

Bayesian Schedule and Cost Risk Analysis

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Agenda

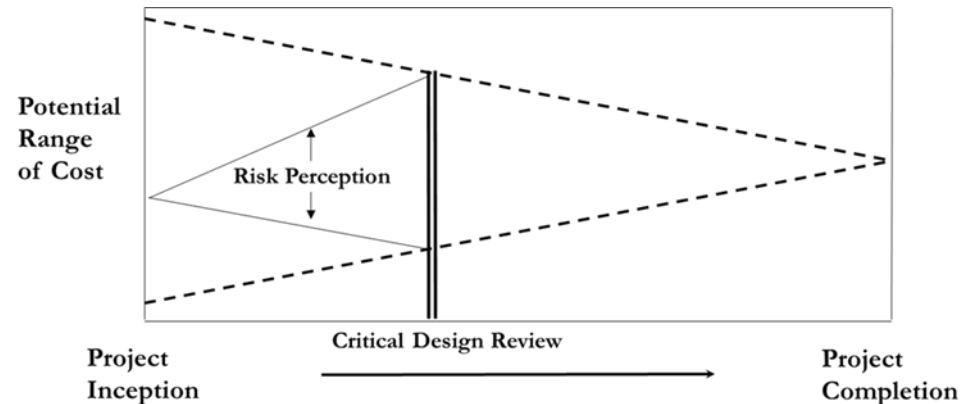
COST SCHEDULE ESTIMATION AND EVALUATION SECTION

- Innovation and Uncertainty
- Bayes Concepts
- Bayes for Cost and Schedule Management

Objective

Why Bayesian Risk Analysis?

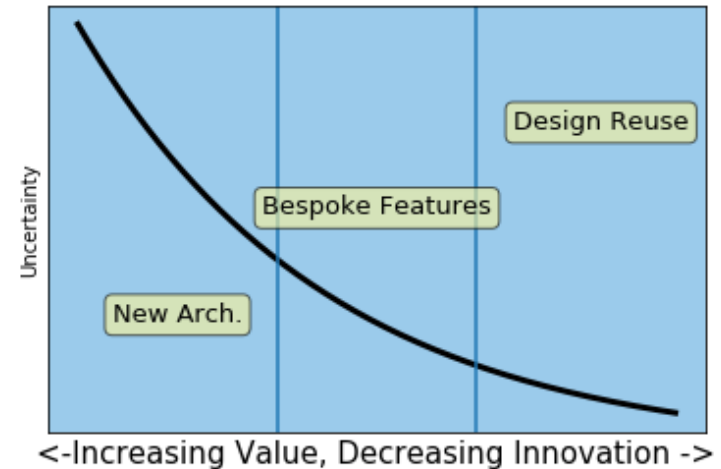
- There are well-established frequentist (traditional) methods for conducting cost and schedule risk analysis
- Why consider Bayes?
- Motivating factor – with Bayes, project progress (or lack thereof) can be used to update cost and schedule risk analyses during a project
- Helps us assess the cone of uncertainty



Risk Curve

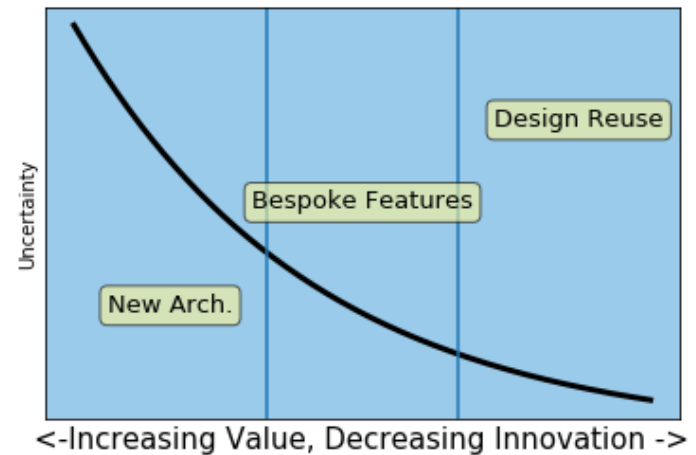
Innovation Drives Uncertainty

- Applies to innovative projects
- Uncertainty is due to incomplete knowledge
- NASA projects are highly innovative and typically take several years to develop
- Bayes provides a way to analyze this uncertainty



