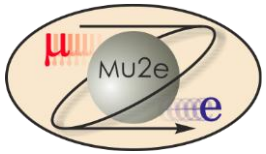
Fermilab

Mu2e Risk Management Process for CD-2



Mike Dinnon
Risk Manager
10/21/2014

Introduction

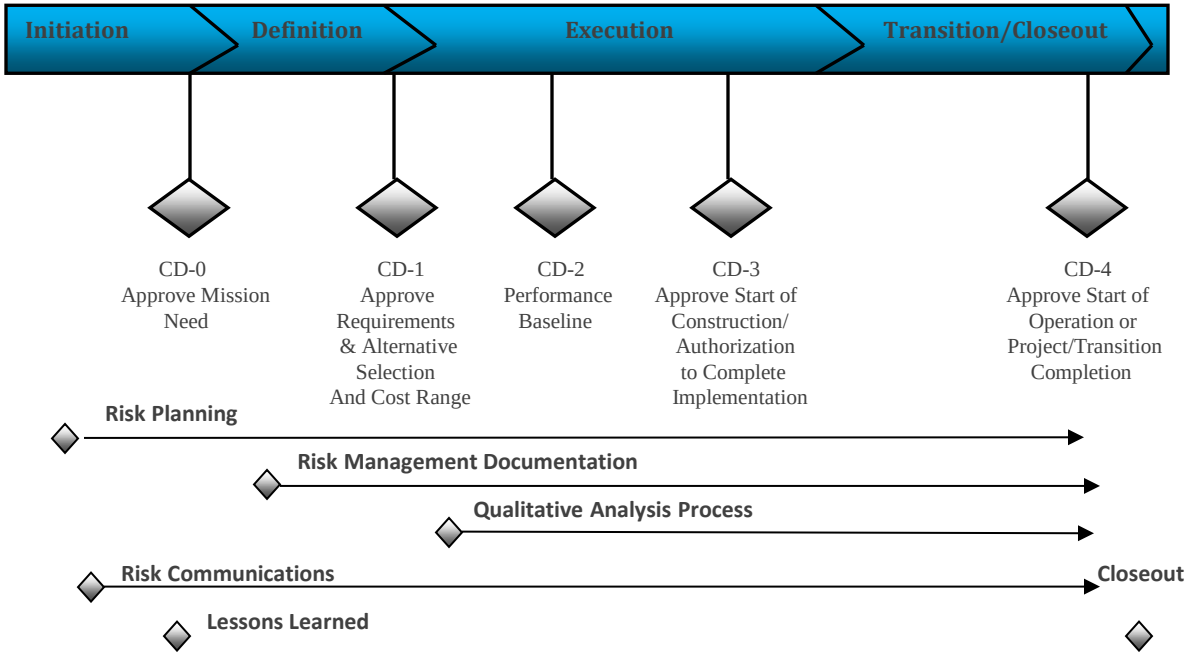
Mike Dinnon

- 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

RISK MANAGEMENT DURING CD PHASES



Critical Decision Phases with continuous and iterative risk management.

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

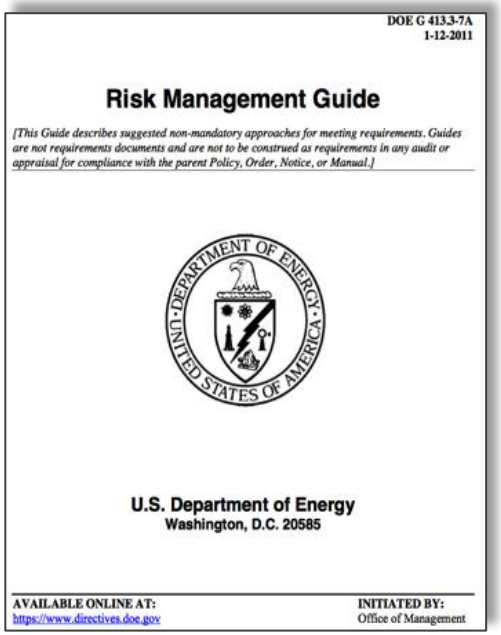
- Goal of Risk Management is to reduce the project threats and capitalize on project opportunities while managing uncertainty

- Mu2e Risk Management plan
  - Based on best practices

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

Risk Management

- We follow established standard practices



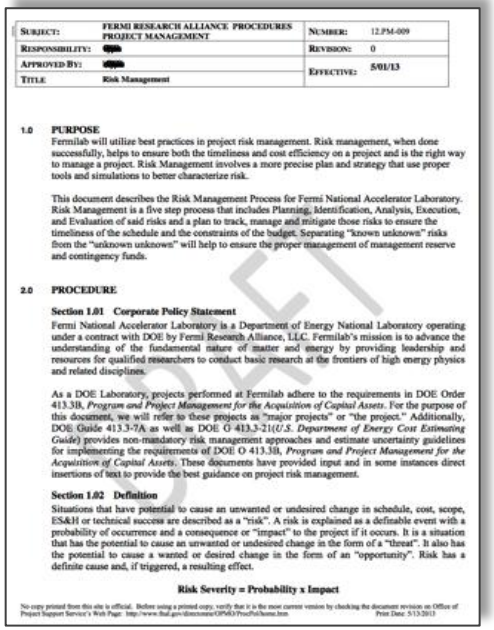
DOE G 413.3-7A
1-12-2011

Risk Management Guide

[This Guide describes suggested non-mandatory approaches for meeting requirements. Guides are not requirements documents and are not to be construed as requirements in any audit or appraisal for compliance with the parent Policy, Order, Notice, or Manual.]

U.S. Department of Energy
Washington, D.C. 20585

AVAILABLE ONLINE AT: https://www.directives.doe.gov
INITIATED BY: Office of Management



SUBJECT:	FERMI RESEARCH ALLIANCE PROCEDURES PROJECT MANAGEMENT	NUMBER:	12.PM-009
RESPONSIBILITY:	[redacted]	REVISION:	0
APPROVED BY:	[redacted]	EFFECTIVE:	5/01/13
TITLE	Risk Management		

1.0 PURPOSE

Fermilab will utilize best practices in project risk management. Risk management, when done successfully, helps to ensure both the timeliness and cost efficiency on a project and is the right way to manage a project. Risk Management involves a more precise plan and strategy that use proper tools and simulations to better characterize risk.

This document describes the Risk Management Process for Fermi National Accelerator Laboratory. Risk Management is a five step process that includes Planning, Identification, Analysis, Execution, and Evaluation of said risks and a plan to track, manage and mitigate those risks to ensure the timeliness of the schedule and the constraints of the budget. Separating "known unknowns" risks from the "unknown unknown" will help to ensure the proper management of management reserve and contingency funds.

2.0 PROCEDURE

Section 1.01 Corporate Policy Statement

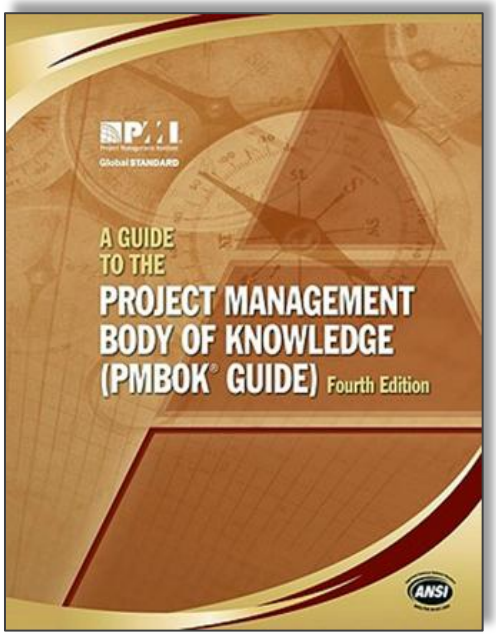
Fermi National Accelerator Laboratory is a Department of Energy National Laboratory operating under a contract with DOE by Fermi Research Alliance, LLC. Fermilab's mission is to advance the understanding of the fundamental nature of matter and energy by providing leadership and resources for qualified researchers to conduct basic research at the frontiers of high energy physics and related disciplines.

