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Software Risk Estimation and Management at JPL

Abstract

The Jet Propulsion Laboratory (JPL) in Pasadena, California is a national laboratory, which is run by the California Institute of Technology for the National Aeronautics and Space Administration (NASA). JPL's primary roll is to build and operate unmanned, robotic space exploration missions throughout our solar system. JPL, as a Federally Funded Research and Development Center, is always incorporating something new into every software or spacecraft system that it designs and builds. As a result dealing with risk and uncertainty in our estimates has always been a major focus. In the past few years, due to unexpected cost growth on our flight missions and flight software, there has been an increased focus on a more integrated and comprehensive approach to the estimation and management of risk. In this talk we will discuss the following topics related to cost risk:

1. How uncertainty has been incorporated into the JPL software model, probabilistic-based estimates, and how risk is addressed at major milestone reviews since 1989.
2. How cost risk is currently being explored via a variety of approaches, from traditional risk lists, to detailed WBS-based risk estimates to the Defect Detection and Prevention" (DDP) tool. Major issues are arising here as to how to make these approaches work together, as well as how to get them used properly within the JPL environment.
3. Current plans and approach for integrating these different approaches to cost risk and diffusing them into the organization.

JPL

Software Risk Estimation and Management at the Jet Propulsion Laboratory

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17th International Forum on

COCOMO and Software Cost Modeling

October 22-25, 2002

Background & Context

- NASA's Jet Propulsion Laboratory is a Federally Funded Research & Development Center whose prime mission is the development and operation of deep space scientific missions
- JPL has had a very strong emphasis on estimating and managing technical risk for over 40 years
- Because of hard launch dates schedule was closely managed
- However, software cost risk has only become a serious focus very recently

History

- **Pre-1989**
  - Limited use of cost models even though Softcost was originally developed at JPL by R. Tauseworth and D. Reifer. JPL Softcost did not estimate software cost risk.
  - Software cost risk addressed only with risk lists with 'loosely' defined mitigation approaches. There was little to no quantification.

- **1989-1996**
  - Developed SCT, a JPL-variant of COCOMO 81 with built-in
    - Monte Carlo algorithms to generate a development effort CDF
    - Calibration
    - Calibration database
    - Used regularly to validate DSN software development effort
  - Software cost risk addressed only with risk lists with 'loosely' defined mitigation approaches. There was little to no quantification except when SCT was used.

History continued

- **1996-2001**
  - Software Cost Estimation and Cost Risk activities took a major step backward under Faster, Better, Cheaper
  - Optimistic assumptions were 'de rigueur'
  - Software cost risk addressed only with risk lists with 'loosely' defined mitigation approaches. There was little to no quantification.

- **2001-Today**
  - Software Quality Improvement project and JPL Costing Office Formed
  - Software cost models and formal cost databases required
    - COCOMO II and SEER-SEM
  - Quantitative software cost risk estimates and analysis required
  - JPL Senior Management now ask "Where is your 'S' curve?"
  - Numerous explorations into quantitative cost and cost risk management

