CPM-200 Principles of Schedule Management Project

Lesson E: Schedule Risk Analysis

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IPMC 2002 Fall Conference

Professional Education Program

Agenda

- Introduction
- Risk on a single task – probability distributions
- Collecting data on task risk
- Risk along a path – Monte Carlo simulation
- Risk with parallel paths – the Merge Bias
- Schedule Risk vs. PERT
- Risk Criticality Index
- Correlated task durations
- Probabilistic branching

Introduction

<u>*USAF Approach to Schedule Risk*</u>

"A Most Probable Schedule (MPS) will be prepared by assessing the durations presented in the offeror's MIPS (this means estimating the longest, the shortest, and the most likely duration for each task, activity, event, and milestone) and preparing a network-based Monte Carlo simulation in order to determine a schedule that has a 90% probable completion date."

Integrated Risk Management Guide,

Aeronautical Systems Center (ASC), draft, 9 April 1994

Overrun Risk is Not a New Issue

"Initial cost and schedule estimates for major projects have invariably been over-optimistic. The risk that cost and schedule constraints will not be met cannot be determined if cost and schedule estimates are given in terms of single points rather than distributions"

Overrun Risk is Not a New Issue (continued)

"A formal risk analysis is putting on the table those problems and fears which heretofore were recognized but intentionally hidden."

Source: "*Final Report*,"
US Air Force Academy Risk Analysis Study Team 1973

Schedule Risk Is Common

"The opening of Denver International Airport, originally scheduled for last October (1993), has been delayed yet again, this time until May 15 (1994) because of problems in troubleshooting its complex baggage system… The delay will cost the city, and United and Continental airlines a total of $30 million."

Aviation and Space Technology, March 7, 1994, p. 32

Reasons for Schedule Risk

- Fundamental uncertainty in the work
- Unrealistic baseline schedule
- Natural, geological causes
- Project complexity

Reasons for Schedule Risk (continued)

- Scheduling abuses
- Relying on participants outside the organization
- Subcontractor late
- Design changes
- Staffing

Reasons for Schedule Risk (continued)

- Manufacturing problems
- Contracting problems
- Customer (government) not supportive
- Cannot get subcontractor under contract

William Cashman, *“Why Schedules Slip…”*

Air Force Institute of Technology (AFIT) Master’s Thesis, 1995

Pitfalls in Relying on CPM

- CPM network scheduling is deterministic
- Single-point activity durations
- OK only if everything goes *according to plan*
- CPM durations are really probabilistic assessments

There are no "facts" about the future

Objectives of a Schedule Risk Assessment

- Improve the accuracy of the schedule dates
- Validate the CPM or contract dates
- Establish a schedule contingency
- Identify the risk-driving events
- Communicate about and understand the project
- Continuously monitor changing schedule risk

"Promises" of a Quantitative Schedule Risk Analysis

- How likely is the project to finish on or before the project completion data?
- By how much might we overrun based on the organization's level of risk aversion?
  - How much time contingency do we need?
- Where is the major risk in the project?
  - Where should we focus risk mitigation resources?
  - Why is this not always the critical path?

A Prerequisite: Robust Schedule Logic

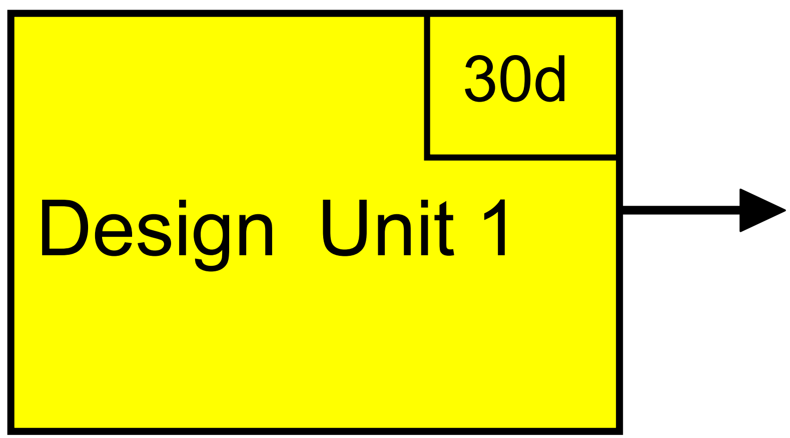
- All activities should have successors
- Do we believe the floats? the critical path?
- Direct, simple Finish-to-Start logic is much preferred
- Sometimes Start-to-Start or Finish-to-Finish logic is needed
- Check to see that it <u>automatically</u> computes the right path and dates when durations change

Good Critical Path Method (CPM) Schedules are Needed

- Schedules should be direct, ***finish-to-start***
- Each activity except the finish milestone needs a successor
- Do not use milestones to stand in for activities
  - Supplier's "Promise dates" do not mean certainty
- Check floats to see if logic needs fixing
- Schedule as if the durations are uncertain
  - Because they are

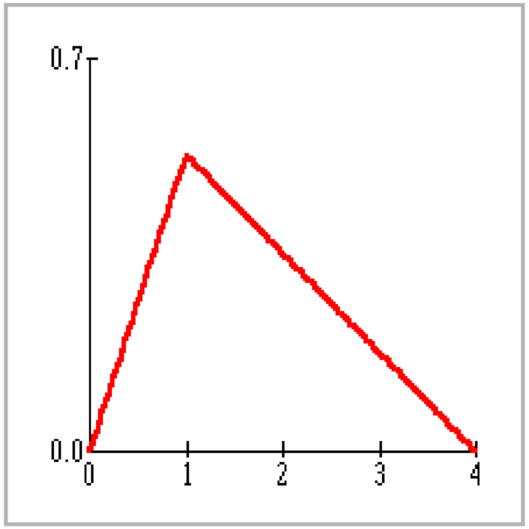
Risk of an Individual Activity

- Simple activity duration estimates are risky



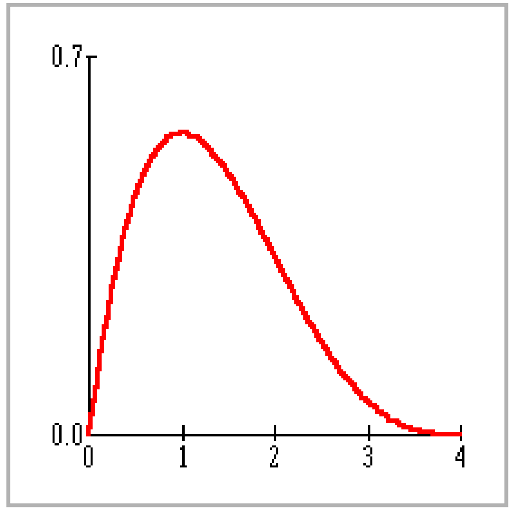
- Activity duration risk is similar to cost element risk

Activity Duration Risk



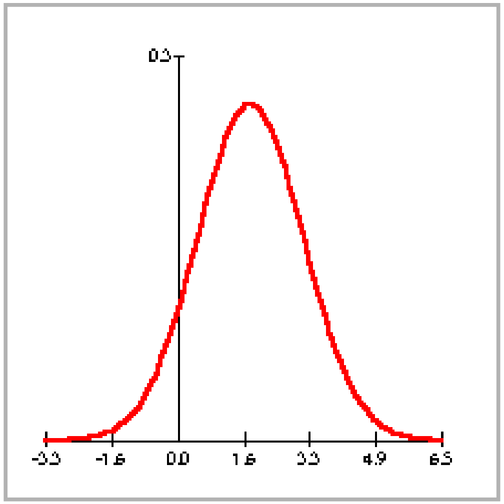
Triangular

- Asymmetrical
- Conservative
- M = (L+ML+H)/3



BETA

- Asymmetrical
- Aggressive
- M=(L+4*ML+H)/6



Normal

- Symmetrical
- Represent many populations

Risk Data Collection

Risk Data Collection

- Major part of a risk analysis effort is gathering the data
- The benefits of collecting data about project risk
  - Conduct a quantitative risk analysis
  - Gain better understanding of the project
  - Build stronger project teams
  - Communicate better about project problems

Main Ideas about Risk Data

- Results reflect the input data
- Input data are judgmental
  - There are often no company or industry data bases on risk
- Concepts of risk are usually new to the participants

Main Ideas about Risk Data (continued)

- Collecting “data” about the future is new to most people
- Some are reluctant to participate -- uncomfortable
- Risk Analyst and Project Manager need to overcome resistance to get good data

Most Difficult Risk Concepts – the Pessimistic Scenario

- Look to history -- what was your worst experience?
- Explore the extremes
- Definition, it is only 1% likely to be worse
  - It will define the extreme value of the distribution
- Not creating risk where none exists
  - No piling up of disaster on disaster if that is too remote
  - Pull back from an unrealistic extreme

Optimistic Scenario

- Optimistic scenario
  - Only 1% likely to be better
- This is the "bare bones" estimate
- Cause of optimistic scenario
  - Events outside your control that may go your way
  - Project decisions in your control
  - This is a source of "opportunities"

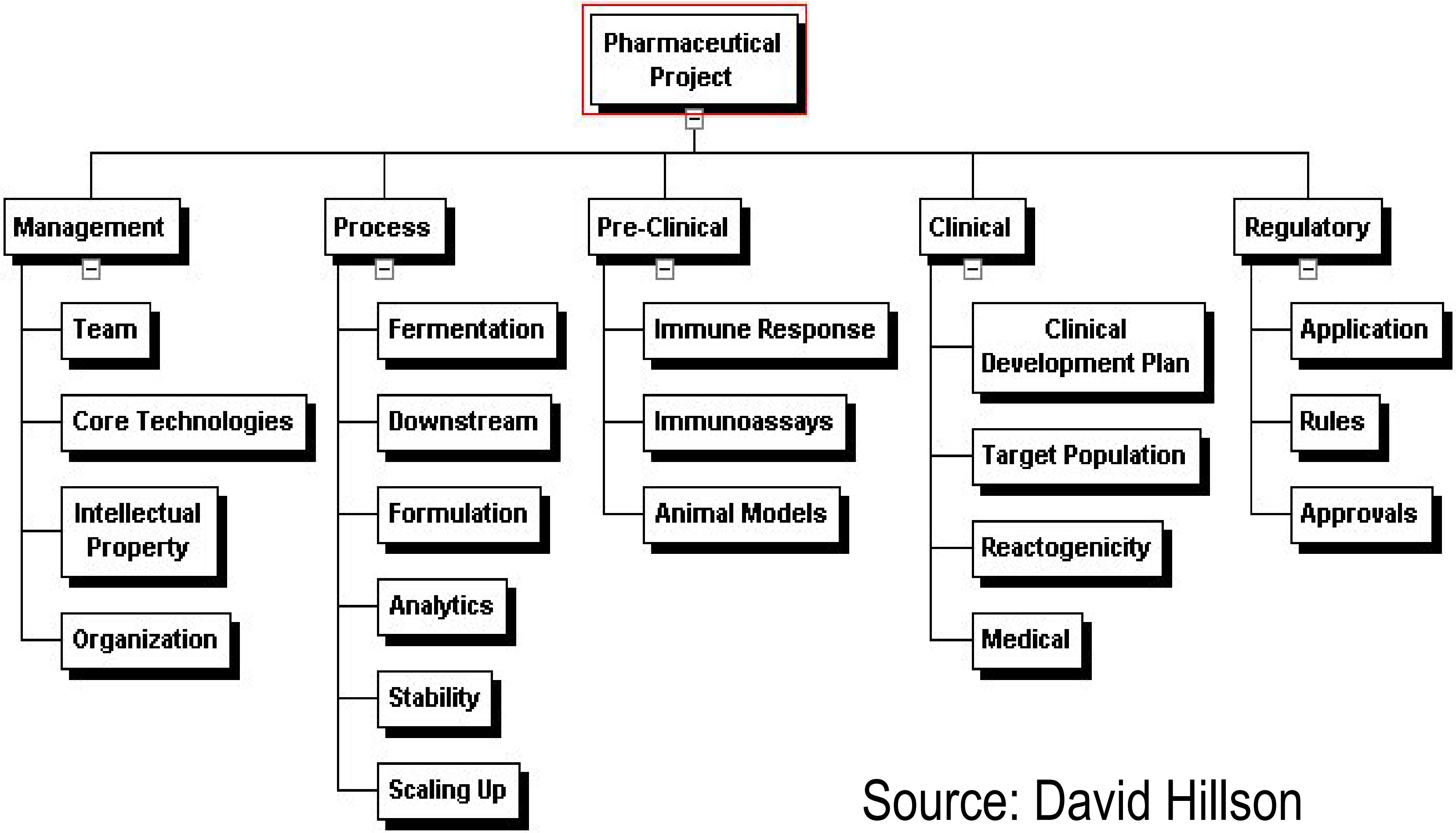
Most Likely Scenario

- What happens, typically, in projects of this type?
- What happens, typically in this company?
- Most likely scenario may not be the estimate in the baseline. You may be surprised that the baseline is:
  - Old or Poorly maintained
  - Missing data
  - Biased to get the bid or Wishful thinking
  - Padded to keep from overrunning

Making Risk Data Gathering Easier

- Need the support of the Project Manager
- Select the right subject matter experts (SMEs)
- Use others in the company to check the SMEs
- Explain what risk analysis is
  - How will top management benefit from good data?

