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FE302
Advanced Facilities Engineering


Foundational Learning


Workflow Learning


Performance Learning

Lesson 2

Cost Estimating

Terminal Learning Objectives
Enabling Learning Objectives

Given a partial requirement, determine the cost risk associated with fulfilling the requirement for a project.

- Discriminate between salient factors that affect the range of final costs
- Using cost risk tools, identify costs based on 50%, 80%, and 99% confidence levels
- Recommend final budget requests based on the results of analysis

Exercise 1 - Parametric Estimate I

- Online estimates
- Current per square foot estimate for common buildings in various locales
- Building type (apartment 1-3 stories)
- Open Shop or Union

Exercise 1 - Parametric Estimate II

- www.building-cost.net
- Here everyone can play, it's a free site
- 2130 SF building; mid-grade finishes; (upgraded floors and walls); no fireplace; 200SF balcony; 400SF unfinished basement; location - York, PA.
- What is the build cost estimate?
- Use Zillow to pull up the sale price for 110 East South Street. What is estimated sale price? Why?

Exercise 2 - Change order estimate

- Piping modification
- Hand out exercise with solution (See BB)
- With the given facts, this can be solved in about 15 minutes on a phone or hand held calculator.
- Takes longer if you have to research the price data and estimate the production rates.
- Application of scrap factors and overheads are involved in this exercise.

Transition

- None of the previous estimates were difficult or time consuming.
- How much does it cost to build a fast food restaurant? Also well known and quick to calculate. If we do a lot of these in the private sector accurate estimates are known.
- Where do we have problems? When the requirements are not well defined or we have not done it often.

What is your Confidence Level?

How confident are you in:

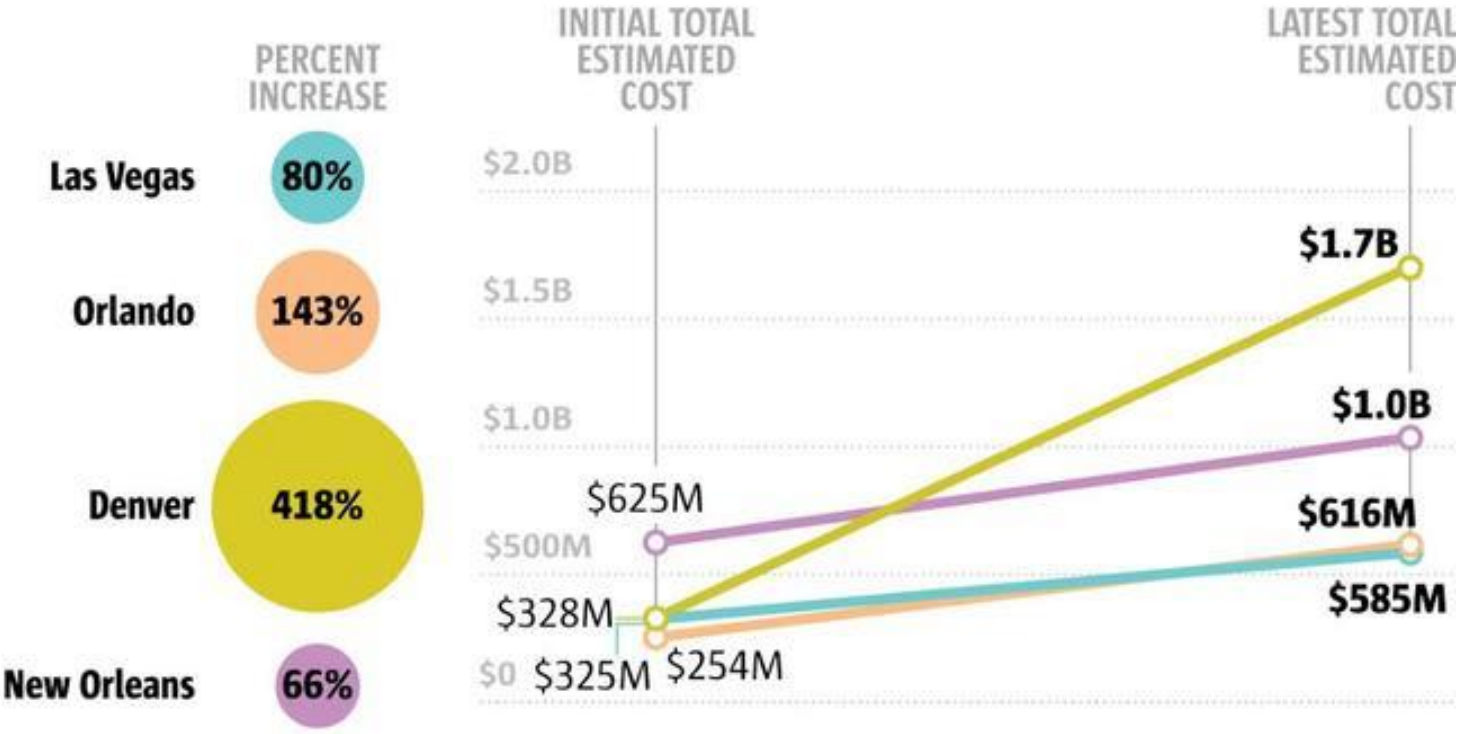
- The time of sunrise and sunset tomorrow?
- The times of high tide and low tide predicted?
- That an airplane will arrive on time?
- That a sprinkler system will work in case of fire?
- That a contractor will finish on schedule?
- That a government estimate is accurate?

How do you assess cost risk?

- What do you consider a reasonable cost overrun on a construction project?
- What do you consider a high overrun?
- What is the record for a cost overrun on a percentage basis?
- How do you improve estimating accuracy (minimize cost variance?)

Four over budget

Four major hospital construction projects undertaken by the U.S. Department of Veterans Affairs in recent years are significantly over-budget. Denver's, located in Aurora, is in by far the worst shape.

