Summary of CBETA Independent Cost Reviews

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Overview

On January 18th and 19th, 2017, independent cost reviews were conducted by phone between BNL and Cornell University for the following five CBETA WBS elements:

WBS	WBS Name	Personnel at BNL	Personnel at Cornell University
1.10	Vacuum System	Mike Mapes (BNL vacuum system expert) Rob Michnoff (BNL)	Yulin Li (CU, responsible for vacuum system) Karl Smolenski (CU, PM) Khianne Williams (BNL, project controls)
1.4	RF systems	Alex Zaltsman (BNL, RF expert) Rob Michnoff (BNL)	Peter Quigley (CU, responsible for RF systems) Karl Smolenski (CU, PM)
1.7	Power Supplies	Bob Lambiase (BNL, power supply expert) Don Bruno (BNL, power supply expert) Rob Michnoff (BNL)	Karl Smolenski (CU, PM) (CU person responsible for power supplies not available) Khianne Williams (BNL, project controls)
1.6	Splitters	Joe Tuozzolo (BNL, mechanical systems expert) Rob Michnoff (BNL)	Dave Burke (CU, responsible for splitters) Karl Smolenski (CU, PM) Khianne Williams (BNL, project controls)
1.8/1.9	Controls/Instrumentation	Rob Michnoff (BNL)	John Dobbins (CU, responsible for controls and instrumentation)

The purpose of the CBETA independent cost reviews is to:
- Determine if the material and labor cost estimates accurately reflect the required work
- Check for possible omissions in the estimate
- Check for details that may result in higher costs than included in the estimate
- Suggest potential cost saving ideas

Each of these five reviews was conducted during a one-hour period of time and consisted mainly of questions and discussions prompted by the BNL system expert.

Vacuum System

Notes from Mike Mapes:

- No vacuum cables, racks, PLC, valve controls were listed under vacuum. It is covered in another section and should be reviewed to ensure scope.
- No chamber support and or support stands were included with survey adjustments. It is covered in the magnet area.

- Fringe field from ion pumps was addressed.
- Adding more isolation valves in ring is not an option due to space restrictions.
- Ring chambers will be round and not extruded oval chambers.
- Splitter/combiner areas are tight and should be checked for design.
- Drawing compatibility was raised and Cornell may be getting a Pro-E seat.
- Cornell will use existing turbo pump carts to pump down and transfer to ion/neg pumps.
- Does the ring need RF shielded conflat gaskets? Or are standard gaskets OK?
- Are there other instrumentation devices other than BPM's listed. Cornell will check on current x-formers.

Notes from Karl Smolenski:

- Ensure that racks and cabling for vacuum system are included somewhere (do not exist in Vacuum), check that they are in Controls.
- Current monitors, one exists and is used before the beam stop, 4 are listed in the parameter list. They are not installed in the FFAG arc. Will more be made, are they in Instrumentation, there is no cost in Vacuum WBS.
- Chamber supports need to be accounted for in the Girder WBS, Fiducials are built into each BPM block in the vacuum system.
- Interface of chamber to magnets is critical (survey, supports, CAD sharing, etc.) Big issue to be tracked (Risk)
- Karl to implement accounting changes due to BPM button count changes...

Additional notes from Rob Michnoff:

- The beam pipes will not be baked out in-situ, so no in-situ bakeout equipment is provided in the estimate.
- The beam pipe material selection – stainless steel or aluminum – has not yet been finalized.
- A common coordinate system needs to be defined so that BNL and CU mechanical drawings and model files can easily be shared.

RF System

Notes from Alex Zaltsman:

- Network analyzer is take out
- Contingency is NOT a part of the estimates
- Majority of the equipment exists, the only large purchase is SSA; would like to see some spares
- Need start-up spares!
- Start-up and conditioning (before beam) not accounted for

Notes from Karl Smolenski:

- remove the cost of the network analyzer (contingency).
- no PM manpower listed (discussion about implementing through the PM WBS or is it included intrinsically in the costing spreadsheet).

- no start up / commissioning manpower listed (in fact there are instances where it is listed).
- Helium / Cryo costs not listed.

Additional notes from Rob Michnoff:
- Deflector RF cavity already exists
- All low level equipment for the cavity tuner exists.
- The ICM low level system is being repurposed. Some reconfiguration is required.
- Spares for high cost equipment are not included. The understanding is that if high cost equipment fails, such as a Klystron, significant downtime will be required to repair the device.
- EPICS software development work is included in the RF estimate. Some RF software development work is also included in the Controls estimate. These efforts need to be reviewed to confirm that the same work does not exist in two places.
- The RF estimate includes a section titled "RF System Maintenance." If this is related to operations after project completion, then we should consider removing this from the estimate. This section of the estimate includes approximately 3300 hours and $13,000 in materials.

