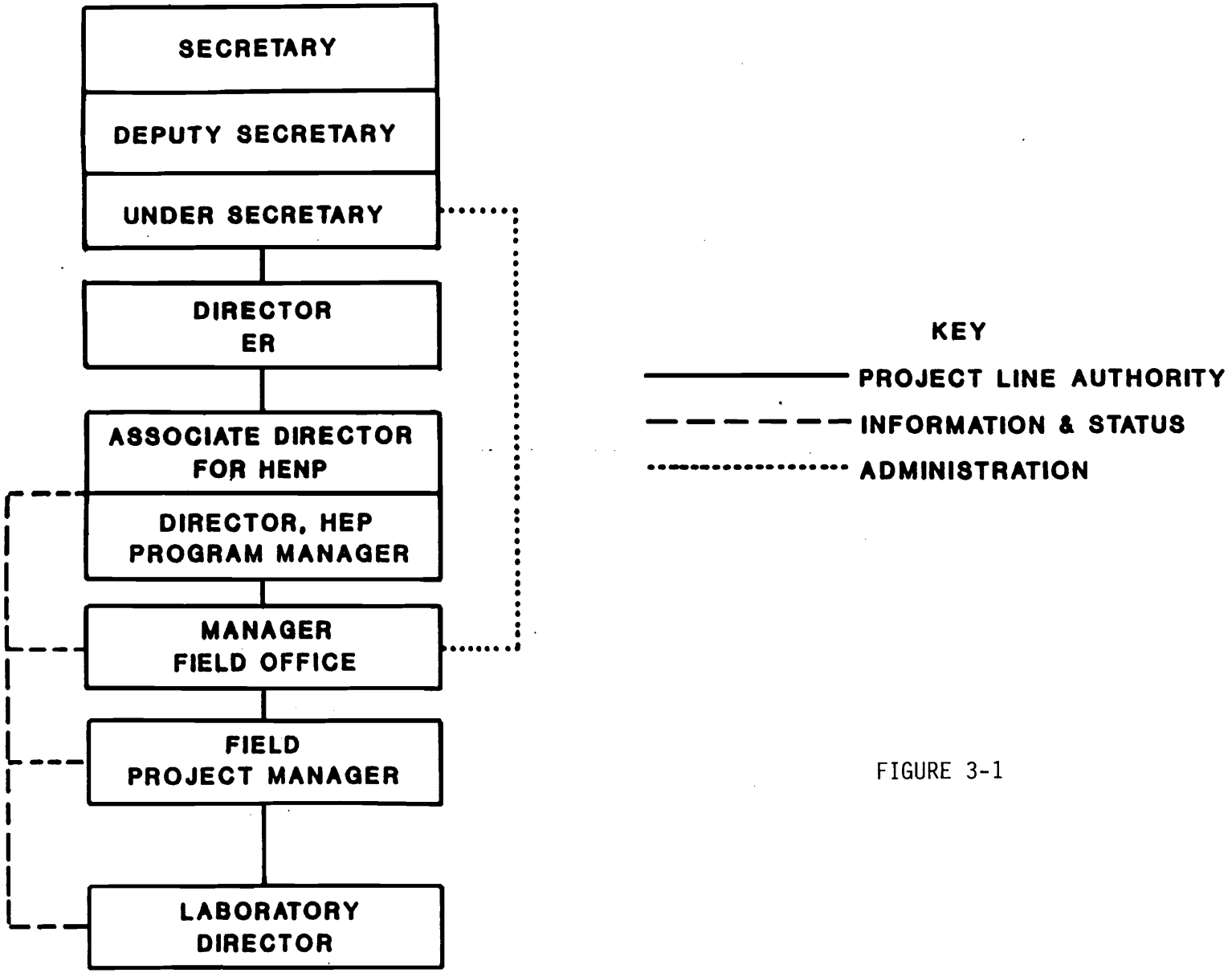


FIGURE 3-1

c. Chicago Operations Office (CH). CH will support BAO in carrying out its project responsibilities.

2. FERMILAB

a. General. The responsibility for carrying out the Tevatron I project has been delegated to the Director of Fermilab, Leon Lederman, and he has in turn delegated the primary responsibility to the Project Manager of the Tevatron I project, John Peoples, Jr.

b. Project Manager. The Project Manager reports to the Laboratory Director and is directly responsible to the Director for meeting the Technical Baseline Criteria of the project within the cost and schedule. The Project Manager is assisted by a Deputy Project Manager, a Construction Manager, and a Project Safety Officer, who reports directly to the Project Manager.

c. Project Organization. The work has been projectized into groups within the Laboratory organization as shown in the chart of Figure 3-2 and as discussed below:

1. Project Office. This is the Laboratory headquarters of the project. This office specifies and assigns all project work. The Construction Manager is part of this group. The management functions of cost and schedule control are carried out by this group, as well as the supervision of the technical work and all reporting and documentation functions.

2. Accelerator Design. This group will carry out the systems design of the project.

3. Magnet and Vacuum. This group will design, fabricate, and install the magnets and vacuum systems of the two rings and the transport lines.

4. Stochastic Cooling. This group will design, fabricate, and install the beam cooling systems for the project. The LBL and Argonne collaborators are working closely with this group.

5. Antiproton Source rf. This group will design, fabricate, and install radiofrequency systems for acceleration and beam manipulation in the Debuncher and Accumulator rings and in the existing Main Ring.

6. Electrical/Electronics Systems. This group will design, fabricate and install the electronic equipment for the project.

7. Antiproton Production. This group will design, fabricate and install the Target Station for initial production of the $\bar{p}$'s.

