

Mu2e Risk Management Process for CD-2



Mike Dinnon Risk Manager 10/21/2014

Mike Dinnon

- 10 years experience at the lab
- Helped develop Fermilab Risk standards
- Worked with Fermilab Projects to develop risk programs (CMS, MicroBoone, Mu2e, LBNE)
- Currently also LBNE Risk Manager





Outline

- Introduction
- Risk Management
- Roles and Responsibilities
- Risk Identification
- Qualitative Analysis
- Quantitative Analysis
- Monitoring
- PRA Monte Carlo
- Cost Risk
- Schedule Risk
- Summary



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RISK MANAGEMENT DURING CD PHASES



Critical Decision Phases with continuous and iterative risk management.



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Risk Management

- Risk = an event with a probability to cause change in the project baseline and impact the project goals
 - Threat: a negative occurrence
 - Opportunity: a positive occurrence
- Goal of Risk Management is to reduce the project threats and capitalize on project opportunities while managing uncertainty
- Mu2e Risk Management plan
 - Based on best practices

http://mu2e-docdb.fnal.gov:8080/cgibin/ShowDocument?docid=461



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Risk Management

We follow established standard practices



- <u>http://science.energy.gov/opa/project-management/processes-and-procedures/</u>
- <u>http://www.fnal.gov/directorate/OPMO/OPMOhome.html</u>
- <u>http://www.pmi.org/PMBOK-Guide-and-Standards.aspx</u>



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Roles and Responsibilities

The Mu2e Project Manager is responsible for:

- Developing the Mu2e Risk Management approach
- Executing the risk mitigation strategy
- Scheduling periodic reviews of project risks
- Assuring that the risk analyses results are appropriately documented, tracked, and closed in the Mu2e Project Risk registry
- Approving, modifying, or assisting in risk abatement strategies
- Chairing the Risk Management Board



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Roles and Responsibilities

The Mu2e Level 2 managers are responsible for:

- Performing a risk analysis including identification of potential risks to the technical, cost, ES&H and schedule success of their WBS system; determining their likelihood of occurring; and estimating their potential impact on the project. This analysis is performed down to WBS level 3 or lower, as appropriate.
- Developing and executing risk mitigation strategies for their Level 2 system
- Informing the Mu2e Project Manager about the significant risks and the status of risk mitigation strategies in their WBS system





Roles and Responsibilities

The Mu2e Risk Manager is responsible for:

- Performing a risk analysis with Primavera Risk Analysis (PRA) on the RLS analyzing cost and schedule impact
- Coordinating risk meetings with the Project Manager and L2 managers
- Developing Risk presentations
- Maintaining risk information in a project risk register

Link: <u>Mu2e Risk Register</u>



Risk Identification

- Risk items are identified by team members and documented.
- Compilation is assembled and reviewed at the Subproject level then submitted to the Project Office.
 - Many meetings with L2's and PM to discuss impacts
 - Solenoids broken down further CD-2 Director's Review recommendation
- Risks are then combined and the Project decides on those risks to be included in the Project risk register.
- Currently Mu2e risk register contains 84 entries
 - 15 opportunities 69 Threats
 - \$6.495M Exposure At 80% Confidence



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• Initial Qualitative analysis of probability and impacts is recorded on a risk form and downloaded to the docdb.