As a DOE Laboratory, projects performed at Fermilab adhere to the requirements in DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*. For the purpose of this document, we will refer to these projects as "major projects" or "the project." Additionally, DOE Guide 413.3-7A as well as DOE G 413.3-21(*U.S. Department of Energy Cost Estimating Guide*) provides non-mandatory risk management approaches and estimate uncertainty guidelines for implementing the requirements of DOE O 413.3B, *Program and Project Management for the Acquisition of Capital Assets*. These documents have provided input and in some instances direct insertions of text to provide the best guidance on project risk management.

Section 1.02 Definition

Situations that have potential to cause an unwanted or undesired change in schedule, cost, scope, ES&H or technical success are described as a "risk". A risk is explained as a definable event with a probability of occurrence and a consequence or "impact" to the project if it occurs. It is a situation that has the potential to cause an unwanted or undesired change in the form of a "threat". It also has the potential to cause a wanted or desired change in the form of an "opportunity". Risk has a definite cause and, if triggered, a resulting effect.

Risk Severity = Probability x Impact



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

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

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:

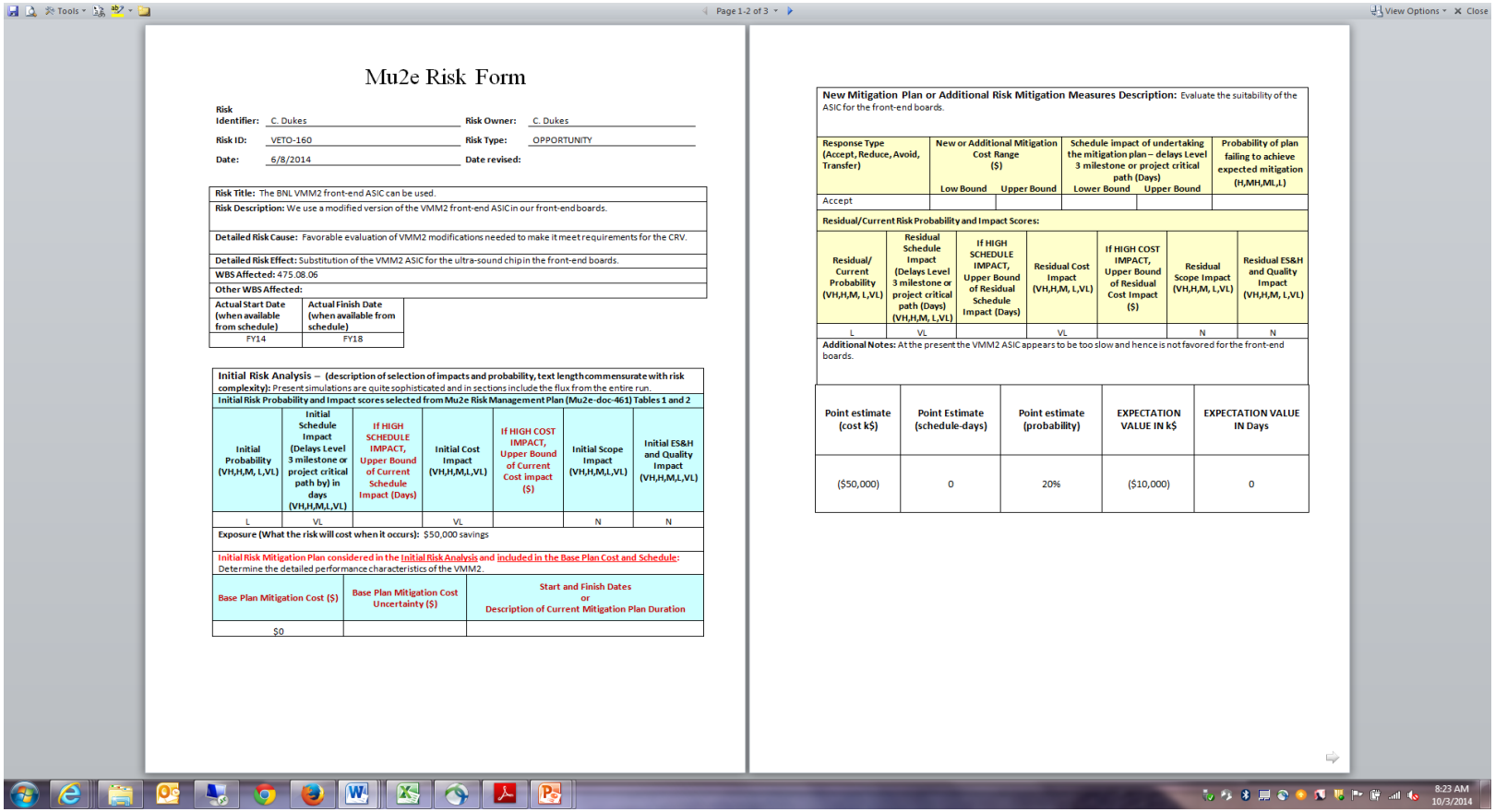
Mu2e Risk Register

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

Qualitative Analysis

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



Mu2e Risk Form

Risk Identifier: C. Dukes | **Risk Owner:** C. Dukes

Risk ID: VETO-160 | **Risk Type:** OPPORTUNITY

Date: 6/8/2014 | **Date revised:**

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-end boards.

Detailed Risk Cause: Favorable evaluation of VMM2 modifications needed to make it meet requirements for the CRV.

Detailed Risk Effect: Substitution of the VMM2 ASIC for the ultra-sound chip in the front-end boards.

WBS Affected: 475.08.06

Other WBS Affected:

Actual Start Date (when available from schedule)	Actual Finish Date (when available from schedule)
FY14	FY18

Initial Risk Analysis – (description of selection of impacts and probability, text length commensurate with risk complexity): Present simulations are quite sophisticated and in sections include the flux from the entire run.

Initial Risk Probability and Impact scores selected from Mu2e Risk Management Plan (Mu2e-doc-461) Tables 1 and 2

Initial Probability (VH,H,M, L,VL)	Initial Schedule Impact (Delays Level 3 milestone or project critical path by) in days (VH,H,M,L,VL)	If HIGH SCHEDULE IMPACT, Upper Bound of Current Schedule Impact (Days)	Initial Cost Impact (VH,H,M,L,VL)	If HIGH COST IMPACT, Upper Bound of Current Cost impact ($)	Initial Scope Impact (VH,H,M,L,VL)	Initial ES&H and Quality Impact (VH,H,M,L,VL)
L	VL		VL		N	N

Exposure (What the risk will cost when it occurs): $50,000 savings

Initial Risk Mitigation Plan considered in the Initial Risk Analysis and included in the Base Plan Cost and Schedule: Determine the detailed performance characteristics of the VMM2.

Base Plan Mitigation Cost ($)	Base Plan Mitigation Cost Uncertainty ($)	Start and Finish Dates or Description of Current Mitigation Plan Duration
$0		

New Mitigation Plan or Additional Risk Mitigation Measures Description: Evaluate the suitability of the ASIC for the front-end boards.

Response Type (Accept, Reduce, Avoid, Transfer)	New or Additional Mitigation Cost Range ($) Low Bound	Upper Bound	Schedule impact of undertaking the mitigation plan – delays Level 3 milestone or project critical path (Days) Lower Bound	Upper Bound	Probability of plan failing to achieve expected mitigation (H,MH,Ml,L)
Accept					

Residual/Current Risk Probability and Impact Scores:

Residual/ Current Probability (VH,H,M, L,VL)	Residual Schedule Impact (Delays Level 3 milestone or project critical path (Days) (VH,H,M, L,VL)	If HIGH SCHEDULE IMPACT, Upper Bound of Residual Schedule Impact (Days)	Residual Cost Impact (VH,H,M, L,VL)	If HIGH COST IMPACT, Upper Bound of Residual Cost Impact ($)	Residual Scope Impact (VH,H,M, L,VL)	Residual ES&H and Quality Impact (VH,H,M, L,VL)
L	VL		VL		N	N

Additional Notes: At the present the VMM2 ASIC appears to be too slow and hence is not favored for the front-end boards.