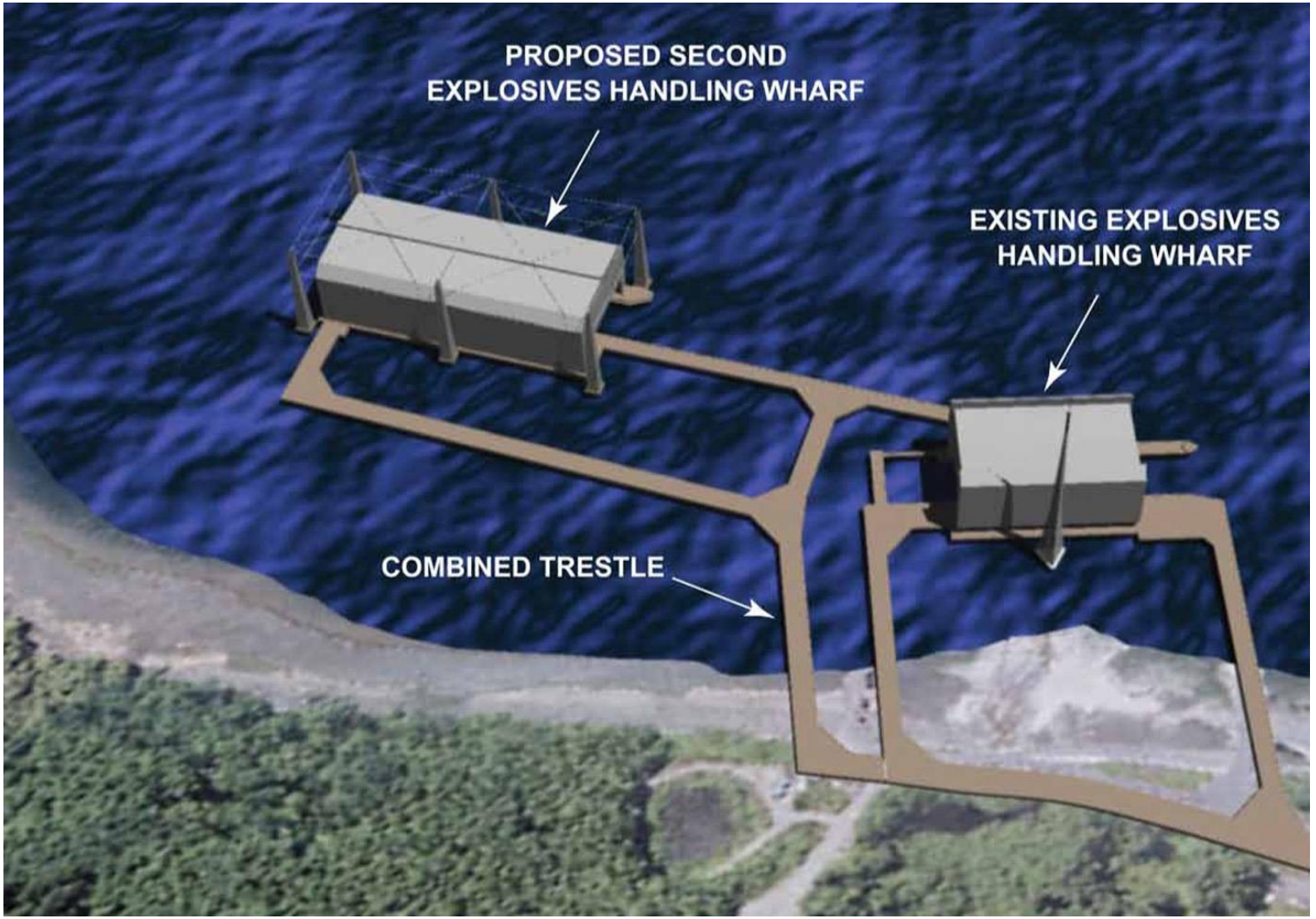


Sources: U.S. Government Accountability Office; Denver Post research *The Denver Post*

Cost Variance?

Cost Variance?

Bangor, WA Pier



Cost Risk Outline

- Where do we apply cost risk?
  - MILCON
  - Civil Works
  - Environmental Remediation
  - Others?
- How do we assess cost risk?
  - Cost Risk Tool
  - Application Exercise

MILCON COST RISK

MILCON Process

- The Department of Defense Form 1391 is the key document in the MILCON process that defines and justifies the project.
- Small projects may be carried out using Operations and Maintenance (O&M) or Unspecified Minor Construction funding, and do not require individual authorization or funding by Congress. Congressional notification is required for large projects.
- Larger projects must usually be individually authorized and funded by Congress. There are exceptions for projects meeting specific criteria, such as emergencies, contingencies, and replacing destroyed facilities.
- MILCON appropriations expire after five years.
- The Army Corps of Engineers and the Naval Facilities Engineering Command are the two construction agents for DOD on most of the planet.

Definition

MILITARY CONSTRUCTION

- Any construction, development, conversion, or extension of any kind carried out with respect to a military installation, whether to satisfy temporary or permanent requirements
- Any acquisition of land
- Construction of a defense access road

