Quantum Modeling of Project Cost and Schedule

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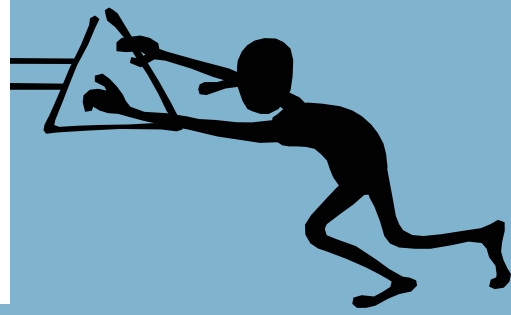
Commercial Companies Project Statistics

Overall project statistics: 25% fail completely, **50%** end up late or over budget *(PwC, 2005)*

IT projects: 31% cancelled before completion; 88% run over schedule, 222% cost overrun *(CSC Corp. 2005).*

Capital Oil/Gas: 35% exceed time, **38%** exceed budget *(BAH, 2007)*



Underestimating Costs in Public Works Projects: *Error or Lie?*

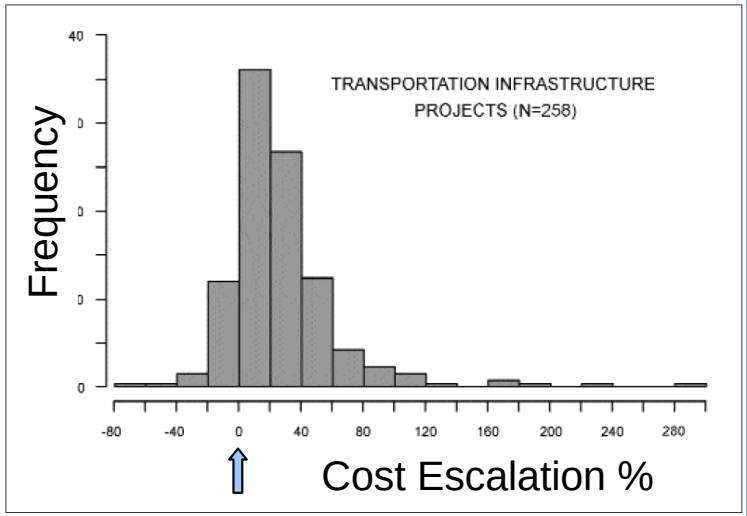


FIGURE 1. Inaccuracy of cost estimates in 258 transportation infrastructure projects (fixed prices).

"Xxxx…found that a pattern of highly misleading forecasts of costs and patronage could not be explained by technical issues and were best explained by lying"
Flyvbjerg, Holm, Buhl, APA Journal, 2002, No. 3

Cost/Time Underestimate in NASA & DoD Projects

Study	Cost/Budget Growth		
	Average	Median	% overruns
NASA in the 90s	36%	26%	78%
NASA in the 70s	43%	26%	75%
NASA in the 80s			
Gruhl study	61%	50%	95%
GAO study	83%	60%	89%
DoD	45%	27%	76%

Source: Schaffer, 2004

Risk and Decisions of Engineers

- **Engineers have choices in how to meet challenging performance requirements**
  - Multiple ways to program a source line of S/W code
  - Multiple ways to design an application specific integrated circuit
  - Multiple ways to solve a structural strength issue
  - Multiple ways to meet a propulsion requirement
  - etc.
- **Some choices result in low or high cost**
- **Some choices result in short or long durations**
- **Additionally, choices by an engineer on one subsystem/component influence choices by other engineers on other subsystems/components**
- **Bottom line: There is uncertainty in specific decisions & their effects on overall project cost and schedule**

Quantum Mechanics

- **The study and prediction of elementary particle behavior**
  - e.g., photons, electrons, neutrons, neutrinos, quarks, etc.
- **However, can't predict individual elementary particle behavior – only aggregate elementary particle behavior**
- **And….only statistically**
  - Can't ever predict exact location of an electron
  - Only can say there is a probability that electrons (plural) will be in a specific location at a specific time with a certain probabilistic confidence
- **So, what's the bridge between monte carlo- and quantum mechanics-based risk analysis?**

Individual Engineer Decisions as Bridge

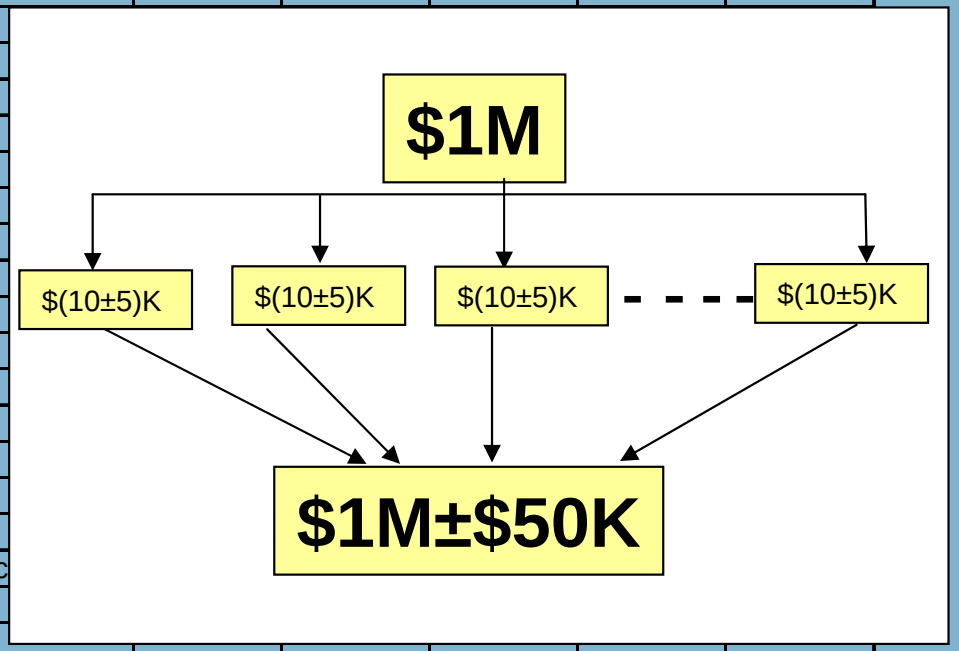
- **Quantum mechanics deals with individual elementary particles as an aggregation, statistically**
- **Monte Carlo simulation deals with results of individual engineer decisions as an aggregation, statistically**
- ***Elementary particles are equivalent to individual engineers***
- ***Each have a "mind of their own"***
- **Quantum mechanics statistically predicts confidence level of the location of elementary particles in space dimension**
- **Monte Carlo statistically predicts confidence level of the location of result of thousands of engineer decisions in the cost and time dimensions**
- ***Only the math is different***