SW Model Architecture

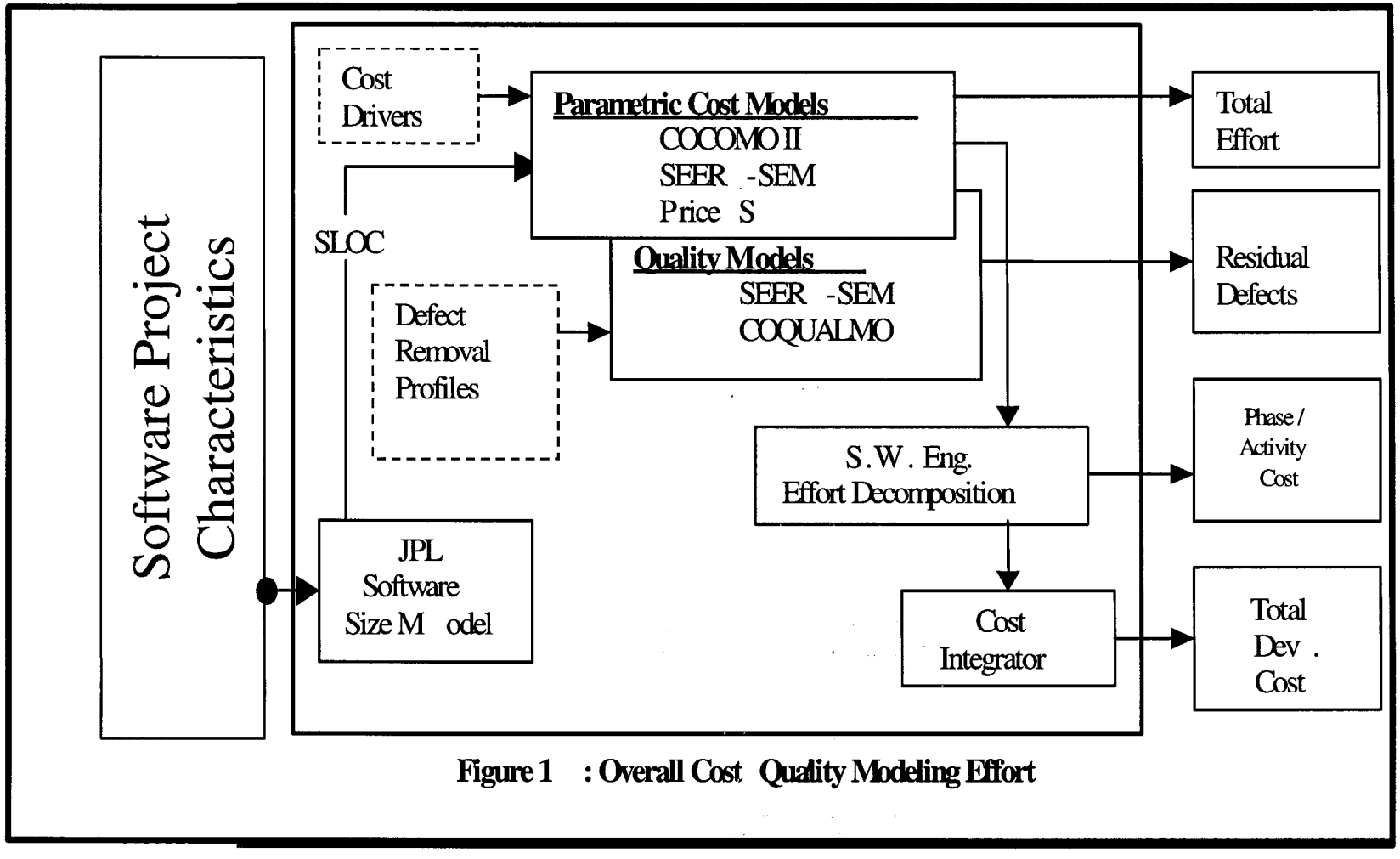
