Fermilab

Mu2e Remote Handling Review
Comparisons: Costs, Risks & Maintainability

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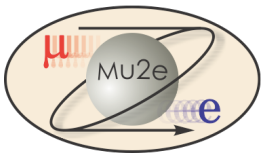


Comparisons: Costs, Risks & Maintainability

- Costs
  - TPC comparison - M. Gardner, M. Campbell
- Risks
  - Impact of mechanical failure – M. Campbell, R. Schultz
- Maintainability
  - Configuration & functional flexibility
- Conclusions

TPC Comparison

	M Campbell	Machine Savings						Total w/ Contingency
			Labor	Material	Total			
		Old	$ 1,356,644	$ 891,620	$ 2,248,264			
		New	$ 1,308,829	$ 372,428	$ 1,681,258			
		New-Old	$ (47,815)	$ (519,192)	$ (567,007)			
			Rates have burden and no escalation	Material rates are direct supplier costs	Net savings in current $	Contingency		
		Overhead	inc. above	$ (88,263)		40%		
		Total	$ (47,815)	$ (607,455)	$ (655,270)	$ (262,107.81)	$	(917,377)
	FESS					Contingency 30%		
		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)
						Contingency 30%		
	FESS	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

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

	Potential Failure Conditions (rad-cooled target)	Impact of Failure - Hoizontal (1 = low, 5 = high)		Impact of Failure - Overhead (1 = low, 5 = high)	
1	window Z-arm gets stuck w/ arm in retract position, not holding old window	1	return robot to RH room to clean/fix	1	lift module back to RH loft to clean/fix
2	window Z-arm gets stuck w/ arm in retract position, holding old window (hot)	3	can return robot to RH room and close the sliding door w/ people in the room behind temp shield wall, but no way to shield window while still being gripped, likely fixable w/ mirrors and long-handled or L-handled tools from behind the temp shield wall but would be difficult, then when that's done: send robot back into TH to dispose window into cask	2	close cask front door, dump air (cask rear door stays up and target stays gripped w/ air-pilot checkvalves), lift module back to RH loft, release 1st checkvalve to open gripper, pull arm to full retract w/ crane, release 2nd checkvalve to lower cask rear door, dispose cask as usual, then clean/fix module
3	window Z-arm gets stuck w/ arm in extend position, not holding window	2	robot cannot fit back thru door but can return robot to position just outside RH room doorway w/ people behind temp shield wall near doorway, likely fixable w/ mirrors and long-handled or L-handled tools	1	lift module back to RH loft to clean/fix
4	window Z-arm gets stuck w/ arm in extend position, holding old window (hot)	2	same as item-3 above	2	dump air (both cask doors stay up and target stays gripped w/ air-pilot checkvalves), lift module back to RH loft, pull arm to mid retract w/ crane, release 1st checkvalve to lower cask front door, release 2nd checkvalve to open gripper, pull arm to full retract w/ crane, release 3rd checkvalve to lower cask rear door, dispose cask as usual, then clean/fix module
5	target Z-arm gets stuck w/ arm in retract position, not holding old target	1	return robot to RH room to clean/fix	1	lift module back to RH loft to clean/fix
6	target Z-arm gets stuck w/ arm in retract position, holding old target (very hot)	4	robot can fit thru door but cannot bring into RH room since target too hot, could possibly drop target onto TH floor, return robot to RH room, close the sliding door, dismantle the robot, then design/build or buy a 2nd robot that can pick-up target from the TH floor and put into cask, then when that's done: re-install original robot (w/ arm repaired) to put in new target.	3	close cask front door, dump air (cask rear door stays up and target stays gripped w/ air-pilot checkvalves), release 1st checkvalve to open gripper, hook back of arm to far wall pulley and use winch down M4 line, retract, release 2nd checkvalve to lower cask rear door, lift module back to RH loft, dispose cask as usual, then clean/fix module
7	target Z-arm gets stuck w/ arm in extend position, not holding old target, arm is inside the PS (or cask in the robot scenario only)	5	robot is trapped inside the TH (no way to retract telescoping arm so cannot move on floor rails), possible solution: design/build a 2nd robot that can be set down next to the first one and attempt to repair the first one (or at least pull back its' telescoping arm) via cameras and remote control, install the 2nd robot by opening up TH ceiling hatch and lowering it into the TH from the outside w/ a rental boom-crane	3	dump air (both cask doors stay up w/ air-pilot checkvalves), hook back of arm to far wall pulley and use winch down M4 line, retract. lift module back to RH loft, then clean/fix module
8	target Z-arm gets stuck w/ arm in extend position, holding old target (very hot), arm is inside the PS (or cask in the robot scenario only)	5	Release target, see above.	3	Release target, see above.