Identifier:		New Mitigation Plan ASIC for the front-end b	Plan or Additional Risk Mitigation Measund boards.	res Description: Evaluate the suitability of
Hikk THE: The DNL VMM2 front-end ASIC can be used. Curver Biold Variant Cover Bi	Identifier; C. Dukes Risk Dv; VETO-160 Risk Ty: C. Dukes OPPORTUNITY OPPORTUNITY Date: 6/8/2014 Date revised:	Response Type (Accept, Reduce, Avoid, Transfer)	New or Additional Mitigation Schedu roid, Cost Range the miti (\$) 3 mile	le impact of undertaking gation plan – delays Level stone or project critical
Detailed Risk cause: Favorable evaluation of VMM2 modifications needed to make it meet requirements for the CRV. Detailed Risk cause: Favorable evaluation of VMM2 modifications needed to make it meet requirements for the CRV. WBS Affected: Other WBS Affected: Favorable evaluation of VMM2 modifications needed to make it meet requirements for the CRV. Intervent Risk Probability of muscal back from schedule) Current Risk Probability of muscal back from schedule) Favorable evaluation of VMM2 modifications for evaluations for evaluations for evaluation of VMM2 modifications for evaluations forevaluatio	Risk Title: The BNL VMM2 front-end ASIC can be used. Risk Description: We use a modified version of the VMM2 front-end ASIC in our front-endboards.	Accept	Low Bound Upper Bound Lower	path (Days) (H,MH,ML,L) Bound Upper Bound
With A available from steadule) With A available schedule) With A available rest Wi	Detailed Risk Cause: Favorable evaluation of VMM2 modifications needed to make it meet requirements for the CRV. Detailed Risk Effects substitution of the VMM2 ASIC for the ultra-sound chipin the front-end boards. WBS Affected: 475 08.05 Other WBS Affected: Actual Stat Date Actual Finish Date	Residual/Current RiskP Residual/ Current Probability (VH,H,M, L,VL) poptc	sk Probability and Impact Scores: Residual IF HIGH Schedule IMPACT, Residual Cost IMPACT, Residual Cost IMPACT, Residual Cost Impact Oper critical Schedule schedule IMPACT, Residual Cost Impact Impact (NH,M, L,VL) Schedule	If HIGH COST IMPACT, Upper Bound of Residual Cost Impact (S) Residual VH,H,M, L,VL) (S)
Initial Risk Analysis - (description disection dimpasts and probability) text englower with risk. complexity: Present analysis and robability is text englower with risk. Initial Risk Analysis - (description disection dimpasts and probability) text englower with risk. Initial Risk Probability and Impact scores selected from Mu2e Risk Management Plan (Mu2e doc-461) Tables 1 and 2. Point Estimate (mast (Description disection dimpasts scores selected from Mu2e Risk Management Plan (Mu2e doc-461) Tables 1 and 2. Initial Score Plan Mu2e Risk Management Plan (Mu2e doc-461) Tables 1 and 2. Initial Probability (Description dispast scores selected from Mu2e Risk Management Plan (Mu2e doc-461) Tables 1 and 2. Initial Score Plan Mu2e Risk Management Plan (Mu2e doc-461) Tables 1 and 2. Initial Score Plan Mu2e Risk Management Plan (Mu2e doc-461) Tables 1 and 2. Initial Probability (VH,HML,VL) probability (VH,HML,VL) path by dry (VH,HML,VL) path by dry (VH,HML,V	(when available (when available from from schedule) schedule) FY14 FY18	L (VH,H,I L V Additional Notes: At the boards.	VL VL VL VL tthe present the VMM2 ASIC appears to be too slip	N N low and hence is not favored for the front-end
Probability Impact (Correct of Correct Of Corre	Initial Risk Analysis – (description of selection of impacts and probability, text length commensurate with risk complexity). Prevent simulations are quite sophisticated and in sections include the flux from the entire run. Initial Risk Probability and Impact socress selected from Mu2e Risk Management Plan (Mu2e-doc-461) Tables 1 and 2 Initial Schedule II HIGH III Initial Schedule III HIGH IIII Initial Cost IIII Initial Schedule IIIII Initial Schedule IIIIIII Initial Cost IIIIIIIIII Initial Schedule IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	Point estimate (cost k\$) (Point Estimate (schedule-days) (probability)	EXPECTATION EXPECTATION VALUE IN k\$ IN Days
L VL VL N Exposure (What the risk will cost when it occurs); 550,000 surves N Initial fish, Mitgation Plan considered in the EntitleRisk Analysis and Induced in the Base Plan Cost and Schedule: Determine the detailed performance characteristics of the VMMZ. Base Plan Mitigation Cost (5) Base Plan Mitigation of Current Mitigation Plan Duration SO Start and Finish Dates	Probability Simescue of path by in days Opper bound forurent impact impact (VH,H,M,L,VL) of Current of current (S) impact (VH,H,M,L,VL) visit Schedule impact (VH,H,M,L,VL) (S) Impact (VH,H,M,L,VL) Impact (VH,H,M,L,VL)	(\$50,000)	0 20%	(\$10,000) 0
Determine the detailed performance characteristics of the VUMU2. Base Plan Mitigation Cost (s) Base Plan Mitigation cost Uncertainty (s) Start and Finish Dates or Description of Current Mitigation Plan Duration \$0 \$	L VL N N N Exposure (What the risk will costs when it occurs): \$50,000 savings Thitla Risk Milligation Plan considered in the Initial Risk Analysis and Included in the Base Plan Cost and Schedule:			
\$0	Determine the detailed performance characteristics of the VVM2. Base Plan Mitigation Cost (5) Base Plan Mitigation Cost (5) Description of Current Mitigation Plan Duration			
	\$0			



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• An overall risk score is given to each risk item by a composite of the impact and probability score.

Table 2: Risk Classification Matrix

			Impact		
Probability	Very	Low	Moderate	High	Very
	Low				High
Very High (> 90%)	Low	Moderate	High	High	High
High (75% - 90%)	Low	Moderate	Moderate	High	High
Moderate (25% - 75%)	Low	Low	Moderate	High	High
Low (10% - 25%)	Low	Low	Moderate	Moderate	High
Very Low (< 10%)	Low	Low	Low	Low	Moderate



Impact assessment table

Impact Risk	Very Low	Low	Moderate	High	Very High
Cost	< \$50K	\$50K - \$100K	\$100K - \$250K	\$250K - \$500K	> \$500K
ES&H	Negligible	Minimal	Concern	Significant risk	High risk
Schedule	Delays Level 3 milestone or Project critical path by < 1 month	Delays Level 3 milestone or Project critical path by 1 - 3 months	Delays Level 3 milestone or Project critical path by 3 - 6 months	Delays level 3 milestone or Project critical path by 6 – 9 months	Delays Level 3 milestone or Project critical path by > 9 months
Technical	Negligible	Negligible, if any, degradation.	Significant technical degradation.	Technical performance effectively useless for attaining physics objectives.	Technical performance useless for attaining physics objectives.

Table 1: Impact Assessment Matrix. Impacts range from Very Low to Very High.



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 Mike Dinnon – DOE CD2/3a Review

• The Risk Register is then populated with the data from the forms and the forms are hyperlinked in the register.

DocDb#-43	320	Next ID 205		
Risk		1	1	
Risk ID	Risk Form DocDb #	Туре	Title	Date of Risk
CAL-108	<u>3347</u>	Threat	INFN cannot deliver full in- kind scope.	FY16-FY20
CONST-049	<u>3351</u>	Opportunity	Conventional construction bids are lower than estimated cost.	FY15
PM-010	<u>3366</u>	Threat	Increase in Fermilab overhead rates	FY16-FY20
ACCEL-015	3331	Threat	Injection damper required for Delivery Ring	FY16-FY19
ACCEL-151	<u>3833</u>	Threat	Redesign the Remote Handling System for Water cooled target	FY16-FY18



The Risk register is then populated with the data supplied by Managers and Risk Owners to generate a Project Level risk contingency using point estimates