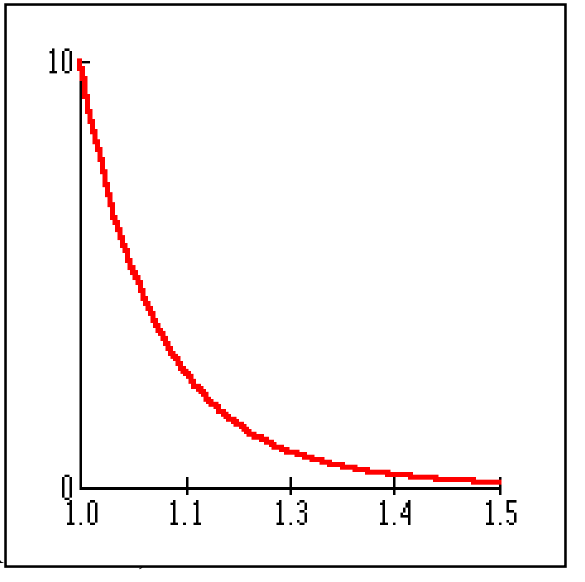
Use a Risk Breakdown Structure



Source: David Hillson

Identify the Data Elements that Contribute the Most Risk

- Relatively few project elements contribute the most risk
- The Pareto distribution
  - Significant few elements and an insignificant many elements
  - "90 - 30 rule"



Prepare for the Risk Interview (continued)

- Select the interviewees carefully
  - Project Team members
  - Company experts outside this project team
  - Experts outside the company (rare occasions)

You may have to exclude the team leader
Leaders may be too identified with their estimates or want to bias the results

The Risk Interview

- Get several experts in a room
  - Gain synergy from back-and-forth of ideas about risk in the meeting
- Brief the teams
- Teams meet first to discuss risk events
- Set aside enough time for interviews

The Risk Interview (continued)

- Assemble any relevant lessons learned or data from prior projects
- "Actuals" are a powerful force in forecasting the future
- No hierarchy in the interview -- modified Delphi technique
- During the Risk Interview
  - Challenge their risk ranges -- risk is usually underestimated
  - Develop final data in interview
  - Complete the interview in one session

After the Interview

- Document the data, assumptions ASAP
- Review the data with the respondents
- Do not be afraid to go back to get clarification, correct errors, get new data
- Some times, seek out new sources of risk data

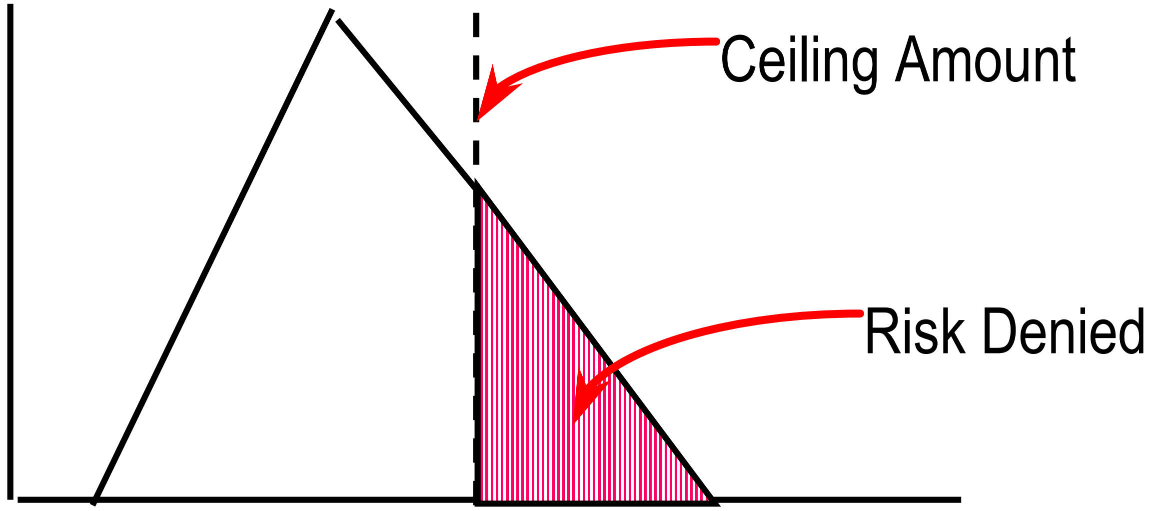
Biases can Make Risk Data Collection Difficult

- Motivational bias
  - Some people do not want to cooperate with the risk analysis process
  - They have their own agenda
- Cognitive bias
  - Even people who want to respond accurately find it difficult
  - Thinking about things going wrong is not easy

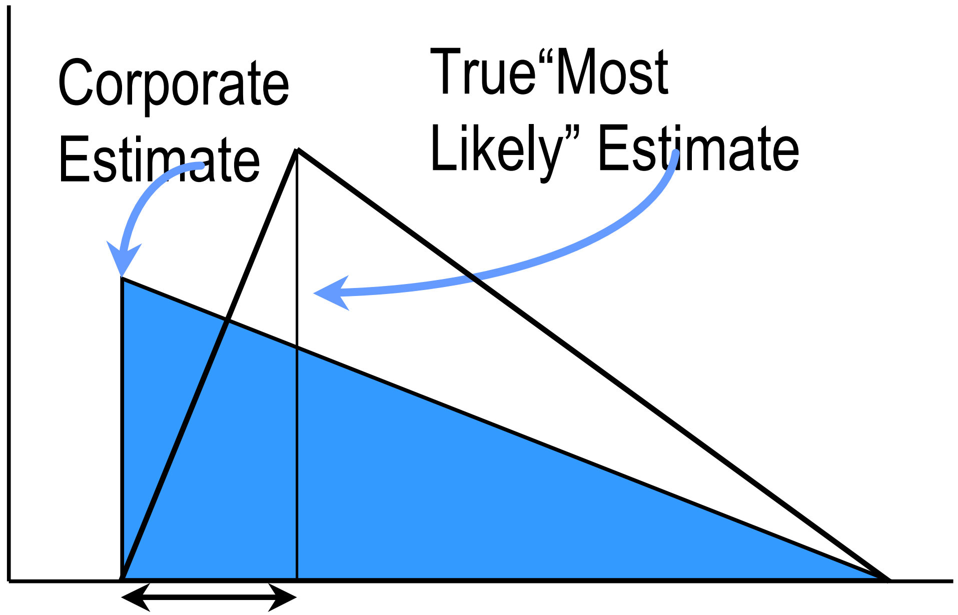
Sources of Motivational Bias

- Not willing to jeopardize the project
- Unwilling to admit uncertainty or inability to do the job
- Afraid of telling people the estimates are not “solid”
- Identified with a specific number, result
- Afraid of “shoot the messenger” response
- Some consequences are just to terrible to contemplate

A Politically-Set Corporate Ceiling

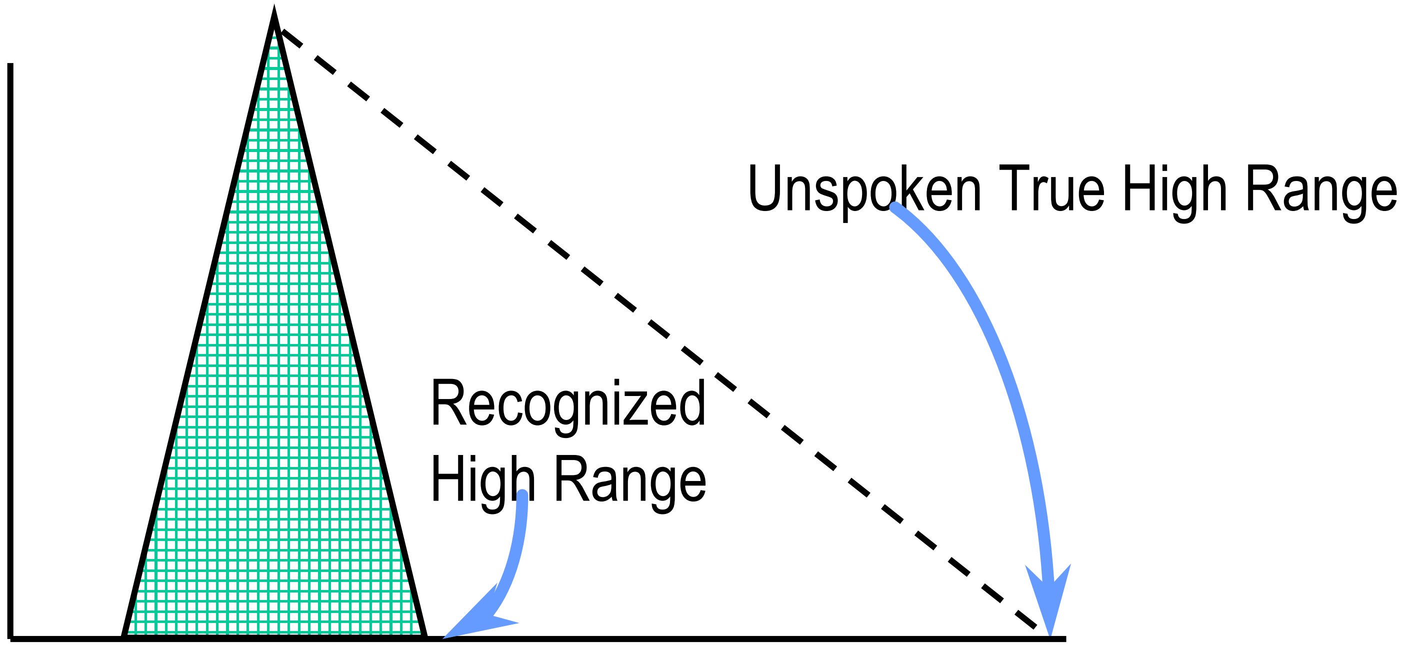


Forced Aggressive, Success – Oriented or Optimistic Estimation



Need to Shift the Most Likely for Risk Analysis

Unstated Assumptions or Terrible Consequences



Cognitive Bias in Quantifying Project Risk

- Cognitive bias is common
  - Even though you want to estimate the risk you find it hard

