Director's Review of the Project X Cost Range Estimate: HE Linac Cryomodules

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Project X Director's Review
March 16, 2009

Outline

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

Scope of Estimated Work

- Items 1.3.1 – 1.3.2 includes the cost to procure, manufacture, test and install the Beta = 0.81 and Beta = 1 cryomodules and all the subcomponents excepting instrumentation / diagnostics.
  - This includes everything up the boundary of the vacuum vessel of the cryomodules, interconnects between cryomodules, and down to the tunnel floor. Segmentation boxes and cryogenic feeds are included in Cryogenics
- There are:
  - 8 installed and 2 spare Beta = 0.81 cryomodules
  - 38 installed and 2 spare Beta = 1 cryomodules.

Project X

1000 kW 8GeV Linac

31 Klystrons (2 types)
445 SC Cavities
58 Cryomodules

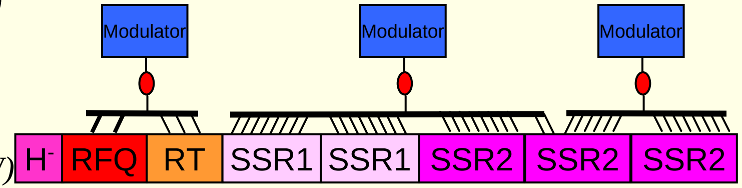
Front End Linac

325 MHz 0-10 MeV

1 Klystron (JPARC 2.5 MW)
RFQ + 18 RT Cavities

325 MHz 10-120 MeV

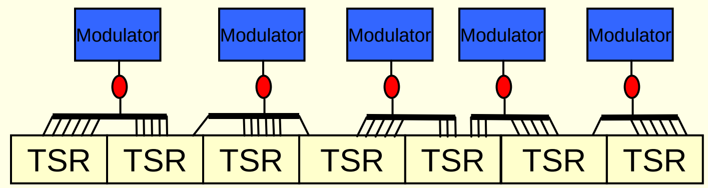
2 Klystrons (JPARC 2.5 MW)
51 Single Spoke Resonators
5 Cryomodules



11 Cavites / Cryomodule

325 MHz 0.12-0.42 GeV

5 Klystrons (JPARC 2.5 MW)
42 Triple Spoke Resonators
7 Cryomodules



6 Cavites-6 quads / Cryomodule

2.5 MW JPARC Klystron

Multi-Cavity Fanout
Phase and Amplitude Control

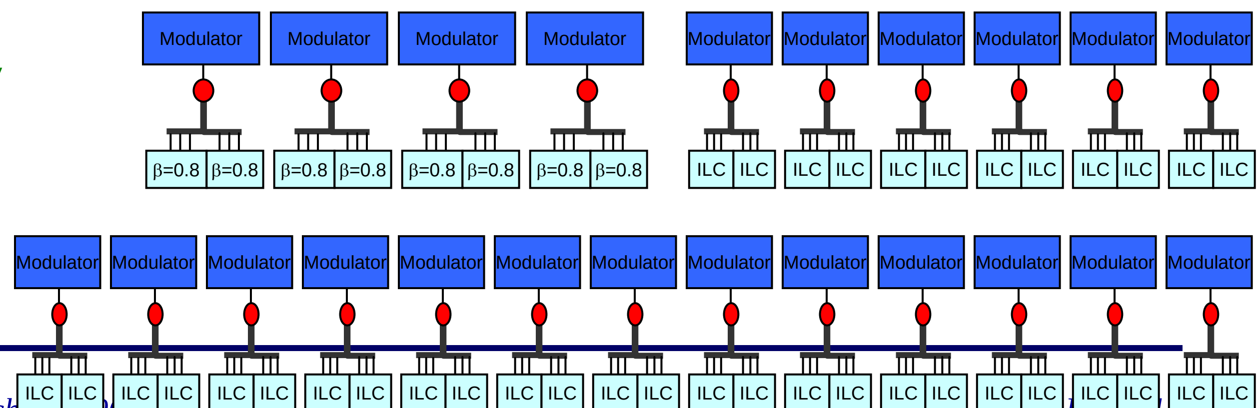
1300 MHz LINAC

1300 MHz 0.42-1.3 GeV

4 Klystrons (ILC 10 MW MBK)
56 Squeezed Cavities (β=0.81)
8 Cryomodules

1300 MHz 1.3-8.0 GeV

19 Klystrons (ILC 10 MW MBK)
296 ILC-identical Cavities
38 ILC-like Cryomodules



Boundary Conditions & Assumptions

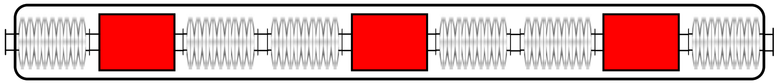
- The 2.4 to 8 GeV Beta = 1 cryomodule design is the Type IV ILC design (CM3 at FNAL)
- The Beta = 0.81 cryomodule design and Beta = 1 cryomodules up to 2.4 GeV are a close derivative of the Type IV ILC design, with the center magnet support / ports duplicated at positions 2 and 8.
- The 9 cell 1.3 GHz ILC style cavity is used in the Beta = 1 cryomodules
  - The Beta = 0.81 cavities are designed to fit in the same slot length
  - The magnet / BPM combination is design to fit in the same slot length
- The coupler design modifications will be minor (highly desirable that the 40mm cold port remain unchanged)

