

# Quantum Modeling of Project Cost and Schedule

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**2008 Joint ISPA/SCEA Annual Conference**

# 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?*

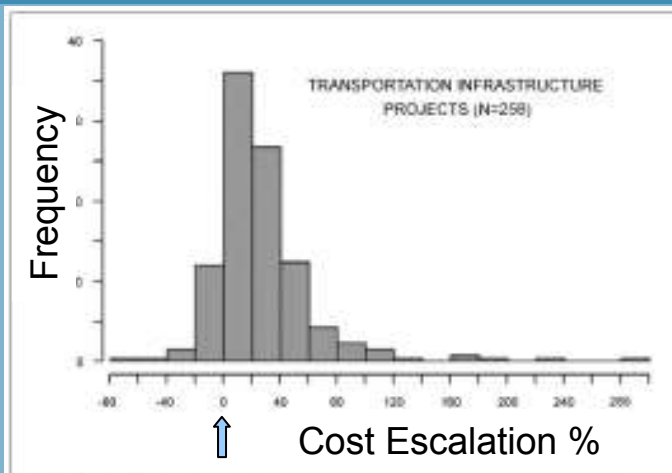


FIGURE 1. Inaccuracy of cost estimates in 258 transportation infrastructure projects (fixed price).

“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		% overruns
	Average	Median	
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

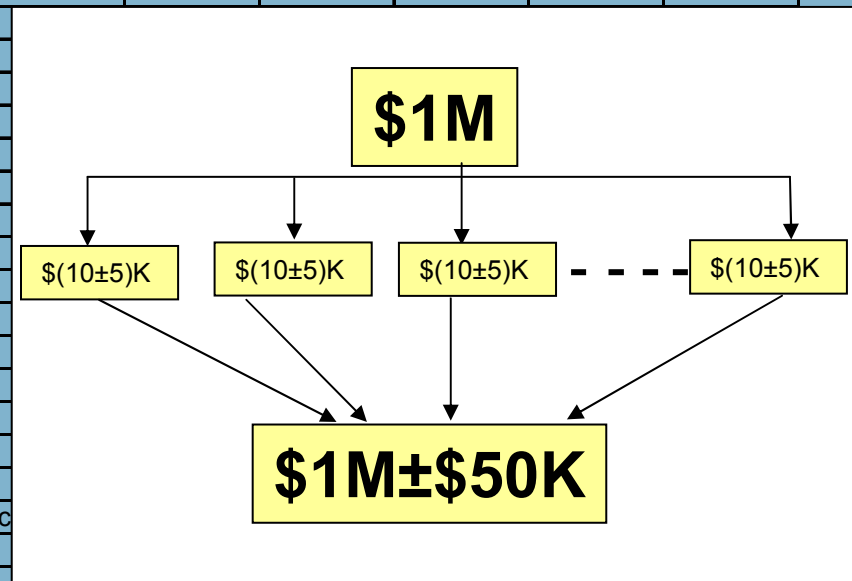
- **Monte Carlo uses simulation math that works on low-ML-high estimates of cost or duration (assuming triangular distributions)**
  - Produces probability density function and cumulative distribution function
- **Quantum mechanics uses math of wave propagation**
  - Produces probability density function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

# Quantum Model for Cost Estimate with Risk

- WBS structure is simplest possible project, without task links and specified distances to milestone
- Fluctuations of WBS elements and their impact on final milestone (total cost) are the same
- Modeling cost provides:
  - Definition of quantum model parameters (task fluctuation amplitudes and phases)
  - Comparison of quantum and classical model predictions for evolving plans with different level of detail

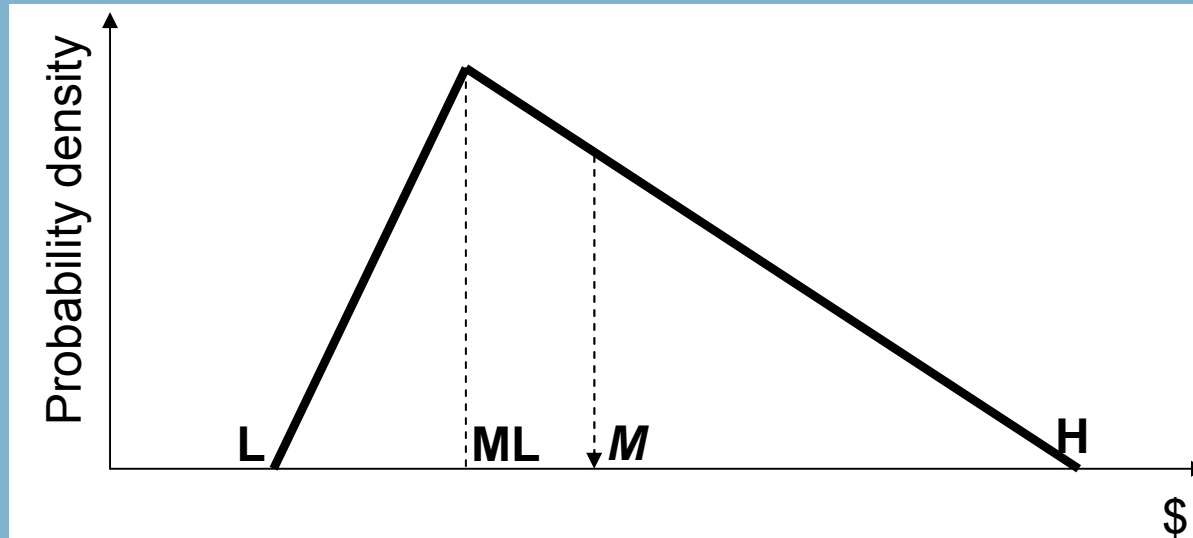
# Why Cost Estimate by Project Sub-Division does not Work?

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					
Laser Receive Antenna					
Laser Conditioning Receiver					



Overall uncertainty  $\Delta = \delta\sqrt{N}$  and may become, for large N, relatively small; **where 30%-100% error comes from?**