Definition

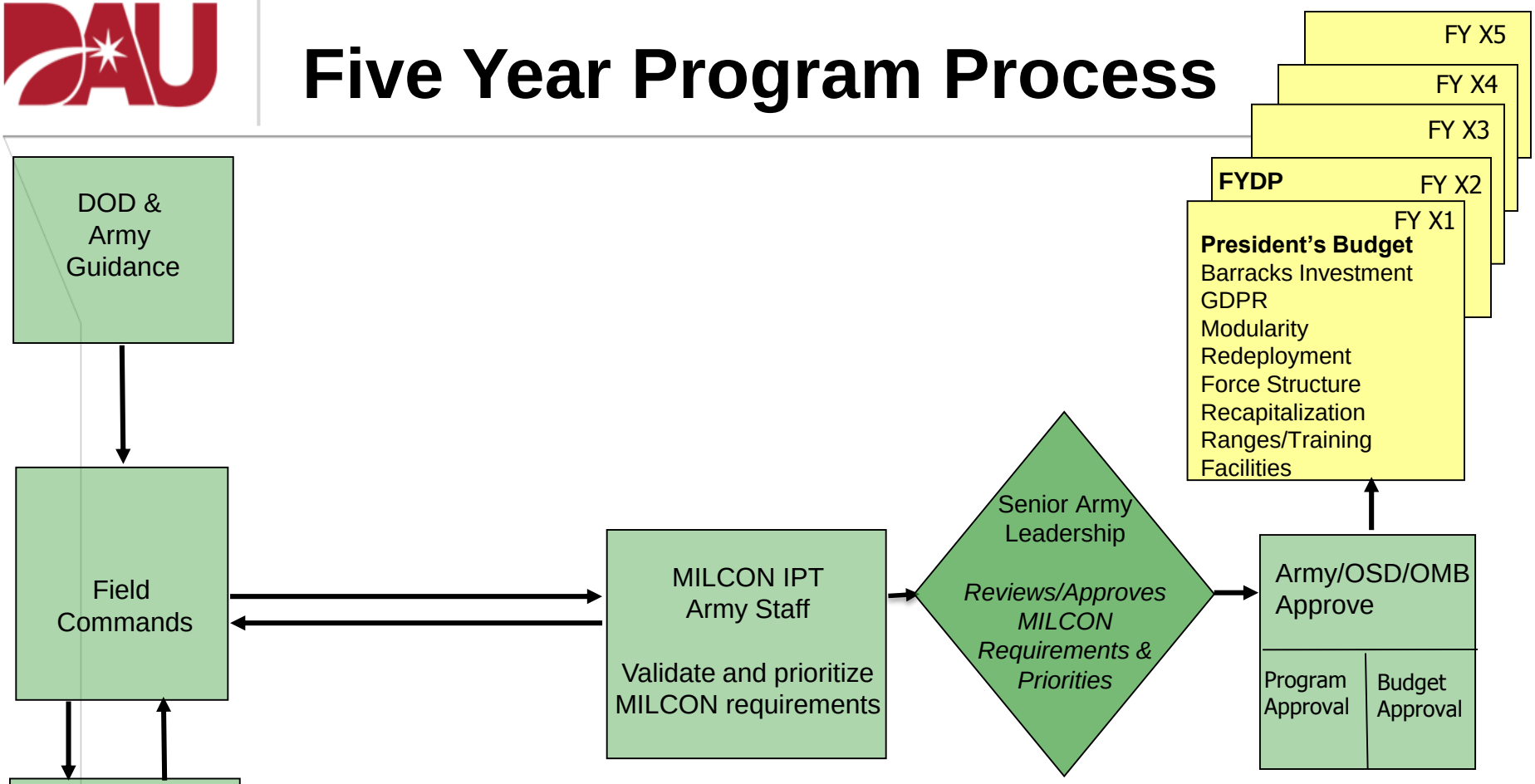
• MILITARY CONSTRUCTION PROJECT

- All military construction work, or any contribution authorized by 10 USC chapter 169, necessary to:
  - Produce a complete and useable facility, improvement to an existing facility or a portion thereof
- May include:
  - Surveys and site preparation
  - Acquisition, conversion, rehabilitation, and installation of facilities
  - Acquisition and installation of equipment integral to the facility
  - Acquisition and installation of supporting facilities (including utilities) incident to the project
  - Planning, supervision, administration, and overhead incident to the project

MILCON Authorities

Permanent Authorities	Annual Authorities
Title 10 U.S.C.	**NDAA for FY XXXX**
• Chapter 169: Military Construction and Military Family Housing I. Military construction II. Military Family Housing III. Administration of Military Construction and Military Family Housing IV. Alternative Authority for Acquisition and Improvement of Military Housing	Division B—Military Construction Authorizations Title XXI—Army Title XXII—Navy Title XXIII—Air Force Title XXIV—Defense Agencies Title XXV—NATO Security Investment Title XXVI—Guard and Reserve Forces Title XXVII—BRAC Title XXVIII—General Provisions

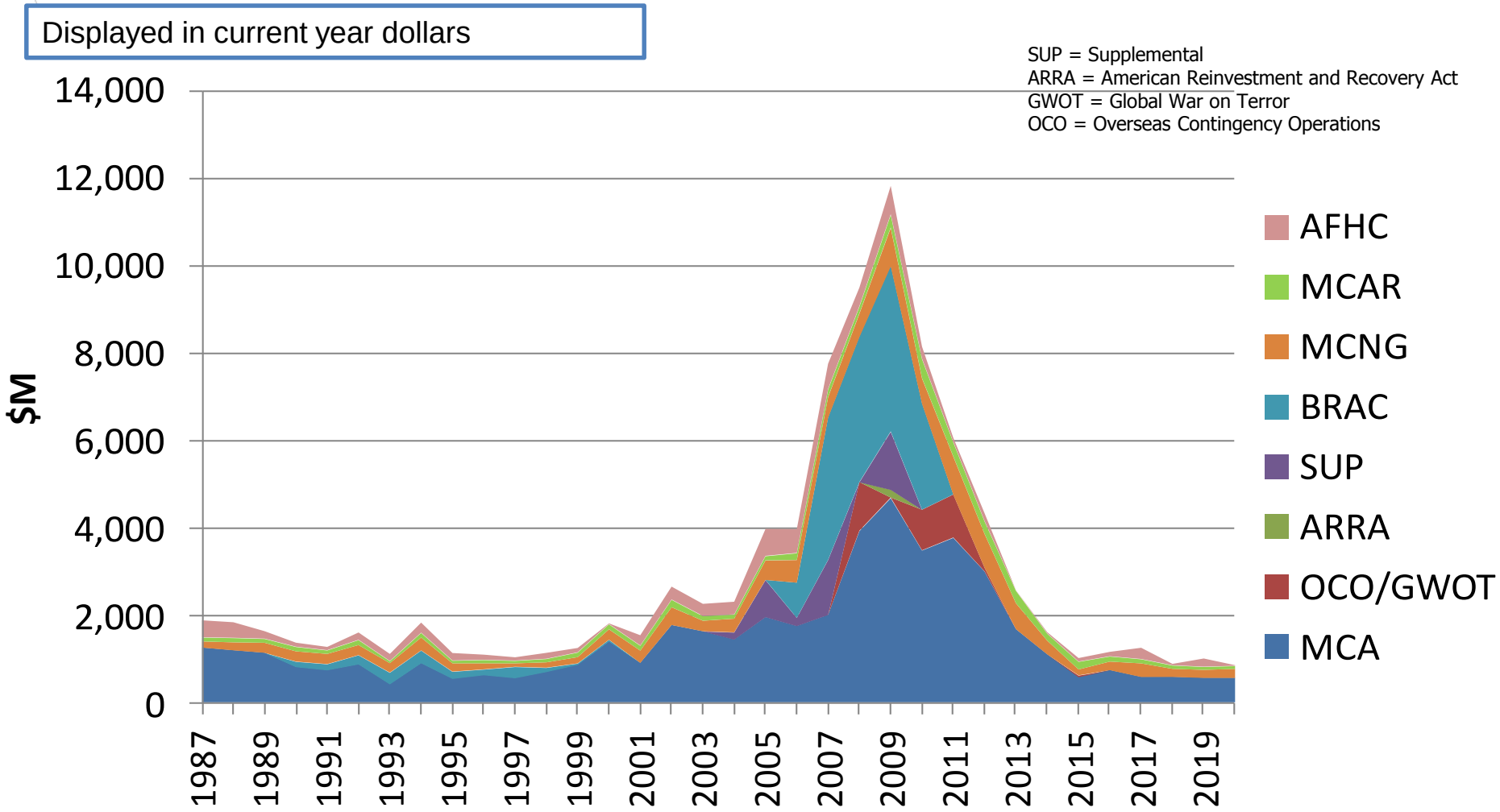
Five Year Program Process



- OSD and Army Leadership establish priorities and issue Guidance
- Installations and USACE develop the requirements (DD 1391's)
- HQ Army Staff validate and prioritize requirements then submit to Senior Army leadership for approval
- Army OSD/OMB reviews and approves Program/Budget
- Congress authorizes and appropriates the budget (DD 1391's)
- USACE executes the program.