Project X

HE Linac Lattice

Beta = 0.81

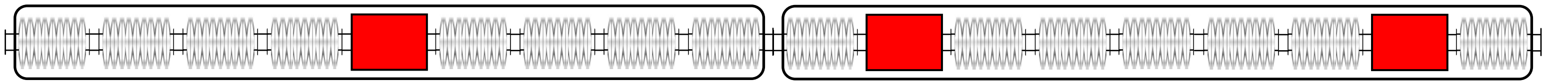
0.42 – 1.3 GeV



Beta = 1.0

1.3 – 2.4 GeV

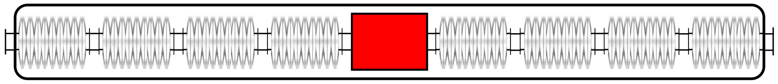
"ILC-1"



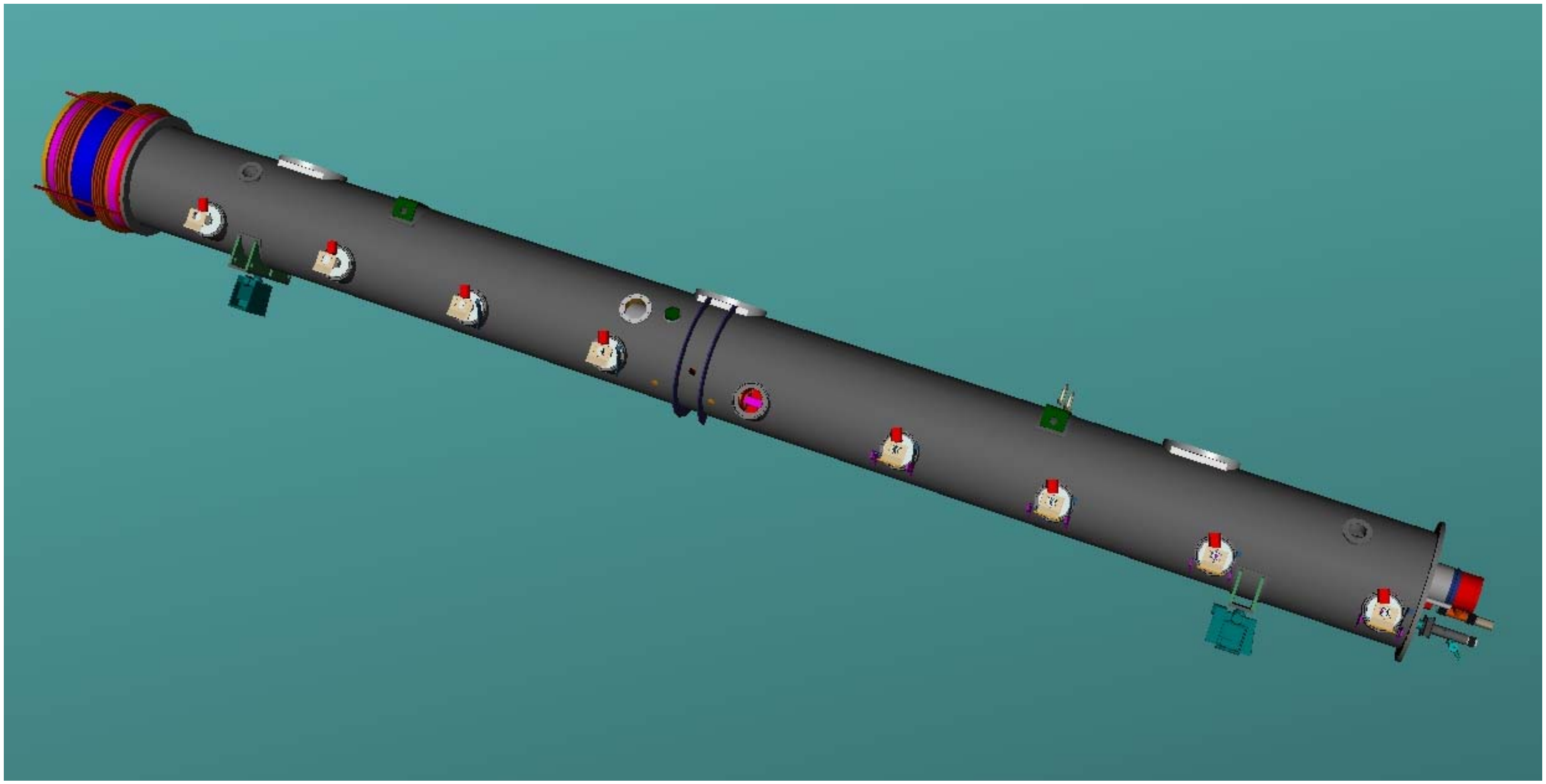
Beta = 1.0

2.4 – 8.0 GeV

"ILC-2"