9	window gripper gets stuck open or closed, not holding window	1	return robot to RH room to clean/fix	1	lift module back to RH loft to clean/fix
10	window gripper gets stuck closed, holding old window (hot), cannot let go of it	3	same as item-2 above	2	move arm to mid retract position, close cask front door, dump air (cask rear door stays up and window stays gripped w/ air-pilot checkvalves), lift module back to RH loft, release 1st checkvalve to vent the stuck gripper, pull arm to full retract w/ crane (cask will have features that prevent the window from passing thru the cask back opening, thus stripping it off), release 2nd checkvalve to lower cask rear door, dispose cask as usual, then clean/fix module
11	target gripper gets stuck open or closed, not holding target	1	return robot to RH room to clean/fix	1	lift module back to RH loft to clean/fix
12	target gripper gets stuck closed, holding old target (very hot), cannot let go of it	5	cannot bring robot into RH room since target too hot, so robot is trapped in the TH, possible solution: design/build a 2nd robot that can be set down next to the first one and attempt to repair the first one (or at least overpower its' grip mechanism and force it to release the target & drop it onto the TH floor) via cameras and remote control, install the 2nd robot by opening up TH ceiling hatch and lowering it into the TH from the outside w/ a rental boom-crane, then at this point, it becomes same as item-6 above	3	move arm to mid retract position, close cask front door, dump air (cask rear door stays up and window stays gripped w/ air-pilot checkvalves), release 1st checkvalve to vent stuck gripper, hook back of arm to far wall pulley and use winch down M4 line, retract, (cask will have features that prevent the window from passing thru the cask back opening, thus stripping it off), release 2nd checkvalve to lower cask rear door, lift module back to RH loft, dispose cask as usual, then clean/fix module
13	cask pneum door open/close motion gets stuck open or won't fully close	2	(assuming CD-2 design: cask resides in TH next to PS) may not be a problem until time comes to remove the cask (if/when full, using outdoor rental crane thru TH ceiling hatch), then will become a significant problem and we will need to somehow place a custom shield block with the crane to cover the open portion	2	lift off stuck door w/ crane, place a new one w/ crane (or fix the original and re-use), lift module back to RH loft, dispose cask as usual, then (if problem was w/ the lift cylinders) clean/fix module
14	overhead module A rotary bolt-circle axis gets stuck anywhere in its' range of travel			1	lift module back to RH loft to clean/fix
15	overhead gantry crane gets stuck in X, Y, or Z anywhere in its' range of travel			2	crane has redundant drives so an axis failure should be overcome by the redundant drive, then can move the crane to a safe position (away from any shine from the hatch), fix the axis, and resume operation
16	robot X or Y axis gets stuck anywhere in their range of travel, not holding anything	1	make sure both arms are retracted, return robot to RH room to clean/fix		
17	robot X or Y axis gets stuck anywhere in their range of travel, holding old window (hot)	3	will not be able to place old window into cask, so cannot let go of it, same as item-2 above		
18	robot X or Y axis gets stuck anywhere in their range of travel, holding old target (very hot)	4	will not be able to place old target into cask, so cannot let go of it, same as item-6 above		
19	robot floor rail axis gets stuck anywhere in its range of travel due to push/pull chain drive failure or linear position sensor failure, whether holding anything or not	1	can fix the problem inside the RH room		
20	robot floor rail axis gets stuck in the TH and cannot return to RH room due to linear bearing sieze-up / failure, not holding anything	5	robot is trapped inside the TH if cannot move on floor rails, possible solution: design/build a 2nd robot that can be set down next to the first one and attempt to dismantle its' attachment to the floor rails and cut all cabling via cameras and remote control tools, install the 2nd robot by opening up TH ceiling hatch and lowering it into the TH from the outside w/ a rental boom-crane, once first robot is separated, lift both robots out of the TH w/ the boom-crane, next: design/build a 3rd robot that can be lowered down into the TH via the boom-crane and perform the target exchange process, this 3rd robot would need to be used for all future target exchanges (always lowered thru the outdoor hatch)		
21	robot floor rail axis gets stuck in the TH and cannot return to RH room due to linear bearing sieze-up / failure, holding old window (hot)	5	same as item-21 above, except: first robot will be holding the old window as it is lifted out the TH hatch to the outside (thus requiring additional shielding and contamination control measures)		