CHART B. TEVATRON I PROJECT MANAGEMENT DIAGRAM

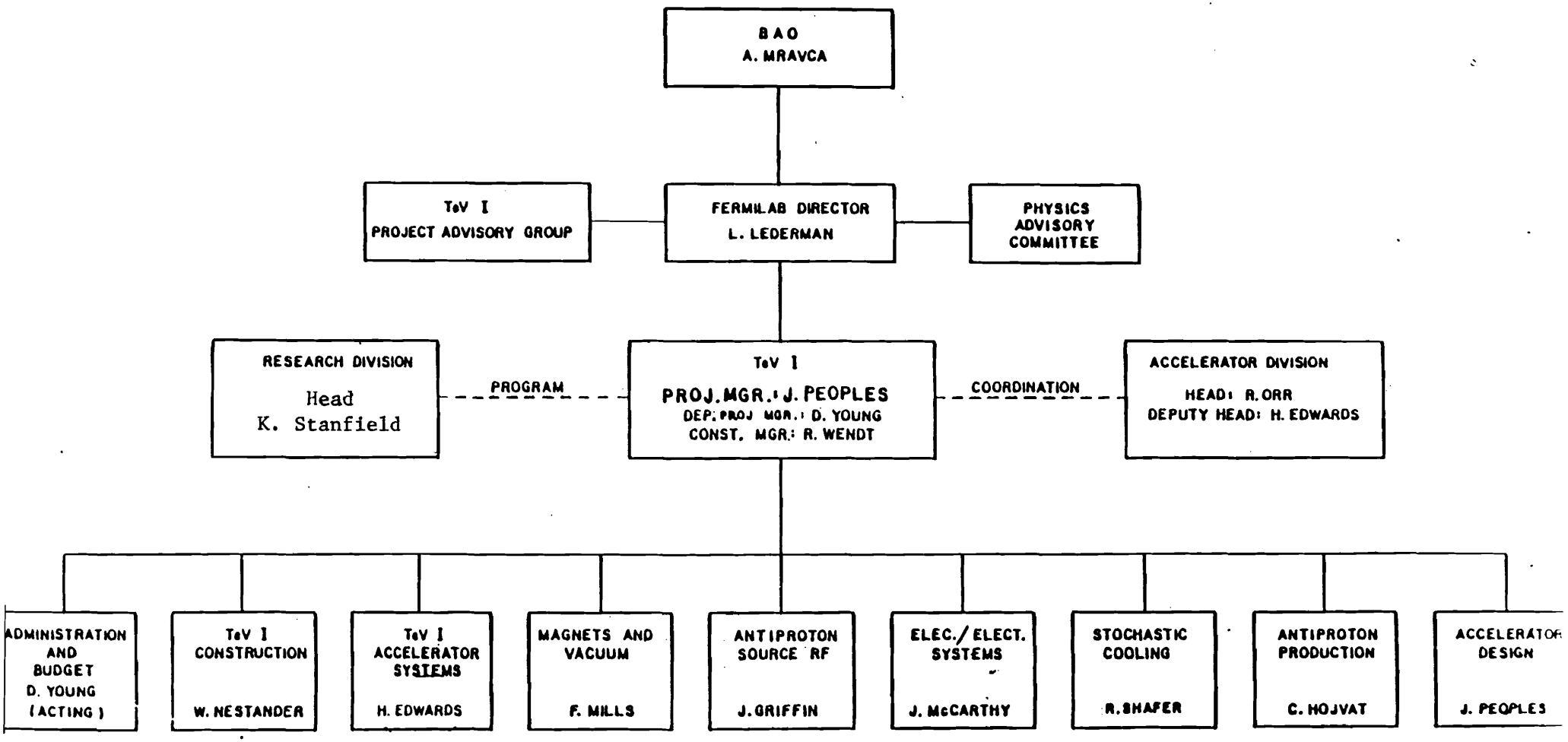


Fig. 3-2

8. Administration and Budget. This group provides staff support in cost and schedule activities, as well as general administrative support.

9. Tevatron I Accelerating Systems. This group will design, fabricate and install accelerating systems in the Superconducting Ring.

10. Tevatron I Construction. The Tevatron Construction Group will provide conceptual design and Title I, Title II, and Title III services for the construction of conventional facilities for the project.

11. A Tevatron I Project Advisory Group (PAG) has been appointed by the Director to carry out periodic in-house reviews and advise him on any decisions regarding the project.

12. The Accelerator Division will provide technical support to the Tevatron I Project particularly in 9 above, the Tevatron I Accelerating Systems Group, and in the design and fabrication of the Interaction Region technical components.

13. The Research Division is responsible for design and fabrication of the Collider Detector. The conventional construction to house this detector is being constructed as part of the Tevatron I Project and liaison is maintained by the Tevatron I Project and the Research Division for the conventional construction and special facilities work.

14. The Physics Advisory Committee is a group of national representation that meets several times a year to advise the Director on acceptance of proposals for specific experiments and on the directions and progress of the overall technical program of the Laboratory. As part of its work, this group reviews the Tevatron I Project.

15. The Director's Office coordinates the different parts of the Fermilab effort and is responsible for carrying out the work of the Laboratory.

d. Laboratory support. The project receives matrix support from the rest of the Laboratory in the following ways:

1. Business Office. All the contractual arrangements for construction and fabrication are carried out by this office, as well as the legal and accounting functions of the Laboratory.

2. Technical Support Section. Design and drafting support is given by this section, as well as quality assurance assistance. This section will aid in fabrication where appropriate.

The Director of the Laboratory decides questions of priority among the projects of the different Fermilab Divisions and Sections.

C. RESPONSIBILITIES

The Fermilab Director has delegated to the Project Manager the responsibility for the overall planning, determination of scope, and management of the Project within the guidance provided by DOE Project Directives. A Project Advisory Group will monitor the project and report to the Director.

The Chicago Operations Office (CH) has delegated primary DOE responsibility for the Project to the Manager of the Batavia Area Office (BAO).

The Office of High Energy and Nuclear Physics in DOE Headquarters through the Program Manager, will provide programmatic direction and technical overview of the Project and will coordinate with other DOE Headquarters Divisions. Appendix C is a responsibility matrix for the project.

1. DOE

a. Headquarters. The Office of High Energy and Nuclear Physics has responsibility for the programmatic and technical direction of the Project. The Director for High Energy Physics has been designated as Program Manager and is responsible for approving major changes to the Project that could alter the technical performance, scope, cost, or scheduled completion of the Project. Specific activities are as noted below. He shall:

- Approve the Project Objectives which are stated in Chapter 2.
- Review and act upon requests for changes in the Project TEC and Total Project Costs
- Review and act upon requests for extensions in the completion of Key Milestones of greater than three months.
- Maintain an overview of cost performance, schedule performance, and technical performance through the monthly Project Progress Reports and through a Headquarters Project Officer who will act as the point of contact with BAO for Headquarters.
- Convene Semi-Annual Project Reviews and concur in the action items which arise from these reviews.
- Issue a Program Guidance Letter to BAO for each fiscal year which will provide budget authorization for the Project.
- Establish and maintain the Construction Project Data Sheet for the Project.

- Concur in the Tevatron I Project Management Plan.

b. BAO

BAO is responsible for ensuring that Fermilab accomplishes the Project Objectives in accordance with the Project Management Plan, specific directives received from HENP and CH, and DOE regulations. This responsibility will be executed by taking the following actions:

- Review and approve the Project Cost Plan.
- Approve Budget Authorization for the TEC at level 3 by issuing Construction Authorization Directives.
- Assure that adequate project management control systems are established by the Project Manager.
- Schedule and conduct a monthly Tevatron I Project meeting with the Project Manager for the purpose of reviewing the status of the project. The agenda for these meetings shall include but not be limited to a review of the status of the following: cost, and obligations, completed effort and work in progress and technical performance of completed effort.
- Review project costs and obligations at level 3 of the Work Breakdown Structure (WBS) on a monthly basis.
- Review the status of Key and Control Milestones on a monthly basis.
- Review and act upon requests for extensions in Key Milestones and Control Milestones of greater than one month.
- Review and approve proposed procurement actions of Fermilab in accordance with the DOE-URA contract.
- Provide Davis-Bacon determinations.
- Approve Title I and Title II reports submitted by the Project Manager.
- Assure that construction programs are executed in a safe manner in accordance with applicable criteria, codes, and standards.
- Approve requests for contingency usage.
- Review and approve baselines and documentation as specified in project control documents and approve changes thereto.
- Assure that project quality assurance procedures are implemented and are effective.
- Participate in final inspections as required and take acceptance

of facility on behalf of the Government.

- Provide liaison and coordination with Headquarters in areas of program requirements. Assure that DOE Headquarters is kept informed on project status.

- Provide Headquarters with a Monthly Project Progress Report.

2. FERMILAB

a. General. Fermilab is responsible for the development, design, construction, fabrication, installation, checkout, and preoperational startup of the Tevatron I Project under DOE Contract No. DE-AC02-76-CHO-3000. The Fermilab Director will have the overall responsibility and authority to carry out the functions required to achieve the technical, cost, and schedule goals of the Tevatron I Project. The Director will establish a project organization that will have designated responsibility for the technical, cost, schedule, procurement, and construction aspects of the project. They will be assisted and advised by the existing Fermilab service, budget, business, and management groups. Routine reviews of project finances will be carried out by the Fermilab Budget Officer together with the appropriate line organization to develop reports of discrepancies for the Project Manager and Director. The responsibility for various Tevatron I systems and associated conventional facilities will be assigned to Fermilab organizations as shown in Figure 3-2. The Project Manager is responsible for the overall Tevatron I Project in accordance with the agreed upon scope from DOE. Technical overview will be maintained by the Fermilab Project Advisory Group reporting to the Fermilab Director.

b. Project Manager. The responsibilities of the Tevatron I Project Manager include the management of all aspects of the design and construction. Among these responsibilities are the following:

- Prepare and maintain the Project Summary Work Breakdown Structure.

- Prepare and maintain the Project Cost Plan.

- Prepare and maintain the Project Master Schedule.

- Prepare and maintain the following Project Control Documents: Tevatron I Design Report.

- Establish and maintain Project Management Control Systems which provide sufficient financial, schedule and technical to achieve the Project Objectives.

- Report to BAO in writing on a monthly basis on the level 3 status of the following: cost and obligations, completed effort and work in progress, and technical performance of completed work. The status report will cover all level 3 WBS elements. Items which are at variance with the Project Objectives will be identified.