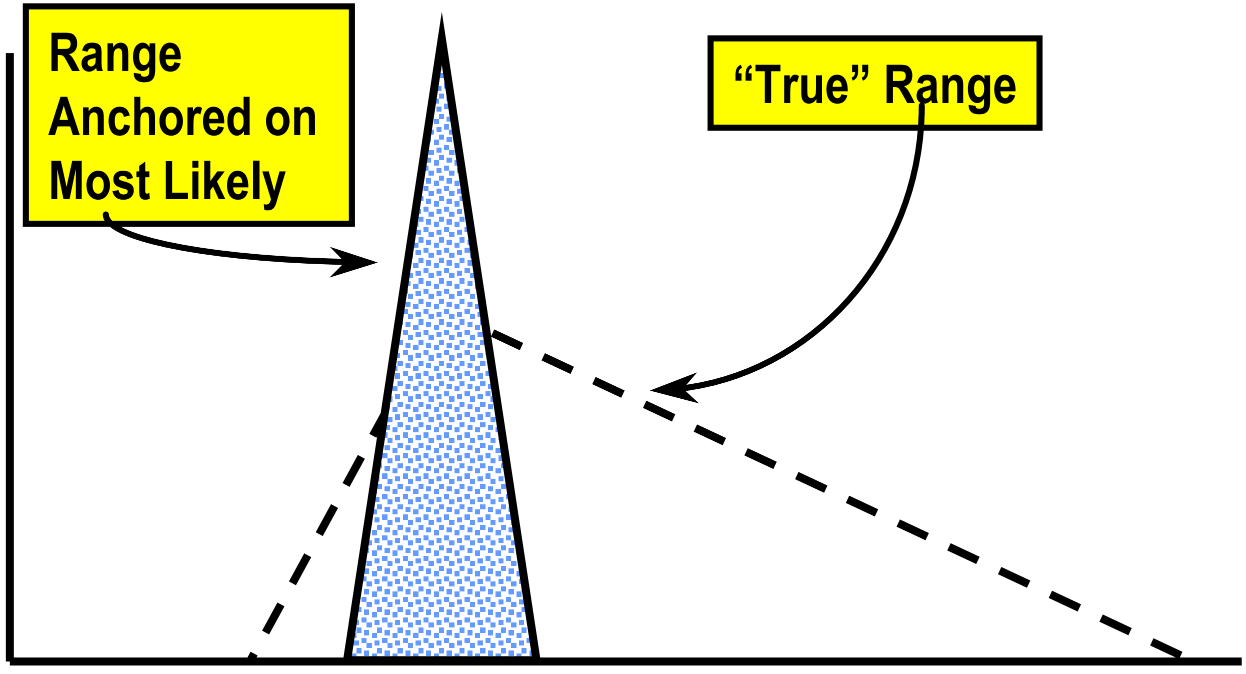
Underestimation of risk is quite common

Anchoring and Adjusting Bias

- "Anchor" on the baseline estimate
  - The anchor takes importance beyond its credibility
- "Adjust" the extreme ranges only slightly from the anchor
- Well-documented in psychological literature
  - Underestimate the true risk of the project
  - Particularly if interviewee is the source of the baseline anchor

  See: A. Tversky and D. Kahneman, "Judgment under Uncertainty: Heuristics and Biases," *Science*, Sept. 26, 1974

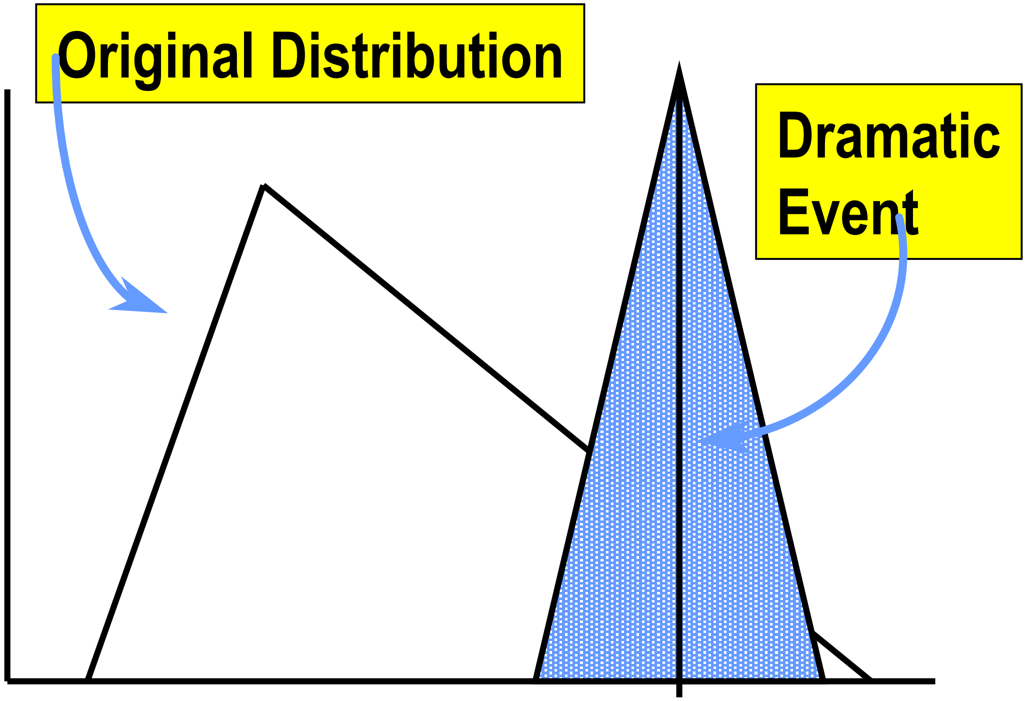
Picture of Underestimating Risk



Availability Bias

- Estimate may be dominated by events are dramatic
- This bias could lead to over-estimation or under-estimation of risk
- Because they are easily recalled, they impact our judgment about project risk
- Remarkable incidents should be used properly to determine risk

Availability Bias can Increase the Perception of Project Risk

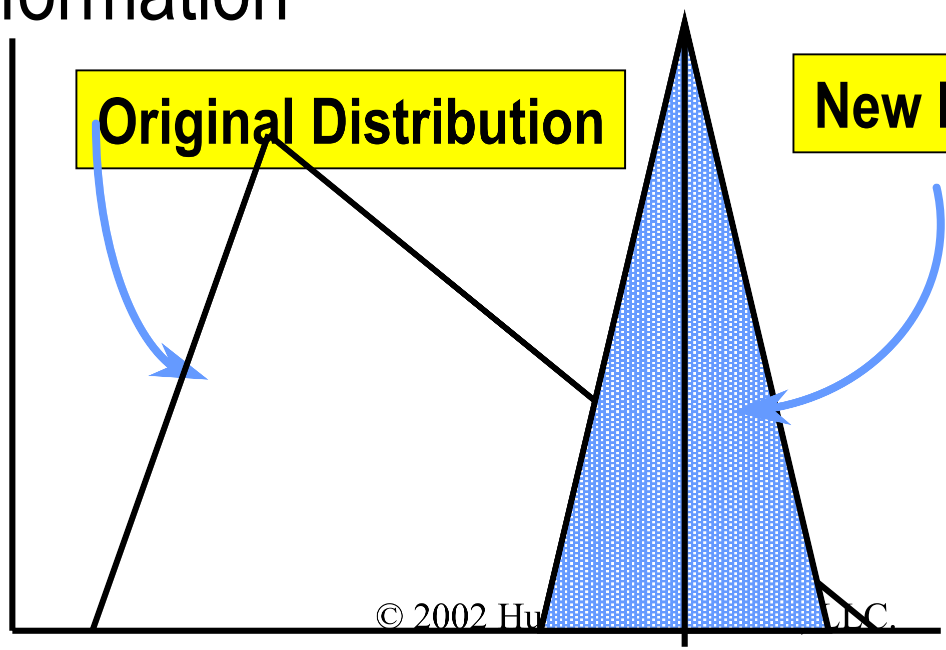


Representative Bias

- What happens if some information becomes available that shows a problem with the project?
  - We thought the project was OK
  - Now, the project seems to be having problems
  - Do these problems “represent” a failed project?
  - Will this project fail, too?

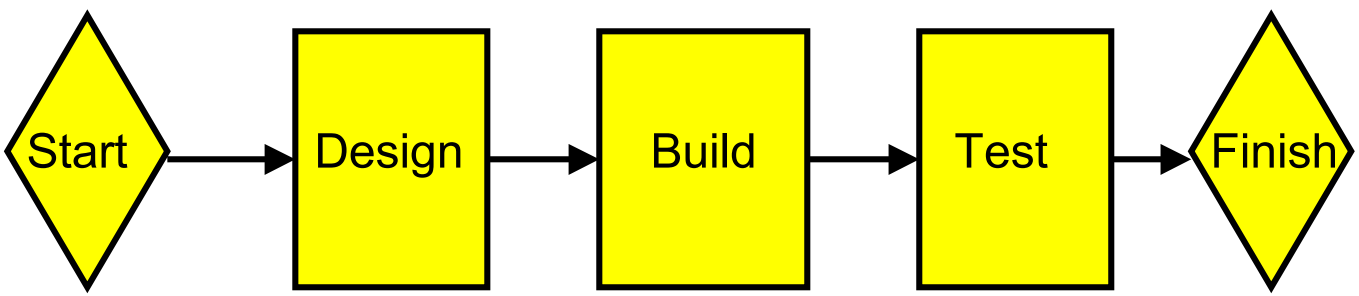
Representative Bias can Give New Information Too Much or Too Little Importance

- How should the new data modify our original assessment that the project will be a success?
- Do not panic, nor should we ignore the new information



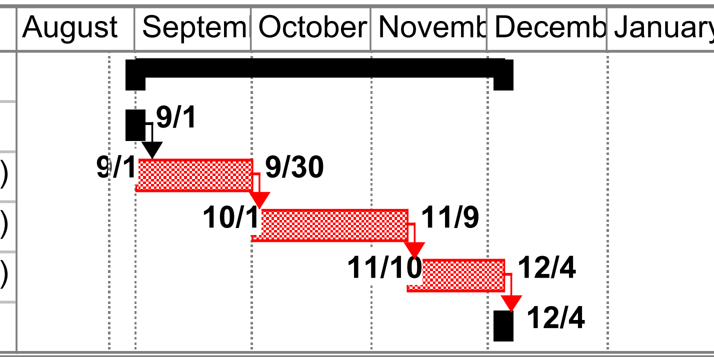
Risk Along a Schedule Path

- Path risk is the combination of the risks of its activities
- This is also like cost risk, adding risks of individual cost elements to get the risk of the total



Original Single-Path Schedule

ID	Name	Duratio	Start	Finish	@RISK: Functions
1	**Project**	**95 d**	**9/1**	**12/4**	
2	Start	0 d	9/1	9/1	
3	Design	30 d	9/1	9/30	Duration=RiskTRIANG(20,30,60)
4	Build	40 d	10/1	11/9	Duration=RiskTRIANG(30,40,65)
5	Test	25 d	11/10	12/4	Duration=RiskTRIANG(18,25,50)
6	Finish	0 d	12/4	12/4	Finish=RiskOUTPUT()



