Director's Review of the Project X Cost Range Estimate: Cryogenics

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Project X Director's Review

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Outline

- Scope of Estimated Work
- Boundary Conditions /Assumptions
- Basis of Estimate
- Potential Technical Revisions
- Role of Outside Collaborators
- Summary

Scope of Estimated Work

- **Cryogenic Plant** – compressors, helium refrigerators, oil removal, gas management, internal purifiers, nitrogen exchanger, valve boxes, plant controls, etc.
- **Cryogenic Distribution System** – feed boxes, bayonet boxes, feed caps, end caps, cryogenic transfer lines, headers, over pressure protection devices, cryogenic load instrumentation, etc.
- **Ancillary Systems** – gas and liquid storage, recovery compressors, cooling towers, dryers, purification system, etc.
- **Cryomodule Test Stand** - CMTB Feed Cap and End Cap, HTS cryogenic infrastructure
  - With primary interfaces to Civil, Controls and Linac SRF components

Boundary Conditions & Assumptions

- Primary interfaces with other systems
  - Civil construction costs (buildings, equipment foundations, etc.) are not included
  - Controls interfaces are at local equipment controllers (PLC, readout, etc). Hardware, software, programming, cabling and other costs associated with connections to a distributed control system are not included
  - Cost and labor for cryogenic part of a distributed control system hardware, configuration and programming are not included
  - LE linac SRF components relief system costs are not included
  - ODH system costs (hardware, cabling, etc) are not included
  - CMTB feed box, controls and instrumentation, installation contract costs are not included

Boundary Conditions & Assumptions (2)

- Anticipated inputs from other efforts
  - HINS and ILC components technical specification:
    - Operating parameters with associated tolerances
    - Cooldown rates and limits
    - Maximum allowable working pressure
    - Reliving requirements
    - Heat Loads
  - Beam screen
    - Operating parameters with associated tolerances
    - Heat Loads
    - Physical interface definition and requirements

Boundary Conditions & Assumptions (3)

- Other assumptions
  - Cost estimate covers hardware commissioning only, no beam commissioning cost is included
  - Tevatron is at 300K and its auxiliary equipment is available for use prior to the CD3
  - Most of the distribution system components to be engineered, designed and built by an outside vendor
  - Piping and component installation to be done by Union workers
  - Cryogenic plant to be built by an outside vendor
  - Cryogenic plant delivery - 2 years
  - Cryogenic plant installation and commissioning – 9 month
  - Cryobuilding beneficial occupancy received prior to the delivery of the cryogenic plant
  - Transportation expenses, taxes and duty costs are not included
  - Technical contingency is included for cryogenic plant capacity only

Boundary Conditions & Assumptions (4)

- Other assumptions
  - Uninterrupted operation for 2-3 years (without scheduled long shut-downs)
  - Continuous cryogenic operation 24h per day/ 7days per week
  - Assumed availability of the cryogenic system is on the order of 99% or better
  - Accelerating components cool down/warm-up time is limited by Beta 1 cryomodules design
  - Potential for Q - decease should be considered
  - Distribution and relieving based on MAWP of > 2 bar warm
  - Components MAWP increases at cold conditions
  - High Energy Linac consist of three cryogenic segments
  - Cost of Cryomodules and String Connecting Boxes supports are not included
  - Beam screen heat load is assumed to be ~1000 W at 80K
  - Interface to beam screen cryogenic transfer line via a bayonet can
  - Low Energy Cryomodules are fed in series
  - TESLA concept is utilized for the High Energy linac cryomodules

Basis of Estimate

1. LHC Project Reports
2. TESLA Design Study
3. Vendor quotes
4. DESY/TTF information
5. SNS Project costs
6. AD/Cryogenic Department historical data
7. Engineering judgment

Cost Range
Cryogenic Plant

Project X Cryogenics	M&S		LABOR, [FTE - years]		
	BOE	Total, [k$]	D	E	T
CRYOGENIC PLANT	**1,2,3,5,6,7**	**23,305**	**2.0**	**7.8**	**4.4**
LP COMPRESSORS	3,7	945			
LP Compressors	3,7	895			
Instrumentation	7	50			
pressure transducers	6	10			
temperature probes	6	6			
flowmeters	6	27			
vibration sensors	6	7			
MAIN COMPRESSORS	3,7	3,467			
Warm Compressors	3,7	2,685			
Oil removal	3,7	341			
Dryer	3,7	341			
Instrumentation	7	100			
pressure transducers	6	25			
temperature probes	6	15			
flowmeters	6	45			
vibration sensors	6	15			
COLD BOX	1,2,3,7	10,785			
NITROGEN EXCHANGER	6,7	170			
LN2 heat exchanger & transfer line	6,7	120			
Warm piping	6,7	50			
VALVE BOX	3,6,7	525			
Cryostat	7	200			
Phase separators (PV)	7	100			
Cryogenics Valves	6	225			
COLD COMPRESSORS	3,5,7	2,000			
CRYOGENIC TRANSFER LINES	6,7	200			
Refrigerator cold boxes to valve box	6,7	50			
LHe storage tanks to valve box	6,7	50			
Bayonet cans and U-tubes	6,7	100			
PLANT CONTROL SYSTEM	3,7	1,204			
INSTALLATION AND COMMISSIONING CONTRACT	3,7	3,439			
SPARE PARTS	3,7	516			
CRYOGENS	3	54			