- Report to DOE on a monthly basis on the status of work accomplished and identify any milestone or control milestone that is in jeopardy of being delayed by more than one month.

- Establish design criteria for all facility systems and obtain the necessary DOE approvals.

- Insure implementation of Fermilab and DOE safety and quality assurance procedures.

c. Construction Manager. The Fermilab Construction Manager will interface with the Fermilab Project Manager and develop working relationships with suppliers, constructors, and specialty subcontractors, etc. The Construction Manager's responsibilities will include:

1. Management of conventional construction associated with Tevatron I.

2. Technical input in design.

3. Continuing review of cost and schedule for conventional construction.

4. Participation in the bidding process, specifically in evaluation of bids and of contractor capability.

IV. WORK BREAKDOWN STRUCTURE

The Project Summary Work Breakdown Structure (PSWBS) that will be used in the technical, cost and schedule controls of the Tevatron I Project is shown in the following:

A. WORK BREAKDOWN STRUCTURE DICTIONARY

1.0 Construction Funded Elements

1.1 Antiproton Source

- 1.1.1 Target System Installation
- 1.1.2 Beam Transport System Fabrication
- 1.1.3 Debuncher
- 1.1.4 Accumulator Retrofit
- 1.1.5 Antiproton Source Conventional Construction

1.2 Accelerator Systems

- 1.2.1 120-GeV Proton Extraction & 8-GeV Antiproton Injection
- 1.2.2 Superconducting Accelerator RF System
- 1.2.3 BO Main Ring Overpass
- 1.2.4 Main Ring to Superconducting Ring Transfer
- 1.2.5 Satellite Refrigerators
- 1.2.6 Superconducting Ring Antiproton Abort System
- 1.2.7 Antiproton Collision Support Systems
- 1.2.8 DO Main Ring Overpass

1.3 Experimental Facilities

- 1.3.1 BO Experimental Area
- 1.3.2 DO Experimental Area
- 1.3.3 BO Interaction Region Magnet System
- 1.3.4 DO Interaction Region Utilities

1.4 Project Administration

- 1.4.1 Project Office
- 1.4.2 Project Support Activities

2.0 Research and Development Funded Elements

2.1 Antiproton Source R&D

- 2.1.1 Target System Prototype
- 2.1.2 Beam Transport
- 2.1.3 Debuncher Prototypes

2.1.4 Accumulator

2.2 Accelerator Systems R&D

2.2.1 120-GeV Proton Extraction & 8-GeV Antiproton Injection
2.2.2 Accelerator RF Systems

2.3 Experimental Facilities R&D

2.3.1 Interaction Region Magnet System Tooling & Prototypes

2.4 Project Administration R&D

2.4.1 Project Office R&D
2.4.2 Project Support Activities R&D

2.5 Operating Costs Accrued during FY 1981
2.5.1 Direct Costs for FY81
2.5.2 G&A for FY81

3.0 Other Project Funding (Capital Equipment)

B. WORK BREAKDOWN STRUCTURE ELEMENT DEFINITION

The Tevatron I project consists of an Antiproton Source, Accelerator Systems, and Experimental Facilities. The project makes it possible to bring protons and antiprotons into collision in the Superconducting Accelerator Ring (Energy Saver Ring) and provides enclosures for detectors within the Main Ring Enclosure. A brief description of each element of the project work breakdown structure (WBS) and the effort to accomplish that element follows:

1.0 Construction Funded Elements

1.1 Antiproton Source

The systems that make it possible to produce and accumulate antiprotons constitute this level 2 element. Protons are accelerated to approximately 120 GeV in the Main Ring, extracted at location F17 and transported to the Target Station. The protons are made to strike a target thereby producing antiprotons which are transported at 8 GeV to the Debuncher, a storage ring. Then they are debunched and stochastically cooled for about 2 seconds. After cooling they are transferred at 8-GeV to the Accumulator, a second storage ring. The cycle of production of antiprotons and their subsequent debunching and cooling in the Debuncher is repeated approximately every 2 seconds. Each successive charge of

antiprotons from the Debuncher is added to the charge of antiprotons previously accumulated in the Accumulator. The total charge in the Accumulator is continuously compressed into a smaller volume of space by the several stochastic cooling systems. When both the density and the number of antiprotons is sufficient to permit colliding beams experiments, a portion of the accumulated antiprotons is extracted in several bunches and transported to the Main Ring at 8 GeV. The subsequent manipulation is described in 1.2 Accelerator Systems.

1.1.1 Target System Installation. This includes the retrofitting of the following; targets, collection lenses, pulsed separation magnets, the beam dump, shielding, controls, power supplies, the remote handling system, and the safety system. Initial development of these components will be done as part of element 2.1.1, Target System Prototypes.

1.1.2 Beam Transport System Fabrication. The Beam Transport System consists of the following beam lines: (a) 120-GeV proton transport from F17 in the Main Ring to the Target Station, (b) 8-GeV antiproton transport from the Target Station to the Debuncher, (c) 8-GeV antiproton transport from the Debuncher to the Accumulator, (d) 8-GeV antiproton transport from the Accumulator to the Main Ring, and (e) 8-GeV proton transport from the Booster to the Debuncher. The work includes engineering and design, procurement, fabrication, installation and testing of the components for transport lines b and c. It includes the work needed to retrofit lines a, d, and e which will be assembled initially as part of element 2.1.2, R&D Beam Transport.

1.1.3 Debuncher. The work includes the engineering and design, procurement, fabrication, installation and testing of the following components; magnets, vacuum system, injection and extraction devices, radiofrequency systems for beam manipulation, control systems, safety systems, and beam monitoring systems for the Debuncher. The functions of the Debuncher are to reduce the momentum spread of each pulse of antiprotons by rf bunch rotation and adiabatic debunching and to reduce the betatron amplitudes of the antiprotons by stochastic cooling.

1.1.4 Accumulator Retrofit. The work includes the retrofit of all Accumulator components to bring the R&D systems up to the project performance specifications. The Accumulator reduces the momentum spread and betatron emittances of the antiproton beam by use of several stochastic cooling systems. Since successive pulses of antiprotons are stored in the Accumulator, the stochastic cooling systems also facilitate the accumulation process. The Accumulator will be built and operated initially to provide data on both stochastic cooling and accumulation techniques. After each system has been developed to the point where it will meet performance specifications for the Tevatron I project, the Accumulator and the stochastic cooling systems will be retrofitted and incorporated into the Antiproton Source. The stochastic cooling system development is included as part of elements 2.1.3 and 2.1.4.

1.1.5 Antiproton Source Conventional Construction. This work includes the

Title I, Title II, Title III, construction, and procurement for the conventional structures of the Antiproton Source. The structures include the below-ground reinforced concrete tunnels for the beam transport lines, the target system, the Debuncher, the Accumulator, and the above-ground service buildings for power supplies, water systems, pumps, and instrumentation, as well as work areas for servicing the components of the Antiproton Source. Site preparation, roads, parking, utilities and conventional building services are also included.

1.2 Accelerator Systems

The function of the Accelerator Systems are to accelerate bunches of protons and antiprotons from 8 GeV to 150 GeV in the Main Ring, to transfer the bunches at 150 GeV to the Superconducting Ring so that proton bunches and antiproton bunches are counterrotating, and to simultaneously accelerate protons and antiprotons to approximately 1 TeV. The accelerator systems manipulate the counterrotating bunches so that they intersect at the appropriate points. The functions also include the acceleration of protons to 120 GeV, and their subsequent bunching and extraction from the Main Ring for the purpose of producing antiprotons. The subsystems to accomplish these objectives are described briefly in the following:

1.2.1 120-GeV Proton Extraction and 8-GeV Antiproton Injection. The proton extraction system transfers protons from the Main Ring at F17 to the 120-GeV proton transport line for the purpose of producing antiprotons. Cold 8-GeV antiprotons are injected into the Main Ring for acceleration to 150 GeV at the same location using many of the same components. The components of the 120-GeV proton extraction system will be initially developed as part of the Accelerator Systems R&D (2.2.1). The Main Ring enclosure modifications which are part of this element include the design, procurement, construction and inspection of a new enclosure in the Main Ring tunnel between F17 and F21. The engineering and design, procurement, fabrication, installation and testing of an 8-GeV kicker and its pulsed power supply for the injection of 8-GeV antiprotons into the Main Ring is also included.

