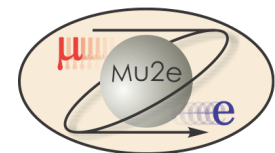




U.S. DEPARTMENT OF
ENERGY Office of
Science

Mu2e Risks

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Total Project Cost and Risk

TPC = base estimate +
100% estimation uncertainty +
90% C.L. cost associated with risks
+ application of burdening and escalation

Most Significant Risks

PM-010: Unexpected increase in Fermilab overhead rates

- Half of Mu2e Project TPC is Fermilab labor.
- Rates can change late in FY but be retroactive to beginning of FY.
- **Probability:** Moderate
- **Impact:** Estimated impact based on analysis of historical data convoluted with anticipated labor obligations in each Division: \$1.5M
- **Mitigation:** Maintain adequate contingency year-by-year to cover retroactive overhead increases.

Most Significant Risks

CAL-108: INFN cannot deliver full in-kind scope

- INFN expected to deliver
 - 1/3 of the crystals
 - 1/2 of the photosensors
 - all front end electronics
 - 1/2 of the waveform digitizers
 - mechanical support
 - laser calibration system
 - half of installation and commissioning effort
- Initially there was a risk that INFN might not fund Mu2e effort
 - Based on significant efforts of our INFN-funded colleagues on Mu2e, INFN has formally approved funding of Mu2e. Exact level of funding to be approved soon.
 - Residual risk that funding will be less than expected. Project would pick up difference, reduce scope of calorimeter or switch to a less expensive crystal with lower performance.

• **Probability:** Low

Mu2e



Most Significant Risks

SOL-157: PS conductor first article does not meet specifications

- PS is the most difficult of the 4 conductor types required for the solenoids
 - R&D produced PS conductor that was marginal. We have made some small tweaks to improve the conductor.
 - First article would be spare. Hold point after first article for full evaluation before proceeding
 - If first article fails, we could incur a delay of a year
- **Probability:** Moderate
- **Impact:** \$2M
- **Mitigation:** Add an additional 100 m prototype prior to first article, at a cost of \$21k (included in baseline cost).
 - Work with the vendor to stockpile materials to minimize potential delay.

Most Significant Risks

ACCEL-015: Injection damper required for Delivery Ring

- Beam injected into the Delivery Ring could have instabilities that result in beam losses and impact performance of resonant extraction system.
- **Probability:** Low, based on beam simulations indicating that injected beam should be stable
- **Impact:** Beam losses (ES&H issue) and poor performance of the accelerator systems providing beam to Mu2e
- **Mitigation:** An injection damper can be deployed that would eliminate this problem at a cost of \$185k. The need for such a device can be evaluated during beam studies well in advance of Mu2e running.

Most Significant Risks

ACCEL-151: Redesign remote handling system to handle a water cooled production target

- Radiatively cooled tungsten target must survive for a year before requiring replacement using a remote handling system.
 - Oxidation at high temperature in 10^{-5} T vacuum could reduce target lifetime. Emissivity measurements of tungsten rods and literature search on tungsten oxidation indicate that target should last for a year. Tests by Rutherford High Power Target Group underway to validate.
 - If tests indicate radiatively cooled target lifetime inadequate, a water-cooled target would be required.
- **Probability:** Low, based on testing to date at Rutherford
- **Impact:** > \$3M to implement a significantly more complicated remote handling system.

Most Significant Risks

CAL-148: Can't develop UV-Extended solid state photodetector that is blind to longer wavelengths for the Calorimeter

- BaF₂ crystals produce scintillation light with a fast and a slow component. The fast component is very fast (< 1ns) and is produced at about 220 nm. The slow component extends to 650 ns and is produced at 310 nm. R&D is underway to develop a solid-state device for use in a magnetic field that has a high quantum efficiency at 220 nm and is relatively blind to longer wavelengths. If this cannot be accomplished, the rate capability of BaF₂ crystals will be compromised.
- **Probability:** Determined to be moderate based on progress of R&D to date.
- **Impact:** Degraded calorimeter performance
- **Mitigation:** Use photodetector that is sensitive to slow light or switch to CsI crystals. In either case the calorimeter performance will be degraded.