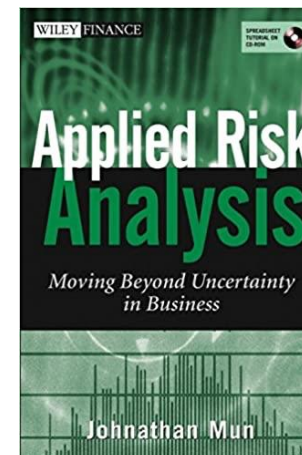
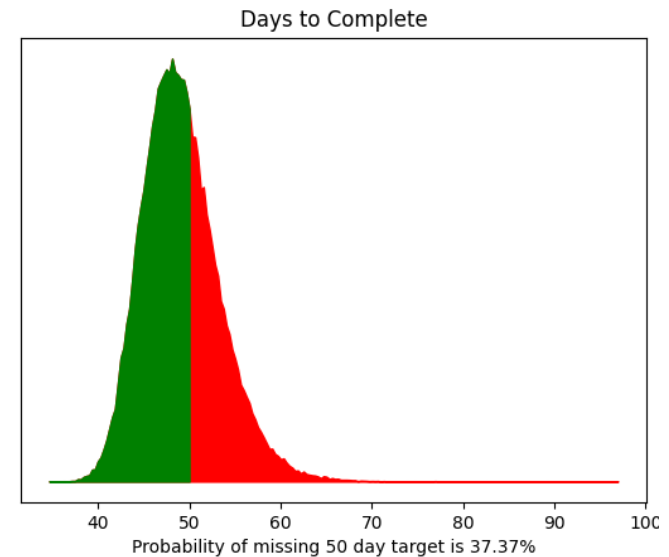
Innovation ↔ Uncertainty

