Software Cost Estimation at JPL

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Mission and System Architecture Section
Software Quality Improvement Project

Topics

- Current State of Software Cost Estimation
- SQI Approach to Improving Current Practice

Current State of Cost Estimation

- On average, based on plans at PDR for DSN upgrades
  - Software cost overruns are 46%
  - Schedule slips by 14%
  - Never deliver all functionality that was originally promised
- Based on 7 mission where flight software experienced >20% cost growth the average cost growth was 50% from PDR

Major Reasons for Cost Overruns

- Current proposal and planning process encourages or demands under-estimating in early stages of lifecycle

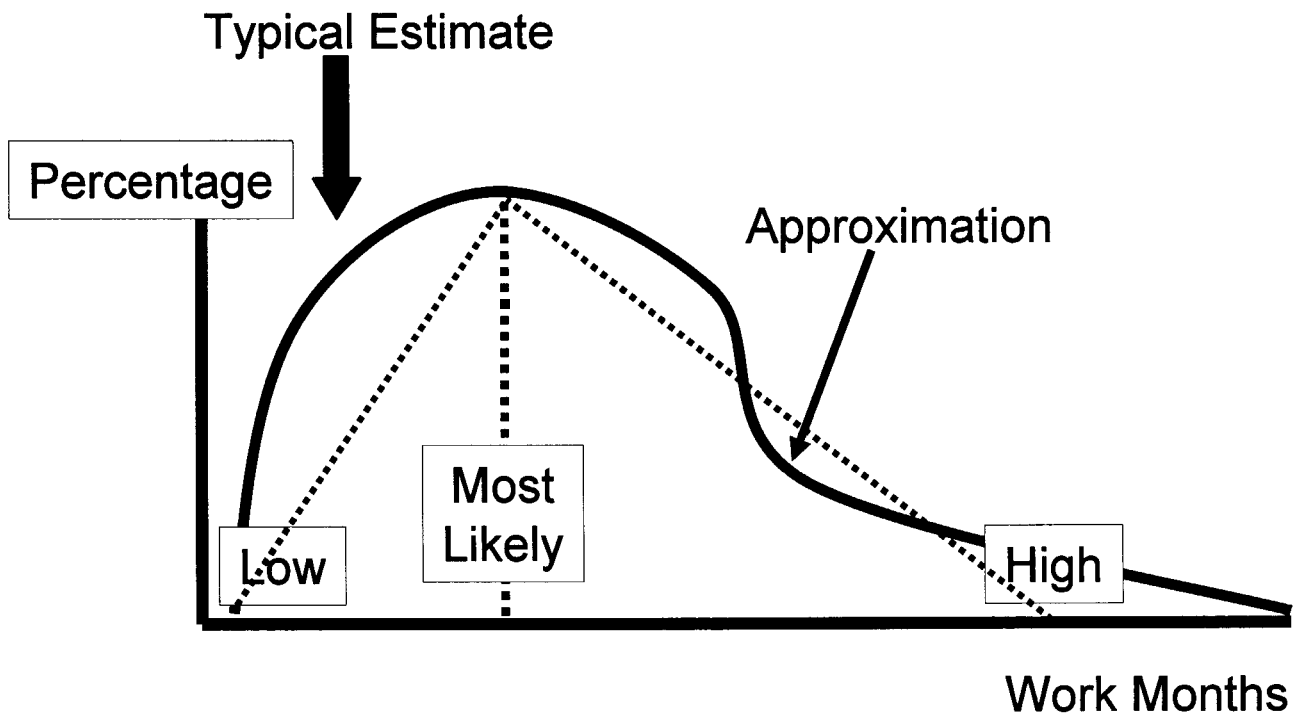
- Optimistic assumptions with respect to
  - Ability to reuse/inherit existing software
    - Based on 22 projects/upgrades, four out of five attempts to inherit major software code elements have "failed"
  - Availability of new technology and products
  - Stability and understanding of requirements
    - Software requirements will change
  - Newness
    - Anything you do for the first time will cost more than you expect

Major Reasons for Cost Overruns

- Classic "I Forgots"
  - Review preparation
  - Documentation
  - Anomaly and ECR's
  - Testing
  - Maintenance
  - Basic management and coordination activities
  - Mission Support Software Components

Fundamental Reason for Under Estimation

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 with Most Likely typically less than the 50th percentile

Reasons for JPL Flight Software Cost Growth

Risk Area	Percentage of Missions Reporting Responses in Risk Area	Summary of Reported Issues
Experience & Teaming	71%	☞ Management and system engineers had extensive hardware experience but insufficient software experience ☞ Weak teaming between hardware, software and systems teams ☞ SW engineers lacked system and mission experience
Planning	71%	☞ Poor planning and estimation practices ☞ Planned inheritance never happened ☞ Insufficient reserves for SW
Requirements & Design	57%	☞ Lack of good system architecture and system partitioning ☞ Lack of good software architecture ☞ Systems decisions made without accounting for impact on software ☞ SW requirements solidify late in the life cycle and are very volatile
Testing	71%	☞ Testbeds; too few, too late, not validated, insufficient capability
Software Inheritance	57%	☞ Inherited code did not behave as advertised, was poorly documented, and required more modification than expected. (5 of 8 missions attempted to inherit software. Of these, 4 reported major problems.)
Tools & Methods	86%	☞ Poor test result analysis tools ☞ Purchased COTS tool never used.
Staffing	71%	☞ High turnover in software staff ☞ SW team was not included in early stages of planning ☞ Integration and SW teams were not available to support ATLO