Risk	Contingency \$
	80%CL
\$	6,495,000

Н	17 High Risk Items
Ν/Ι	30 Medium Risk
IVI	Items
Ĺ	37 Low Risk Items

Opportunity	15 Opportunities -\$3M
Threat	69 Threats

Total	
Mitigation	\$ 8,542,000
Costs	



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Preparation for Full Risk Analysis

• The Project parameters are entered into PRA

Items in the	e scale 5 💌		Add Impact T	ypes D	elete Impac	t Type Items	in the scale	5 💌		
	Drobobility		Impact Type	es	Score?	Very Low	Low	Medium	High	Very High
	Probability		Schedule-De	elays Leve		<=30	>30	>90	>180	>270
Very High	>00%		Cost		\checkmark	<=\$50,000	>\$50,000	>\$100,000	>\$250,000	>\$500,000
very nign	/ 50 76					Negligible	Negligible, if	Significant	Technical	Technical
High	>75%		Technical				any, degradation.	degradation.	effectively useless for	useless for attaining
Medium	>25%		ES&H			Negligible	Minimal	Concern	Significant Risk	High Risk
Low	>10%									
Low Very Low	>10%									
Very Low	>10% <=10%		bability and Im	ipact Scoring	1 (PID)					
Low Very Low olerance Sc. Items in th	>10% <=10%	Pro	obability and Im	npact Scoring	g (PID) ————————————————————————————————————	pact O Avera	age of Impacts	C Average (of Individual Im	pact Scores
Low Very Low olerance Sc. Items in th	>10% <=10% cale he scale 3 💌	Pro	obability and In sk score is base	ipact Scoring ed on: ⓒ	g (PID)	pact C Avera	age of Impacts	O Average o	of Individual Im	pact Scores
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Low Very Low olerance Sc. Items in th	>10% <=10% cale he scale 3 • Color Score	Pro	obability and Im sk score is base	ipact Scoring ed on: © Impacts Very Low	g (PID) — Highest Im	pact C Avera	age of Impacts	C Average o	of Individual Im	pact Scores y High
Low Very Low olerance Sc. Items in th High	>10% <=10% tale the scale 3 • Color Score >23	Pro Ri	obability and Im sk score is base ary High %	ipact Scoring ed on: Impacts Very Low 5	g (PID) — Highest Im	pact C Avera Low 12	age of Impacts Medium 24	C Average of High	of Individual Im Ver 72	pact Scores y High
Low Very Low Olerance Sc. Items in th High	>10% <=10% tale the scale 3 • Color Score >23	Pro Ri Vi	obability and Im sk score is base ary High %	Ipact Scoring ed on: • Impacts Very Low 5 4	g (PID)	pact C Avera Low 12 5	age of Impacts Medium 24 14	C Average of High 36 28	of Individual Im Ver 72 56	pact Scores y High
Low Very Low Olerance Scco Items in th High High	>10% <=10% tale the scale 3 ▼ Color Score >23 >5	Pro Ri Vi Hi	obability and Im sk score is base ary High % igh % edium %	Ipact Scoring ed on: Impacts Very Low 5 4 3) (PID)	pact C Avera Low 12 5	age of Impacts Medium 24 14 10	C Average of High 36 28 24	of Individual Im Ver 72 56 40	pact Scores y High
Low Very Low olerance Scco Items in th High Medium	>10% <=10% tale the scale 3 ▼ Color Score >23 >5 >5	Pro Ri Hi Lo	obability and Im sk score is base ary High % igh % edium % ow %	ipact Scoring ad on: Impacts Very Low 5 4 3 2	g (PID)	pact C Avera Low 12 5 5	Medium 24 14 10 6	C Average of High 36 28 24 12	of Individual Im Ver 72 56 40 24	pact Scores y High

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Preparation for Full Risk Analysis

• The information is then input into the PRA tool to start the ranking and analysis process

