Risk Management in Major International Projects at Fermilab and CERN

Lucas Taylor, Fermilab

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NSF Research Infrastructure Workshop, Washington DC

Who am I?

Currently

- **Fermilab Risk Manager** – leading the Lab's risk management program for a project portfolio of $5.8B
- **Risk Manager** for LBNF-DUNE, PIP-II, CMS projects
- **Associate Project Manager** (cost, schedule, risk) for the HL-LHC CMS Upgrades project* at CERN

  * **$320M of DOE/NSF funding**, including $43M of Phase 1 Upgrades

Background

- **PhD Particle Physicist**
  - CMS, L3, Pierre Auger Observatory, UA1 experiments
- **Project Management Professional** (PMP)

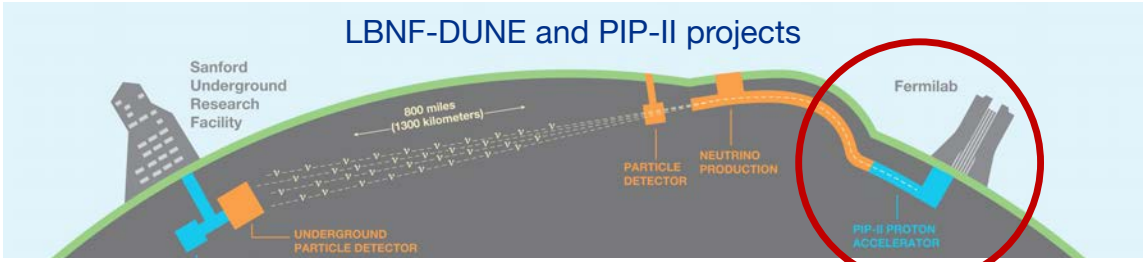
Fermilab is America's premier laboratory for particle physics and accelerator research, supported by the U.S. Department of Energy

Outline

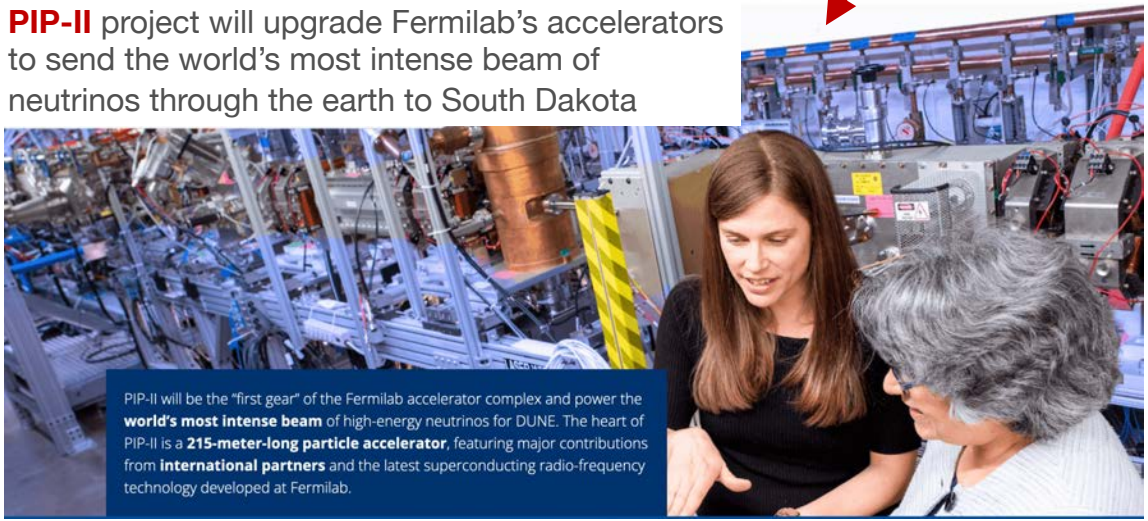
- Fermilab's portfolio of projects
- Risk management process and best practices
- How we identify and analyse risks
- Risk mitigation, responses, monitoring and control
- Lessons learned
- Q&A

Fermilab Project Portfolio

Total Project Cost		($B)
LBNF-DUNE	Long Baseline Neutrino Facility / Deep Underground Neutrino Expt.	3.3
PIP-II	Proton Improvement Plan II (Fermilab accelerator upgrades)	1.0
HL-LHC AUP	US upgrades of the Large Hadron Collider at CERN	0.5
HL-LHC CMS	US upgrades of the CMS Detector at CERN	
Mu2e	Muon to Electron Conversion experiment	0.3
Other projects	SBN, MAGIS-100, ADMX-EFR...	0.1
Total - Science Projects		5.1
UIP	Utilities Improvement Project	0.3
ACORN	Accelerator Controls Operations Research Network	0.1
IERC	Integrated Engineering Research Center	0.1
GPPs / AIPs	General Plant Projects and Accelerator Improvement Projects	0.1
Partner projects	Contributions to partner projects: LCLS-II-HE, Super-CDMS, PPU	0.1
Total - Other Projects		0.7
Fermilab Projects - Total		5.8



PIP-II project will upgrade Fermilab's accelerators to send the world's most intense beam of neutrinos through the earth to South Dakota