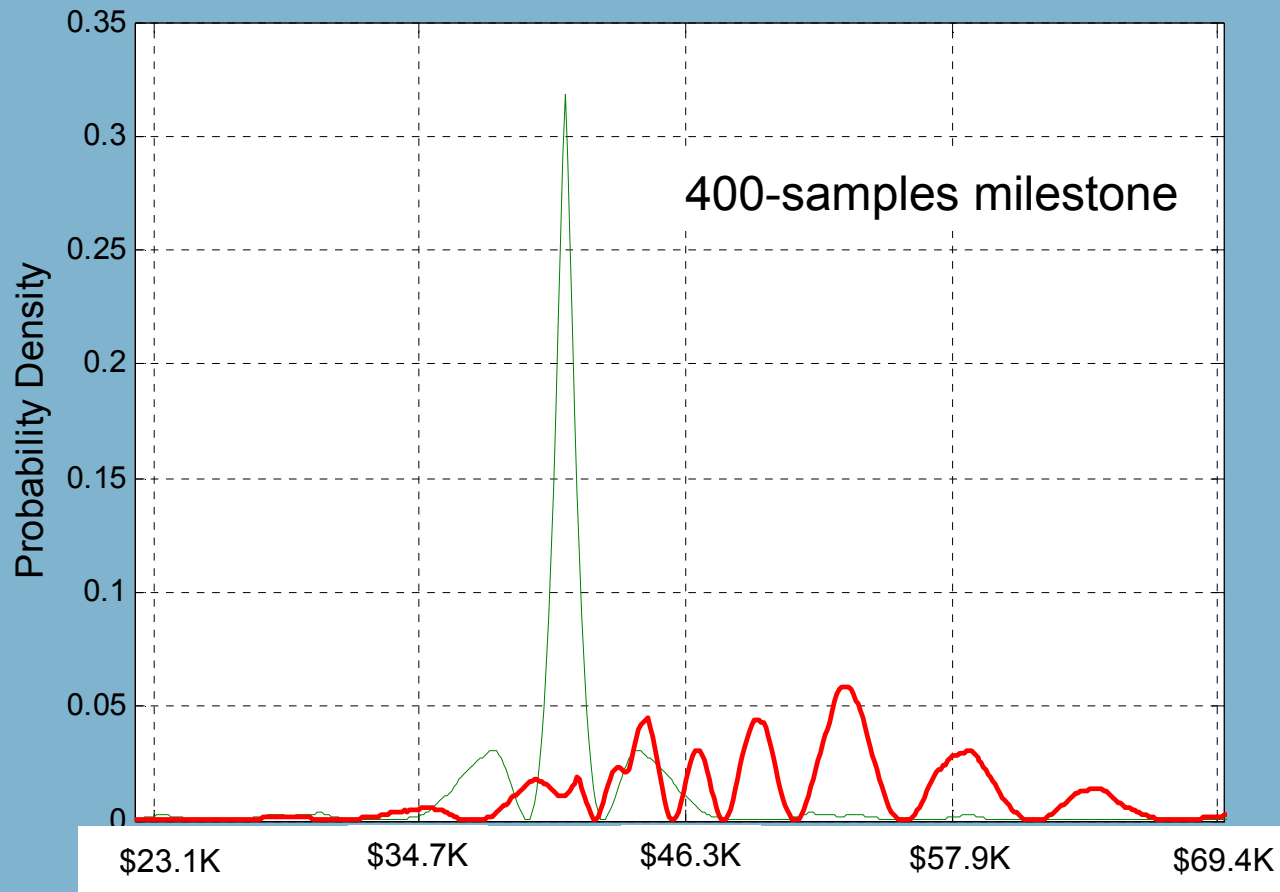
# Why is Distribution Function Asymmetric?



Asymmetric probability density distribution function is needed to provide adequate Monte Carlo simulation results, but why?

