

Project Schedule Risk Analysis

Introduction

Activity distributions and data entry

Risk along a schedule path

Risk of parallel paths -- the “Merge Bias”

Effect of limited resources

Effect of constraints

Sensitivity Analysis

“Risk Critical Path”

Risk in schedules

Probabilistic branching

Conditional branching

Correlation

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 Analysis

Improve the accuracy of the schedule dates

Validate the CPM or contract dates

Establish a schedule contingency

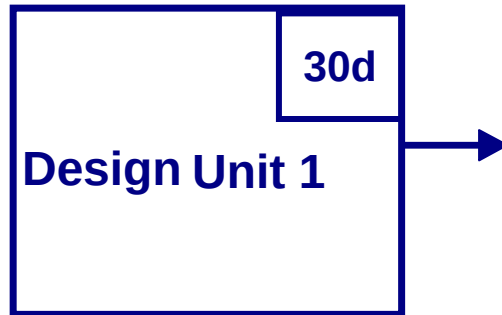
Identify the risk-driving events

Communicate about and understand the project

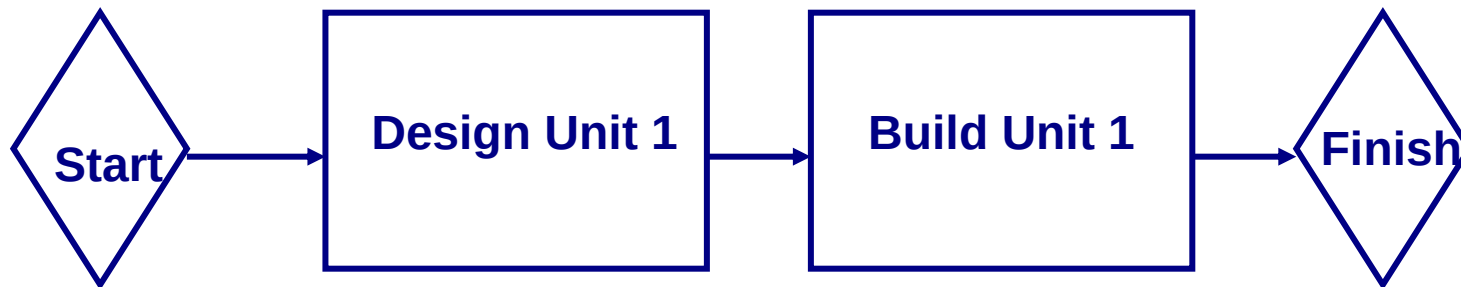
Continuously monitor changing schedule risk

Three Basic Components of Schedule Risk Analysis

Risk of the activity duration

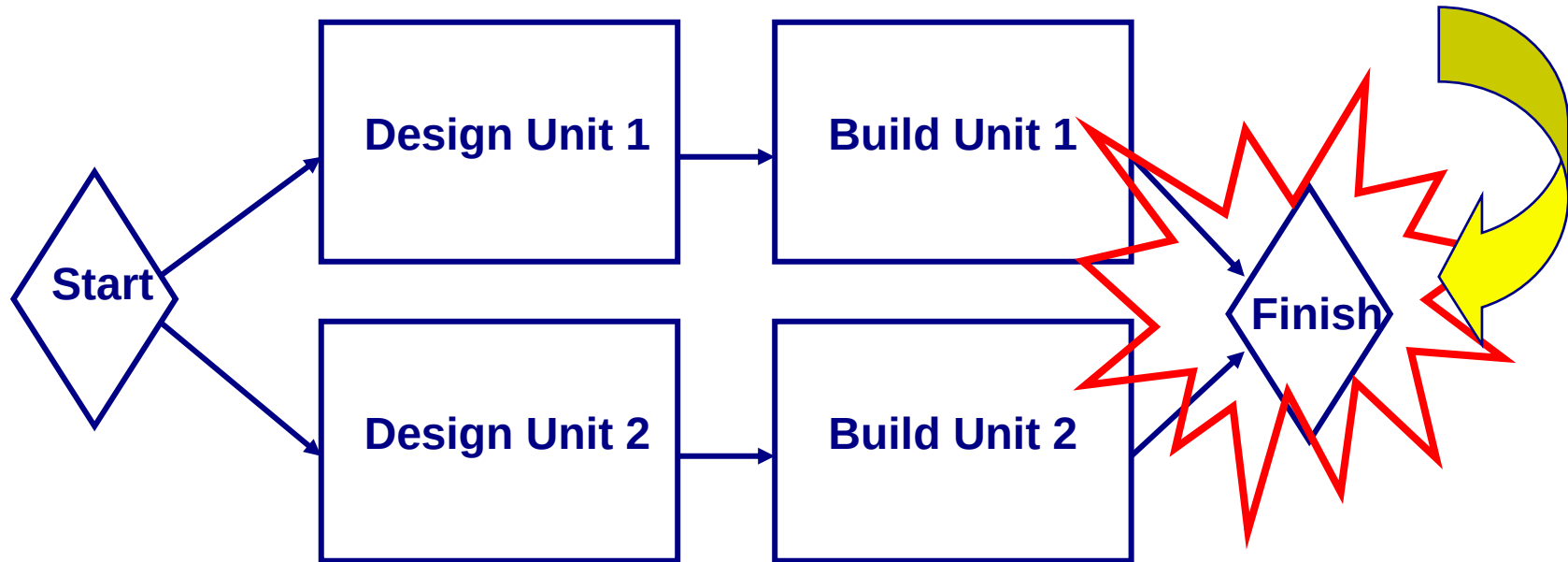


Risk of duration along a Path

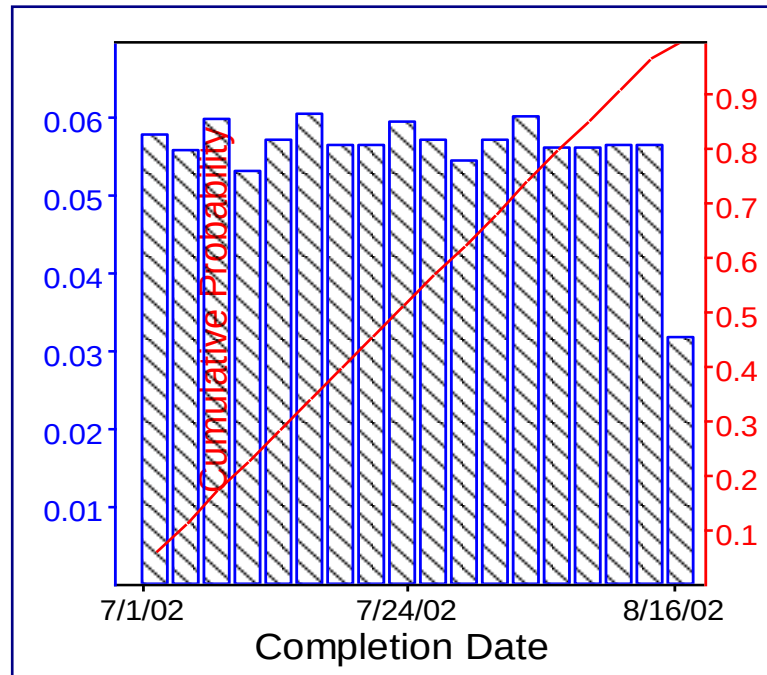


Three Basic Components of Schedule Risk Analysis

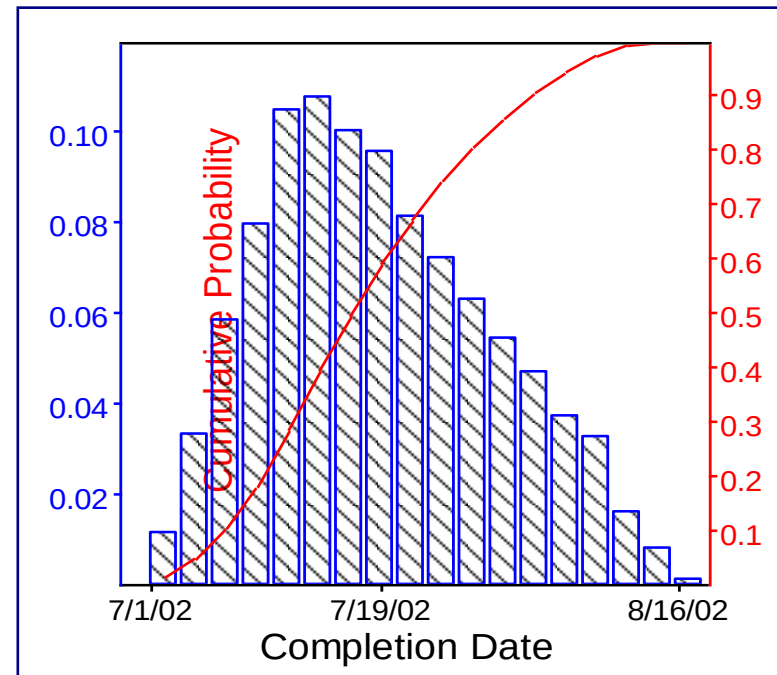
Risk at a point where parallel paths merge



4 Common Probability Distributions

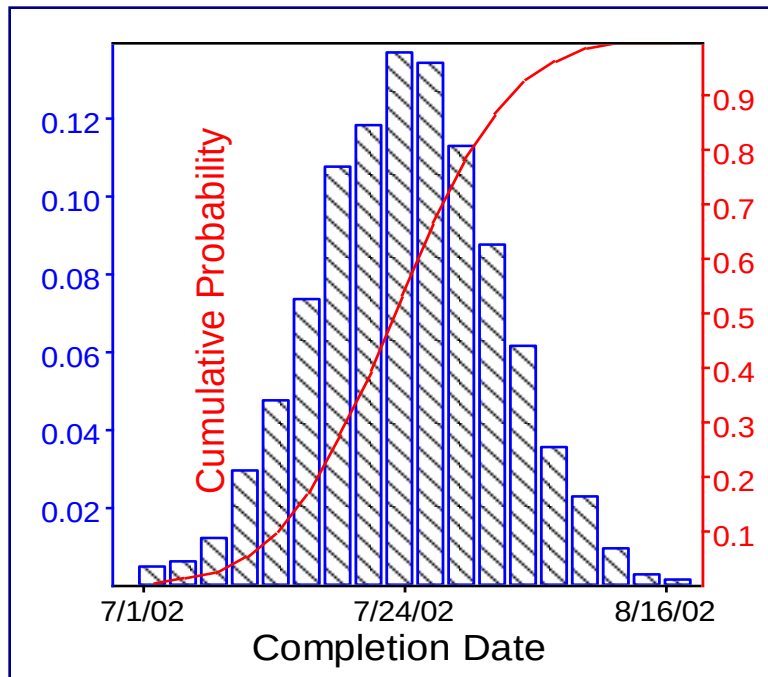


Uniform

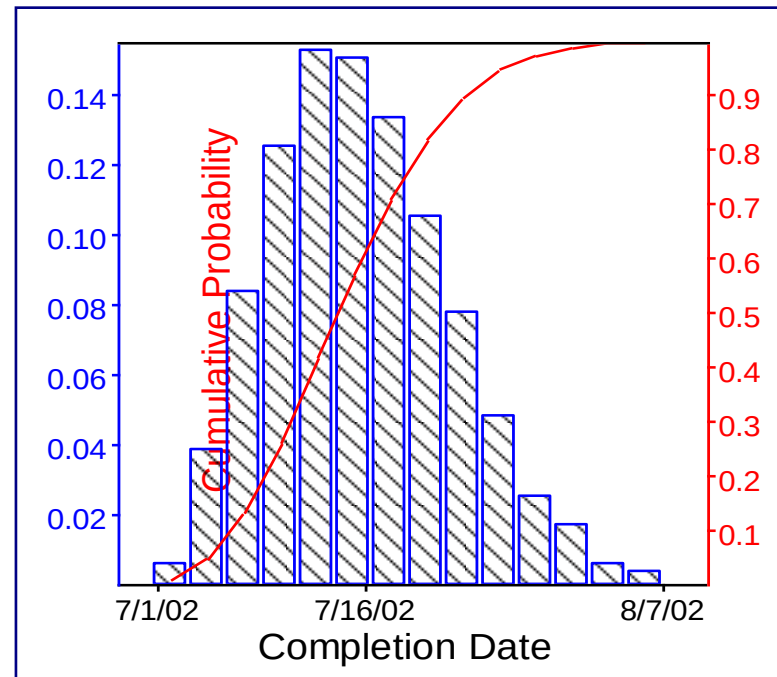


Triangular

4 Common Probability Distributions (continued)



Normal



BETA

Data Collection

Assemble subject matter experts including people on the project

Ask them to review the highest-risk items

- Pareto analysis – top 30% + of the elements contains most of the risk

Experts review elements

- What areas are risky? What causes the risk?
- What are the optimistic (low), most likely and pessimistic (high) durations for those elements?
- Baseline schedule may not be the “most likely” duration

Data Collection (continued)

Judgmental estimates. Do not have historical data

Motivational biases

- Want to make the project look good – project manager
- Do not want to be seen as unable to do the job

Cognitive biases

- Anchoring and Adjusting – underestimate risk
- Availability – focus on what is dramatic or current
- Representative – what does the information represent
- Unthinkable consequences

Data Collection (continued)

