Report date: 18 February 2017 **Authors:** Karl Smolenski, Steve Peggs

CBETA Quarterly Report – February 2017

Project Director (BNL):	Steve Peggs	Peggs@bnl.gov
Project Manager (BNL):	Rob Michnoff	Michnoff@bnl.gov
Project Manager (Cornell):	Karl Smolenski	Karl.Smolenski@cornell.edu
Principle Investigator (Cornell):	Georg Hoffstaetter	Georg.Hoffstaetter@cornell.edu
Principle Investigator (BNL):	Dejan Trbojevic	Trbojevic@bnl.gov

Cornell University (CU) and the Brookhaven National Laboratory (BNL) are designing, building and commissioning the Cornell-BNL ERL Test Accelerator (CBETA), a 4-pass, 150 MeV electron Energy Recovery Linac that is a prototype for advanced technology to be used in the future BNL eRHIC accelerator.

This Quarterly Report records the progress in the period October 31 2016 (when NYSERDA funding began) until January 31 2017. It describes the project status, and communicates future activities and milestones, especially in the next quarter.

Executive Summary – Deliverables Completed

1. A 4 mA electron beam was run through the DC electron source and Injector Cryomodule, sufficient for CBETA commissioning and initial operations.
2. BNL integrated their Beam Position Monitor (BPM) electronics into the CU control system and successfully recorded data with actual beams. This gives great confidence that the electronics will satisfy the BPM requirements.
3. An FFAG Magnet Review was held at BNL in December. The Halbach technology style was selected as the most viable path forward for CBETA permanent magnets in the FFAG return arc.
4. The Design Report document was completed in January.
5. A meeting of the Advisory Committee technical panel was convened at CU on January 30 and 31 to review the status of the physics and engineering design status. Technical Milestone 1 has been completed on schedule – “Engineering Design Documentation Complete” – on the basis of the Advisory Committee report to the Oversight Board.
6. The project is now moving into high gear as engineering, procurement, and construction ramp up.
7. Project Management documentation developed in this quarter includes a current cost analysis, a preliminary schedule, a risk register, a revised Project Management Plan, a Work Breakdown Structure (WBS) dictionary, and an extensive parameter list.
8. Overall labor spending is on track, within an approximation that has been used for this first Quarterly Report. More accurate earned value information will be provided in future Quarterly Reports, evaluating the actual work performed versus the expected.
9. Major procurements in the next quarter include conventional magnets for the splitters, magnet power supplies, and components for the vacuum system, for the water cooling system, and for the Halbach magnets.

Quarterly Report - February 2017

Table of Contents

Progress

On November 17 the baseline lattice for the accelerator was released. The lattice defines the exact location of every component in the accelerator, but in particular defines the magnet locations and field strengths. With the baseline lattice defined the remaining engineering tasks continued on a firmer footing, with clear requirements for the magnets, their power supplies, the vacuum system, space for instrumentation, et cetera.

In December an electron beam was run through the DC electron source and Injector Cryomodule. The injector was ramped to a total beam current of 4 mA, sufficient for all initial CBETA running. A week of operations was dedicated to running the injector with a prototype Beam Position Monitor designed at CU, sending signals to BPM read out electronics developed at BNL. Staff from BNL integrated their electronics into the existing control system and successfully recorded data with actual beams, giving great confidence that the electronics will support the proposed BPM requirements. Injector parameters for all beam operations through the Fractional Arc Test in spring 2018 are now well tested.

In January the Main Linac Cryomodule (MLC) was warmed from liquid helium temperatures to room temperature over the course of two weeks. The MLC warmed as expected. The instrumentation and cryogenic infrastructure was removed and the MLC was prepared and moved to its final location where it will remain for the duration of CBETA construction and commissioning.

On December 21 an FFAG Magnet Review was held at BNL, using a panel of magnet experts from BNL and CU who are not directly involved in the CBETA accelerator. The comments of the reviewers are available on the CBETA website www.classe.cornell.edu/CBETA_PM The Halbach technology style was selected as the most viable path forward for CBETA permanent magnets in the FFAG return arc, especially considering the need for an economical solution to the more than 200 magnets required for the full machine.

On January 24 an almost-final 237-page version of the Design Report detailing the design of the accelerator was completed and released. This report is available at the CBETA website www.classe.cornell.edu/CBETA_PM

On January 30 and 31 a Technical Review of the project was held at CU by the Advisory Committee – an international panel of experts with a background in advanced accelerators. The panel heard from each of the

CBETA technical coordinators, and considered the status of each subsystem. The panel's conclusions are available at the CBETA website. The panel was impressed with the technical progress the design team has made over the past year. They reported to the Oversight Board that:

> *The Committee believes that the baseline design as described in the design report is consistent with both the KPP [Key Performance Parameters] and the UPP [Ultimate Performance Parameters] parameter sets.*
>
> *The engineering design is sufficiently mature to warrant the start of construction activities.*

This is the basis for declaring that the project has achieved Technical Milestone 1: "Engineering Design Documentation Complete".