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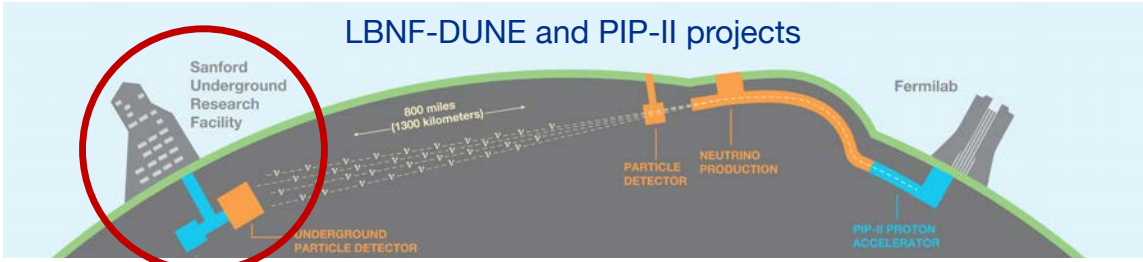

Long Baseline Neutrino Facility (LBNF) project excavates enormous caverns about 1 mile underground in South Dakota and provides cryogenics infrastructure

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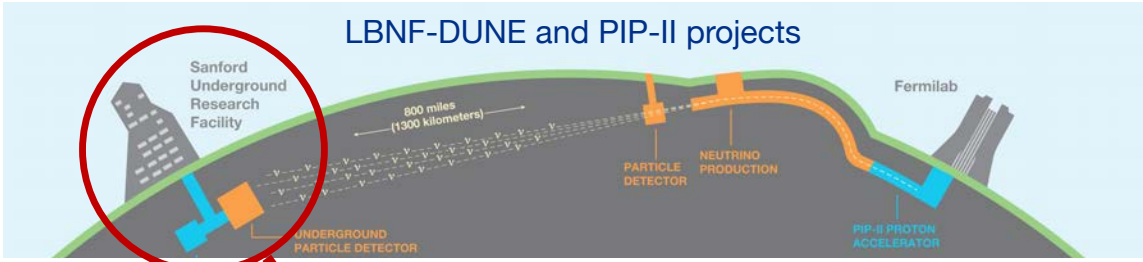

Deep Underground Neutrino Experiment (DUNE) uses immense particle detectors to record neutrino interactions with unprecedented precision

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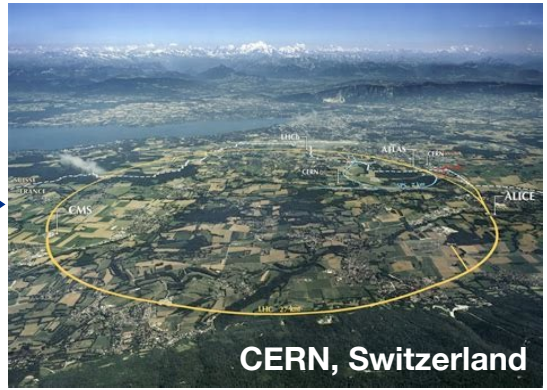
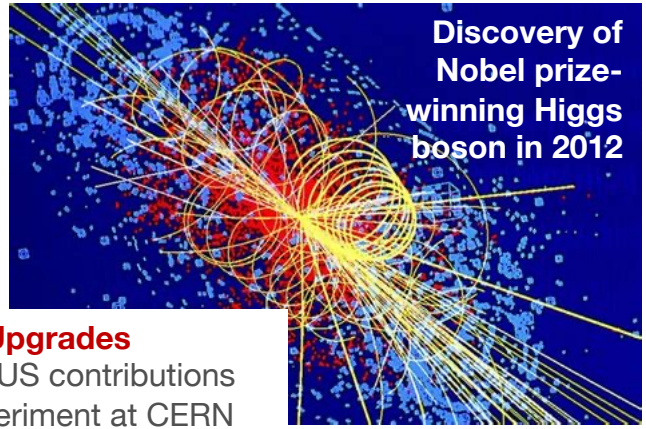
HL-LHC Accelerator Upgrades
project delivers US contributions to CERN's Large Hadron Collider



CERN, Switzerland


Large Hadron Collider


CMS Experiment


Discovery of Nobel prize-winning Higgs boson in 2012

HL-LHC CMS Upgrades
project delivers US contributions to the CMS experiment at CERN

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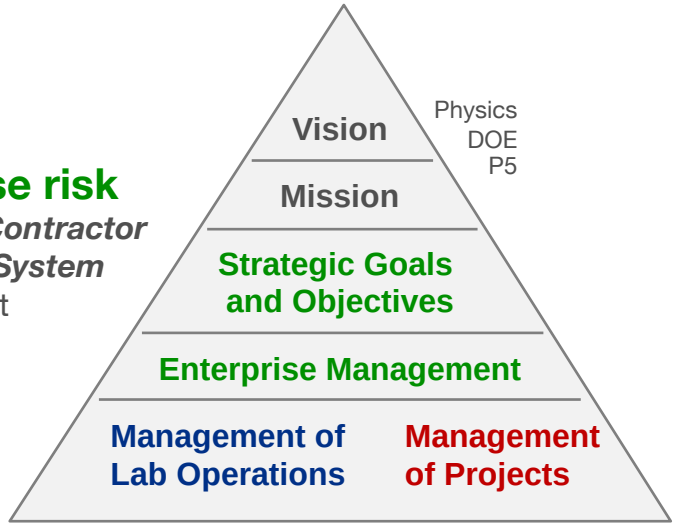
Infrastructure projects
Enable Fermilab's facilities to support the scientific program

Risk Management at Fermilab

Enterprise risk
Purview of ***Contractor Assurance System*** management



Operations risk
Purview of ***Line Management*** for ES&H, engineering, finance, procurement, legal, IT, etc.