Power Supplies

Notes from Karl Smolenski:
- Need for Stability / Ripple specifications
- Septa power supplies could be a disaster, perhaps 60k$ per septum
- Further definition of requirements needed before worrying about power supplies

Additional notes from Rob Michnoff:
- Bob Lambiase pointed out that the power supply module may include several channels in one enclosure. If this is the case, the number of channels per enclosure should be stated in the spreadsheet and it would be beneficial to show the unit cost per enclosure and number of enclosures as opposed to number of channels. It would also be helpful to keep the number of total channels in another column.
- Reducing the number of spares should be explored. But this may depend on the number of channels per enclosure as described in the previous bullet.
- Bob Lambiase indicated that the present Septa magnet design is based on a 2-turn coil and would require power supply current of 2000-3000 A and a fraction of a volt. This is an unacceptable solution because the power supply cost would be very high. A different magnet design is required.
- Injection and diagnostic line power supplies are not provided in the estimate. These power supplies may already exist, but this needs to be confirmed.
- Quantities and cost of power supplies for the FFAG magnets need to be updated. Power supplies for the FFAG quadrupole correctors will not be provided. Only power supplies for the FFAG dipole correctors will be provided.

- Septa magnet design is required before accurate cost estimate of septa power supplies can be generated.
- FFAG dipole corrector magnet design is required before accurate cost estimate of corresponding power supplies can be generated.

Splitter Magnets

Notes from Karl Smolenski:

- Counts need to be double / triple checked (36 dipoles)
- Spares should be limited to 1 complete unit, perhaps only a set of coils?
- Common magnets are conventional and based on an existing Cornell design (20k$ => 15k$)
- Septa design work is critical and continues at BNL. Joe T. is providing needed engineering
- Extraction line magnets are existing (Karl to double check)
- System layout design time may not be accounted for.

Additional notes from Rob Michnoff:

- What voltage should be used for hi-potting?
- Need to confirm that all magnet chambers are included in the vacuum estimate.
- Thermal issues related to septa magnet need to be reviewed.
- 32 of the magnets in the splitter sections need to be movable in order to adjust path lengths. Motors are included in the estimate to provide this adjustment. Would it make sense to consider eliminating the motion control and manually make these adjustments?
- Dave Burke explained that connector bulkheads (or patch panels) are planned to be provided at each magnet to keep wiring clean. Will this require additional cables from the magnet to the connector bulkhead? If so, these additional cables need to be included in the estimate. The present power supply estimate includes one cable per power supply.
- We might consider requesting that the magnet manufacturer include rigidly mounted connectors as part of the magnet assembly. This should also be considered for the FFAG corrector magnets.

Controls

Notes from Rob Michnoff:

- Orbit correction application development is provided in the estimate. Are other high level application programs required to control and monitor the machine?
- Controls development work is included in several sections of the estimate. Review is required to confirm that the same effort is not included in multiple sections.
- Machine protection system estimate seems low. A more complete system definition is required.

Instrumentation

Beam Current Transformers

- The components list shows 4 beam current transformers, but only 2 are included in the instrumentation estimate.
- Need to determine if only 2 current transformers are adequate. The anticipated locations would be one in the injection line and one in the dump line.
- The specific type of current transformer to satisfy the variety of operational modes needs to be determined. Single bunch operation would typically use an ICT (integrating current transformer), while bunch trains may require a DCCT (DC current transformer). With only 23.8 ns space between bunches (31 1300 MHz RF periods), a Bergoz ICT would smear the bunch trains together because the raw output from the ICT generates a minimum ~70ns pulse width. Discussions with a beam current transformer manufacturer are required.
- Specific electronics hardware and processing requires careful consideration in order to provide a difference between 2 beam current transformers as required for machine protection. This concept has already been developed at BNL, but additional challenges exist for CBETA. Specifically, time correlating injected bunches with extracted bunches for beam loss subtraction will not be trivial.
- Is it feasible to use BPM button pickups to perform beam current measurements, including performing a difference as required for beam loss interlocking? (J. Dobbins) This will require careful consideration but could help to reduce the cost. Absolute current measurements may prove to be quite difficult.

View Screens

- 32 view screens are presently included in the estimate. The vacuum components for the view screens have not been included in the vacuum section and need to be added.
- We might consider installing a bare minimum number of view screens, but install vacuum ports to allow future screens to be installed.

Beam Loss Monitors

- 40 beam loss monitors are included in the present estimate, but the minimum required number has not yet been determined. It may be lower than 40 and it may be higher than 40.
- Are loss monitor cables included in the estimate?
- Would it be feasible to use fewer loss monitors and provide sufficient coverage by using the technique used for LEReC, which is running a fiber optic cable along a length of the beam pipe and connecting to a PMT? If so, what is the minimum number of required loss monitor channels?
- Cost estimate for loss monitor system seems low. A more complete definition of system hardware is needed in order to provide a realistic estimate.

Beam Position Monitors

- The present estimate assumes that buttons will be connected directly to the V301 BPM hardware module. If patch panels or additional electronic modules (such as amplifiers and/or analog switches) are required then additional costs will be incurred.
- No V301 spare modules are presently included in the estimate. A minimum number of at least 5, maybe 10 should be added.

