

**Director's Review of the Project X  
Cost Range Estimate:  
325MHz & 1300MHz RF Systems**

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Project X Director's Review  
March 16, 2009



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



- 325 MHz RF Station Unit (8 Stations)
  - High level RF
    - RF power to warm copper & cold superconducting cavities
    - RF power to RFQ
    - Includes Klystron, Modulator, Charging Supply, HV Pulse Transformer, Circulators, loads, power splitters, waveguide, directional couplers, high power vector modulators, etc.
  - Low Level RF
    - Includes all down converters, A-D's' D-A's, FPGA's, software, etc to regulate cavity gradient (magnitude & phase).



- 1300 MHz RF Station Unit (23 stations)
  - High level RF
    - RF power all cold superconducting cavities
    - Includes Klystron, Modulator, Charging Supply, HV Pulse Transformer, Circulators, loads, power splitters, waveguide distribution, directional couplers, high power vector modulators, etc.
  - Low Level RF
    - Includes all down converters, A-D's' D-A's, FPGA's, software, etc to regulate cavity gradient (magnitude & phase).
  - Installation & Testing

# Boundary Conditions & Assumptions



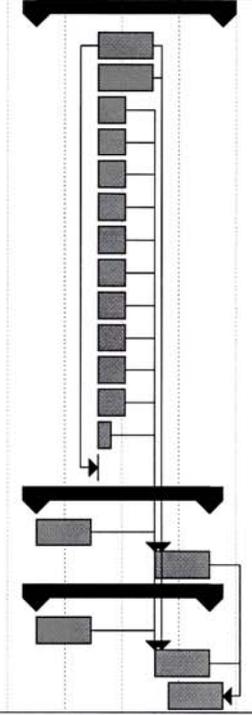
- Primary interfaces with other systems
  - 325 MHz System
    - Part of HINS
    - Accelerator controls
    - Up to cavity couplers
    - Utilities (AC power and LCW)
  - 1300MHz System
    - NML is the test bed for components and system control
    - Accelerator controls
    - Up to cavity couplers
    - Utilities (AC power and LCW)



- LE Linac 325MHz (8 stations)
- Experience: Costs based on recent purchases or quotes
- Total M&S Cost \$20,600K
  - RF Station #1 \$ 2,177K
  - RF Station #2 \$ 4,231K
  - RF Station #3 \$ 3,748K
  - RF Station #4 \$ 2,219K
  - RF Station #5 \$ 2,095K
  - RF Station #6 \$ 2,095K
  - RF Station #7 \$ 2,095K
  - RF Station #8 \$ 1,951K
- Spares \$3,928K
- Total Labor
  - Mechanical Engineer 0.5FTE Years
  - Electrical Engineer 6.0FTE Years
  - Electrical Technician 6.5FTE Years
  - Mechanical Technician 7.0FTE Years



ID	WBS	Task Name	Duration	Start	Finish	Cost	'09	'10	'11	'12	'13	'14	'15	'16
1	<b>1.2.8</b>	<b>325 MHz RF and Distribution</b>	<b>854 days</b>	<b>Tue 7/3/12</b>	<b>Fri 10/9/15</b>	<b>\$24,561,990.00</b>								
2	1.2.8.1	Klystrons 1-8	250 days	Fri 8/2/13	Thu 7/17/14	\$4,464,000.00								
3	1.2.8.2	Modulator K1-8	250 days	Fri 8/2/13	Thu 7/17/14	\$2,480,000.00								
4	1.2.8.3	Circulators K1-8	125 days	Fri 8/2/13	Thu 1/23/14	\$480,000.00								
5	1.2.8.4	Waveguides K1-8	125 days	Fri 8/2/13	Thu 1/23/14	\$865,580.00								
6	1.2.8.5	K1 Transmission	125 days	Fri 8/2/13	Thu 1/23/14	\$1,175,600.00								
7	1.2.8.6	K2 Transmission	125 days	Fri 8/2/13	Thu 1/23/14	\$3,198,400.00								
8	1.2.8.7	K3 Transmission	125 days	Fri 8/2/13	Thu 1/23/14	\$2,715,200.00								
9	1.2.8.8	K4 Transmission	125 days	Fri 8/2/13	Thu 1/23/14	\$1,186,400.00								
10	1.2.8.9	K5 Transmission	125 days	Fri 8/2/13	Thu 1/23/14	\$1,032,200.00								
11	1.2.8.10	K6 Transmission	125 days	Fri 8/2/13	Thu 1/23/14	\$1,032,200.00								
12	1.2.8.11	K7 Transmission	125 days	Fri 8/2/13	Thu 1/23/14	\$1,032,200.00								
13	1.2.8.12	K8 Transmission	125 days	Fri 8/2/13	Thu 1/23/14	\$949,800.00								
14	1.2.8.13	Fanback Vector Sum & Reflected Power	60 days	Fri 8/2/13	Thu 10/24/13	\$21,610.00								
15	1.2.8.14	Spare Klystron / Modulator	1 day	Fri 8/2/13	Fri 8/2/13	\$3,928,800.00								
16	<b>1.2.8.15</b>	<b>Klystron Modulator</b>	<b>793 days</b>	<b>Tue 7/3/12</b>	<b>Thu 7/16/15</b>	<b>\$0.00</b>								
17	1.2.8.15.1	Klystron Modulator Design	250 days	Tue 7/3/12	Mon 6/17/13	\$0.00								
18	1.2.8.15.2	Klystron Modulator Fab & Assy	250 days	Fri 8/1/14	Thu 7/16/15	\$0.00								
19	<b>1.2.8.16</b>	<b>Distribution System Labor</b>	<b>793 days</b>	<b>Tue 7/3/12</b>	<b>Thu 7/16/15</b>	<b>\$0.00</b>								
20	1.2.8.16.1	Distribution System Design	250 days	Tue 7/3/12	Mon 6/17/13	\$0.00								
21	1.2.8.16.2	Distribution System Fab & Assy	250 days	Fri 8/1/14	Thu 7/16/15	\$0.00								
22	1.2.8.17	Installation	250 days	Mon 10/27/14	Fri 10/9/15	\$0.00								