The conventional electromagnets needed for the two "splitter" sections were modeled using Opera software. Initial contact was made with seven potential vendors. The specifications and requirements were developed into a Request For Proposals solicitation that will be sent out to vendors in early February.

Cost and Schedule Planning

In late January the project management team was heavily involved in preparations for the Cost and Schedule Review, held at BNL on February 6 and 7, just after the period discussed in this Quarterly Review. (The review went well. It will be discussed as one part of a longer Cost and Schedule section, in the next Quarterly Report.)

Project Management documentation that was prepared for the Cost and Schedule review included a cost analysis, schedule, a risk register, a revised Project Management Plan, a Work Breakdown Structure (WBS) dictionary, and an extensive parameter list, all of which are available at the CBETA website www.classe.cornell.edu/CBETA_PM

A master schedule for the project is currently under development and will be available in April. Initial work is proceeding based on an interim schedule for the activities surrounding the preparations for the MLC beam testing this summer. The MLC beam test schedule is an appendix to this report.

The table of technical milestones that defines the highest level of schedule planning is shown in Figure 1.

Figure 1 Technical milestones.

#	NYSERDA milestone	Baseline	Actual	Forecast
	NYSERDA funding start date		31-Oct-16	
1	Engineering design documentation complete	31-Jan-17	31-Jan-17	31-Jan-17
2	Prototype girder assembled	30-Apr-17		30-Apr-17
3	Magnet production approved	30-Jun-17		30-Jun-17
4	**Beam through Main Linac Cryomodule**	**31-Aug-17**		**31-Aug-17**
5	First production hybrid magnet tested	31-Dec-17		31-Dec-17
6	**Fractional Arc Test: beam through MLC & girder**	**30-Apr-18**		**30-Apr-18**
7	Girder production run complete	30-Nov-18		30-Nov-18
8	Final assembly & pre-beam commissioning complete	28-Feb-19		28-Feb-19
9	Single pass beam with factor of 2 energy scan	30-Jun-19		30-Jun-19
10	Single pass beam with energy recovery	31-Oct-19		31-Oct-19
11	Four pass beam with energy recovery (low current)	31-Dec-19		31-Dec-19
12	Project complete	30-Apr-20		30-Apr-20

Quarterly Cost Summary

Project expenditures in the current quarter are summarized in Figure 2, separately for Cornell and BNL. Although permanent magnet material and other components related to the prototype magnet girder have already been procured by BNL, these expenses will only be included in the BNL cost summary table when those expenses have been disbursed to the vendor. This occurs after the materials have been received.

In future Quarterly Reports we will provide earned value information on the work performed versus the expected. At the time of generating this first Quarterly Report we are working from a partial schedule, making it difficult to compare actual work versus expected work costs. In order to provide an approximate analysis, we calculated the actual labor cost as a percentage of the total predicted labor cost for each of 13 subsystem categories within the Work Breakdown Structure, under the approximation that labor costs for each subsystem will be approximately constant throughout the project. This analysis shows that the DC Gun/Injector and RF Systems are spending ahead of predictions, reflecting the large amount of early work going on to ready the Injector and RF System for the MLC test in the summer of 2017. Some WBS items, such as Safety and Beam Commissioning, show relatively minor charges, because they have not yet ramped up yet. Overall labor spending is on track.

Figure 2 Quarterly cost summary

Cornell CBETA Quarterly Report
Nov. 16, 2016 - Jan. 31, 2017

WBS	Title	Labor	M&S	Travel	Other	Total
1	Project management	$ 91,505.44	$ 14,010.98	$ 3,318.35	$ -	$ 108,834.77
2	Accelerator physics	$ 64,325.06	$ -	$ -	$ 405.10	$ 64,730.16
3	DC gun/injector	$ 28,778.20	$ 58,263.83	$ -	$ -	$ 87,042.03
4	RF systems	$ 107,446.61	$ 13,924.71	$ -	$ -	$ 121,371.32
5	FFAG magnets & girders	$ 6.00	$ -	$ 183.60	$ -	$ 189.60
6	Splitters	$ 31,330.19	$ -	$ -	$ -	$ 31,330.19
7	Power supplies	$ 26,622.67	$ -	$ -	$ -	$ 26,622.67
8	Controls	$ 15,248.15	$ -	$ -	$ -	$ 15,248.15
9	Instrumentation	$ 18,585.34	$ -	$ -	$ -	$ 18,585.34
10	Vacuum system & beam stop	$ 32,046.17	$ 356.86	$ -	$ -	$ 32,403.03
11	System integration	$ 47,343.91	$ 32,747.02	$ -	$ 19,690.89	$ 99,781.82
12	Beam commissioning	$ 10,635.31	$ -	$ -	$ -	$ 10,635.31
13	Safety	$ 8,845.00	$ -	$ -	$ -	$ 8,845.00
Total		**$ 482,718.05**	**$ 119,303.40**	**$ 3,501.95**	**$ 20,095.99**	**$ 625,619.39**