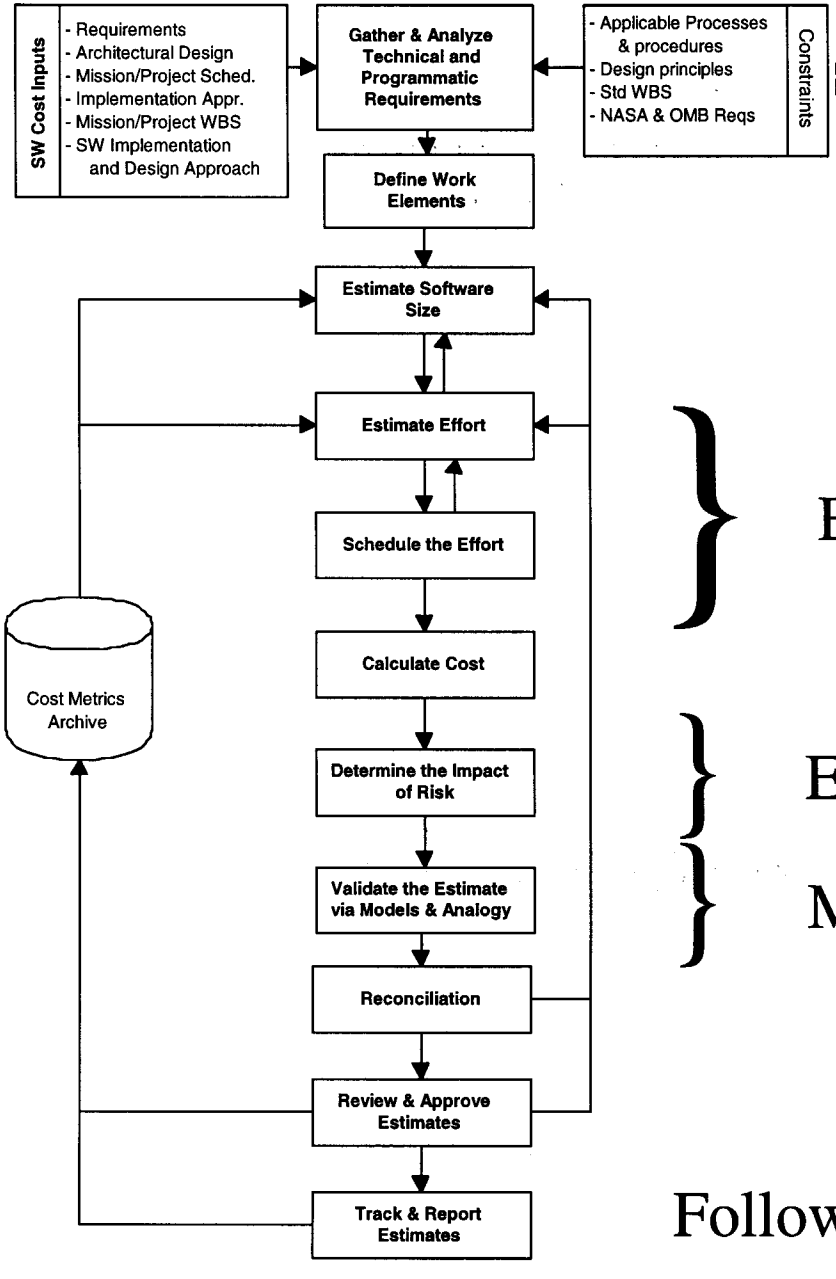