1.2.2 Superconducting Accelerator RF System. The work includes the engineering and design, procurement, fabrication, installation and testing of the rf systems used to accelerate the antiprotons in the Superconducting Accelerator. This element also includes the design, procurement, construction and inspection of an enlargement to the presently existing rf service building at F0 to provide the space and utilities for the rf system components.

1.2.3 B0 Main Ring Overpass. The work consists of alterations to the Main Ring enclosure near A39 and B19, new reinforced concrete enclosures between A42 and B18 and relocating the Main Ring components presently located between A39 and B19 in these enclosures. This permits the Main Ring beam to pass over the Colliding Detector at B0, thereby eliminating the

interference between the Main Ring and the B0 Detector. The work includes design, procurement, construction and inspection of the modifications and new structures. The relocation of existing magnets and their services, the fabrication of new magnets, the modification of power supplies and controls, and the modifications to the cryogenic distribution system for the Superconducting Ring are included in this element.

1.2.4 Main Ring to Superconducting Ring Transfer. The work includes engineering and design, procurement, fabrication, installation and testing of the magnets, vacuum systems, special devices, controls, and power supplies used in the transport system which transfers the antiproton beam from the Main Ring at 150 GeV to the Superconducting Ring.

1.2.5 Satellite Refrigerators. This item includes the engineering and design, procurement, fabrication, installation, and testing of twelve satellite refrigerators and related transfer lines, controls and operating systems, for the Superconducting Accelerator. When completed this item allows sustained operation at the highest energy.

1.2.6 Superconducting Ring Antiproton Abort System. This includes the engineering and design, procurement, fabrication, installation and testing of the abort system which consists of magnets, supports, controls, power supplies, and a beam dump. It permits the extraction and safe disposal of circulating antiprotons in the Superconducting Accelerator in case of equipment failure. A service building that houses above-ground components is included in this element.

1.2.7 Antiproton Collision Support Systems. This item provides for certain devices for the Accelerator Systems which when installed will make it possible to achieve the project design specifications. The scope of work includes the engineering and design, procurement and fabrication of the components which will allow the Tevatron to be operated as a storage ring for protons and antiprotons. This includes the addition of cables and electronics to the Tevatron beam position monitors and addition of other beam diagnostics, which will be used to detect antiproton beams and proton beams simultaneously. Additional equipment of this type will be added as the need is identified during the initial tests of colliding beams.

During the initial tests of the antiproton source the need for improvements to the Main Ring which will make it possible to increase the Main Ring beam intensity and quality and the effective rate at which protons are delivered to the antiproton production target were identified. During the initial tests of accelerating and coalescing antiprotons the need for improvements to the Main Ring which will make these processes more efficient were identified. These improvements will require the procurement and fabrication of devices which when installed in the Main Ring will make it possible to realize the design luminosity and antiproton accumulation rate. These devices will include diagnostics, correction magnets, correction magnet power supplies, controls, and modifications to the Main Ring vacuum chamber.

Certain other ancillary systems will need to be improved in the accelerator systems. The scope of work includes the production engineering and design, procurement and fabrication of replacement quadrupole magnets for the 8 GeV transport line between the Booster Accelerator and the Main Ring. It includes the construction of duct banks and the addition of 13.8 kV feeders under the Ring Road between locations B1 and C0 and between C0 and F0 including the connection of these feeders to existing transformer pads and underground vaults.

1.2.8 D0 Main Ring Overpass. The work consists of alterations to the Main Ring enclosure in the vicinity of D0 and the relocation of Main Ring components presently located in this vicinity. This permits the Main Ring beam to pass far enough away from the collision point in the Colliding Detector at D0 so as to eliminate the interference between the Main Ring and the D0 detector. The work includes design, procurement, construction and inspection of the modification to the Main Ring structure. The relocation of existing magnets and their services, the fabrication of new magnets, the modifications to the cryogenic distribution system for the Superconducting Ring are included in this element.

1.3 Experimental Facilities

The facilities include two experimental areas which provide space and utilities for experimental detectors within the Superconducting ring. In addition, the facilities include magnets, power supplies and controls which will optimize the rate of proton-antiproton collisions for each type of experiment. A brief description of these facilities follows:

1.3.1 B0 Experimental Area. The work includes Title I, Title II, Title III, and construction of an underground reinforced-concrete enclosure for a detector and an above-ground steel frame building.

1.3.2 D0 Experimental Area. The work includes Title I, Title II, and Title III, and construction of an underground reinforced-concrete enclosure for detectors, the collision hall at D0 and an above-ground steel frame building connected to the underground reinforced-concrete enclosure, the assembly hall.

It also includes the relocation of the transfer line and the headers between C4 and D1 away from the Main Ring berm, in order to permit cryofluids and gases to flow from C4 to D1 during the construction of the collision hall.

1.3.3 B0 Interaction Region Magnet System. This item includes the engineering and design, procurement, fabrication, installation and testing of a system composed of high-gradient superconducting quadrupoles and superconducting correction elements, a refrigeration system, power supplies, quench protection, controls, conventional magnets, beam position

sensors, luminosity monitors, mechanical supports, vacuum system, and such other elements as will be necessary to both focus the proton and antiproton beams to a small diameter and to bring the two beams into collision with a maximum collision rate within the experimental detector at B0.

1.3.4 D0 Interaction Region Utilities.. This item includes modifications in existing installed systems so that an interaction magnet system similar to the one installed at B0 can be installed at a later date when required to both focus the proton and antiproton beams to a smaller diameter and to bring the two beams into collision with a maximum collision rate within the experimental detector at D0. It also includes special power supplies with the same specifications as those used in the B0 Interaction Region Magnet System.

1.4 Project Administration

1.4.1 Project Office. This items includes the direct costs of the Tevatron I project administration and management. It includes among other things such items as telephone charges, computer rental charges, travel, consulting expenses, project administration salaries, publishing and printing expenses, office supplies, which are necessary for the timely execution of the construction funded elements of the project and the reporting of the project's progress to DOE and the Laboratory Director.

1.4.2 Project Support Activities. This item includes the incremental indirect costs incurred by the Business Services Sections, Personnel Services Section, and the Directorate in the process of supporting the execution of the Tevatron I project construction funded elements.

2.0 Research and Development Funded Elements

The R&D activities associated with the Tevatron I Construction Project which will be carried out concurrently with the construction funded phase of the project are as follows; the development of target systems, the development of stochastic cooling systems, and the development of prototypes. Operating funds identified for this purpose will be used to support the R&D effort. A description of these activities follows:

2.1 Antiproton Source R&D

2.1.1 Target System Prototypes. It includes the engineering and design, procurement, fabrication, installation, and testing of prototype targets, magnetic lenses, pulsed separation magnets, beam dumps, associated power supplies, shielding, remote handling, cooling, and services. Beam testing with approximately 120-GeV protons will be carried out to ascertain component lifetimes as a function of proton intensity and to measure performance of these components in the collection and production of antiprotons.

2.1.2 R&D Beam Transport. This effort includes the engineering and

design, procurement, fabrication, installation and testing of those beam transport systems which are needed to provide a source of protons to the target station, and a source of protons and antiprotons to the Accumulator. The effort includes the engineering and design, procurement, fabrication and testing of prototype injection kickers, septa magnets, beam scrapers, and shutter devices.

2.1.3 Debuncher Prototypes. This work includes the engineering and design, procurement, fabrication, and testing of prototype magnets, rf systems, and stochastic cooling systems for the Debuncher (1.1.3). The Debuncher stochastic cooling systems will initially be tested with beam in the Accumulator as part of the effort in 2.1.4.