MILCON Facilities Investment

Displayed in current year dollars



Funding levels reverted back to pre-2000 levels

Civil Works

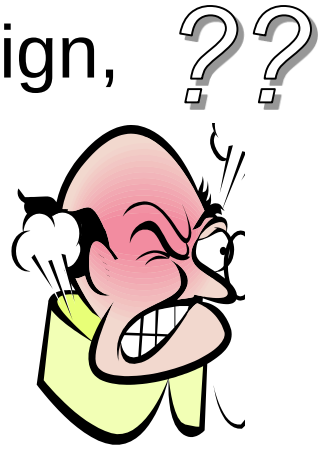
Identification of Risks and Contingencies

Risk Based Contingencies

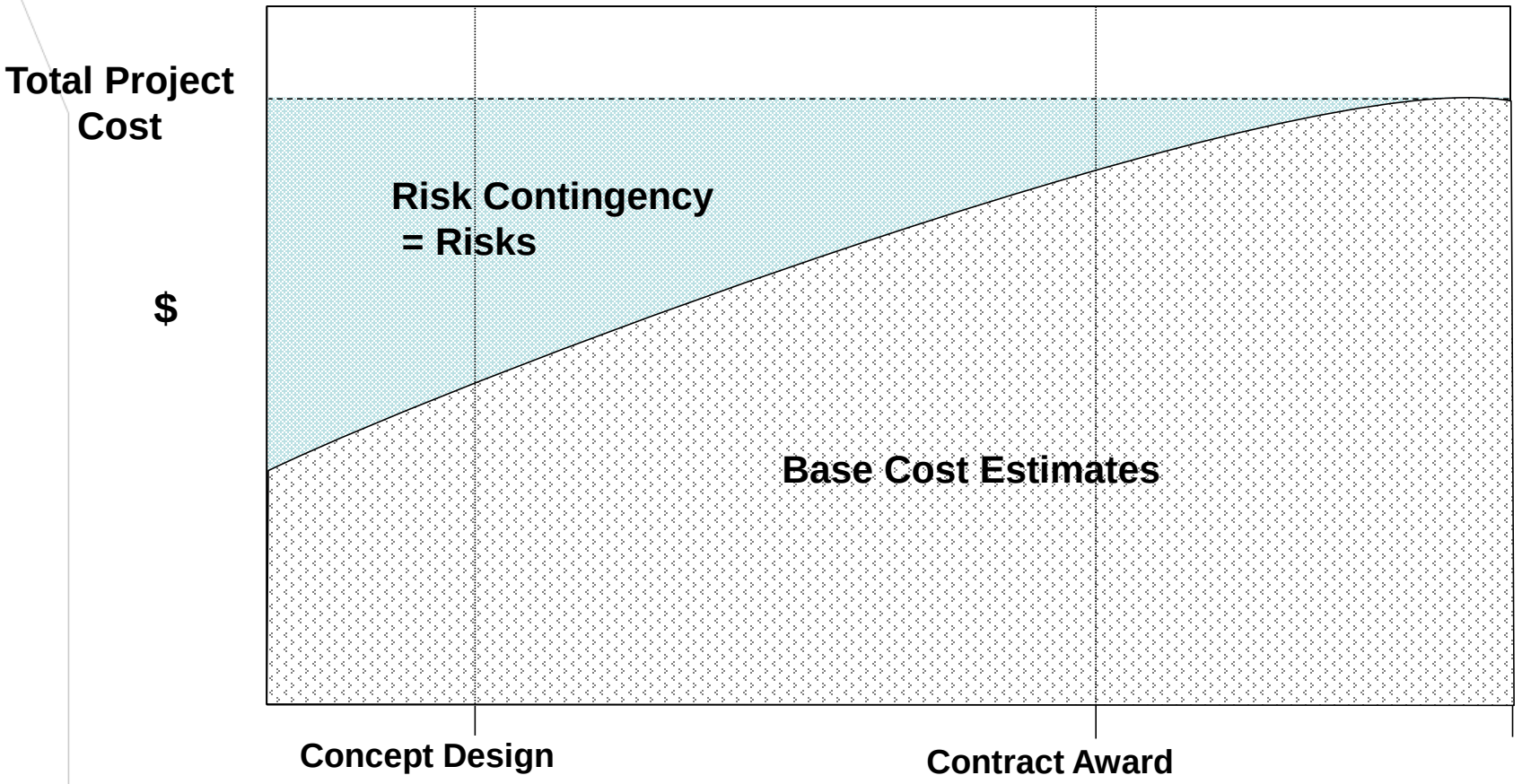
- Changed Philosophy from “the old days”
- All Features
- Risk-Based Logic
- Abbreviated Risk Analysis (<$40M)
- Monte Carlo CSRA > $40M Project Cost
- Formal Report in Cost Appendix

Why Risk Analysis?

- Over 25% of Civil Projects are out of compliance on cost and schedule (MG Walsh memo in 2013)
- Changing processes (planning, design, acquisition, construction methods)
- Compressed schedules
- Less design information
- Multiple players (internal/external)
- Historically inadequate contingencies
- Section 902 applies to water projects



Contingencies thru Project Development



Environmental Cost Risk

Overview

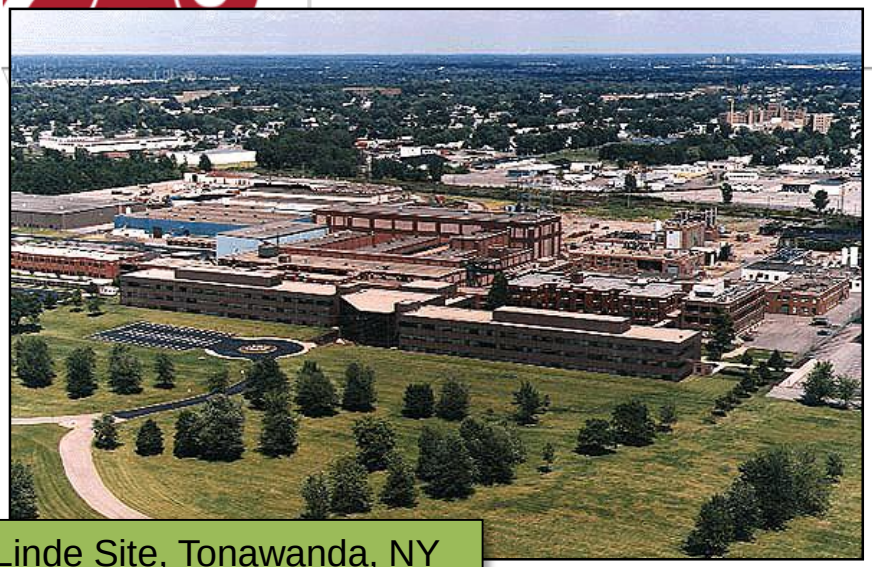
- Program Name: Formerly Utilized Sites Remedial Action Program (FUSRAP)
- Mission: Investigate and remediate radiological & chemical contamination at sites involved in the early atomic weapons program
- Location: Great Lakes and Ohio River Division (LRD)
- Projects: Remedial Action Phase Projects