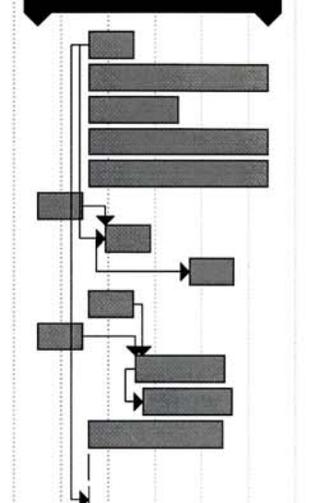
# Project X Basis of Estimate – (Cont)



- HE Linac 1300MHz (23 stations)
- Costs based on recent purchases, quotes, & engineering estimates
- Total M&S Cost 59,907K
- Spares M&S Cost 7,000K
- Total labor
  - Mechanical Engineer 3.0FTE Years
  - Electrical Engineer 24.4FTE Years
  - Design Drafter 1.8FTE Years
  - Scientist 6.5FTE Years
  - Electronic Technician 36.4FTE Years
  - Mechanical Technician 14.1FTE Years



ID	WBS	Task Name	Duration	Start	Finish	Cost	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18
1	1.3.4	<b>1.3 GHz RF and Distribution</b>	<b>1284 days</b>	<b>Tue 7/3/12</b>	<b>Fri 6/2/17</b>	<b>\$66,907,204.00</b>										
2	1.3.4.1	Klystrons	250 days	Mon 8/5/13	Fri 7/18/14	\$16,387,500.00										
3	1.3.4.2	HV Modulator	1000 days	Mon 8/5/13	Fri 6/2/17	\$14,110,500.00										
4	1.3.4.3	Solid State Driver Amp	500 days	Mon 8/5/13	Fri 7/3/15	\$920,000.00										
5	1.3.4.4	Controls / Monitoring / Cabling / Misc	1000 days	Mon 8/5/13	Fri 6/2/17	\$2,787,600.00										
6	1.3.4.5	High Power Station Waveguide	1000 days	Mon 8/5/13	Fri 6/2/17	\$1,357,460.00										
7	1.3.4.6	High Power Station Layouts	250 days	Tue 7/3/12	Mon 6/17/13	\$0.00										
8	1.3.4.7	High Power Station Testing	250 days	Wed 12/11/13	Tue 11/25/14	\$0.00										
9	1.3.4.8	High Power Station Installation	250 days	Mon 9/28/15	Fri 9/9/16	\$0.00										
10	1.3.4.9	Waveguide Distribution M&S	250 days	Fri 8/2/13	Thu 7/17/14	\$14,465,344.00										
11	1.3.4.10	Waveguide Layout Design	250 days	Tue 7/3/12	Mon 6/17/13	\$0.00										
12	1.3.4.11	Waveguide Distribution Assembly	500 days	Fri 8/1/14	Thu 6/30/16	\$0.00										
13	1.3.4.12	Waveguide Distribution Tests	500 days	Mon 9/29/14	Fri 8/26/16	\$0.00										
14	1.3.4.13	HP Vector Modulators and PS	750 days	Fri 8/2/13	Thu 6/16/16	\$7,756,800.00										
15	1.14	1.3 GHz Test Equip/Diagnostic Tools	1 day	Fri 8/2/13	Fri 8/2/13	\$2,122,000.00										
16	1.15	Spare 1.3 GHz RF	1 day	Mon 8/5/13	Mon 8/5/13	\$7,000,000.00										





## LE Linac 325MHz RF System

- Possible substitution of individual 325MHz IOT's for each cavity in place of 8 x 2.5 Mwatt klystrons and 107 vector modulators.
- Raw material costs (copper, steel, etc)

- **HE Linac 1300MHz RF System**

- High power WR650 fast vector modulator.
  - Only one prototype built to date by AFT rated at 550Kwatts
  - No high power testing done to date (scheduled for NML)
  - Possible new technology using Ferroelectric materials should be evaluated
  - Cost reduction
  - Verify adequate performance for cavity regulation
  - Raw Material costs (copper, steel, etc)



- LE Linac 325 MHz
  - Possible individual IOT's and/or solid state amplifiers, eliminating low power and high power vector modulators
  
- HE Linac 1300MHz
  - More cost effective WR650 distribution system
  - Retain relatively convenient adjustability of power distribution levels to cavities (look at DESY or KEK system).
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- LE Linac 325MHz
    - Industry -
  
  - HE Linac 1300MHz RF System
    - SLAC - Have worked with SLAC on the NML's high power distribution system. It would be logical for SLAC & Fermilab to have a "team" approach to design and procurement of high level rf system components.
    - Industry – Work with industry to develop multiple sources for klystrons, waveguide components, vector modulators, etc.



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- LE 325MHz Linac
    - Careful study of IOT costs and commercial vendor availability.
    - RF System costs estimate well defined
  
  - HE 1300MHz Linac
    - Study alternative distribution systems for cost reduction
    - Industrialize as much as possible