Point estimate (cost k$)	Point Estimate (schedule-days)	Point estimate (probability)	EXPECTATION VALUE IN k$	EXPECTATION VALUE IN Days
($50,000)	0	20%	($10,000)	0

Qualitative Analysis

- 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**	**Low**	**Moderate**	**High**	**Very 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

Qualitative Analysis

- Impact assessment table

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

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.

Qualitative Analysis

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

DocDb#-4320 Next ID 205

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

Qualitative Analysis

- 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

H	17 High Risk Items
M	30 Medium Risk Items
L	37 Low Risk Items

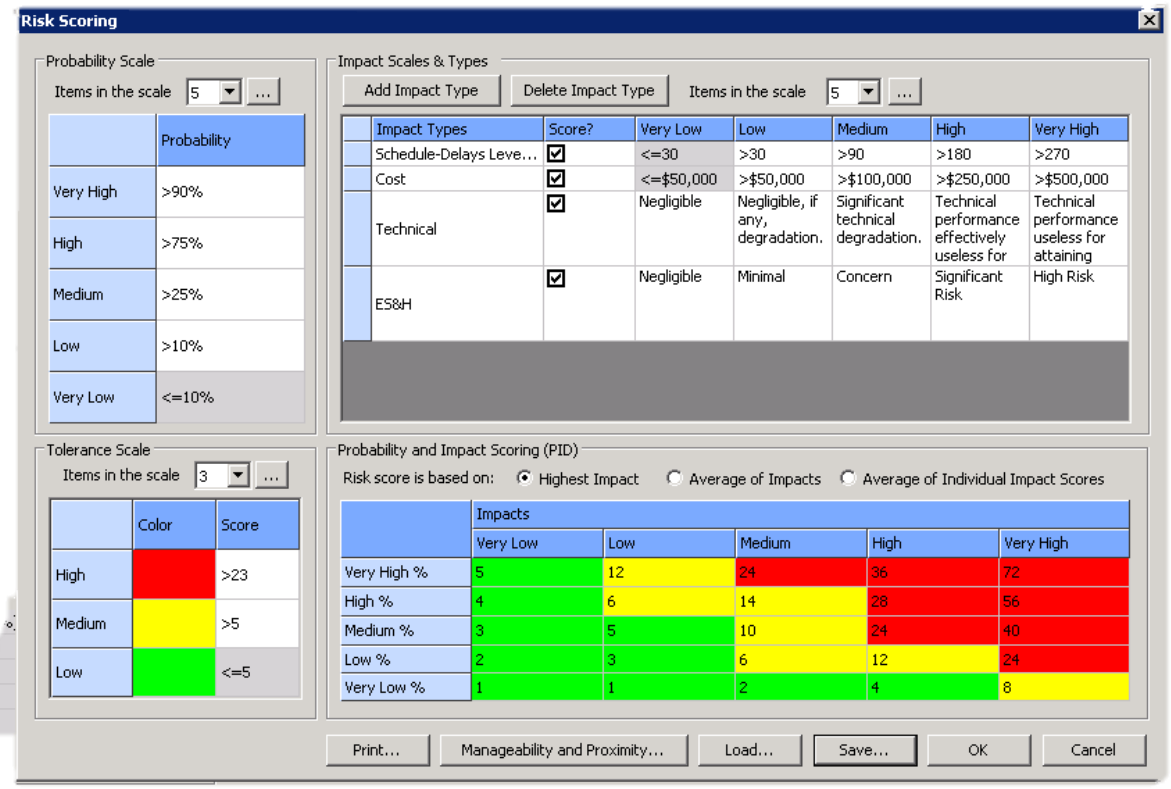
Opportunity	15 Opportunities -$3M
Threat	69 Threats