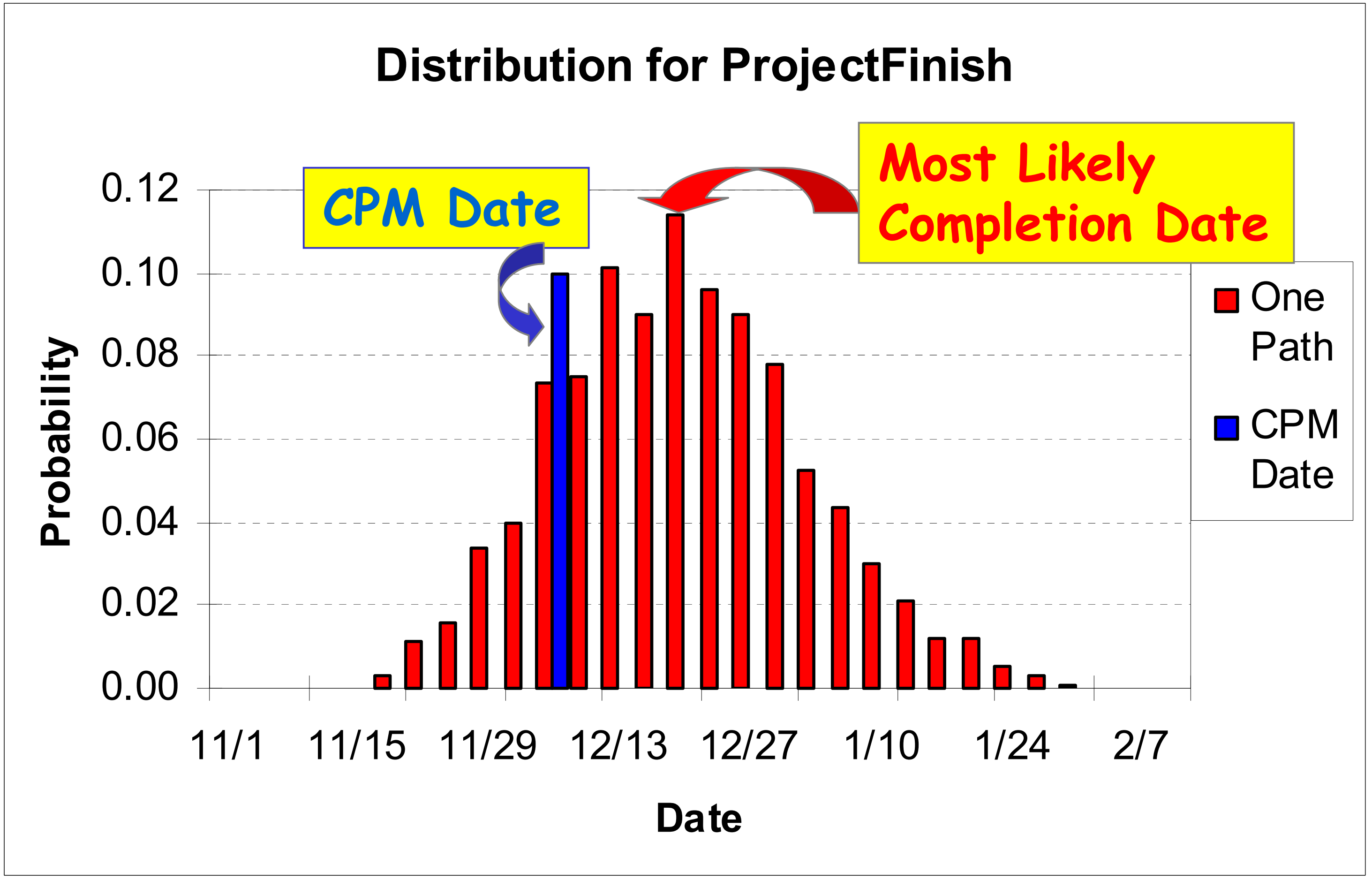
CPM schedule finishes on December 4. What is the likelihood?

Simulation Tools: @RISK for Project Professional from Palisade Corp. & RISK+ from C/S Solutions, Inc. are MS Project Add-ins. Primavera P3 has Monte Carlo. PERTMASTER (UK) and Open Plan Professional simulate

Monte Carlo Simulation

- A simulation explores all combinations of durations of uncertain (and certain) activities
- Durations are chosen at random from input distributions
- The project is calculated (Press [F-9]) CPM
- Completion dates computed many times
- Distribution of completion dates
- Cumulative likelihood provides results

Completion Dates from Simulation



The Fallacy of Most Likely Durations

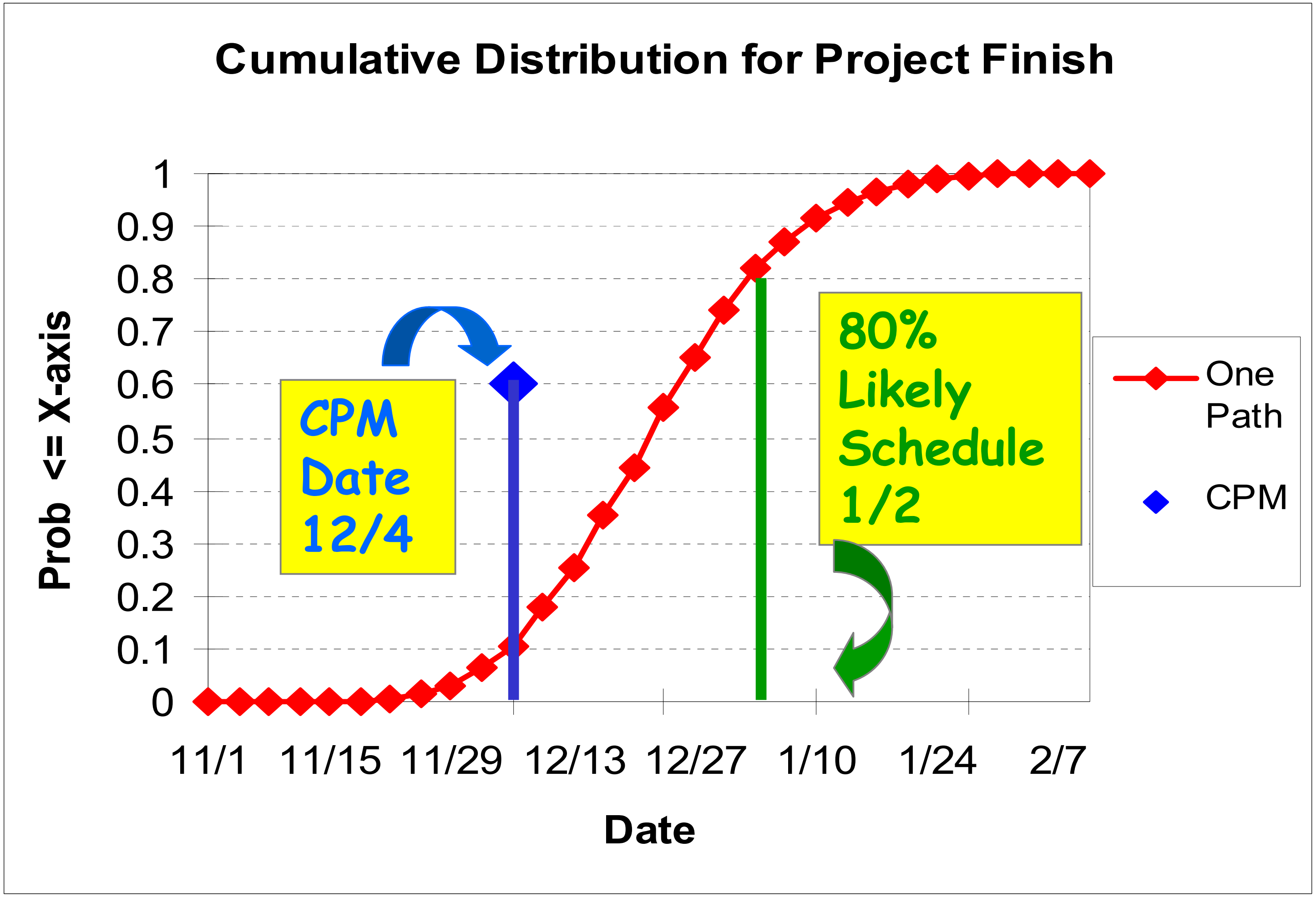
- People sometimes say:

  "Well, at least if we use the best estimates in our schedule the CPM completion date is the most likely date. Isn't it?"

No, Never!

- In this case,
  - CPM says December 4
  - *But the Most Likely completion date is December 21*

Cumulative Distribution -- December 10 is only 10% Likely

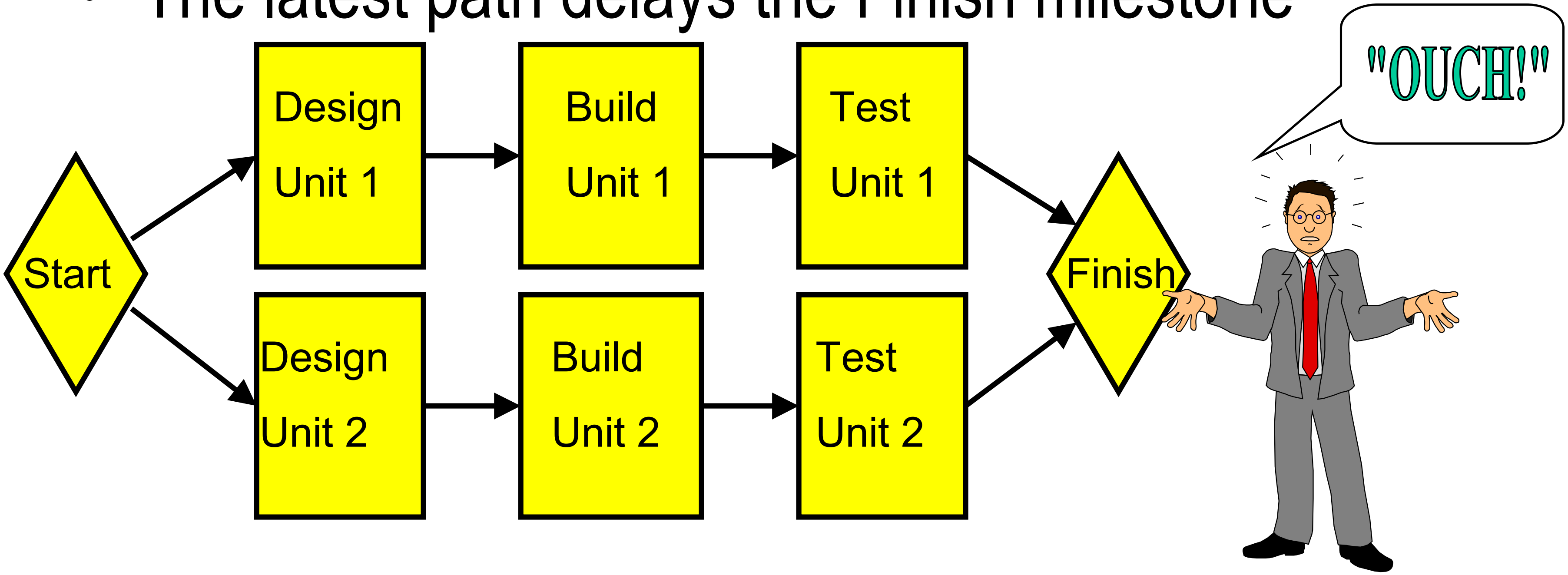


Results for Simple Single-Path Schedule: CPM < 10%

Summary Statistics for Project Finish	
Minimum	11/19
Maximum	2/4
Mean	12/22
Std	13.3
Mode	12/21
10%	12/5
20%	12/11
30%	12/15
40%	12/18
50%	12/22
60%	12/25
70%	12/29
80%	1/2
90%	1/9

Risk at Merge Points: "Merge Bias"

- Parallel paths merge at many points in a real schedule
- The latest path delays the Finish milestone

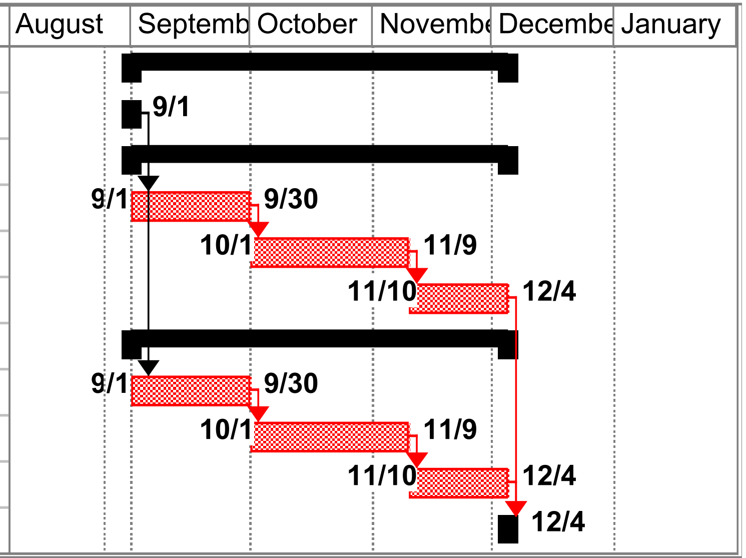


Schedule Overrun Risk at Merge Points

- With parallel paths and merge points
- Any delay may potentially delay the project
- The “unders” do not offset the “overs”
- This extra risk is called the “Merge Bias”