			Pre-Mitigatio	on (Data Date	= 05/01/2014)			Post-mitigati	on				Details										
	T/O	Title	Probability	Schedule	. Cost Technical	E	Score	Probability	Schedule	. Cost Technical	E Sc	ore	Owner	Description	Cause	Effect	RBS	Status	Manageability	Proximity	Start Date	End Date	Expos
171	т	Production cable does not meet s	VL (5%)	H (225)	N N	N	4	VL (5%)	H (225)	N N	N 4		Unassigned					Proposed		Mid Term	09/03/2014	09/03/2014	
72	т	Magnet fabrication failure due to	VL (5%)	H (225)	VH M	N	8	VL (5%)	H (225)	VH M	N B		Unassigned					Proposed		Mid Term	09/03/2014	09/03/2014	_
73	т	Completed magnet does not pass	VL (5%)	M (135)	N N	N	2	VL (5%)	M (135)	N N	N 2		Unassigned					Proposed		Mid Term	09/03/2014	09/03/2014	_
74	т	Vendor delays not caused by FNAL	L (17%)	L (60)	N N	N	3	L (17%)	L (60)	N N	N 3		Unassigned					Proposed		Mid Term	09/03/2014	09/03/2014	_
75	т	Magnet is damaged during shippi	VL (5%)	H (225)	N N	N	4	VL (5%)	H (225)	N N	N 4		Unassigned					Proposed		Mid Term	09/03/2014	09/03/2014	
176	т	Operational failure during final ac	VL (5%)	VH (405)	VH N	N	8	VL (5%)	VH (405)	VH N	N B		Unassigned					Proposed		Mid Term	09/03/2014	09/03/2014	
77	т	Magnet Fabrication Failure due to	VL (5%)	M (135)	H N	N	4	VL (5%)	M (135)	H N	N 4		Unassigned					Proposed		Mid Term	09/03/2014	09/03/2014	
78	т	Completed magnet does not pass	VL (5%)	M (135)	N N	N	2	VL (5%)	M (135)	N N	N 2		Unassigned					Proposed		Mid Term	09/03/2014	09/03/2014	
79	т	Vendor delays not caused by FNAL	L (17%)	L (60)	N N	N	3	L (17%)	L (60)	N N	N 3		Unassigned					Proposed		Mid Term	09/03/2014	09/03/2014	
80	т	Magnet is damaged during shippi	VL (5%)	H (225)	N N	N	4	VL (5%)	H (225)	N N	N 4		Unassigned					Proposed		Mid Term	09/03/2014	09/03/2014	
181	т	Operational failure during final ac	VL (5%)	VH (405)	VH N	N	8	VL (5%)	VH (405)	VH N	N 8		Unassigned					Proposed		Mid Term	09/03/2014	09/03/2014	
32	т	Delay in FNAL supplied processes	L (17%)	L (60)	N N	N	3	L (17%)	L (60)	N N	N 3		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
33	т	Magnet fabrication failure due to	M (50%)	L (60)	M N	N	10	M (50%)	L (60)	M N	N 10		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
34	т	Vendor delays not caused by FNAL	L (17%)	L (60)	N N	N	3	L (17%)	L (60)	N N	N 3		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
35	т	Damage to the coil module during	VL (5%)	L (60)	M N	N	2	VL (5%)	L (60)	M N	N 2		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
186	т	Failure of design or fabrication of	VL (5%)	H (225)	H N	N	4	VL (5%)	H (225)	H N	N 4		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
87	т	Integrated module out of toleran	VL (5%)	L (60)	N N	N	1	VL (5%)	L (60)	N N	N 1		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
88	т	Final assembled magnet does not	VL (5%)	H (225)	H N	N	4	VL (5%)	H (225)	H N	N 4		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
189	т	Fermilab space or personnel reso	VL (5%)	M (135)	VH N	N	8	VL (5%)	M (135)	VH N	N 8		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	INFN cannot deliver full in-kind sc	L (17%)	N (0)	VH H	N	24	L (17%)	N (0)	VH H	N 24		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	0	Conventional construction bids ar	M (50%)	N (0)	VH N	N	40	M (50%)	N (0)	VH N	N 40		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Increase in Fermilab overhead rates	M (50%)	N (0)	VH N	N	40	M (50%)	N (0)	VH N	N 40		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Injection damper required for Deli	L (17%)	N (0)	N VH	N	24	L (17%)	N (0)	N VH	N 24		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Redesign the Remote Handling S	L (17%)	N (0)	VH M	N	24	L (17%)	N (0)	VH M	N 24		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Cannot develop UV-extended soli	M (50%)	N (0)	H N	N	24	M (50%)	N (0)	H N	N 24		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	ConventionI construction bids exc	L	N	VH N	N	0	L	N	VH N	N O		Unassigned					Managed(Cl.,		Overdue	05/01/2014	01/26/2022	
	т	Detector installation takes longer	M (50%)	M (135)	H N	N	24	M (50%)	M (135)	H N	N 24		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Construction funds not available	L	N	N N	N	0	L	N	N N	N O		Unassigned					Managed(Cl		Overdue	05/01/2014	01/26/2022	
	0	Commodity prices decrease	L (17%)	N (0)	VH N	N	24	L (17%)	N (0)	VH N	N 24		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Commodity prices escalate faster	L	N	VH N	N	24	L	N	VH N	N 24		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Interface problems with the solen	L	н	VH N	N	24	L	н	VH N	N 24		Unassigned					Open		Overdue	05/01/2014	01/26/2022	
	т	Insufficient testing of DS and/or	L	VH	VH N	N	24	L	VH	VH N	N 24		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Production Solenoid must be insta	м	N	H N	N	24	M	N	H N	N 24		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	0	Cryo Distribution Box Funded by	м	VH	VH N	N	40	M	VH	VH N	N 40		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Insufficient manpower for DAQ s	м	N	H N	N	24	M	N	H N	N 24		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	More CRV coverage is needed.	H (82%)	N (0)	VL N	N	4	H (82%)	N (0)	VL N	N 4		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	18 Tracker stations is inadequate	M	N	H M	N	24	M	N	н м	N 24		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Cannot use TLMs to control beam	L (17%)	N (0)	VH N	N	24	L(17%)	N (0)	VH N	N 24		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Additional resources required in P	L (17%)	N (0)	H N	N	12	L(17%)	N (0)	H N	N 12		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Mylar creep limits tracker lifetime	L (17%)	VL (15)	VL H	N	12	L (17%)	VL (15)	VL H	N 12		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Simulations indicate that neutron	L (17%)	N (0)	н н	N	12	L(17%)	N (0)	н н	N 12		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Can't control size and shape of fi	L (17%)	H (225)	н м	N	12	L(17%)	H (225)	н м	N 12		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	0	Fewer Resources than anticipate	L (17%)	N (0)	M N	N	6	L(17%)	N (0)	M N	N 6		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	0	Drop in price of COTS components	H (82%)	N (0)	L (N	N	6	H (82%)	N (0)	L (N	N 6		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	0	Drop in price of 3D printing	M (50%)	N (0)	M N	N	10	M (50%)	N (0)	M N	N 10		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Need to switch straw manufacturer	L (17%)	H (225)	VL N	N	12	L (17%)	H (225)	VL N	N 12		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Gain loss in tracker.	L (17%)	M (135)	H L	N	12	L (17%)	M (135)	H L	N 12		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	т	Detector support structure not s	L (17%)	N (0)	M M	N	6	L(17%)	N (0)	M M	N 6		Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	
	_		·. ·.	1111				1. L	1.1									1 1 1			-	1 1 1	
	_																						

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- Many different scenarios are run against the RLS to determine what effects the risk items have on the schedule.
- Estimate the impact on the project by using probability, cost impacts, schedule impacts, and mitigation plans.
- Determine the best action to reduce the risk effect
 - Develop Mitigations
 - Transfer Options
- Update the risk register with quantitative data and prepare to analyze the schedule.