Brookhaven CBETA Quarterly Report
Oct 31, 2016 - Jan. 31, 2017

WBS	Title	Labor	M&S	Travel	Other	Total
1	Project management	$73,046.18				$ 73,046.18
2	Accelerator physics	$51,499.92				$ 51,499.92
3	DC gun/injector					$ -
4	RF systems					$ -
5	FFAG magnets & girders	$35,169.49				$ 35,169.49
6	Splitters					$ -
7	Power supplies					$ -
8	Controls					$ -
9	Instrumentation					$ -
10	Vacuum system & beam stop					$ -
11	System integration					$ -
12	Beam commissioning					$ -
13	Safety					$ -
Total		**$159,715.59**	**$ -**	**$ -**	**$ -**	**$ 159,715.59**

Activities for the Next Quarter

The project is now moving into high gear as engineering, procurement, and construction ramp up. The activities most critical to ensure rapid progress on the project are:

1. Finalizing the optimum baseline lattice – for example, to account in all detail for the Halbach magnet technology down-select.
2. Constructing the merger and diagnostic beamlines that connect to the MLC and to the existing injector.
3. Cooling the MLC to liquid helium temperatures and re-establishing beam instrumentation for operations.
4. Preparing for the MLC test this summer – for example, further injector running with the diagnostics beamline.
5. Finalizing the vacuum system design, and producing a prototype vacuum chamber for the prototype girder assembly.
6. Reviewing the splitter design, and procuring the splitter magnets and power supplies needed for the Fractional Arc Test.
7. Finalizing the design of the vacuum side of the BPM and other beam instrumentation hardware required for the Fractional Arc Test.
8. Continuing to develop the master assembly model.

Major Procurements in the Next Quarter

A number of upcoming major procurements are necessary to maintain progress towards the near term milestones:

1. Conventional magnets for the splitters. This is one of the two largest procurements. It will be structured with a number of progress payments over the 12-18 months of the contract. A preliminary batch of magnets (10-20% delivery) is required by November 2017. Payments will be stretched out over the course of the contract.
2. Many components will be ordered for the production of the vacuum system (for example pumps, flanges, and valves).
3. Components for the water-cooling system will be purchased, to be ready for installation in summer 2017.
4. Power supplies for the splitter magnets and corrector magnets, required for the Fractional Arc Test, will be purchased.