Figure 1 : Overall Cost Quality Modeling Effort

Software Estimation Steps



Save History

Engineering Estimate

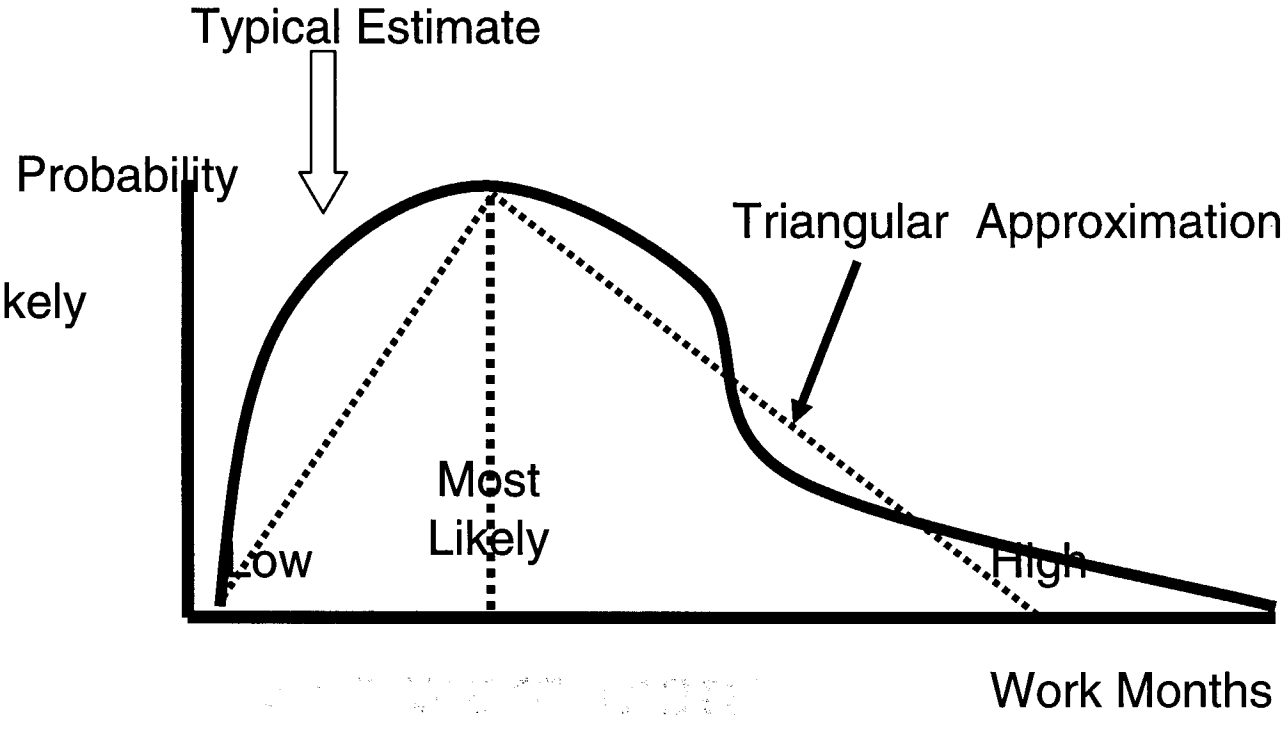
Estimate Risk

Model-Based Estimate

Follow Through

Training Software Managers

Downward bias very likely if estimator does not formally account for underlying probability distribution



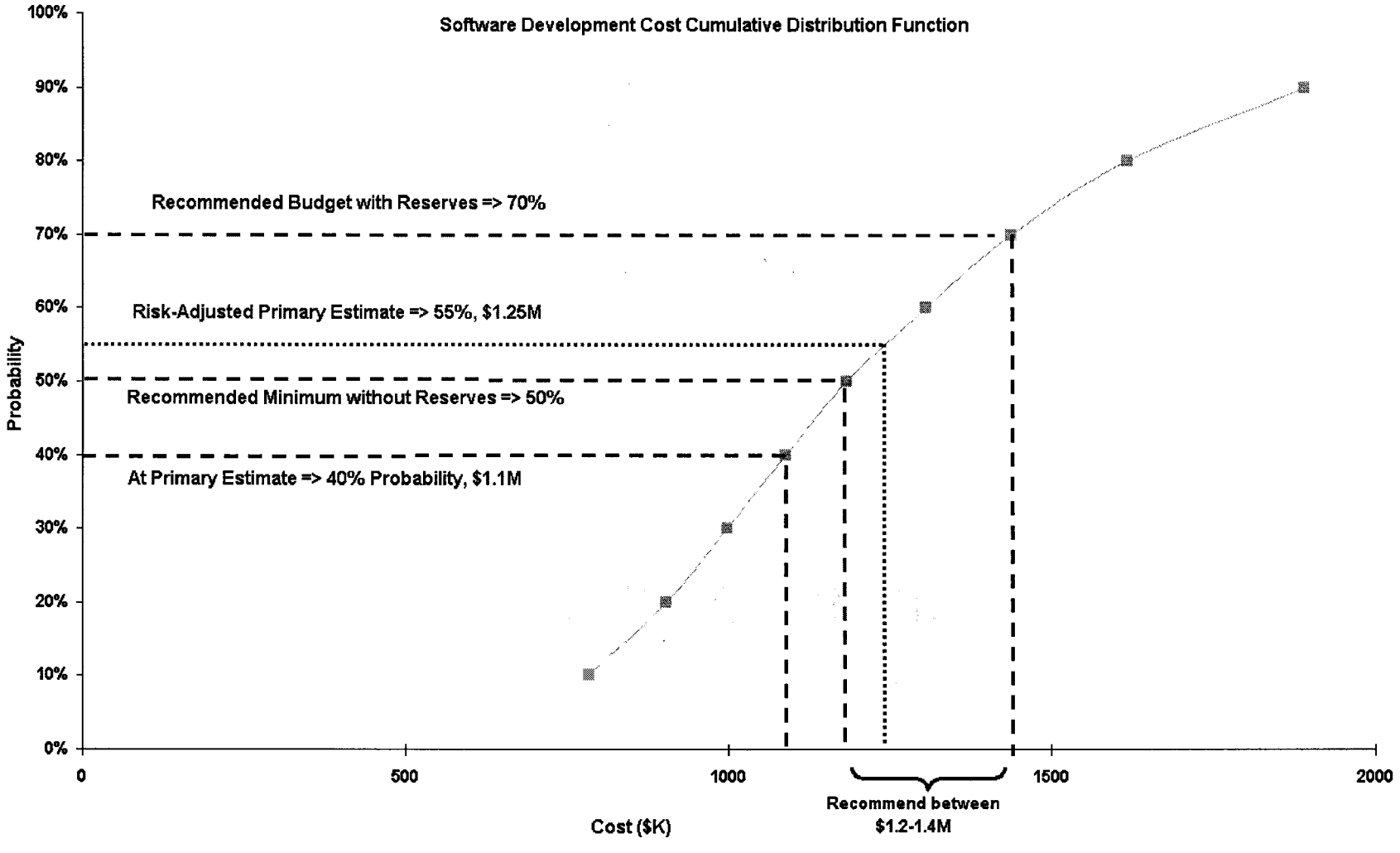
Typically cost, effort, SLOC distributions are highly skewed to the right