Contents

- BLUF
- Situation
- Problem
- Solution
- Conclusion

Confidence Level	2010 CTC	Duration (years)	2009 CTC	Duration (years)
5%	$22,702,000	3.5	$22,013,000	3.5
10%	$23,588,000	3.6	$22,848,000	3.6
20%	$24,607,000	3.7	$24,051,000	3.7
30%	$25,744,000	3.8	$25,104,000	3.8
40%	$26,775,000	3.9	$26,188,000	3.8
50%	$28,089,000	3.9	$27,395,000	3.9
60%	$29,797,000	4.0	$28,784,000	4.0
70%	$31,291,000	4.1	$30,463,000	4.1
80%	**$33,441,000**	**4.2**	**$32,590,000**	**4.2**
90%	$36,357,000	4.4	$35,624,000	4.4
99%	$42,399,000	4.9	$42,358,000	4.8

Example: Linde Site, Tonawanda NY



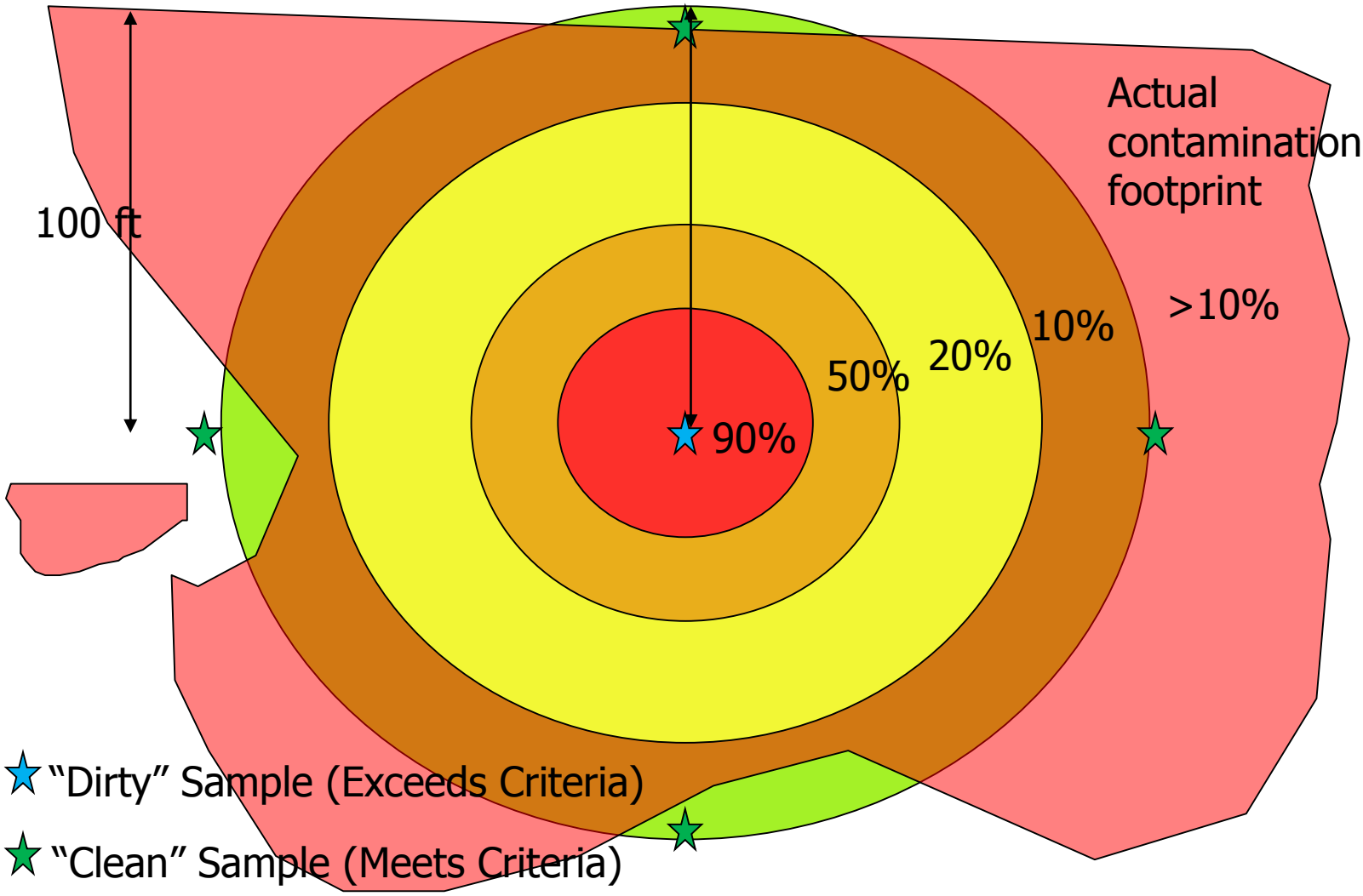
Linde Site, Tonawanda, NY

Property Owner: Praxair Incorporated
Property Size: 105 acres
Property Use: Praxair's center of expertise for industrial gas production research and development. 1,200 employees on site
Surrounding Land Use: Residential, schools, commercial

Linde Project: Risk Realities & Realizations

- Failure to complete on time (as promised)
- Failure to complete on budget (as promised)
- Making promises (w/out buy-in on risks)
- Hope + Enthusiasm + Money ≠ Strategy
- Failure to confront and communicate the brutal facts
- Overly reliant upon contractor projections
- Arbitrary “Contingency %” in budgets
- “Silver Bullet” solutions and other distractions
- When you finally realize you’ve dug yourself into a hole…stop digging!

Risk Management: Contaminated Soil Volume



Solution: Cost & Schedule Risk Analysis

- Project Delivery Team
  - Buffalo District (LRB)
  - Walla Walla District (Cost District of Expertise)
    - Project Time & Cost, Risk Strategics (Walla Walla Contractors)
  - Argonne National Lab (development of base volume estimates)