Conduct the “Risk Interview” with facilitator

Challenge the teams’ ranges

Identify the places where failure might occur
– tests fail

- Likelihood of failure
- Time to diagnose, plan and execute response, retest

Document the issues and findings

Data Entry & Data Editing

Data can be entered by task

Data can be entered as common % ranges

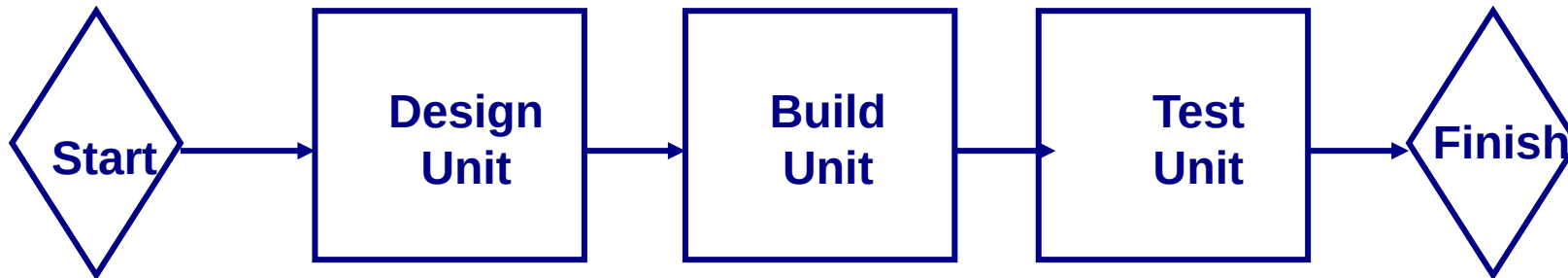
Entering or editing in Excel and copying over is easy

Select activities manually or by a code in some field, to indicate similarities among activities

- E.g. all test activities get -25% and +100%
- E.g. all fabrication activities get -30% and +40%
- This is called “risk banding”

Risk Along a Contiguous Schedule Path

Path risk is the combination of the risks of its activities

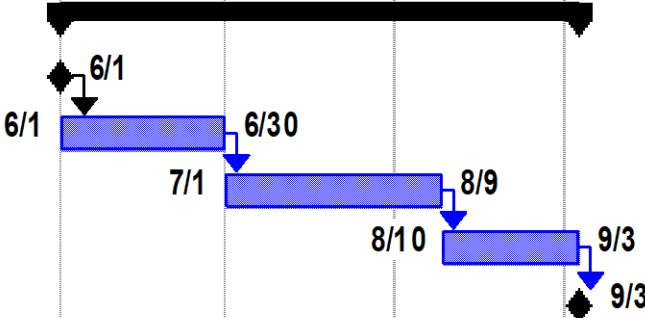


This is also like cost risk, adding risks of individual cost elements to get the risk of the total

Really Simple Schedule

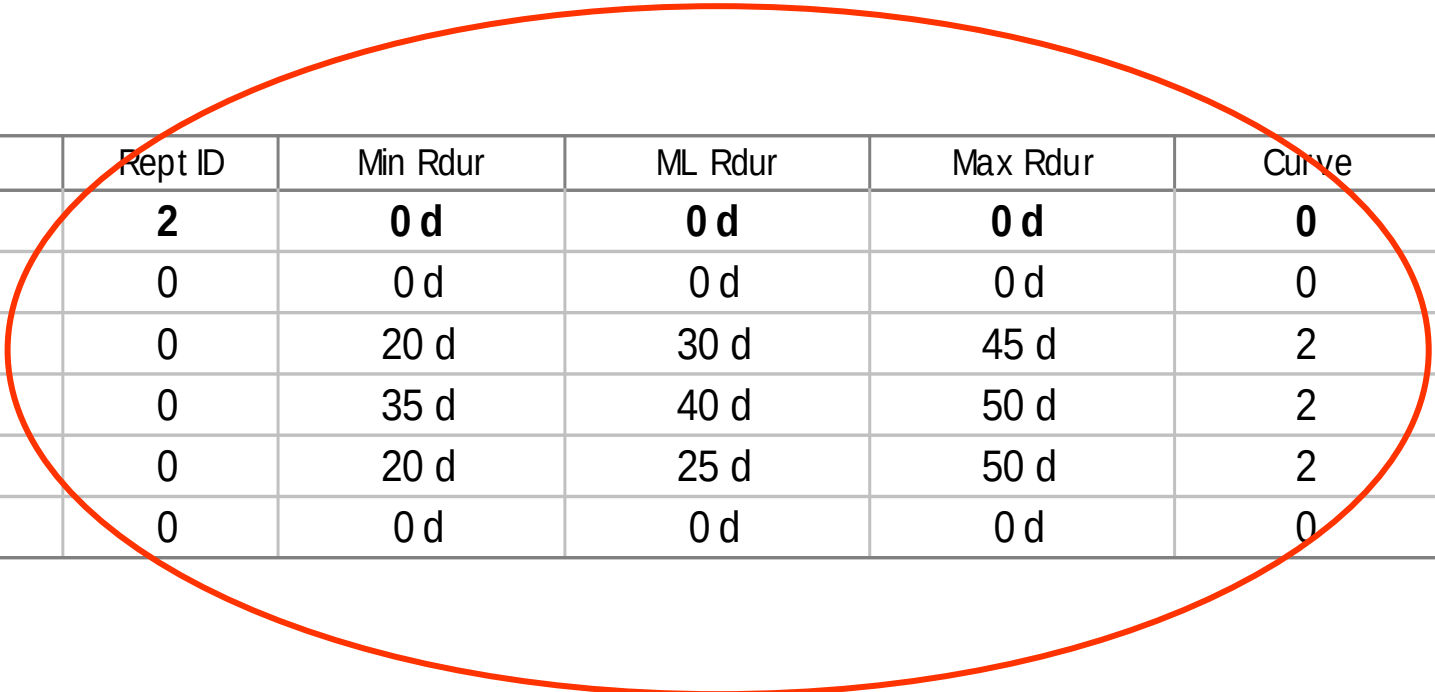
This schedule finishes on September 3

- 7-day weeks, like a model changeover, refinery turnaround

ID	Task Name	Duration	Start	May	June	July	August	September	October	
1	Project	95 d	6/1/02							
2	Start	0 d	6/1/02		6/1					
3	Design Unit	30 d	6/1/02		6/1	6/30				
4	Build Unit	40 d	7/1/02			7/1	8/9			
5	Test Unit	25 d	8/10/02				8/10	9/3		
6	Finish	0 d	9/3/02					9/3		

If we can get into trouble with this simple schedule, we can get into trouble with real project schedules

Add Duration Risk to the Schedule using Triangular Distributions



ID	Task Name	Rept ID	Min Rdur	ML Rdur	Max Rdur	Curve
1	Project	2	0 d	0 d	0 d	0
2	Start	0	0 d	0 d	0 d	0
3	Design Unit	0	20 d	30 d	45 d	2
4	Build Unit	0	35 d	40 d	50 d	2
5	Test Unit	0	20 d	25 d	50 d	2
6	Finish	0	0 d	0 d	0 d	0

We are using Risk+ from C/S Solutions. Other packages are @RISK from Palisade and Monte Carlo from Primavera. PERTMASTER Professional and Open Plan Professional have simulation capabilities built-in.

What is a Simulation?

How do you find total project results?

- Cannot add distributions
- Must combine distributions

Combining distributions using simulation

- Almost all possible combinations of durations
- “Perform” the project many times

Combine Distributions by Simulation

Monte Carlo simulation

- Very General
- 50-year old method

Computer “performs” project many times

- Exercise is a “simulation”
- Each calculation is an “iteration”

Brute force solution

- All combinations of possible costs or durations

Number of Iterations

How many iterations should we do?

- Accuracy demanded
- 2,500 is sufficient
- Final reports, ==> 10,000 iterations

Latin Hypercube

- Stratified sampling for more accuracy

Common Sense Results can be Wrong!

“Well, if we just use the right “most likely” durations in our schedules we will get the most likely completion date. Right?”

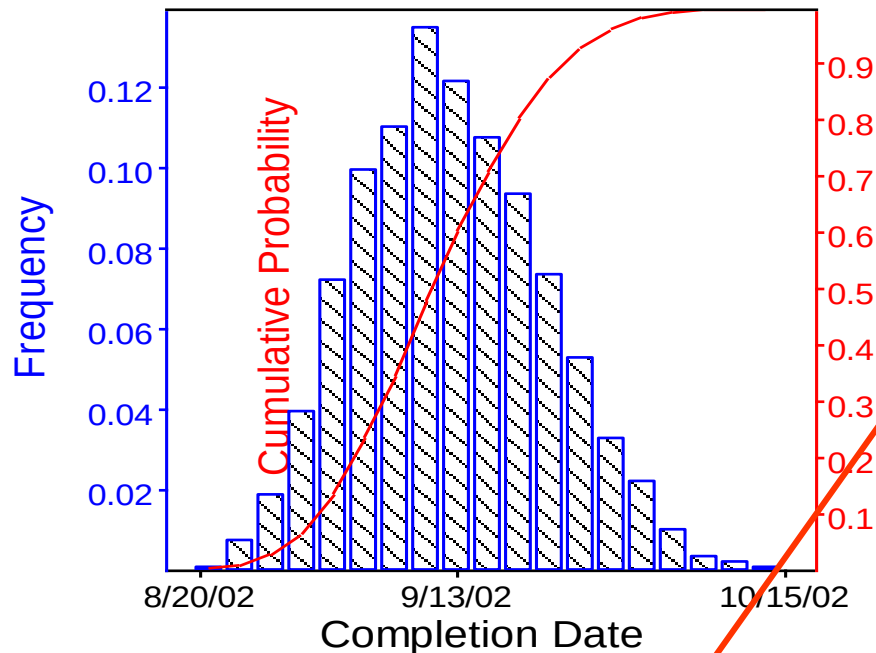
Wrong!

Monte Carlo Simulation Results for Really Simple Schedule

CPM date is not even the most likely – That's about 9/10

Date: 10/25/2001 3:42:21 PM
Samples: 5000
Unique ID: 2
Name: Project

Completion Std Deviation: 8.98 d
Confidence Interval: 0.25 d
Each bar represents 3 d



Completion Probability Table

<u>Prob</u>	<u>Date</u>	<u>Prob</u>	<u>Date</u>
0.05	8/31/02	0.55	9/14/02
0.10	9/2/02	0.60	9/15/02
0.15	9/4/02	0.65	9/17/02
0.20	9/5/02	0.70	9/18/02
0.25	9/7/02	0.75	9/20/02
0.30	9/8/02	0.80	9/21/02
0.35	9/10/02	0.85	9/23/02
0.40	9/11/02	0.90	9/26/02
0.45	9/12/02	0.95	9/29/02
0.50	9/13/02	1.00	10/15/02

Nominal 9/3 Finish Date

CPM date 9/3 is <15% Likely to be met

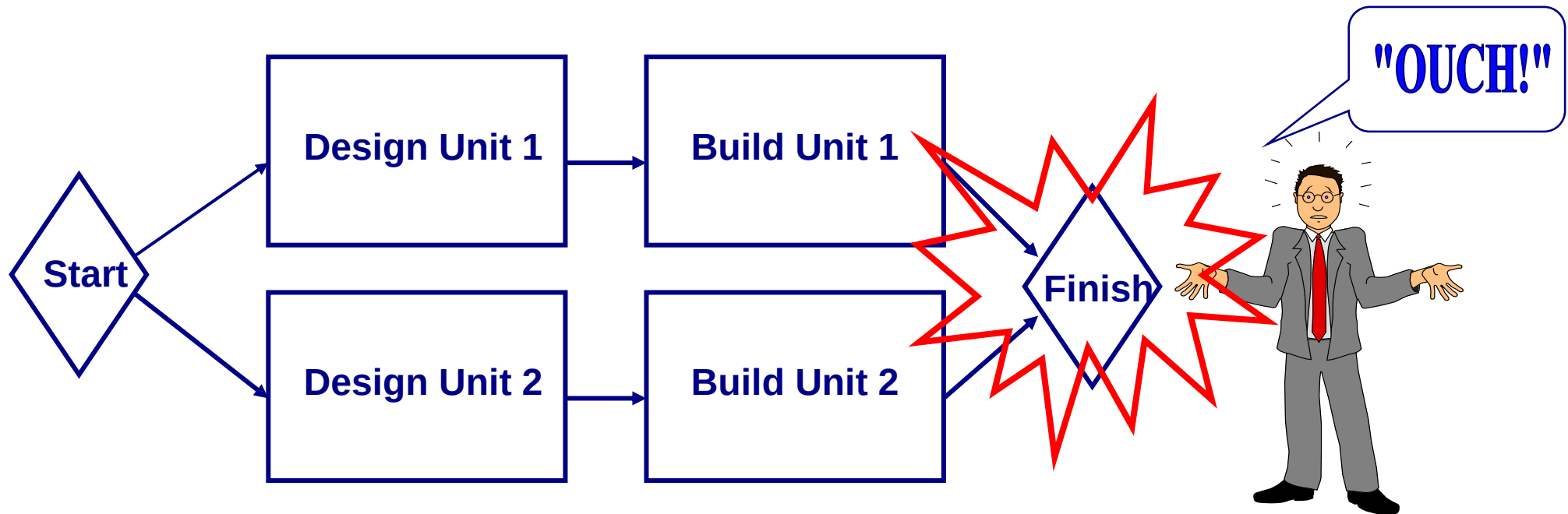
80% Target is 9/21

Risk at Merge Points: The “Merge Bias”

Many parallel paths merge in a real schedule

Finish driven by the latest converging path

Merge Bias has been understood for 40 years



Much Schedule Overrun Risk Occurs at Merge Points

Complex schedules have activities in parallel

Merge points are important events

- Completion of the project
- Major design review
- Beginning integration and test

Delay on any path may potentially delay the project

This extra risk is called the “Merge Bias”

Example of Merge Bias

Example of the Merge Bias

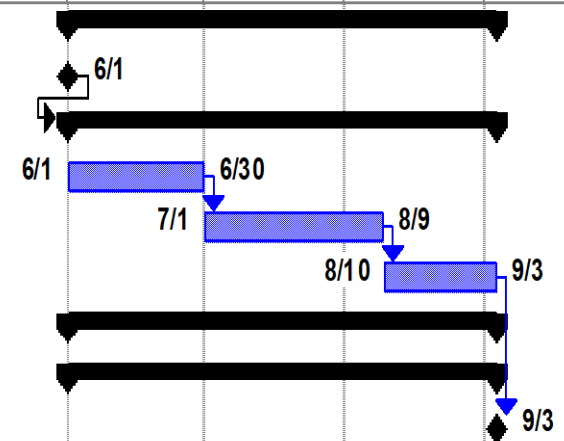
- Make three project paths that are exactly the same
- Same durations
- Same risks
- Start on the same day

CPM says this project, too, finishes on June 17

Is this reasonable? Is this project just as risky as the one-path project? More risky? Somehow less risky?