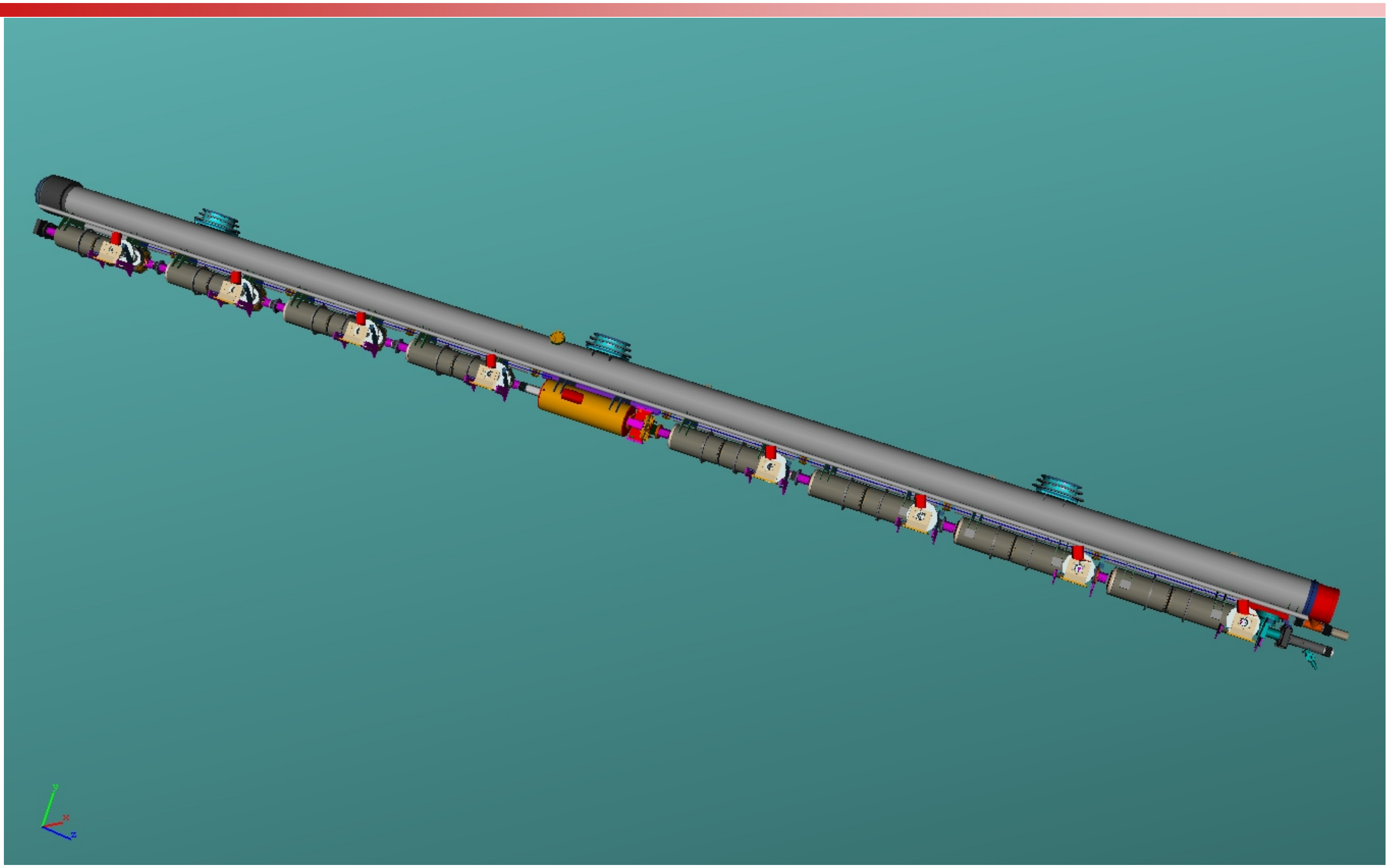


Boundary Conditions & Assumptions



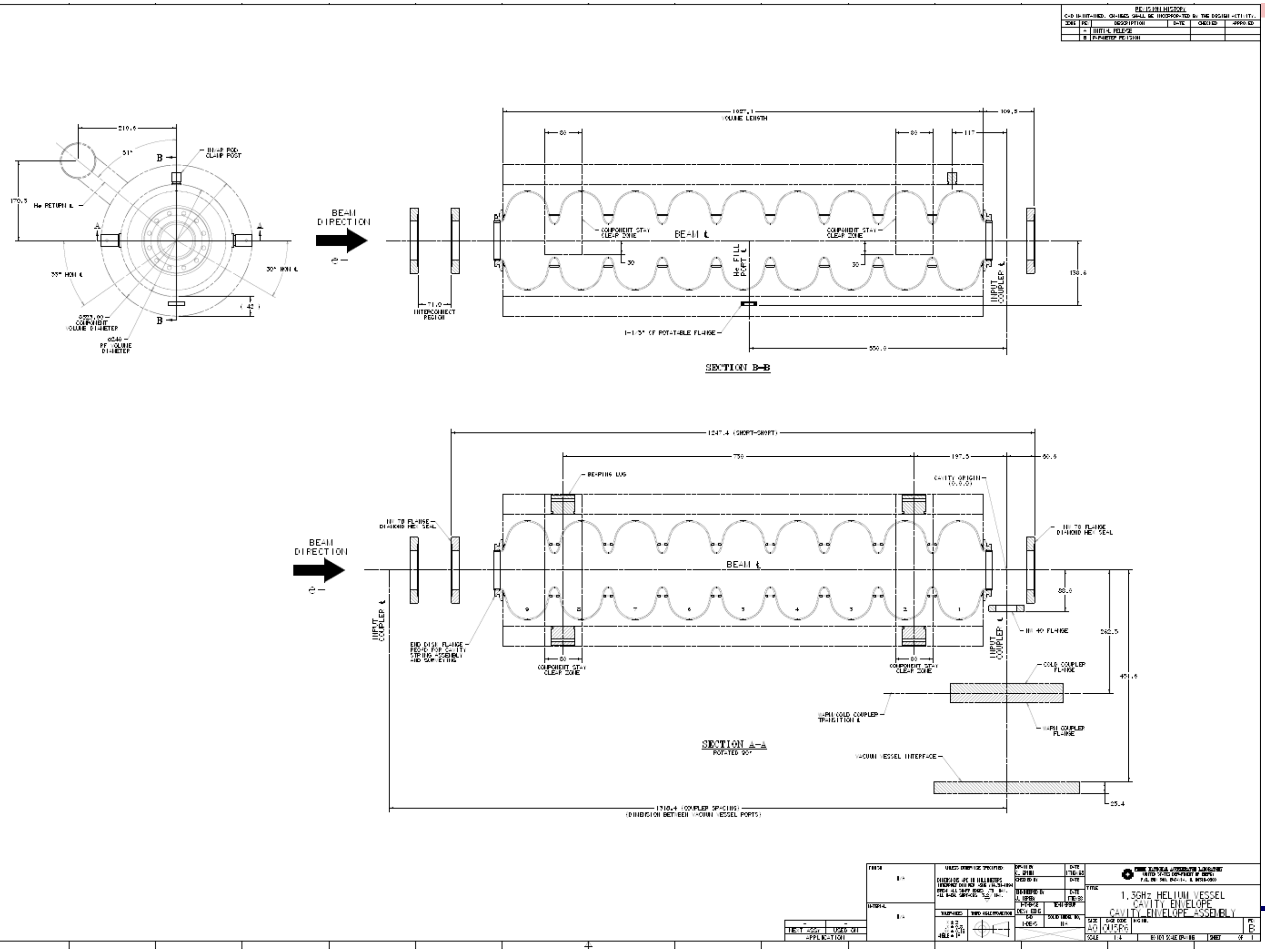
Q:\TD_SCRF\ILC_CRYOMODULES\T4CM_compl_assy_JT, thanks to Chuck Grimm and Don Mitchell

Boundary Conditions & Assumptions



Project X

Boundary Conditions & Assumptions



Boundary Conditions & Assumptions

- The SRF Infrastructure program will:
  - Enhance the Vertical Testing System infrastructure (with FNAL / India Collaboration)
  - Enhance the Horizontal Testing System infrastructure (with FNAL / India Collaboration)
  - Expand the MP9 clean room to a 2 rail system
  - Install a second set of cryomodule assembly tooling in the space already available in ICB
- Horizontal cryomodule test infrastructure at NML will be largely developed by infrastructure funds. Incremental cryomodule test stands will be purchased by the Project (covered under cryogenics)
- The worldwide cavity production / processing programs will succeed in the next 4 years in developing methods to successfully and reproducibly produce 9 cell Beta = 1 cavities with an average gradient of 25MV/m. This processing will be able to be transferred to the Beta = 0.81 cavity production at a gradient of 23 MV/m.
- Several US procured Type IV cryomodules will be procured and assembled in the years leading up to CD-3
  - In addition, XFEL prototypes and pre-production will be starting in earnest in 2010

Basis of Estimate

- For the purposes of this exercise, the Beta = 0.81 and Beta =1 cryomodules and components are assumed to be the same
- A single cryomodule contains 9 elements. In the 8 Beta =0.81 and the first 10 Beta = 1 cryomodules these elements are normally cavities, but magnets may be inserted at positions 2, 5 and/or 8.
- In the last 26 Beta = 1 cryomodules, a standard Type IV cryomodule of 4 cavities / magnet / 4 cavities is used.
- The Beta = 0.81 fabrication / assembly is assumed to be a separate line
- The Beta = 1 cavity assembly and test is assumed to happen in 2 parallel lines, with cryomodule assembly happening at a single location with capacity 1 cryomodule per month
- A production model was made w/ the above assumptions, and costs then rolled up at a higher level to the global MS Project file.