Only the Math is Different

- **Monte Carlo uses simulation math that works on low-ML-high estimates of cost or duration (assuming triangular distributions)**
  - Produces probability density function and cumulative distribution function
- **Quantum mechanics uses math of wave propagation**
  - Produces probability density function and cumulative distribution function

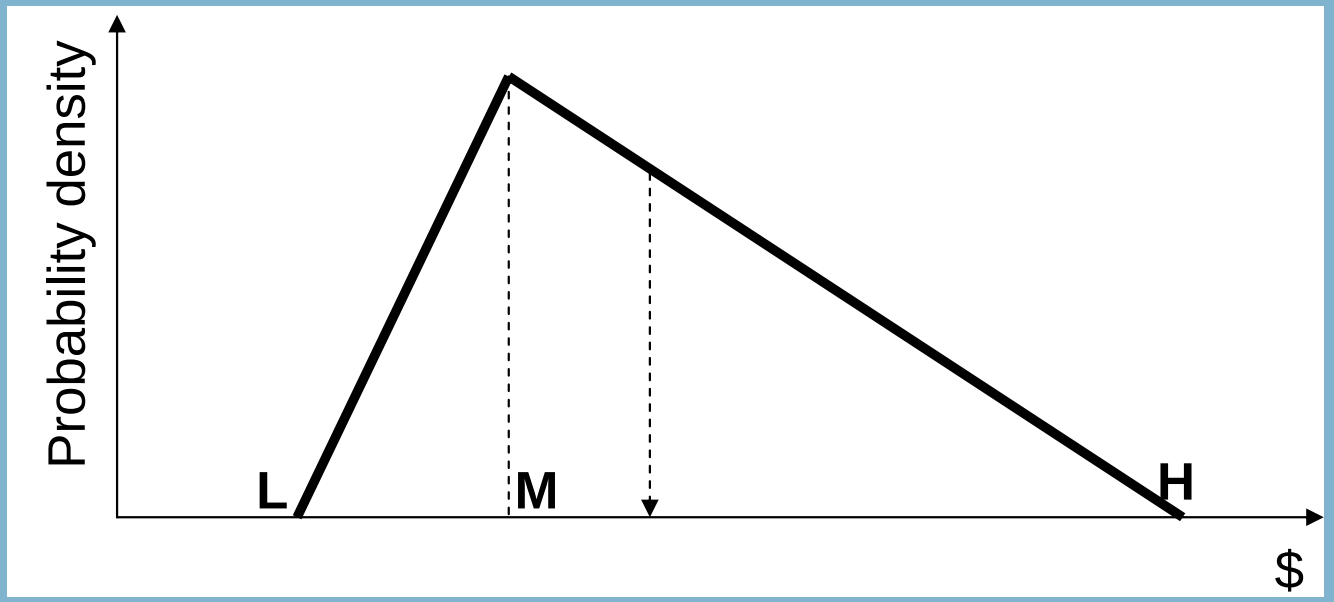
Why Cost Estimate by Project Sub-Division does not Work?

	SPACE SOLAR POWER SATELLITE SYSTEM				
Work Breakdown Structure (WBS	**FY2008**	**FY2009**	**FY2010**	**FY2011**	**FY2012**
		SRR		**SDR**	
Space Solar Power Satellite					
Project Management					
Systems Engineering					
Safety and Mission Assurance					
Science/Technology					
Payloads					
Transmit Payload					
System Engineering					
Project Management					
Solar Power Collector					
Solar Power Converter					
Laser Amplifier/Transmitter					
Laser Transmit Antenna					
Ground Support Equip					
Transmit Payload Assembly Test & Chec					
Receive Payload					
System Engineering					
Project Management					



- Full uncertainty $\Delta = \delta\sqrt{N}$;
- For real plan, Monte Carlo simulation yields exact distribution;
- **Where 30%-100% error comes from?**

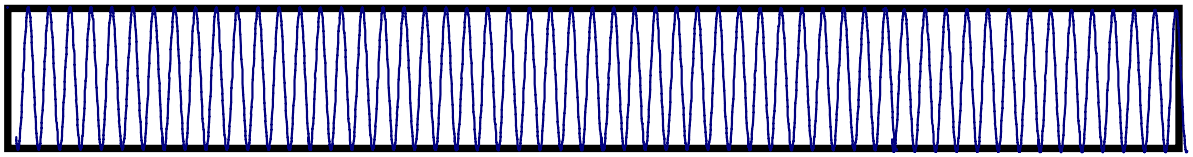
Why is Distribution Function Asymmetric?



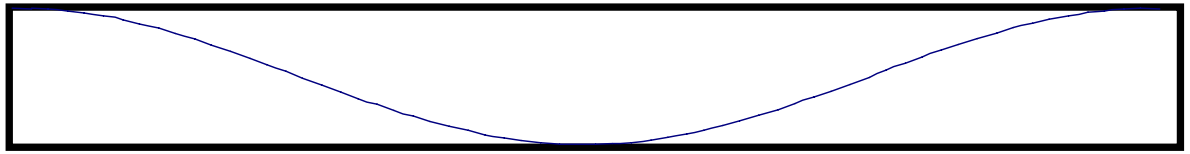
- This type of activity distribution function is needed to fit Monte Carlo simulation results, but why?
- The answer is **Time Factor**, restricting task completion within project schedule, and **Uncertainty of Human Task**