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

Total Mitigation Costs	$ 8,542,000

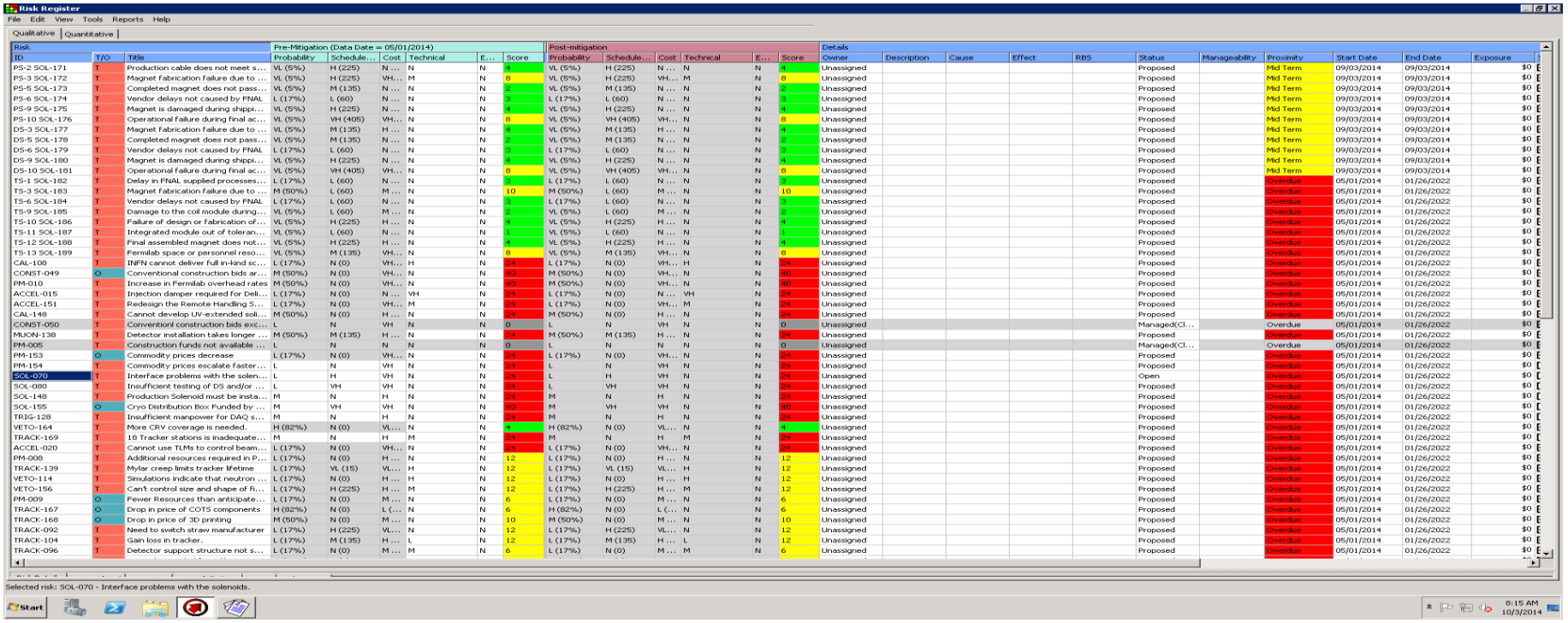
Preparation for Full Risk Analysis

- The Project parameters are entered into PRA



Preparation for Full Risk Analysis

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



Risk ID	T/O	Title	Pre-Mitigation (Data Date = 05/01/2014) Probability	Schedule...	Cost	Technical	E...	Score	Post-mitigation Probability	Schedule...	Cost	Technical	E...	Score	Details Owner	Description	Cause	Effect	RBS	Status	Manageability	Proximity	Start Date	End Date	Exposure
PS-2 SOL-171	T	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	$0
PS-3 SOL-172	T	Magnet fabrication failure due to ...	VL (5%)	H (225)	VH...	M	N	8	VL (5%)	H (225)	VH...	M	N	8	Unassigned					Proposed		Mid Term	09/03/2014	09/03/2014	$0
PS-5 SOL-173	T	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	$0
PS-6 SOL-174	T	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	$0
PS-9 SOL-175	T	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	$0
PS-10 SOL-176	T	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	$0
DS-3 SOL-177	T	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	$0
DS-5 SOL-178	T	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	$0
DS-6 SOL-179	T	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	$0
DS-9 SOL-180	T	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	$0
DS-10 SOL-181	T	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	$0
TS-1 SOL-182	T	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	$0
TS-3 SOL-183	T	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	$0
TS-6 SOL-184	T	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	$0
TS-9 SOL-185	T	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	$0
TS-10 SOL-186	T	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	$0
TS-11 SOL-187	T	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	$0
TS-12 SOL-188	T	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	$0
TS-13 SOL-189	T	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	$0
CAL-108	T	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
CONST-049	O	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	$0
PM-010	T	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	$0
ACCEL-015	T	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	$0
ACCEL-151	T	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	$0
CAL-148	T	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	$0
CONST-050	T	Conventionl construction bids exc...	L	N	VH	N	N	0	L	N	VH	N	N	0	Unassigned					Managed(Cl...		Overdue	05/01/2014	01/26/2022	$0
MUON-138	T	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	$0
PM-005	T	Construction funds not available ...	L	N	N	N	N	0	L	N	N	N	N	0	Unassigned					Managed(Cl...		Overdue	05/01/2014	01/26/2022	$0
PM-153	O	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	$0
PM-154	T	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	$0
SOL-070	T	Interface problems with the solen...	L	H	VH	N	N	24	L	H	VH	N	N	24	Unassigned					Open		Overdue	05/01/2014	01/26/2022	$0
SOL-080	T	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	$0
SOL-148	T	Production Solenoid must be insta...	M	N	H	N	N	24	M	N	H	N	N	24	Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	$0
SOL-155	O	Cryo Distribution Box Funded by ...	M	VH	VH	N	N	40	M	VH	VH	N	N	40	Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	$0
TRIG-128	T	Insufficient manpower for DAQ s...	M	N	H	N	N	24	M	N	H	N	N	24	Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	$0
VETO-164	T	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	$0
TRACK-169	T	18 Tracker stations is inadequate...	M	N	H	M	N	24	M	N	H	M	N	24	Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	$0
ACCEL-020	T	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	$0
PM-008	T	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	$0
TRACK-139	T	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	$0
VETO-114	T	Simulations indicate that neutron ...	L (17%)	N (0)	H ...	H	N	12	L (17%)	N (0)	H ...	H	N	12	Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	$0
VETO-156	T	Can't control size and shape of fi...	L (17%)	H (225)	H ...	M	N	12	L (17%)	H (225)	H ...	M	N	12	Unassigned					Proposed		Overdue	05/01/2014	01/26/2022	$0
PM-009	O	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
TRACK-167	O	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
TRACK-168	O	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	$0
TRACK-092	T	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	$0
TRACK-104	T	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	$0
TRACK-096	T	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	$0

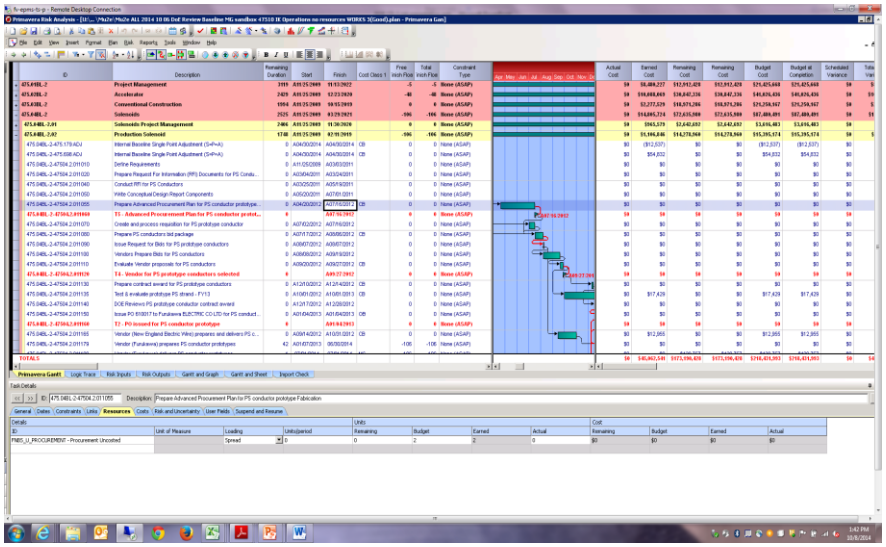
Quantitative Analysis

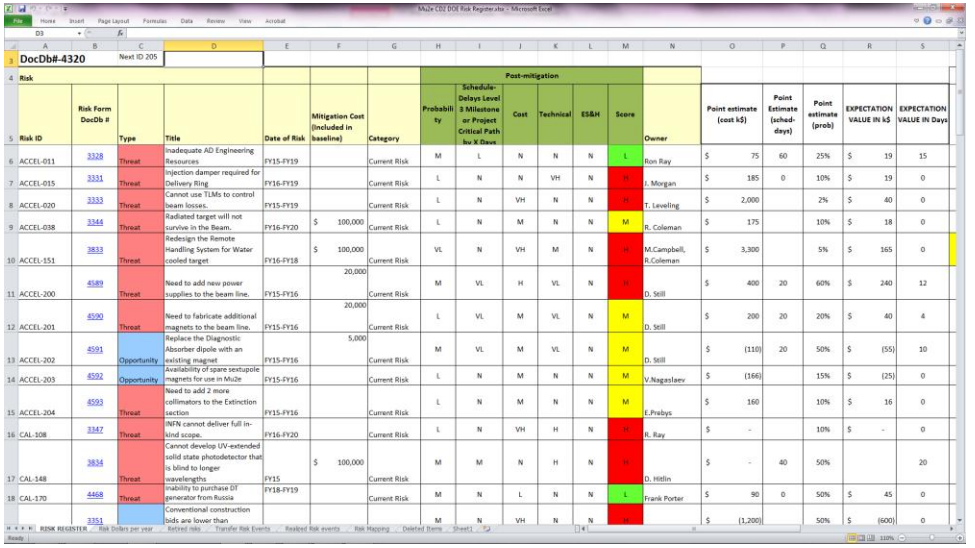
- Many different scenarios are run against the RLS to determine what effects the risk items have on the schedule.
- Estimate the impact on the project by using probability, cost impacts, schedule impacts, and mitigation plans.
- Determine the best action to reduce the risk effect
  - Develop Mitigations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

