Director's Review of the Project X Cost Range Estimate: Transfer Line Components

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Project X Director's Review
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Outline

- Scope of Estimated Work
  - Components (M&S (construction, purchase, installation)
    - Magnets
    - Power supplies
    - Vacuum
    - Collimation
    - Phase Rotator (cavity & RF system)
    - Linac Dump
- Basis of Estimate
- Cost Estimate
- Technical/Cost Risks
- Summary

Scope of Estimate

TL Magnets

- Transfer Line Magnets
  - 69 permanent magnet c-magnets for the arc
  - 3 electromagnet c-magnets for dump switch
  - 4 vertical bend magnets
  - 7 horizontal dipoles (2 lengths)
  - 64 permanent magnet quadrupoles
  - 64 trim dipoles for orbit control
  - 24 trim quads for matching
- Estimates include EDIA, M&S, construction labor, and tooling as required
- Estimated Magnets, stands, and installation
- M&S 3,198K$ & Labor 13.96 FTE-years

Basis of Estimate

TL Magnets

- Magnets
  - Estimates performed by Technical Division staff
  - Based upon previous experience in the construction of similar types of magnets or purchase costs
- Stands
  - Based on stand construction estimates for similar magnet types from previous construction
- Installation
  - Assume contract labor
  - Based upon magnet and stand installation contracts from MI and RR

Cost Estimate

Project X

TL Magnets

ITEM		Unit	M&S Cost $	Quantity	M&S Tot. $k	Sci FTE-yr	Eng. FTE-yr	Draft/Mach FTE-yr	Tech. FTE-yr
Magnets	EE				$3,198	0	5.75	2.175	6.035
PM Dipoles	EE	ea		69	$1,662	0	1.725	0.525	1.975
PM Quadrupoles	EE	ea		64	$795	0	1.525	0.525	1.8
Dump Switch dipoles	EE			3	$38	0	0.625	0.25	0.625
PM Vertical Bend Dipoles	EE			4	$89	0	0.375	0.125	0.125
H Achromat Dipole 1 (PM)	EE			5	$112	0	0.375	0.125	0.15
H Achromat Dipole 2 (PM)	EE			2	$45	0	0.375	0.125	0.06
Trim Dipoles	EE			64	$313	0	0.375	0.25	1.3
Trim Quads (MQT)	EE			24	$144	0	0.375	0.25	0

PM Dipoles	EE	ea		69	$1,662	0	1.725	0.525	1.975
Construction					$1,489	0	1.6	0.4	1.975
Magnet EDIA						0	1.6	0.4	0
R&D Prototype		lot	$32,500	1	$33				
Tooling		lot	$90,800	1	$91				
Magnet Construction (M&S)		ea	$19,791	69	$1,366				1.975
Magnet Measurements									
Installation					$173	0	0.125	0.125	0
Magent Installation		ea	$390	69	$27				
Installation EDIA							0.125	0.125	
Stand Construction (M&S)		ea	$2,000	69	$138				
Installation		ea	$120	69	$8				

Technical Risks

TL Magnets

- Permanent magnet c-magnet
  - Only a crude conceptual magnetic design was constructed.
  - Conceptual ideas included for stiffening
  - A detailed magnetic and structural design may alter cost estimate (30% cost variance impact TPC <0.06%)
  - Cost estimate within global 40% contingency
- Permanent magnet quads
  - Very little technical risk as these are duplicates of existing magnets
- Trim dipoles
  - Very little technical risk
  - Estimated construction of existing MI trim dipoles
  - Strength could be reduced hence reducing cost
- Trim quads
  - Very little technical risk
  - Duplicate of existing magnets
  - Cost exposure as last magnets made at good price in INFP(?)

Scope:

Power Supplies

- With major bends and quads as permanent magnets
  - Linac dump switch power supply
  - Dipole trim supply
  - Quad trim supply
- Trim supply includes installation
- M&S 286K$ & Labor 1.33 FTE-years

Basis of Estimate

Power Supplies

- Dump switch power supply
  - Based on expected resistance and inductance of magnet string a 10-12 kW supply is expected… used EE Support estimate of $1K/kW and rounded to 20K$
  - Purchase supply (c.f. Spang)
- Trim Supplies (both dipole and quad)
  - Used costs of FNAL design trim supplies used in MI
  - Included cable pulls
  - Installation costs

Cost Estimate

Power Supplies

ITEM		Unit	M&S Cost $	Quantity	M&S Tot. $k	Sci FTE-yr	Eng. FTE-yr	Draft/Mach FTE-yr	Tech. FTE-yr
Power Supplies					$286	0	0.75	0.201	1.375
Dump Switch dipoles	WAG		$20,000	1	$20	0	0.25	0.067	0.125
Construction						0	0.25	0.067	0
Installation						0	0	0	0.125
Dipole Correctors	EE		$3,980	64	$169	0	0.25	0.067	0.875
Construction					$104	0	0.25	0.067	0.75
Installation					$65	0	0	0	0.125
Quad Trims	EE		$3,708	24	$97	0	0.25	0.067	0.375
Construction					$44	0	0.25	0.067	0.25
Installation					$53	0	0	0	0.125