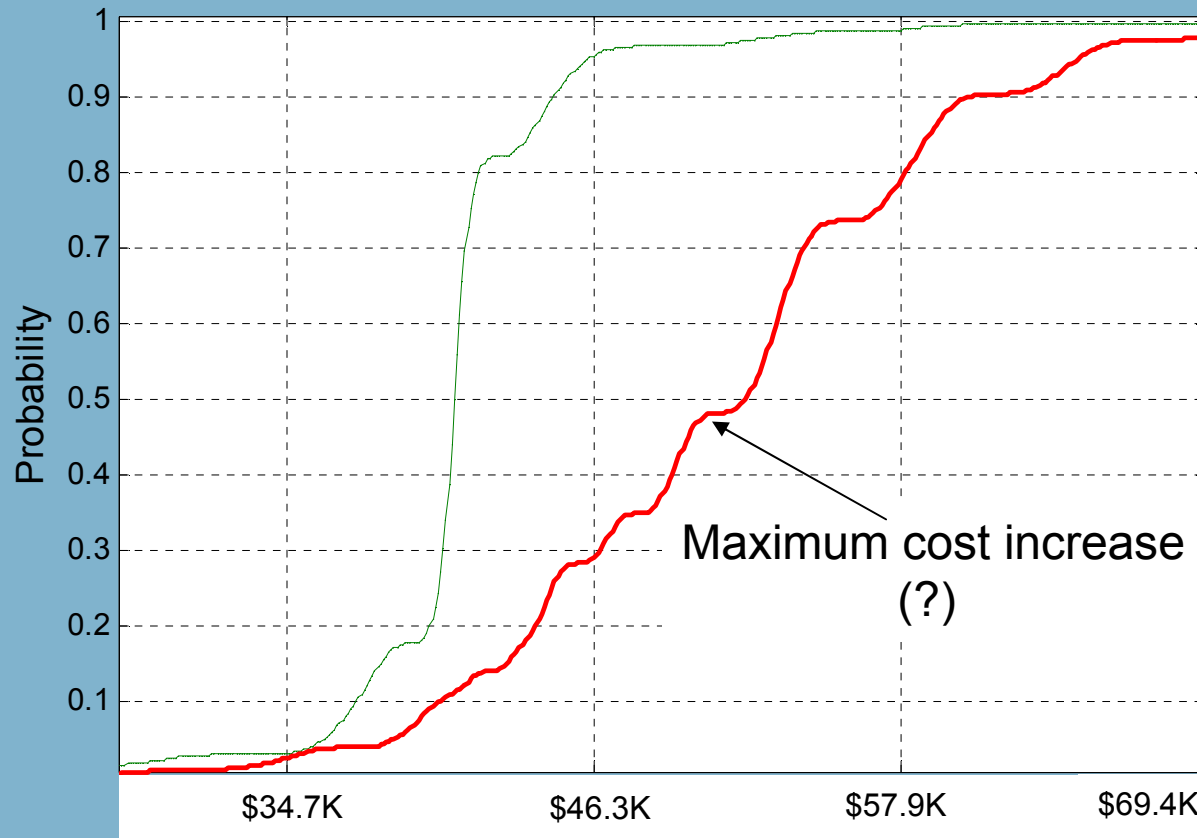


# Probability Density for Zero and Max Risk



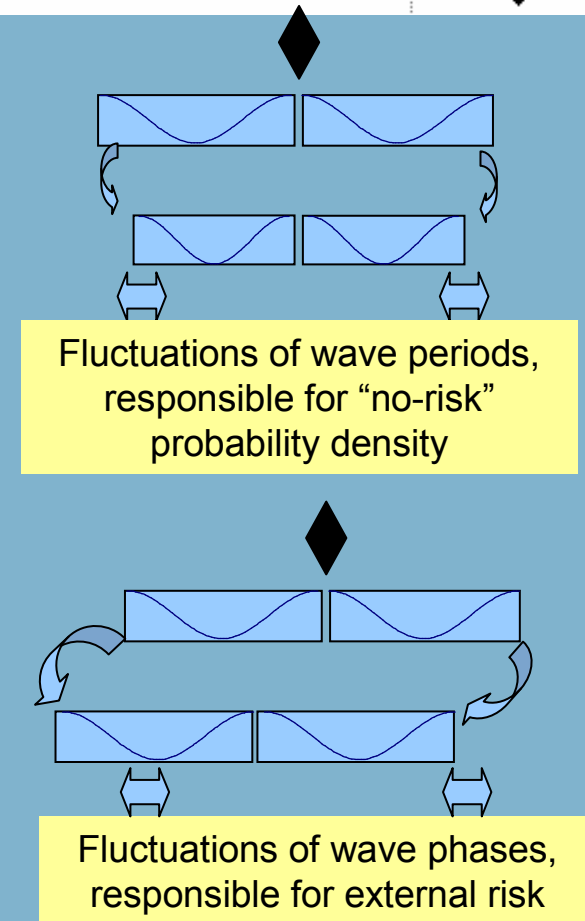
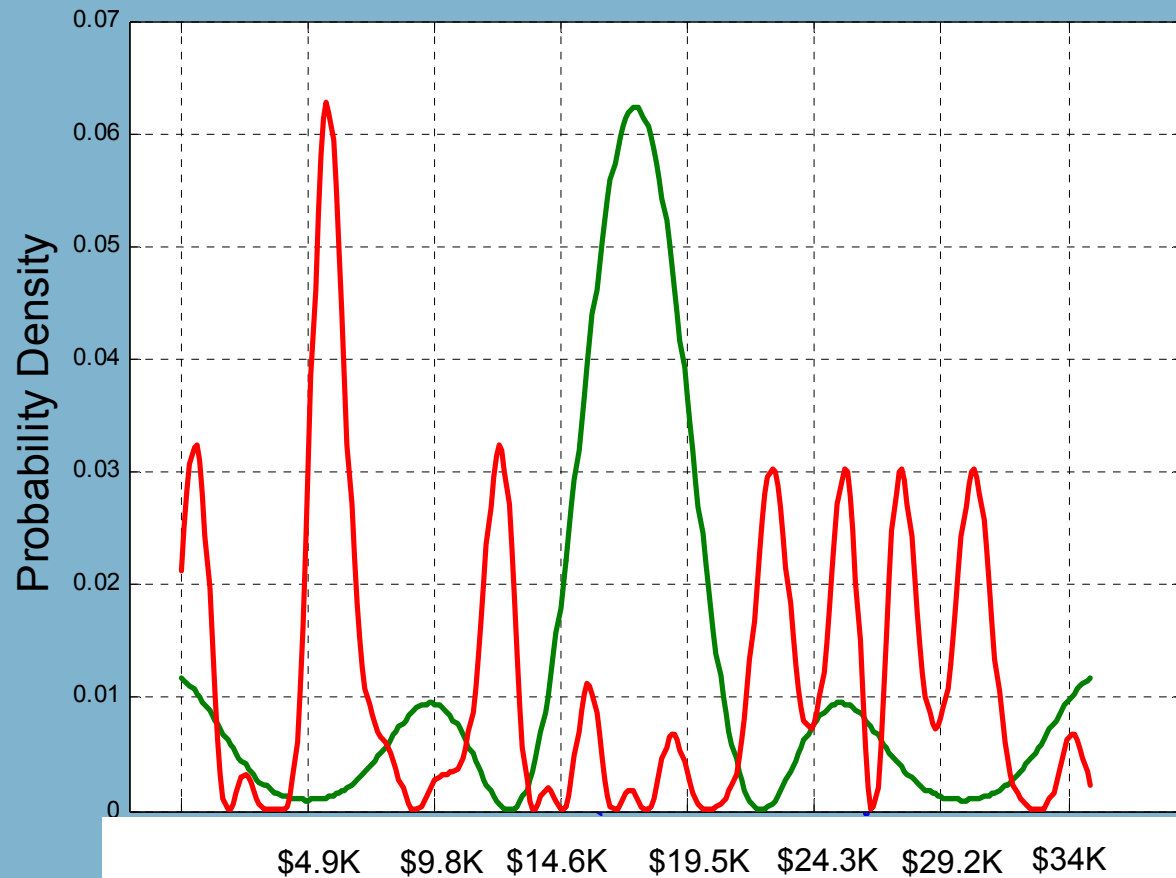
For no external risk, probability density is fully symmetric (WBS risk), and for maximum risk – fully asymmetric

# S-curve – Best and Worst Case

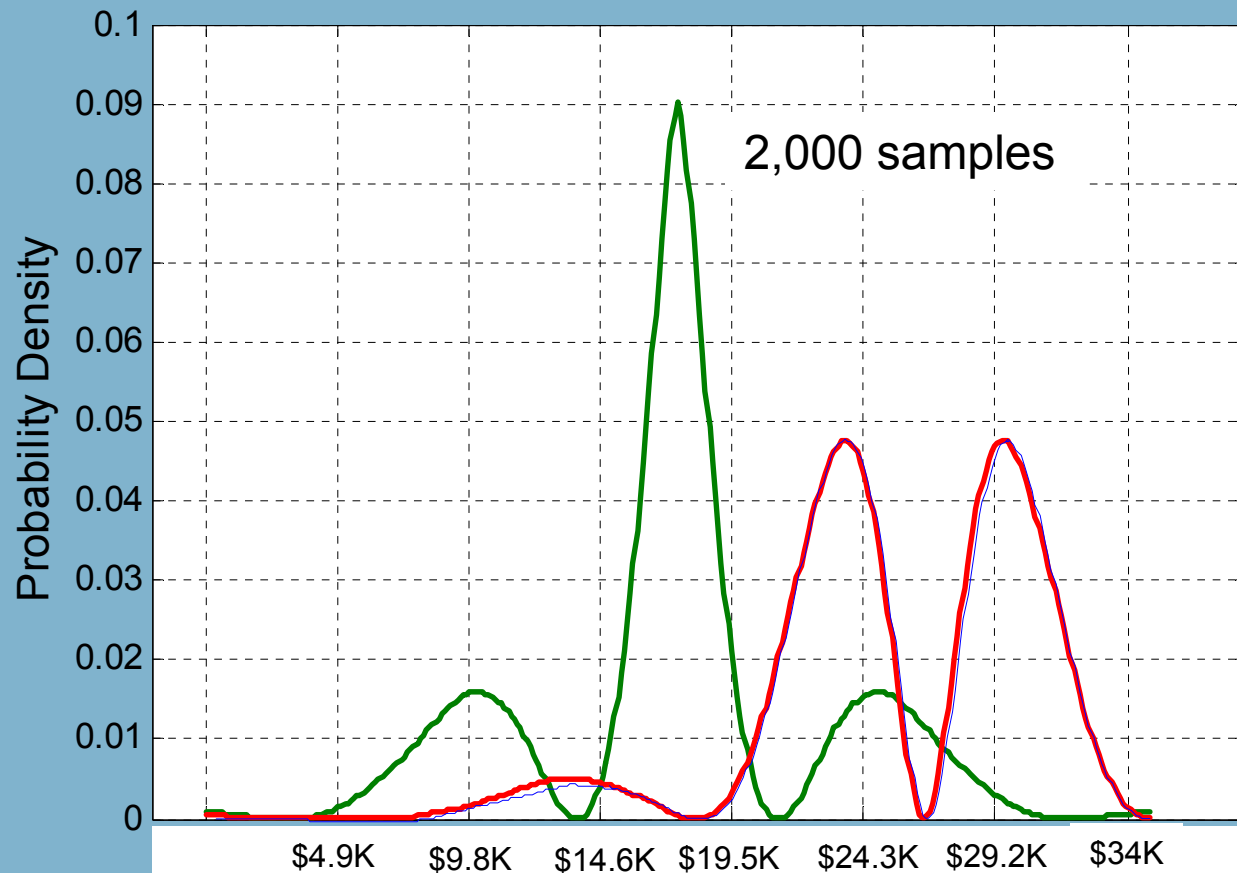


# How Quantum Cost Estimate Works

ID	Task Name	Duration	Start	Finish	Predk	July 2008														August 2008			
						20	23	26	29	2	5	8	11	14	17	20	23	26	29	1	4	7	10
1	Write code	30 days	Thu 6/26/08	Wed 8/6/08		[Gantt bar for Write code]														[Gantt bar for August 2008]			
2	GUI	30 days	Thu 6/26/08	Wed 8/6/08		[Gantt bar for GUI]														[Gantt bar for August 2008]			
3	Milestone	0 days	Fri 8/8/08	Fri 8/8/08	1,2															8/8			