Project risk
Purview of ***Deputy Lab Director for Projects*** (Chief Project Officer)

Fermilab Risk Manager
Responsible for developing and supporting risk processes, tools, training, workshops, reviews etc.

Risk: Effect of uncertainty on objectives

- **Threats** may or may not happen, and have negative impacts → we aim to minimize them

  Example: ***Magnet damaged in transit***

- **Opportunities** may or may not happen, and have positive impacts → we aim to maximize them

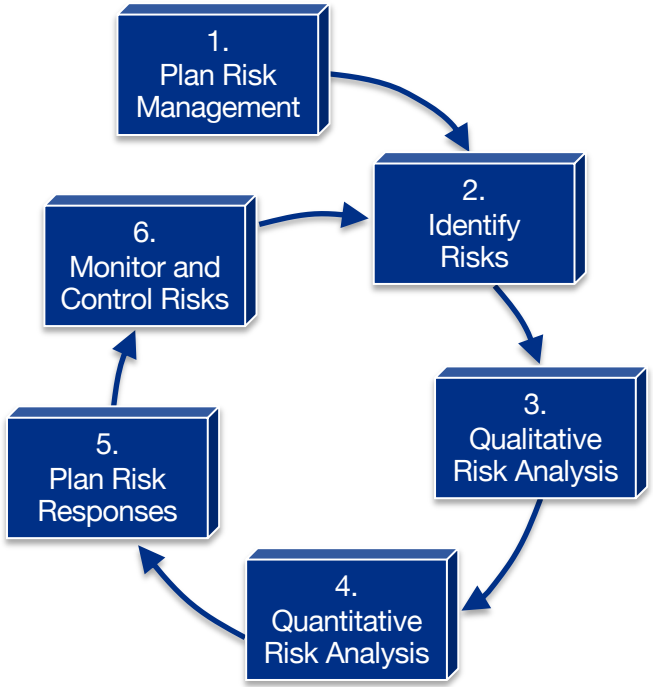
  Example: ***Vendor develops better or cheaper Si chip***

- **Uncertainties** may have positive or negative impacts → we aim to manage them

  Examples: ***Inflation, foreign exchange rates, or commodity prices may fluctuate up and down***

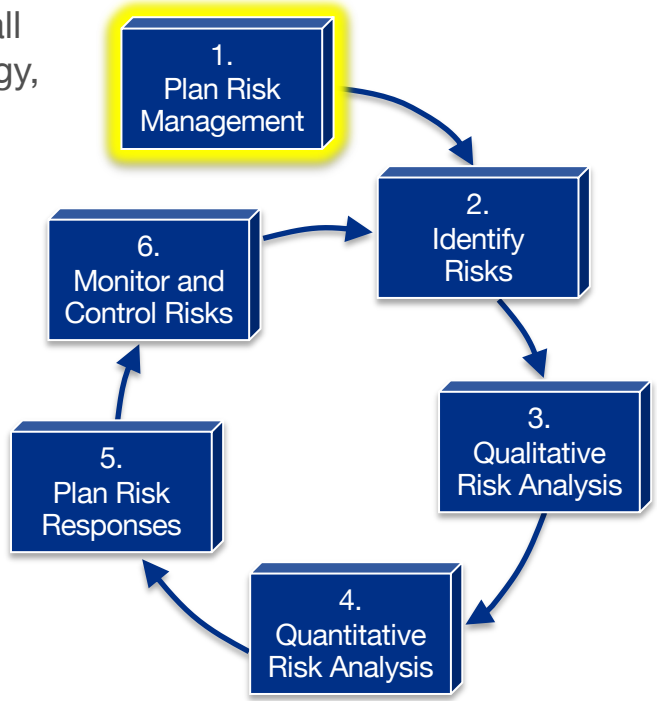
  Some uncertainties have 100% probability

Project Risk Management Process



Project Risk Management Planning

Goal: Develop the overall risk management strategy, establish processes, assign responsibilities



Many standard operating procedures help mitigate risk

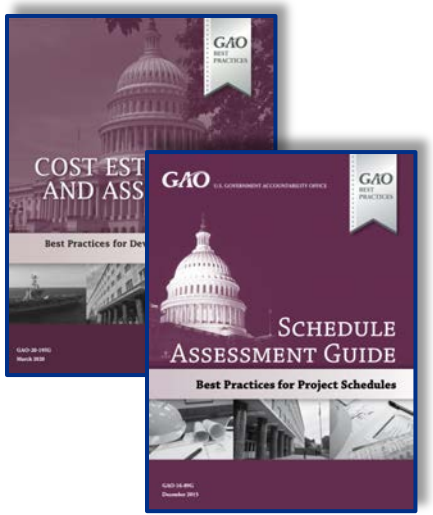
- ES&H, security…
- Engineering, QA/QC…
- Finance, procurement, legal…

Risk management best practices

ISO 31000 / ANSI-PMI

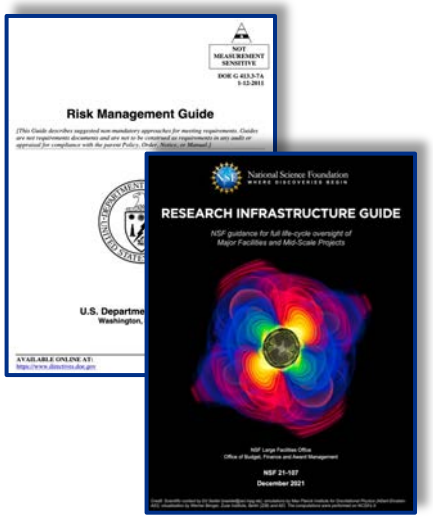
[PMBOK] Project Management Institute, "A Guide to the Project Management Body of Knowledge (PMBOK Guide)", 7th Edition, 2021. ANSI/PMI 99-001-2021. https://www.pmi.org/pmbok-guide-standards/foundational/pmbok