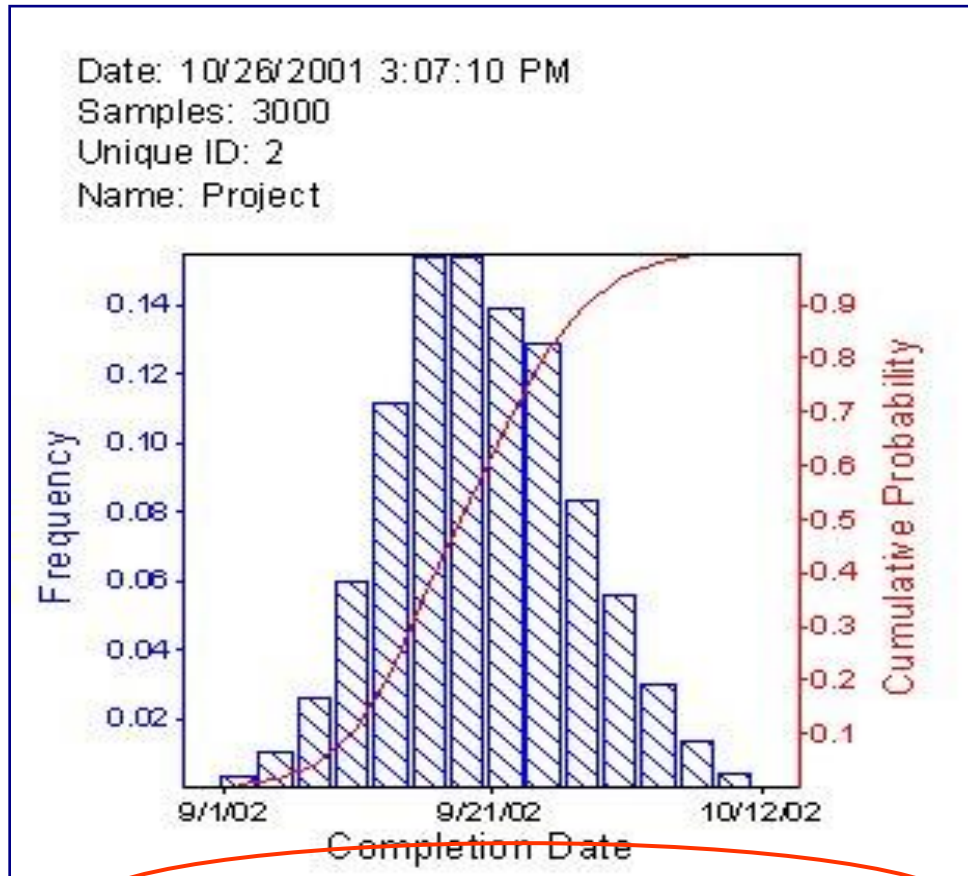
This Schedule has three Equal Parallel Paths

ID	Task Name	Rept ID	Min Rdur	ML Rdur	Max Rdur	Curve	May	June	July	August	September
1	Project	2	0 d	0 d	0 d	0					
2	Start	0	0 d	0 d	0 d	0					
3	Unit 1	1	0 d	0 d	0 d	0					
4	Design Unit 1	0	20 d	30 d	45 d	2					
5	Build Unit 1	0	35 d	40 d	50 d	2					
6	Test Unit 1	0	20 d	25 d	50 d	2					
7	Unit 2	1	0 d	0 d	0 d	0					
11	Unit 3	1	0 d	0 d	0 d	0					
15	Finish	0	0 d	0 d	0 d	0					

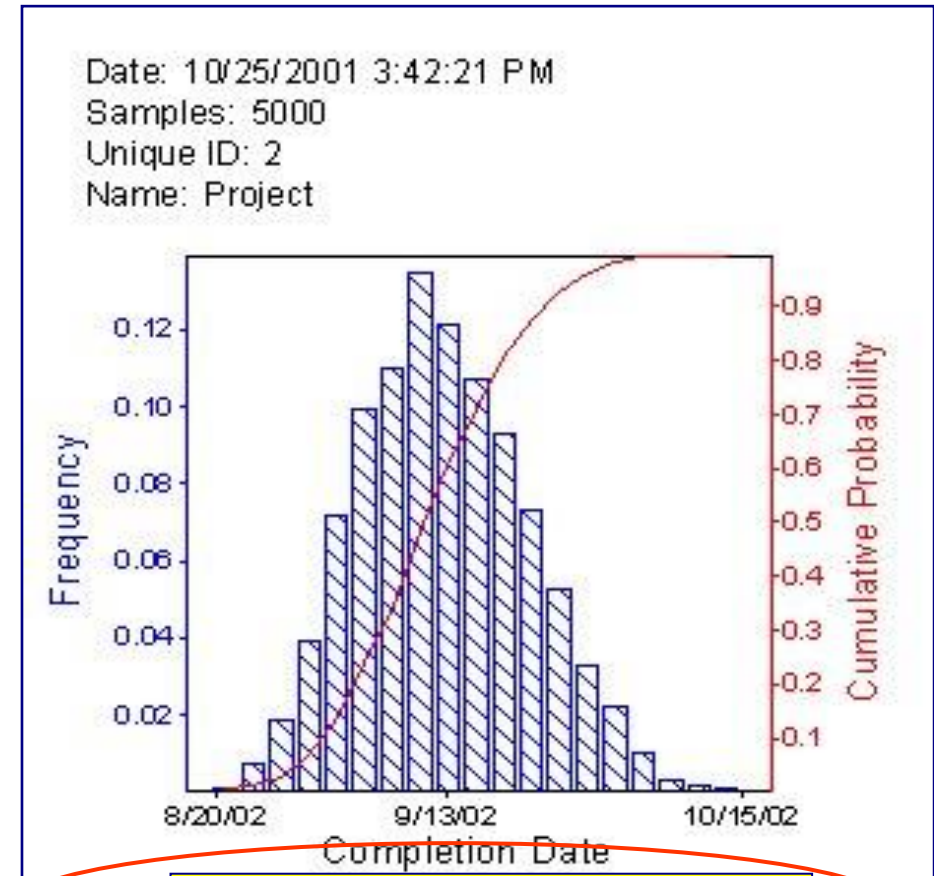


Two paths are collapsed
Each path has exactly the same structure

Evidence of the Merge Bias



Three Path Schedule



One Path Schedule

Evidence of Merge Bias (continued)

Completion Std Deviation: 7.03 d
Confidence Interval: 0.25 d
Each bar represents 3 d

Completion Probability Table

<u>Prob</u>	<u>Date</u>	<u>Prob</u>	<u>Date</u>
0.05	9/10/02	0.55	9/22/02
0.10	9/12/02	0.60	9/23/02
0.15	9/14/02	0.65	9/24/02
0.20	9/15/02	0.70	9/25/02
0.25	9/16/02	0.75	9/26/02
0.30	9/17/02	0.80	9/27/02
0.35	9/18/02	0.85	9/29/02
0.40	9/19/02	0.90	10/1/02
0.45	9/20/02	0.95	10/3/02
0.50	9/21/02	1.00	10/12/02

Three Path Schedule

Completion Std Deviation: 8.98 d
Confidence Interval: 0.25 d
Each bar represents 3 d

Completion Probability Table

<u>Prob</u>	<u>Date</u>	<u>Prob</u>	<u>Date</u>
0.05	8/31/02	0.55	9/14/02
0.10	9/2/02	0.60	9/15/02
0.15	9/4/02	0.65	9/17/02
0.20	9/5/02	0.70	9/18/02
0.25	9/7/02	0.75	9/20/02
0.30	9/8/02	0.80	9/21/02
0.35	9/10/02	0.85	9/23/02
0.40	9/11/02	0.90	9/26/02
0.45	9/12/02	0.95	9/29/02
0.50	9/13/02	1.00	10/15/02

One Path Schedule

What's Happening Here?

Likelihood of Two Events at Once

Likelihood of Two Occurances Occuring Together				
Path A	Path B	Path A	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%

Success is only in the green area

Other scenarios represent failure

Resource Problems

With real projects resources may be scarce

Unless resources are added, some activities must be delayed or stretched out

Critical Path Method (CPM) scheduling allows resource leveling and delays the project

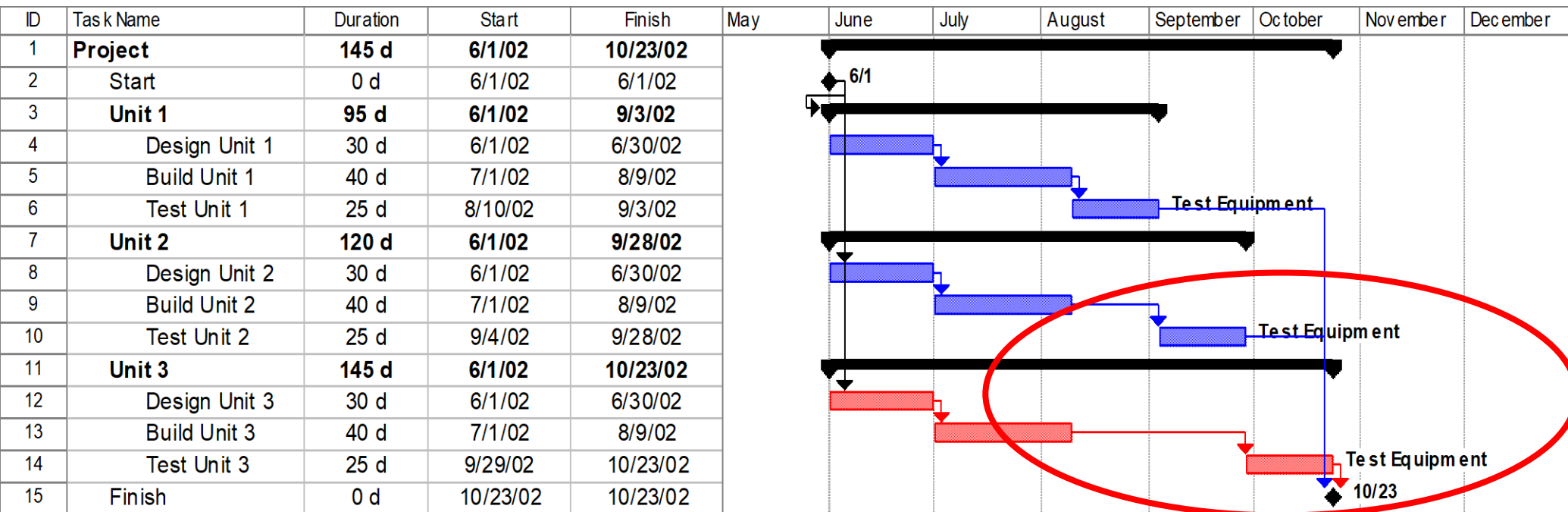
Each iteration is a CPM solution

Each iteration must be resource-leveled

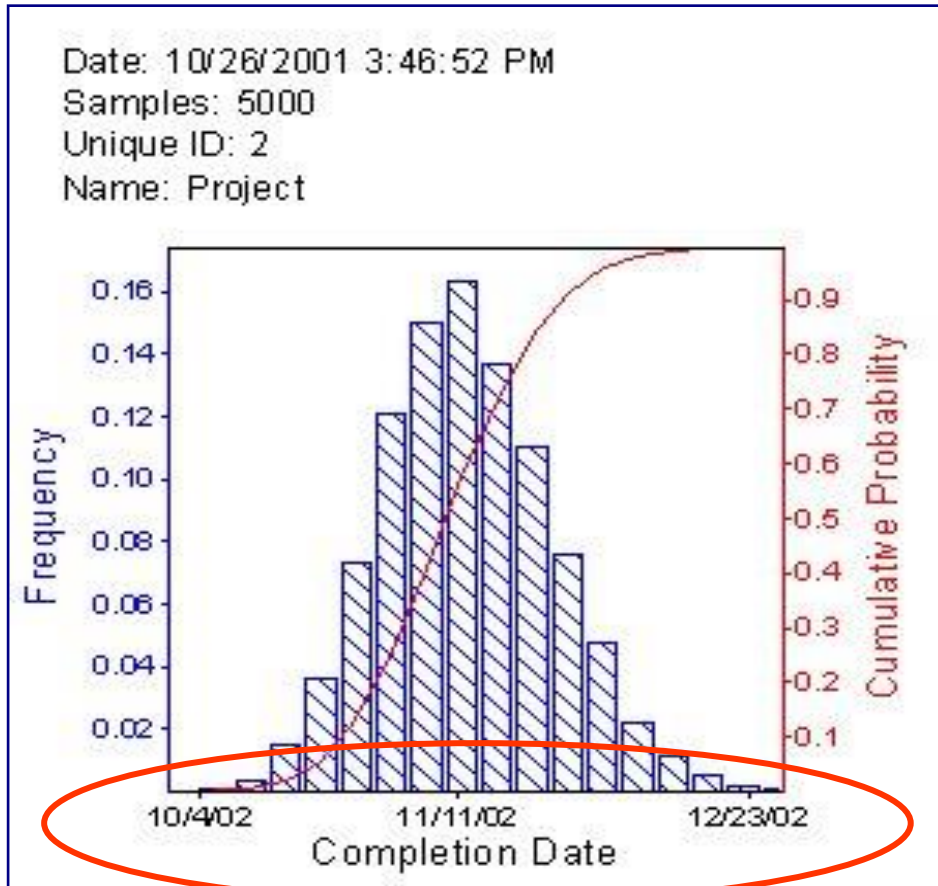
What Happens if Resources are Limited?