Project X

Basis of Estimate

Microsoft Project - B1Assy

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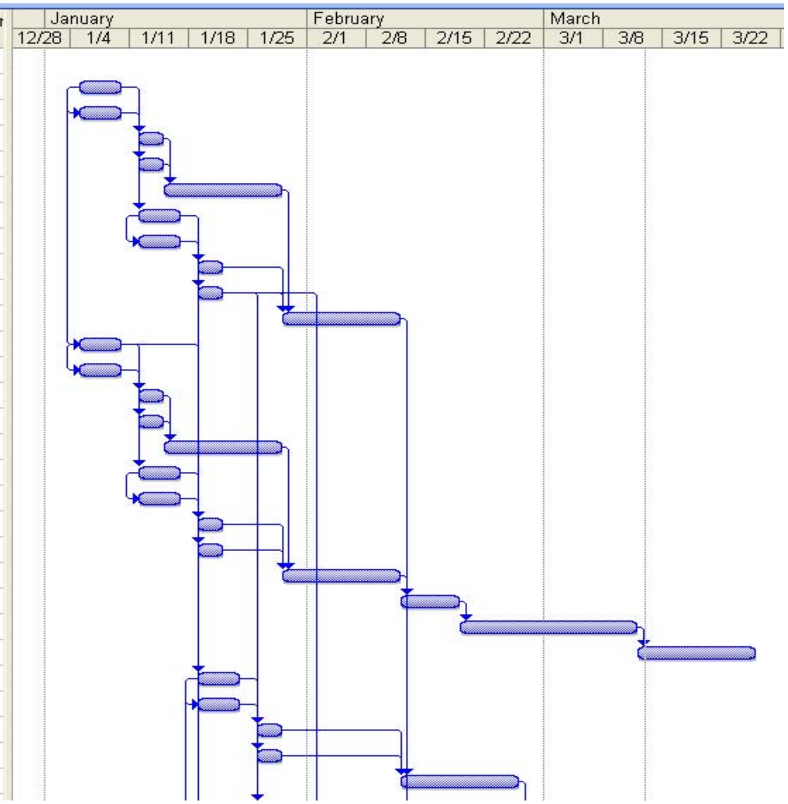
	Task Name	Duration	Predeces	Start	Finish	Resour
2						
3	Vertical Test Cavity 1	5 days		Mon 1/5/09	Fri 1/9/09	
4	Vertical Test Cavity 2	5 days	3SS	Mon 1/5/09	Fri 1/9/09	
5	Dress Cavity 1	3 days	3	Mon 1/12/09	Wed 1/14/09	
6	Dress Cavity 2	3 days	4	Mon 1/12/09	Wed 1/14/09	
7	Horizontal Test Cav 1-2	10 days	5,6	Thu 1/15/09	Wed 1/28/09	
8	Vertical Test Cavity 3	5 days	4	Mon 1/12/09	Fri 1/16/09	
9	Vertical Test Cavity 4	5 days	8SS	Mon 1/12/09	Fri 1/16/09	
10	Dress Cavity 3	3 days	8	Mon 1/19/09	Wed 1/21/09	
11	Dress Cavity 4	3 days	9	Mon 1/19/09	Wed 1/21/09	
12	Horizontal Test Cav 3-4	10 days	11,10,7	Thu 1/29/09	Wed 2/11/09	
13	Vertical Test Cavity 5	5 days	3SS	Mon 1/5/09	Fri 1/9/09	
14	Vertical Test Cavity 6	5 days	13SS	Mon 1/5/09	Fri 1/9/09	
15	Dress Cavity 5	3 days	13	Mon 1/12/09	Wed 1/14/09	
16	Dress Cavity 6	3 days	14	Mon 1/12/09	Wed 1/14/09	
17	Horizontal Test Cav 5-6	10 days	15,16	Thu 1/15/09	Wed 1/28/09	
18	Vertical Test Cavity 7	5 days	14	Mon 1/12/09	Fri 1/16/09	
19	Vertical Test Cavity 8	5 days	18SS	Mon 1/12/09	Fri 1/16/09	
20	Dress Cavity 7	3 days	18	Mon 1/19/09	Wed 1/21/09	
21	Dress Cavity 8	3 days	19	Mon 1/19/09	Wed 1/21/09	
22	Horizontal Test Cav 7-8	10 days	17,20,21	Thu 1/29/09	Wed 2/11/09	
23	String Assembly	5 days	12,22	Thu 2/12/09	Wed 2/18/09	
24	Cryomdodule Final Asserr	15 days	23	Thu 2/19/09	Wed 3/11/09	
25	Cryomodule Test	10 days	24	Thu 3/12/09	Wed 3/25/09	
26	Vertical Test Cavity 1	5 days	9	Mon 1/19/09	Fri 1/23/09	
27	Vertical Test Cavity 2	5 days	26SS	Mon 1/19/09	Fri 1/23/09	
28	Dress Cavity 1	3 days	26,11	Mon 1/26/09	Wed 1/28/09	
29	Dress Cavity 2	3 days	27,11	Mon 1/26/09	Wed 1/28/09	
30	Horizontal Test Cav 1-2	10 days	28,29,12	Thu 2/12/09	Wed 2/25/09	



*In Beta = 1 only ½ of the cavities are horizontally tested

Project X Basis of Estimate

- In the Beta = 0.81 section there are a total of 56 cavities, 14 doublets, and 2 quadrupoles, for a total of 72 items which are packaged into 8 cryomodules
- In the first section of the Beta = 1 section, up to 2.4 GeV, there are 72 cavities and 18 quadrupoles packaged into 10 cryomodules.
- In the remaining Beta = 1 section, there are 224 cavities and 28 quadrupoles packaged in 28 cryomodules.
- In the ICD there are installed 352 cavities and 60 magnets in 46 cryomodules
- There are 405 cavities, 60 magnets in 50 cryomodules and associated equipment in the MS Project file