GAO



[GAO] Best Practices for: Project Cost, https://www.gao.gov/products/gao-20-195g; and Project Schedules https://www.gao.gov/products/gao-16-89g)

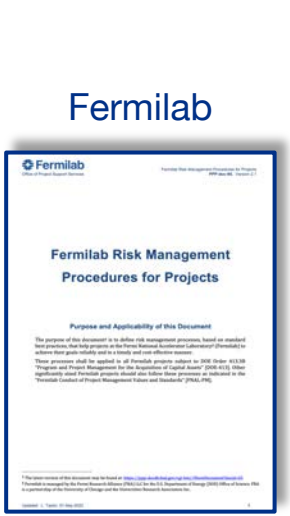
DOE 413.3b / NSF RIG



[DOE] Risk Management Guide for DOE O 413.3b projects, https://www.directives.doe.gov/directives-documents/400-series/0413.3-EGuide-07a-chg2-ltdchg

[NSF] NSF Research Infrastructure Guide, https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf21107

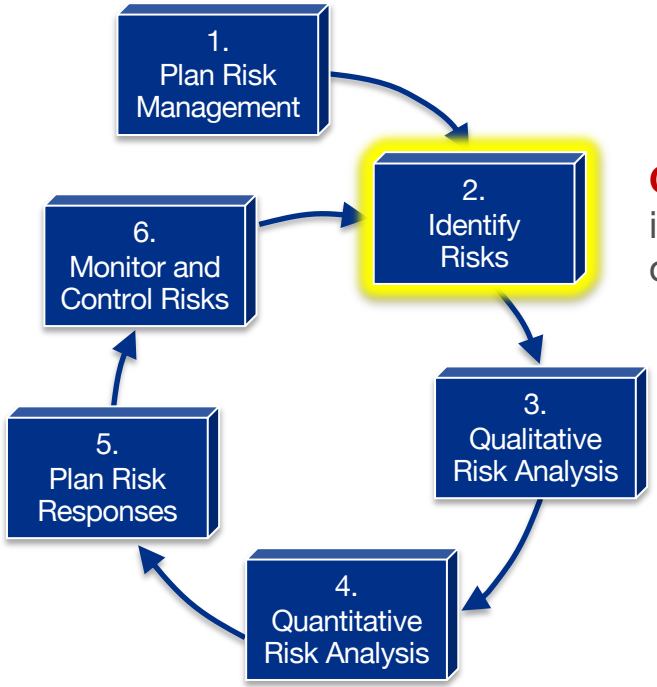
Fermilab



[FNAL] Fermilab Risk Management Procedures, PPP-doc-65, on request from taylorl@fnal.gov

Project's risk approach is described in ***Project Execution Plan*** and ***Risk Mgmt. Plan***

Risk Identification



Goal: produce a list of risks that could impact the project's objectives, in terms of scope, cost, schedule, safety…

How do we identify risks?

Risk workshops

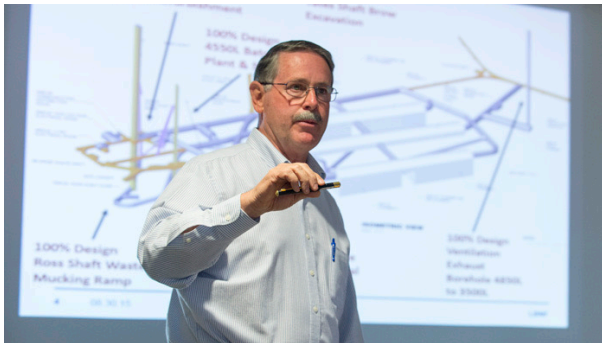
all stakeholders: management, technical, admin, external experts

Risk interviews

Open questions e.g. “what keeps you awake at night?”