Limited Test Equipment means delaying Units 2 & 3

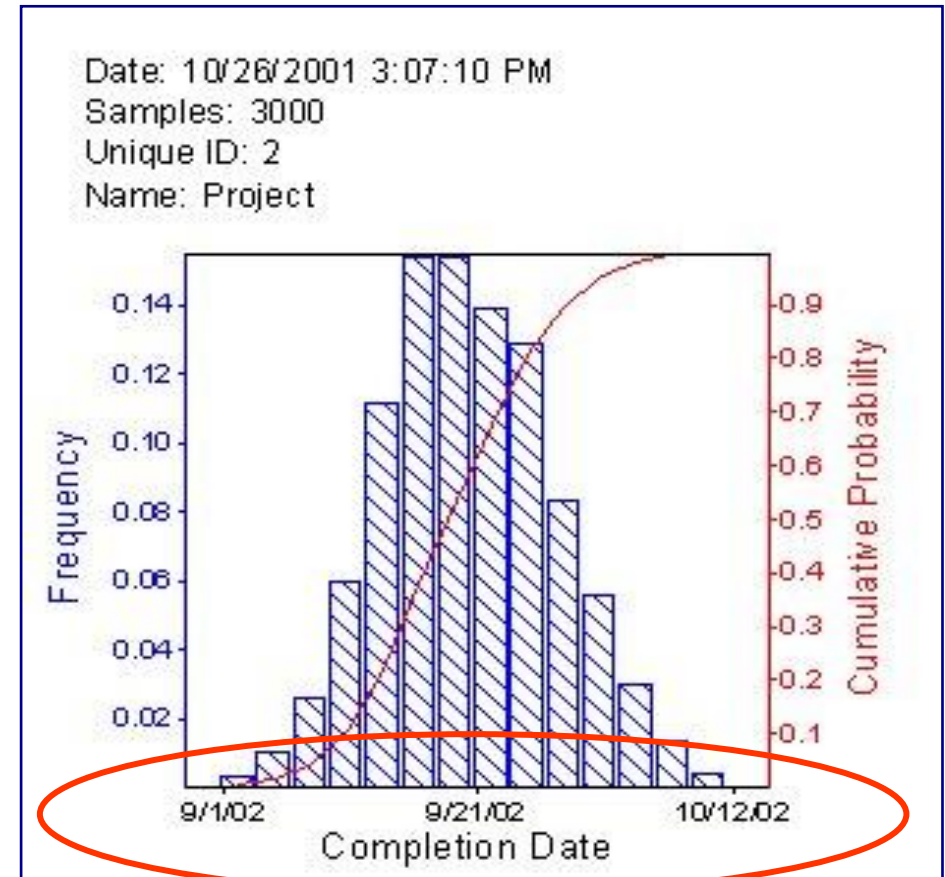
Resource leveling delays completion from 9/3 to 10/23



Leveling Resources and Schedule Risk



**Resource Levelled
Simulation**



**Simulation Not
Resource Levelled**

Imposing Constraint Dates on the Project Finish Date

Constraints are placed on the important delivery dates

This can help CPM scheduling

- Negative float develop feasible schedules

Constraints are also used to make the project show success

Constraints left in the schedule frustrate risk analysis of the very items you care about

Imposing Constraint Dates on the Project Finish Date (continued)

We leave the Must Finish On 9/3/02 constraint on the finish milestone

Project	2	0 d	0 d	0 d	0
Start	0	0 d	0 d	0 d	0
Design Unit	0	20 d	30 d	45 d	2
Build Unit	0	35 d	40 d	50 d	2
Test Unit	0				
Finish	0				

Task Information

General

Predecessors

Resources

Advanced

Notes

Name:
Duration:
☐ Estimated

Constrain task:

Deadline:

Constraint type:
Constraint date:

Task type:
☒ Effort

Calendar:
☐ S...

WBS code:

☒ Mark task as milestone

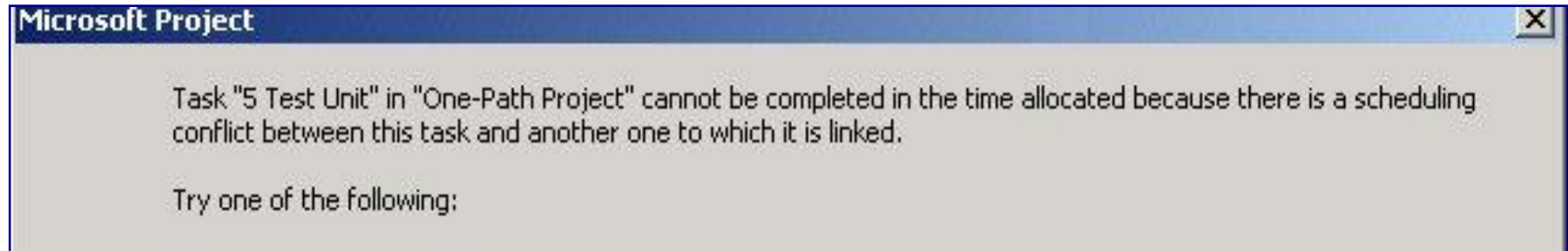
September, 2002

Sun	Mon	Tue	Wed	Thu	Fri	Sat
25	26	27	28	29	30	31
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	1	2	3	4	5

Today: 10/26/2001

Effect of a Not Later Than Or Must Finish On Constraint on the Simulation

Project gives you a message about the constraint



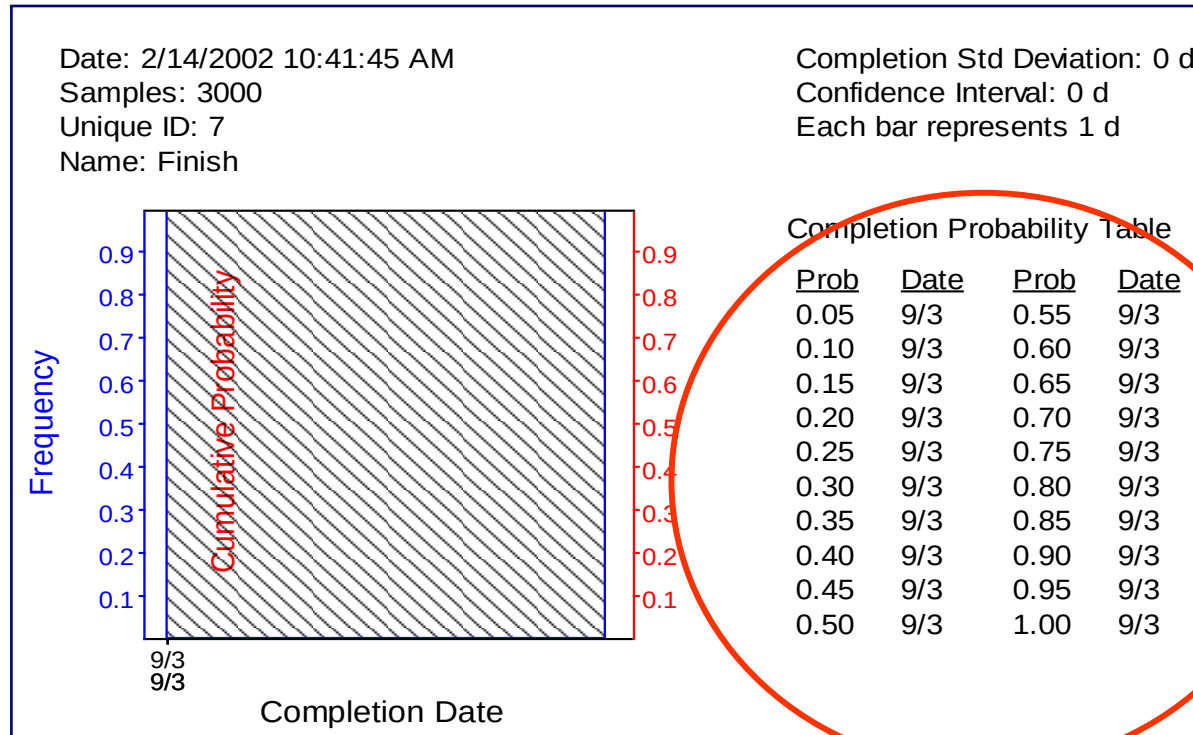
This tells you that you have a constraint that is binding

You can complete if you manually click the message

Do Not Turn Off the Scheduling Messages

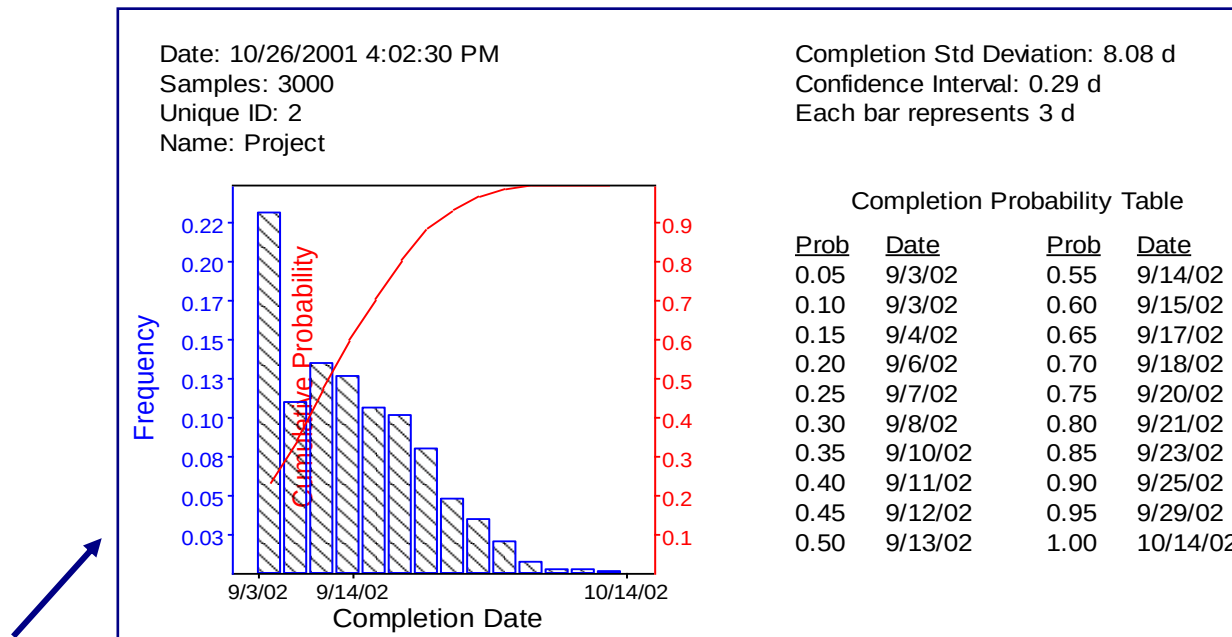
If you turn off messages you will never know whether you have constraints that bind

Effect of a Must Finish On Constraint



Effect of “Must Finish On” Constraint

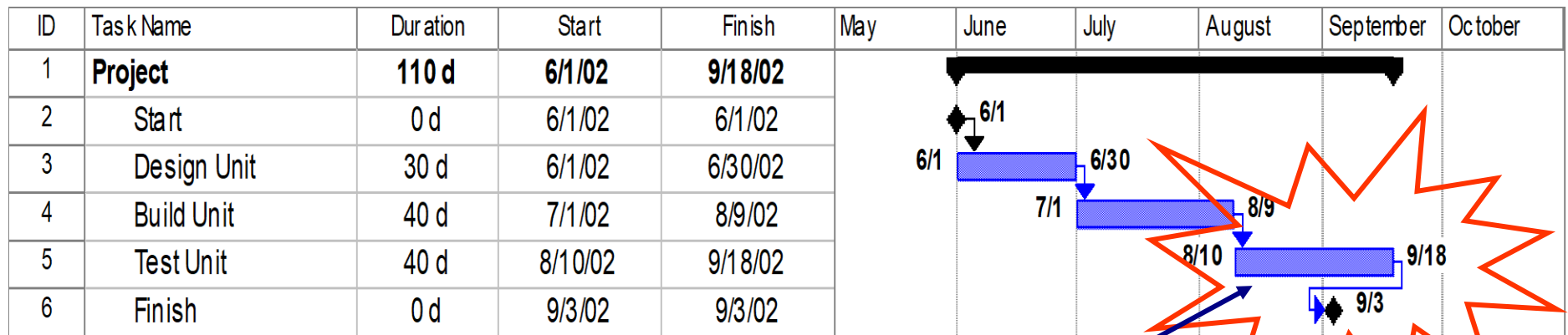
- If the results are gathered at the summary task, the results show only the “threat” side of the distribution



Cannot go Earlier since the Milestone does not Move

“Must Finish ON” will have Different Results if you use Summary Bar or Milestone

- What’s happening here? MS Project allows the predecessor activities extend PAST the FIXED milestone



Even if finish milestone might not be later, Test Unit can be, in Project. We’re using the Project summary bar for our results