Point estimates tend to fall between the low and most likely distribution parameters and Most Likely is typically less then 50th percentile

Uncertainty & Cost Risk Overview

Known	Estimate Uncertainty
I Forgot's	Standard WBS Templates & Checklists
Known Unknowns	Risk Lists Quantitative Risk Assessment
Unknown Unknowns	Design Principle Reserve Percentage

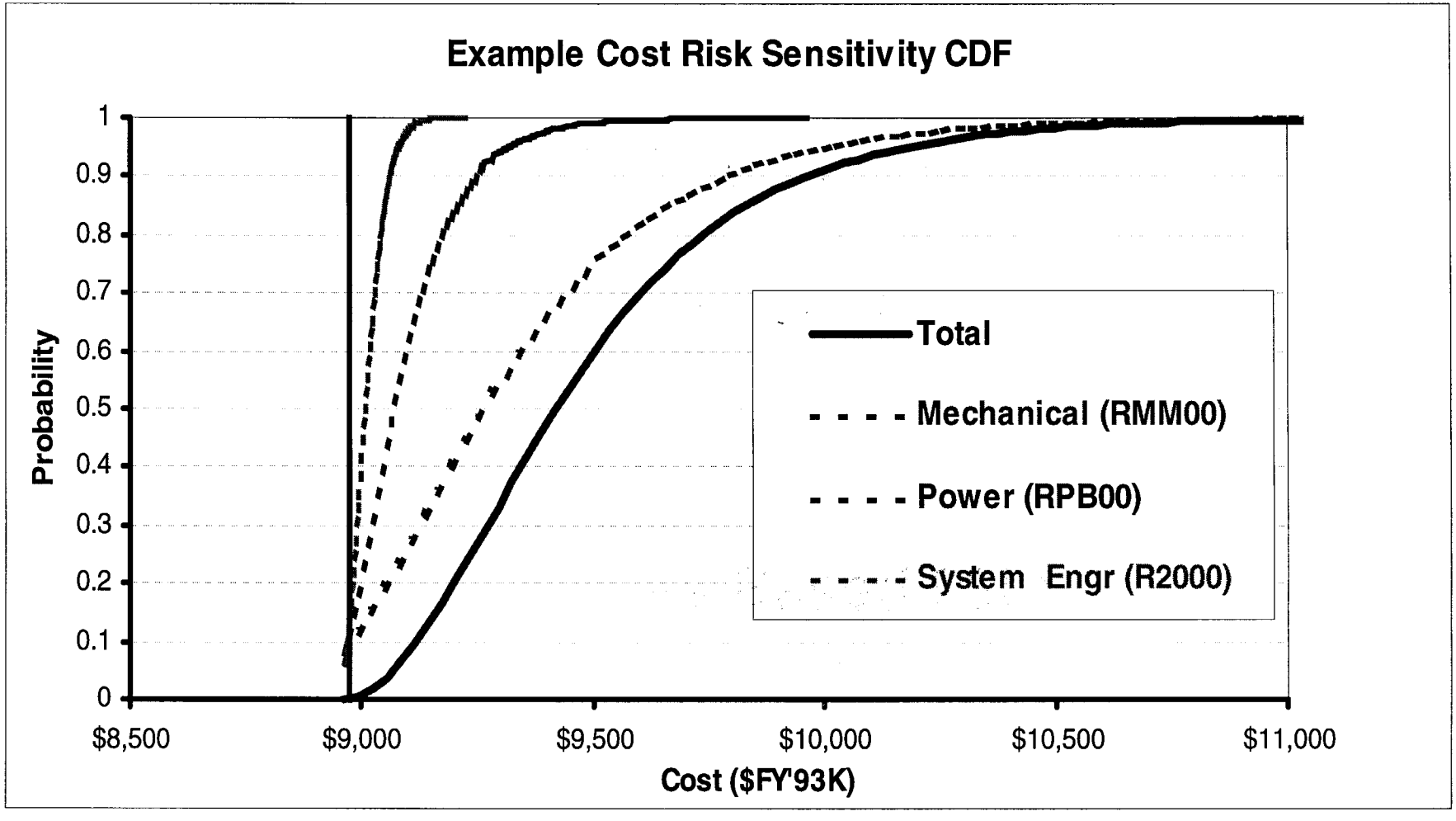
Standard JPL SW Cost Risk Estimate



Future Cost Risk Methods

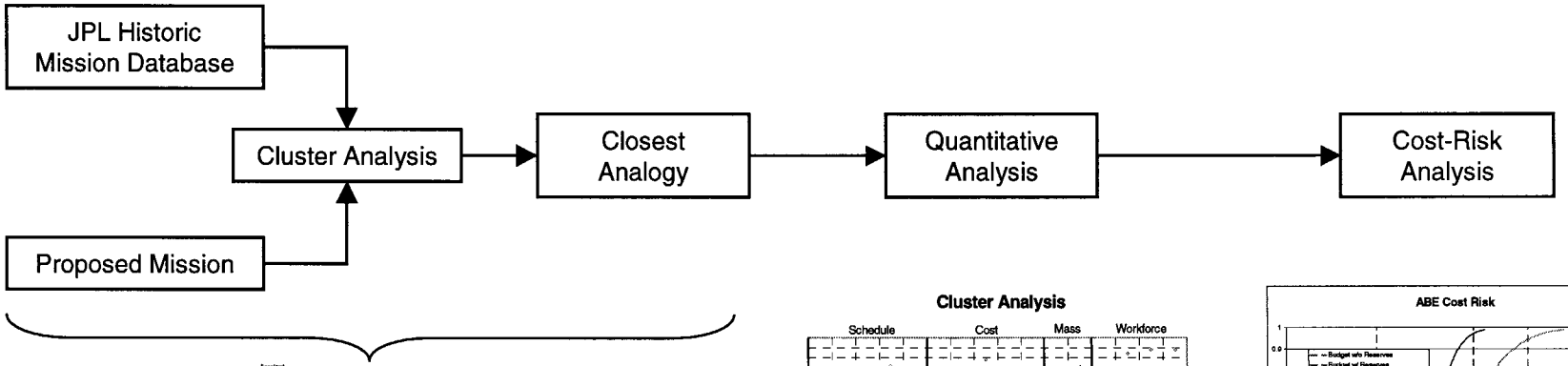
- Estimating 99th percentile and assuming a Log Normal distribution instead of Low, Likely, and High