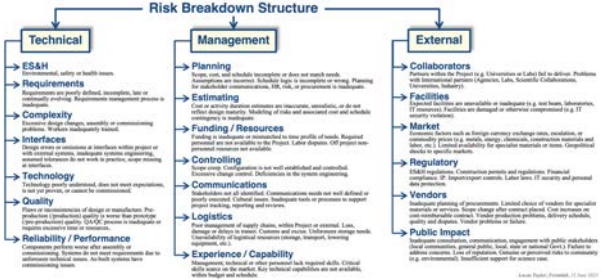
Review project documents

technical designs, costs, schedules…



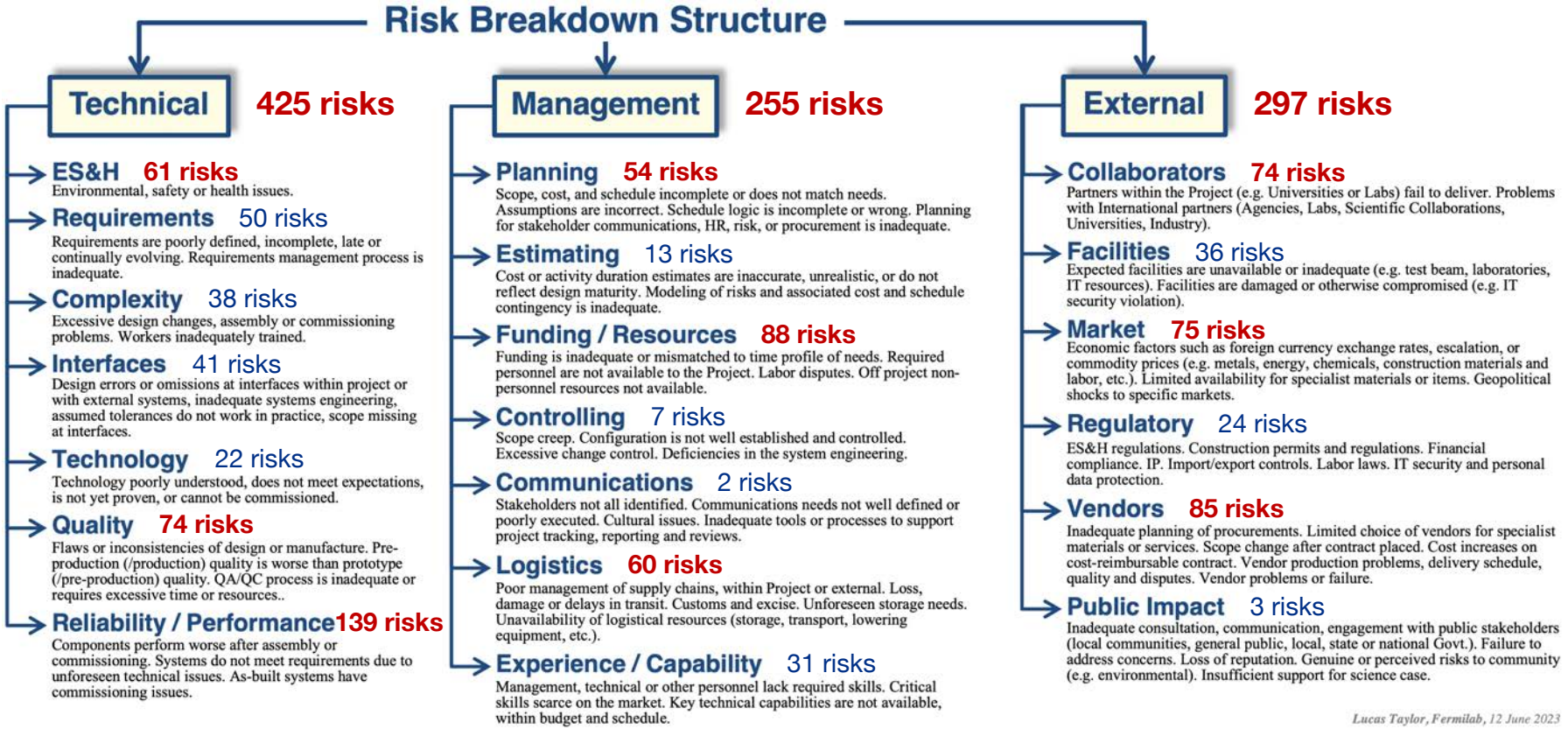
Review Risk Breakdown Structure

to ensure wide risk coverage

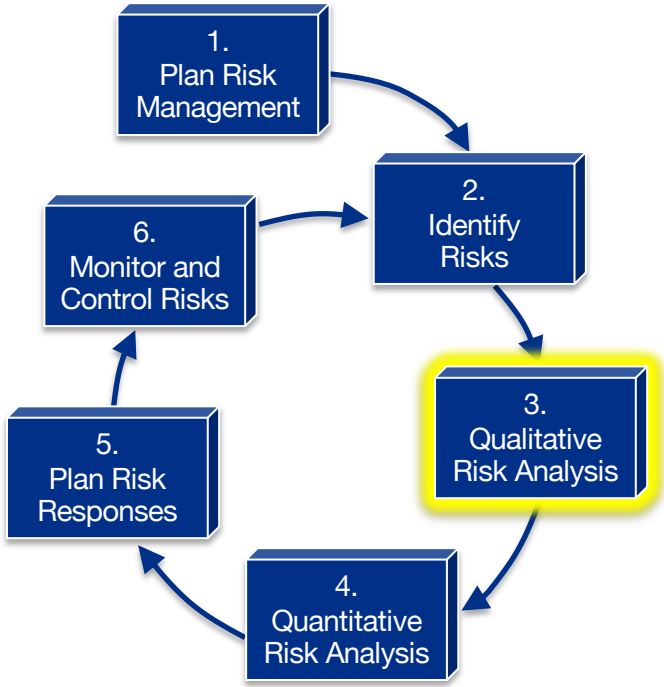


Fermilab

Open risks for Fermilab projects 977 risks



Qualitative Risk Analysis



Goal: estimate risk probabilities and the cost, schedule, and technical impacts, and hence rank the risks

Risk Register data – Excel or web DB

- **General risk metadata**

  Risk ID, Title, Project, Risk Type, RBS, Owner, WBS, Status, Start Date, End Date …

- **Summary** – *IF THEN* statement of **cause → effect**. Example:

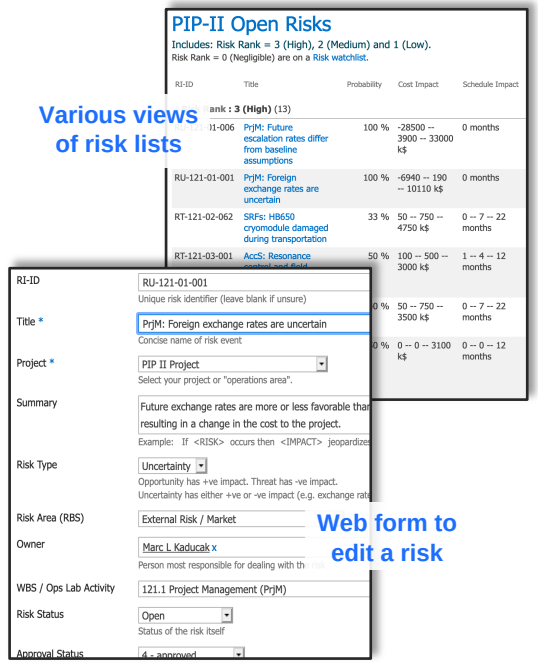
  IF *magnet is damaged in transit*

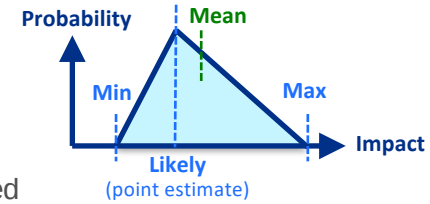
  THEN *repair work results in delay and cost increase*

- **Risk Mitigations** – pre-emptive actions in baseline plans
- **Risk Responses** – that only are executed if the risk occurs

- **Risk Probability** from 0% – 100% (post-mitigation)
- **Impacts**: **Technical**, **Cost** and **Schedule** (delays)

  1-point (single value), 2-point (range), or 3-point (triangle)
  - How probability and impacts were estimated and which work activities are impacted



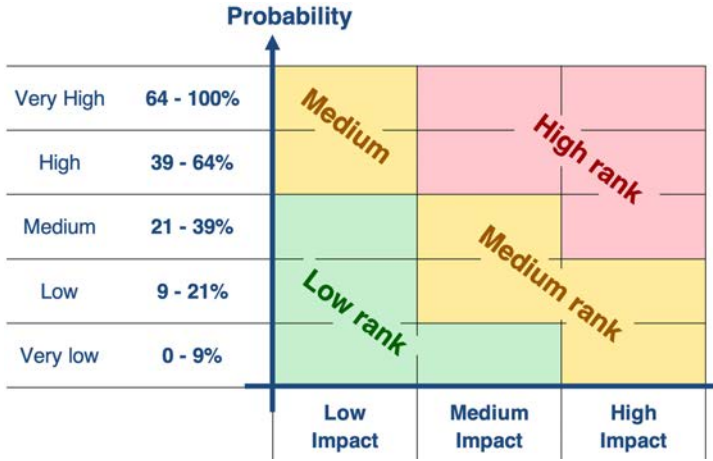


Fermilab

Risk Ranking

- Risks are ranked using a 2-D matrix of **Probability** *vs.* **Impact**
  - **High rank**: Potential failure to meet project goals → Project Director / Manager
  - **Medium rank**: Significant impact on objective(s) → L2 Manager
  - **Low rank**: Modest impact on objective(s) → L3 Manager

- **Risk impact thresholds** are tailored according to the total project cost (TPC) and the project duration



Example

Risk Impact Scoring*		Low Impact	Medium Impact	High Impact
Technical Impact		Somewhat sub-standard	Significantly sub-standard	Project goals in jeopardy
Cost Impact	*General guidance*	*< 0.1 % of TPC*	*(0.1–1)% of TPC*	*> 1 % of TPC*
	Example: Project cost = $100M	< 0.1 M$	(0.1 – 1) M$	> 1 M$
Schedule Impact	*General guidance*	*< 2 % of project duration*	*(2 –5)% of project duration*	*> 5% of project duration*
	Example: Project duration = 4 years	< 1 month	1 – 2.5 months	> 2.5 months

* The overall risk impact score is the maximum of (1) technical impact, (2) cost impact and (3) schedule impact

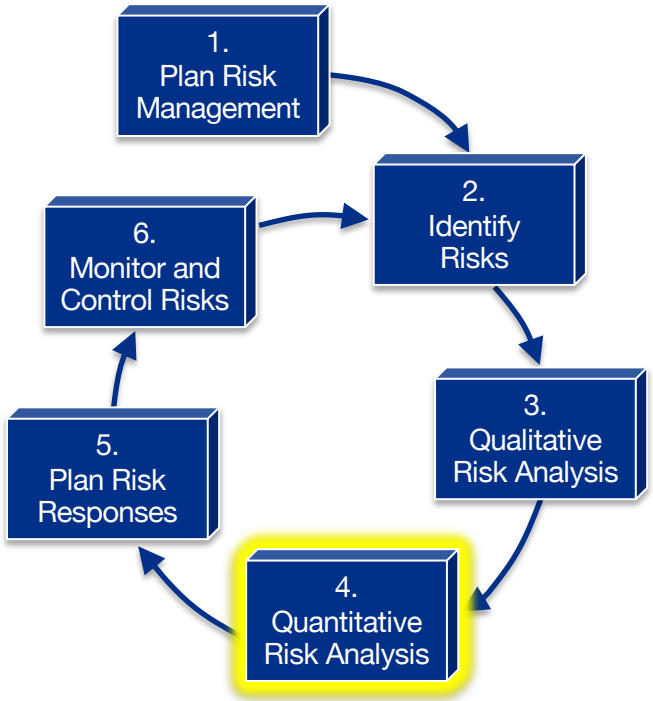
Open risks for Fermilab projects (141 high rank)