General notes

- Some WBS sections include controls hardware and software while others do not. This may be ok, but all sections should be reviewed to confirm that all required controls work is included somewhere in the estimate.
- Searching for alternative design options should continue to be a high priority, with the goal of decreasing costs without sacrificing machine performance scope.
- Consistency between quantities defined in the components list and the estimates needs to be confirmed.
- Equipment rack space should be reviewed to ensure that adequate space is provided for all electronic equipment.
- There was some discussion during both the power supply and splitter reviews about exploring the possibility of having a single vendor supply both the splitter magnets and associated power supplies under one requisition. The general consensus is that it would be better to keep them separate. Combining them may limit the number of potential bidders and could actually increase the cost if one vendor needs to subcontract another vendor.
- Burdened costs need to be included where required.
- Need to confirm if magnet chambers are included in the vacuum estimate.
- The total number of labor hours for the RF section is considerably higher than the other sections reviewed. This should be reviewed and checked for accuracy. The table below provides the number of labor hours for each of the sections reviewed.

WBS	WBS Name	Labor hours in estimate
1.10	Vacuum System	5,580
1.4	RF systems	15,399
1.7	Power Supplies	4,046
1.6	Splitters/Combiners	7318
1.8	Controls	5578
1.9	Instrumentation	5413

Significant details that need to be addressed

- Will the vacuum beam pipe material be stainless steel or aluminum? What are the cost implications of each? What are the pros and cons of each?
- Septa magnet designs needs to be completed. Current and voltage requirements need to be defined.
- Septa power supplies need to be selected after Septa magnet designs are complete.

- Can cost of splitter magnets be further reduced below $15k?
- FFAG dipole corrector magnet design needs to be completed. Current and voltage requirements need to be defined.
- BPM button mounting orientation needs to be finalized. There were email discussions about mounting the buttons symmetrically at a 45 degree angle to avoid potential synchrotron radiation from affecting the horizontal outside button. If synchrotron radiation is not an issue for CBETA then the preference from an electronic processing standpoint would be to mount the buttons orthogonally.
- FFAG dipole corrector power supplies need to be selected after the magnet design is complete.
- The minimum required number of view screens needs to be determined.
- The minimum required number of beam loss monitors needs to be determined.
- Beam current transformer quantity and type need to be determined. This may have cost impact. Vendor quotations should be obtained. (Bergoz is one option.)
- Nesting splitter power supplies should be explored as an option for cost reduction.
- Specific burden rates for CBETA need to be identified and incorporated into the estimate.
- What magnets will be used for the injection and diagnostic beam lines? Do they exist? If not, are these magnets included in the estimate? (Extraction line magnets are included in the estimate.)
- What are the machine protection system requirements? What systems will need to be interfaced to the machine protection system? Developing custom systems to perform functions such as integrating and subtracting injection and extraction beam current monitor measurement for loss detection and beam interlock will increase costs. Months of development effort may be required.

- What beam current will cause machine damage on a ms time scale and 1s time scale? A focused 40 mA beam in one spot has been determined to be capable of melting the beam pipe in a time measured in microseconds. (J. Dobbins)
- What is a safe operating beam current? i.e. a current that one can run the machine continuously at without possibility of damage. Adam and John suspect that a "safe" operating current for commissioning might be about 50 nA. This needs to be confirmed. (Shielding is being designed for a loss of 1 watt/meter. At 42 MeV that's ~24 nA and less at higher energies.) (J. Dobbins)
- What single point loss value should interlock the beam? (J. Dobbins)
- Is high current operation a requirement to be provided within the $25M budget? (J. Dobbins)
- Is a post-mortem system required to capture and log signals (such as loss monitors) when a beam interlock occurs? This is not presently included in the estimate and would cost ~$200k (J. Dobbins)
- There is plenty of evidence in literature that radiation damage of the NdFeB magnets is a real possibility especially with the Halbach magnets as they are the likely absorbent of lost beam (just outside the beam-pipe, no protecting iron). Should there be a line in the WBS for dosage monitoring so that if a magnet suffers loss of magnetization we have some data to go with that? (J. Dobbins)

- How will emittance be measured? The components list spreadsheet shows one emittance measurement system, but the instrumentation estimate does not include an emittance measurement device.
- Specific locations and quantities of BPM buttons and electronics need to be determined. (Numbers like 192 4-button sets and 138 electronic modules have been discussed but finalization is required. And estimates need to be updated to reflect the final quantities.)
- Yulin pointed out that the splitter configuration is not well defined yet. This needs to be determined right away in order to provide accurate cost estimates, and to satisfy the design complete milestone.
- The present vacuum estimate includes sections labeled "Initial beam pipes between splitter and combiner" and "final beam pipes between splitter and combiner." Yulin explained that different beam pipe configurations will be required for different number of beam passes. Reworks are very expensive. The estimate includes only 2 reconfigurations. If more are required costs will increase. Is it feasible to develop a design that would prevent or at least limit the number of reworks? Can we design the system to allow path length changes for the different number of passes while limiting the work required to reconfigure the lines?

- Power supply regulation specification is required. How accurately do the dipole and quadrupole correctors need to stay on a set current (1%, 0.1%, etc.)? (J. Tuozzolo)
- What is a reasonable (not expensive) level of current ripple for 8V, 3A, 24W power supply specification? (J. Tuozzolo)