Project X Basis of Estimate

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HE Linac RD&D Plan

ID	WBS	Task Name	Base Labor	Base M&S	Cost	Dur	Start	Finish	Predecessors	Successors	
1	**1**	**Project X**	**$188,942,289**	**$554,603,484**	**$743,545,773**	**2369 d**	**Wed 10/1/08**	**Tue 3/13/18**			
2	**1.1**	**Project Management**	**$19,889,856**	**$3,597,000**	**$23,486,856**	**2182 d**	**Wed 7/1/09**	**Tue 3/13/18**			
12	**1.2**	**LE Linac**	**$22,495,803**	**$80,213,390**	**$102,709,193**	**2274 d**	**Wed 10/1/08**	**Fri 10/20/17**			
92	**1.3**	**HE Linac**	**$27,096,446**	**$195,471,724**	**$222,568,170**	**2344 d**	**Wed 10/1/08**	**Tue 2/6/18**			
93	**1.3.1**	**Beta = 0.81 Cryomodules**	**$2,430,140**	**$20,264,260**	**$22,694,400**	**927 d**	**Tue 7/3/12**	**Tue 3/15/16**			
94	1.3.1.1	Cavity Fabrication	$0	$8,450,000	$8,450,000	280 d	Fri 8/2/13	Fri 9/12/14	9	95	
95	1.3.1.2	VTS Testing	$355,080	$139,260	$494,340	165 d	Mon 9/15/14	Tue 5/12/15	94	96FF+5 d,39SS	Cat 1:
96	1.3.1.3	Cavity Dressing	$136,500	$0	$136,500	165 d	Mon 9/22/14	Tue 5/19/15	95FF+5 d	97SS+5 d	Cat 1:
97	1.3.1.4	Horizontal Testing	$608,400	$320,000	$928,400	325 d	Mon 9/29/14	Tue 1/19/16	96SS+5 d	98FF+20 d	Cat 1:
98	1.3.1.5	String Assembly	$42,000	$0	$42,000	200 d	Wed 4/29/15	Tue 2/16/16	97FF+20 d	99SS+5 d	Cat 1:
99	1.3.1.6	Cryomodule Assembly	$309,600	$0	$309,600	200 d	Wed 5/6/15	Tue 2/23/16	98SS+5 d	100SS+15 d,110SS	Cat 1:
100	1.3.1.7	Cryomodule Test	$374,400	$200,000	$574,400	200 d	Thu 5/28/15	Tue 3/15/16	99SS+15 d	111SS+20 d	Cat 1:
101	1.3.1.8	Power Couplers	$0	$1,560,000	$1,560,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
102	1.3.1.9	Blade Tuner	$0	$1,950,000	$1,950,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
103	1.3.1.10	Pipes / Connections / He Vessel	$0	$3,575,000	$3,575,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
104	1.3.1.11	HOM Couplers / Instrumentation	$0	$600,000	$600,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
105	1.3.1.12	String Bellows / Pipes	$0	$560,000	$560,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
106	1.3.1.13	Magnets	$0	$560,000	$560,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
107	1.3.1.14	HGRP Weldment / Cryomodule Pipes / Shielc	$0	$1,350,000	$1,350,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
108	1.3.1.15	Vacuum Vessel	$0	$1,000,000	$1,000,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
109	1.3.1.16	Design in (RD&D Plan)	$0	$0	$0	1 d	Tue 7/3/12	Tue 7/3/12	7		
110	1.3.1.17	Assembly Oversight	$310,400	$0	$310,400	200 d	Wed 5/6/15	Tue 2/23/16	99SS		Cat 4:
111	1.3.1.18	Installation	$293,760	$0	$293,760	80 d	Mon 9/28/15	Tue 1/26/16	9,381,100SS+20 d	435,134	Cat 2:
112	**1.3.2**	**Beta = 1.0 Cryomodules**	**$10,334,280**	**$98,737,400**	**$109,071,680**	**1402 d**	**Tue 7/3/12**	**Tue 2/6/18**			
113	1.3.2.1	Cavity Fabrication 1	$0	$44,200,000	$44,200,000	280 d	Fri 8/2/13	Fri 9/12/14	9	117FF,114	
114	1.3.2.2	VTS Testing 1 (VTS2,3)	$914,600	$358,700	$1,273,300	425 d	Mon 9/15/14	Tue 5/24/16	113	115SS+5 d,118SS	Cat 1:

Basis of Estimate

12	1.2	⊞ **LE Linac**	**$22,495,803**	**$80,213,390**	**$102,709,193**	**2274 d**	**Wed 10/1/08**	**Fri 10/20/17**			
92	1.3	⊟ **HE Linac**	**$27,096,446**	**$195,471,724**	**$222,568,170**	**2344 d**	**Wed 10/1/08**	**Tue 2/6/18**			
93	1.3.1	⊞ **Beta = 0.81 Cryomodules**	**$2,430,140**	**$20,264,260**	**$22,694,400**	**927 d**	**Tue 7/3/12**	**Tue 3/15/16**			
112	1.3.2	⊟ **Beta = 1.0 Cryomodules**	**$10,334,280**	**$98,737,400**	**$109,071,680**	**1402 d**	**Tue 7/3/12**	**Tue 2/6/18**			
113	1.3.2.1	Cavity Fabrication 1	$0	$44,200,000	$44,200,000	280 d	Fri 8/2/13	Fri 9/12/14	9	117FF,114	
114	1.3.2.2	VTS Testing 1 (VTS2,3)	$914,600	$358,700	$1,273,300	425 d	Mon 9/15/14	Tue 5/24/16	113	115SS+5 d,118SS	Cat 1:
115	1.3.2.3	Cavity Dressing 1	$657,900	$0	$657,900	425 d	Mon 9/22/14	Wed 6/1/16	114SS+5 d	116SS+5 d,133SS	Cat 1:
116	1.3.2.4	Horizontal Testing 1 (HTS2,3...)	$861,120	$440,000	$1,301,120	460 d	Mon 9/29/14	Thu 7/28/16	115SS+5 d	121SS+20 d	Cat 1:
117	1.3.2.5	Cavity Fabrication 2 (Placeholder)	$0	$0	$0	1 d	Fri 9/12/14	Fri 9/12/14	113FF		
118	1.3.2.6	VTS Testing 2 (VTS 2,3)	$914,600	$358,700	$1,273,300	425 d	Mon 9/15/14	Tue 5/24/16	114SS	119SS+5 d	Cat 1:
119	1.3.2.7	Cavity Dressing 2	$657,900	$0	$657,900	425 d	Mon 9/22/14	Wed 6/1/16	118SS+5 d	120SS+5 d	Cat 1:
120	1.3.2.8	Horizontal Testing 2 (HTS2,3....)	$861,120	$440,000	$1,301,120	460 d	Mon 9/29/14	Thu 7/28/16	119SS+5 d	121FF+20 d	Cat 1:
121	1.3.2.9	String Assembly	$168,000	$0	$168,000	800 d	Mon 10/27/14	Mon 1/8/18	116SS+20 d,120FF+20 d	122SS+5 d	Cat 1:
122	1.3.2.10	Cryomodule Assembly	$1,427,200	$0	$1,427,200	800 d	Mon 11/3/14	Tue 1/16/18	121SS+5 d	123SS+15 d	Cat 1:
123	1.3.2.11	Cryomodule Test	$1,497,600	$0	$1,497,600	800 d	Mon 11/24/14	Tue 2/6/18	122SS+15 d	134SS+20 d	Cat 1:
124	1.3.2.12	Power Couplers	$0	$8,160,000	$8,160,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
125	1.3.2.13	Blade Tuner	$0	$10,200,000	$10,200,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
126	1.3.2.14	Pipes / Connections / He Vessel	$0	$18,700,000	$18,700,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
127	1.3.2.15	HOM Couplers / Instrumentation	$0	$2,400,000	$2,400,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
128	1.3.2.16	String Bellows / Pipes	$0	$2,240,000	$2,240,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
129	1.3.2.17	Magnets	$0	$1,840,000	$1,840,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
130	1.3.2.18	HGRP Weldment / Cryomodule Pipes / Shielc	$0	$5,400,000	$5,400,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
131	1.3.2.19	Vacuum Vessel	$0	$4,000,000	$4,000,000	1 d	Fri 8/2/13	Fri 8/2/13	9		
132	1.3.2.20	Design (ILC)	$0	$0	$0	1 d	Tue 7/3/12	Tue 7/3/12	7		
133	1.3.2.21	Assembly Oversight	$1,272,640	$0	$1,272,640	820 d	Mon 9/22/14	Thu 12/28/17	115SS		Cat 4:
134	1.3.2.22	Installation	$1,101,600	$0	$1,101,600	475 d	Wed 1/27/16	Tue 12/12/17	111,123SS+20 d,381	435	Cat 2:
135	1.3.3	Debuncher Beta = 1.0 (copper) Cavity	$585,360	$1,174,070	$1,759,430	250 d	Fri 8/2/13	Thu 7/31/14	9		Cat 1:
136	1.3.4	⊞ **1.3 GHz RF and Distribution**	**$8,074,580**	**$66,907,204**	**$74,981,784**	**1272 d**	**Tue 7/3/12**	**Thu 7/27/17**			
152	1.3.5	⊞ **1.3GHz LLRF and Global LLRF Systems**	**$1,753,700**	**$3,013,790**	**$4,767,490**	**1000 d**	**Wed 4/3/13**	**Tue 3/28/17**			
165	1.3.6	⊞ **HE Linac RD&D Plan**	**$3,918,386**	**$5,375,000**	**$9,293,386**	**1004 d**	**Wed 10/1/08**	**Fri 9/28/12**			

Basis of Estimate

For 50 Beta = 0.81 and Beta = 1 cryomodules, this estimate averages to 2.7M$ per cryomodule (direct)

In 2008 42 Proton Driver type cryomodules were estimated at 1.8-1.9M$ each (direct)*

The expected incremental cost for the next single cryomodule produced is 3.4M$ (direct)*

- *these costs did not include horizontal testing of dressed cavities, which adds 70k$ per cryomodule

Project X

Basis of Estimate

The estimate is based on

- recent purchases of small quantities
- recent operating experience
- discussion with XFEL colleagues and comparison with experience at DESY and plans at Saclay
- other historical sources

Unfortunately due to HEP funding in the US last year, and delays in the XFEL startup, more concrete numbers are not readily available for all items. This situation should be much better understood at CD-2 (July 2012)