- **External risks** (75 high rank) are generally hard to mitigate
  - Examples: escalation, exchange rates, commodity prices, Covid-19, supply chains, labor market, construction market, taxes, customs duties, partner/vendor delays
    - Assess impacts using data sources such as: Federal Reserve banks, Dept. of Commerce, Dept. of Labor, industry sources, past experience, expert judgement
- **Technical risks** (33 high rank) are project-specific but with common themes
  - Examples: ES&H issues, failure to meet specifications for technical performance or reliability, or changes in requirements or interfaces
- **Management risks** (33 high rank)
  - Examples: unavailability of personnel or skills, funding shortfalls or delays (e.g. CRs), logistics, damage in transit

Quantitative Risk Analysis

Goal: aggregate the collective impacts of all risks to determine the risk drivers and the cost and schedule contingency needs

Quantitative Risk Analysis



Three types of contingency

- **Budget Contingency** [NSF, p 6.2.3-1]
  is budget set aside to cover uncertainties in cost estimates and the cost impacts of risks
- **Schedule Contingency**
  is time set aside to cover duration estimate uncertainties and schedule impacts of risks
- **Scope Contingency**
  is scope that can be dropped if the project is running very late or over budget
  - typically ~10% of total scope

Risk Monte Carlo Model

Aggregates cost and schedule impacts of all the project's risks

- Risk probabilities
- Cost impacts
- Schedule impacts

Risk Register
(e.g. Excel)

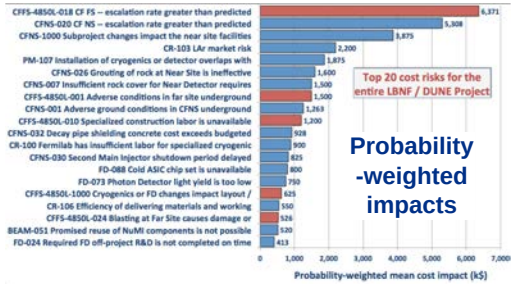
Project schedule
(e.g. P6)

- All the project's work activities
- Logical links between activities
- Activity costs and durations
- Associated estimate uncertainties

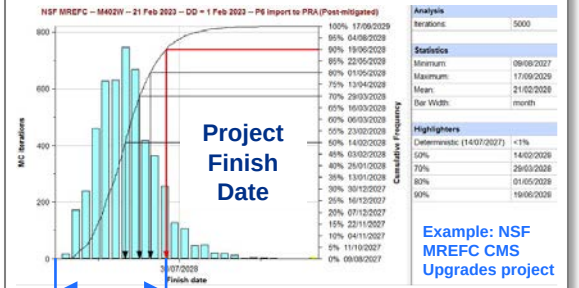
1. Risks occur – or not – according to their probabilities
2. Sample risk cost and schedule impact distributions
3. Generate a new risk-adjusted project outcome (scenario)
4. Repeat 1000s of times

Risk MC Tool
(e.g. Primavera Risk Analysis - PRA)

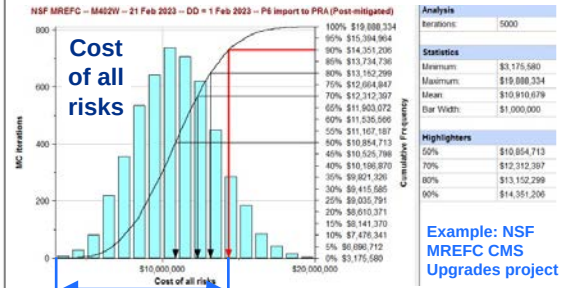
Risk tools: @Risk (Palisade), Crystal Ball (Oracle), Polaris (Booz Allen Hamilton), Primavera Risk Analysis (Oracle), Acumen RISK (Deltek) Risky Project (Intaver Institute), JACS (Tecolote), Full Monte (Barbecana), Safran Risk



"Tornado" charts of cost and schedule risk drivers



11.2 months of schedule contingency at 90% CL

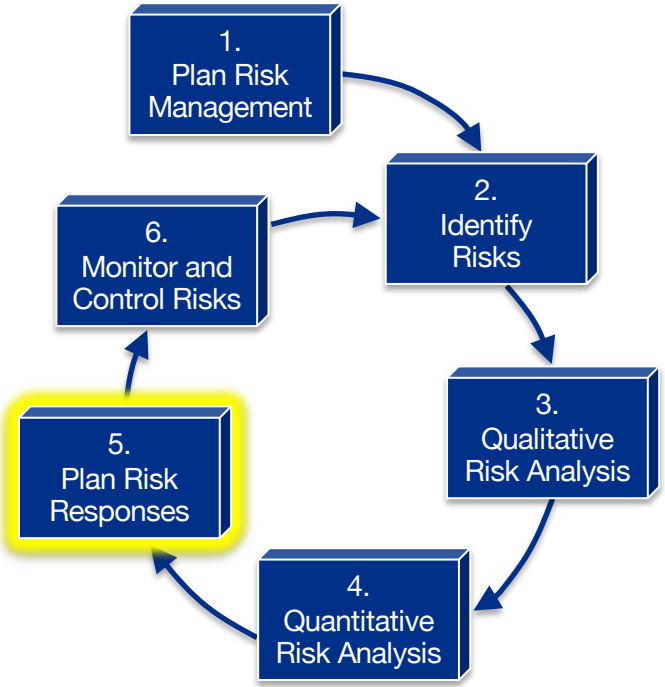


$14.4M of risk-based cost contingency at 90% CL

Management manages risks and contingency to ensure project will finish on time and within budget