Effect of “Finish Not Later Than” Constraint

Date: 10/26/2001 4:01:13 PM

Samples: 3000

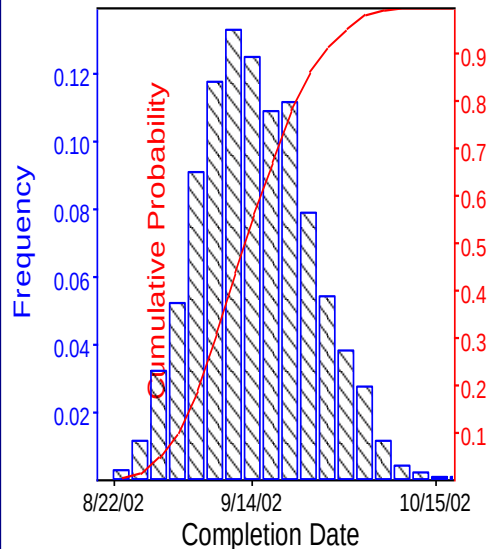
Unique ID: 2

Name: Project

Completion Std Deviation: 8.81 d

Confidence Interval: 0.31 d

Each bar represents 3 d



Completion Probability Table

Prob	Date	Prob	Date
0.05	8/31/02	0.55	9/14/02
0.10	9/3/02	0.60	9/15/02
0.15	9/4/02	0.65	9/17/02
0.20	9/6/02	0.70	9/18/02
0.25	9/7/02	0.75	9/20/02
0.30	9/8/02	0.80	9/21/02
0.35	9/9/02	0.85	9/23/02
0.40	9/11/02	0.90	9/25/02
0.45	9/12/02	0.95	9/29/02
0.50	9/13/02	1.00	10/15/02

Date: 2/14/2002 10:53:00 AM

Samples: 3000

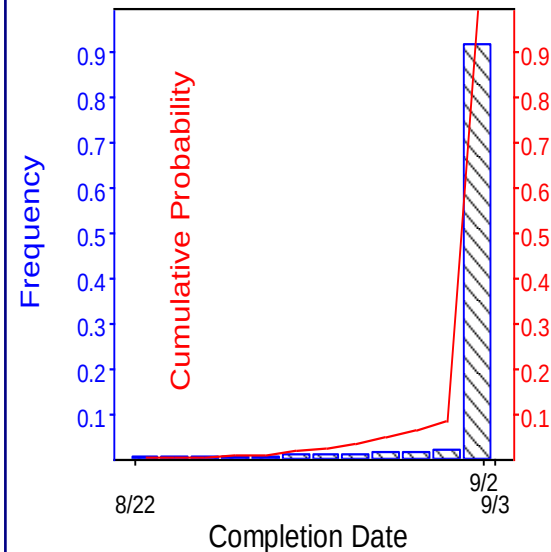
Unique ID: 7

Name: Finish

Completion Std Deviation: 1.28 d

Confidence Interval: 0.04 d

Each bar represents 1 d



Completion Probability Table

Prob	Date	Prob	Date
0.05	8/31	0.55	9/2
0.10	9/2	0.60	9/2
0.15	9/2	0.65	9/2
0.20	9/2	0.70	9/2
0.25	9/2	0.75	9/2
0.30	9/2	0.80	9/2
0.35	9/2	0.85	9/2
0.40	9/2	0.90	9/2
0.45	9/2	0.95	9/2
0.50	9/2	1.00	9/2

**Collecting data at the Summary Bar –
Correct because MS Project allows
activities to exceed the date**

**Collecting data at the Finish Milestone –
Incorrect because Constraint holds**

What are the Highest Risk Activities?

We do not know in advance which path will delay the project

Monte Carlo simulation tells us which is most likely

- Activities on critical path in most iterations

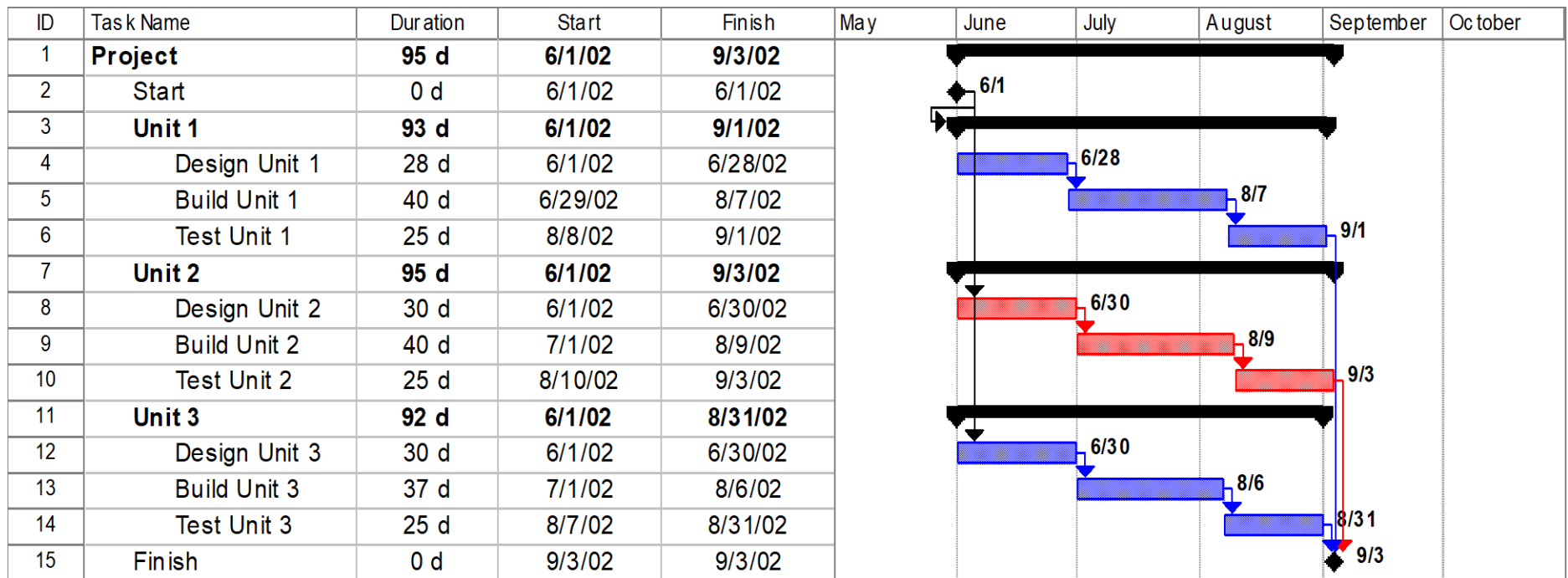
Path delaying the project may not be the critical path identified by CPM

This is “Schedule Critical” not Technically Critical

- Combination of risk and low float (slack)

What are the Highest-Risk Activities?

Units 1 & 3 are Shorter and Not Risk Mitigated



“Critical” Unit 2 is Identified for Risk Mitigation

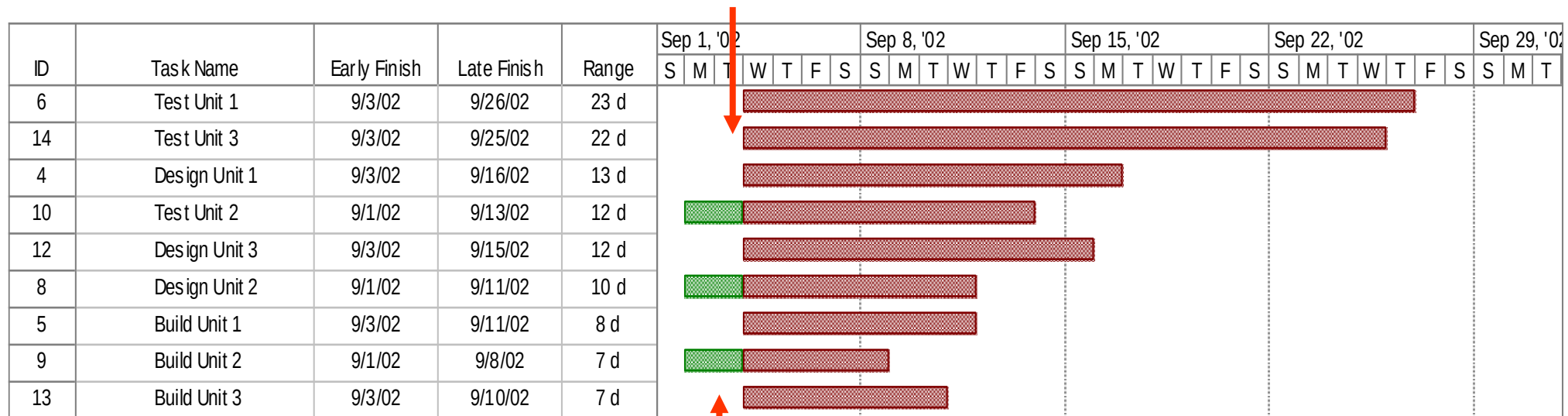
What are the Highest-Risk Activities? (continued)

ID	Task Name	Rept ID	Min Rdur	ML Rdur	Max Rdur	Curve
1	Project	2	0 d	0 d	0 d	0
2	Start	0	0 d	0 d	0 d	0
3	Unit 1	1	0 d	0 d	0 d	0
4	Design Unit 1	0	18 d	28 d	43 d	2
5	Build Unit 1	0	35 d	40 d	50 d	2
6	Test Unit 1	0	20 d	25 d	50 d	2
7	Unit 2	1	0 d	0 d	0 d	0
8	Design Unit 2	0	26 d	30 d	38 d	2
9	Build Unit 2	0	36 d	40 d	45 d	2
10	Test Unit 2	0	22 d	25 d	35 d	2
11	Unit 3	1	0 d	0 d	0 d	0
12	Design Unit 3	0	20 d	30 d	45 d	2
13	Build Unit 3	0	32 d	37 d	47 d	2
14	Test Unit 3	0	20 d	25 d	50 d	2

**Unit 2 is
Closely
Managed
but Units 1
& 3 still
Have Risk**

Use Sensitivity Analysis First

Even if Units 1 & 3 are shorter, Unit 2 keeps schedule from shortening



**Opportunities only in the CPM
critical path for Unit 2**

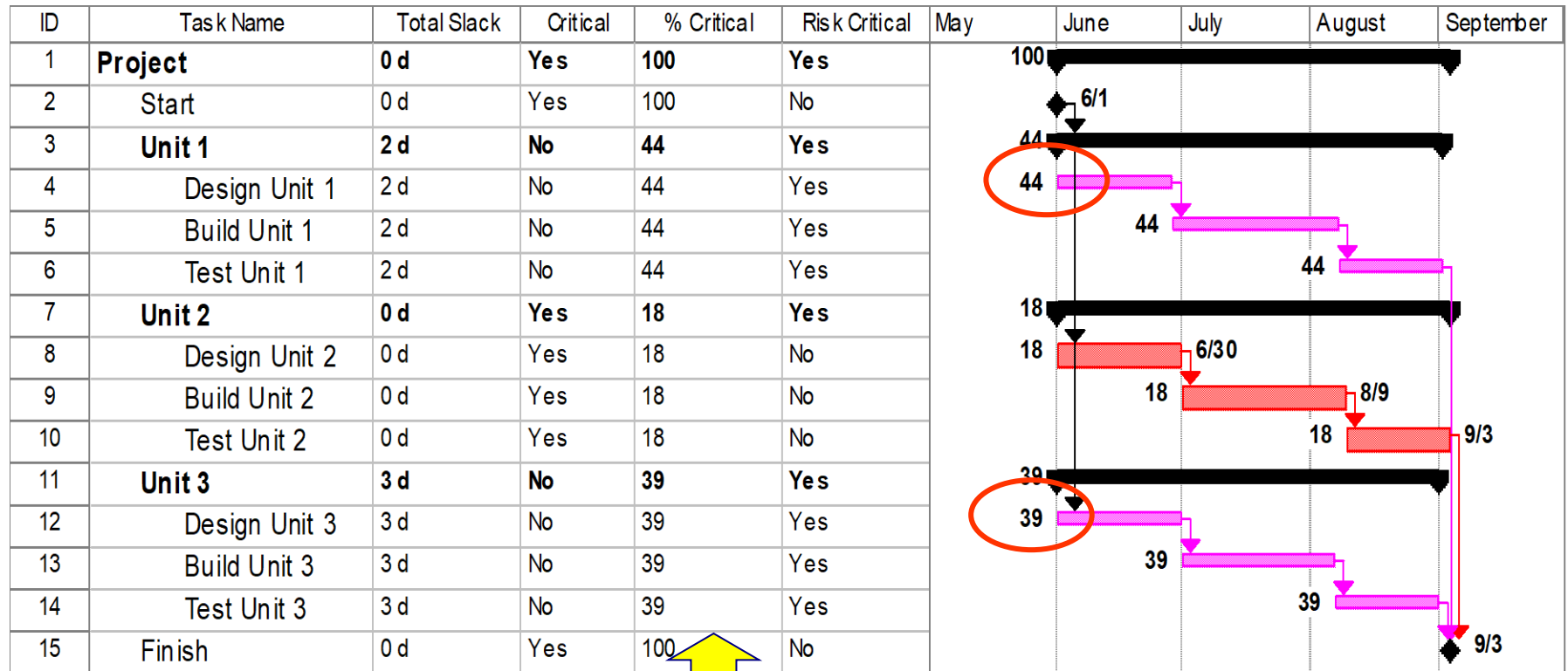
Risk Criticality of Activities

Risk Criticality is the likelihood that an activity will be on the path that delays the project

- Activity may not be technically risky
- Activity may not be risky, but path is

Percentage of iterations on the critical path

Risk Critical GANTT Chart



The “Critical Path” has been managed and is only 18% likely to delay the project.
Now turn attention to Units 1 & 3

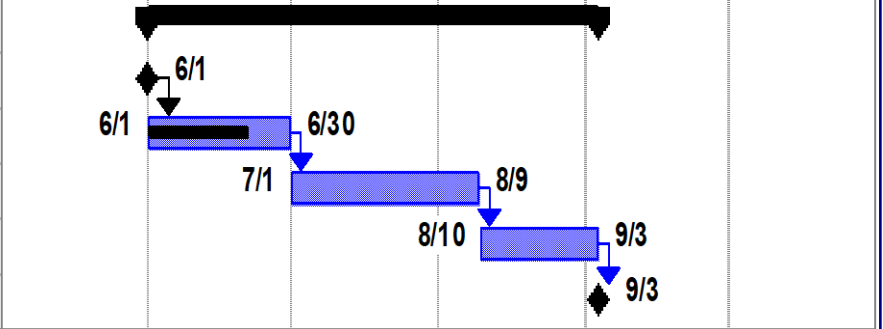
Handling Stated Activities

Risk range on remaining duration – Actuals are not risky

Hence the “Min Rdur,” ML Rdur,” “Max Rdur”

What happens when an activity has actual progress?