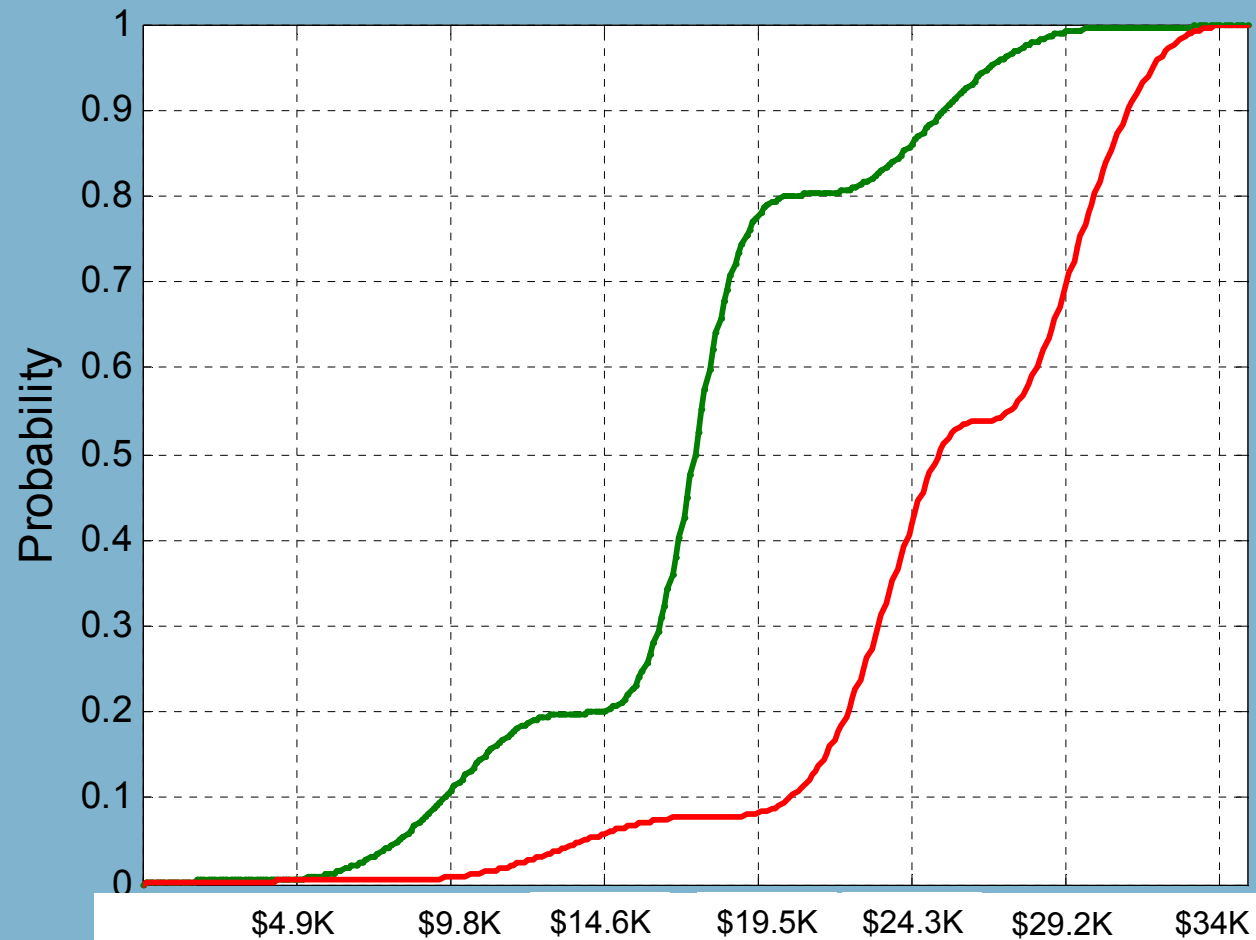


# Increased Costs Due to Long-Long Correlations

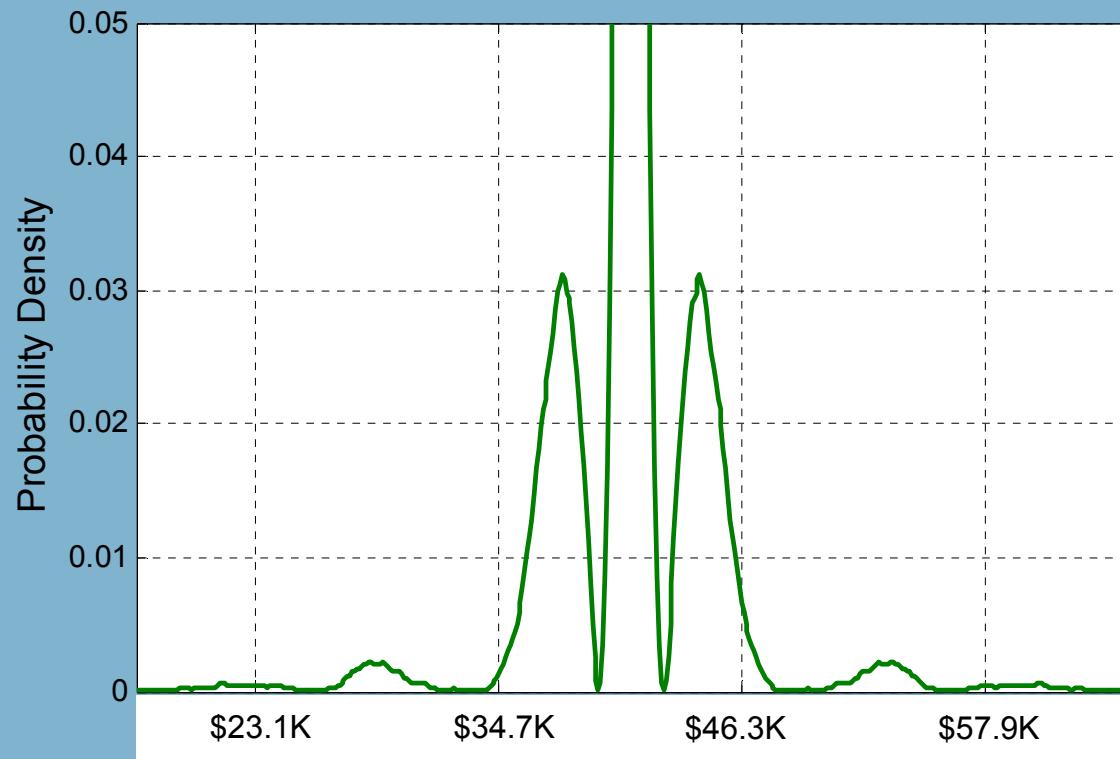


Math procedure is numerical inverse Fourier transform (NIFT)

