Appendix 1. Cost Estimates

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A1.1 Introduction

The cost of a synchrotron-based Proton Driver and of the modifications and upgrades of the Main Injector and associated beam lines have been estimated using the "bottoms up" method. After the design of each technical system is completed, it is given to an experienced engineer who has built similar systems before who makes a cost estimate that contains sufficient details based on previous work. In this Appendix, however, we only list the cost estimate of each technical system without including these details. We believe this is sufficient at this stage of the design study. The cost estimate for civil construction is done in the same way. A Work Breakdown Structure (WBS) is not incorporated but will be produced when it is required.

This is the so-called "unloaded" cost estimate. In other words, it does not include G&A (lab overhead) and contingency. These items will be added later following guidelines provided by the Fermilab Director and the DOE. The ED&I costs are included in the cost estimates and are assumed to be 17% across the board.

All the figures are in FY 2002 U.S. dollars. No inflation is included.

A1.2 Cost Estimate of a Synchrotron-based 8 GeV Proton Driver

Table A1.1 lists the cost estimate of a synchrotron-based 8 GeV Proton Driver. It includes an 8 GeV synchrotron, a 200 MeV linac extension (to bring the total linac energy to 600 MeV), a 600 MeV beam transport line, an 8 GeV beam transport line, improvements in the present H^- source and Linac, and civil construction. The total cost is about $170M. Compared with PD1 (of which the cost is about $242M), the saving is about $72M. This saving mainly comes from the magnets, power supplies and civil construction. This is because the machine size is smaller; the number of magnets and magnet aperture are also reduced. An additional cost item of PD2 is the conventional construction required for the linac extension (technical systems and a gallery), about $20M, which is not required by PD1.

(Note: In the Appendix of Chapter 8 we discussed an upgrade of the aging original 1972 DTL linac; the cost of such an upgrade is not included here since although desirable it is not required by PD2.)

It should be pointed out that a result of this cost saving is a reduction of the proton beam power. In PD1, the Proton Driver is a 1 MW machine. In PD2, it is reduced to 0.5 MW.

A1.3 Cost Estimate of the Main Injector and Beam Lines Upgrades

Table A1.2 lists the estimated costs of the required modifications and upgrades of the Main Injector and associated beam lines in order to make the Main Injector a 2 MW machine. Included are the rf system and power supply upgrades, a gamma-t jump system, four large aperture quadrupoles, major modification of the kickers, a longitudinal feedback system, collimators, upgrade of the MI-40 beam dump, and controls and utilities upgrades. The table also includes the cost estimate of the NuMI and MiniBooNE upgrade in order for these beam lines to take full advantage of the higher beam power that would be available from the upgraded Main Injector and Proton Driver. Upgrades to the NuMI and MiniBooneNE detectors are not included.

The main cost item in the MI upgrade is the rf system. Most other items cost around $1M or below. There are two possible ways to implement the MI upgrade. It can be done as a single "all-included" Fermilab project. Or the upgrade can be accomplished through a series of accelerator improvement projects (AIPs).

There is a large uncertainty in the cost estimate for the NuMI beam line upgrade to 2 MW. A lot of the data that are necessary for making a reliable cost estimate are not available at this time. The actual cost could be twice as high or 50% lower than that listed in the table (about $9M).

Table A1.1. Cost Estimate of a Synchrotron-based 8 GeV Proton Driver (in K$)

1	**Technical Systems**			115,813
1.1	8 GeV Synchrotron		92,426	
1.1.1	*Magnets*	27,329		
1.1.2	*Power supplies*	25,968		
1.1.3	*RF*	5,115		
1.1.4	*Vacuum*	6,061		
1.1.5	*Collimators*	325		
1.1.6	*Injection system*	938		
1.1.7	*Extraction system*	2,189		
1.1.8	*Instrumentation*	2,393		
1.1.9	*Controls*	2,468		
1.1.10	*Utilities*	4,931		
1.1.11	*Installation*	1,280		
1.1.12	*ED&I*	13,429		
1.2	Linac Improvements and Upgrade		20,475	
1.2.1	*Front end and RFQ*	3,000		
1.2.2	*New drift tube Tank #1*	1,000		
1.2.3	*Transfer line to new CCL*	1,800		
1.2.4	*New CCL modules and klystrons*	11,100		
1.2.5	*Controls and diagnostics*	600		
1.2.6	*ED&I*	2,975		
1.3	600 MeV Transport Line		1,053	
1.3.1	*Magnets*	720		
1.3.2	*Power supplies*	180		
1.3.3	*ED&I*	153		
1.4	8 GeV Transport Line		1,859	
1.4.1	*Magnets*	1,271		
1.4.2	*Power supplies*	318		
1.4.3	*ED&I*	270		
2	**Civil Construction**			43,468
2.1	8 GeV Synchrotron		17,500	
2.1.1	*Enclosure*	7,000		
2.1.2	*Service buildings*	7,000		
2.1.3	*Utility support building*	3,500		
2.2	Linac extension		2,500	
2.3	600 MeV Transport Line		1,800	
2.4	8 GeV Transport Line		2,200	
2.5	Site work		4,800	
2.6	Subcontractors OH&P		5,760	
2.7	ED&I		5,875	
2.8	Environmental controls and permits		3,033	
3	**Project Management**			10,000
	TOTAL ($k)			169,281

Table A1.2. Cost Estimate of Main Injector and Beam Lines Upgrades (in K$)

1	**Main Injector Upgrade**			23,502
1.1	RF system		14,238	
1.1.1	*Modulator*	3,400		
1.1.2	*Power amplifier*	1,390		
1.1.3	*Anode supplies*	1,098		
1.1.4	*Cavity modifications*	1,250		
1.1.5	*Driver amplifiers*	3,600		
1.1.6	*Installation*	3,500		
1.2	Main power supplies		430	
1.2.1	*Bend bus*	210		
1.2.2	*Quad bus*	220		
1.3	Gamma-t jump system		490	
1.3.1	*Pulsed quads*	130		
1.3.2	*Power supplies*	320		
1.3.3	*Beam pipes*	40		
1.4	Large aperture quadrupole		710	
1.4.1	*Magnets*	360		
1.4.2	*Tooling*	350		
1.5	Kickers		1,060	
1.5.1	*PFN and cooling*	370		
1.5.2	*Magnets*	690		
1.6	Longitudinal feedback		625	
1.7	Collimators		325	
1.8	Beam dump		500	
1.9	Controls		303	
1.10	Utilities		1,406	
1.11	ED&I		3,415	
2	**NuMI Upgrade**			8,920
2.1	Collimators		180	
2.2	Target and cooling		750	
2.3	Kicker and horn power supplies		90	
2.4	Target Hall chase cooling		1,000	
2.5	Target Hall shielding		3,000	
2.6	Install Target Hall shielding		1,000	
2.7	Install Hadron Absorber		500	
2.8	Hadron Absorber cooling		1000	
2.9	Decay pipe cooling		1,000	
2.10	Additional cooling ponds		400	
3	**MiniBooNE Upgrade**			250
4	**Project Management**			3,000
	TOTAL ($k)			35,672

Note: For the option of an 8 GeV superconducting proton linac, one needs to add two more items:

- A new H^- injection system in the Main Injector;
- A new extraction scheme for the MiniBooNE experiment.

The cost of these two items is not included in this table.