PRA Monte Carlo

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





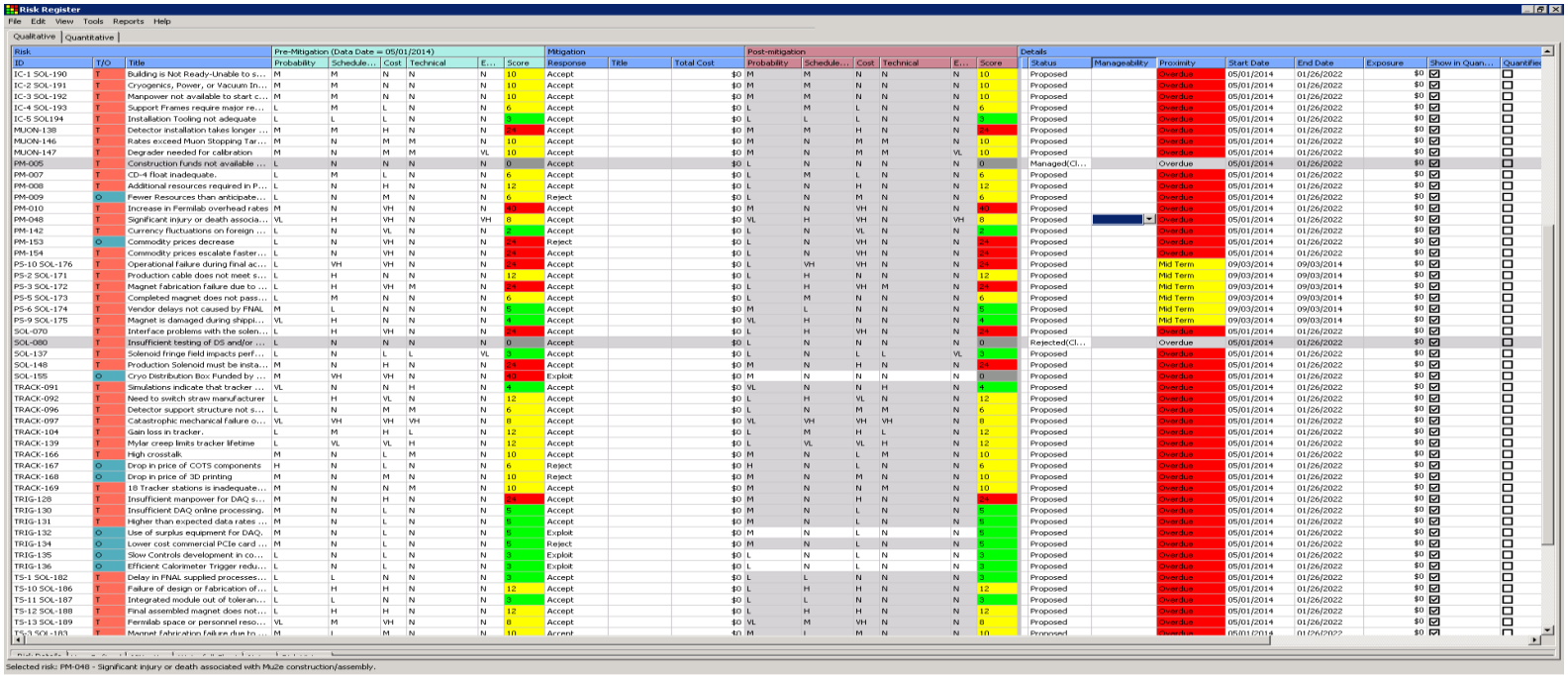
DocDb#-4320 Next ID 205

Risk ID	Risk Form DocDb #	Type	Title	Date of Risk	Mitigation Cost (included in baseline)	Category	Post-mitigation: 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
ACCEL-011	3328	Threat	Inadequate AD Engineering Resources	FY15-FY19		Current Risk	M	L	N	N	N	L	Ron Ray	$ 75	60	25%	$ 19	15
ACCEL-015	3331	Threat	Injection damper required for Delivery Ring	FY16-FY19		Current Risk	L	N	N	VH	N	H	J. Morgan	$ 185	0	10%	$ 19	0
ACCEL-020	3333	Threat	Cannot use TLMs to control beam losses.	FY15-FY19		Current Risk	L	N	VH	N	N	H	T. Leveling	$ 2,000		2%	$ 40	0
ACCEL-038	3344	Threat	Radiated target will not survive in the Beam.	FY16-FY20	$ 100,000	Current Risk	L	N	M	N	N	M	R. Coleman	$ 175		10%	$ 18	0
ACCEL-151	3833	Threat	Redesign the Remote Handling System for Water cooled target	FY16-FY18	$ 100,000	Current Risk	VL	N	VH	M	N	H	M.Campbell, R.Coleman	$ 3,300		5%	$ 165	0
ACCEL-200	4589	Threat	Need to add new power supplies to the beam line.	FY15-FY16	20,000	Current Risk	M	VL	H	VL	N	H	D. Still	$ 400	20	60%	$ 240	12
ACCEL-201	4590	Threat	Need to fabricate additional magnets to the beam line.	FY15-FY16	20,000	Current Risk	L	VL	M	VL	N	M	D. Still	$ 200	20	20%	$ 40	4
ACCEL-202	4591	Opportunity	Replace the Diagnostic Absorber dipole with an existing magnet	FY15-FY16	5,000	Current Risk	M	VL	M	VL	N	M	D. Still	$ (110)	20	50%	$ (55)	10
ACCEL-203	4592	Opportunity	Availability of spare sextupole magnets for use in Mu2e	FY15-FY16		Current Risk	L	N	M	N	N	M	V.Nagaslaev	$ (166)		15%	$ (25)	0
ACCEL-204	4593	Threat	Need to add 2 more collimators to the Extinction section	FY15-FY16		Current Risk	L	N	M	N	N	M	E.Prebys	$ 160		10%	$ 16	0
CAL-108	3347	Threat	INFN cannot deliver full in-kind scope.	FY16-FY20		Current Risk	L	N	VH	H	N	H	R. Ray	$ -		10%	$ -	0
CAL-148	3834	Threat	Cannot develop UV-extended solid state photodetector that is blind to longer wavelengths	FY15	$ 100,000	Current Risk	M	M	N	H	N	H	D. Hitlin	$ -	40	50%		20
CAL-170	4468	Threat	Inability to purchase DT generator from Russia	FY18-FY19		Current Risk	M	N	L	N	N	L	Frank Porter	$ 90	0	50%	$ 45	0
	3351		Conventional construction bids are lower than				M	N	VH	N	N	H		$ (1,200)		50%	$ (600)	0