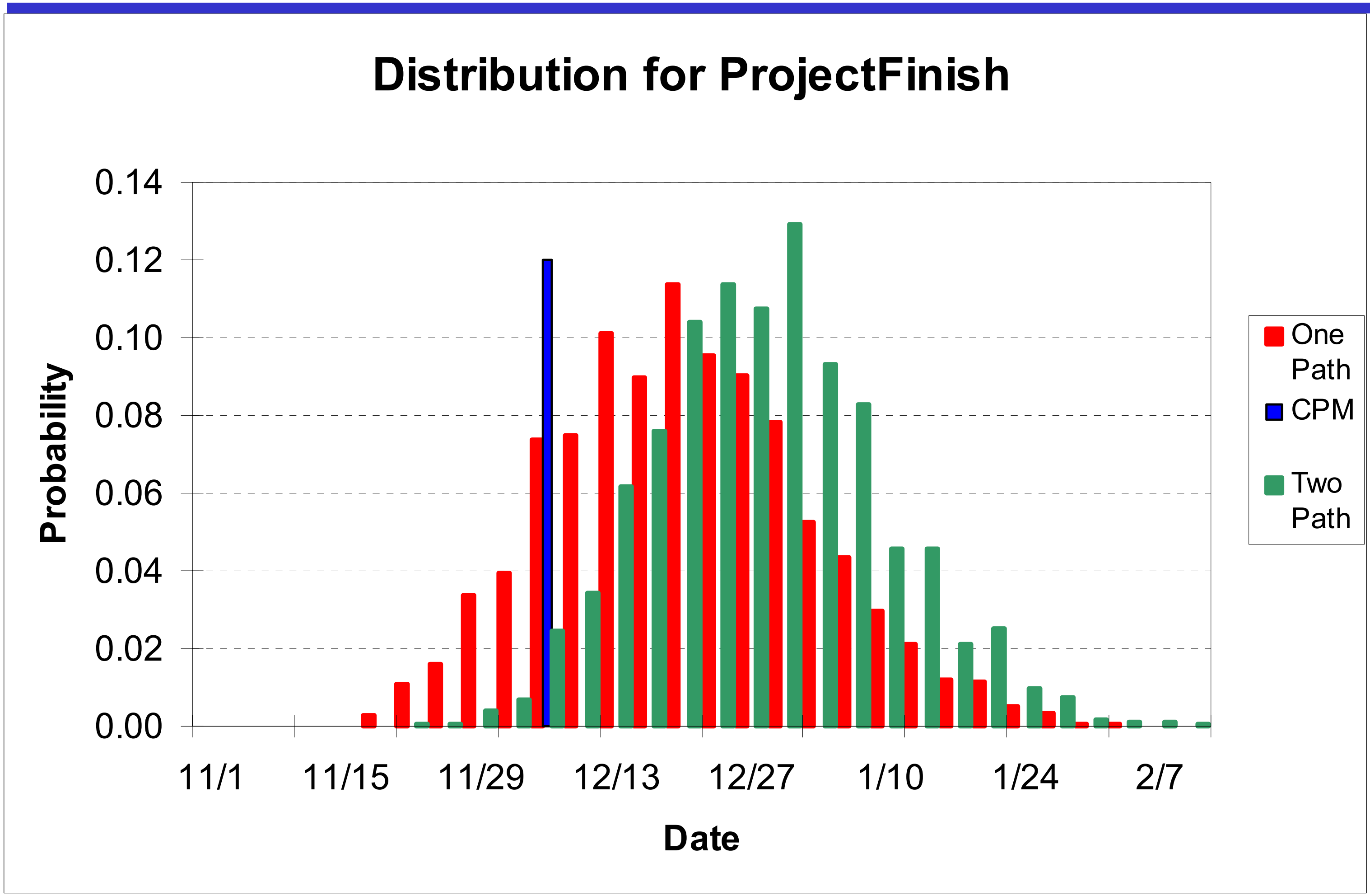
Simple Two-Path Project

ID	Name	Duratior	Start	Finish	@RISK: Functions
1	**Project**	**95 d**	**9/1**	**12/4**	
2	Start	0 d	9/1	9/1	
3	**Component A**	**95 d**	**9/1**	**12/4**	
4	Design A	30 d	9/1	9/30	Duration=RiskTRIANG(20,30,60)
5	Build A	40 d	10/1	11/9	Duration=RiskTRIANG(30,40,65)
6	Test A	25 d	11/10	12/4	Duration=RiskTRIANG(18,25,50)
7	**Component B**	**95 d**	**9/1**	**12/4**	
8	Design B	30 d	9/1	9/30	Duration=RiskTRIANG(20,30,60)
9	Build B	40 d	10/1	11/9	Duration=RiskTRIANG(30,40,65)
10	Test B	25 d	11/10	12/4	Duration=RiskTRIANG(18,25,50)
11	Finish	0 d	12/4	12/4	Finish=RiskOUTPUT()

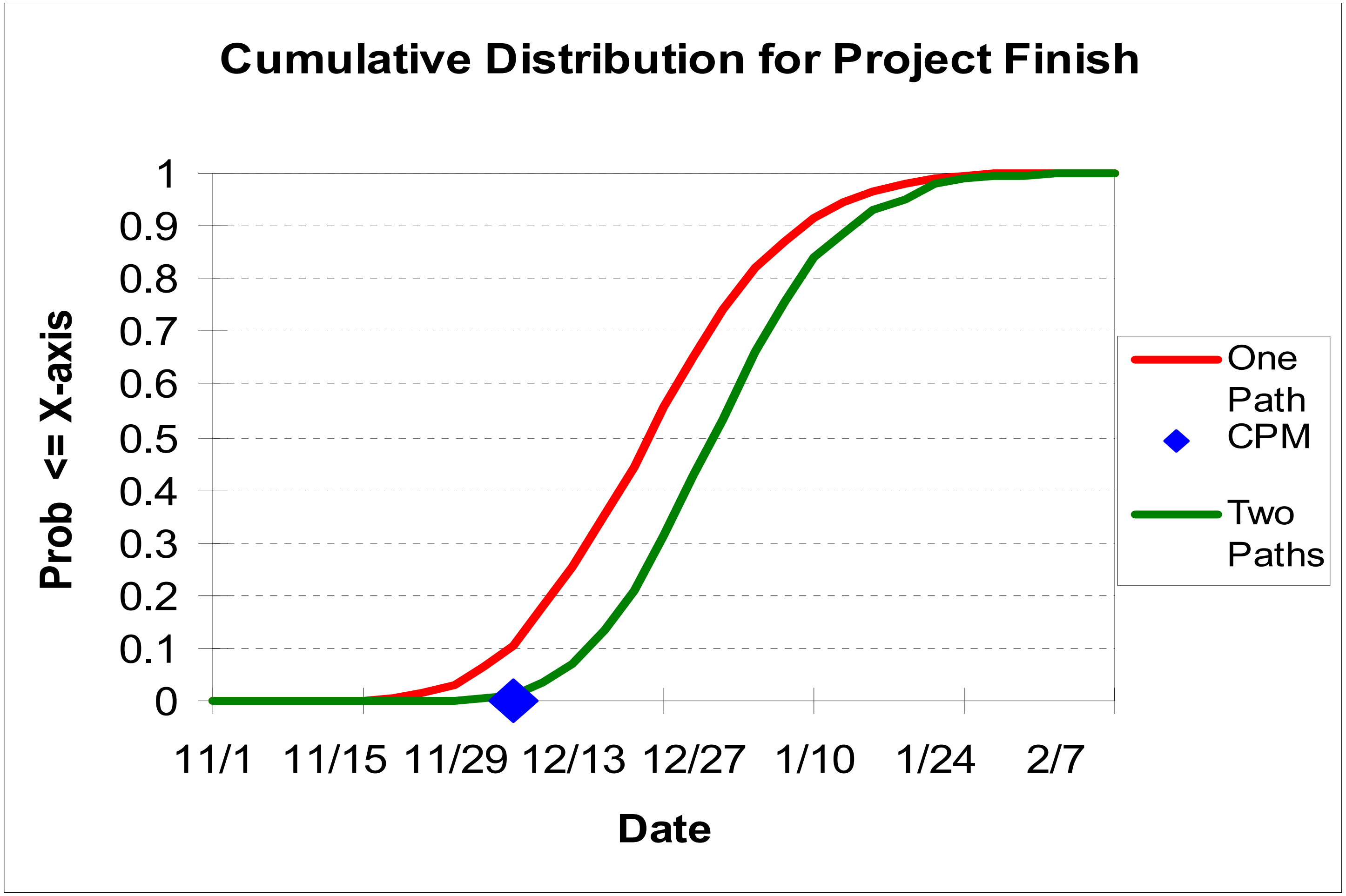


- CPM says this project also completes on December 4
- But, Risk is greater than for the single-path project!

Effect of Two Paths on Distribution



Effect of the Merge Bias



Comparison of Two Risky Schedules: CPM < 5%

Evidence for the Merge Bias		
Summary Statistics for Project Finish		
	One Path	Two Paths
Minimum	11/19	11/25
Maximum	2/4	2/11
Mean	12/22	12/30
Std. Dev.	13.3	12.0
Mode	12/21	12/24
10%	12/5	12/15
20%	12/11	12/20
30%	12/15	12/23
40%	12/18	12/26
50%	12/22	12/29
60%	12/25	1/1
70%	12/29	1/5
80%	1/2	1/9
90%	1/9	1/15

One Path CPM

Two Path CPM

80%

What's Happening Here? Two Events Occurring Together

- How likely is it that two events will occur together?

Likelihood of Two Outcomes Occurring Together				
All Possible Outcomes				
Path 1	Path 2	Path 1	Path B	Joint Probability
Complete	Complete	10%	10%	1%
Complete	Not Complete	10%	90%	9%
Not Complete	Complete	90%	10%	9%
Not Complete	Not Complete	90%	90%	81%
		Total Likelihood		100%

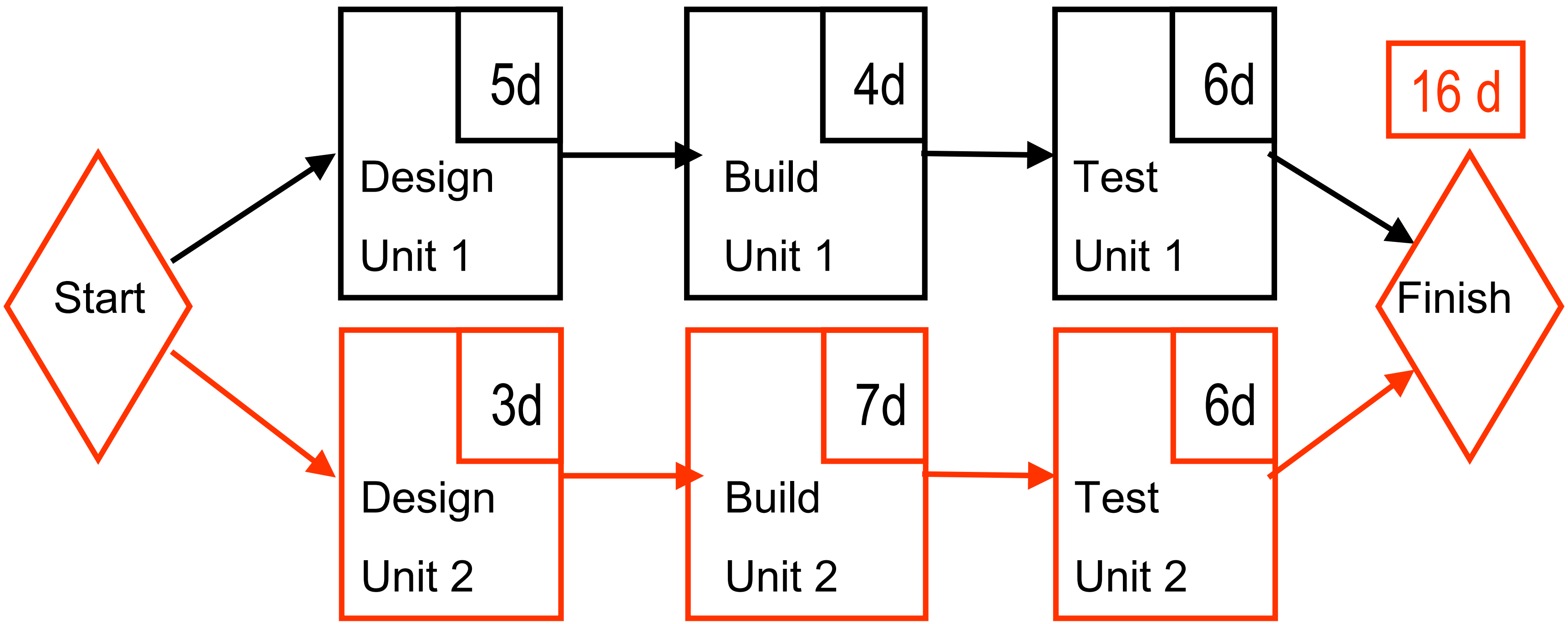
Monte Carlo Simulation vs. PERT

- A Monte Carlo simulation is the correct way to determine the impact of schedule risk at merge points
- An older way was the Program Evaluation and Review Technique (PERT) that used the Method of Moments analysis