Risk Response Planning

Goal: plan actions to reduce risk threats and increase opportunities



Strategies for handling risk threats

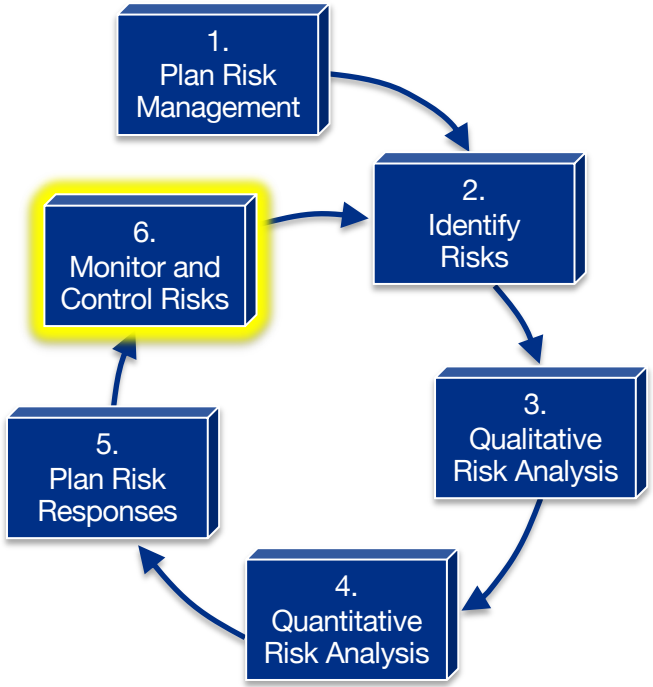
- **Risk mitigations** reduce the likelihood or impact of a risk threat before it happens
- **Risk avoidance** eliminates a risk by changing the base plan
- **Risk transfer** shifts responsibility for the impacts to a third party
- **Risk acceptance** is doing nothing because there is no cost-effective mitigation, or the risk is in the far future
- **Risk responses** are actions taken after a risk occurs to manage the consequence

- **Example**: test pre-production items before commencing full production
- **Example**: risk of vendor failing is avoided by placing contracts with multiple vendors
- **Example**: purchase insurance for items that could be lost or damaged in transit
- **Example**: accept that future exchange rates are beyond the control of the project
- **Example**: repair a magnet that was damaged in transit

Similar (converse) strategies apply to risk opportunities

Risk Monitoring and Control

Goal: Monitor and update risks, manage mitigations and responses, retire risks, identify new risks, report on risk, improve risk processes



Typical approach

- **Project Manager** is ultimately responsible for risk management
- **Risk Management Board** comprises the core management team, ensuring that risk is an integral part of decision making
- **Risk Owners** execute risk mitigations and response plans
- **Risk Manager** supports risk activities, risk register, MC analysis

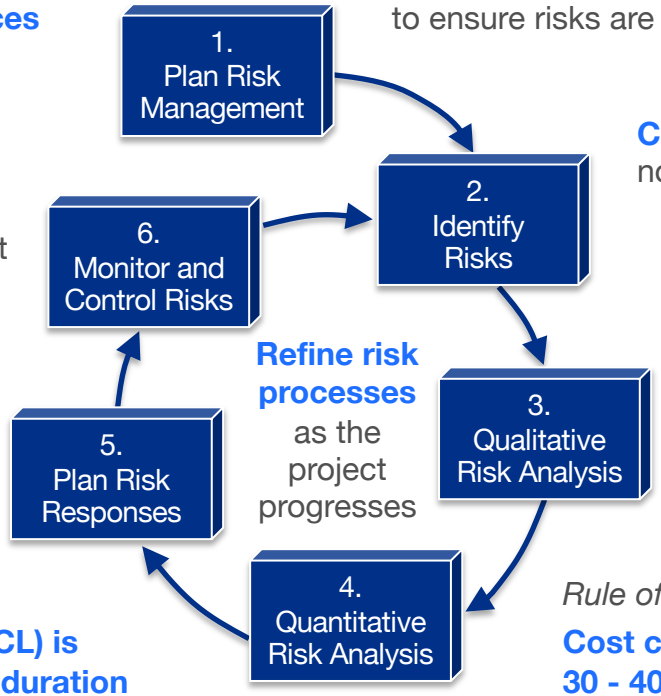
Lessons learned

Start early with risk and follow best practices

Create an open culture for risk discussions to ensure risks are handled effectively

Schedule risk is often more challenging than cost risk
Carefully monitor critical path, risk-adjusted finish dates, float and schedule contingency

Capture risk data as numerical values not qualitatively (e.g. “unlikely”)



Risk estimates only need to be roughly accurate – risk is intrinsically imprecise

Be wary of low probability, high impact risks – impacts can be hard to handle if the risk occurs

Refine risk processes as the project progresses

Use a risk MC model to aggregate uncertainties and risks

Rule of thumb #2:

Schedule contingency (at 90% CL) is typically 25 – 35% of remaining duration
(~3-4 months per year of duration)

Rule of thumb #1:

Cost contingency (at 90% CL) is typically 30 - 40% of base cost to go
(~2/3 estimate uncertainty and ~1/3 risk)

Thank you

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