- Using Cluster analysis to identify analogous projects
- Formal cost risk analysis, mitigation and tracking with DDP

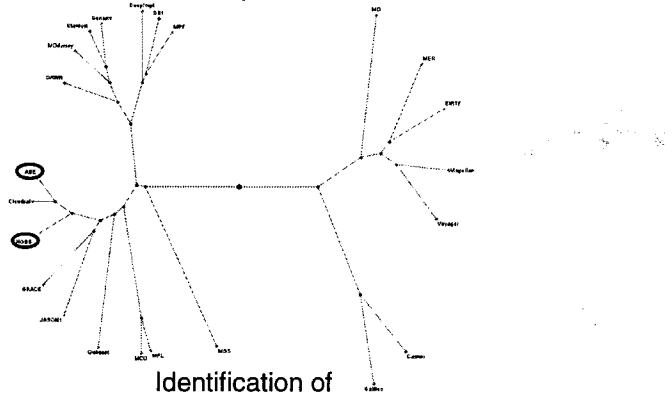
Cost Risk Estimates Based 99th Percentile



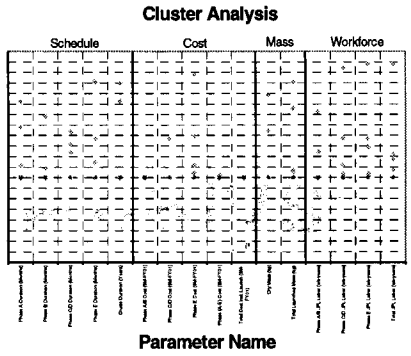
Cluster Analysis

- **Incorporate cluster analysis information to quantify total cost risk**
  - Identification of closest analogy should be based on proposal values or similarity to current vintage of estimate
  - Quantitative analysis is focused on history of actual values for analogy mission