Risk Monte Carlo using the PRA tool

1. Read in all the required input data to PRA

- Full RLS from P6 database
- Current Fermilab (labor + escalation) rates exported from Cobra
- Risk register entries from forms





Risk Monte Carlo using the PRA tool

2. Set up the MC using parameters from risk entries

- Cost and schedule impacts
- Link to RLS activities
- Correlations included in analysis

1.4								_									(
<	710	Title	Pre-Mitigatio	n (Data Date	e = 05/01/2014)		Pages	Mitigation	Tala	Total Cost	Post-mitiga	tion	Cash	Technical			Details	Managemental	Department	Charle Dates	Ford Date	Evenue Chaule Ou	
501-100	T	Puilding is Not Deadual Inable to s	Probability	Schedule	AL AL	E	5core	Assent	TKIO	Total Cost	40 M	Schedule	. Cost	Technical	E	10	Dropocod	manageacuty	Proximity	DE/01/2014	01/26/2022	snowin Qua	an Quarker
501-191		Crucosolics, Power, or Vacuum In	14	14	N N	N	10	Accept			\$0 M	M	DI DI	N	N	10	Proposed		Overdue	05/01/2014	01/26/2022	\$0 F	- H
501-192	T	Mappower not available to start c	M	10	N N	N	10	Accept			40 M	M	N	N	N	10	Proposed		Overdue	05/01/2014	01/26/2022	\$0	- H
501-193	T	Support Frames require major re-	1	10	I N	N	6	Accept			40 1	M	1	N	N	6	Proposed		Overdue	05/01/2014	01/26/2022	\$0 2	- H
SOL 194	T	Installation Tooling not adequate	L.	1	L N	N	3	Accept			40 1	1	i.	N	N	3	Proposed		Overdue	05/01/2014	01/26/2022	\$0 K	H
N-138	T	Detector installation takes longer	M	14	H N	N	24	Accept			40 M	M	н	N	N	24	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	— H
N-146	т	Rates exceed Muon Stopping Tar	M	N	M M	N	10	Accept			\$0 M	N	M	M	N	10	Proposed		Overdue	05/01/2014	01/26/2022	\$0	- H
₩-147	т	Degrader needed for calibration	M	N	MM	VL.	10	Accept			\$0 M	N	M	M	VL.	10	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	
05	T	Construction funds not available	L	N	N N	N	0	Accept			\$0 L	N	N	N	N	0	Managed(Cl.,		Overdue	05/01/2014	01/26/2022	\$0 2	
07	т	CD-4 float inadequate.	L	м	L N	N	6	Accept			10 L	M	L	N	N	6	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
38	т	Additional resources required in P	L	N	H N	N	12	Accept			\$0 L	N	н	N	N	12	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
09	0	Fewer Resources than anticipate	L	N	M N	N	6	Reject			\$0 L	N	M	N	N	6	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	
10	т	Increase in Fermilab overhead rates	м	N	VH N	N	40	Accept			\$0 M	N	VH	N	N	40	Proposed		Overdue	05/01/2014	01/26/2022	\$0 2	
18	т	Significant injury or death associa	VL.	н	VH N	VH	8	Accept			\$0 VL	н	VH	N	VH	8	Proposed	-	Overdue	05/01/2014	01/26/2022	\$0 🔽	
12	т	Currency fluctuations on foreign	L	N	VL N	N	2	Accept			\$0 L	N	VL	N	N	2	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	
53	0	Commodity prices decrease	L	N	VH N	N	24	Reject			\$0 L	N	VH	N	N	24	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗸	
54	т	Commodity prices escalate faster	L	N	VH N	N	24	Accept			\$0 L	N	VH	N	N	24	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
SOL-176	т	Operational failure during final ac	L	VH	VH N	N	24	Accept			\$0 L	VH	VH	N	N	24	Proposed		Mid Term	09/03/2014	09/03/2014	\$0 🗹	
5OL-171	т	Production cable does not meet s	L	н	N N	N	12	Accept			\$0 L	н	N	N	N	12	Proposed		Mid Term	09/03/2014	09/03/2014	\$0 🔽	
SOL-172	т	Magnet fabrication failure due to	L	н	VH M	N	24	Accept			\$0 L	н	VH	M	N	24	Proposed		Mid Term	09/03/2014	09/03/2014	\$0 🗸	
OL-173	т	Completed magnet does not pass	L	м	N N	N	6	Accept			\$0 L	M	N	N	N	6	Proposed		Mid Term	09/03/2014	09/03/2014	\$0 🔽	
50L-174	т	Vendor delays not caused by FNAL	M	L	N N	N	5	Accept			\$0 M	L	N	N	N	5	Proposed		Mid Term	09/03/2014	09/03/2014	\$0 🔽	
5OL-175	т	Magnet is damaged during shippi	VL.	н	N N	N	4	Accept			\$0 VL	н	N	N	N	4	Proposed		Mid Term	09/03/2014	09/03/2014	\$0 🔽	
070	т	Interface problems with the solen	L	н	VH N	N	24	Accept			\$0 L	н	VH	N	N	24	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	
080	т	Insufficient testing of DS and/or	L	N	N N	N	0	Accept			\$0 L	N	N	N	N	0	Rejected(Cl.		Overdue	05/01/2014	01/26/2022	\$0 🔽	
.37	т	Solenoid fringe field impacts perf	L	N	L L	VL.	3	Accept			\$0 L	N	L	L	VL	3	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
48	т	Production Solenoid must be insta	M	N	H N	N	24	Accept			\$0 M	N	н	N	N	24	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	
155	0	Cryo Distribution Box Funded by	M	VH	VH N	N	40	Exploit			\$0 M	N	N	N	N	0	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
K-091	т	Simulations indicate that tracker	VL.	N	N H	N	4	Accept			\$0 VL	N	N	н	N	4	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	
K-092	т	Need to switch straw manufacturer	L	н	VL N	N	12	Accept			\$0 L	н	VL	N	N	12	Proposed		Overdue	05/01/2014	01/26/2022	\$0 2	
K-096	т	Detector support structure not s	ī.	N	M M	N	6	Accept			\$0 L	N	M	M	N	6	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
K+097	т	Catastrophic mechanical failure o	VL.	VH	VH VH	N	8	Accept			40 VL	VH	VH	VH	N	8	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	
K-104	т	Gain loss in tracker.	L	м	H L	N	12	Accept			\$0 L	M	н	L	N	12	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
K-139	т	Mylar creep limits tracker lifetime	L	VL.	VL H	N	12	Accept			\$0 L	VL	VL.	н	N	12	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	
K-166	т	High crosstalk	M	N	L M	N	10	Accept			\$0 M	N	L	M	N	10	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	
K-167	0	Drop in price of COTS components	н	N	L N	N	6	Reject			\$0 H	N	L	N	N	6	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	
K-168	0	Drop in price of 3D printing	M	N	M N	N	10	Reject			\$0 M	N	M	N	N	10	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗸	
K-169	т	18 Tracker stations is inadequate	M	N	N M	N	10	Accept			\$0 M	N	N	M	N	10	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	
128	т	Insufficient manpower for DAQ s	м	N	H N	N	24	Accept			\$0 M	N	н	N	N	24	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
130	т	Insufficient DAQ online processing.	M	N	L N	N	5	Accept			\$0 M	N	L	N	N	5	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
131	т	Higher than expected data rates	M	N	L N	N	5	Accept			\$0 M	N	L	N	N	5	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	
132	0	Use of surplus equipment for DAO,	M	N	L N	N	5	Exploit			\$0 M	N	L	N	N	5	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	
134	0	Lower cost commercial PCIe card	м	N	L N	N	5	Reject			\$0 M	N	L	N	N	5	Proposed		Overdue	05/01/2014	01/26/2022	\$0 2	
135	0	Slow Controls development in co	L	N	L N	N	3	Exploit			\$0 L	N	L	N	N	3	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
136	0	Efficient Calorimeter Trigger redu	L	N	L N	N	3	Exploit			\$0 L	N	L	N	N	3	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
SOL-182	т	Delay in FNAL supplied processes	L	L	N N	N	3	Accept			\$0 L	L	N	N	N	3	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
SOL-186	т	Failure of design or fabrication of	L	н	H N	N	12	Accept			\$0 L	н	н	N	N	12	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
SOL-187	т	Integrated module out of toleran	L	L	N N	N	3	Accept			\$0 L	L	N	N	N	3	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
SOL-188	т	Final assembled magnet does not	L	н	H N	N	12	Accept			40 L	н	н	N	N	12	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🔽	
SOL-189	т	Fermilab space or personnel reso	VL	м	VH N	N	8	Accept			\$0 VL	M	VH	N	N	8	Proposed		Overdue	05/01/2014	01/26/2022	\$0 🗹	
01-183		Manager & Calculation Calling and the			100 10		10															40 17	