Impact of Failure

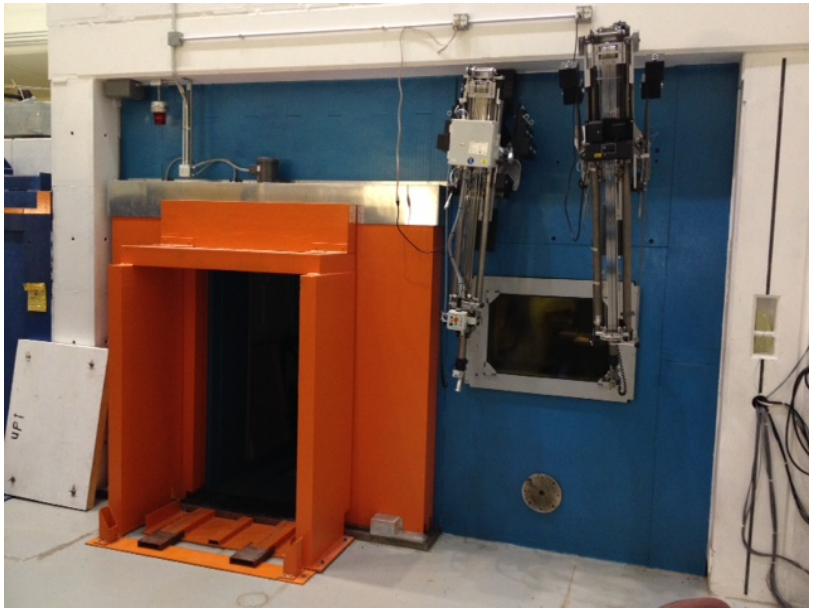
- Conclusions
  - Horizontal scheme will always have a higher Impact of Failure
    - Due to telescoping arm
    - Due to lack of flexibility that crane provides
    - Higher likelihood of operational downtime and expense
    - Recovery time from a 4/5 class failure could be months
  - Systems with fail 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