PRA Monte Carlo

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

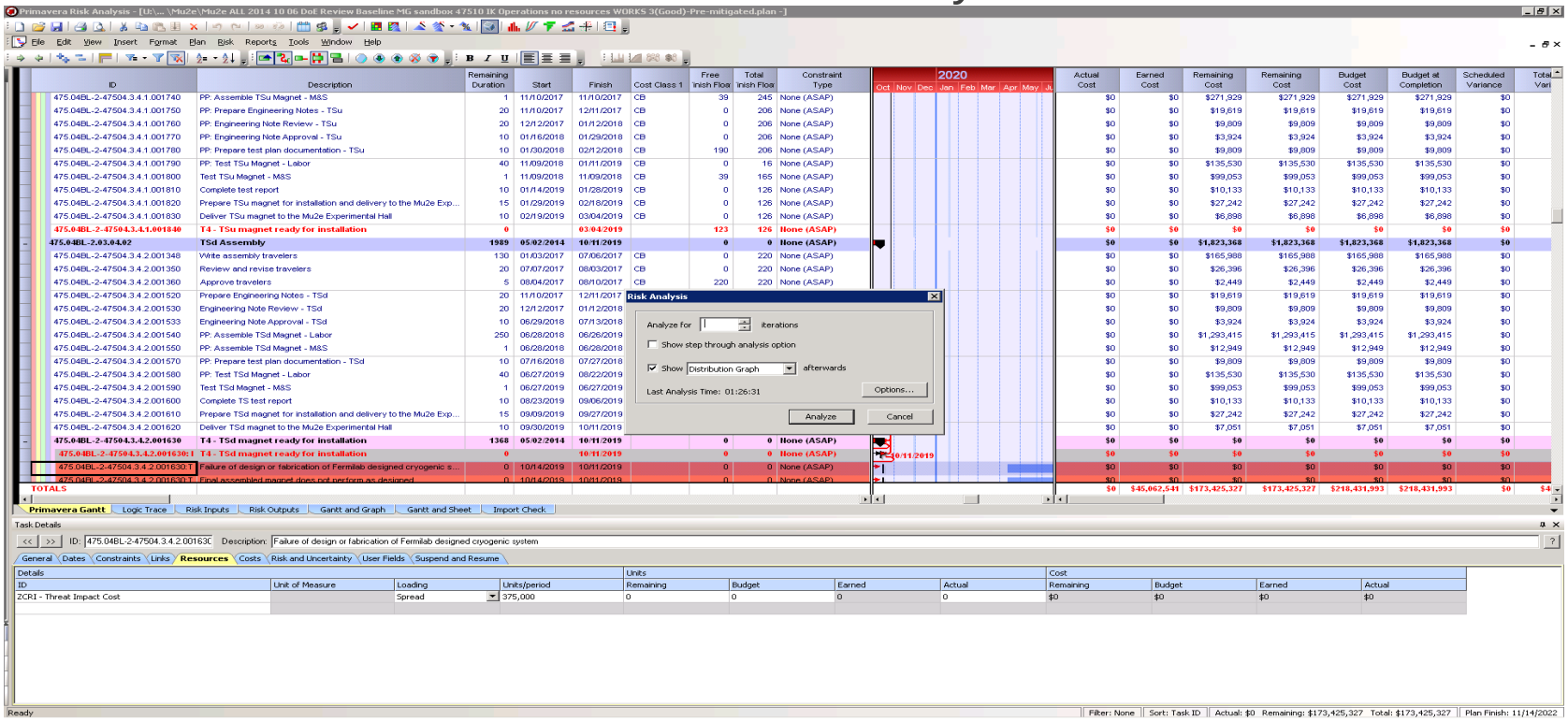


PRA Monte Carlo

Risk Monte Carlo using the PRA tool

3. Run the Monte Carlo

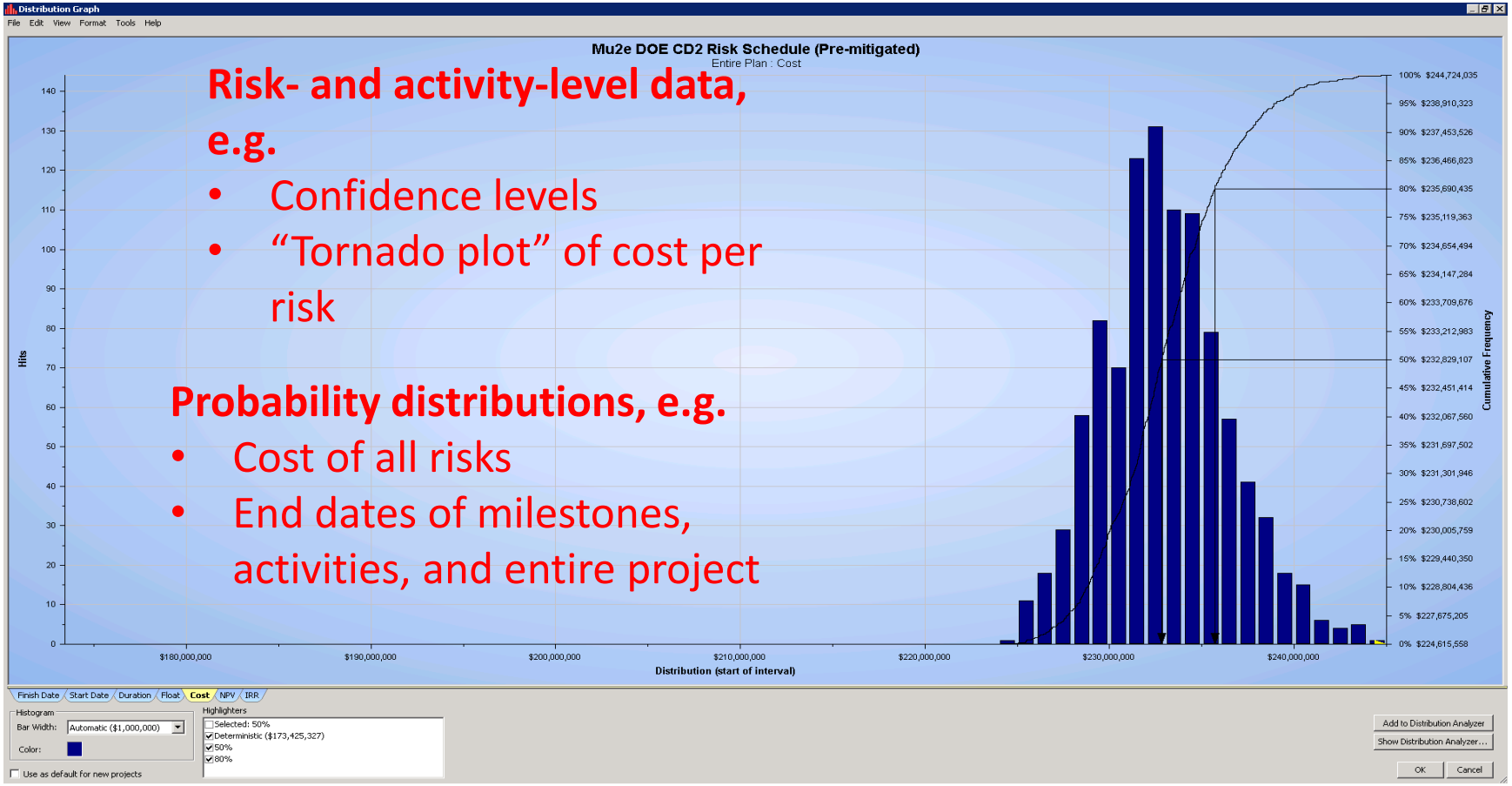
- Throw the dice based on inputs
- Create risk scenarios and run many iterations



PRA Monte Carlo

Full Risk Monte Carlo using the PRA tool

4. Analyze the data



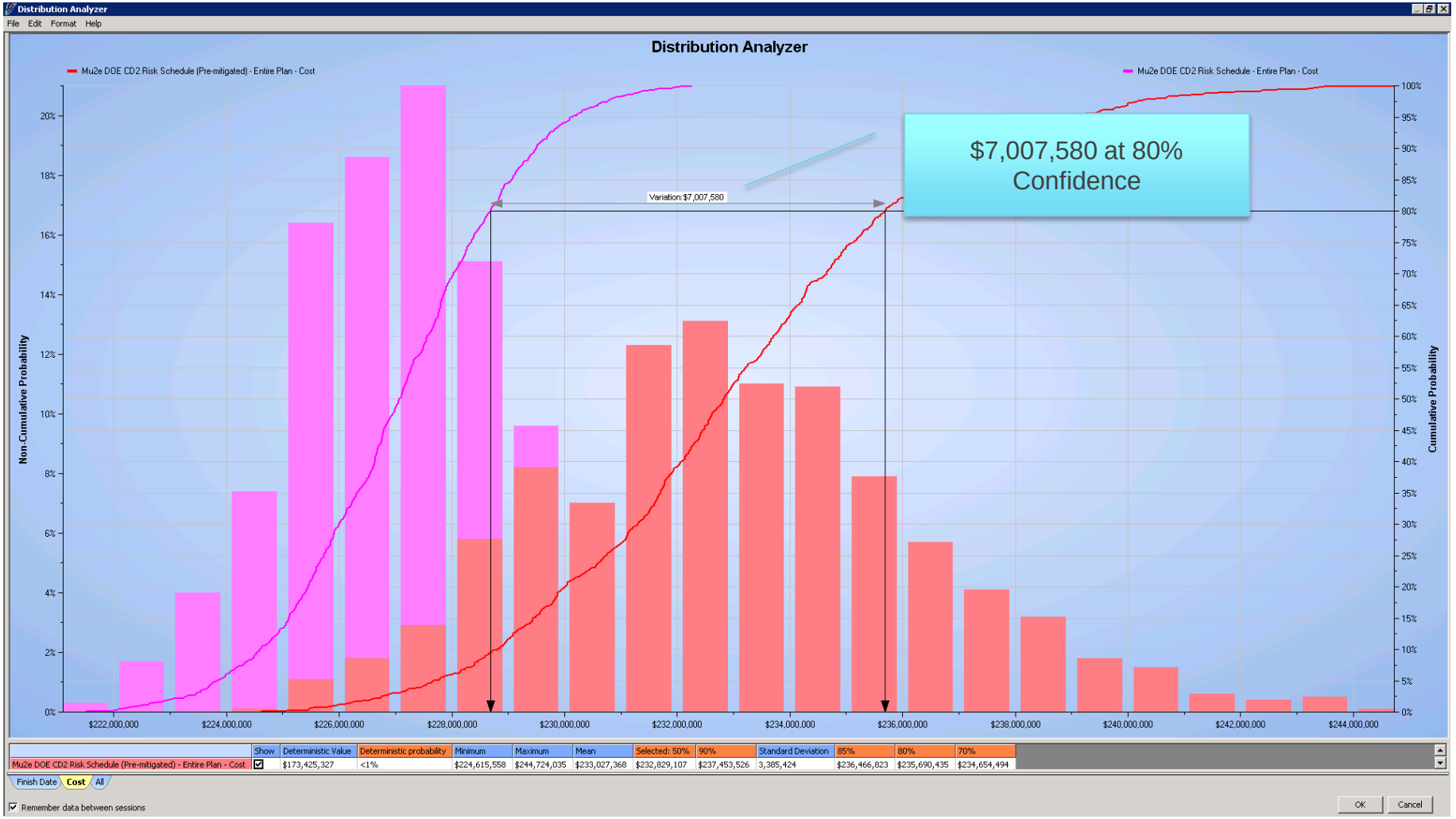
Risk- and activity-level data, e.g.