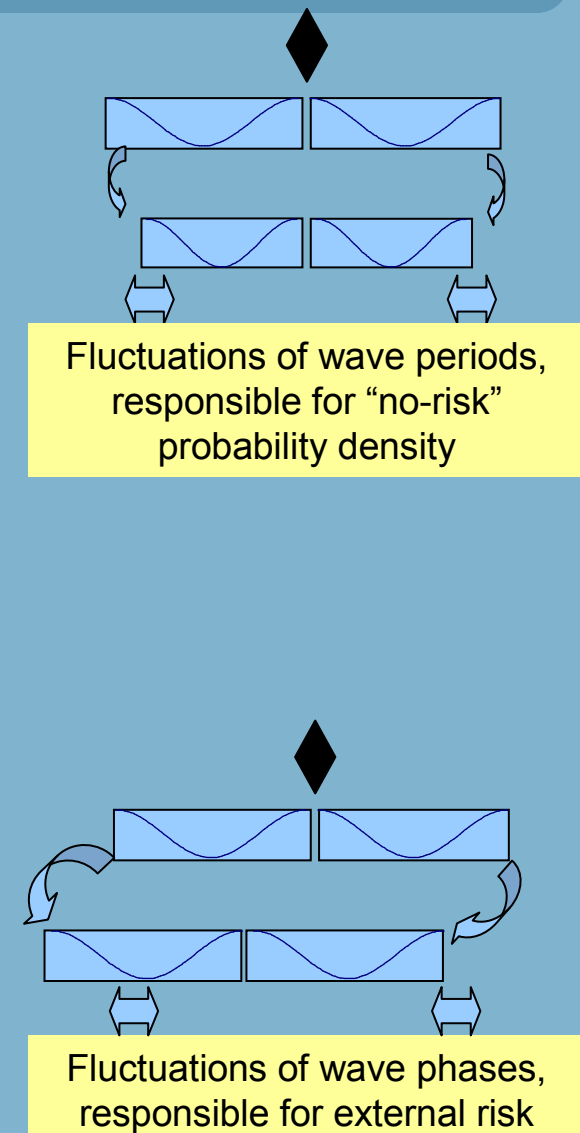
# S-curve for 2-task Project



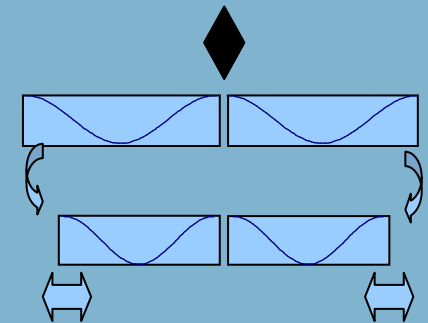
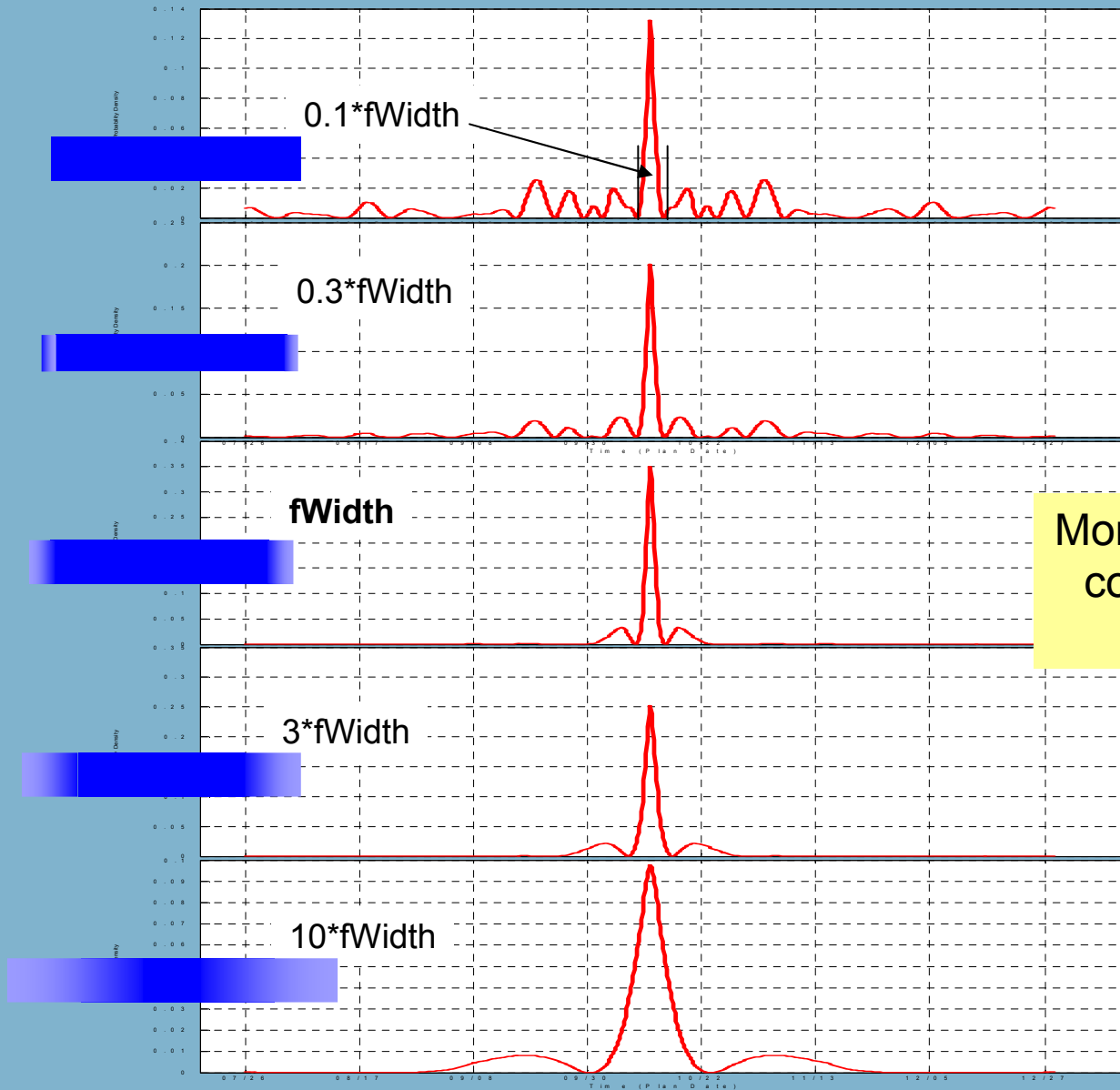
# Cost Management – How Task Periods and Phases Relate



In projects, fluctuations of wave periods and phases are strongly correlated by external risk