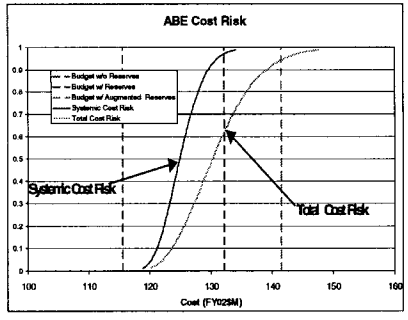




Identification of Cluster for a Proposed Mission and Closest Analogy



Quantitative Analysis Highlighting Proposed Mission & Closest Analogy



Systemic and Total Cost-Risk Comparison Using External Cost Fraction

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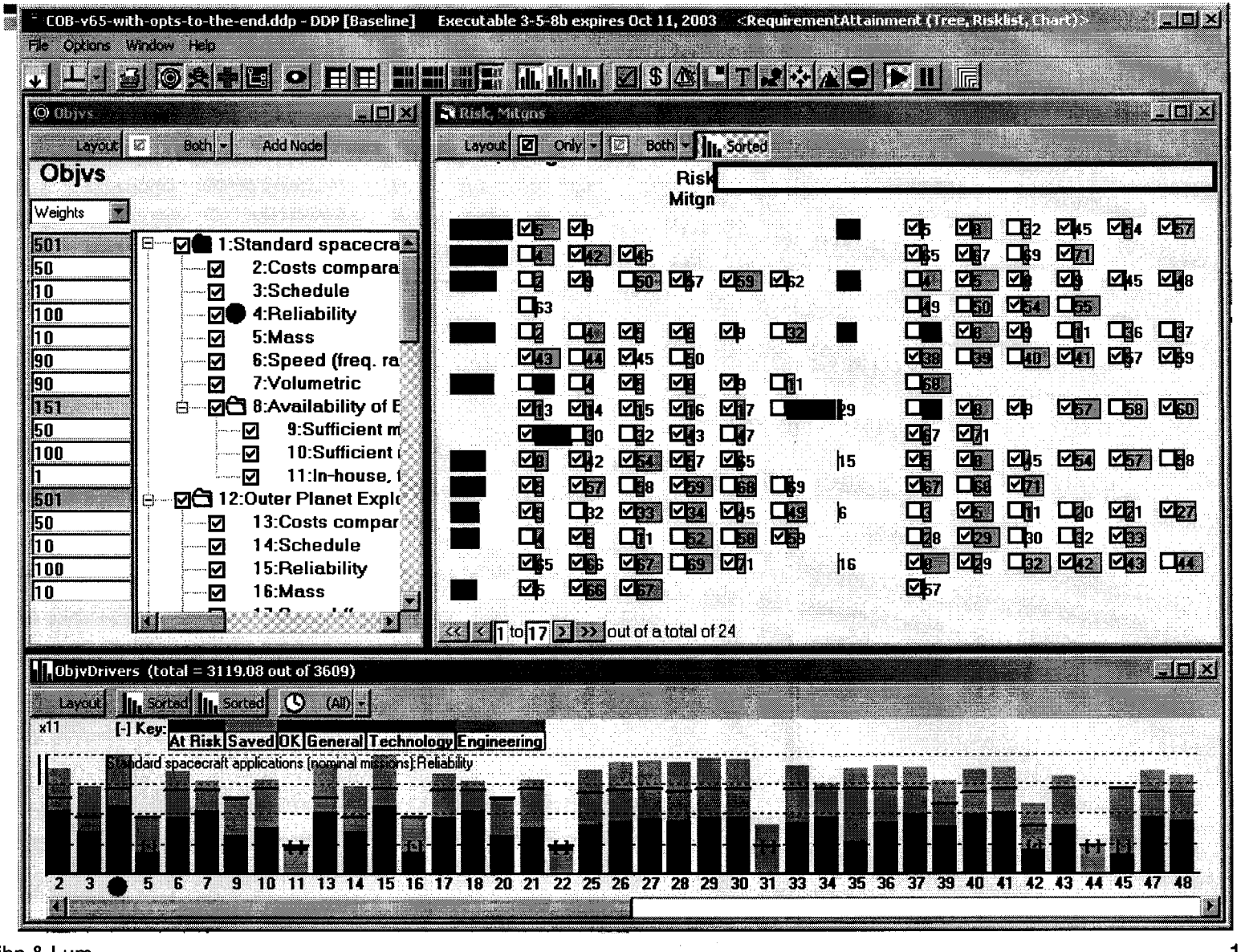
DDP