Cost Range
Distribution System

Project X Cryogenics	M&S		LABOR, [FTE - years]		
	BOE	Total, [k$]	D	E	T
DISTRIBUTION SYSTEM	**3,4,6,7**	**13,537**	**5.5**	**12.4**	**14.0**
TUNNEL FEED BOX	6,7	800			
Bayonet box	6,7	250			
Refrigerator valve boxes to bayonet box transfer line	6,7	200			
Bayonet box to tunnel transfer line	6,7	50			
Feed Box	6,7	300			
LOW ENERGY CRYOUNIT FEED CAP	6,7	200			
LOW ENERGY CRYOUNIT END CAP	6,7	200			
WRF SOLENOIDS TRANSFER LINE	6	40			
WRF FEED CAP	7	30			
WRF END CAP	7	30			
HIGH ENERGY CRYOUNIT FEED CAP	3,4	180			
HIGH ENERGY CRYOUNIT END CAP	3,4	200			
STRING CONNECTING BOX	3,7	3,150			
SEGMENTATION BOX	3,7	3,720			
Segmentation Box	3,7	2,920			
Cryo bypass	3,7	400			
Bayonet cans and U-tubes	3,7	400			
SERVICE TRANSFERLINE (STL)	6,7	400			
STL BAYONET BOX	6,7	600			
UTUBES	6,7	175			
RECOVERY HEADERS	3,6,7	83			
INSTALLATION CONTRACTS	7	2,029			
CONTROLS	7	500			
INSTRUMENTATION	7	500			
AUXILIARY LOAD TRANSFERLINE w/expansion boxes	6,7	700			

Cost Range
Ancillary Systems

Project X Cryogenics	M&S		LABOR, [FTE - years]		
	BOE	Total, [k$]	D	E	T
ANCILLARY SYSTEMS	**6,7**	**2,495**	**5.7**	**7.0**	**4.5**
CRYO INSULATING VACUUM SYSTEM	7	50			
Hardware	7	50			
INVENTORY MANAGEMENT SYSTEM	6,7	100			
Warm piping	6,7	100			
CRYOGENIC STORAGE	6,7	200			
Helium storage	6,7	100			
Nitrogen storage	6,7	100			
RECOVERY COMPRESSORS	6,7	275			
Compressors	6,7	75			
Oil removal system	6,7	100			
Warm piping	6,7	100			
EXTERNAL HELIUM DRYER	6,7	80			
EXTERNAL HELIUM PURIFIER	6,7	160			
GAS ANALYZERS (H20, N2)	6,7	75			
RECOVERY HEATER	7	250			
INSTRUMENT AIR	7	50			
COOLING TOWERS	6,7	375			
WARM INTERCONNECT PIPING	7	150			
LOCAL CONTROLS	7	200			
INSTALLATION CONTRACTS	7	530			

Cost Range
Cryogenics Total

Project X Cryogenics	M&S	LABOR, [FTE - years]		
	Total, [k$]	D	E	T
CRYOGENIC PLANT	23,305	2.0	7.8	4.4
DISTRIBUTION SYSTEM	13,537	5.5	12.4	14.0
ANCILLARY SYSTEMS	2,495	5.7	7.0	4.5
TESTING CRYO INFRASTRUCTURE	1,000	4.6	13.2	10.0
LABOR BY CATEGORIES		18	40	33
TOTAL M&S, [k$]	40,336			
TOTAL, [FTE]		91		

Potential Technical Revisions

- Potential technical revisions and potential effect on the bottom line
  - System heat load
  - Number of cryogenic units, strings, segments
  - SRF components technical and operating parameters:
    - Pressure and temperature tolerances
    - MAWP
    - Cooldown/warm-up constraints
    - Relief rates
  - System reliability and availability requirements
  - Tevatron components usability

Collaborators

- TJNAF cryogenic group, in principal, has agreed to participate in tasks related to cryogenic plant procurement

Summary

- Project X Cryogenic System direct cost range
  - M&S is $40.336M
  - FNAL Labor is 91 [FTE – years]
- Technical risks deemed to be either low or medium/low.
- TJNAF collaborators role requires further definition