Task Activity Cycles

Machine Task

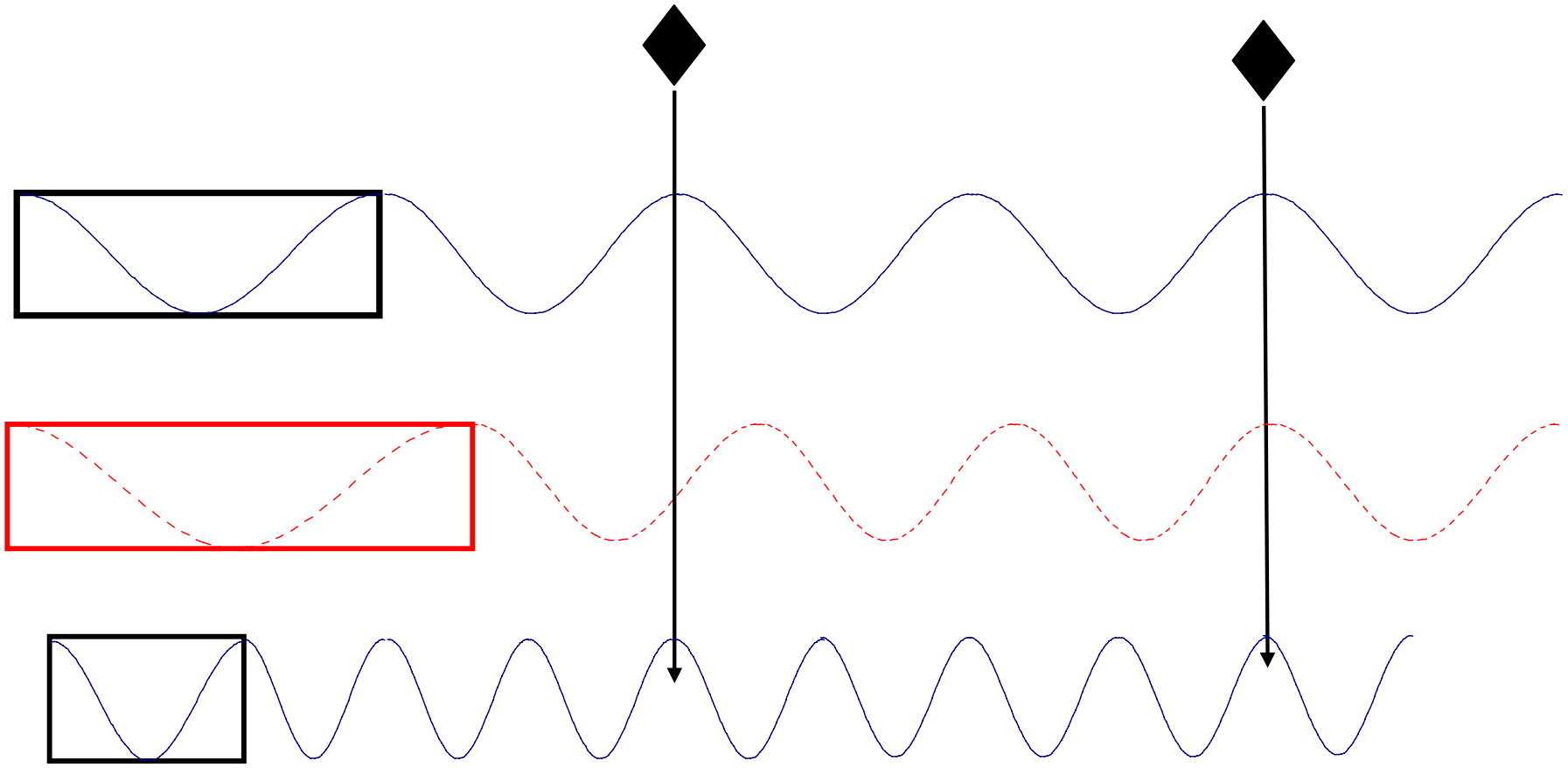


Human Task



In machine tasks, he number of activity cycles is unlimited
Human tasks have small number of cycles, usually one

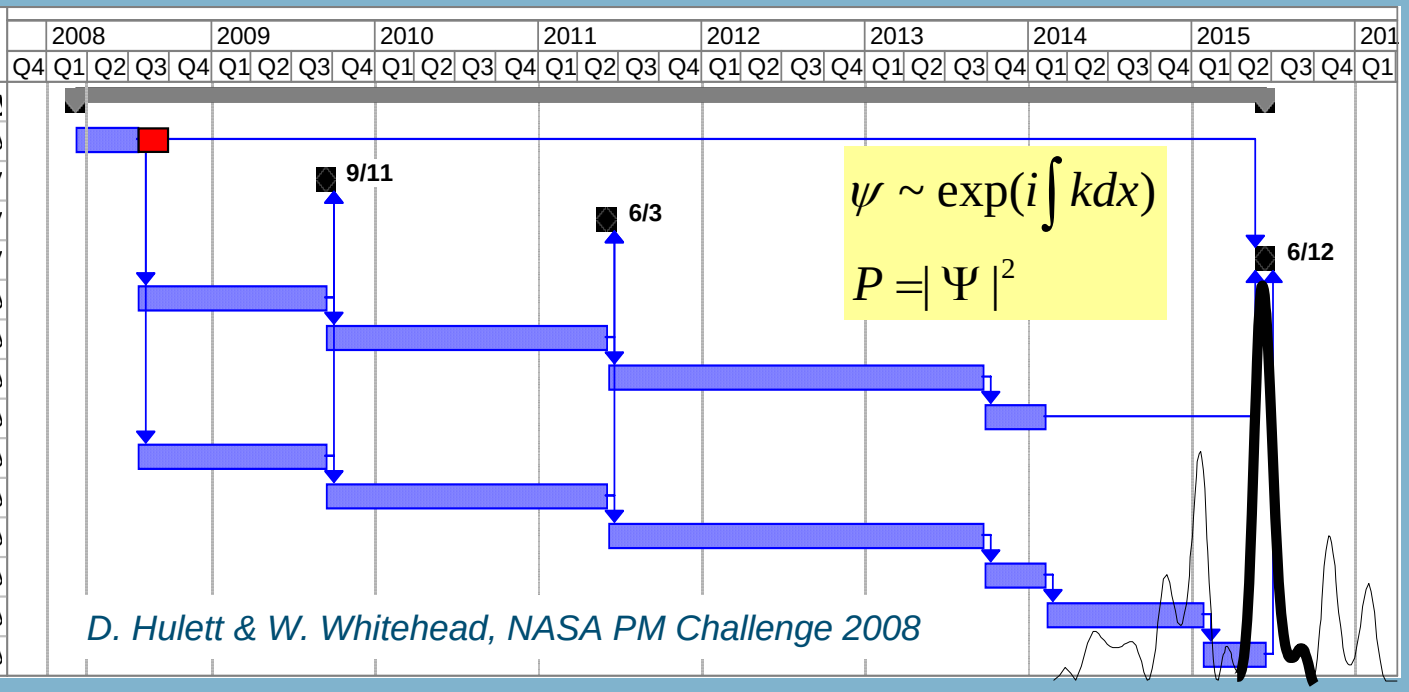
Task Aggregation at Milestone (Activity Waves)



- Tasks have to be dragged to milestone and added coherently
- Human and machine tasks are similar if uncertainty is low