- Design Unit has 70% complete, 9 days to go
- On track to finish on 9/3

ID	Task Name	Duration	Start	Finish	May	June	July	August	September	October
1	Project	95 d	6/1/02	9/3/02						
2	Start	0 d	6/1/02	6/1/02						
3	Design Unit	30 d	6/1/02	6/30/02						
4	Build Unit	40 d	7/1/02	8/9/02						
5	Test Unit	25 d	8/10/02	9/3/02						
6	Finish	0 d	9/3/02	9/3/02						

Adjusting the Durations for 15 days of Actual Progress

ID	Task Name	Rept ID	Min Rdur	ML Rdur	Max Rdur	Curve
1	Project	2	0 d	0 d	0 d	0
2	Start	0	0 d	0 d	0 d	0
3	Design Unit	0	20 d	30 d	45 d	2
4	Build Unit	0	35 d	40 d	50 d	2
5	Test Unit	0	20 d	25 d	50 d	2
6	Finish	0	0 d	0 d	0 d	0

Leave original risk ranges even though Design has progress? NO!

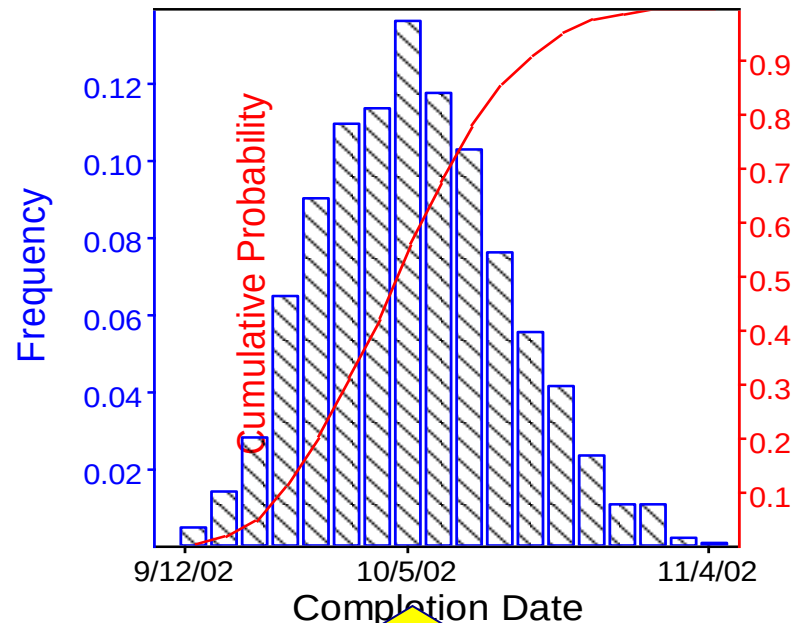
ID	Task Name	Rept ID	Min Rdur	ML Rdur	Max Rdur	Curve
1	Project	2	0 d	0 d	0 d	0
2	Start	0	0 d	0 d	0 d	0
3	Design Unit	0	5 d	9 d	15 d	2
4	Build Unit	0	35 d	40 d	50 d	2
5	Test Unit	0	20 d	25 d	50 d	2
6	Finish	0	0 d	0 d	0 d	0

With only 9 days to go on Design, risk ranges adjusted to remaining duration. YES!

Handling Stated Activities (continued)

Date: 10/26/2001 4:37:46 PM
Samples: 3000
Unique ID: 2
Name: Project

Completion Std Deviation: 9.03 d
Confidence Interval: 0.32 d
Each bar represents 3 d



Completion Probability Table

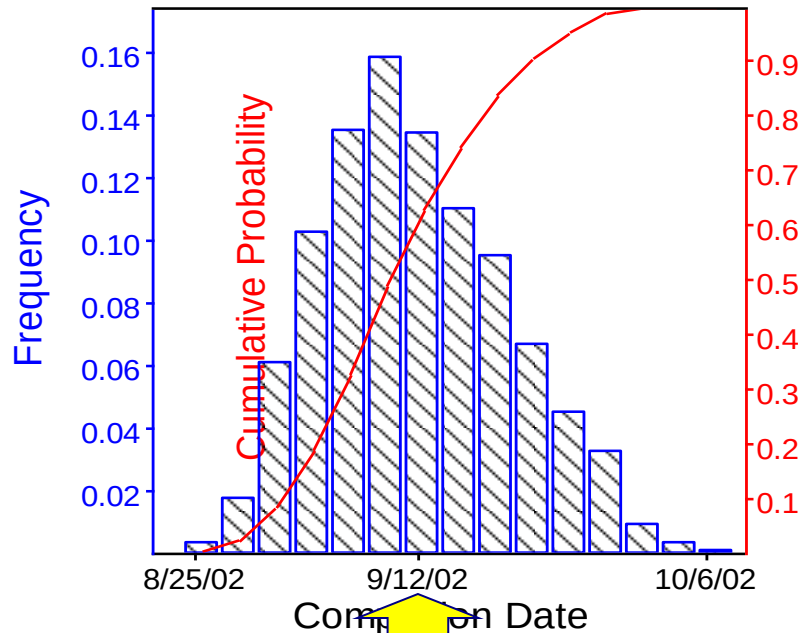
<u>Prob</u>	<u>Date</u>	<u>Prob</u>	<u>Date</u>
0.05	9/21/02	0.55	10/5/02
0.10	9/23/02	0.60	10/6/02
0.15	9/25/02	0.65	10/8/02
0.20	9/26/02	0.70	10/9/02
0.25	9/28/02	0.75	10/10/02
0.30	9/29/02	0.80	10/12/02
0.35	9/30/02	0.85	10/14/02
0.40	10/2/02	0.90	10/17/02
0.45	10/3/02	0.95	10/20/02
0.50	10/4/02	1.00	11/4/02

If you do not change the risk ranges, expected completion is 10/5

Handling Stated Activities (continued)

Date: 10/26/2001 4:46:38 PM
Samples: 3000
Unique ID: 2
Name: Project

Completion Std Deviation: 7.57 d
Confidence Interval: 0.27 d
Each bar represents 3 d



Completion Probability Table

<u>Prob</u>	<u>Date</u>	<u>Prob</u>	<u>Date</u>
0.05	9/1/02	0.55	9/13/02
0.10	9/3/02	0.60	9/14/02
0.15	9/5/02	0.65	9/15/02
0.20	9/6/02	0.70	9/16/02
0.25	9/7/02	0.75	9/18/02
0.30	9/8/02	0.80	9/19/02
0.35	9/9/02	0.85	9/21/02
0.40	9/10/02	0.90	9/23/02
0.45	9/11/02	0.95	9/26/02
0.50	9/12/02	1.00	10/6/02

**After changing the risk ranges to reflect progress,
expected completion is 9/12**

Probabilistic Branching

Many projects have points where there is a possibility of failure, a discontinuous event

Have to model the likelihood of the failure and its consequence for the schedule

Called “Probabilistic Branching”

Probabilistic branching is an advanced feature found in Risk+, @RISK, PERTMASTER and Monte Carlo

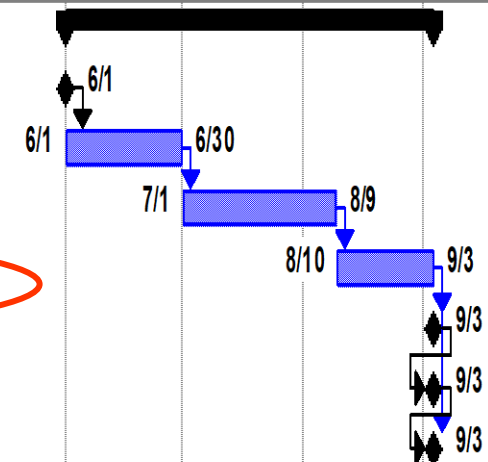
Model the Probabilistic Branch

Typically we do not include failure in schedule

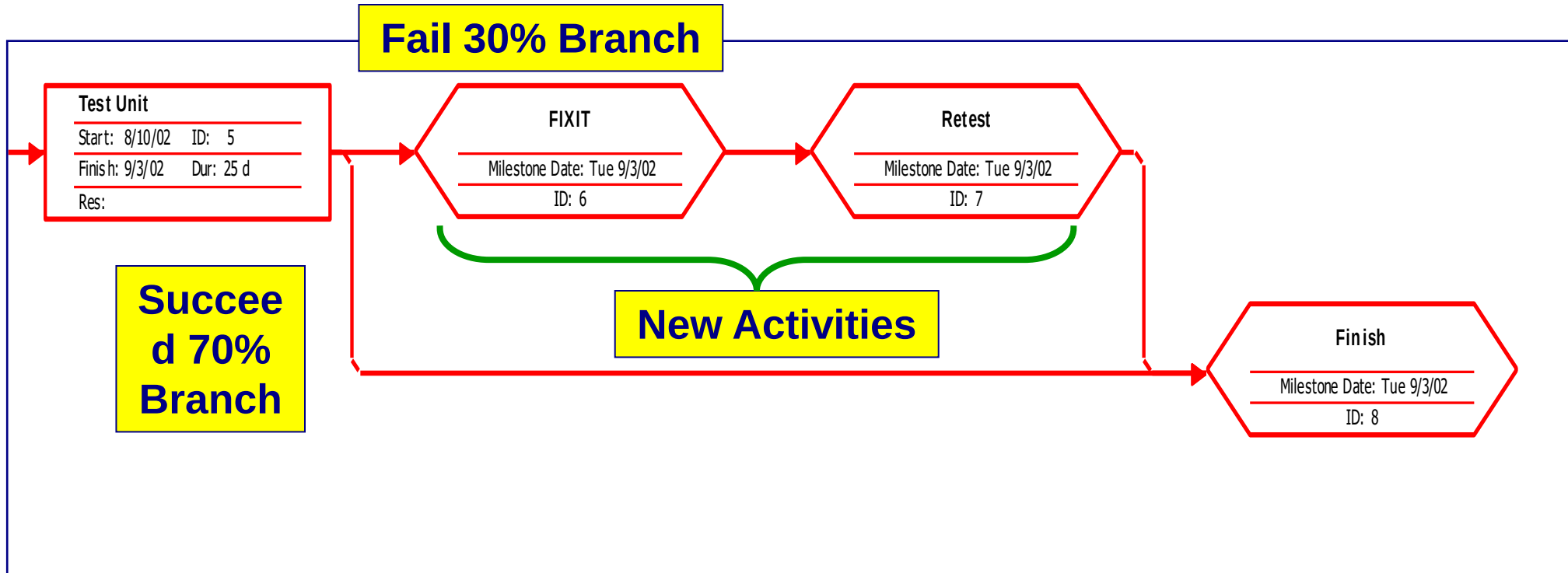
- Add FIXIT and Retest
- Preserve the 9/3 finish date (with 0 duration)

Enter ranges for the new activities

ID	Task Name	Duration	Rept ID	Mn Rdur	ML Rdur	Max Rdur	Curve	May	June	July	August	September	October
1	Project	95 d	2	0 d	0 d	0 d	0						
2	Start	0 d	0	0 d	0 d	0 d	0						
3	Design Unit	30 d	0	5 d	9 d	15 d	2						
4	Build Unit	40 d	0	35 d	40 d	50 d	2						
5	Test Unit	25 d	0	20 d	25 d	50 d	2						
6	FIXIT	0 d	0	15 d	30 d	60 d	0						
7	Retest	0 d	0	20 d	25 d	35 d	0						
8	Finish	0 d	0	0 d	0 d	0 d	0						



Logic of Probabilistic Branch



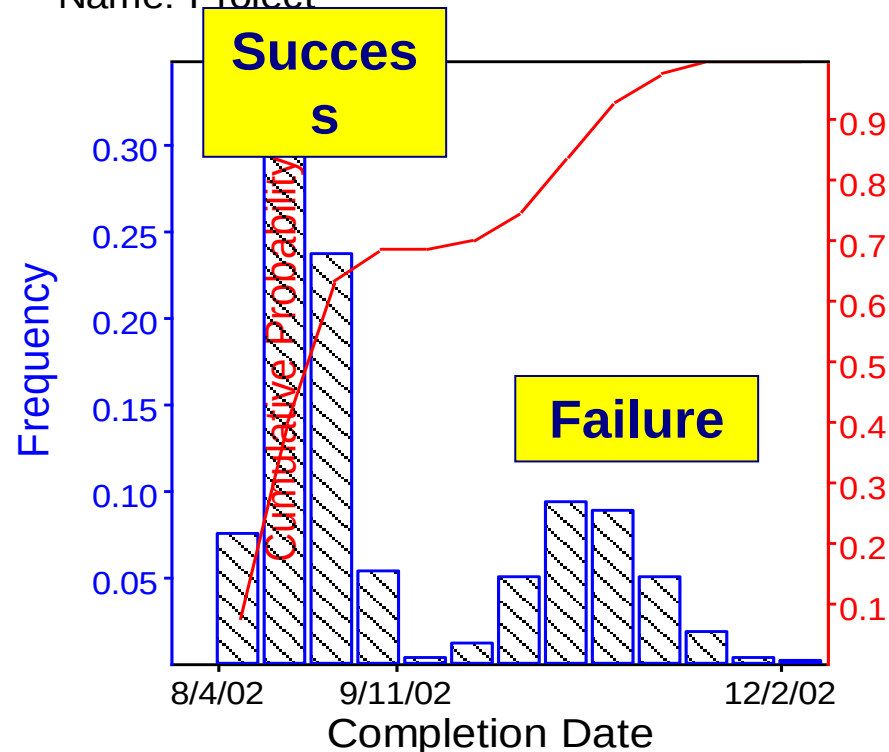
Branching in the Risk Entry Table

ID	Task Name	Rept ID	Min Rdur	ML Rdur	Max Rdur	Curve	Branch Def	Branch ID
1	Project	2	0 d	0 d	0 d	0		
2	Start	0	0 d	0 d	0 d	0		
3	Design Unit	0	5 d	9 d	15 d	2		
4	Build Unit	0	35 d	40 d	50 d	2		
5	Test Unit	0	20 d	25 d	50 d	2	6:30,8:70	
6	FIXIT	0	15 d	30 d	60 d	2		6
7	Retest	0	20 d	25 d	35 d	2		6
8	Finish	0	0 d	0 d	0 d	0		

Typical Bi-Modal Result Distribution

Date: 10/27/2001 8:45:14 AM
Samples: 3000
Unique ID: 1
Name: Project

Completion Std Deviation: 30.03 d
Confidence Interval: 1.08 d
Each bar represents 10 d



Completion Probability Table

Prob	Date	Prob	Date
0.05	8/12/02	0.55	8/29/02
0.10	8/14/02	0.60	9/1/02
0.15	8/16/02	0.65	9/4/02
0.20	8/18/02	0.70	10/3/02
0.25	8/19/02	0.75	10/13/02
0.30	8/21/02	0.80	10/18/02
0.35	8/22/02	0.85	10/23/02
0.40	8/24/02	0.90	10/29/02
0.45	8/25/02	0.95	11/5/02
0.50	8/27/02	1.00	12/2/02

Conditional Branching

Contingency Planning Problem

Propulsion System Alternative A is preferred by customer

- Alternative A is new and risky

Alternative B is the back up, contingency plan

- Acceptable, not preferred

We care about the schedule, too

How long do we stick with Alternative A and under what condition do we go to Alternative B?

