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| Beam Line Toroids AIP  **BASIS of ESTIMATE FORM (BoE)** | **Document Number:** Mu2e-doc-1577  **Date of Estimate:** 5/4/12  **Prepared by:**  Brian Drendel |

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| WBS Category Number: MuAIP.02.03.01  WBS Category Name: Beam Line Toroids  Control Account (number and name): |
| Costing Method:  \_\_\_ Existing P.O. \_\_\_ Prior Experience (source: )  \_\_\_ Catalog Listing / Vendor Quote \_\_\_ Expert Opinion  \_\_\_ Budgetary Estimate \_\_\_ Pre-conceptual Design  \_X\_ Engineering Experience \_\_\_ Other (description: ) |
| External Supporting Documents: 1. A. Ibrahim, B. Drendel, “Toroid and DCCT upgrade for Mu2e Storage Rings and Beam Lines,” Mu2e Documents Database #1180, February 2012. |

Update the existing Beam Line toroids to make intensity measurements for both g-2 and Mu2e operations in the P1, P2, M1, M2, M3 and Delivery Ring Abort lines. Modify existing electronics, hardware and cabling to meet updated performance requirements.

**Preliminary Design:**

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| WBS Category Name: Preliminary Design of infrastructure improvements to the beam lines |
| Costing Method:  \_\_\_ Existing P.O. \_\_\_ Prior Experience (source: )  \_\_\_ Catalog Listing / Vendor Quote \_\_\_ Expert Opinion  \_\_\_ Budgetary Estimate \_\_\_ Pre-conceptual Design  \_X\_ Engineering Experience \_\_\_ Other (description: ) |

The preliminary design will continue to develop requirements and specifications for improvements and upgrades to components/hardware and provide data for completing the design effort. The information will also establish data for use by project management to determine a high confidence level in the specifications. Effort will focus on providing documentation to determine if the proposed design meets project requirements.

**Preliminary Design Labor:**  Costing was determined via consultation Accelerator Division Instrumentation Engineers and is detailed in the supporting documentation1. Contingencies follow labor contingency rule #3.

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| **Activity ID** | **Description** | **Resource ID**  **(mu2e-doc-1305)** | **Base Est.**  **(hours)** | **Cont.**  **(%)** | **Base Est. + Cont.**  **(hours)** |
| MuAIP.02.03.01.02 | Engineering design and oversight | FNAD.ENGNRING.PHYST (Engineering Physicist) | 20 | 30% | 26 |
| MuAIP.02.03.01.02 | Engineering design and oversight | FNAD.ELTN.DESIGN.EN  (Instrumentation Engineer) | 113 | 30% | 147 |

(labor estimates assume 85% efficiency)

**Final Design Labor:**

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| WBS Category Name: Final Design of infrastructure improvements to the beam lines |
| Costing Method:  \_\_\_ Existing P.O. \_\_\_ Prior Experience (source: )  \_\_\_ Catalog Listing / Vendor Quote \_\_\_ Expert Opinion  \_\_\_ Budgetary Estimate \_\_\_ Pre-conceptual Design  \_X\_ Engineering Experience \_\_\_ Other (description: ) |

The final design will provide the documents necessary to repurpose and upgrade required components/hardware. Effort will focus on finalization of documentation.

**Final Design Labor:** Costing was determined via consultation Accelerator Division Instrumentation Engineers and is detailed in the supporting documentation1. Contingencies follow labor contingency rule #3.

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| **Activity ID** | **Description** | **Resource ID**  **(mu2e-doc-1305)** | **Base Est.**  **(hours)** | **Cont.**  **(%)** | **Base Est. + Cont.**  **(hours)** |
| MuAIP.02.03.01.03 | Engineering design and oversight | FNAD.ENGNRING.PHYST (Engineering Physicist) | 25 | 30% | 33 |
| MuAIP.02.03.01.03 | Engineering design and oversight | FNAD.ELTN.DESIGN.EN  (Instrumentation Engineer) | 113 | 30% | 147 |

(labor estimates assume 85% efficiency)

**Implementation:**

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| WBS Category Name: Implementation of infrastructure improvements to the beam lines |
| Costing Method:  \_\_\_ Existing P.O. \_\_\_ Prior Experience (source: )  \_\_\_ Catalog Listing / Vendor Quote \_\_\_ Expert Opinion  \_\_\_ Budgetary Estimate \_\_\_ Pre-conceptual Design  \_X\_ Engineering Experience \_\_\_ Other (description: ) |

Implementation will include the installation of components and hardware necessary to support a fully functioning system. Effort will involve repurpose and refurbishing of components to meet project requirements. Included will be the installation and testing of items to ensure functionality.

**Implementation M&S and Labor:** Costing was determined via consultation Accelerator Division Instrumentation Engineers and is detailed in the supporting documentation1. Contingencies follow labor contingency rule #3. M&S contingencies were determined by M&S contingency rule #5.