Most Significant Risks

SOL-66: Critical path delayed due to solenoid schedule delay

- Solenoids drive the Project schedule. DS defines the critical path but the PS and TS are not far off. Significant delay to any of the solenoids delays the entire project that also leads to a cost increase.
- **Probability:** Moderate probability of delay of up to a year for one of the three solenoids.
- **Impact:** Using PRA, the cost associated with a 1 year delay of the DS is \$1.4M.
- **Mitigation:** Flexible installation sequence. Close monitoring of vendor. Considering vendor schedule incentives in contract.

Most Significant Risks

SOL-148: Production Solenoid must be installed through PS hatch using a large rented crane

- The PS is scheduled to arrive before the others, allowing it to be lowered into the beam enclosure through the TS hatch using the two 30-ton building cranes. If it arrives later than the other solenoids it may be necessary to lower it through the PS hatch with a large rental crane and crew. Because the crane would not be able to set up directly adjacent to the hatch, significant boom extension would be necessary, requiring a significantly sized crane.
- **Probability:** Moderate
- **Impact:** \$300k

Most Significant Risks

TRIG-128: Insufficient manpower for DAQ software

- The DAQ effort is dominated by software costs. Part of that effort is on project and part of it is off project, to be written by physicists.
 - A large fraction of the NOvA DAQ software development effort was based on uncoded scientific labor, with good results. It is likely that the same approach will work for Mu2e. In the event that uncoded labor resources are not available, additional coded labor resources (up to 2 FTE) might be necessary.
- **Probability:** Moderate
- **Impact:** \$500k for coded resources.