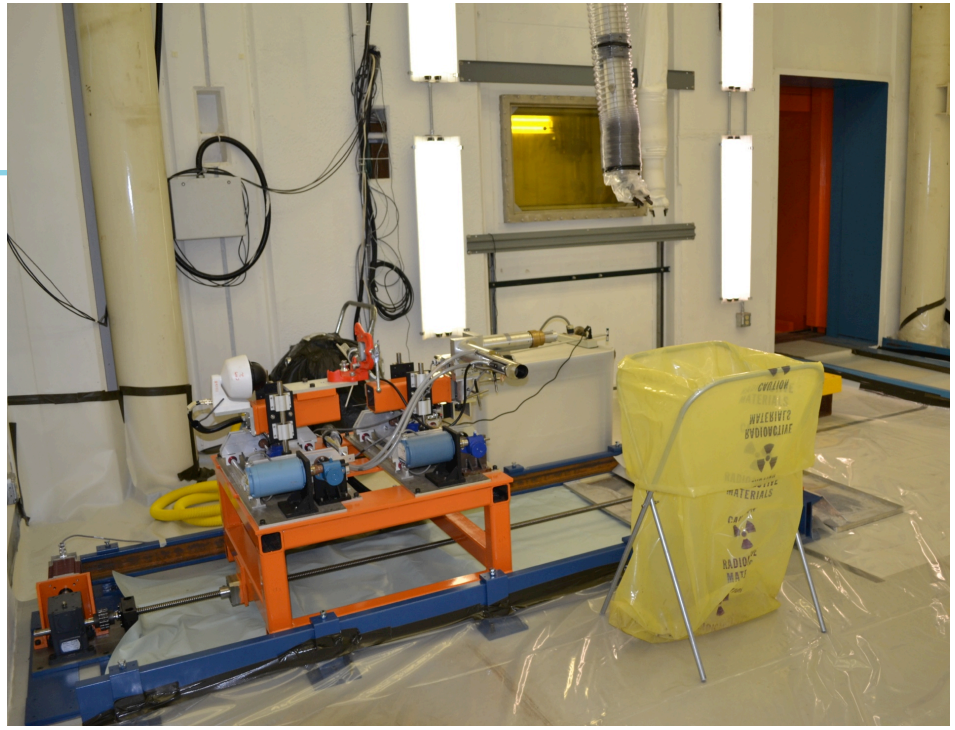
- Remote handling systems need to be maintained:
  - General maintenance
  - Alterations, repairs
  - R&D
  - Trial and error
  - Operator practice time

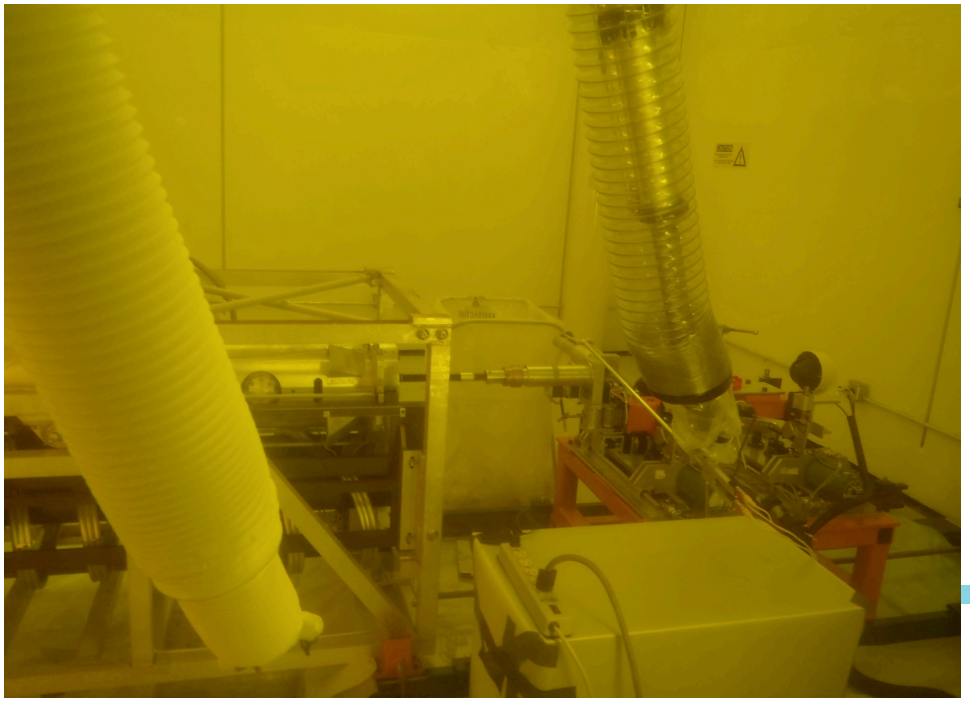


- Experience at the C0 RHF hot cell:
  - Things take a LOT longer than expected in a radioactive environment: PPE, shielding, contamination controls, etc.
  - R&D, assembly, practicing, implementation, etc.
  - C0 is not constrained by beam operations