ected risk: PM-048 - Significant injury or death associated with Mu2e construction/assembly.



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🛠 Fermilab

Risk Monte Carlo using the PRA tool

3. Run the Monte Carlo

- Throw the dice based on inputs
- Create risk scenarios and run many iterations

| 1.001740 PP. Assemble 1.001740 PP. Assemble 1.001750 PP. Engineerin; 1.001700 PP. Engineerin; 1.001700 PP. Engineerin; 1.001700 PP. Tent Tsu Min 1.001700 PP. Tent Tsu Min 1.001700 PP. Tent Tsu Min 1.001800 Tent Tsu Ming 1.001802 Prepare Tsu min 1.001803 Text Assemble 1.001804 Tsu Ming | ISU Magnet - MAS
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| 0.01770 PP: Engineerin 0.01770 PP: Propare te 0.01780 PP: Test TSu May 0.01810 Test TSu May 0.01810 Complete test 0.01820 Prepare TSu may 0.01810 Complete test 0.01830 Deliver TSu may 1.001840 TA - TSu may TSG Assemb VWte assemb | Note Approval - TSu
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 |
| .001780 PP. Prepare to .001780 PP. Test TSu M .001800 Test TSu Magn .001800 Complete test .001830 Prepare TSu m .001830 Deliver TSu magn .001840 T4 - TSu magn .001840 Ydt assemb .001830 Vitte assemb | st plan documentation - TSu
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ieport
agnet for installation and delivery
gnet to the Mu2e Experimental Ha
net ready for installation | to the Mu2e Exp | 10
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 | None (ASAP) | | | | \$0 | \$0
 | \$9,809 | \$9,809 | \$9,809 | \$9,809 |
 |
| 1.001790 PP: Test TSu M 1.001800 Test TSu Megr 1.001810 Complete test 1.001820 Prepare TSu m 1.001830 Deliver TSu ms 1.001840 T4 - TSu magr 1.001840 TSd Assembly 2.001346 Write assembly | egnet - Lebor
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| 1.001800 Test TSu Megr 1.001810 Complete test 1.001820 Prepare TSu m 1.001830 Deliver TSu m 1.001840 T4 - TSu mag TSI Assemble 2001348 2.001348 Write assemble | et - MSS
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 | (B) | |
 | None (ASAP) | | | | 50 | \$0
 | \$135,530 | \$135,530 | \$135,530 | \$135,530 |
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| .001810 Complete test .001820 Prepare TSu m .001830 Deliver TSu mag .001840 T4 - TSu mag .001348 Write assembly | eport
agnet for installation and delivery
gnet to the Mu2e Experimental Ha
net ready for installation | to the Mu2e Exp | 10 | 01/14/2019 |