Dipole Correctors	EE		$3,980	64	$169	0	0.25	0.067	0.875
Construction					$104	0	0.25	0.067	0.75
PS EDIA					$0		0.25	0.067	
R&D prototype			$0		$0				
Power supply construction			$1,500	64	$96				0.75
Raw supply		house	$2,000	4	$8				
Installation					$65	0	0	0	0.125
Installation			$0	0	$0				0.125
Cables		ea	$300	64	$19				
Cable Installation		day	$3,000	14	$42				
Controls			$1,000	4	$4				

Technical/Cost Risk

Power Supplies

- No technical risk
- Estimate can be refined upon final design

Scope

Vacuum

- Assume length of transfer line is ~1.2 km and contains a cryo beam screen inside the warm beam tube.
- The beam line is broken up into approx 20 meter half cells
- Assume beam screen does not go through the quads, collimation absorbers, etc.
- Assume cryogenics is supplied to the tunnel
- Includes: vacuum beam pipe, extruded cryo shield, super insulation, transitions, feed throughs, ion pumps/ps, instrumentation
- Assume roughing pumps, and miscellaneous equipment recycled from Tevatron
- M&S 630K$ & Labor of 4.225 FTE-years

Basis of Estimate

Vacuum

- Warm beam pipe, stands ,valves estimates are based upon Nova vacuum system estimates
- Ion pumps and ps are based upon current prices
- Cryo screen and support pieces are estimates based upon LHC experience with cryo shields.

Cost Estimate

Project X

Vacuum

ITEM	Unit	M&S Cost $	Quantity	M&S Tot. $k	Sci FTE-yr	Eng. FTE-yr	Draft/Mach FTE-yr	Tech. FTE-yr
Vacuum System				$630	0	1.5	0.5	2.225
Cold beam tube assembly				$266	0	1	0.5	1.25
Vacuum pumps				$240	0	0.25	0	0.375
Power Supplies				$120	0	0.125	0	0.5
Guages/Instrumentation				$5	0	0.125	0	0.1

ITEM	Unit	M&S Cost $	Quantity	M&S Tot. $k	Sci FTE-yr	Eng. FTE-yr	Draft/Mach FTE-yr	Tech. FTE-yr
Cold beam tube assembly				$266	0	1	0.5	1.25
Construction				$213	0	1	0.5	0.5
EDIA						0.5	0.25	
R&D prototype						0.5	0.25	0.5
cryo shield	m	$13	1200	$16				
insulation	m	$10	1200	$12				
insulating vacuum chamber	m	$100	1200	$120				
transitions	each	$145	200	$29				
bellows/feedthroughs	each	$180	200	$36				
Installation				$53	0	0	0	0.75
beam valves	ea	$5,000	7	$35				
beam tube stands	ea	$100	180	$18				
installation								0.75

Technical/Cost Risk

Project X

Vacuum

- Estimate based upon conceptual design with rough counts of elements.
- A realistic thermal model of the beam pipe and beam screen needs to be created to model the heat load to specify the required cryogenic volume
- Estimates did not include consumables, air handling system, or roughing pumps(assumed to be recycled)

Scope:
Collimation

- Two collimation systems
  - Transverse X6 (roughly 8 kW per absorber -> round to 10 kW)
  - Momentum X1   (10 kW)
- Movable collimation foil system
- Movable transverse collimation absorbers
- Fixed momentum collimation absorber
- RAW system

- Transverse M&S 870K$ & Labor 4.5 FTE-years
- Momentum M&S 265K$ & Labor 3.75 FTE-years

Basis of Estimate

Collimation

- Shielding
  - Steel
  - Concrete
  - marble
- Vacuum chamber
- Motion control system
  - Assume identical to systems currently in use at FNAL

Cost Estimate

Collimation

ITEM	Unit	M&S Cost $	Quantity	M&S Tot. $k	Sci FTE-yr	Eng. FTE-yr	Draft/Mach FTE-yr	Tech. FTE-yr
Transverse Collimation (10 kW ea)				$870	0	2	0.625	1.875
Collimation Foil System		$15,000	6	$90	0	0.5	0.125	0.125
Collimation Absorber		$120,000	6	$720	0	1	0.25	1.5
RAW System	EE	$10,000	6	$60	0	0.5	0.25	0.25
Momentum Collimation (10 kW)				$265	0	2	0.75	1
Collimation Foil System		$15,000	1	$15	0	0.5	0.25	0.5
Collimation Absorber		$240,000	1	$240	0	1	0.25	0.25
RAW System	EE	$10,000	1	$10	0	0.5	0.25	0.25