COB-v65-with-opts-to-the-end.ddp - DDP [Baseline]
Executable 3-5-8b expires Oct 11, 2003
<RequirementAttainment (Tree, Risklist, Chart)>
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1:Standard spacecra
2:Costs compara
3:Schedule
4:Reliability
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10:Sufficient
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12:Outer Planet Explo
13:Costs compar
14:Schedule
15:Reliability
16:Mass
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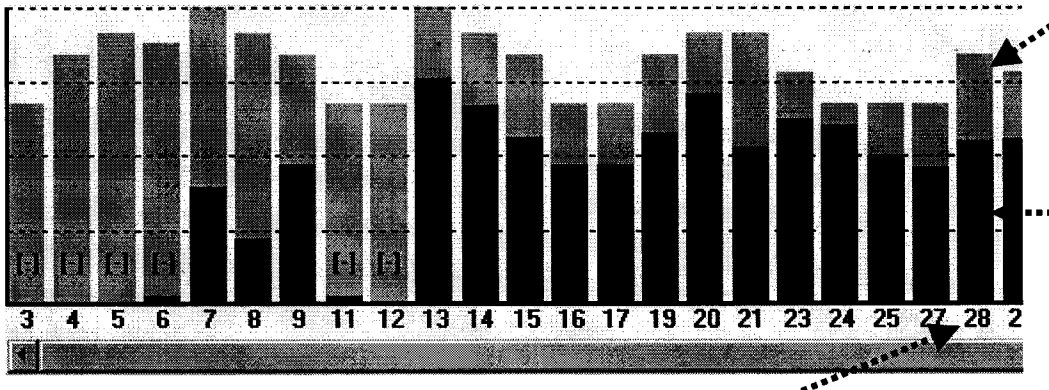
1 to 17 out of a total of 24
ObjvDrivers (total = 3119.08 out of 3609)
Layout Sorted Sorted (All)
x11
[-] Key: At Risk Saved OK General Technology Engineering
Standard spacecraft applications (nominal missions):Reliability
2 3 5 6 7 9 10 11 13 14 15 16 17 18 20 21 22 25 26 27 28 29 30 31 33 34 35 36 37 39 40 41 42 43 44 45 47 48

DDP Visualizations - Bar Charts

FMs bar chart

Unsorted – order matches leaf elements in FM tree

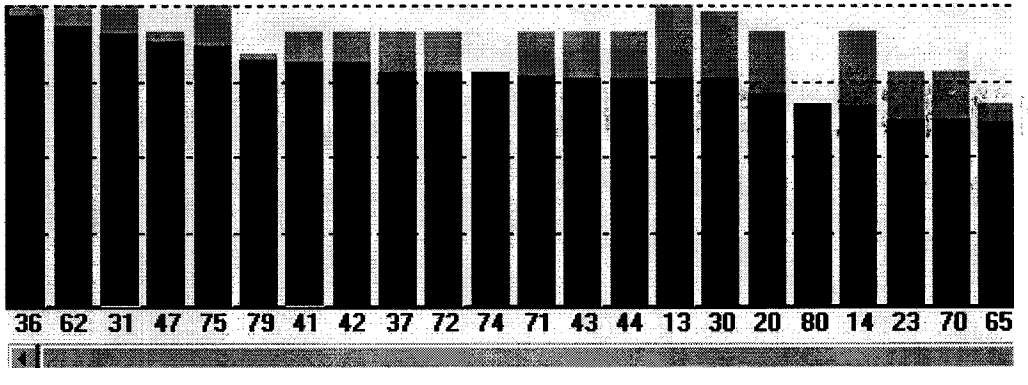


Item number in tree

Green: of this FM's total Impact on Requirements, that *saved* by PACTs

Red: of this FM's total Impact on Requirements, that *remaining* despite PACTs

Sorted – in decreasing order of remaining risk



Requirements bar chart – how much each is impacted

PACTs bar chart – how much impact each is saving

Conclusion

We may be late bloomers

but we are fast learners