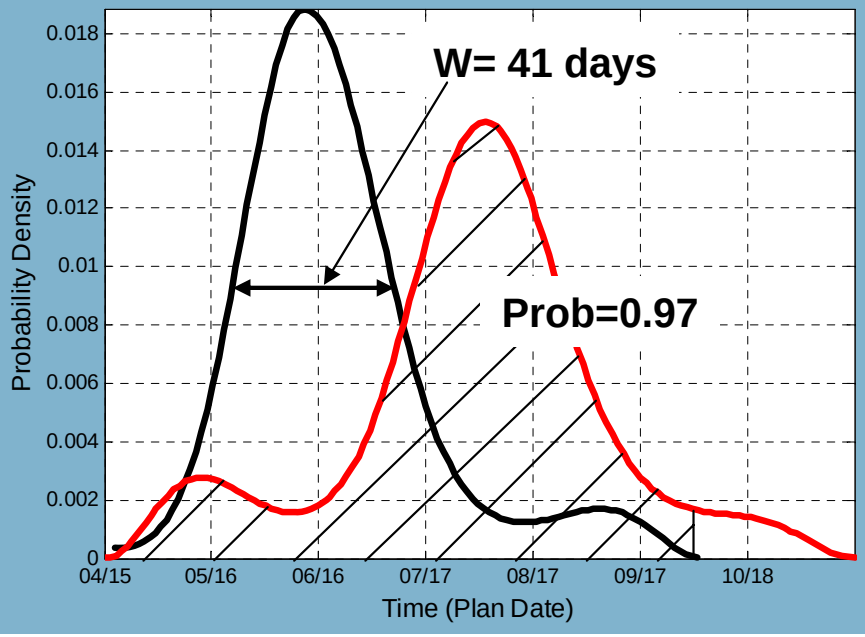
Quantum Model

ID	Task Name	Duration
0	**Project Summary**	**1900 da**
1	1 Requirements defi	100 da
2	2 PDR Spacecraft	0 day
3	3 CDR Spacecraft	0 day
4	4 Ship to Launch sit	0 day
5	5 FS preliminary des	300 da
6	6 FS Final Design	450 da
7	7 FS Fabrication	600 da
8	8 Test US Engine	100 da
9	9 US Preliminary de	300 da
10	10 US Final design	450 da
11	11 US Fabrication	600 da
12	12 US Test	100 da
13	13 Integration	250 da
14	14 Integration Testir	100 da



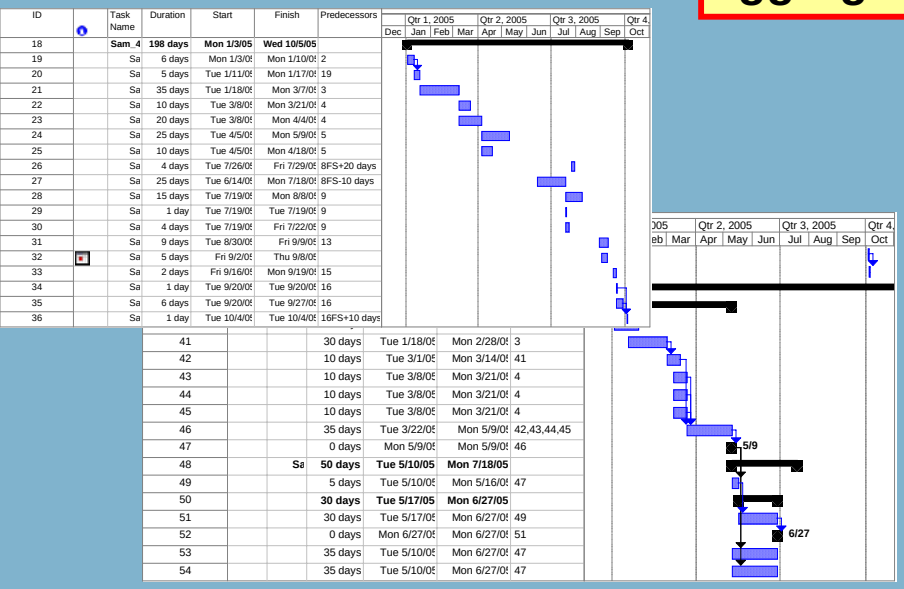
D. Hulett & W. Whitehead, NASA PM Challenge 2008

Scaled by risks, milestone width W provides universal unit of task delay.

