Mu2e Remote Handling Review
Comparisons: Costs, Risks & Maintainability

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Comparisons: Costs, Risks & Maintainability

• Costs
  – TPC comparison - M. Gardner, M. Campbell

• Risks
  – Impact of mechanical failure – M. Campbell, R. Schultz

• Maintainability
  – Configuration & functional flexibility

• Conclusions
## TPC Comparison

<table>
<thead>
<tr>
<th></th>
<th>M Campbell</th>
<th>Machine Savings</th>
<th>Total w/ Contingency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Labor</td>
<td>Material</td>
<td></td>
</tr>
<tr>
<td>Old</td>
<td>$1,356,644</td>
<td>$891,620</td>
<td>$2,248,264</td>
</tr>
<tr>
<td>New</td>
<td>$1,308,829</td>
<td>$372,428</td>
<td>$1,681,258</td>
</tr>
<tr>
<td>New-Old</td>
<td>$(47,815)</td>
<td>$(519,192)</td>
<td>$(567,007)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rates have burden and no escalation inc. above</td>
<td></td>
</tr>
<tr>
<td>Overhead</td>
<td></td>
<td>$88,263</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$(47,815)</td>
<td>$(607,455)</td>
<td>$(655,270)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contingency 40%</td>
<td>$(262,107.81)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$(917,377)</td>
</tr>
</tbody>
</table>

|                | FESS        |                                       |                      |
| Old Building scope reduction | $200,000 |                      |
| EDIA reduction  | $42,000   |                      |
| Indirects on EDIA reduction | $18,900 |                      |
| Indirects on scope reduction | $(260,900) | $(78,270.00) | $(339,170) |
|                | New Building Costs | $1,594,000 |                      |
| EDIA           | $334,740   |                      |
| Indirects on EDIA | $150,633 |                      |
| Indirects on new building cost | $95,000 | $2,174,373 | $652,311.90 | $2,826,685 |
|                | Net increase to project | $1.25M |                      |
|                |             |                                       | $1,570,138           |

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**Mu2e**

**Fermilab**
Reliability?

- Reliability of single point failure systems is irrelevant in the context of highly radioactive Remote Handling Systems
  - Must assume failure is a possibility
  - What do you do when that happens???

- For Remote Handling Systems
  - Impact of failure is necessary, regardless of reliability…
## Impact of Failure

- 24 possible failure conditions considered
  - Analysis done by M. Campbell, R. Schultz
  - First pass (not exhaustive)
  - Based on conceptual designs
  - System failure, not individual parts

- Rated 1-5
  - 1 = Low (Green) Easy to fix
  - 3 = Medium (Yellow) Difficult but possible
  - 5 = High (Red) Very difficult, unclear

- Side by side comparisons of both scheme’s
Impact of Failure

• Conclusions
  – Horizontal scheme will always have a higher Impact of Failure
    • Due to telescoping arm
    • Due to lack of flexibility that crane provides
    • Higher likelihood of operational downtime and expense
    • Recovery time from a 4/5 class failure could be months
  – Systems with fail safe (or redundancy) are strongly preferred
    • Probability of 2-point failures is very low, but it is still possible
    • Designs like this are not easy, nor always possible
Maintainability

• In engineering, Maintainability is the ease with which a product can be maintained in order to:
  – isolate/correct defects or their cause
  – repair/replace faulty or worn out components
    • without replacing still working parts
  – prevent unexpected breakdowns
  – maximize a product’s useful life
  – maximize efficiency, reliability and safety
  – make future maintenance easier
  – cope with a changed environment
Maintainability

• Remote handling systems need to be maintained:
  – General maintenance
  – Alterations, repairs
  – R&D
  – Trial and error
  – Operator practice time

• Experience at the C0 RHF hot cell:
  – Things take a LOT longer than expected in a radioactive environment: PPE, shielding, contamination controls, etc.
  – R&D, assembly, practicing, implementation, etc.
  – C0 is not constrained by beam operations
C0 RHF – Hot Cell

• Mu2e Target Hall RH will be similar to C0 hot cell - contaminated environment, radioactive material

• PPE & shielding required makes even the simplest task difficult

• Cameras lack depth of field
Maintainability

• Horizontal Scheme - Remote Handling Room
  – Is inaccessible during beam operations
  – Some equipment will be removed from the room
    • Electronics only?
    • Possibly entire robot
  – Assembly-disassembly of contaminated robot is time consuming
  – Any practice would have to be performed during shutdown
    • or on separate practice robot ($$$)
  – This setup will increase operational downtime
Maintainability

• Overhead Scheme - Remote Handling Area
  – Likely Accessible during beam operations

    – This *probably* allows for activities during operations
      • Assembly/disassembly
      • Repairs, alterations
      • Practice time!!!

    – Minimizes operational downtime
Operating Notes – vertical scheme service building access

Yellow box indicates remote handling equipment service area

Prompt dose rate 0.1-3 mrem/hr

Occupancy at the discretion of AD ES&H

Requires radiation work permit
## Target Change-out Time

<table>
<thead>
<tr>
<th>Task</th>
<th>Horizontal</th>
<th>Overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cool down &amp; shield block removal</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Install robot, controls, assembly, calibrate</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Operator training, practice, adjustments</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Target change</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Dismantle robot, controls, electronics</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Reinstall blocks, hatch</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td><strong>Days</strong></td>
<td><strong>25</strong></td>
<td><strong>15</strong></td>
</tr>
<tr>
<td><strong>Weeks</strong></td>
<td><strong>5</strong></td>
<td><strong>3</strong></td>
</tr>
</tbody>
</table>

- Overhead scenario allows access to robot during operations
  - Assembly & disassembly not necessary
  - Plenty of time for calibration, practice, adjustments, etc.
Maintainability

• Conclusions
  – Remote Handling systems
    • take time to maintain
    • take time to use due to contamination controls
    • take practice to use effectively
  – Overhead scheme will minimize operational downtime
    • ~3 weeks for target change-out
  – Horizontal scheme operations will take longer
    • ~5 weeks for target change-out
Overhead Advantages

• Target removal arm is non-telescoping
  – Less complex, less likely to fail, easier to mitigate problems

• Does not rely on floor level-ness

• More easily allows for Convectively Cooled target
  – Horizontal robot is not designed for 10’ long target
  – Would be difficult to retrofit for CC target after area is contaminated

• Overhead crane gives future flexibility

• Likely allows building access during beam operations
  – Robot/module setup, testing, operator practice time

• PS magnetic field
  – Overhead RH area estimates 10-30 Gauss
  – Horizontal RH area estimates 50-250 Gauss
Horizontal Advantages

- Costs less by $1.25M
Comparisons: Costs, Risks & Maintainability

• Costs
  – Overhead scheme increases TPC by $1.25M

• Technical Risks
  – Horizontal scheme has higher Impact of Mechanical Failure

• Maintainability
  – Overhead scheme will reduce change-out time due to probable access during beam operations
Charge to Review Committee

- Horizontal Scheme
  - Is baseline (horizontal) technically sound?
    - Risks, contingencies, radiological hazards been addressed?
- Overhead Scheme
  - Is alternative (overhead) technically sound?
    - Risks, contingencies, radiological hazards been addressed?
    - Are there significant advantages to warrant increased cost?
- Complete assessment of both schemes
  - not necessarily a choice or preference

- Ask for committee to meet and submit questions by 5:00
  - Design team will respond to questions Wednesday morning