2.1.4 Accumulator. This work includes the engineering and design, procurement, fabrication, installation, and the testing of the magnets, vacuum system, radiofrequency system, power supplies, stochastic cooling system, control system, and beam monitoring system for the Accumulator. The work also includes the engineering and design, procurement, fabrication, and testing of Accumulator prototype components. The Accumulator will be developed as a device that will allow the evaluation of stochastic cooling systems with proton and antiproton beams. The development of stochastic cooling systems will be done as part of 2.1.3 and this element.

2.2 Accelerator System R&D

2.2.1 120-GeV Extraction and 8-GeV Antiproton Injection R&D. This work includes the engineering and design, procurement, fabrication, installation and testing of the elements in the 120-GeV proton extraction system in the Main Ring at F17. The system consists of magnets, septa, modifications to the present Main Ring kickers, power supplies, d.c. bus, cooling water distribution, controls, magnet supports and beam sensors.

2.2.2 Accelerator RF Systems. This work includes engineering and design, procurement, fabrication, installation and testing of a low level rf system for bunch rotation (shortening) and a low frequency rf system for coalescing bunches in the Main Ring. It includes the engineering and design, procurement, fabrication and testing of prototypes for this system.

2.3 Experimental Facilities R&D

2.3.1 Interaction Region Magnet System Prototype. The work consists of the engineering and design, procurement, fabrication of the fixtures, tooling, dies and instrumentation necessary to build prototype high-field quadrupoles of the type which will be used in the interaction region at B0 in the Superconducting Accelerator. It includes the effort to build the prototype magnets.

2.4 Project Administration R&D

2.4.1 Project Office R&D. This item includes the direct costs of the

Tevatron I project R&D administration and management not covered under existing Laboratory services and systems. It includes among other things such items as telephone charges, computer rental charges, travel, consulting expenses, administration salaries, publishing and printing expenses, office supplies, which are necessary for the timely execution of the R&D funded elements of the project and the reporting of the projects progress to DOE and the Laboratory Director.

2.4.2 Project Support Activities R&D. This item includes the costs incurred by the Business Services Section, Personnel Services Section, and the Directorate in direct support of the execution of the Tevatron I project R&D funded elements.

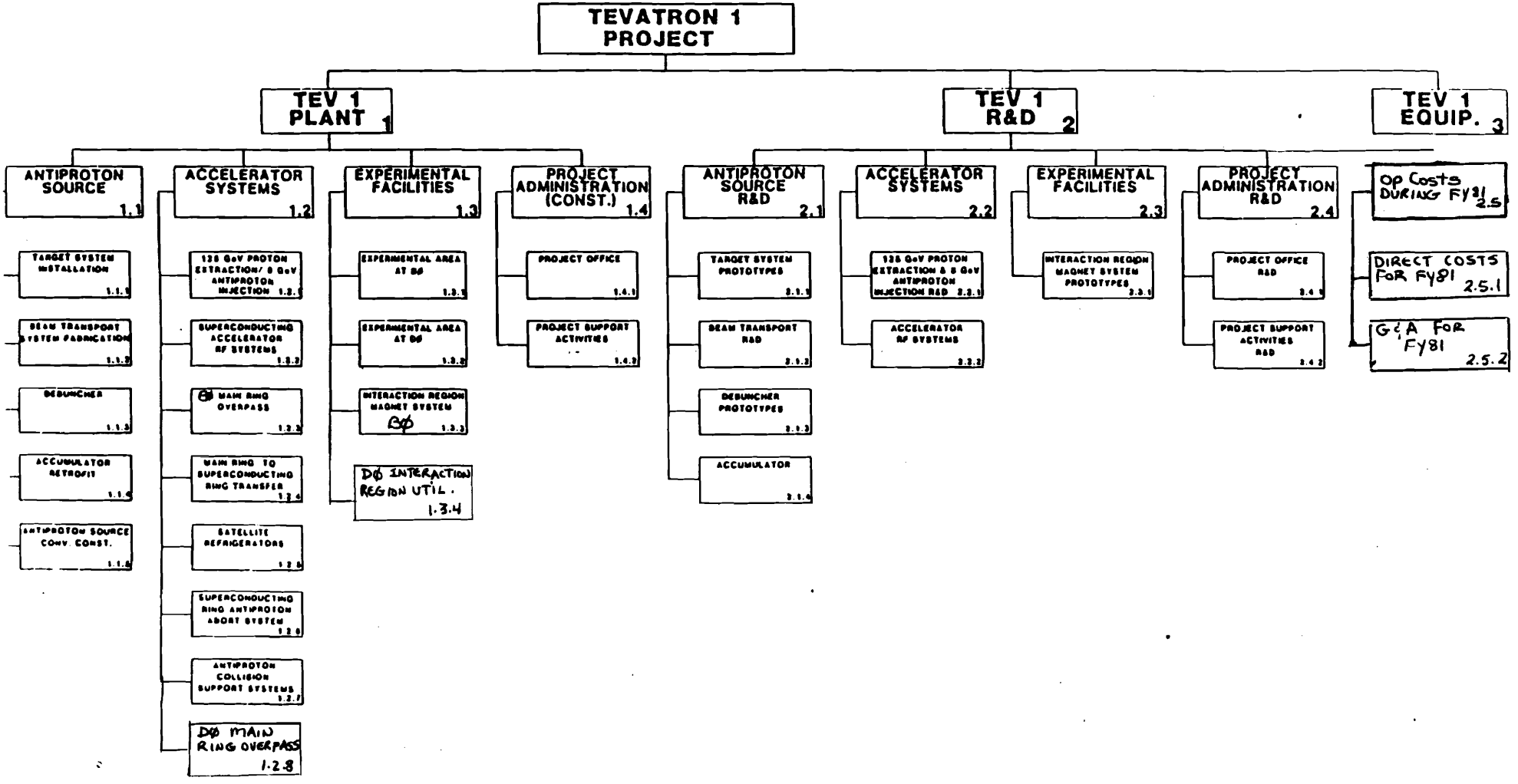
2.5 Operating Costs Accrued During FY 81

2.5.1 Direct Costs for FY 81. This item includes the direct costs of the Tevatron I Project R&D accrued during FY 81.

2.5.2 G&A for FY 81. This item includes the costs incurred by the Business Services Section, Personnel Service Section, and the Directorate in support of the execution of the Tevatron I Project R&D effort during FY 81.

3.0 Capital Equipment Funded Elements

These elements will include beam transport magnets, control system equipment, and commercial instrumentation and diagnostic equipment.



TEV 1 WORK BREAKDOWN STRUCTURE

V. WORK PLAN

The previous Chapter described what will be accomplished in the Tevatron I project. This chapter describes the methods by which the work will be accomplished.

A. GENERAL DESCRIPTION OF WORK

1. Required Research and Development Effort

The research and development effort supporting the Project has been underway at Fermilab for a number of years and will continue to the completion of the project. It is directed at refining the methods of cooling and accumulation of antiprotons, improving the production and collection of antiprotons, developing techniques for rebunching proton and antiproton beams in the Main Ring and after the Energy Saver begins operations in 1983, the storage of beams in the Energy Saver.

In order to evaluate the performance of beam cooling systems, a circulating particle beam with a lifetime in excess of 20 hours is needed. A storage ring that can contain protons is an ideal means of accomplishing this task. The Accumulator will be built as a research and development device for this purpose. It will be able to accept and store 8 GeV protons from the Main Ring. In addition, a beam line from the 8 GeV Booster will be built to provide protons during Main Ring shutdowns.

The work will be directed to investigate the following subjects: the development of efficient methods of producing antiproton beams with protons; the development of efficient methods of collecting antiprotons that are produced when protons interact with a dense target; the development of efficient methods of increasing the density of antiprotons in phase space (all covered under item 2.1 of the WBS); the development of efficient methods of accumulating and utilizing antiprotons in a storage ring (item 2.2 and 2.3 of the WBS). The R&D effort also includes the development of prototype components of the Antiproton Source such as magnets, vacuum components, rf cavities, and power sources, and cooling system components.