Appendix: Main Linac Cryomodule Beam Test Schedule

CBETA Project — MLC Relocation

ID	Task Name	Duration	Work	Start	Finish
1	**MLC relocation**	**39 days**	**1,582.8 hrs**	**Tue 1/3/17**	**Fri 2/24/17**
2	Final layout of MLC, beamlines, beam-stop, pump-skid, HX can	9 days	144 hrs	Tue 1/3/17	Fri 1/13/17
3	MLC tests and measurements complete	0 days	0 hrs	Tue 1/3/17	Tue 1/3/17
4	Warmup MLC	12 days	76.8 hrs	Tue 1/3/17	Wed 1/18/17
5	ICM warmup; cap 2k line	2 days	48 hrs	Mon 1/30/17	Tue 1/31/17
6	Develop formal Lift Plan	10 days	56 hrs	Tue 1/3/17	Mon 1/16/17
7	Remove dump shielding and dump (purge dump cooling GN2)	2 days	64 hrs	Thu 1/12/17	Fri 1/13/17
8	Disconnect beamline instrumentation and utilities	5 days	160 hrs	Mon 1/16/17	Fri 1/20/17
9	Remove beamline components	5 days	40 hrs	Mon 1/16/17	Fri 1/20/17
10	Disconnect utilities (beamline and MLC)	5 days	80 hrs	Mon 1/23/17	Fri 1/27/17
11	Vent insulation vacuum and disconnect cryo lines	1 day	24 hrs	Thu 1/19/17	Thu 1/19/17
12	Disconnect instrumentation and controls	3 days	78 hrs	Mon 1/23/17	Wed 1/25/17
13	Change vacuum pumps from Gamma to Minni-Vac (cables?)	1 day	8 hrs	Thu 1/26/17	Thu 1/26/17
14	Move MLC and Cry-Con rack (PLCs) as necessary	1 day	8 hrs	Fri 1/27/17	Fri 1/27/17
15	Prep MLC for move: Lock wire position monitor, lock posts, etc.	1 day	16 hrs	Thu 1/26/17	Thu 1/26/17
16	Prepare new MLC location	1 day	24 hrs	Fri 1/27/17	Fri 1/27/17
17	Secure MLC to stands (TBD)	1 day	24 hrs	Mon 1/30/17	Mon 1/30/17
18	Prepare spreader bar and rigging equipment	1 day	16 hrs	Mon 1/30/17	Mon 1/30/17
19	Unbolt MLC stands from floor	1 day	24 hrs	Tue 1/31/17	Tue 1/31/17
20	**Move cryomodule to beamline location**	1 day	72 hrs	Wed 2/1/17	Wed 2/1/17
21	Survey MLC into position	3 days	56 hrs	Thu 2/2/17	Mon 2/6/17
22	Bolt MLC stands to floor, final survey	1 day	32 hrs	Tue 2/7/17	Tue 2/7/17
23	Relocate MLC-PLC and Cryo-con racks	2 days	16 hrs	Wed 2/8/17	Thu 2/9/17
24	Reconnect instrumentation	5 days	160 hrs	Fri 2/10/17	Thu 2/16/17
25	Change vacuum pumps back	1 day	8 hrs	Fri 2/17/17	Fri 2/17/17
26	Restore utilities (beamline and MLC)	5 days	80 hrs	Fri 2/17/17	Thu 2/23/17
27	Make MLC beamline connections and Faraday cup (clean rooms)	10 days	220 hrs	Wed 2/8/17	Tue 2/21/17
28	Fabricate and install wave guide stand	3 days	48 hrs	Wed 2/22/17	Fri 2/24/17
29	**Cryogenics**	**321 days**	**1,485.6 hrs**	**Mon 1/11/16**	**Mon 4/3/17**
30	Repair MLC pump skid blower (Vendor)	20 days	0 hrs	Mon 1/23/17	Fri 2/17/17
31	MLC transferline design and fabrication	30 days	588 hrs	Mon 1/16/17	Fri 2/24/17
32	MLC elbow transferline design and fabrication	15 days	340 hrs	Mon 2/13/17	Fri 3/3/17
33	Disconnect HX can, cap MLC hole	1 day	16 hrs	Thu 1/19/17	Thu 1/19/17
34	Relocate MLC pump skid	3 days	45.6 hrs	Wed 2/8/17	Fri 2/10/17
35	Relocate and install HX can	5 days	120 hrs	Mon 3/6/17	Fri 3/10/17
36	Install transferlines for MLC pump skid	5 days	120 hrs	Mon 3/13/17	Fri 3/17/17
37	Design, fabricate and install pumping line	5 days	120 hrs	Mon 3/20/17	Fri 3/24/17
38	Restore ICM pumping and skid	1 day	16 hrs	Mon 3/27/17	Mon 3/27/17
39	Re-install instrumentation and controls	5 days	120 hrs	Tue 3/28/17	Mon 4/3/17
40					

CBETA Project — MLC Relocation

ID	Task Name	Duration	Work	Start	Finish
41					
42	**L0E and RF area**	**333 days**	**76 hrs**	**Mon 1/11/16**	**Wed 4/19/17**
43	Modify east side shield wall to accommodate MLC move	0.5 days	12 hrs	Thu 1/19/17	Thu 1/19/17
44	Modify east side shield wall to accommodate test beam-stop	2 days	32 hrs	Fri 4/14/17	Mon 4/17/17
45	Install shielding around beam-stop	2 days	32 hrs	Tue 4/18/17	Wed 4/19/17
46					
47	**Operations**	**383 days**	**1,520 hrs**	**Mon 1/11/16**	**Wed 6/28/17**
48	Cooldown	10 days	400 hrs	Tue 4/4/17	Mon 4/17/17
49	ERL beamline operations when possible (need to resolve shielding and interlock issues)	30 days	240 hrs	Wed 2/22/17	Tue 4/4/17
50	Relocate HPA	5 days	80 hrs	Tue 4/4/17	Mon 4/10/17
51	MLC testing-commissioning	20 days	320 hrs	Thu 4/20/17	Wed 5/17/17
52	Beam through MLC into beam-stop	30 days	480 hrs	Thu 5/18/17	Wed 6/28/17
53					
54	**Safety**	**42 days**	**107.2 hrs**	**Tue 4/4/17**	**Wed 5/31/17**
55	Interlock modifications	10 days	80 hrs	Thu 4/20/17	Wed 5/3/17
56	Radiation safety surveys	30 days	24 hrs	Thu 4/20/17	Wed 5/31/17
57	Safety Committee review and approval	2 days	3.2 hrs	Tue 4/4/17	Wed 4/5/17