PERT always underestimated risk at merge points

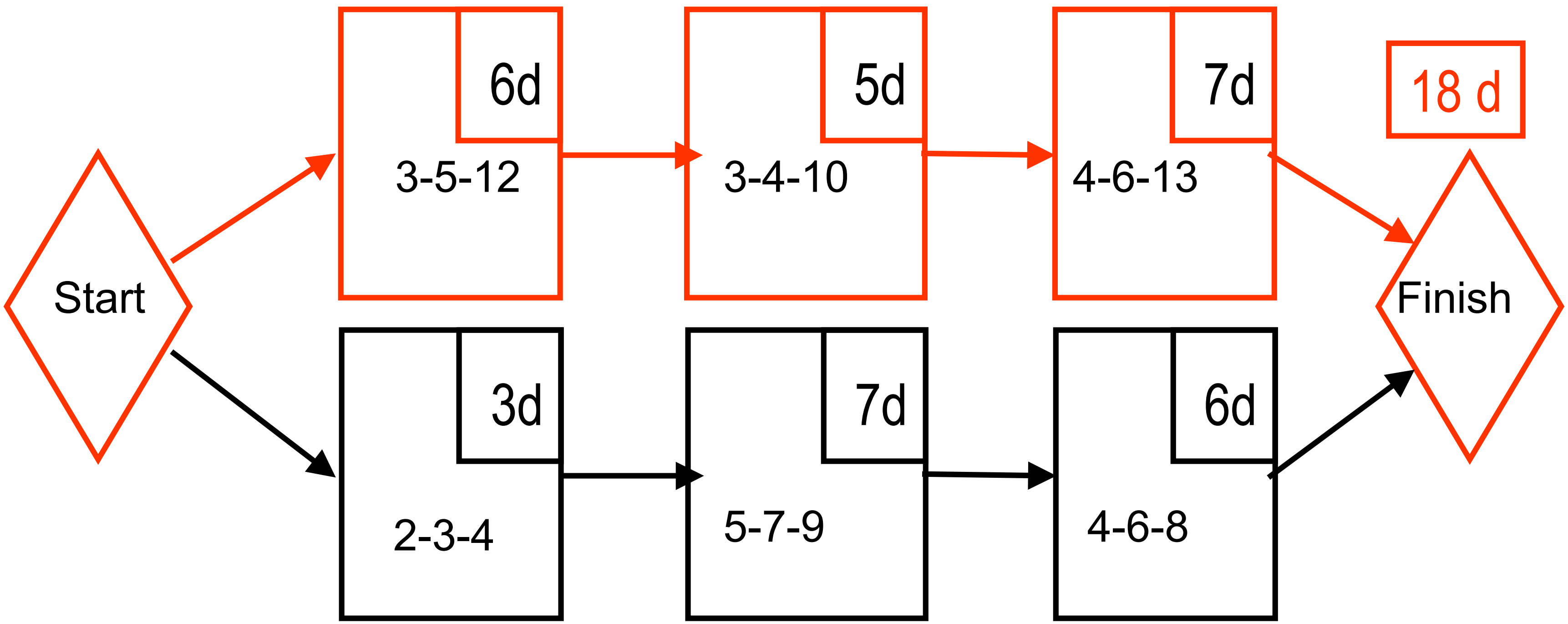
PERT Example -- CPM Schedule

- The original schedule uses single-point estimates



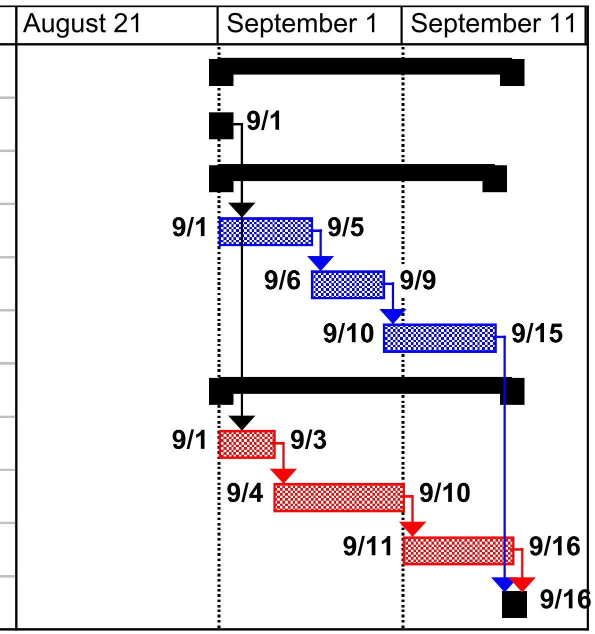
PERT Approach (BETA) Changes Path and Date

- Use the BETA formula, Mean = (L + 4*ML + H) / 6
- Derive new completion date and critical path

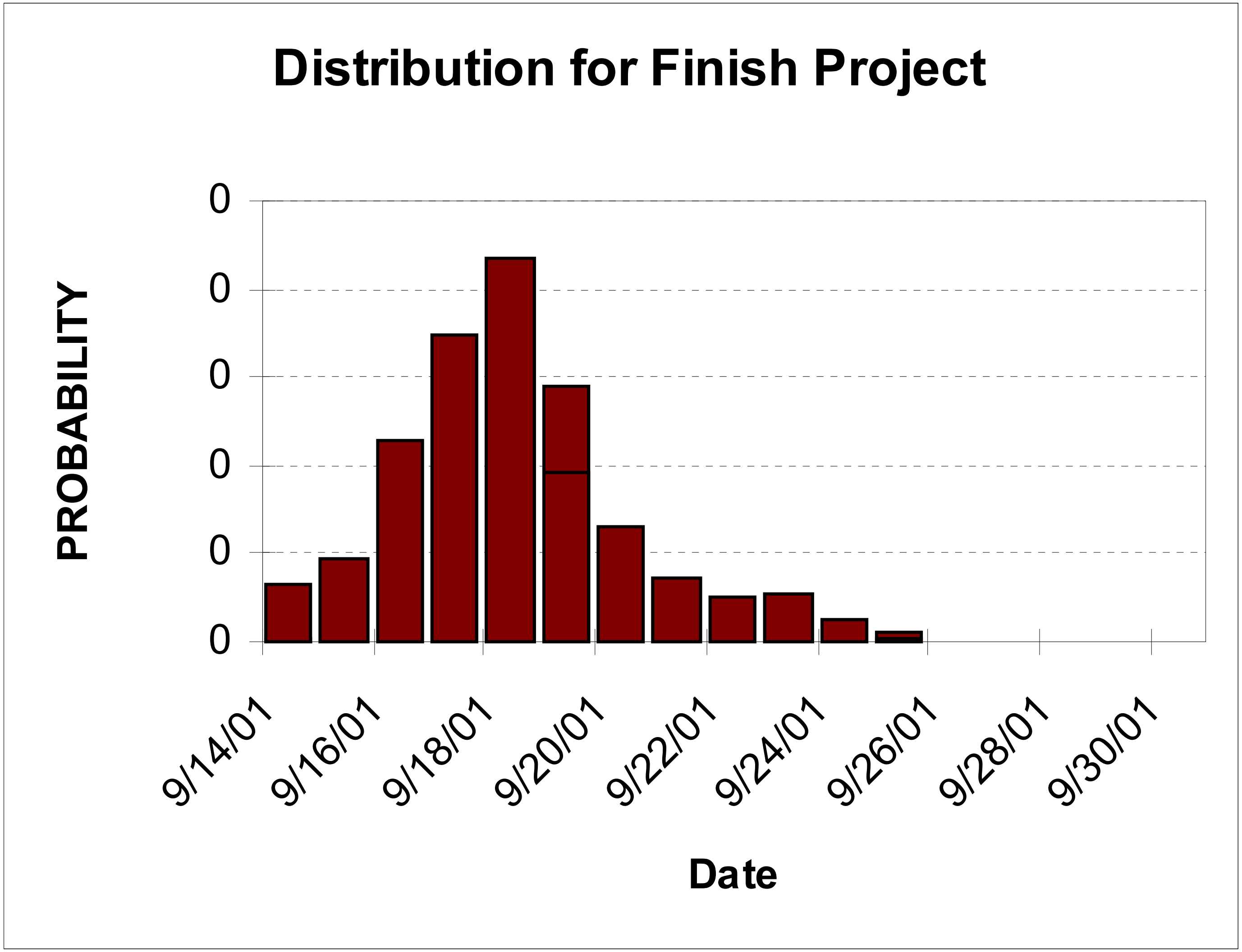


Simulation of PERT

ID	Name	Duratio	Start	Finish	@RISK: Functions
1	**Total Project**	**16 d**	**9/1/01**	**9/16/01**	
2	Start Project	0 d	9/1/01	9/1/01	
3	**Unit 1**	**15 d**	**9/1/01**	**9/15/01**	
4	Design Unit 1	5 d	9/1/01	9/5/01	Duration=RiskPERT(3,5,12)
5	Build Unit 1	4 d	9/6/01	9/9/01	Duration=RiskPERT(3,4,10)
6	Test Unit 1	6 d	9/10/01	9/15/01	Duration=RiskPERT(4,6,13)
7	**Unit 2**	**16 d**	**9/1/01**	**9/16/01**	
8	Design Unit 2	3 d	9/1/01	9/3/01	Duration=RiskPERT(2,3,4)
9	Test Unit 2	7 d	9/4/01	9/10/01	Duration=RiskPERT5,7,9)
10	Build Unit 2	6 d	9/11/01	9/16/01	Duration=RiskPERT(4,6,8)
11	Finish Project	0 d	9/16/01	9/16/01	Finish=RiskOUTPUT()



Simulation with BETA Distributions



Simulation Shows More Risk

Summary Statistics			
Name	Minimum	Mean	Maximum
Finish Project	9/14/01	9/19/01	9/29/01

Percentage	Finish Date
10%	9/16
20%	9/17
30%	9/17
40%	9/18
50%	9/18
60%	9/19
70%	9/19
80%	9/20
90%	9/21

Simulation computes the distribution and provides the S-Curve

Monte Carlo Simulation and PERT

- Some modern software includes a PERT tool
  - Microsoft Project
  - Scitor Project Scheduler
- These tools will underestimate risk in real schedules

See: David Hulett, "Project Schedule Risk Analysis: Monte Carlo Simulation or PERT?" *PM Network*, February 2000, pp. 43 ff

Defining the Risk Critical Path / Activities

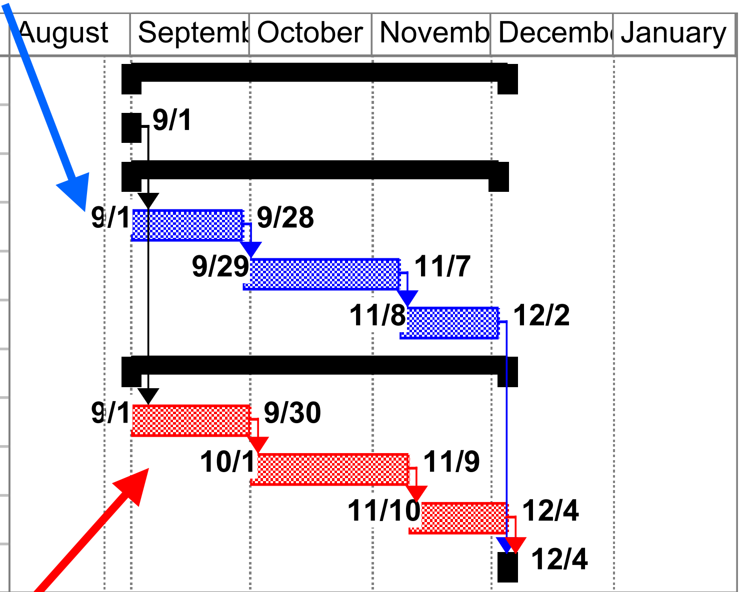
- With hundreds or thousands of activities, which are most likely to delay the project?
  - Depends on risk, project structure (float)
- Simulation program records whether an activity was critical in each iteration