The plan decribing the R&D in support of Tevatron I is included in the Fermi National Accelerator Laboratory annual budget request is submitted to the U.S. Department of Energy.

2. PLAN WORK TO BE ACCOMPLISHED; CONSTRUCTION EFFORT

The effort funded by line-item construction funds authorized for the Tevatron I project includes both conventional and special facilities. Both were described in Chapter IV, Section B.

B. METHODS TO ACCOMPLISH THE WORK

1. ACCELERATOR SYSTEMS DESIGN AND ENGINEERING DESIGN

a. Accelerator systems design. The Tevatron I Project will establish performance specifications for all level 3 and 4 WBS elements and document these in the Tevatron I Project Design Report which is the system design description. These performance specifications will formalize the Project Objectives in detail. When appropriate, they will be reviewed by the Project Advisory Group. Outside consultants will be employed as deemed necessary to review specific designs of critical systems. The final design of the conventional facilities and the technical components will conform to the performance specifications described in the Design Report.

b. Engineering design of conventional facilities. Conventional facilities will be designed by the Tevatron Construction Group using criteria developed by the Tevatron I Project Manager and given in the Design Report. Title I reports will be prepared for the purpose of describing the plans for building the conventional facilities which are included in the Antiproton Source, Accelerator Systems, the Experimental Area at BO, and the Experimental Area at DO. Title I reports will be submitted to BAO for approval by the DOE Project Manager prior to initiating the Title II specifications. Title II drawings and specifications will be prepared for all conventional construction subcontracts. Title II specifications will include an outline Critical Path Network schedule. Title II drawings and specifications will be submitted to BAO for approval by the DOE Project Manager.

c. Engineering design of special facilities. The special facilities will be designed by the scientific and engineering staff of Fermilab to the specifications contained in the Tevatron I Project Design Report. The Antiproton Source will be designed by the Tevatron I staff with assistance from the Technical Support Section and the Accelerator Division. Components for Accelerator Systems, WBS elements 1.2 and 2.2 will be designed by the Accelerator Division with assistance from the Technical Support Section (on the basis of criteria developed by the Tevatron I staff). The Interaction Region Magnet Systems, which is part of Experimental Facilities, will be designed by the Accelerator Division with assistance from the Technical Support Section on the basis of specifications from the Tevatron I Design Report and the criteria for the Colliding Detector Facility.

2. CONSTRUCTION AND FABRICATION

a. Conventional facilities. The construction of conventional facilities will be accomplished by fixed price competitive bid contracts whenever possible. Public bids will be solicited from qualified contractors on the basis of approved plans and specifications and in accordance with applicable DOE regulations. Bids will be received and publicly opened in accordance with Fermilab procurement policies, reviewed by the Business Manager, Construction Manager and Project Manager, and recommendations submitted for review by the Director. Following review by the Director, a draft contract prepared by the Contract Department of the Business Services Section will be submitted for approval by BAO. Upon approval by DOE and execution of the contract, the Fermilab Business Manager will issue a notice to proceed to the contractor.

Management of the construction effort will be the responsibility of the Tevatron I Construction Manager.

b. Special facilities. Fabrication, assembly, and installation of special facilities will be done by Fermilab under the direction of the Project Manager. Components, subassemblies or assemblies, will be procured from commercial sources on the basis of competitive proposals whenever possible in accordance with Fermilab procurement policies. Fermilab specialists will provide components, subassemblies or assemblies, when suitable technical, cost, or schedule capability does not exist from normal commercial sources or other specialists.

3. PROCUREMENT PLAN

a. General. All major procurements and construction contracts will be reviewed and approved by the Department of Energy, Batavia Area Office, as required by the prime contract with DOE or by separate procurement instructions issued by DOE through BAO to Fermilab.

The following subsections of this chapter describe how procurements will be managed for conventional facilities construction and for special facilities fabrication, and the small business plan.

A detailed procurement schedule will be submitted separately.

b. Conventional facilities. The Construction Manager will prepare a plan which identifies all major subcontracts for conventional facilities. He will identify all items which will be obtained through Fermilab procurement and be supplied to the construction contractor for installation. The plan will be compatible with the Project Control Milestones.

The Construction Manager, with assistance from the Tevatron Construction Group, will make recommendations to the Project Manager on advance procurement of long lead time items. The Construction Manager will monitor the timely placement of these subcontracts and purchase orders and will undertake to assure timely receipt of components and materials using all measures available, including requests for assistance and approval from the Department of Energy and will coordinate with Fermilab subcontractors.

- Solicitation of prices for these items will be processed by the Business Services Section in accordance with Fermilab procurement policies. The Business Services Section with the assistance of the Construction Manager will evaluate the proposals and following their approval by the Project Manager will forward them to DOE for approval.

c. Special Facilities. The Project Manager will prepare a procurement plan for all major procurement items. Evaluation of prices, proposals and vendors will be made prior to award by the Business Office. Documentation and approval of all procurement actions will be in accordance with Fermilab procurement policies.

d. Small Business Plan. The Contracting and Purchasing Departments will be encouraged to do business with small and disadvantaged contractors in accordance with the plan for such activities as outlined in the prime contract between the URA and Department of Energy.

4. INSPECTION AND ACCEPTANCE

a. Conventional Facilities. The Construction Manager will be responsible for the inspection of work performed by the construction contractors and subcontractors. He will be responsible on behalf of Fermilab for the acceptance of items furnished by Fermilab to the construction contractor. The final inspection of the work performed under each contract will be performed by the Project Manager, Construction Manager, representatives of the Fermilab Plant Management Group, and representatives of the DOE. Formal acceptance will be evidenced in writing by Fermilab.

b. Special Facilities. The Project Manager will be responsible for adherence to specifications, plans and standards of all special components and systems. This responsibility applies equally to procurement from in-house and outside sources and will include the final assembly and installation. These activities will be monitored and reviewed by the Project Advisory Group.

Project staff members will perform in-plant inspections and on-site inspections of work in progress. Group leaders will be responsible for the acceptance of components and subsystems of systems within their assigned areas of responsibility. The services of expert consultants will be utilized as appropriate.

c. Overall Facilities. The final inspection and acceptance of the completed facility will be performed by Fermilab in conjunction with the Department of Energy.

5. QUALITY ASSURANCE

The Director of Fermilab, as part of the Fermilab QA Program, has delegated responsibility for the quality assurance of every project to the Division or Section Head responsible for that project. He has also appointed a Fermilab Quality Assurance Coordinator to assist the Division and Section Heads in carrying out this responsibility and to keep records of all Fermilab Quality Assurance requirements.

The Project Manager has appointed a Tev I Quality Assurance Manager to monitor the QA activities of the Tev I staff. The Fermilab Quality Assurance Coordinator will assist and review the activities of the Tev I Quality Assurance Manager.

Quality Assurance will be an integral part of the design, procurement, fabrication and construction activities associated with the Project. The Quality Assurance Plan for the project will be implemented in conjunction with the Quality Assurance Program already in place at Fermilab.

C. TECHNICAL CRITERIA

1. CONVENTIONAL FACILITIES

The design and construction will be guided by applicable standards and codes as set forth in:

1. DOE Manual 6430 (Draft) General Design Criteria.
2. DOE Manual 5480 Series, Operational Safety Standards.
3. Where necessary, more stringent standards may be established to meet particular needs of the project.

2. SPECIAL FACILITIES

The accelerator and experimental facilities systems will conform to the applicable standards as referenced in 1 above whenever appropriate. However, the project work generally is so specialized as forefront physics technology related to research and development that Fermilab will supplement the standards as appropriate. Fermilab's long experience in beam and target design, construction and operation has resulted in the compilation of a large number of specifications, design guides, and in-house standards. In instances where these standards are appropriate, they will be applied to the project. In cases where neither type of standard is appropriate, the responsible system group will develop appropriate standards for review and authorization by the Project Manager, the Director, and where appropriate, DOE.