**Conditional branching is an advanced feature found in
@RISK, Monte Carlo and Risk+**

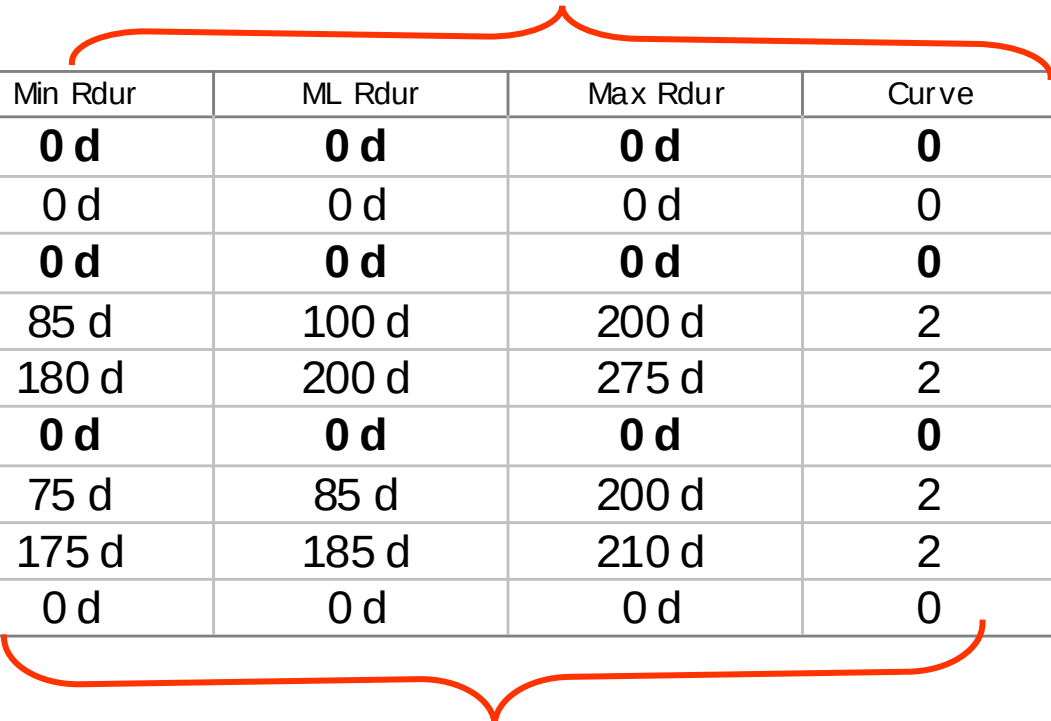
Schedule with Alternatives A & B

ID	Task Name	Duration	Start	Finish	2nd Quarter	3rd Quarter	4th Quarter	1st Quarter	2nd Quarter	3rd Quarter
1	Project	300 d	6/1/02	3/27/03						
2	Start	0 d	6/1/02	6/1/02						
3	Preferred Alt A	300 d	6/1/02	3/27/03						
4	Design Alt. A	100 d	6/1/02	9/8/02						
5	Build and Test Alt. A	200 d	9/9/02	3/27/03						
6	Backup Alt. B	298 d	6/1/02	3/25/03						
7	Design Alt. B	85 d	6/1/02	8/24/02						
8	Build and Test Alt. B	185 d	9/22/02	3/25/03						
9	Finish	0 d	3/27/03	3/27/03						

Build and Test Alt. B SNET 9/22, the day after the decision about Alt. A

Risk Information for Alternatives A and B

Alternative A has Wider Ranges, Longer Design Time

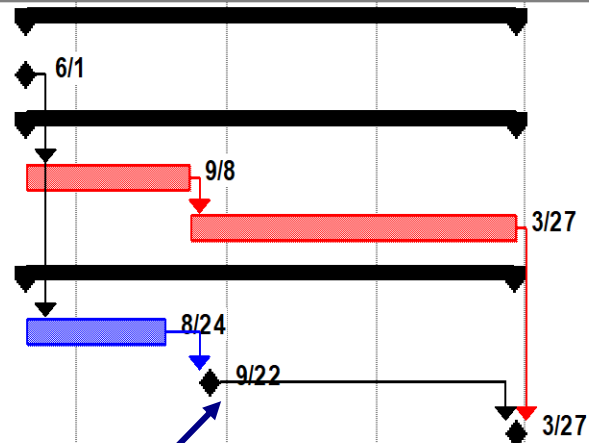


ID	Task Name	Rept ID	Min Rdur	ML Rdur	Max Rdur	Curve
1	Project	2	0 d	0 d	0 d	0
2	Start	0	0 d	0 d	0 d	0
3	Preferred Alt A	0	0 d	0 d	0 d	0
4	Design Alt. A	0	85 d	100 d	200 d	2
5	Build and Test Alt.	0	180 d	200 d	275 d	2
6	Backup Alt. B	0	0 d	0 d	0 d	0
7	Design Alt. B	0	75 d	85 d	200 d	2
8	Build and Test Alt.	0	175 d	185 d	210 d	2
9	Finish	0	0 d	0 d	0 d	0

Alternative B is Less Desirable but Less Risky

What Happens if there is No Backup Alt. B?

ID	Task Name	Duration	Start	Finish	2nd Quarter	3rd Quarter	4th Quarter	1st Quarter	2nd Quarter	3rd Quarter
1	Project	300 d	6/1/02	3/27/03						
2	Start	0 d	6/1/02	6/1/02						
3	Preferred Alt A	300 d	6/1/02	3/27/03						
4	Design Alt. A	100 d	6/1/02	9/8/02						
5	Build and Test Alt. A	200 d	9/9/02	3/27/03						
6	Backup Alt. B	298 d	6/1/02	3/25/03						
7	Design Alt. B	85 d	6/1/02	8/24/02						
8	Build and Test Alt. B	0 d	9/22/02	9/22/02						
9	Finish	0 d	3/27/03	3/27/03						

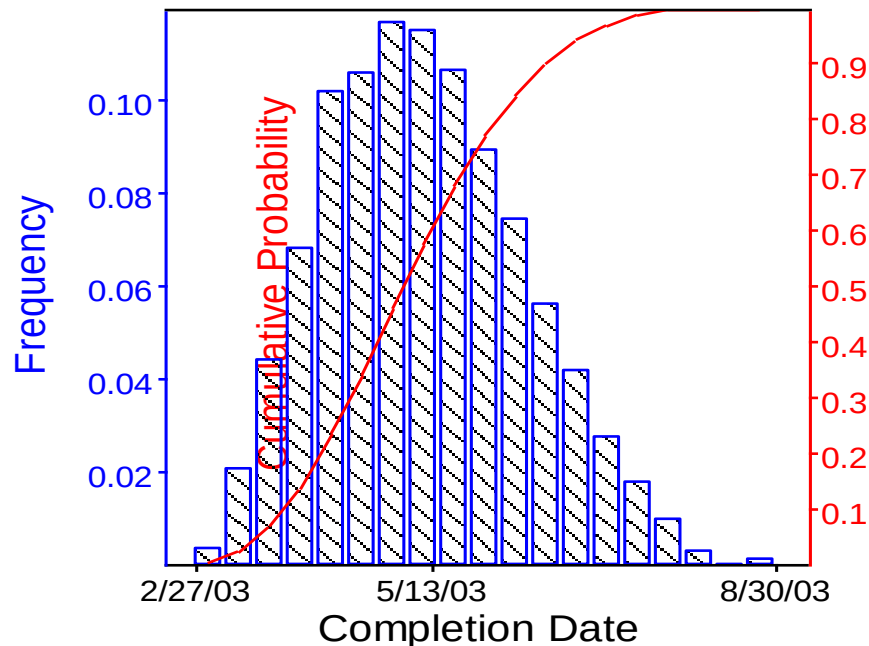


Zero out Build and Test Alt. B so Alt. A is the only one

*If Must Go with Alt. A, (if there is No Alt. B),
80% Date is 6/10/03*

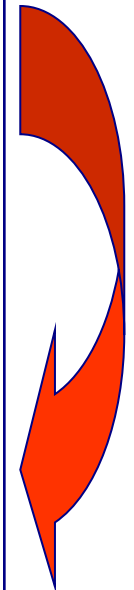
Date: 11/20/2001 9:28:10 PM
Samples: 3000
Unique ID: 2
Name: Project

Completion Std Deviation: 32.04 d
Confidence Interval: 1.15 d
Each bar represents 10 d



Completion Probability Table

<u>Prob</u>	<u>Date</u>	<u>Prob</u>	<u>Date</u>
0.05	3/25/03	0.55	5/16/03
0.10	4/3/03	0.60	5/19/03
0.15	4/9/03	0.65	5/25/03
0.20	4/14/03	0.70	5/29/03
0.25	4/19/03	0.75	6/4/03
0.30	4/23/03	0.80	6/10/03
0.35	4/28/03	0.85	6/17/03
0.40	5/2/03	0.90	6/26/03
0.45	5/6/03	0.95	7/10/03
0.50	5/11/03	1.00	8/30/03



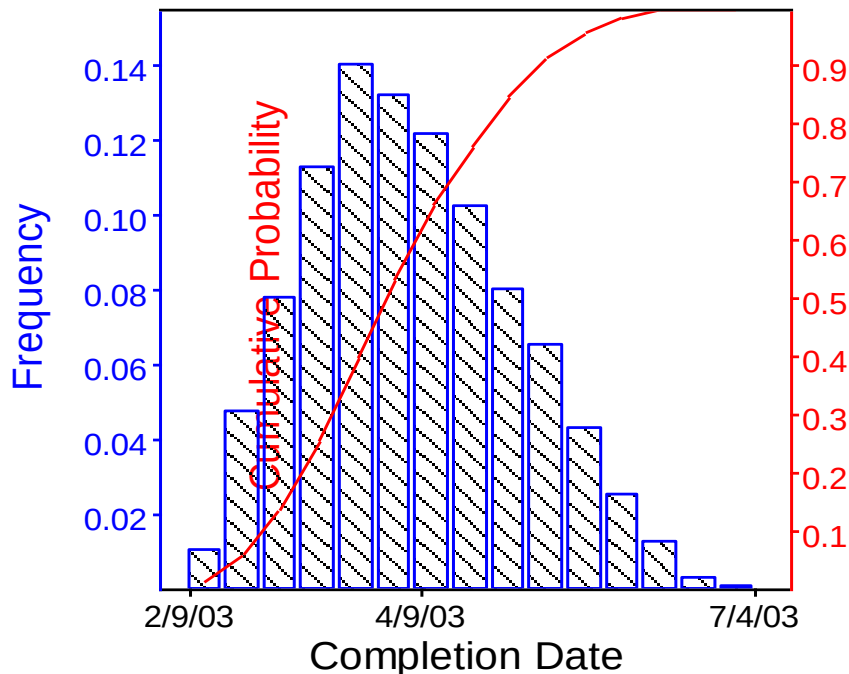
If No Alternative B, Alternative A is 100% Likely

ID	Task Name	Total Slack	Critical	% Critical	2nd Quarter	3rd Quarter	4th Quarter	1st Quarter	2nd Quarter	3rd Quarter
1	Project	0 d	Yes	100	The Gantt chart illustrates the project schedule across six quarters. The project bar (black) spans from the start of the 2nd Quarter to the end of the 3rd Quarter, with a value of 100. Below it, Preferred Alt. A (red) also spans from the start of the 2nd Quarter to the end of the 3rd Quarter, with a value of 100. Backup Alt. B (blue) spans from the start of the 2nd Quarter to the end of the 2nd Quarter, with a value of 0. The finish bar (black) spans from the start of the 3rd Quarter to the end of the 3rd Quarter, with a value of 3/27. Milestones are marked with diamonds: 6/1, 8/24, and 3/27.					
2	Start	0 d	Yes	100						
3	Preferred Alt A	0 d	Yes	100						
4	Design Alt. A	0 d	Yes	100						
5	Build and Test Alt. A	0 d	Yes	100						
6	Backup Alt. B	215 d	No	0						
7	Design Alt. B	215 d	No	0						
8	Build and Test Alt. B	215 d	No	0						
9	Finish	0 d	Yes	100						

Choosing Alt. B if Alt. A Design is Later than 9/21 – 80% Date is Now 5/3/03

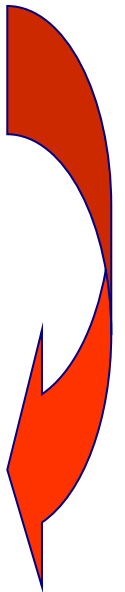
Date: 11/20/2001 9:35:44 PM
Samples: 3000
Unique ID: 2
Name: Project

Completion Std Deviation: 26.91 d
Confidence Interval: 0.96 d
Each bar represents 10 d



Completion Probability Table

<u>Prob</u>	<u>Date</u>	<u>Prob</u>	<u>Date</u>
0.05	2/27/03	0.55	4/11/03
0.10	3/6/03	0.60	4/14/03
0.15	3/12/03	0.65	4/18/03
0.20	3/16/03	0.70	4/23/03
0.25	3/20/03	0.75	4/28/03
0.30	3/24/03	0.80	5/3/03
0.35	3/27/03	0.85	5/10/03
0.40	3/31/03	0.90	5/17/03
0.45	4/3/03	0.95	5/28/03
0.50	4/7/03	1.00	7/4/03



Switch to Alt. B if Design on Alt. A is Later than 9/21 – Which Technology is Used?