- Uncertainty is due to incomplete knowledge
- Bayes is the math of uncertainty

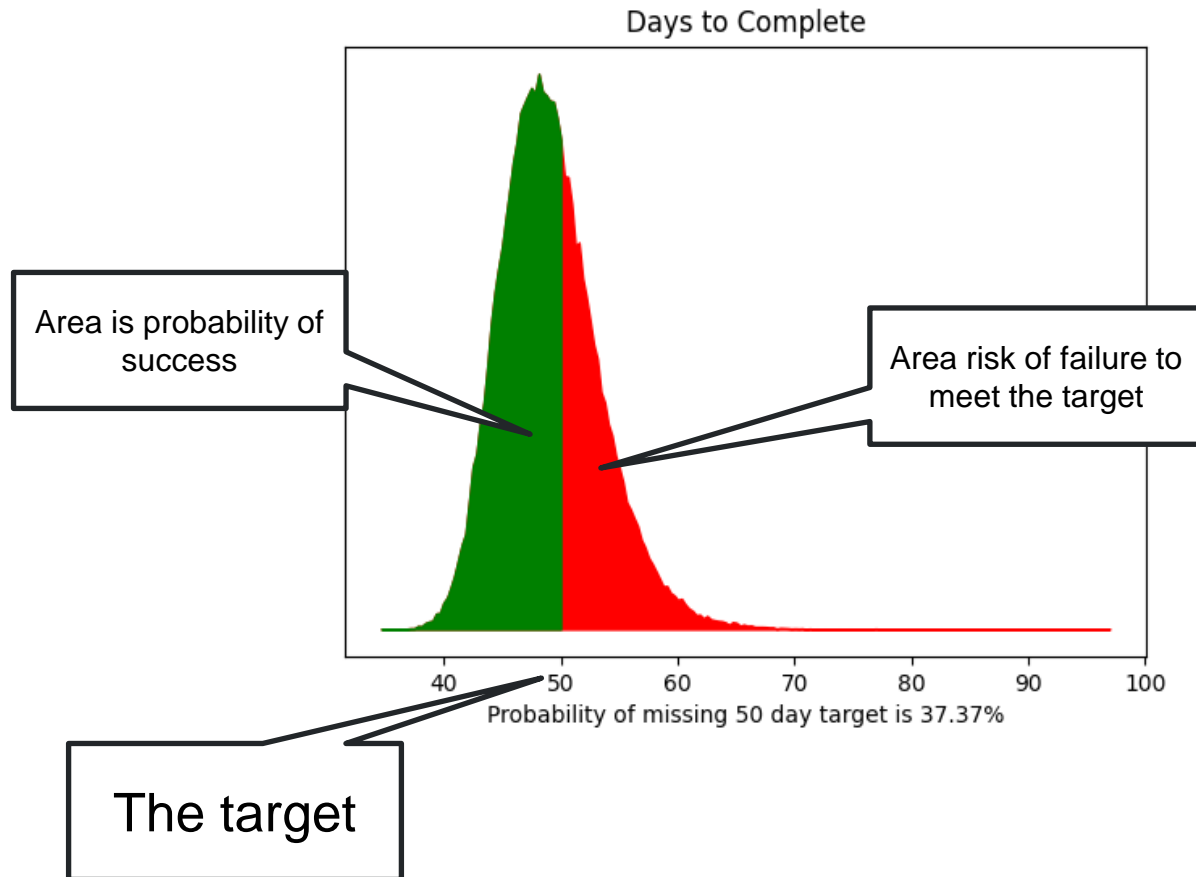


Bayes is Applied Probability

- Based on axioms (e.g., Komolgorov)
- Two main ideas
 - Uncertain quantities are random variables specified by pdf's
 - Generally use non-parametric statistics for analysis
 - Bayes Theorem: Random variables can be updated with new evidence
- Risk analysis: Risk is the probability of missing a target

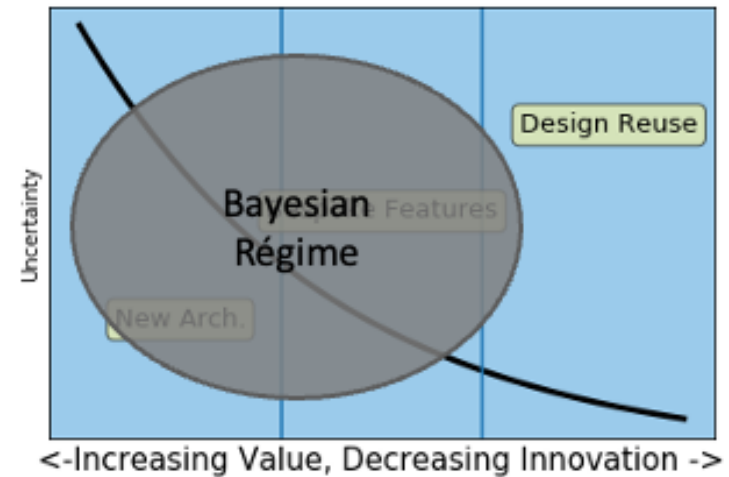


Using PDFs to Measure Risk



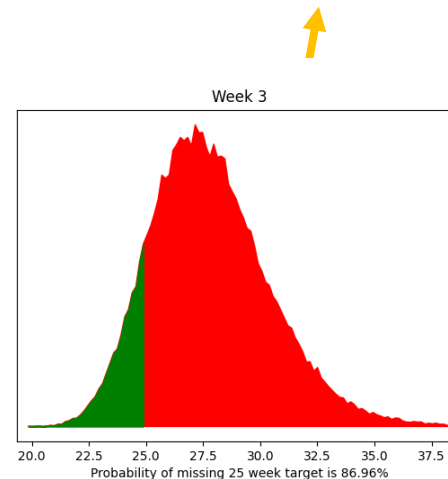
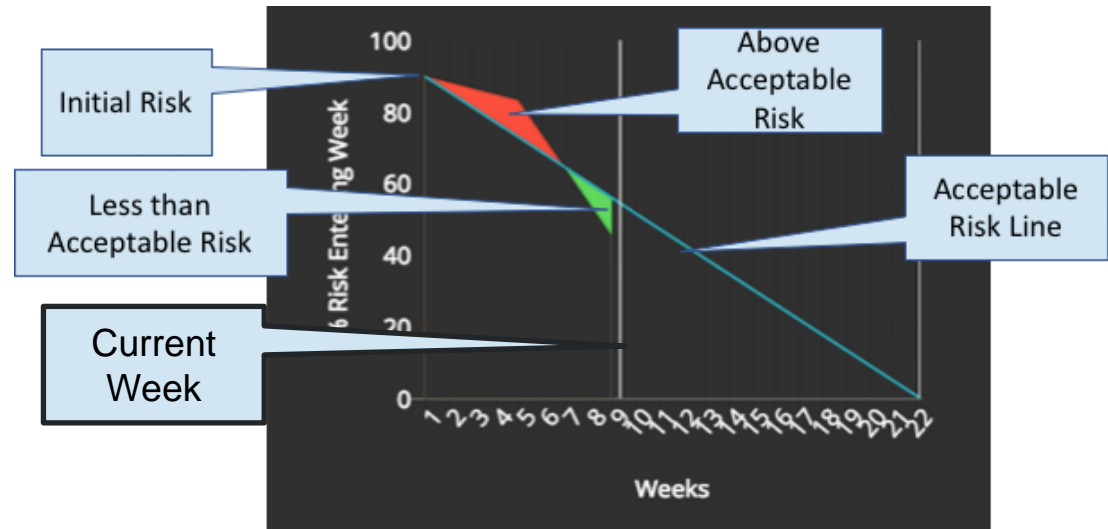
Cost and Schedule Management are Bayesian