Design and drawing files will be maintained for calculations and up-to-date prints. Design review will be undertaken systematically so that criteria and alternative approaches can be evaluated for cost effectiveness, quality assurance, safety, conformity with project objectives, and operational reliability. Specifications will be prepared with drawings that identify material, describe manufacturing processes where necessary, and define the criteria for acceptance, as well as the testing methods. Applicable standards will be referenced.

D. CODES, STANDARDS, AND SPECIFICATIONS

1. DAVIS-BACON DETERMINATIONS

Davis-Bacon determinations will be made by the Department of Energy Davis-Bacon Committee.

2. SAFETY AND HEALTH

All work performed on site will be accomplished in accordance with Fermilab's formal procedures as outlined in its approved safety manual. All subcontracts for work performed on site will include standard language

requiring compliance with Fermilab safety instructions, DOE safety regulations, and all applicable provisions of federal, state, and municipal safety laws.

The safety program for the construction of the conventional facilities will be monitored directly by the Construction Manager. The project safety officer will be the Accelerator Division Safety Officer. He will have overall staff responsibility for conventional and special facility safety reviews. He will be assisted by the Accelerator Division Safety Group, the Safety Section at Fermilab, and by the Batavia Area Office of the Department of Energy.

3. EQUAL EMPLOYMENT OPPORTUNITY (EEO)

All contracts will contain approved standard contract articles and the award of construction will be subject to the submittal of satisfactory affirmative action assurance as outlined in the Fermilab/DOE prime contract.

VI. SCHEDULE AND LOGIC DIAGRAM

The Construction Project Data Sheet (Appendix A) shows initiation of the project in First Quarter FY 1981 with completion in Fourth Quarter FY 1986.

The completion date will have to be extended until the Fourth Quarter of FY 1987 due to the late start of construction of the D0 Experimental Area and the enlarged volume to accommodate the experimental physics program.

The Tevatron I Work Schedule is shown in Appendix B at Level 2 of the WBS with the current key milestones listed. The key milestones were also listed in Chaper 2. The work schedule at Level 3 of the WBS is shown in Appendix D with the control milestones highlighted. The key and control milestones are displayed in the Tevatron I Milestone Chart, Appendix E.

The master schedule includes 87 control milestones that will be used to monitor progress on the project. The integrated schedules show the design, fabrication, installation and commissioning of both the construction and research and development effort.

VII. COST ESTIMATE

The total estimated baseline cost of the project (TEC) has been established at $84,000,000. The baseline R&D cost is $48,163,000, resulting in a baseline total project cost (TPC) of $134,504,000. This is set forth in the Construction Project Data Sheets of 1986 (Appendix A).

A. COST BREAKDOWN BY WBS

A summary of the costs itemized according to the first, second, and third level of the Work Breakdown Structure is shown in the table that follows. These estimates represent the "Baseline" cost estimate of the Project.

The costs contain an estimate for all Fermilab and subcontract labor for the engineering, design, fabrication, installation and inspection and testing of all components. Administration personnel costs are included in the Project Office element of the WBS.

Table I
Tevatron I Baseline Cost Estimate of 10/84
(in then-year thousands of dollars)

1.0	Construction Funded Elements		84,000
1.1	Antiproton Source		40,369
1.1.1	Target System Installation	1185	
1.1.2	Beam Transport System Fabrication	6,133	
1.1.3	Debuncher	17,840	
1.1.4	Accumulator Retrofit	3,843	
1.1.5	Antiproton Source Conventional Construction	11,368	
1.2	Accelerator Systems		16,099
1.2.1	120-GeV Proton Extraction & 8-GeV Antiproton Injection	784	
1.2.2	Superconducting Accelerator RF System	2,087	
1.2.3	BO Main Ring Overpass	4,545	
1.2.4	Main Ring to Superconducting Ring Transfer	830	
1.2.5	Satellite Refrigerators	4,103	
1.2.6	Superconducting Ring Antiproton Abort System	481	
1.2.7	Antiproton Collision Support Systems	2,380	
1.2.8	DO Main Ring Overpass	889	
1.3	Experimental Facilities		19,377
1.3.1	BO Experimental Area	7,240	
1.3.2	DO Experimental Area	7,678	
1.3.3	BO Interaction Region Magnet System	2,859	
1.3.4	DO Interaction Region Utilities	1,600	
1.4	Project Administration		1,815
1.4.1	Project Office	1,287	
1.4.2	Project Support Activities	528	
	CONTINGENCY FOR CONSTRUCTION FUNDED ELEMENTS (not allocated in WBS)		6,340

2.0 Research and Development 48,163

2.1 Antiproton Source R&D 28,606

2.1.1 Target System Prototype ... 2,122
2.1.2 Beam Transport 4,258
2.1.3 Debuncher Prototypes 825
2.1.4 Accumulator 21,401

2.2 Accelerator Systems R&D 1,490

2.2.1 120-GeV Proton Extraction & 8-GeV Antiproton Injection R&D 880
2.2.2 Accelerator RF Systems 610

2.3 Experimental Facilities R&D 693

2.3.1 Interaction Region Magnet System Prototypes 693

2.4 Project Administration R&D 15,153

2.4.1 Project Office R&D 2,943
2.4.2 Project Support Activities R&D 12,210

2.5 Operating Costs accrued during FY 1981 2,221

2.5.1 Direct Costs for FY81 1,682
2.5.2 G&A for FY81 539

3.0 Other Project Funding (Capital Equipment) 2,341

TOTAL PROJECT COST (TPC) $134,504

B. COST PLAN

The estimated project cost and obligations by fiscal year for the duration of the effort for Levels 2 and 3 of the Work Breakdown Structure is shown in Table II. The figures are expressed in then-year dollars.

Table II(A)
Tevatron I (Construction Costs)
(in thousands of dollars)

WBS No.	Title	Prior Fiscal Years	FY82	FY83	FY84	FY85	FY86	TOTAL
1.1	Antiproton Source							
1.1.1	Target System	$ 0	$ 0	$ 25	$ 448	$ 451	$ 211	$ 1185
1.1.2	Beam Transport	0	0	346	2972	2815	119	6133
1.1.3	Debuncher	0	0	1331	10557	5912	40	17840
1.1.4	Accumulator Retrofit	0	0	189	1710	1904	40	3843
1.1.5	Antiproton Source Conv. Const.	26	151	1900	8149	1142	0	11368
	1.1 TOTAL	26	151	3791	23886	12224	291	40369
1.2	Accelerator Systems							
1.2.1	120 GeV Prot. Ext. & 8 GeV Inj.	0	11	120	511	142	0	784
1.2.2	Superconducting Accel RF Systems	121	115	286	930	586	49	2087
1.2.3	B0 Main Ring Overpass	0	0	31	470	1955	2088	4545
1.2.4	MR to SC Ring Transfer	0	0	3	501	326	0	830
1.2.5	Satellite Refrig.	905	2530	593	75	0	0	4103
1.2.6	Superconducting Ring Antiproton Abort System	0	0	0	273	208	0	481
1.2.7	Antiproton Collision Supp. Sys.	0	0	0	781	299	1300	2380
1.2.8	D0 Main Ring Overpass	0	0	0	493	315	81	889
	1.2 TOTAL	1026	2656	1033	4034	3831	3518	16099
1.3	Experimental Facilities							
1.3.1	Experimental Area at B0	159	1349	5428	174	130	0	7240
1.3.2	Experimental Area at D0	0	0	39	153	2930	4556	7678
1.3.3	B0 Interaction Region Mag. Sys.	0	0	1177	1429	253	0	2859
1.3.4	D0 Interaction Region Utilities	0	0	0	0	650	950	1600
	1.3 TOTAL	159	1349	6644	1756	3963	5506	19377
1.4	Project Administration							
1.4.1	Project Office	0	0	294	642	787	-436	1287
1.4.2	Project Support Activities	0	26	82	212	146	62	528
	1.4 TOTAL	0	26	376	854	933	-374	1815
	Contingency	0	0	0	0	0	6340	6340
	TOTAL	$1211	$4182	$11844	$30530	$20951	$15281	$84000

Table II(B)
Tevatron I (R&D)
(in thousands of dollars)