Technical/Cost Risk

Collimation

- Conceptual design of collimation system will be addressed in the RD&D which could modify absorber capacity
- Shielding size based upon recent MI collimation experience
- Absorber design to be done in RD&D plan
- Assumed RAW system required, to be re-evaluated in RD&D plan
- Estimates are conservative

Scope

Energy Correction Cavity

- Energy Correction Cavity
  - Warm 1300 Mhz cavity installed in beam line for passive correction of linac RF energy error/phase jitter and for longitudinal injection painting in energy.
  - RF system (copy of high energy linac RF system)
    - 10 MW klystron
    - Modulator system
    - RF distribution, waveguides
- M&S 2,715K$ & Labor 2.5 FTE-years

Basis of Estimate

Energy Correction Cavity

- Warm Cavity
  - Used M&S costs from a previous PD cost estimate
- RF System
  - Based on M&S Estimates for the 1300 MHz RF system in this exercise
  - Estimates incremental engineering labor

Project X

Cost Estimate
Energy Correction Cavity

ITEM		Unit	M&S Cost $	Quantity	M&S Tot. $k	Sci FTE-yr	Eng. FTE-yr	Draft/Mach FTE-yr	Tech. FTE-yr
RF Phase Rotator	PD				$2,715		2.5		
RF Cavity					1039 *		1		
EDIA							0.5		
Cavity					$1,039		0.5		
Installation									
Klystron					866		0.5		
EDIA					$866		0.5		
Klystron/Install					$0				
Modulator					460		0.5		
EDIA					$460		0.5		
Modulator/Install					$0				
Wave guides					191		0.5		
EDIA					$190		0.5		
Waveguide/Install					$0				
Controls					159		0		
EDIA									
Controls					$160				
Install									

* It has recently found that the warm (copper) cavity has also been included in section 1.3.3 with an M&S of $1,174,040 and SWF of $585,630 based upon an escalated value from the 2005 Proton Driver est.

Technical/Cost Risk

Project X

Energy Correction Cavity

- Re-evaluate requirements for cavity during the RD&D phase
- Estimate is not a fully engineering estimate
- Cavity specifications are not fully specified
- Cavity structure is not designed (although a system of similar requirements is in operation at SLAC)
- Risks addressed in the construction of the 1300 MHz RF system
- Labor associated with RF system only incremental to the design and construction of remaining linac systems
- These risks will be addressed during the RD&D phase with collaboration of Fermilab and LBNL
- Cost impact evaluated during preliminary design but should be on the order of 0.1% TPC.

Scope:

Linac Dump

- The cost estimate for the linac dump includes the core absorber, shielding, RAW system, and installation
- Thermal monitoring is assumed in the cost of the absorber core
- Assumes the installation before the enclosure ceiling is in place.

- M&S 735K$ & Labor 4.125 FTE-years

Basis of Estimate

Linac Dump

- Absorber core
  - Educated estimate
- Shielding
  - Scaled from MI8 collimation shielding project
- RAW
  - Based upon a estimate of $1K/kW for a total price installed
- Installation
  - Estimated rigging costs of $10K/day for 8 work days

Cost Estimate

Linac Dump

ITEM		Unit	M&S Cost $	Quantity	M&S Tot. $k	Sci FTE-yr	Eng. FTE-yr	Draft/Mach FTE-yr	Tech. FTE-yr
Linac Dump (200 kW)					$735	0	2.5	1	0.625
Absorber core			$55,000	1	$55	0	0.5	0.25	0
Shielding			$400,000	1	$400	0	1	0.25	0
Installation (core+shielding)			$80,000	1	$80	0	0.5	0.25	0.5
RAW System	EE		$200,000	1	$200	0	0.5	0.25	0.125

Technical/Cost Risk

Linac Dump

- There are no technical risks upon the completion of the Engineering design
- The assumed beam power is increased which would increase costs of core, cooling and shielding.
- Design is similar to many of the beam dumps constructed at FNAL, but most similar to that constructed for the MI
- A radiation model is required to determine actual composition and amount of shielding
- Since estimate was based on shielding weight an engineering design is required for a more accurate estimate

Summary

- All components required for the transfer line estimated based upon requirements of ICD
- Assumed transfer line made up of permanent magnets with dipole and quad trims for steering and matching (c.f. Current Booster to MI transport line and Recycler ring)
- Cost drivers: Magnets and Phase rotator cavity
- Changing to electromagnets may yield some cost savings, but at added installation complexity and operational expense.
- None of the components present technical risks that cannot be addressed by careful design.