- The initial plans are prior beliefs
- The evidence consists of expenditure and completion rates:
- Small data



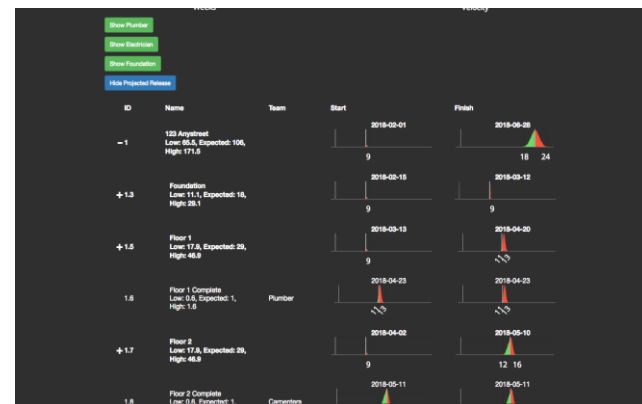
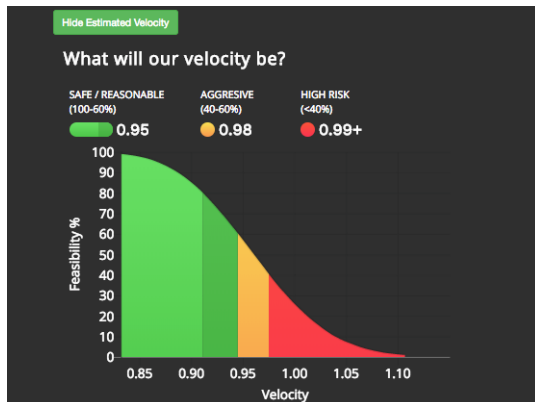
Tracking Risk

- Initial risk at the outset
- Zero risk prior to ship
- Progress is measured by working off risk



Schedule Reports

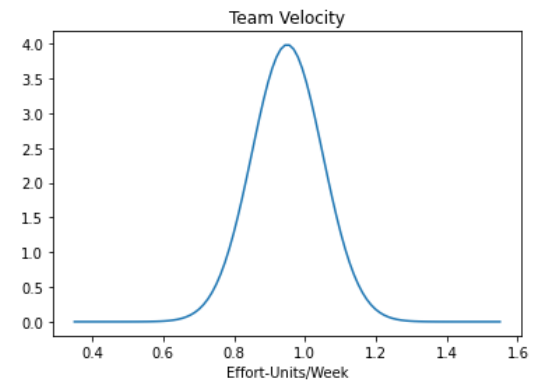
- PDF of time to complete at each level of the hierarchy
- Risk work off
- PDF of velocity for sprint planning



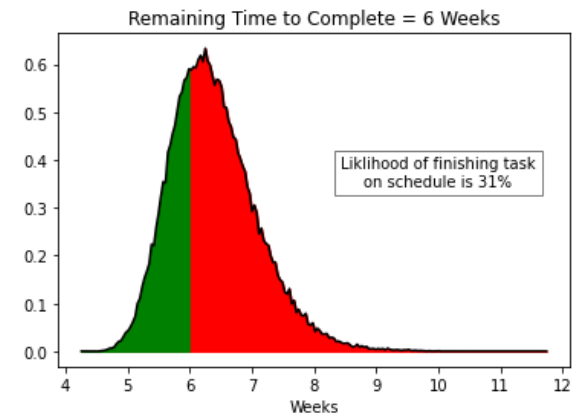
Overview of How to Apply Bayes to Project Time-to-Complete

- Create pdfs of future durations
 - Future tasks:
 - 3-point triangular distributions
 - InProgress tasks:
 - Collect the sequence of (% complete)/(actual durations)
 - Use Bayesian parameter learning to infer team velocity
 - Use pdf arithmetic to divide remaining effort by velocity find the pdf of the remaining time to complete tasks
- Rollup pdfs with Monte Carlo project simulation to get schedule charts