WBS No.	Title	Prior Fiscal Years	FY82	FY83	FY84	FY85	FY86	TOTAL
2.1	Antiproton Source R&D							
2.1.1	Target Station	$ 0	$ 331	$ 768	$ 877	$ 146	$ 0	$ 2122
2.1.2	Beam Transport	0	170	620	2319	1149	0	4258
2.1.3	Debuncher	0	94	330	353	48	0	825
2.1.4	Accumulator	0	755	6406	10073	4167	0	21401
	2.1 TOTAL	0	1350	8124	13622	5510	0	28606
2.2	Accelerator Systems R&D							
2.2.1	120 GeV Prot. Ext. & 8 GeV Inj.	0	149	26	609	96	0	880
2.2.2	Accel RF Systems	0	168	112	320	10	0	610
	2.2 TOTAL	0	317	138	929	106	0	1490
2.3	Experimental Facilities R&D							
2.3.1	Interaction Region Magnets System	0	0	693	0	0	0	693
	2.3 TOTAL	0	0	693	0	0	0	693
2.4	Project Administration R&D							
2.4.1	Project Office	0	786	808	909	440	0	2943
2.4.2	Project Support Activities	0	884	3507	5627	2193	0	12210
	2.4 TOTAL	0	1670	4315	6536	2632	0	15153
2.5.1	FY81 Direct Costs	1682	0	0	0	0	0	1682
2.5.2	FY81 G&A Costs	539	0	0	0	0	0	539
	2.5 TOTAL	2221	0	0	0	0	0	2221
	TOTAL	$2221	$3337	$13270	$21087	$ 8248	$ 0	$48163

VIII. PERFORMANCE CRITERIA

The performance criteria in this chapter are given at a level equivalent to Level 3 of the Work Breakdown Structure. These are the detailed criteria by which progress in system performance will be judged by the Project Manager.

1. TARGET AND COLLECTION SYSTEM

- Target to withstand a 1.6 μsec pulse of 2×10^{12} 120-GeV protons every 2 sec.

- Collection system to collect 5×10^{7} antiprotons within a 3% momentum spread and 20π mm-mrad transverse emittances (in each plane) for 2×10^{12} 120-GeV protons on target.*

2. BEAM TRANSPORT

a. Target to Debuncher

- Maximum operating energy 8 GeV

- 75% transmission from collection lens to Debuncher over 4% momentum spread and 25π mm-mrad transverse emittance.

b. Accumulator to Main Ring

- Maximum operating energy 8 GeV

- 90% transmission from Accumulator to Main Ring over 0.2% momentum spread and 2π mm-mrad transverse emittance.

3. DEBUNCHER

- Nominal operating energy 8 GeV

- Transverse acceptance 20π mm-mrad at 8 GeV

- Momentum acceptance 4% at 8 Gev

- maximum values of 0.2% momentum spread and 7π mm-mrad transverse emittance for an initial momentum spread of 3% and transverse emittance of 20π mm-mmrad and 5×10^{7} antiprotons per cycle.

- Debunching and cooling cycle time 2.0 sec.

*The momentum spread and transverse emittances are defined throughout to include 95% of the beam.

4. ACCUMULATOR

- Nominal operating energy 8 GeV
- Transverse acceptance 10π mm-mrad at 8 GeV
- Momentum acceptance 2.5% at 8 GeV
- Stacking rate 2.2×10^{7} antiprotons every 2 sec., corresponding to 2×10^{11} stacked in 5 hours.
- Maximum stack momentum spread 0.2% at 8 GeV
- Maximum transverse emittance 2π mm-mrad at 8 GeV

5. MAIN RING

a. Proton acceleration for Antiproton Production

- Nominal energy 120 GeV
- Minimum intensity 2×10^{12} protons per 1.5 μsec pulse
- Bunch time spread at extraction 1.0 μsec
- Nominal cycle time 2.0 sec.
- Extraction efficiency 90%

b. Proton Acceleration for Proton-Antiproton Collisions

- Injection energy 8 GeV
- Nominal transfer energy 150 GeV
- Maximum transverse emittance 0.12π mm-mrad at 150 GeV
- Maximum bunch longitudinal emittance 1.5 eV-sec at 150 GeV
- Minimum bunch intensity 0.7×10^{11} protons

c. Antiproton Acceleration for Proton-Antiproton Collisions

- Injection energy at 8 GeV
- Nominal transfer energy 150 GeV
- Maximum transverse emittance 0.12π mm-mrad at 150 GeV
- Maximum bunch longitudinal emittance 1.5 eV-sec at 150 GeV
- Minimum bunch intensity 0.7×10^{11} antiprotons

6. TEVATRON SUPERCONDUCTING STORAGE RING

- Number of bunches of protons and antiprotons 1 to 6
- Maximum operating energy 1 TeV
- Minimum bunch intensity at injection 0.6×10^{11}
- Minimum β at B0 1 m

IX. ORGANIZATION

A. GENERAL

The DOE organizational relationships are shown in Figure 3-1. Details of the respective responsibilities of the Office of Energy Research (ER) and the Chicago Operations Office are outlined below. Should unresolved administrative conflicts exist between CH and ER, the issues will be resolved by the Under Secretary to whom both the Manager of CH and the Director of ER report.

B. DOE PARTICIPANTS

1. Headquarters - ER

The Director for High Energy Physics has been designated as Program Manager and is responsible for approving major changes to the Project which could alter the technical performance, scope, cost, or schedule completion of the Project. Specific activities are as noted below. He shall:

1. Approve:
   (a) The Program Plan for fiscal year budget and funding level totals;

   (b) Technical requirements such as those listed in Chapter VIII (Tevatron I Performance Criteria) and major changes thereto;

   (c) The facility operational availability date;

   (d) The Project Total Estimated Cost and major changes thereto;

   (e) Key scheduled milestones as agreed to with BAO and Fermilab and greater than three month delays in projected completion of key milestones.

2. Provide a Headquarters coordinator who acts as the point of contact for the BAO concerning Headquarters interaction.

3. Maintain overview of the project activities via coordinated periodic meetings, reviews, project reports, and other means to assure that the project objectives are being effectively met.

4. Assure that adequate research and development work necessary to support the design and construction is carried out in a timely manner.

5. Concur in the Tevatron I Project Management Plan.

6. Establish and maintain Congressional budget data sheets for the project.

2. FIELD-BATAVIA AREA OFFICE (BAO)

The Area Manager BAO has the primary DOE-CH responsibility for the contracts administration and project management of all activities and projects assigned to Universities Research Association, Inc. as operator of Fermilab. As such, that office has the responsibility for assuring satisfactory execution and completion of the Tevatron I Project.

Within the CH, the BAO is assigned the government management responsibility for the Project, including the responsibility for assuring the establishment of sound management organizations, plans and systems for effective project execution, and local administration. The BAO will be supported by the Chicago Operations Office in the areas of Project planning and controls, audit, safety, counsel, patents, quality assurance, personnel, security, and accelerator technology.

The BAO is responsible for assuring sound management and administration in accordance with established DOE policies and procedures, the approved Congressional Data Sheet, and specific directives received from the program division and CH. These are summarized below:

1. MANAGEMENT AND ADMINISTRATION

The BAO shall:

(a) See that project management systems and controls are established by Fermilab with the goal of assuring project completion in accordance with the approved technical objectives, schedules, and budgets.

(b) Review and approve procurement actions of Fermilab in accordance with the DOE-URA contract and obtain high level approvals, as required.

(c) Provide Davis-Bacon determinations and evaluate contract and subcontract actions and procurements.

(d) Review funding requirements and take appropriate actions.

(e) Provide guidance to Fermilab for procurement actions and authorize the scope for predetermined work breakdown structure elements and changes thereto.

(f) Approve the project master schedule and delays of greater than one month in projected completion of control milestones, plus project budget, and performance measurement baselines and changes thereto.

(g) Assure that Headquarters is kept informed on project status.

(h) Approve subcontract actions and procurements as required by the contract.

(i) Approve the Initial Project Cost Estimate Baseline.