 | | 39 | 165
 | None (ASAP) | | | | \$0 | \$0
 | \$99.053 | \$99.053 | \$99.053 | \$99,053 |
 |
| 1.001820 Prepare TSum 1.001830 Deliver TSum 1.001830 T4 - TSum 1.001840 T4 - TSum 1.501840 Virite assembly | agnet for installation and delivery
gnet to the Mu2e Experimental Ha
net ready for installation | to the Mu2e Exp | | | 01/28/2019

 | CB | | 126
 | None (ASAP) | | | | \$0 | \$0
 | \$10,133 | \$10,133 | \$10,133 | \$10,133 |
 |
| 1.001830 Deliver TSu ma
1.001840 T4 - TSu mag
TSd Assemb
2.001348 Write assembly | gnet to the Mu2e Experimental Ha | | 15 | 01/29/2019 | 02/18/2019

 | CB | | 126
 | None (ASAP) | | | | \$0 | \$0
 | \$27,242 | \$27,242 | \$27,242 | \$27,242 |
 |
| 1.001840 T4 - TSu mag
TSd Assemb
2.001348 Write assembl | net ready for installation | 4 | 10 | 02/19/2019 | 03/04/2019

 | св | | 126
 | None (ASAP) | | | | \$0 | \$0
 | \$6,898 | \$6,898 | \$6,898 | \$6,898 |
 |
| TSd Assemb
2.001348 VVrite assembl | | | 0 | | 03/04/2019

 | | 123 | 126
 | None (ASAP) | | | | \$0 | \$0
 | \$0 | \$0 | \$0 | \$0 |
 |
| 2.001348 VVrite assembl | ly | | 1989 | 05/02/2014 | 10/11/2019

 | - | 0 | 0 0
 | None (ASAP) | | | | \$0 | \$0
 | \$1,823,368 | \$1,823,368 | \$1,823,368 | \$1,823,368 |
 |
| | travelers | | 130 | 01/03/2017 | 07/06/2017

 | CB | 0 | 220
 | None (ASAP) | • | | | \$0 | \$0
 | \$165,988 | \$165,988 | \$165,988 | \$165,988 |
 |
| 2.001350 Review and re | vise travelers | | 20 | 07/07/2017 | 08/03/2017

 | св | | 220
 | None (ASAP) | | | | \$0 | \$0
 | \$26,396 | \$26,396 | \$26,396 | \$26,396 |
 |
| 2.001360 Approve trave | lers | | 5 | 08/04/2017 | 08/10/2017

 | св | 220 | 220
 | None (ASAP) | | | | \$0 | \$0
 | \$2,449 | \$2,449 | \$2,449 | \$2,449 |
 |
| 2.001520 Prepare Engine | ering Notes - TSd | | 20 | 11/10/2017 | 12/11/2017

 | Risk Analysis | s |
 | | | × | | \$0 | \$0
 | \$19,619 | \$19,619 | \$19,619 | \$19,619 |
 |
| 2.001530 Engineering No | te Review - TSd | | 20 | 12/12/2017 | 01/12/2018

 | | |
 | | | | | \$0 | \$0
 | \$9,809 | \$9,809 | \$9,809 | \$9,809 |
 |
| 2.001533 Engineering No | te Approval - TSd | | 10 | 06/29/2018 | 07/13/2018

 | Analyze fi | ior [] | - ite
 | rations | | | | \$0 | \$0
 | \$3,924 | \$3,924 | \$3,924 | \$3,924 |
 |
| 2.001540 PP: Assemble | rSd Magnet - Labor | | 250 | 06/28/2018 | 06/26/2019

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 | raciona | | | | \$0 | \$0
 | \$1,293,415 | \$1,293,415 | \$1,293,415 | \$1,293,415 |
 |
| 2.001550 PP: Assemble | rSd Magnet - M&S | | 1 | 06/28/2018 | 06/28/2018

 | □ Show | step throu | gh analysis
 | option | | | | \$0 | \$0
 | \$12,949 | \$12,949 | \$12,949 | \$12,949 |
 |
| 2.001570 PP: Prepare te | st plan documentation - TSd | | 10 | 07/16/2018 | 07/27/2018

 | | |
 | | | | | \$0 | \$0
 | \$9,809 | \$9,809 | \$9,809 | \$9,809 |
 |
| 2.001580 PP: Test TSd M | agnet - Labor | | 40 | 06/27/2019 | 08/22/2019

 | I♥ Show | Distributio | on Graph
 | | | | | \$0 | \$0
 | \$135,530 | \$135,530 | \$135,530 | \$135,530 |
 |
| 2.001590 Test TSd Magn | et - M&S | | 1 | 06/27/2019 | 06/27/2019

 | Last Analy | vsis Time: (| 01:26:31
 | | Options | . 1 | | \$0 | \$0
 | \$99,053 | \$99,053 | \$99,053 | \$99,053 |
 |
| 2.001600 Complete TS to | st report | | 10 | 08/23/2019 | 09/06/2019

 | Case many | ,55 11101 1 | 01120101
 | | · · · · | | | \$0 | \$0
 | \$10,133 | \$10,133 | \$10,133 | \$10,133 |
 |
| 2.001610 Prepare TSd m | agnet for installation and delivery | to the Mu2e Exp | 15 | 09/09/2019 | 09/27/2019

 | | |
 | Analyze | Cancel | | | \$0 | \$0
 | \$27,242 | \$27,242 | \$27,242 | \$27,242 |
 |
| 2.001620 Deliver TSd ma | gnet to the Mu2e Experimental Ha | 1 | 10 | 09/30/2019 | 10/11/2019

 | | |
 | | · | | | \$0 | \$0
 | \$7,051 | \$7,051 | \$7,051 | \$7,051 |
 |
| 2.001630 T4 - TSd mag | net ready for installation | | 1368 | 05/02/2014 | 10/11/2019

 | | 0 |) 0
 | None (ASAP) | | | | \$0 | \$0
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| l.2.001630:1 T4 - TSd mag | net ready for installation | | 0 | | 10/11/2019