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

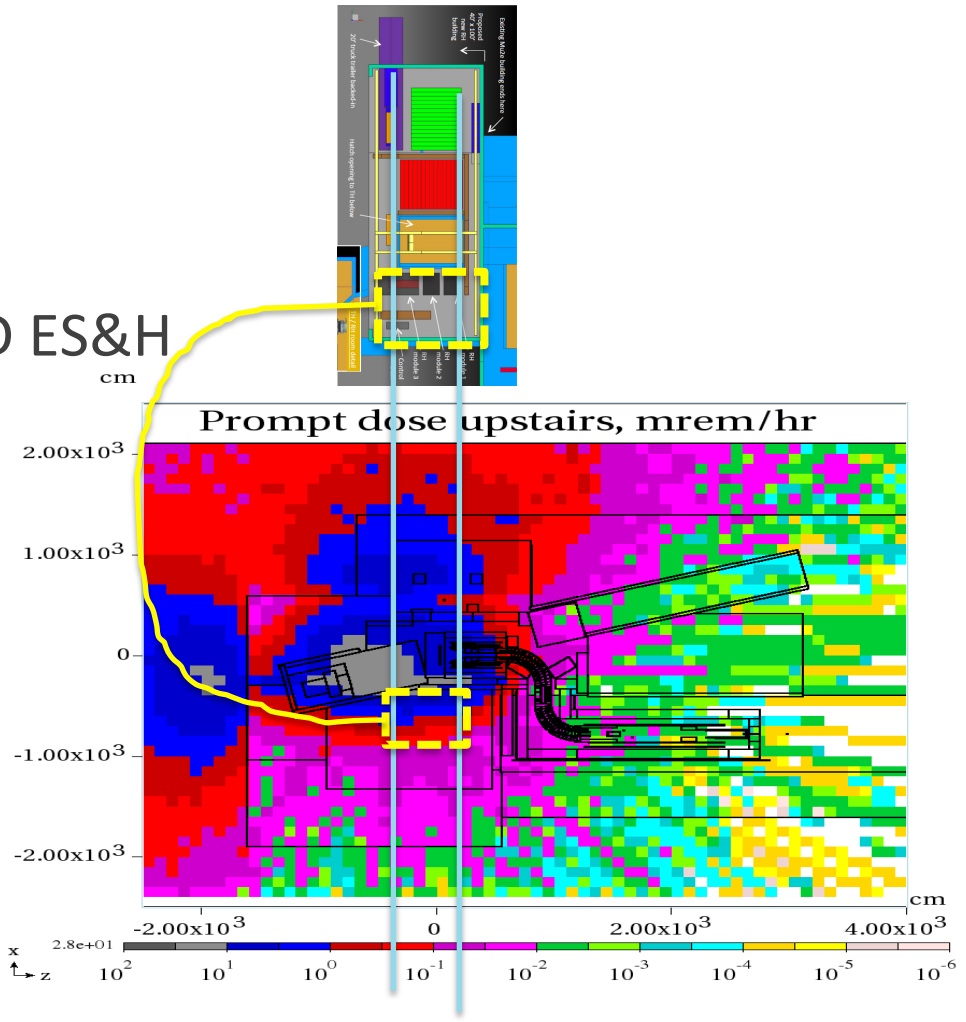
Operating Notes – vertical scheme service building access

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

	Horizontal	Overhead
Cool down & shield block removal	5	5
Install robot, controls, assembly, calibrate	6	-
Operator training, practice, adjustments	5	-
Target change	3	6
Dismantle robot, controls, electronics	4	-
Reinstall blocks, hatch	2	4
Days	**25**	**15**
Weeks	**5**	**3**

- 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