- Confidence levels
- "Tornado plot" of cost per risk

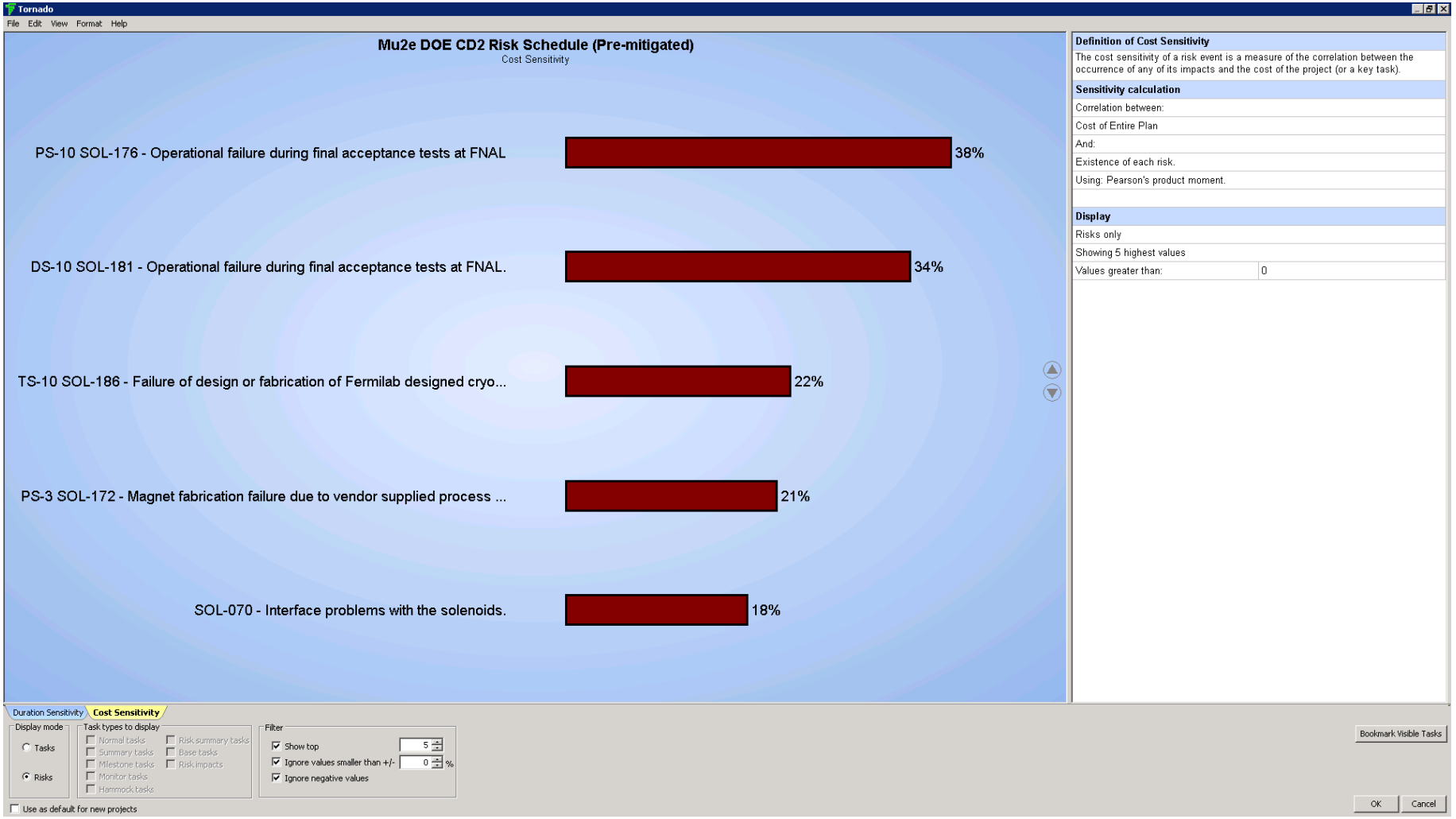
Probability distributions, e.g.

- Cost of all risks
- End dates of milestones, activities, and entire project

Cost Risk


Distribution Analyzer
File Edit Format Help
Distribution Analyzer
Mu2e DOE CD2 Risk Schedule (Pre-mitigated) - Entire Plan - Cost
Mu2e DOE CD2 Risk Schedule - Entire Plan - Cost
Variation:$7,007,580
$7,007,580 at 80% Confidence
Non-Cumulative Probability
Cumulative Probability
$222,000,000
$224,000,000
$226,000,000
$228,000,000
$230,000,000
$232,000,000
$234,000,000
$236,000,000
$238,000,000
$240,000,000
$242,000,000
$244,000,000
Show | Deterministic Value | Deterministic probability | Minimum | Maximum | Mean | Selected: 50% | 90% | Standard Deviation | 85% | 80% | 70%
Mu2e DOE CD2 Risk Schedule (Pre-mitigated) - Entire Plan - Cost | $173,425,327 | <1% | $224,615,558 | $244,724,035 | $233,027,368 | $232,829,107 | $237,453,526 | 3,385,424 | $236,466,823 | $235,690,435 | $234,654,494
Finish Date | Cost | All
Remember data between sessions
OK
Cancel