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| **Activity ID** | **Description** | **Resource ID**  **(mu2e-doc-1305)** | **Base Est.**  **(hours)** | **Cont.**  **(%)** | **Base Est. + Cont.**  **(hours)** |
| MuAIP.02.03.01.04 | Refurbish motor assembly feed can and electronics | FN.M&S.STND | $7.2K | 40% | $10K |
| MuAIP.02.03.01.04 | Engineering design and oversight | FNAD.ENGNRING.PHYST (Engineering Physicist) | 25 | 30% | 33 |
| MuAIP.02.03.01.04 | Engineering oversight | FNAD.ELTN.DESIGN.EN  (Instrumentation Engineer) | 113 | 30% | 147 |
| MuAIP.02.03.01.04 | Refurbish and installation of components | FNAD.ELTN.TECH  (Instrumentation Technician) | 300 | 30% | 390 |
| MuAIP.02.03.01.04 | Controls Programming | FNAD.APDEV.SYSTMAYST (Front End Programmer) | 4 | 30% | 5.2 |

(labor estimates assume 85% efficiency)**Additional Background Information**

Toroids will be the primary beam intensity measurement device for the P1, P2, M1, M2, M3 and Delivery Ring abort lines. Labor and M&S cost estimates were generated via consultation with Accelerator Division Instrumentation Engineers and are documented in the Multiwire/SEM costing spreadsheet1. A number of different options were being considered. This estimate does not include the specific low intensity operation required of the g-2 M2, M3 and Delivery Ring abort lines.

* Base Plan: Use existing toroids and insulators, and do not add a second toroid to the AP3 line. Do not move Tor109. Existing NIM electronics will be used. Costing is the sum of the cost of P1, P2 and M1 toroids (covered in one costing spreadsheet)1 and M3 and Debuncher Abort toroids (covered in a separate costing spreadsheet)1. Assumptions have been made that only a very minimal amount of maintenance will need to be performed on the toroid electronics since beam intensities should be similar to Pbar operations. Assume that no significant controls work will be required to keep existing working systems communicating over ACNET.
* Option 1: Use existing toroids and insulators, and do not add a second toroid to the AP3 line. Tor109 is moved to the M3 line. All toroids have general maintenance and repairs performed. Existing NIM electronics will be used. Costing is the sum of the cost of P1, P2 and M1 toroids (covered in one costing spreadsheet)1 and M3 and Debuncher Abort toroids (covered in a separate costing spreadsheet)1.
* Option 2: Use existing toroids and insulators, and do not add a second toroid to the AP3 line. Except at new location for TOR109, all tunnel installations have general maintenance performed on them. VME crate, controllers and timing cards will be repurposed from other locations.
* Option 3: Use existing toroids and insulators, and do not add a second toroid to the AP3 line. Except at new location for TOR109, all tunnel installations only have general maintenance performed on them. VME crate, controllers and timing cards will be repurposed from other locations. New transition board for analog conditioning will be designed and procured.
* Option 4: Use existing toroids and insulators. TOR109 will be moved. Install spare toroid and insulator from AP2 line to add a second toroid to the AP3 line. Only 2 tunnel installations will be replaced; all others only have general maintenance performed on them. VME crate, controllers and timing cards will be repurposed from other locations. New transition board for analog conditioning will be designed and procured.
* Option 5: Use existing toroids and insulators. TOR109 will be moved. Install newly purchased toroid (3100) and insulator to add a second toroid to the AP3 line. Only 2 tunnel installations will be replaced; all others only have general maintenance performed on them. VME crate, controllers and timing cards will be repurposed from other locations. New transition board for analog conditioning will be designed and procured.
* Option 6: Use existing toroids and insulators. Install newly purchased toroid (3100) and insulator to add a second toroid to the AP3 line. All tunnel installation will be reviewed and modifited to follow standardized system model. New VME crate, controllers and timing cards will be purchased. New transition board for analog conditioning will be designed and procured.

Costing assumes that the pre-target beam transport path is identical to g-2. Mu2E estimates assumes all work on the pretarget transport was done for g-2, except for moving Mu2E. To simplify Mu2E estimates, It is assumed g-2 work included (1) installation of a 2nd toroid in the P2line, (2) procurement of a signal conditional board for all pretarget toroids, and (3) installation of VME electronics for all pre-target toroids.

**Labor**: Total labor hours for preliminary design, final design and implementation stages of the project. The base plan and six other options have been considered.

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| Total Labor Hours | | | | | | | |
|  | Base | 1 | 2 | 3 | 4 | 5 | 6 |
| Engineering Physicist | 70 | 80 | 80 | 90 | 90 | 90 | 100 |
| Electrical Engineer | 450 | 602 | 1538 | 1538 | 1790 | 1804 | 1820 |
| Electrical Technician | 320 | 462 | 1734 | 1758 | 2070 | 2073 | 2205 |
| Front End Programmer | 4 | 180 | 2080 | 2080 | 2340 | 2340 | 2340 |
| Machine Shop | 0 | 60 | 60 | 60 | 180 | 240 | 540 |
| Mechanical Drafter | 0 | 43 | 43 | 43 | 87 | 87 | 133 |
| Mechanical Engineer | 0 | 43 | 43 | 43 | 87 | 87 | 133 |
| Mechanical Technician | 0 | 43 | 43 | 43 | 87 | 87 | 133 |
| Vacuum/Alignment Crew | 0 | 60 | 60 | 60 | 120 | 120 | 120 |
| EE Support Designer | 0 | 0 | 120 | 160 | 160 | 160 | 160 |
| EE Support Drafter | 0 | 0 | 120 | 160 | 160 | 160 | 160 |

**M&S:** Total M&S for preliminary design, final design and implementation stages of the project. The base plan and six other options have been considered.

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| M&S Totals | | | | | | | |
|  | Base | 1 | 2 | 3 | 4 | 5 | 6 |
| Totals | $7.2K | $7.2K | $12K | $13.8K | $21.2K | $26.2K | $49.7K |

References:

1. Ibrahim, B. Drendel, “Toroid and DCCT upgrade for Mu2e Storage Rings and Beam Lines,” Mu2e Documents Database #1180, February 2012.