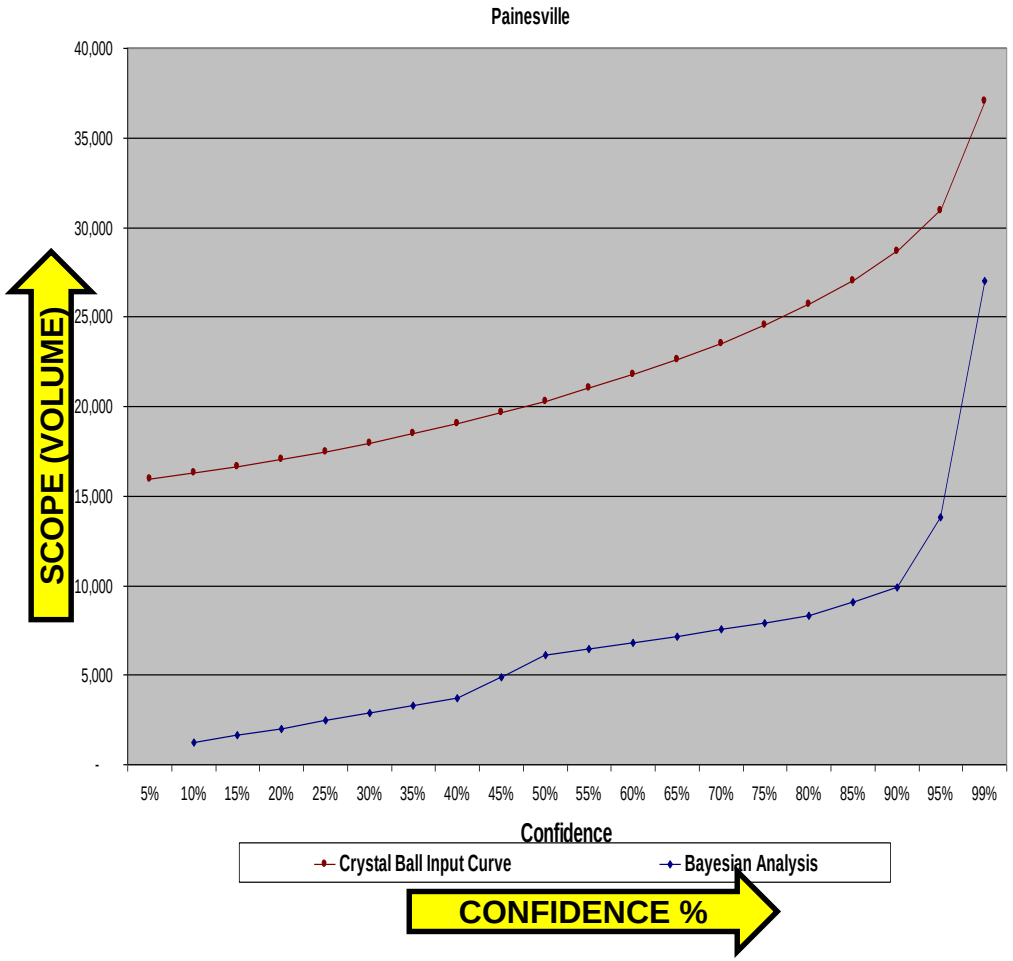
- Quality Assurance
  - HQ
  - Great Lakes and Ohio River Division (LRD)
  - LRB
  - Environmental & Munitions Center of Expertise (EM-CX)

Process

1. Develop Range of Contaminated Soil Volume Estimates for sites where investigation phases are complete
2. Update Project Cost-to-Complete Estimate & Schedule
3. Develop and Refine Project Risk Registers
4. Perform Cost and Schedule Risk Analysis
5. Present Cost Ranges Based on Modeled Risks
6. Engage Vertical Team to Determine Acceptable Risk and Associated Cost

1. Develop Contaminated Soil Volume Estimates

- Geostatistics, based on Bayesian analysis, using:
  - Analytical data from historical and USACE investigations
  - Historical aerial photo analysis results
  - “Soft” data such as historical narrative and local anecdotes
- Based on previous project experience, PDT chooses high end of volume estimate curve as a minimum bounding value for Crystal Ball input distribution
- This bounding value includes soil volumes associated with known and potential areas of contamination
- Crystal Ball input distribution models the risk of encountering greater, and previously unpredicted, contaminated soil volumes (“unknown unknowns”)



2. Update Project Cost-to-Complete Estimate & Schedule

- Base cost estimate developed using upper end of estimated contaminated soil volume curve
- Remedial action costs developed in MCACES/MII format
- Range of cost estimates were developed based on different contaminated soil volume values on the site curve
- This range of cost estimates allowed the risk analyst to more effectively predict how the volume risk factor would affect project cost

3. Develop and Refine Project Risk Registers

- Detailed register of specific project risks, spanning all aspects of management and execution
- Register includes between 60 and 90 specific risks within 13 project risk categories
- Each risk is assigned a qualitative likelihood and impact for both cost and schedule
- Full PDT brainstorming meeting to review, discuss, and refine risk register
- Revised project risk register is used as input to Crystal Ball risk analysis software
- Principal risk driver for these sites is the potential for contaminated soil volume changes

Risk Level

Likelihood of Occurrence	Negligible	Marginal	Significant	Critical	Crisis
Very Likely	Low	Moderate	High	High	High
Likely	Low	Moderate	High	High	High
Unlikely	Low	Low	Moderate	Moderate	High
Very Unlikely	Low	Low	Low	Low	High