Cost Risk

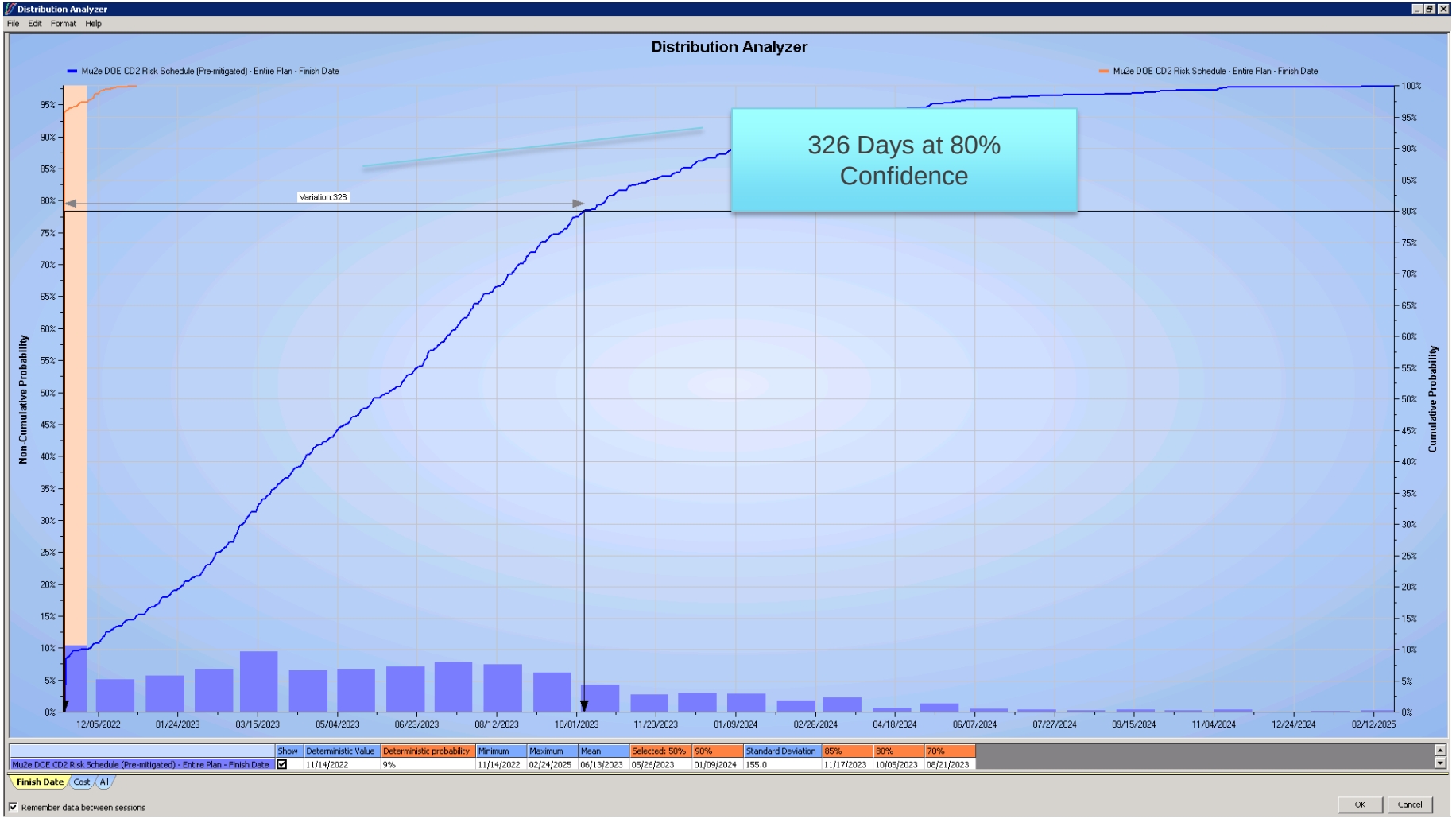

Tornado
File Edit View Format Help
Mu2e DOE CD2 Risk Schedule (Pre-mitigated)
Cost Sensitivity
PS-10 SOL-176 - Operational failure during final acceptance tests at FNAL
38%
DS-10 SOL-181 - Operational failure during final acceptance tests at FNAL.
34%
TS-10 SOL-186 - Failure of design or fabrication of Fermilab designed cryo...
22%
PS-3 SOL-172 - Magnet fabrication failure due to vendor supplied process ...
21%
SOL-070 - Interface problems with the solenoids.
18%
Definition of Cost Sensitivity
The cost sensitivity of a risk event is a measure of the correlation between the occurrence of any of its impacts and the cost of the project (or a key task).
Sensitivity calculation
Correlation between:
Cost of Entire Plan
And:
Existence of each risk.
Using: Pearson's product moment.
Display
Risks only
Showing 5 highest values
Values greater than: 0
Duration Sensitivity
Cost Sensitivity
Display mode
Tasks
Risks
Task types to display
Normal tasks
Summary tasks
Milestone tasks
Monitor tasks
Hammock tasks
Risk summary tasks
Base tasks
Risk impacts
Filter
Show top 5
Ignore values smaller than +/- 0 %
Ignore negative values
Bookmark Visible Tasks
Use as default for new projects
OK
Cancel

Cost Risk

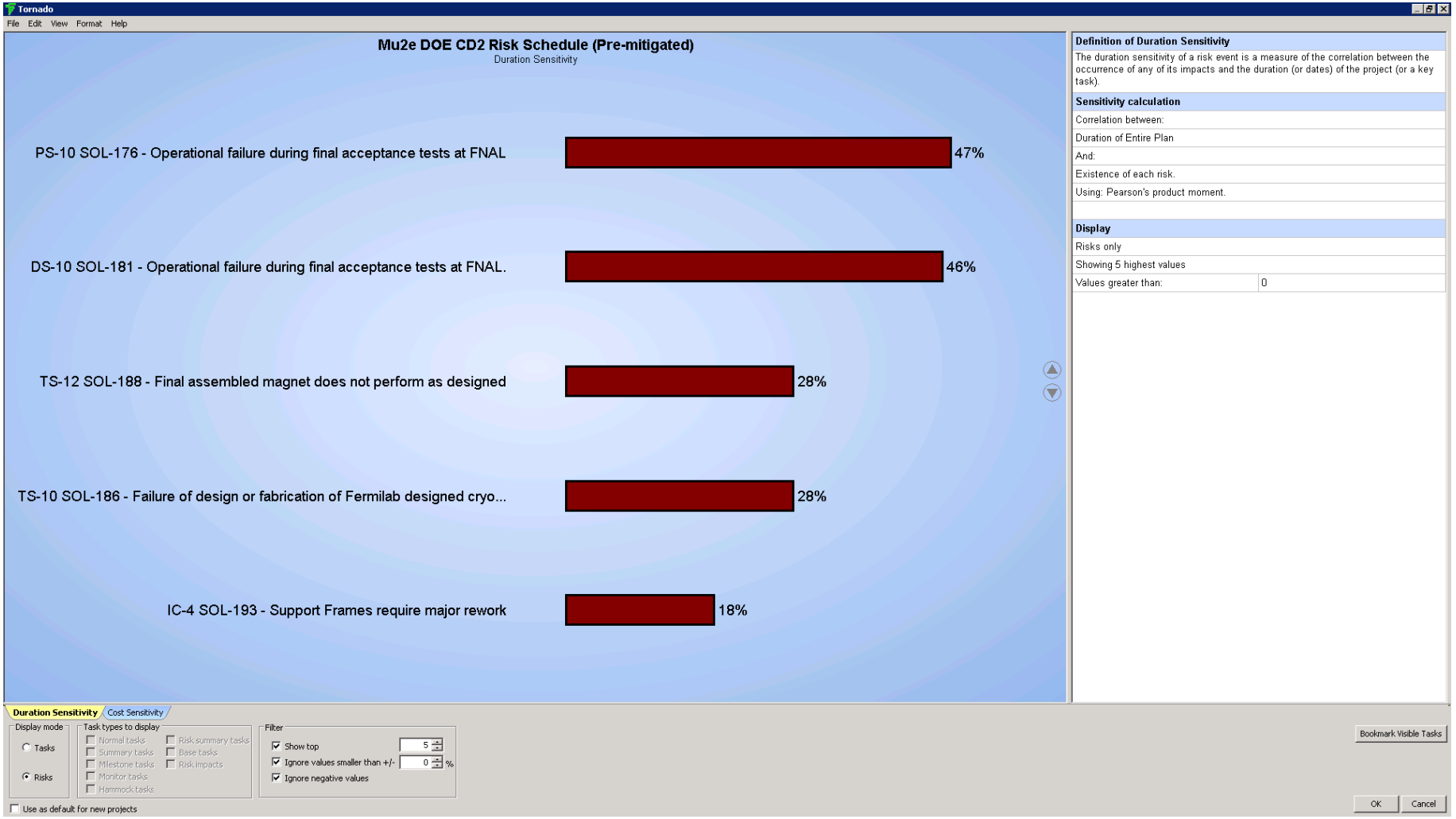
- Risk Register entries

Risk ID	Risk Form DocDb #	Type	Title	Probability	Schedule-Delays Level 3 Milestone or Project Critical Path by X Days	Cost	Technical	ES&H	Score	Point estimate (cost k$)
SOL-176	4561	Threat	Operational failure during final acceptance tests at FNAL.	VL	VH	VH	N	N	M	$ 4,500
SOL-181	4566	Threat	Operational failure during final acceptance tests at FNAL.	VL	VH	VH	N	N	M	$ 4,500
SOL-186	4571	Threat	Failure of design or fabrication of Fermilab designed cryogenic system	VL	H	H	N	N	L	$ 2,500
SOL-172	4557	Threat	DS Magnet fabrication failure due to process or component	VL	H	VH	M	N	M	$ 4,000
SOL-070	3368	Threat	Interface problems with the solenoids.	L	H	VH	N	N	H	$ 1,000

Schedule Risk



Schedule Risk



Schedule Risk

- Risk Register Entries

Risk ID	Risk Form DocDb #	Type	Title	Probability	Schedule-Delays Level 3 Milestone or Project Critical Path by X Days	Cost	Technical	ES&H	Score	Point estimate (cost k$)
SOL-176	4561	Threat	Operational failure during final acceptance tests at FNAL.	VL	VH	VH	N	N	M	$ 4,500
SOL-181	4566	Threat	Operational failure during final acceptance tests at FNAL.	VL	VH	VH	N	N	M	$ 4,500
SOL-188	4573	Threat	Final assembled magnet does not perform as designed	VL	H	H	N	N	L	$ 2,500
SOL-186	4571	Threat	Failure of design or fabrication of Fermilab designed cryogenic system	VL	H	H	N	N	L	$ 2,500
SOL-193	4578	Threat	Support Frames require major rework	VL	M	L	N	N	L	$ 1,100

Top Risk Drivers

- Common to Cost and Schedule

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

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 support 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