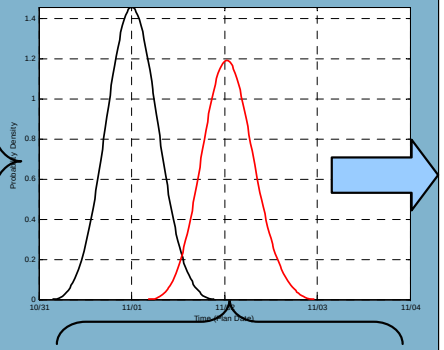


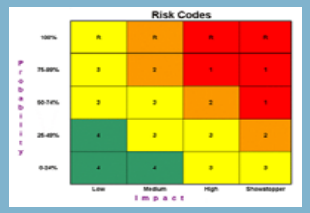
Risks Affect Milestone Directly

Aggregate Tasks

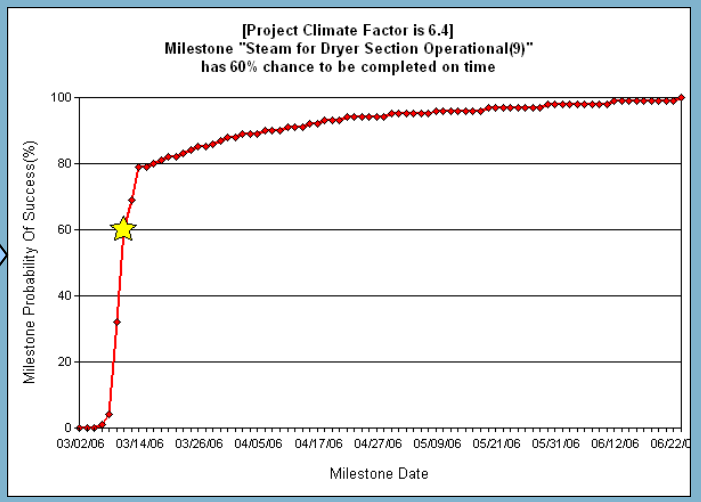


ID	Task Name	Duration	Start	Finish	Predecessors
18	Sam_4	198 days	Mon 1/3/05	Wed 10/5/05	
19	Sa	6 days	Mon 1/3/0	Mon 1/10/0	2
20	Sa	5 days	Tue 1/11/0	Mon 1/17/0	19
21	Sa	35 days	Tue 1/18/0	Mon 3/7/0	3
22	Sa	10 days	Tue 3/8/0	Mon 3/21/0	4
23	Sa	20 days	Tue 3/8/0	Mon 4/4/0	4
24	Sa	25 days	Tue 4/5/0	Mon 5/9/0	5
25	Sa	10 days	Tue 4/5/0	Mon 4/18/0	5
26	Sa	4 days	Tue 7/26/0	Fri 7/29/0	8FS+20 days
27	Sa	25 days	Tue 6/14/0	Mon 7/18/0	8FS-10 days
28	Sa	15 days	Tue 7/19/0	Mon 8/8/0	9
29	Sa	1 day	Tue 7/19/0	Tue 7/19/0	9
30	Sa	4 days	Tue 7/19/0	Fri 7/22/0	9
31	Sa	9 days	Tue 8/30/0	Fri 9/9/0	13
32	Sa	5 days	Fri 9/2/0	Thu 9/8/0	
33	Sa	2 days	Fri 9/16/0	Mon 9/19/0	15
34	Sa	1 day	Tue 9/20/0	Tue 9/20/0	16
35	Sa	6 days	Tue 9/20/0	Tue 9/27/0	16
36	Sa	1 day	Tue 10/4/0	Tue 10/4/0	16FS+10 days
41		30 days	Tue 1/18/0	Mon 2/28/0	3
42		10 days	Tue 3/1/0	Mon 3/14/0	41
43		10 days	Tue 3/8/0	Mon 3/21/0	4
44		10 days	Tue 3/8/0	Mon 3/21/0	4
45		10 days	Tue 3/8/0	Mon 3/21/0	4
46		35 days	Tue 3/22/0	Mon 5/9/0	42,43,44,45
47		0 days	Mon 5/9/0	Mon 5/9/0	46
48	Sa	50 days	Tue 5/10/05	Mon 7/18/05	
49		5 days	Tue 5/10/0	Mon 5/16/0	47
50		30 days	Tue 5/17/05	Mon 6/27/05	
51		30 days	Tue 5/17/0	Mon 6/27/0	49
52		0 days	Mon 6/27/0	Mon 6/27/0	51
53		35 days	Tue 5/10/0	Mon 6/27/0	47
54		35 days	Tue 5/10/0	Mon 6/27/0	47