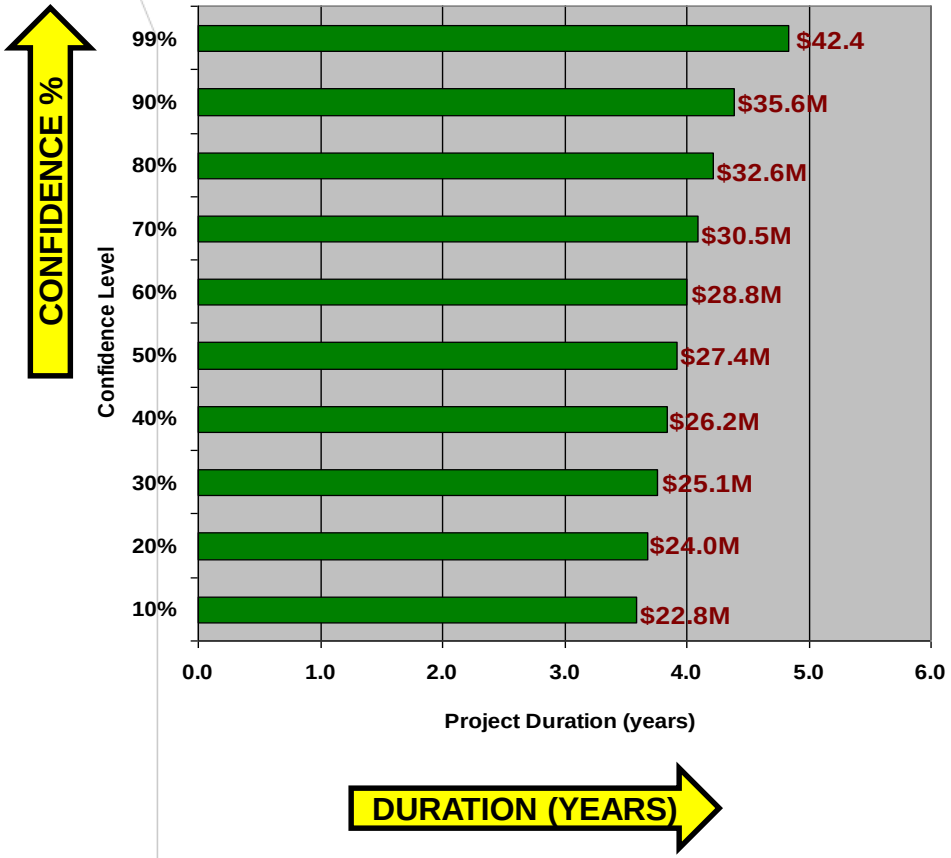
Impact or Consequence of Occurrence

4. Perform Cost and Schedule Risk Analysis

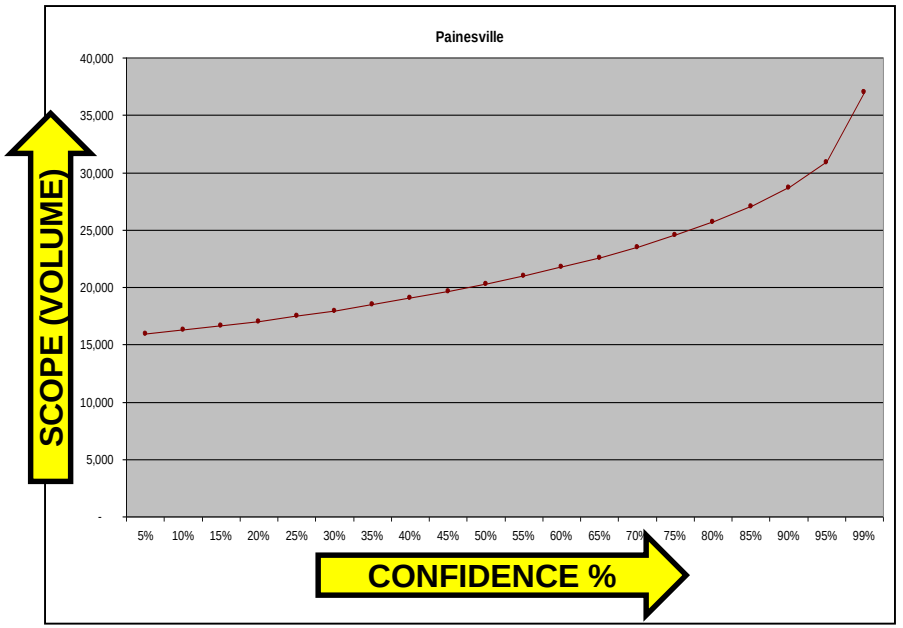
- USACE Cost Engineering Directory of Expertise (DX) included on PDT for cost and schedule risk analysis (CSRA)
- Risk Analyst uses PDT-developed risk registers as input
- Quantifies cost and schedule risks based on detailed qualitative PDT input and baseline cost estimate
- Output is a range of Cost-to-Complete Estimates and associated confidence levels
- PDT reviews outputs and risk distribution functions and refines model
- Determines appropriate confidence level to apply to all sites (80% commonly used for programming within USACE)

5. Cost Risk Analysis (Example: Painesville Site)

Cost & Schedule Range



Scope (Volume) Range



6. Determine Acceptable Risk & Associated Cost

	CONFIDENCE % COSTS TO COMPLETE		
SITE	50%	80%	99%
Painesville	$27 M	$33 M	$42 M
Linde	$66 M	$106 M	$193 M
SLDA	$142 M	$274 M	$442 M
Luckey	$142 M	$309 M	$596 M
Seaway	$84 M	$121 M	$149 M
TOTAL	$461 M	$843 M	$1,422 M

50% confidence level = risk neutral ≠ acceptable
80% confidence level = risk averse = acceptable
99% confidence level = extremely risk averse ≠ acceptable

Summary

- Environmental remediation = significant threats, uncertainties and risks to scope, schedule, budget, quality
- Risk Mgt: Quantitative + Qualitative = Confidence
  - Risk registers (categories, risks, probability, impacts)
  - Statistical Monte-Carlo analysis of impacts to cost & schedule
  - Corporate buy-in on risk management process
- LRD uses 80% confidence values for budgeting, scheduling & committing to FUSRAP project completions
- Continuous improvement: Update CSRA estimates at least annually to provide best possible input to FUSRAP budgeting process

Analysis tool

- How do you use the cost risk tool?
- Monte Carlo @risk tool
- Setting up the simulation
- Excel Rand function and F9 does a Monte Carlo one iteration at a time. The @Risk tool does multiple F9's and tabulates results
- If you have XL, know the Rand() function and have a pad and paper, you can do Monte Carlo.

Analysis Tool

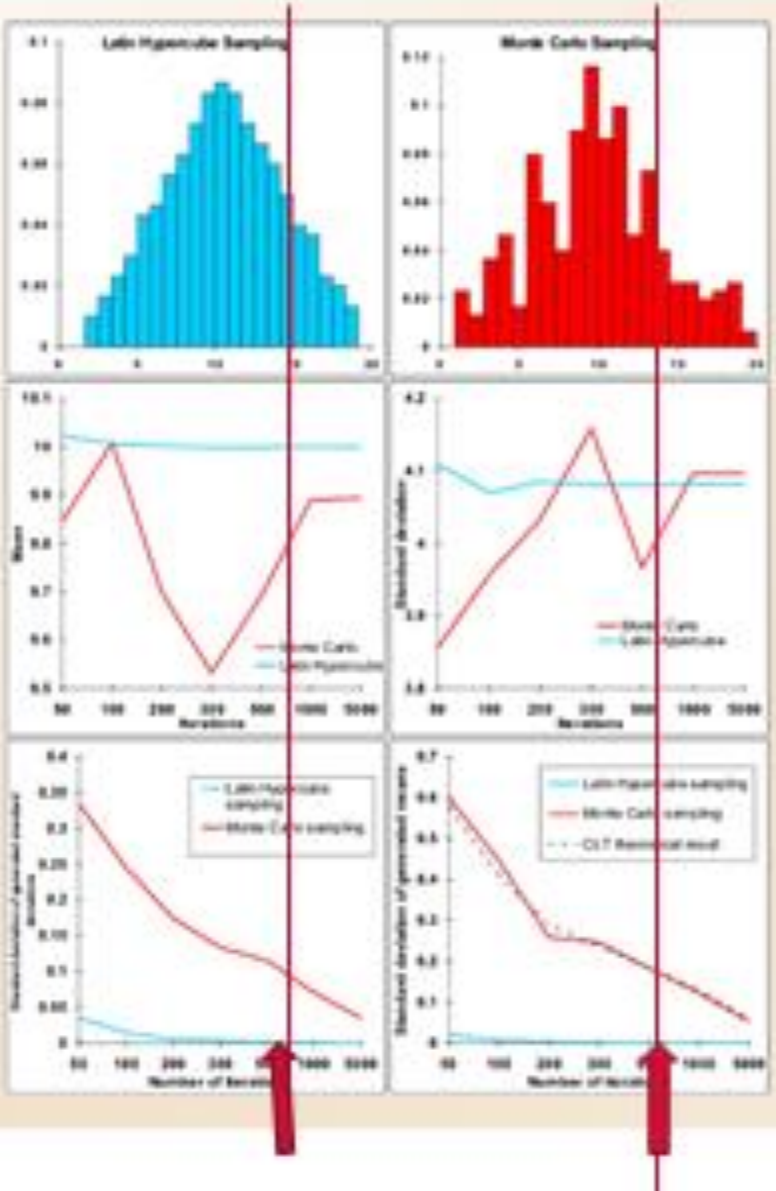
- So just how does Monte Carlo Work on these applications?
- Say you have 10,000 hours of labor but not sure if the Construction Wage Rate is $25 or $40 an hour. You need a DOL decision on that. And the equipment on the job will rent for 50,000-60,000 a month for 3 months. First is a discrete function, the second is a uniform distribution.