Project X

Basis of Estimate

Parts…

Item	Unit Cost $K	Quantity Required	Total Cost $K	Comments
9-cell Cavity	100	8	800	Avg recent AES / Accel bids for 6 9 cell cavities
Power Coupler	24	8	192	Recent CPI; some trouble w/ processing to be worked out
Cavity Processing (1 Cycle)	30	8	240	Jlab; ANL/FNAL target
Helium Vessel	20	8	160	Recent AES study suggests material not issue, for qty >100 robotic automation of mfr saves 5k$/part
Misc. Parts	20	8	160	Blank offs, pickup probes, seals, hardware, etc.
Magnetic Shielding	15	8	120	
	Dressed Cavity Subtotal		1672	
Vacuum vessel, cold mass, support posts, & thermal shields	235	1	235	~10% higher than current European estimate; 5K shield needed?
Cavity interconnecting bellows & gate valves	56	1	56	
Blade Tuners & components	30	8	240	Including motors, harmonic drives and electronics
Quadrupole magnet	40	1	40	Need design; similar sized/qty magnets ~30k$ in LHC
Instrumentation and misc. hardware, plus superinsulation	60	1	60	
	Cryomodule Subtotal		**2303**	

Project X Basis of Estimate

Labor…

VTS…from operating experience

- assume VTS 2 & 3 can each test 2 cavities at a time
- Each test (warm to warm) is 1 week, work leveling is done by shifting between dewars
- A average crew of 6 operators / techs, with 1 engineer / scientist for oversight during the duration. Cryo losses and consumables of 211k$ per year

HTS…extrapolated from operating experience

- assume HTS 2 & 3 can each test 2 cavities at a time. Only 50% of the Beta = 1 cavities are HTS tested.
- Each test (warm to warm) is 2 weeks
- A average crew of 5 operators techs,with 1 engineer / scientist for oversight during the durantion. Cryo losses and consumables at 20k$ per month. A month shutdown per year is assumed.

Full Cryomodule test…

- 1 per month. Same crew as HTS, similar to LHC magnet experience in IB1

Basis of Estimate

Labor…

Cavity Dressing(each)

- 3 techs, 1.5 scientist / engineer / process engineer for duration of task

String Assembly (each)

- 3 techs 1 week

Cryomodule Assembly(each)

- 4 techs 1 week, 2 engineer / process engineer

Assembly Oversight (each)

- 1 scientist, 1 engineer, 1 lead tech

Installation

- 4 techs 1 week + oversight

These numbers are from discussions with DESY/Saclay colleagues, and appear consistent with extrapolations of our limited experience

Technical Risks

Assuming the worldwide cavity program continues, the overall technical risk is moderate.

- Recent cavity results, particularly if duplicated by US vendors, are quite promising. Further efforts should either make a higher baseline gradient possible or potentially lead to reduced processing costs.
- The current power coupler limits must be understood, and design modifications made to accommodate the PX power requirements. There is some risk that the cryomodule design will have to change to accommodate these features.
- The Beta = 0.81 cavities and cryomodules are assumed to be close relatives of the Type IV cryomodule but as yet the design is not complete; the RD&D plan includes both cavities and a prototype cryomodule.
- The cavity tuner location is yet to be proven; this should be addressed in the next few years by ongoing ILC R&D.
- The magnet system designs need to be specified, designed, and prototyped.

While not directly ‘technical’, a related topic is applying enough effort such that the costs can be held or improved, in a direction consistent with worldwide expectations.

Potential Technical Revisions

- Cavity gradient. Depending on the success of the ILC program, a higher gradient may be possible, with a savings in some cryomodules.
- Cavity testing. The XFEL model does not include a horizontal test of an assembled cavity / coupler. There is some savings in cost and time; however the hand off point from collaborators may be more difficult.
- Are the HOM couplers needed for this machine? This would simplify the end group design, and save on cavity and instrumentation costs. While a topic of interest for PX (and others, including CERN), and simulations can be run, proving this experimentally may be difficult.
- Is the 5K shield needed? The heat load may not change much, but heat intercepts for the penetrations in the cryomodule for couplers, etc are still needed.
- Are the Piezo tuners needed at 25MV/m? Simulations are planned; one middle course may be to install them but hold off on the external electronics until a later date (and higher gradient) are achieved in operation.
- European colleagues suggest that the cryomodule parts should cost on order 2/3 of what we are anticipating paying in small quantities; working w/ US vendors should help move toward similar improvements.
- Indian collaborators are looking at ways to achieve alignment off the gas return pipe and cavity tuning with mechanisms that may be simpler and more robust than the methods currently in use.

Collaborators

As these cryomodules are closely related to XFEL and ILC designs, our collaborators include DESY, Saclay, INFN, and KEK on those designs.

India has recently signed an MoU with FNAL that includes design effort on the 0.81 cryomodules,among other things.

The Beta = 1 cavities are the ILC design, therefore the collaboration is the same as the ILC effort. Processing occurs at JLab and ANL/FNAL at the moment.

The Beta = 0.81 cavities were prototyped at MSU, but the effort stopped with the US funding crisis of FY08. This effort is restarted in the RD&D plan.

The coupler design, and potential modifications, are handled currently through a collaboration between Fermilab and SLAC.

Summary

- The Cryomodules for the HE Linac in the ICD are strongly based on the XFEL / ILC Type IV design and have been estimated based on current (limited) experience
- The technical risk in the design is low to moderate; with the start of XFEL prototypes and pre-production next year in addition to US efforts there will be ample opportunity to learn from others.
- The joint efforts of the next few years on cavity and cryomodule design and construction give the opportunity for design improvements and or cost savings to be achieved.