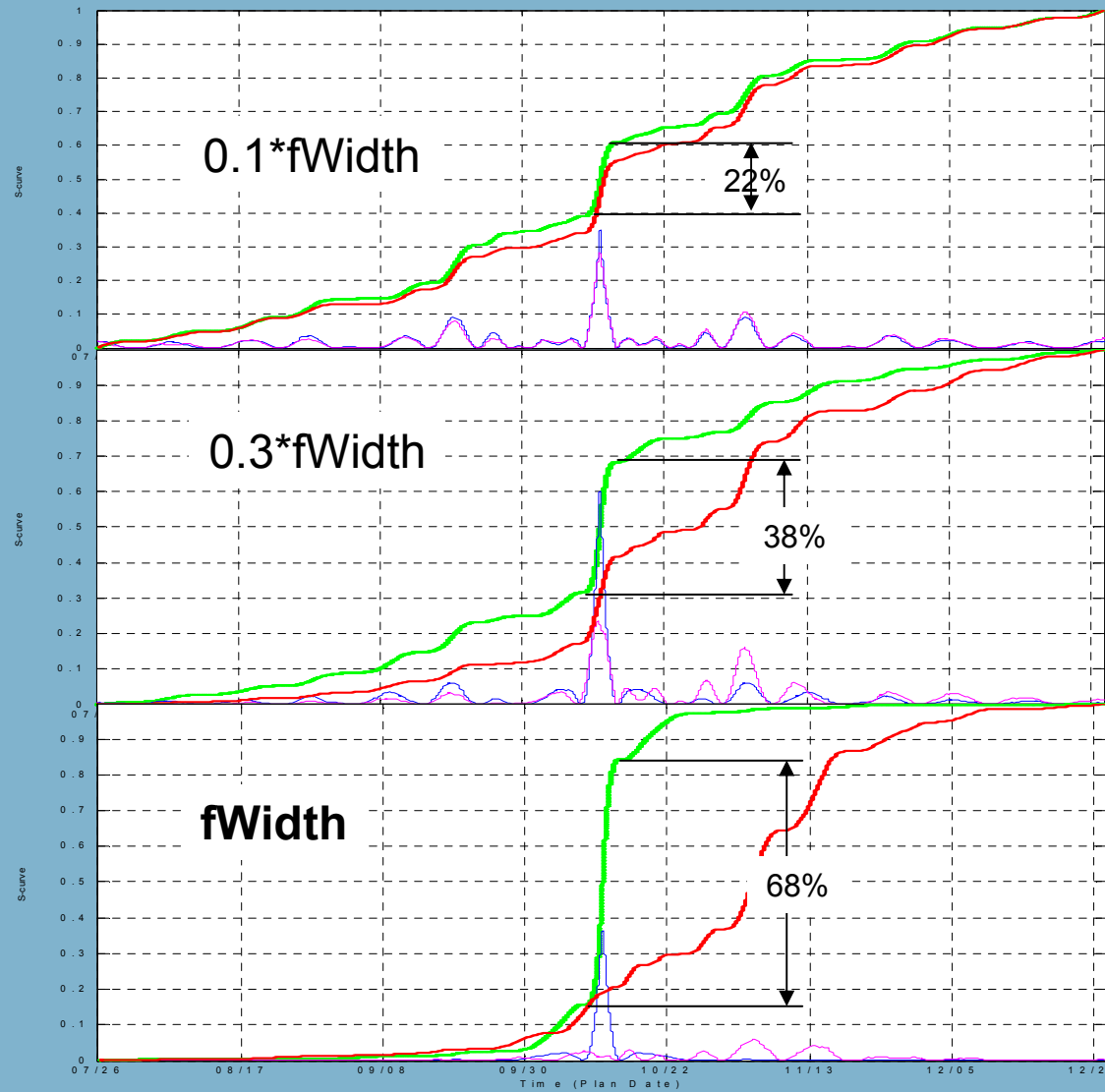


# Task Duration (Wave Periods) Fluctuations

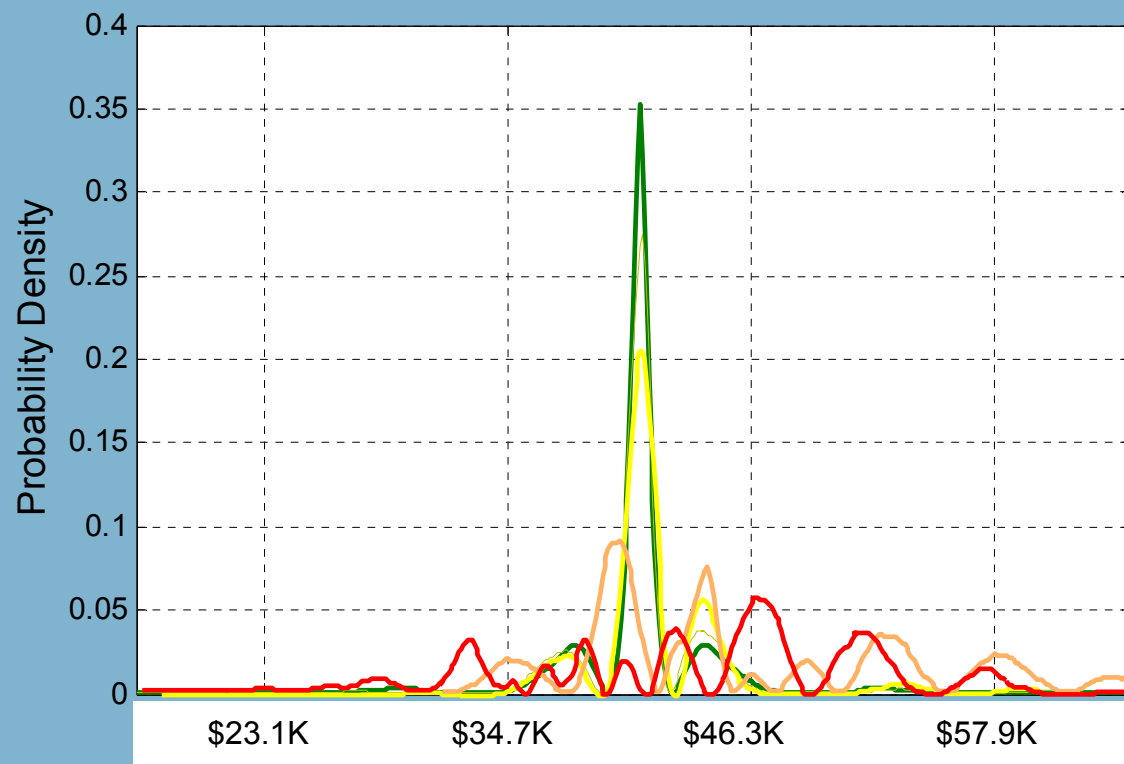


Monte Carlo simulation contracts probability density

# Task Fluctuations and % of Planned Work

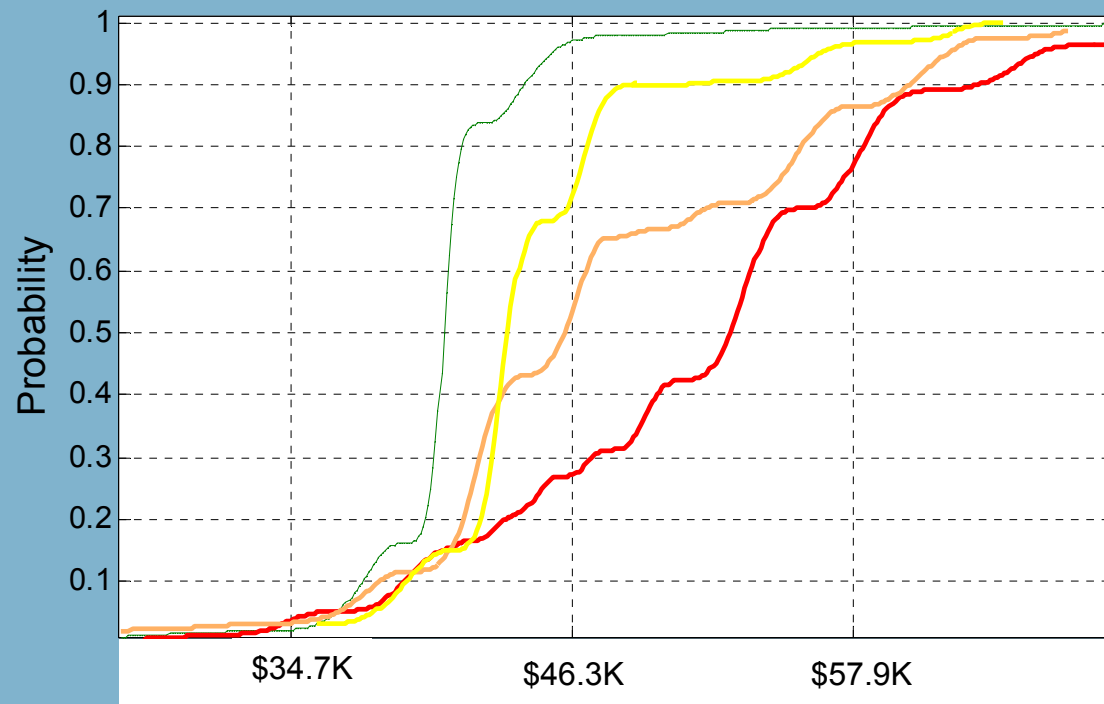


# External Risk: "Absolute" Calibration



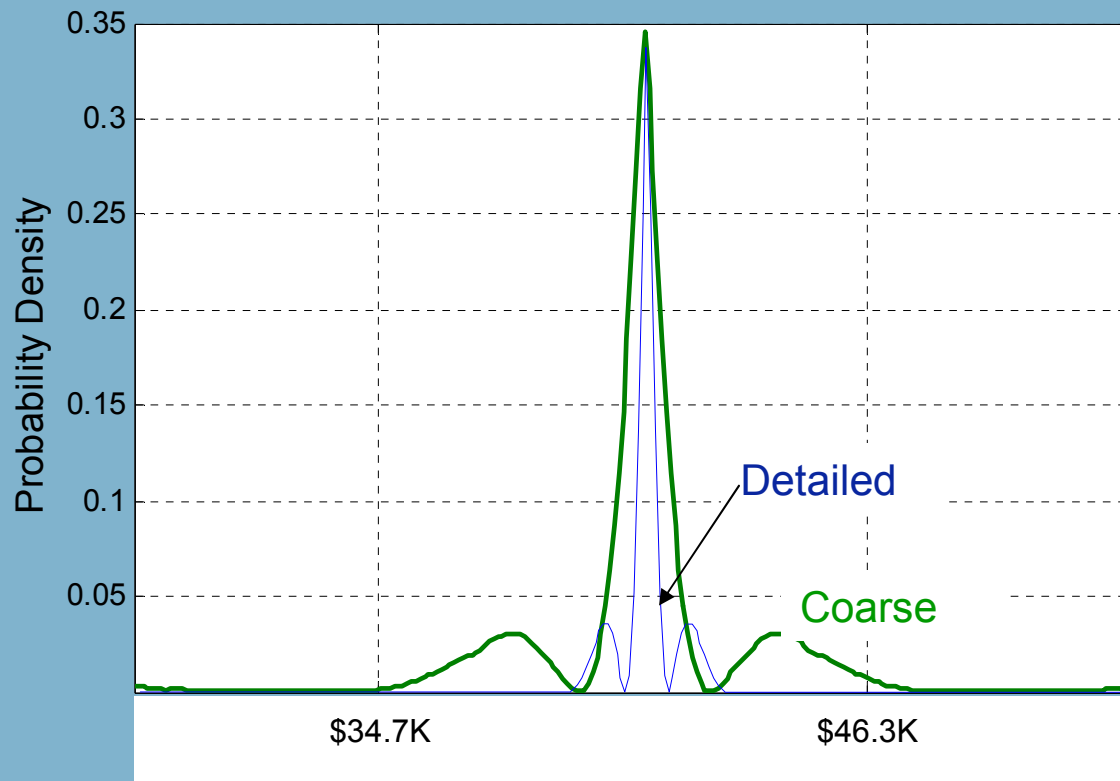
Monte Carlo simulation expands probability density