Most Significant Risks

DocDb#-4320

| Risk | | | | | | | | | | | | | | Post-mitigation | | | | |
|-----------|-------------------|-------------|--|--------------|--|--------------|-------------|--|------|-----------|------|-------|-----------------------|---------------------------|-----------------------------|-----------------------|--------------------------|---------------------------|
| Risk ID | Risk Form DocDb # | Type | Title | Date of Risk | Mitigation Cost (Included in baseline) | Category | Probability | Schedule-Delays Level 3 Milestone or Project Critical Path by X Days | Cost | Technical | ES&H | Score | Owner | Point estimate (cost k\$) | Point Estimate (sched-days) | Point estimate (prob) | EXPECTATION VALUE IN K\$ | EXPECTATION VALUE IN Days |
| CAL-108 | 3347 | Threat | INFN cannot deliver full in-kind scope. | FY14-FY19 | | Current Risk | L | N | VH | H | N | 40 | R. Ray | \$ 1,000 | | 10% | \$ 100 | 0 |
| CONST-049 | 3351 | Opportunity | Conventional construction bids are lower than estimated cost. | FY14 | | Current Risk | M | N | VH | N | N | 40 | T. Lackowski | \$ (1,200) | | 50% | \$ (600) | 0 |
| PM-010 | 3366 | Threat | Unexpected increase in Fermilab overhead rates | FY14-FY19 | | Current Risk | M | N | VH | N | N | 40 | Ron Ray | \$ 1,500 | 0 | 50% | \$ 750 | 0 |
| SOL-157 | 4225 | Threat | PS conductor first article does not meet specifications | FY15-FY16 | \$ 400,000 | Current Risk | M | VH | VH | M | N | 40 | M. Lamm | \$ 2,000 | 250 | 25% | \$ 500 | 62.5 |
| ACCEL-015 | 3331 | Threat | Injection damper required for Delivery Ring | FY16-FY19 | | Current Risk | L | N | N | VH | N | 24 | J. Morgan | \$ 185 | 0 | 10% | \$ 19 | 0 |
| ACCEL-151 | 3833 | Threat | Redesign the Remote Handling System for Water cooled target | FY14-FY17 | \$ 100,000 | Current Risk | L | N | VH | M | N | 24 | M.Campbell, R.Coleman | \$ 3,300 | | 10% | \$ 330 | 0 |
| CAL-148 | 3834 | Threat | Cannot develop UV-extended solid state photodetector that is blind to longer wavelengths | FY14-FY15 | \$ 100,000 | Current Risk | M | M | N | H | N | 24 | D. Hitlin | \$ - | 40 | 50% | | 20 |
| CONST-050 | 3352 | Threat | Conventional construction bids exceed estimated cost. | FY14 | | Current Risk | L | N | VH | N | N | 24 | T. Lackowski | \$ 1,200 | | 10% | \$ 120 | 0 |
| MUON-138 | 3360 | Threat | Detector installation takes longer than expected. | FY19 | | Current Risk | M | M | H | N | N | 24 | G. Ginther | \$ 400 | 0 | 50% | \$ 200 | 0 |
| PM-005 | 3362 | Threat | Construction funds not available as assumed. | FY14 | | Current Risk | L | H | VH | N | N | 24 | Ron Ray | \$ 500 | 120 | 10% | \$ 50 | 12 |
| PM-153 | 3844 | Opportunity | Commodity prices decrease | FY15-FY17 | | Current Risk | L | N | VH | N | N | 24 | Ron Ray | \$ (1,173) | | 50% | \$ (587) | |
| PM-154 | 3845 | Threat | Commodity prices escalate faster than inflation | FY15-FY17 | | Current Risk | L | N | VH | N | N | 24 | Ron Ray | \$ 1,173 | | 10% | \$ 117 | |
| SOL-066 | 3367 | Threat | Critical path delayed due to solenoid schedule delay. | FY18-FY20 | \$ 20,000 | Current Risk | M | H | VH | N | N | 24 | M. Lamm | \$ 1,384 | 200 | 50% | \$ 692 | 100 |
| SOL-070 | 3368 | Threat | Interface problems with the solenoids. | FY14-FY19 | | Current Risk | L | H | VH | N | N | 24 | M. Lamm | \$ 1,000 | 60 | 20% | \$ 200 | 12 |
| SOL-080 | 3372 | Threat | Insufficient testing of DS and/or PS at Vendor | FY18-FY20 | \$ 50,000 | Current Risk | L | VH | VH | N | N | 24 | M. Lamm | \$ 2,000 | 200 | 10% | \$ 200 | 20 |
| SOL-148 | 3837 | Threat | Production Solenoid must be installed through PS hatch using a large rented crane. | FY18-19 | | Current Risk | M | N | H | N | N | 24 | T. Page | \$ 300 | | 50% | \$ 150 | 0 |
| SOL-155 | 3954 | Opportunity | Cryo Distribution Box Funded by Cryo AIP | FY16-FY18 | | Current Risk | M | VH | VH | N | N | 24 | M. Lamm | \$ (2,500) | | 50% | \$ (1,250) | 0 |
| TRIG-128 | 3393 | Threat | Insufficient manpower for DAQ software. | FY14-FY19 | | Current Risk | M | N | H | N | N | 24 | M. Bowden | \$ 500 | | 25% | \$ 125 | 0 |
| VETO-164 | 4258 | Threat | More CRV coverage is needed. | FY14-FY15 | | Current Risk | H | N | VL | N | N | 24 | C. Dukes | \$ 60 | 0 | 80% | \$ 48 | 0 |
| ACCEL-020 | 3333 | Threat | Cannot use TLMs to control beam losses. | FY14-FY19 | | Current Risk | L | N | VH | N | N | 24 | T. Leveling | \$ 2,000 | | 2% | \$ 40 | 0 |

Contingency Management

- CAMs are given spending authority adding up to the base cost of their Control Accounts.
- Contingency use is governed by Mu2e Configuration Management Plan and the Mu2e PEP, summarized below.
- Contingency log will be developed to record and track contingency usage.
- Available contingency will be included in monthly EVMS reports.

| | Deputy Director For Science Programs | Associate Director of Science for HEP | Federal Project Director | Mu2e Project Manager |
|-------------|--|---|--|---|
| Cost | Must approve any increase in TPC, TEC, or OPC. | Must approve any contingency usage over \$5M for a single item or any cumulative change greater than 50% of a Level 2 WBS | Must approve cumulative contingency use of \$1M across entire Project. Sum re-sets after sign-off. | Must approve any change that increases the cost of a single item by more than \$50k |

Summary

- Mu2e has been practicing Risk Management since well before CD-1.
- Risks actively managed.
- Dedicated Risk Manager in the Project Office
- Contingency management/change control plan in place.