Run the simulation

Labor	Equipment	Total
25000	156,099	181,099
25000	166,333	191,333
40000	172,271	212,271
25000	165,198	190,198
40000	179,321	219,321

- Etc to 1000 or 10000 simulations. Then plot the points on a histogram and you have your distribution.

Get 80% of the numbers to the left



What is the Engine for this?

- Rand function. That function “rolls the dice” and creates a uniform distribution.
- 50,000 + Rand()*10,000 returns a number randomly between 50,000 and 60,000.
- For a discrete distribution the rand function is used this as shown below.
- IF(Rand()>0.5,25000,40000) will return either 25000 or 40000 depending on dice roll.

Exercise 3 – Monte Carlo

- See Exercise 3 in Student Materials, Blackboard
- Using criteria in handout and @risk tool, fill out answers to the questions included. These answers would then be used to request appropriate funding for the project.

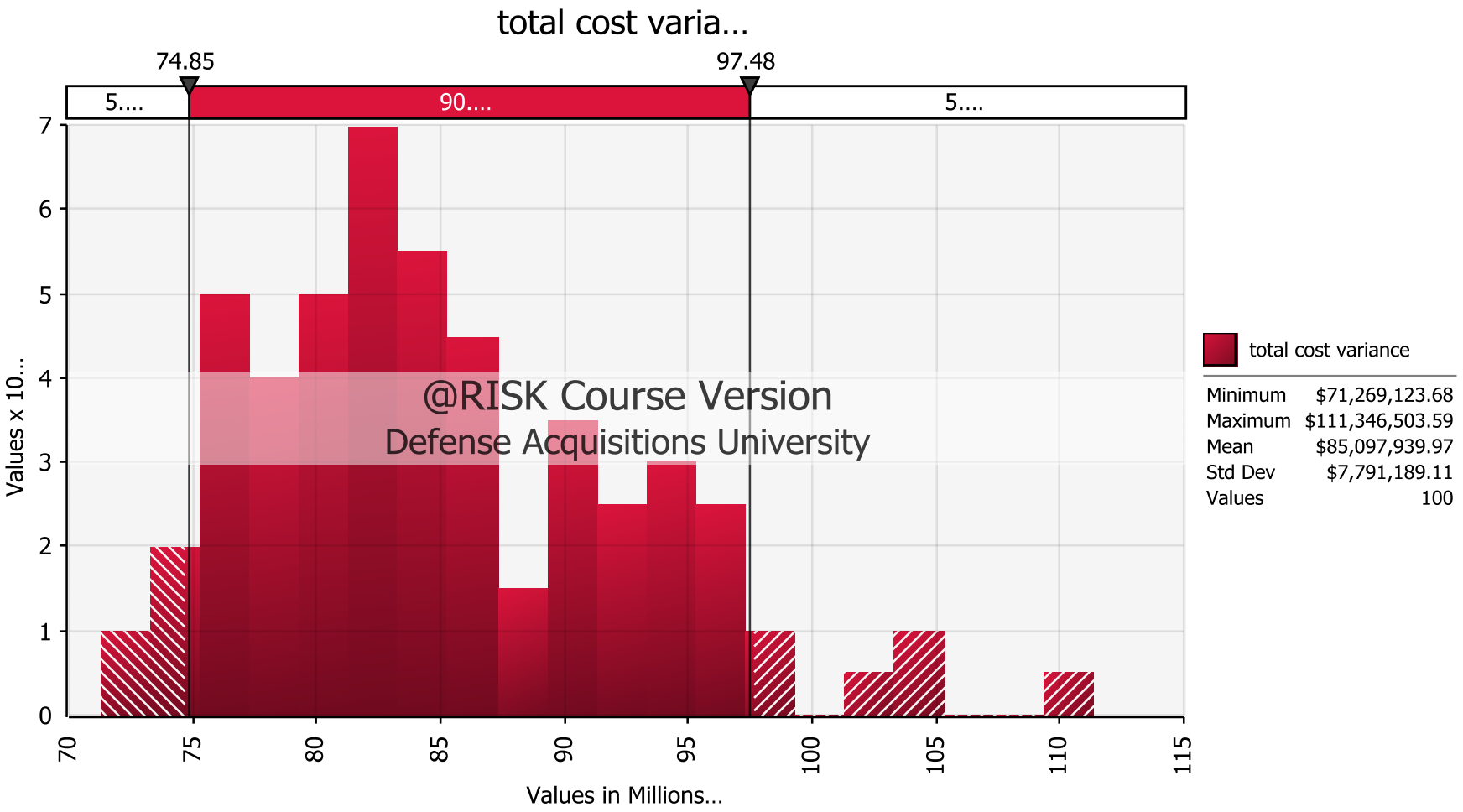
Exercise 3 Briefing

- You are planning a support facility for a Romanian Air Base taken over by the US.
- US troops will definitely be there.
- A few other NATO countries will send troops.
- You have to estimate the costs of barracks, gym and office space.
- A few countries object to being domiciled with troops of other countries.
- There are different requirements for permanent and transient personnel.
- There is a currency risk due to economic issues in the EU at the moment. State department projections are included in the project.

Exercise 3 Briefing (Continued)

- Using @risk you will estimate the amount of money required for this project.
- If you can't get @risk working you can do an "F9 Monte Carlo" by hitting the F9 key 10 times, ordering the output from low to high and selecting the 8th number in the list as your 80% confidence level.
- It produces a very rough 80% estimate, but any port in a storm.
- Go.

Ex 3. Estimate



Tabular output of @risk

	total cost variance
Cell	Cost Calcs!D22
Minimum	$71,269,123.68
Maximum	$111,346,503.59
Mean	$85,097,939.97
Mode	$81,621,059.59
Median	$83,312,493.79
Std Dev	$7,791,189.11
1%	$71,269,123.68
5%	$74,848,948.83
10%	$75,850,737.36
15%	$77,030,089.32
20%	$78,698,252.78
25%	$79,589,807.50
30%	$80,299,500.32
35%	$81,375,957.68
40%	$81,715,682.91
45%	$82,604,241.98
50%	$83,312,493.79
55%	$84,263,815.56
60%	$85,407,714.55
65%	$86,574,201.28
70%	$87,794,559.27
75%	$90,552,603.25
80%	$91,496,883.99
85%	$94,183,228.61
90%	$95,622,741.77
95%	$97,477,079.90
99%	$104,703,678.98