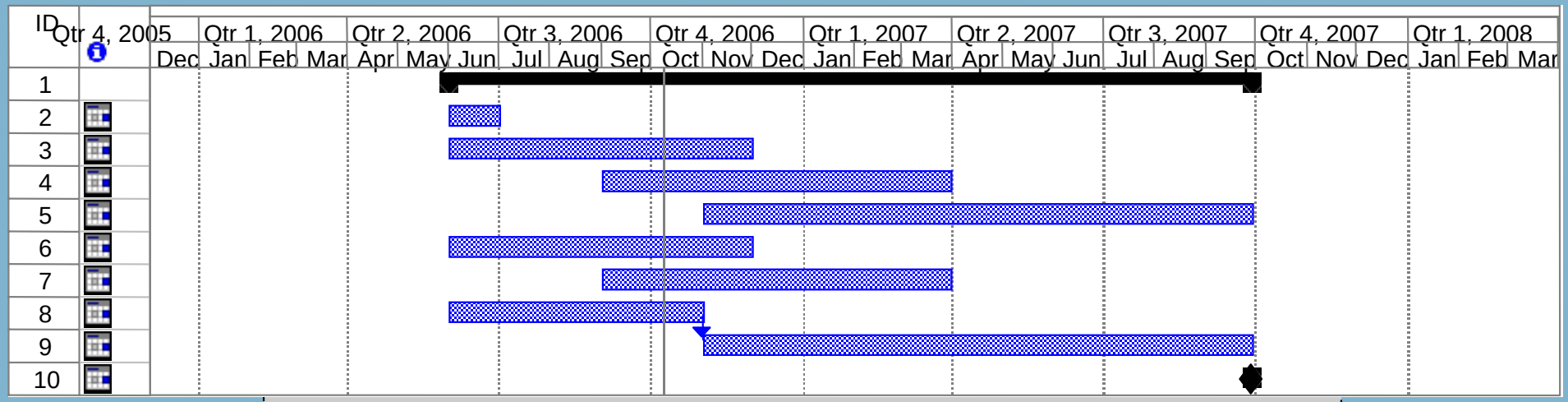


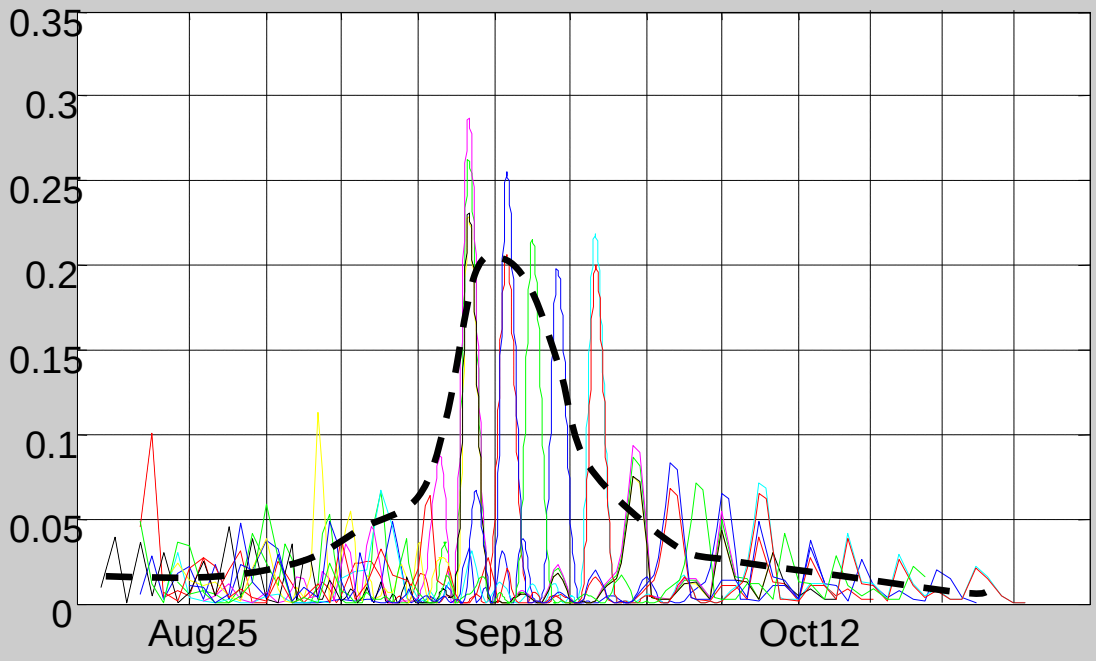
Calculate Probability



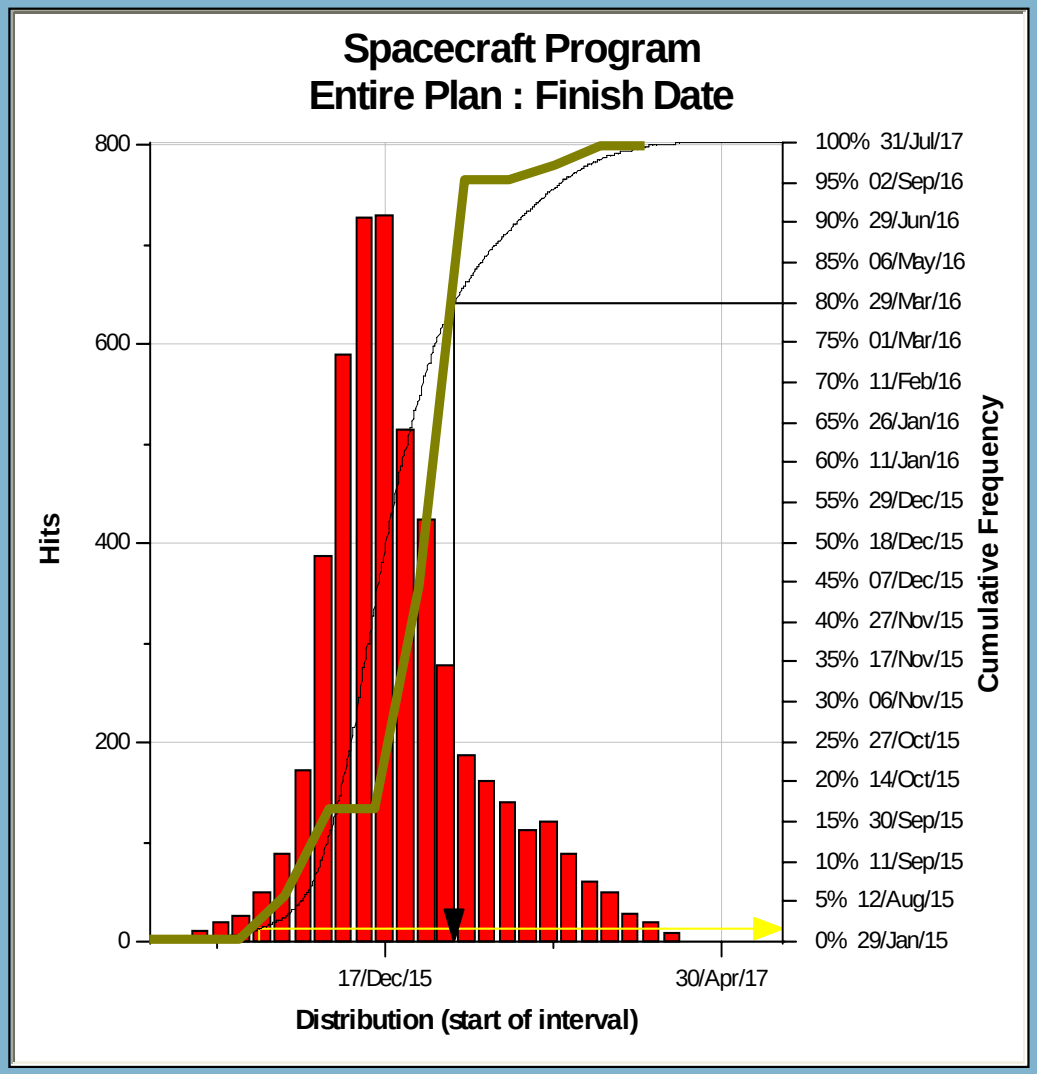
Apply Risks

Time Constraint Causes Distribution Function Asymmetry

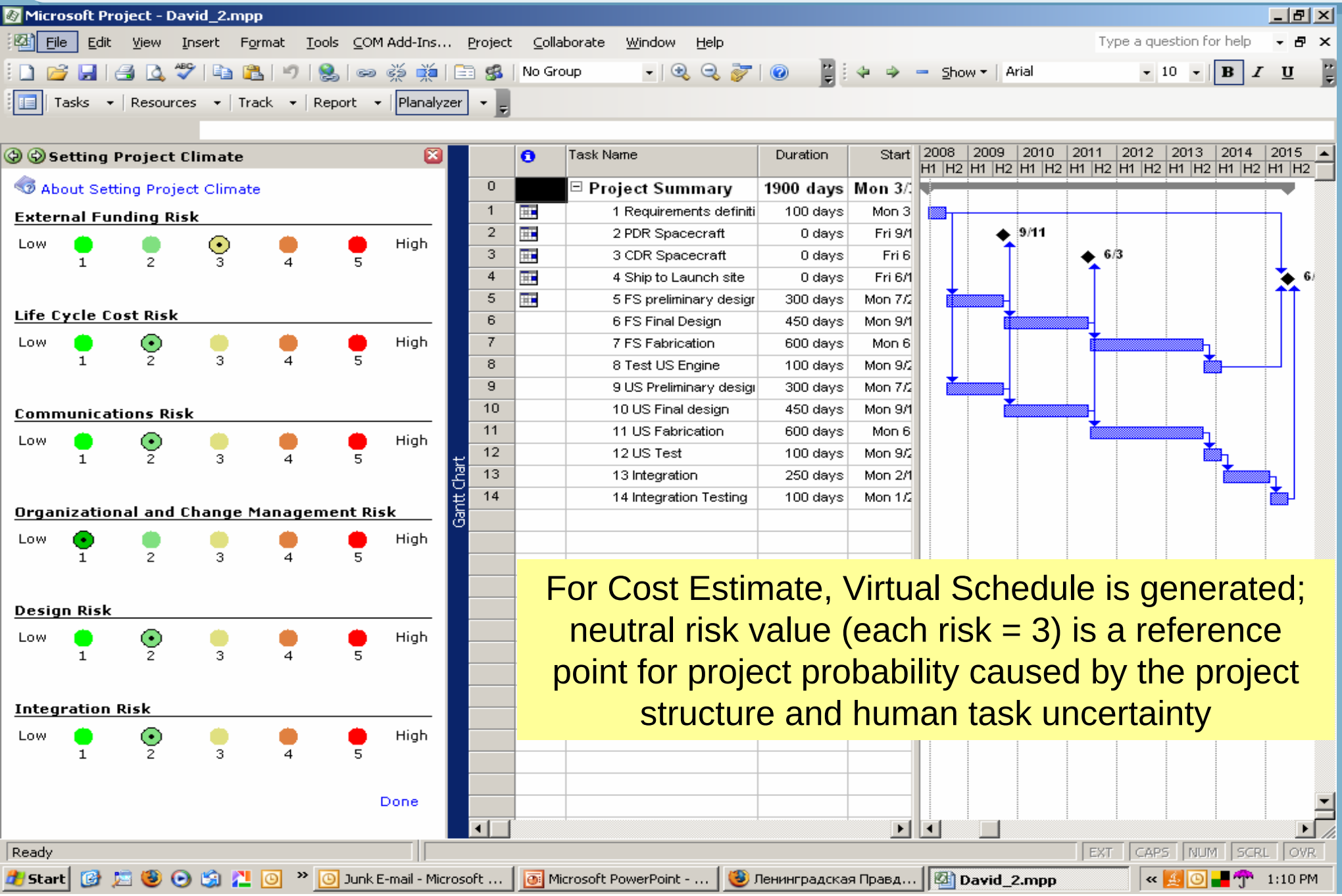




Comparison with Monte Carlo Simulations

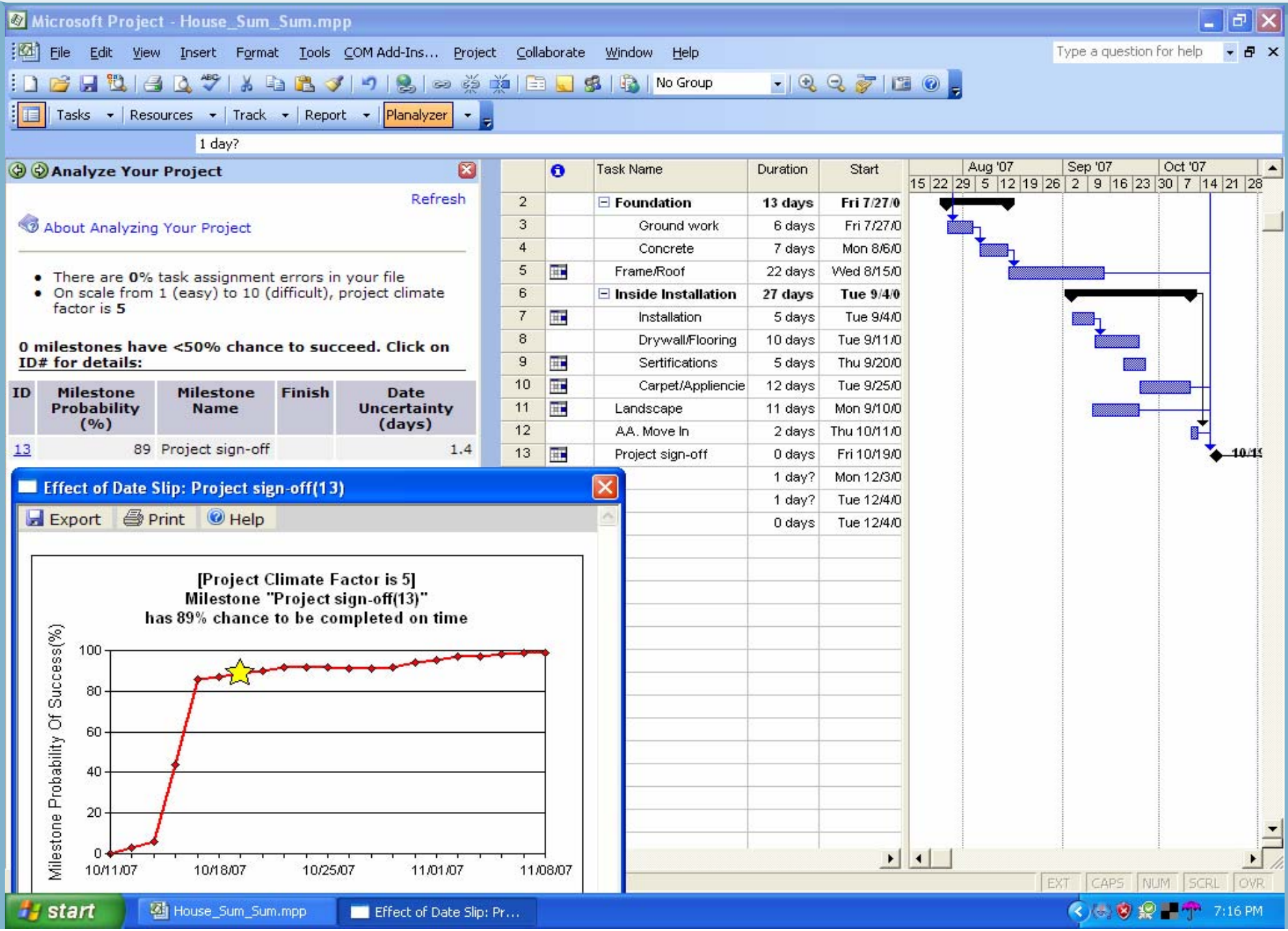


Qualitative Risks Assessment