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 | None (ASAP) | 10/11 | /2019 | | \$0 | \$0
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 |
| .2.001630:T Failure of desig | gn or fabrication of Fermilab desig | ned cryogenic s | 0 | 10/14/2019 | 10/11/2019

 | | C |) 0
 | None (ASAP) | 1 | | | \$0 | \$0
 | \$0 | \$0 | \$0 | \$0 |
 |
| 2 001630 T Final assemble | d magnet does not perform as de- | signed | 0 | 10/14/2019 | 10/11/2019

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 | \$173.425.327 | \$173,425,327 | \$218 421 992 | \$249,424,992 |
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Full Risk Monte Carlo using the PRA tool

4. Analyze the data





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Cost Risk



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Cost Risk



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Cost Risk

• Risk Register entries

Risk ID	Risk Form DocDb #	Туре	Title	Probabili ty	Schedule- Delays Level 3 Milestone or Project Critical Path by X Days	Cost	Technical	ES&H	Score	Point estimate (cost k\$)
601.476	<u>4561</u>	These	Operational failure during final acceptance tests at	VL	VH	VH	N	N	м	\$ 4,500
SOL-176	<u>4566</u>	Threat	FNAL. Operational failure during final acceptance tests at FNAL.	VL	νн	VH	N	N	м	\$ 4,500
SOL-186	<u>4571</u>	Threat	Failure of design or fabrication of Fermilab designed cryogenic system	VL	Н	Н	N	N	L	\$ 2,500
SOL-172	<u>4557</u>	Threat	DS Magnet fabrication failure due to process or component	VL	Н	VH	М	Ν	М	\$ 4,000
SOL-070	<u>3368</u>	Threat	Interface problems with the solenoids.	L	Н	VH	N	Ν	Н	\$ 1,000





Schedule Risk



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Schedule Risk



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27 Mike Dinnon – DOE CD2/3a Review

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Schedule Risk

• Risk Register Entries

Risk ID	Risk Form DocDb #	Туре	Title	Probabili ty	Schedule- Delays Level 3 Milestone or Project Critical Path by X Days	Cost	Technical	ES&H	Score	Point estimate (cost k\$)
	4561		Operational failure during	VI	VH	νн	N	N	М	Ś 4.500
SOL-176	4501	Threat	FNAL.			VII				ү _т ,500
			Operational failure during							
	<u>4566</u>		final acceptance tests at	VL	VH	VH	N	Ν	М	\$ 4,500
SOL-181		Threat	FNAL.							
			Final assembled magnet							
	<u>4573</u>		does not perform as	VL	Н	Н	N	Ν	L	\$ 2,500
SOL-188		Threat	designed							
			Failure of design or							
	<u>4571</u>		fabrication of Fermilab	VL	Н	Н	N	Ν	L	\$ 2,500
SOL-186		Threat	designed cryogenic system							
	1570		Support Frames require		NA		N	N		ć 1 100
SOL-193	4376	Threat	major rework		IVI		IN	IN	L	Ş 1,100

Mu2e



Top Risk Drivers

Common to Cost and Schedule

Risk ID	Risk Form DocDb #	Туре	Title	Probabili ty	Schedule- Delays Level 3 Milestone or Project Critical Path by X Days	Cost	Technical	ES&H	Score	Point estimate (cost k\$)
			Operational failure during							
	<u>4561</u>		final acceptance tests at	VL	VH	VH	Ν	Ν	М	\$ 4,500
SOL-176		Threat	FNAL.							
			Operational failure during							
	<u>4566</u>		final acceptance tests at	VL	VH	VH	N	Ν	М	\$ 4,500
SOL-181		Threat	FNAL.							
			Failure of design or							
	<u>4571</u>		fabrication of Fermilab	VL	н	Н	N	Ν	L	\$ 2,500
SOL-186		Threat	designed cryogenic system							

Fermilab

10/21/14



Monitoring

- The risk owner has a significant role in risk monitoring.
- The risk owner will update information on the risk item's form promptly following recognition. The risk form revision is submitted to the Risk Manager who assigns the change for review with the PM. Upon approval of the change, the Risk Manager will update the Risk Register accordingly.
- After CD-2, the Risk Manager will prepare a monthly report that identifies any and all changes to the Risk Register in the previous month for discussion with the RMB.



Updates since CD-1

- Updated solenoid analysis at a more granular level helps to differentiate the risk between the DS, TS and PS
- 55 risk events retired or transferred to operations
- 6 opportunities realized at a savings of \$1.7M
- > \$8.5M spent to mitigate risks
- Realized Accelerator and Tracker Opportunities and merged them into the schedule
- Expanded analysis to include cost delta of risk events





Summary

- Mu2e has a solid foundation of risk entries that all members have agreed on.
- A Risk Management Plan has been developed by the project and established a robust risk management process.
- Risk items have been evaluated qualitatively and quantitatively.
- Risks have been simulated in the full RLS using the PRA MC to <u>support</u> Project cost and schedule risk estimates.
- The Mu2e Project can be completed on time within budget with:
 - Risk Contingency of \$ 6.495M
 - Schedule float of 24 months



Thank You