# S-curve Evolution



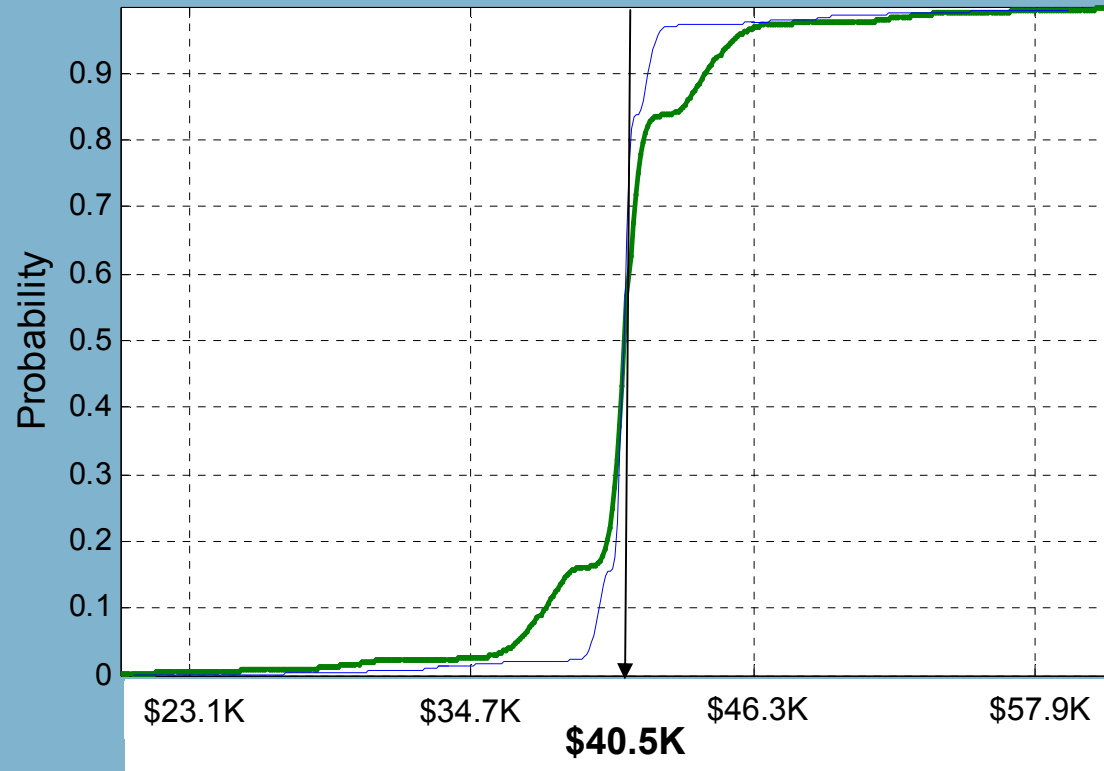


# Classical Limit for Probability Density

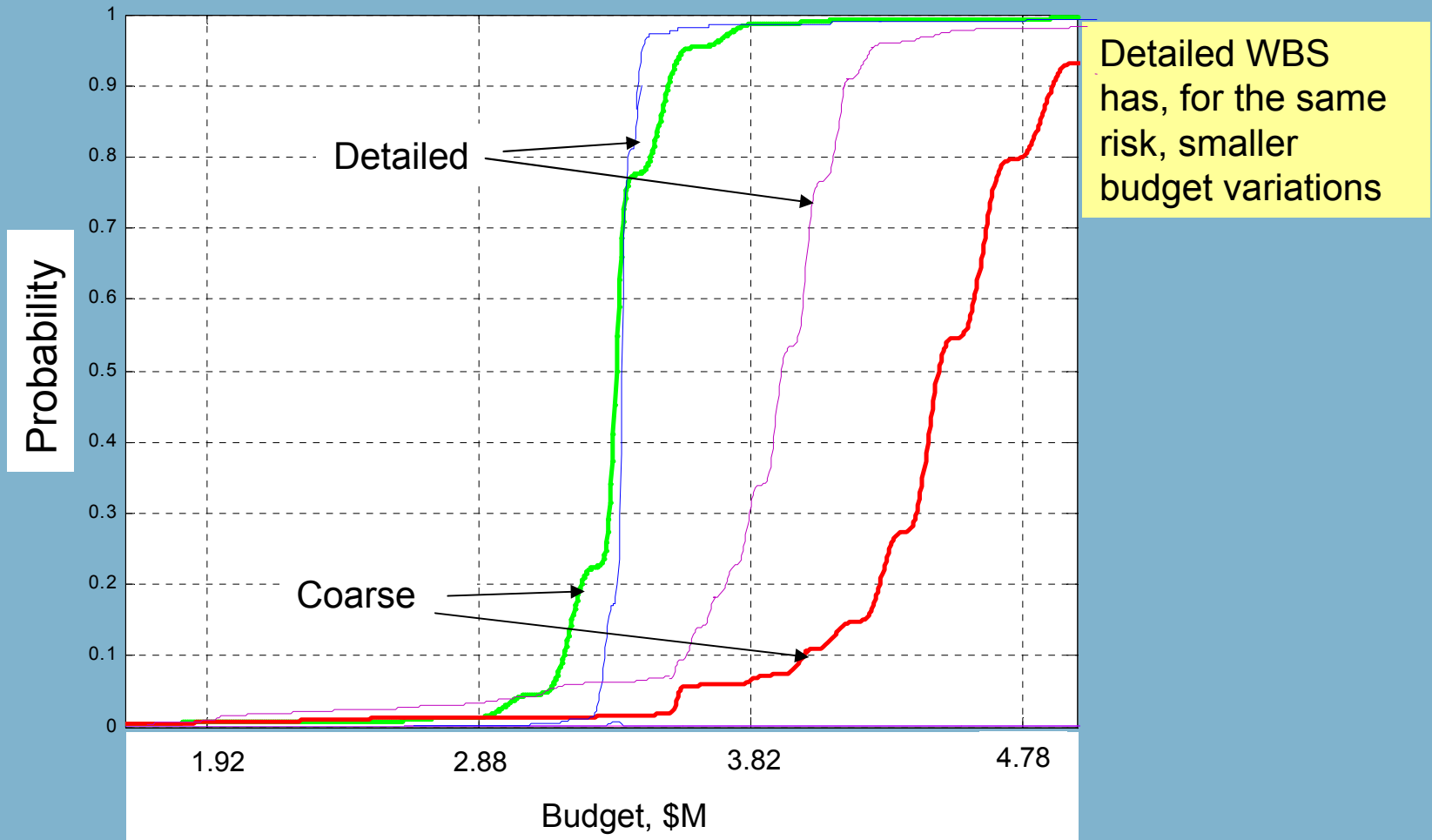


In detailed plan, probability density wings are narrower though the “mass” of tasks (amount of work to be done) is exactly the same

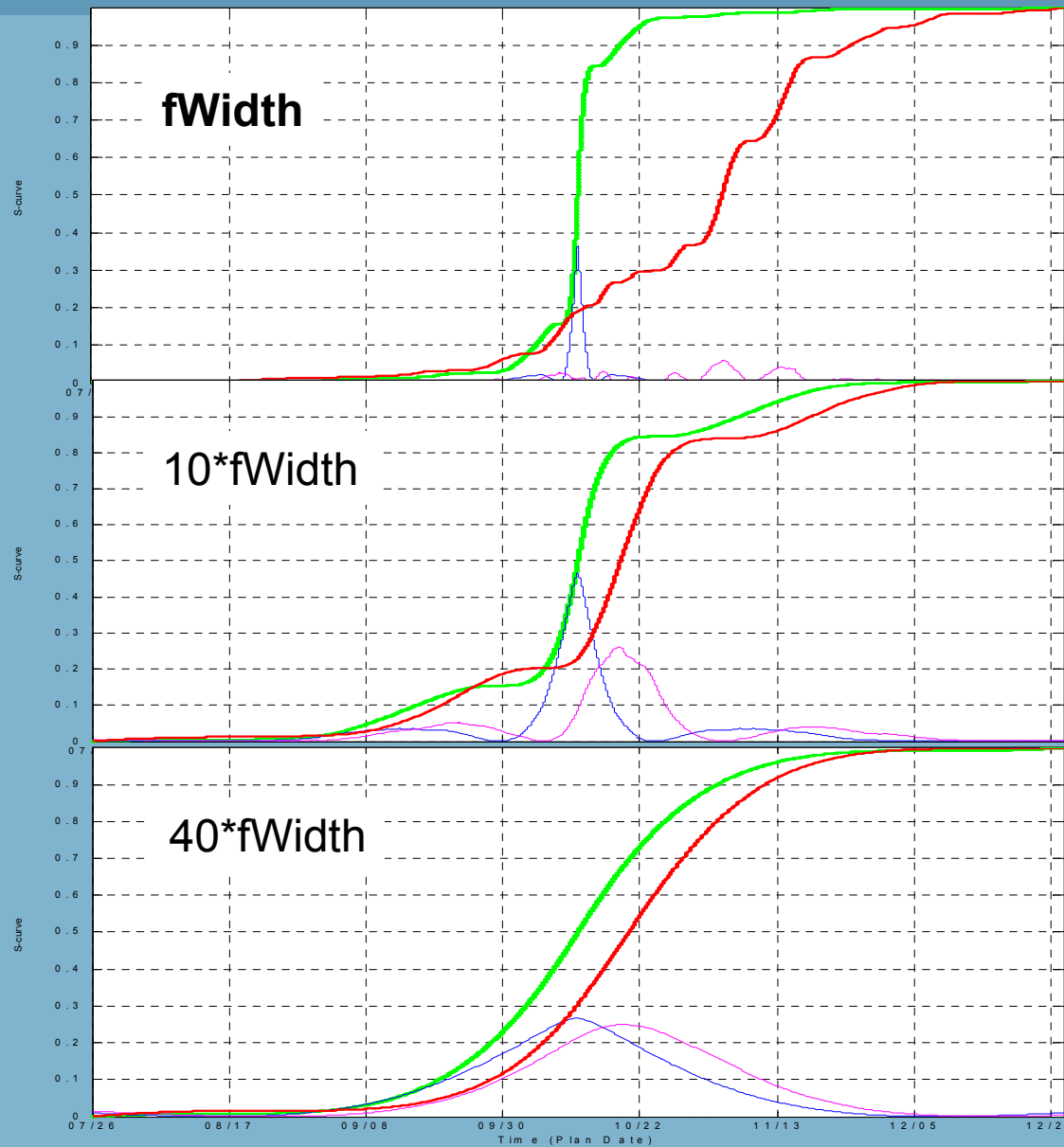
# Classical Limit for “No-Risk” S-curve



# S-curves Comparison

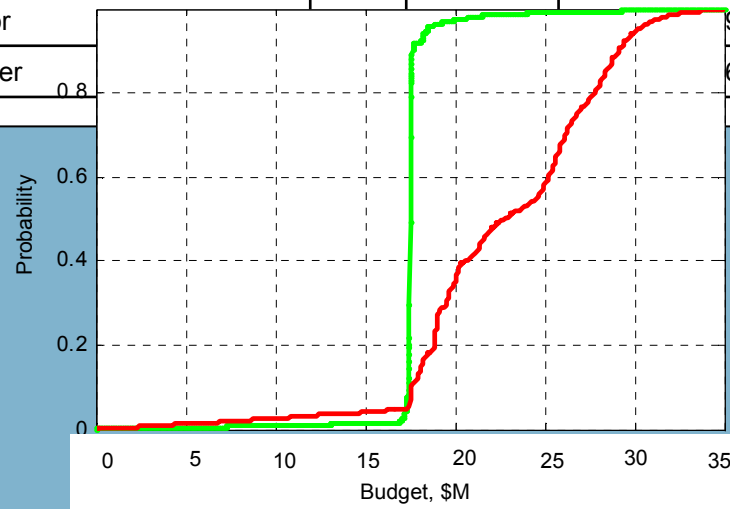


# S-curve Classical Limit for Large Fluctuations



# Next Step: Direct Comparison

WBS/CES Description	Appr op	Unique ID	Baseline	Variation
*SSPS1 Estimate		*Estimate		
Space Solar Power Satellite			\$ 1761002.019 (26%) *	
Project Management			8685.637568	707.4710896
Systems Engineering			9878.419554	208.2857501
Safety and Mission Assurance			766.0434917	336.8854202
Science/Technology			6540.982966	222.9529445
Payloads			5352.127256	479.6274433
Transmit Payload			8026.723375	22.26677652
System Engineering			4448.618085	610.6282068
Project Management			4617.698868	630.9158753
Solar Power Collector			96.032092	797.2519142
Solar Power Converter			608.64836	740.4745969



# Summary

- Quantum model provides adequate estimate of WBS cost variations
- WBS Risk and External Risk are useful concepts for cost analysis
- Quantum model provides theory of project cost increase when external risk exists
- For detailed WBS and large task variations, quantum and classical models merge