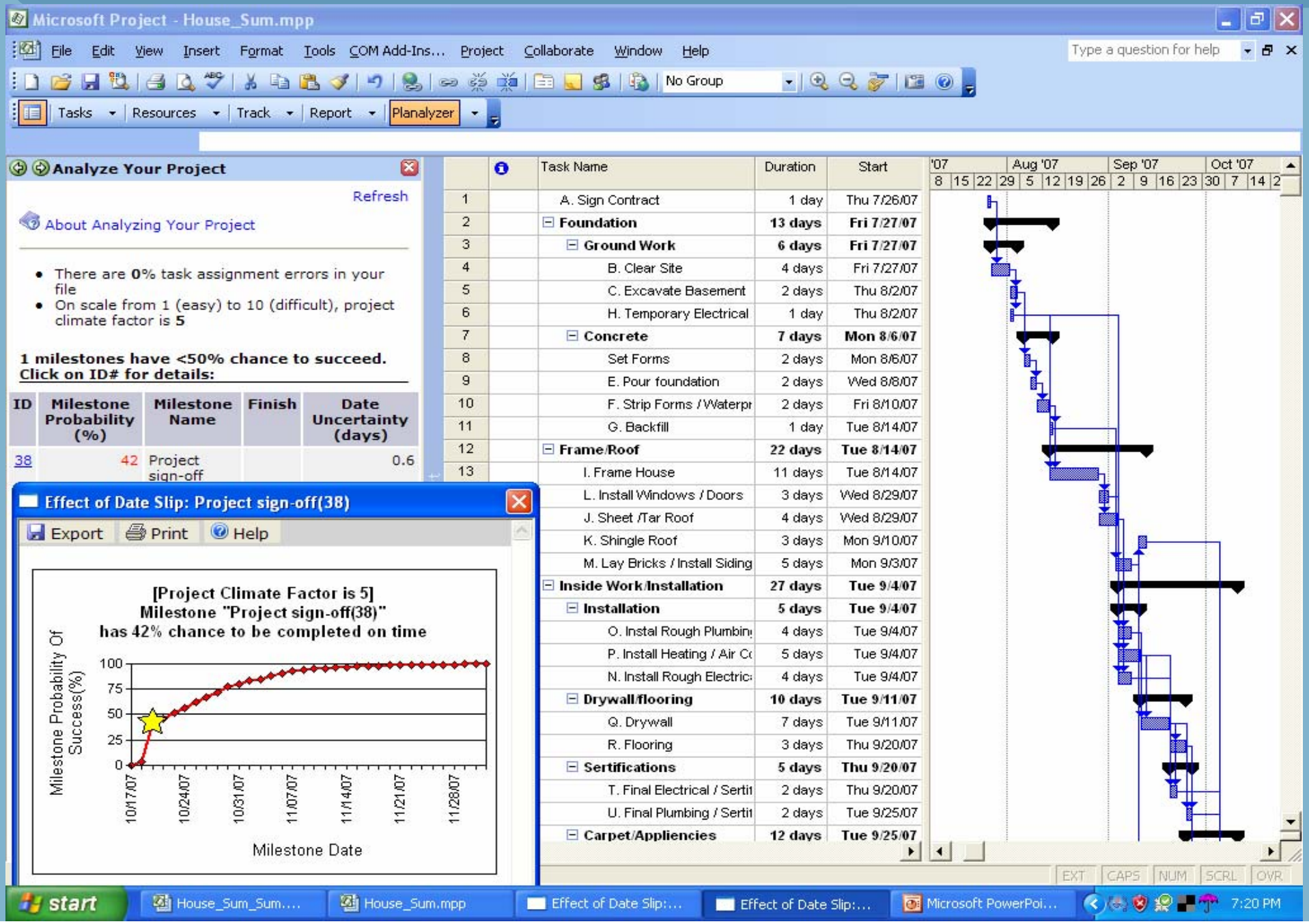


For Cost Estimate, Virtual Schedule is generated; neutral risk value (each risk = 3) is a reference point for project probability caused by the project structure and human task uncertainty

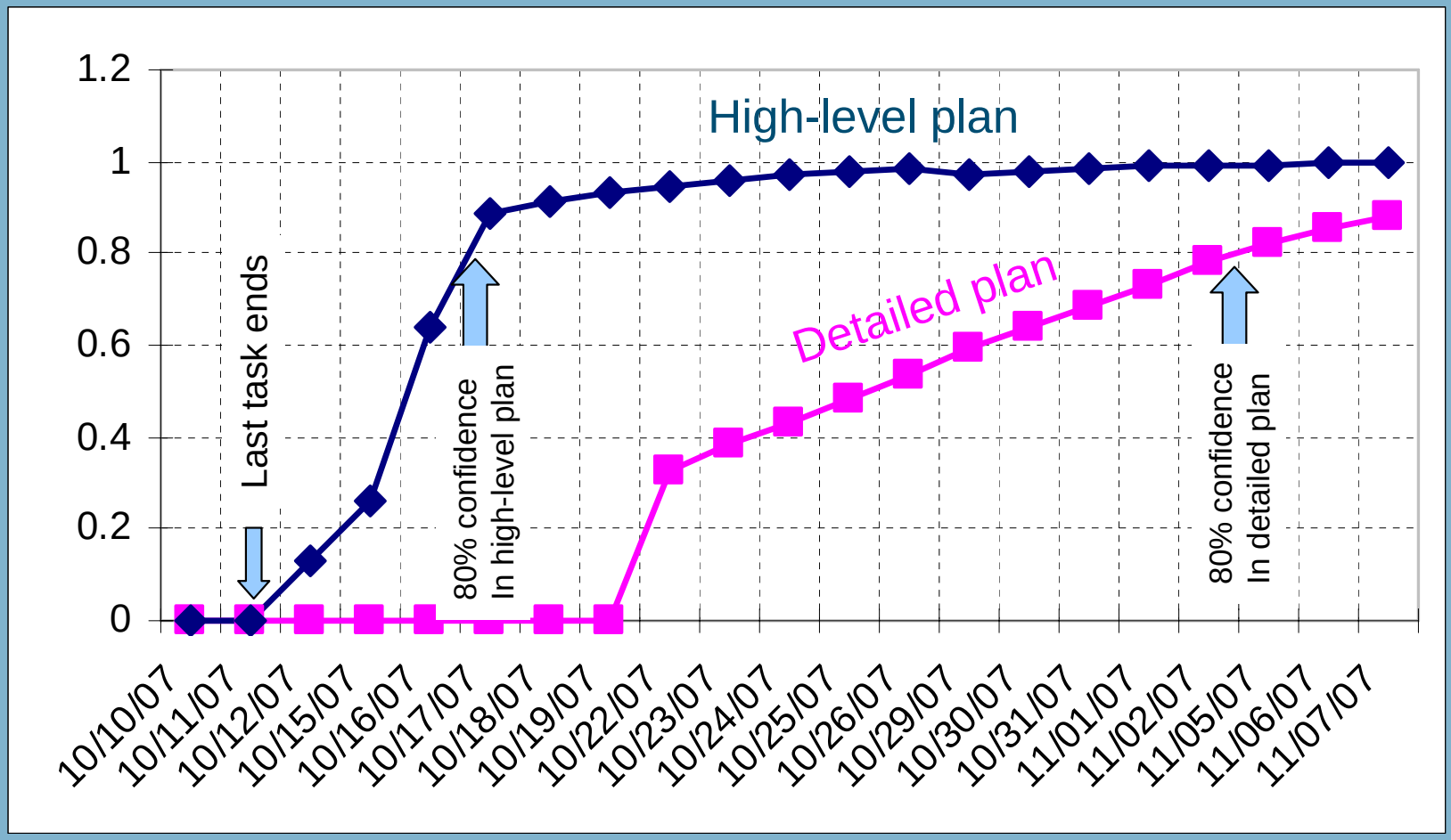
Example: High-Level Plan to Build House



Project Evolves: Detailed Plan to Build House



S-curve Evolution



Summary: Cost and Schedule are Related

- Cost has to be considered together with schedule
- Human tasks are well presented by quantum model
- Asymmetry of probability density is due to project time constraint, not asymmetry of individual activities

- Approach supports fast accumulation of knowledge, improves predictability of cost and project performance