Remaining Effort ÷



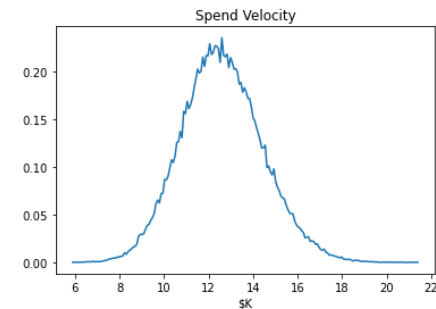
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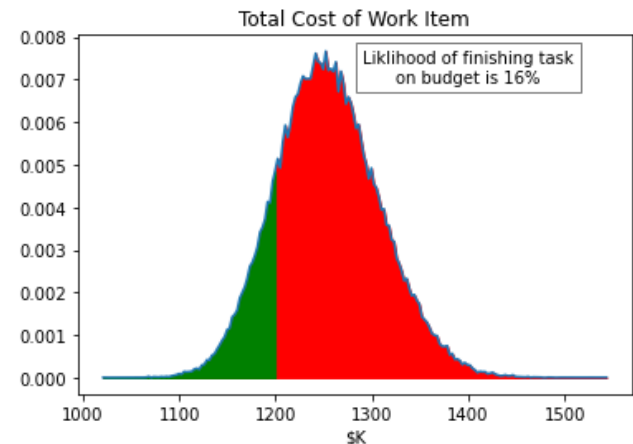
Overview of How to Apply Bayes to Costs-to-Complete

- Create pdfs of future expenditures
 - Future costs:
 - Existing cost model
 - 3-point triangular distributions
 - InProgress tasks:
 - Collect the sequence of (money spent)/(% complete)
 - Use Bayesian parameter learning to infer spend velocity
 - Use pdf arithmetic to multiply the remaining effort by spending velocity find the pdf of the cost to complete task
 - Add spent-to-date to get total cost
- Sum work item pdfs to get pdf of cost to complete and total cost

remaining effort x

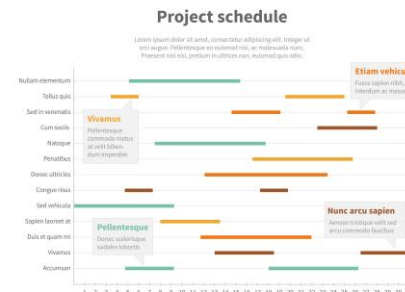
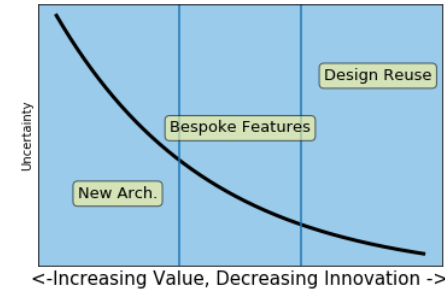


+ spent to date =



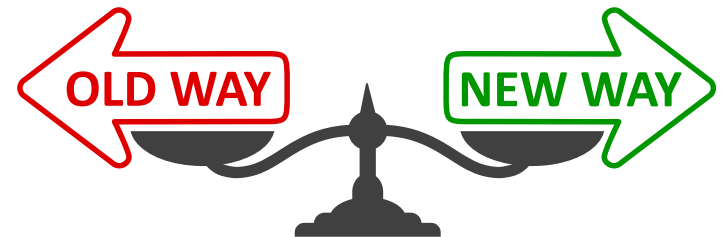
Strengths

- Reinforces iterative, agile, learning practices
- Works for both Incremental Gantt and Agile programs
- Enables needed transparency for sharing risk
- Provides early warning, avoiding the green, green, green, red phenomenon.
- Enables better collaboration in dealing with uncertainty and risk
- Is fractal:
 - Gantt: scales from subtasks to tasks to projects to projects of projects.
 - Agile: Epics to features to products to systems



Caveats

- You need to have good track-in-progress completions.
 - Percent complete over elapsed time of in-process efforts
 - Actual completion dates
- It may require some cultural change
 - Amount of transparency
 - Maintaining program files



Summary and Next Steps

- Risk analysis can be conducted using traditional frequentist or Bayesian methods
- The Bayesian approach to risk analysis has a key advantage – with this approach, you can update risk analyses conducted not only at major milestones, such as Preliminary Design Review and Critical Design Review but also throughout delivery using project progress statistics
- Consider using this approach in cost and schedule risk analyses
- Next ideas
 - Apply to JCL analysis updates
 - Consider quantitative portfolio management across directorates and even all of NASA



The Wheel of Fortune in
Carmina Burana