Plan A is Chosen only 33% of the Time

ID	Task Name	Total Slack	Critical	% Critical	2nd Quarter	3rd Quarter	4th Quarter	1st Quarter	2nd Quarter	3rd Quarter
1	Project	0 d	Yes	100	100					
2	Start	0 d	Yes	100	6/1					
3	Preferred Alt A	0 d	Yes	33	33					
4	Design Alt. A	0 d	Yes	33	33					
5	Build and Test Alt. A	0 d	Yes	33		33				
6	Backup Alt. B	30 d	No	67	67					
7	Design Alt. B	30 d	No	67	67					
8	Build and Test Alt. B	30 d	No	67		67				
9	Finish	0 d	Yes	100						3/27

Plan B is Chosen 67% of the Time

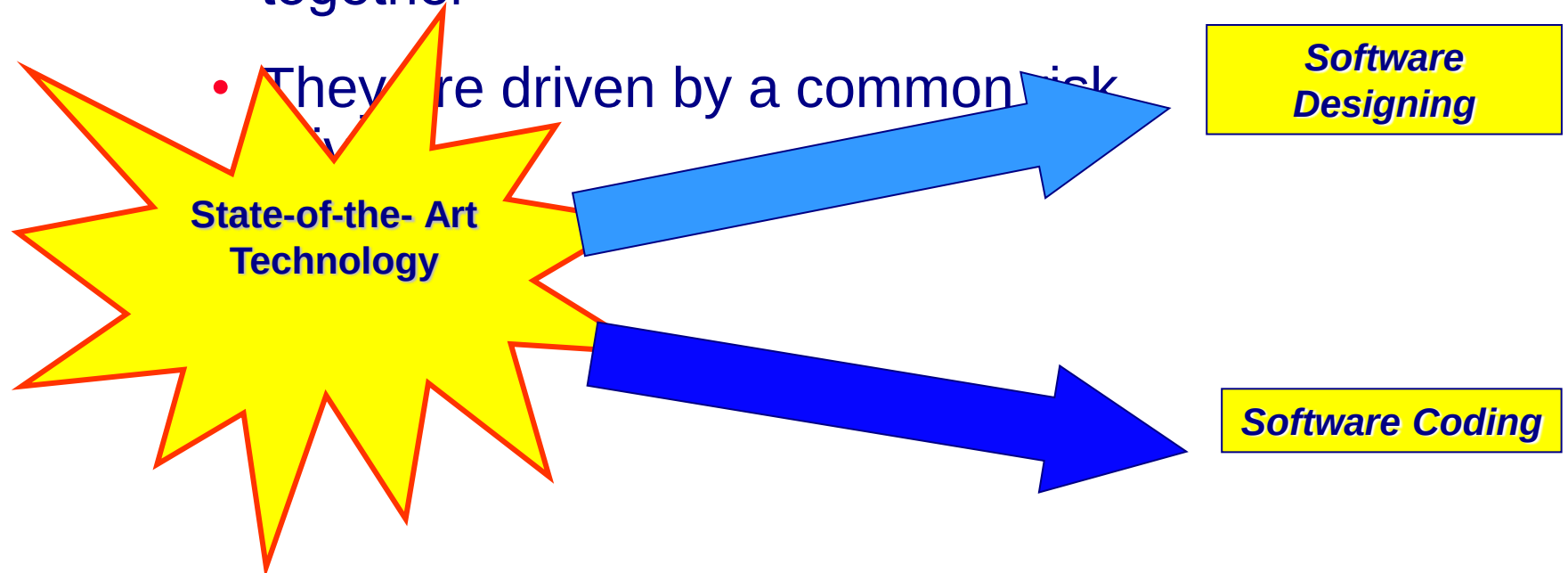
Summary of Conditional Branch Exercise

Results of Scenario		
Scenario	Technology A Only, No Plan B	Decide Plan B at 9/21/02
Mean Date	5/13	4/9
Probability 80%	6/10	5/3
Probability Using Tech A	100%	33%

Causes of Correlation

Correlation between activity durations

- When two activities' durations “move together”
- They are driven by a common risk



For Ease of Data Entry, Use Quick Setup

For expediency, use risk banding

- Low = -25%
- High = +50%
- Distribution = triangular

Correlation is an advanced feature found in @RISK, PERTMASTER and Risk+. Monte Carlo has rudimentary correlation

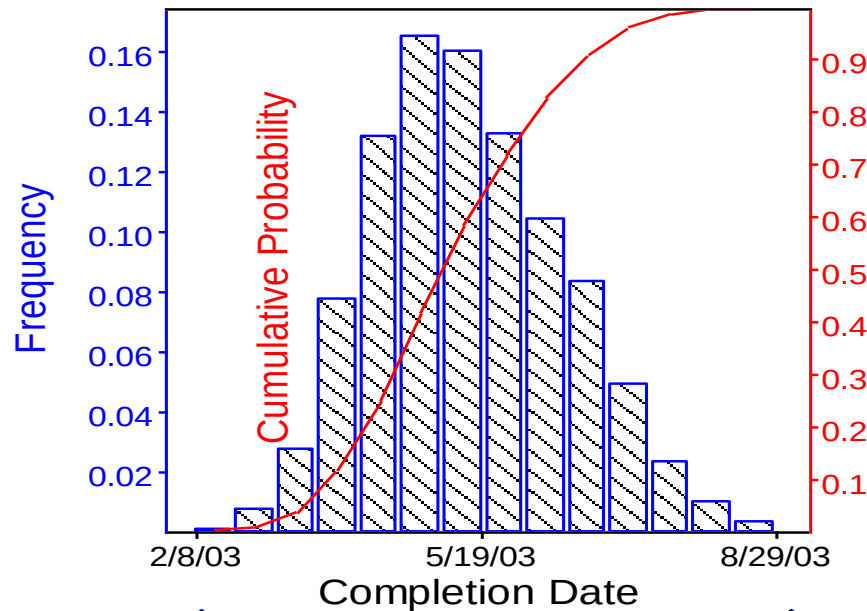
ID	Task Name	Rept ID	Min Rdur	ML Rdur	Max Rdur	Curve	2nd Quarter	3rd Quarter	4th Quarter	1st Quarter	2nd Quarter
1	Project	2	0 d	0 d	0 d	0					
2	Start	0	0 d	0 d	0 d	2					
3	Design	0	56.25 d	75 d	112.5 d	2					
4	Code Software	0	150 d	200 d	300 d	2					
5	Unit Test Software	0	37.5 d	50 d	75 d	2					
6	Finish	0	0 d	0 d	0 d	2					

Simulation With No Correlation

Sigma 34.1 days

Date: 11/12/2001 9:15:12 PM
Samples: 3000
Unique ID: 1
Name: Project

Completion Std Deviation: 34.11 d
Confidence Interval: 1.22 d
Each bar represents 15 d



Completion Probability Table

<u>Prob</u>	<u>Date</u>	<u>Prob</u>	<u>Date</u>
0.05	3/28/03	0.55	5/20/03
0.10	4/7/03	0.60	5/25/03
0.15	4/13/03	0.65	5/30/03
0.20	4/18/03	0.70	6/5/03
0.25	4/23/03	0.75	6/11/03
0.30	4/29/03	0.80	6/18/03
0.35	5/3/03	0.85	6/26/03
0.40	5/7/03	0.90	7/4/03
0.45	5/11/03	0.95	7/18/03
0.50	5/15/03	1.00	8/29/03

No Correlations

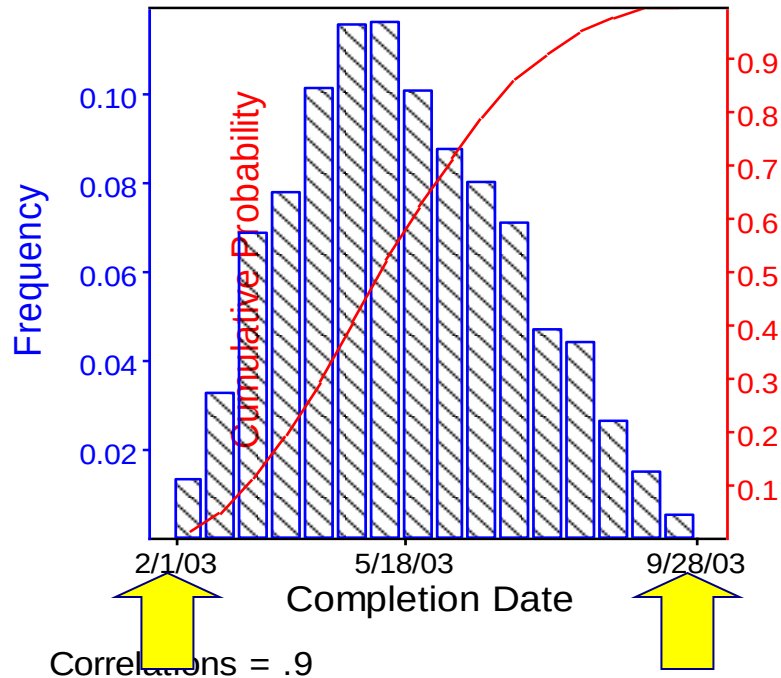
Range 2/8 – 8/29/03

Results of Correlated Durations

Sigma 49.2 d, Larger than 34.1 d

Date: 11/12/2001 9:11:06 PM
Samples: 3000
Unique ID: 1
Name: Project

Completion Std Deviation: 49.24 d
Confidence Interval: 1.76 d
Each bar represents 15 d



Completion Probability Table

<u>Prob</u>	<u>Date</u>	<u>Prob</u>	<u>Date</u>
0.05	3/4/03	0.55	5/20/03
0.10	3/15/03	0.60	5/27/03
0.15	3/25/03	0.65	6/4/03
0.20	4/3/03	0.70	6/13/03
0.25	4/11/03	0.75	6/22/03
0.30	4/18/03	0.80	7/2/03
0.35	4/24/03	0.85	7/12/03
0.40	4/30/03	0.90	7/26/03
0.45	5/7/03	0.95	8/12/03
0.50	5/13/03	1.00	9/28/03

Range 2/1 – 9/28, Wider than 2/8 – 8/28

Correlation Methods

Most software uses Spearman rank order correlation

- @RISK for Project, PERTMASTER, Excel and Crystal Ball for Excel
- No known relationship to Pearson correlation

Risk+ has just adopted correlation and uses Pearson's approach

- This is what we think of when we specify correlation
- Uses a Lurie-Goldberg iteration for non-normal distributions

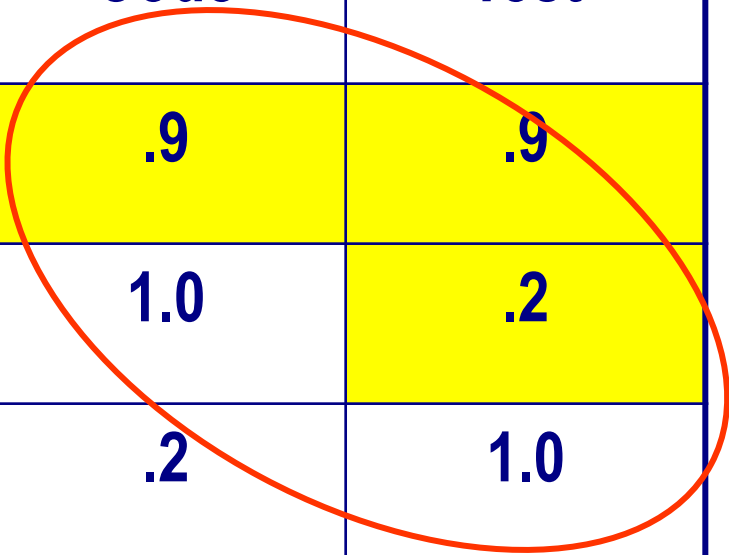
Monte Carlo just uses perfect positive correlation

This Correlation Matrix is Not Feasible

Correlation Matrix may be infeasible

Eigenvalue (determinant) test used to test feasibility

	Design	Code	Test
Design	1.0	.9	.9
Code	.9	1.0	.2
Test	.9	.2	1.0



Software Performs Test

Alerts the user

- The matrix is inconsistent with the natural world
- These coefficients could not coexist

The program then offers to adjust the matrix so that it just barely passes the test

- The user can see where the problems are
- Risk+ allows the user to indicate the relative confidence of the coefficients, and adjusts mainly the less confident ones

Schedule Risk Analysis Summary

Introduction

Activity distributions and data entry

Risk along a schedule path

Risk of parallel paths -- the “Merge Bias”

Effect of limited resources

Effect of constraints

Schedule Risk Analysis Summary (continued)

Sensitivity Analysis

“Risk Critical Path”

Risk in statused schedules

Probabilistic branching

Conditional branching

Correlations