Percent of iterations each activity was critical = its Criticality Index

Schedule with Risk Management of Critical Unit B

Slack Path Not Managed

ID	Name	Duratio	Start	Finish	@RISK: Functions
1	**Project**	**95 d**	**9/1**	**12/4**	
2	Start	0 d	9/1	9/1	
3	**Component A**	**93 d**	**9/1**	**12/2**	
4	Design A	28 d	9/1	9/28	Duration=RiskTRIANG(18,28,58)
5	Build A	40 d	9/29	11/7	Duration=RiskTRIANG(30,40,65)
6	Test A	25 d	11/8	12/2	Duration=RiskTRIANG(18,25,50)
7	**Component B**	**95 d**	**9/1**	**12/4**	
8	Design B	30 d	9/1	9/30	Duration=RiskTRIANG(25,30,40)
9	Build B	40 d	10/1	11/9	Duration=RiskTRIANG(35,40,50)
10	Test B	25 d	11/10	12/4	Duration=RiskTRIANG(20,25,30)
11	Finish	0 d	12/4	12/4	Finish=RiskOUTPUT()



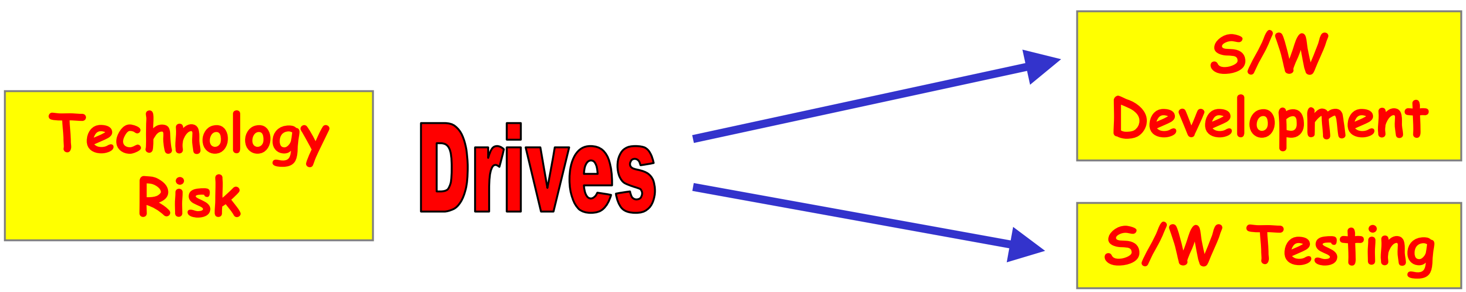
Risk Managed Critical Path

Criticality or % of Iterations on Critical Path

Criticality Index	
Task	Percent Critical
Component A	80%
Design A	80%
Build A	80%
Test A	80%
Component B	20%
Design B	20%
Build B	20%
Test B	20%

Correlation Between Activity Durations

- Correlation when some risk factor (“driver”) affects the durations of two activities together
- Difficult technology makes design and build take longer
- Severe working conditions affect design and build
- Permit uncertainty affect design and build



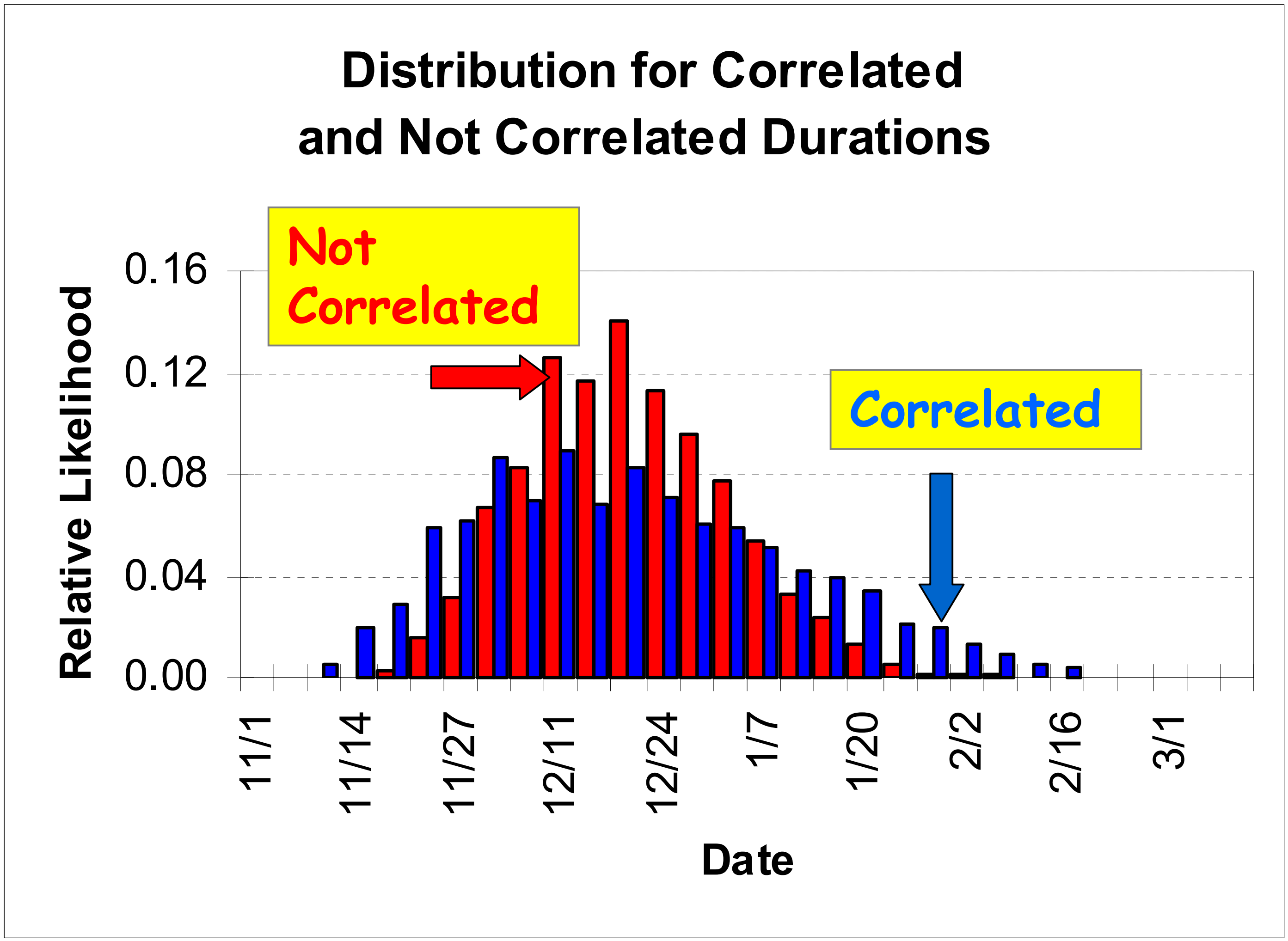
Correlation

- Correlation makes the durations “move” together
- If one activity takes longer than estimated the other does too
- Both activities will take more (or less) time together
- Correlation increases the risk of extreme results

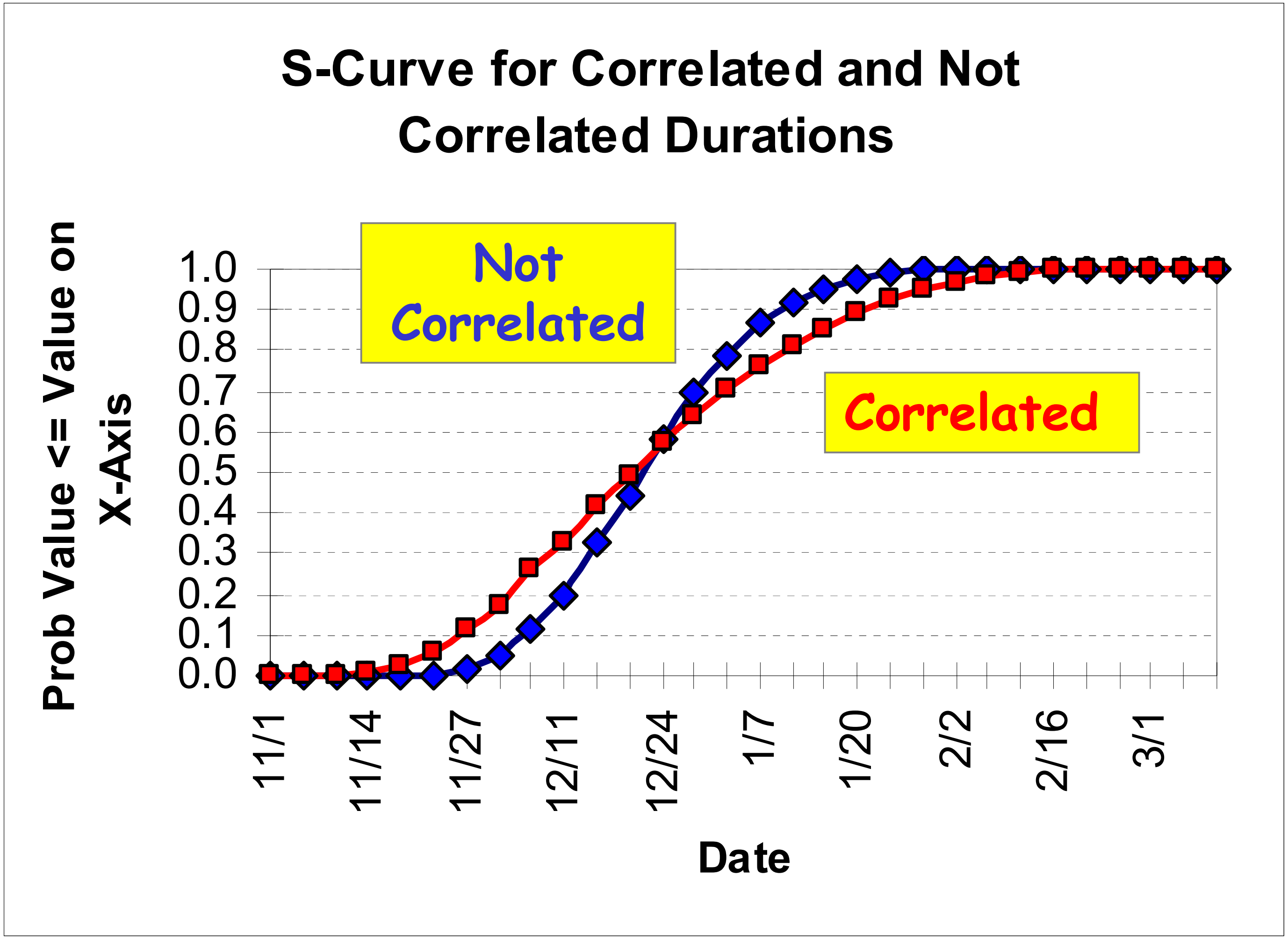
Add Significant Correlation to Single Path Schedule

Correlation Matrix			
	Design / Duration	Build / Duration	Test / Duration
Design/Duration	1	0.8	0.6
Build/Duration	0.8	1	0.9
Test/Duration	0.6	0.9	1

Correlations Increase the Spread of the Results Distribution



Correlations Increase the Spread of the Results Distribution

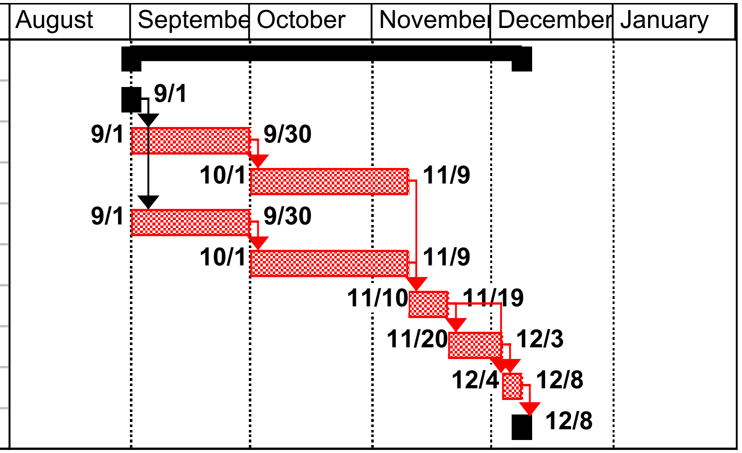


Probabilistic Branching

- When the outcome of an activity is not certain
  - Article is not certain to pass the test the first time
- The successor activity may be one or the other
  - Pass the test? ==> Certify
  - Fail the test? ==> End Test, Diagnose, FIXIT and retest
- Each one of these is a “branch” and has some probability

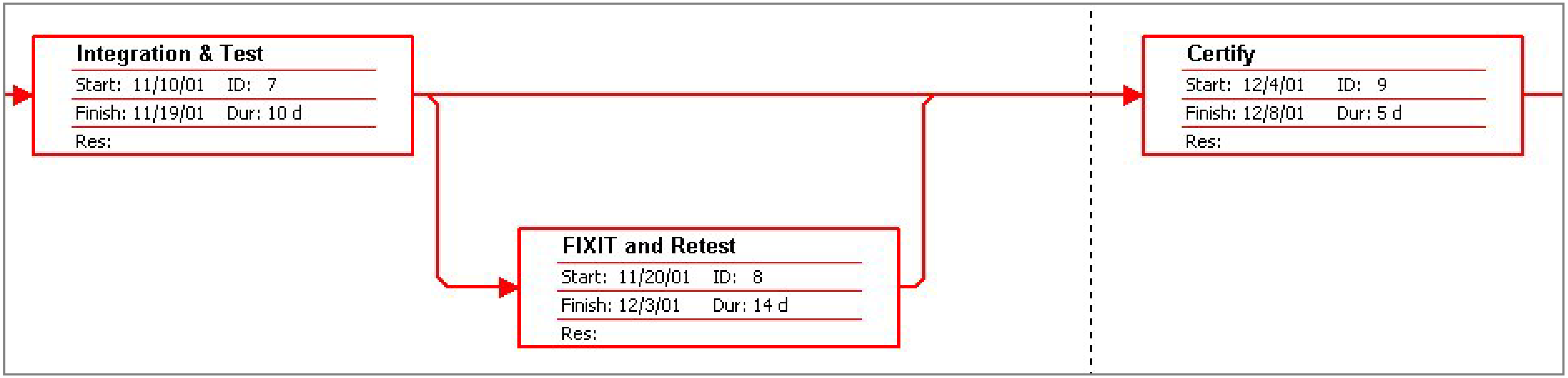
Probabilistic Branching

ID	Name	Duration	Start	Finish	@RISK: Functions
1	**Total Project**	**99 d**	**9/1**	**12/8**	
2	Start	0 d	9/1	9/1	
3	Design Unit 1	30 d	9/1	9/30	Duration=RiskTRIANG(20,30,60)
4	Build Unit 1	40 d	10/1	11/9	Duration=RiskTRIANG(30,40,65)
5	Design Unit 2	30 d	9/1	9/30	Duration=RiskTRIANG(20,30,60)
6	Build Unit 2	40 d	10/1	11/9	Duration=RiskTRIANG(30,40,65)
7	Integration & Test	10 d	11/10	11/19	RiskBRANCH(.3,.7,{t8},{t9})
8	FIXIT and Retest	14 d	11/20	12/3	Duration=RiskTRIANG(40,45,60)
9	Certify	5 d	12/4	12/8	
10	Finish	0 d	12/8	12/8	Finish=RiskOUTPUT()

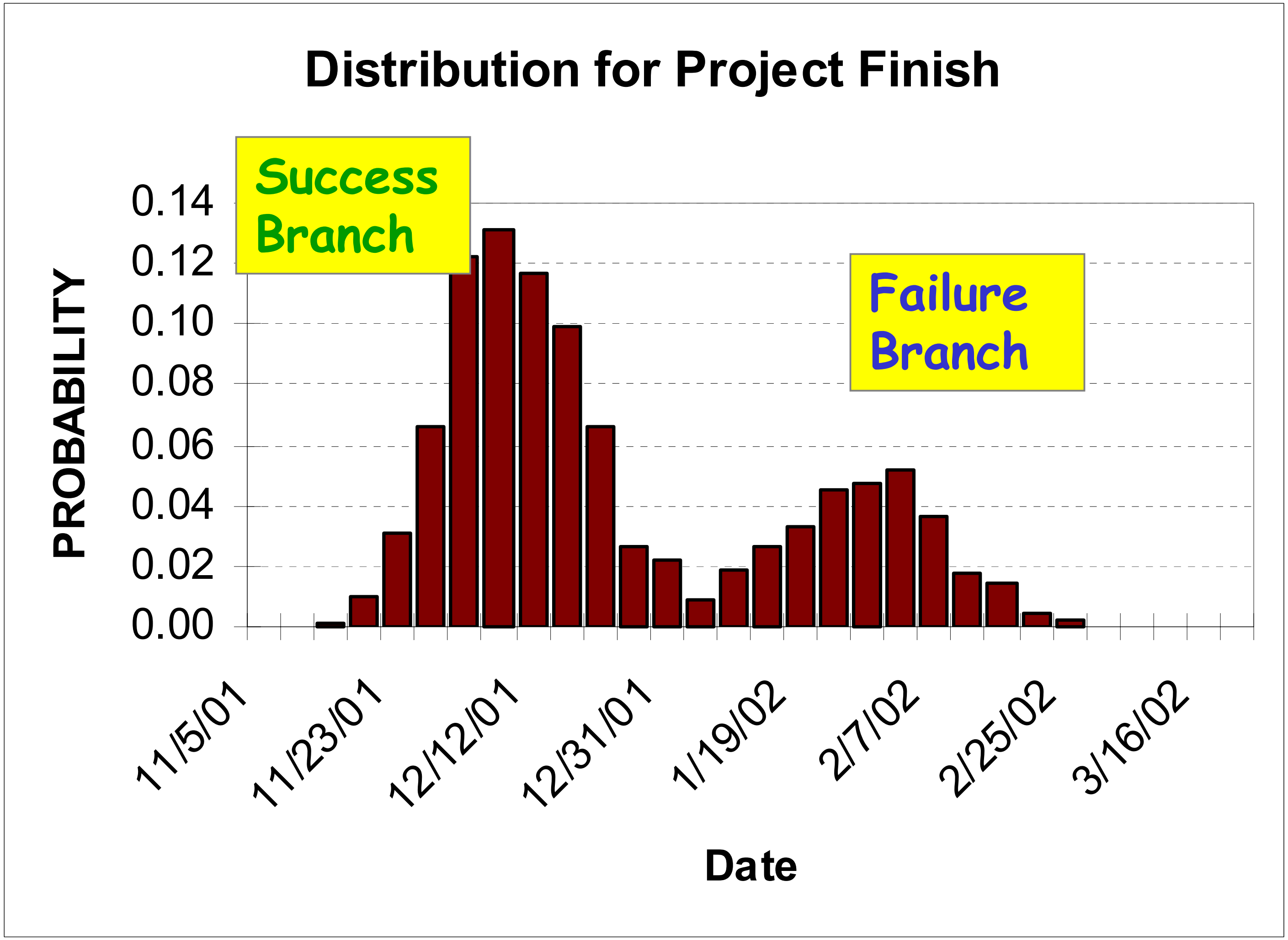


I Recommend Indicating the Possibility of Failure in the CPM Schedule – Here at the Expected Value of the Most Likely Duration

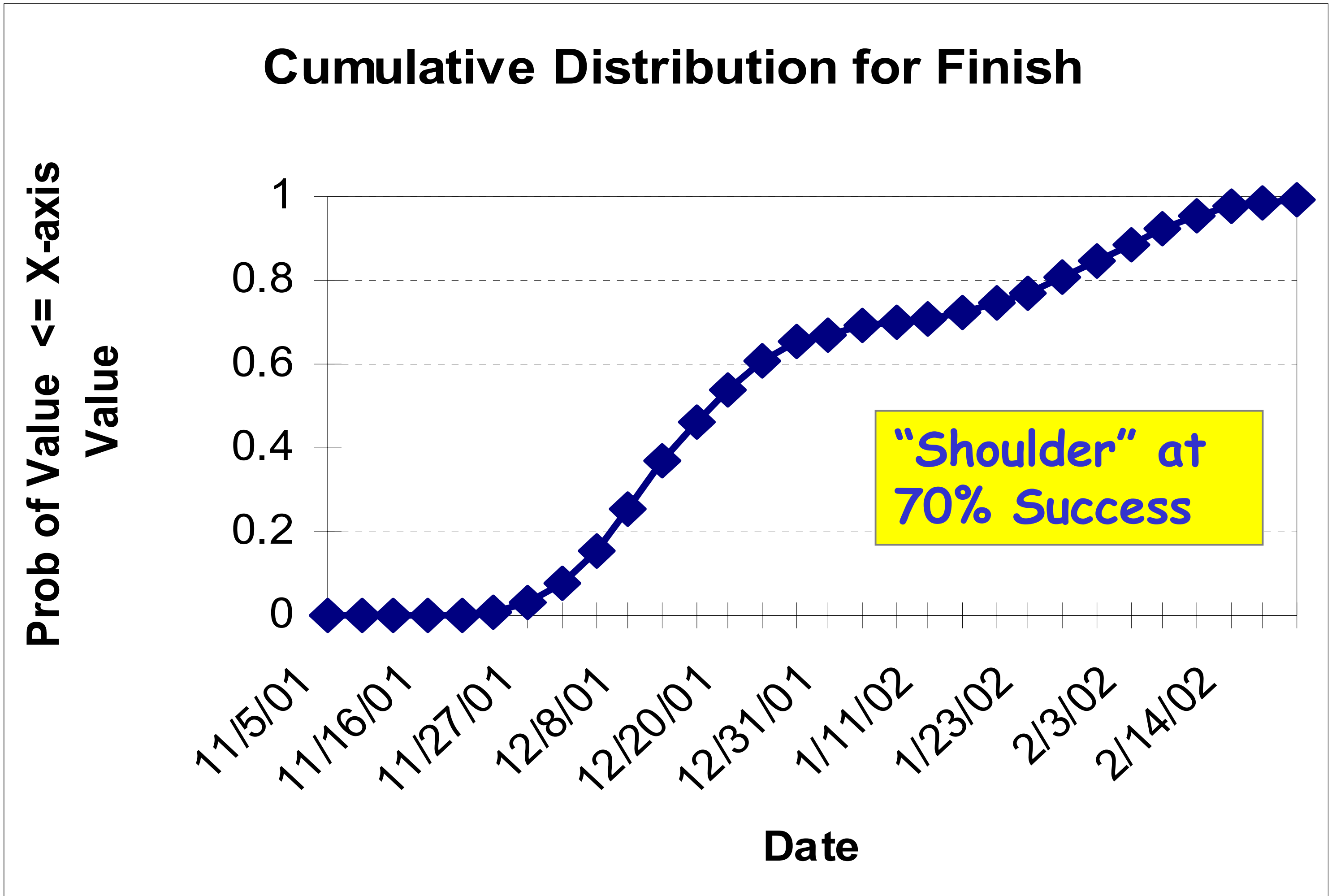
Network Logic of Test Failure Probabilistic Branch



Probabilistic Branching Histogram



Cumulative Distribution of Probabilistic Branch



Summary

- Introduction
- Risk on a single task – probability distributions
- Collecting data on task risk
- Risk along a path – Monte Carlo simulation
- Risk with parallel paths – the Merge Bias
- Schedule Risk vs. PERT
- Risk Criticality Index
- Correlated task durations
- Probabilistic branching

Project Schedule Risk Analysis

CPM-200 Principles of Schedule Management

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