Reasons for JPL Flight Software Cost Growth

RISK AREA	Range	Mean
Experience & Teaming	5-15%	10%
Planning	20-50%	35%
Requirements & Design	10-50%	25%
Testing	10-30%	15%
Tools	5-20%	5%
Staffing	5 -25%	10%

Some Good News

- Estimation accuracy improves dramatically with
  - Domain experience
  - Increased frequency of cost estimation experience

SQI Approach to Improving Current Practice

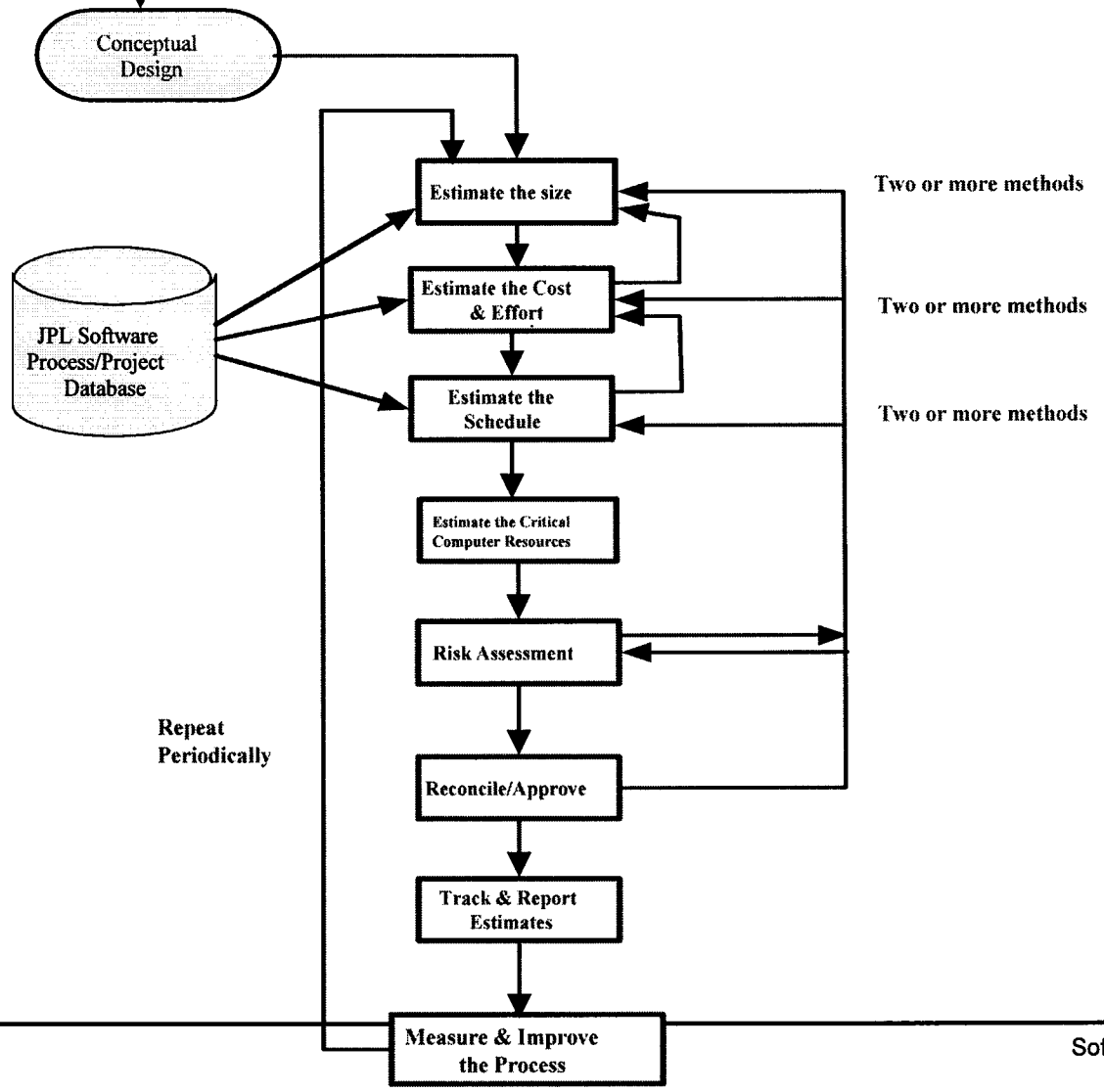
- The Software Cost Activities are funded primarily from SQI with supplement support from the Costing Office and IND (TMOD)
  - SW Cost estimation process
  - SW Cost estimation models, techniques and supporting engineering models
  - Cost Risk
  - SW Cost Metrics Database
  - Software Cost Estimation Handbook
  - Project/Mission Engagement Strategy

How To Do A Better Job

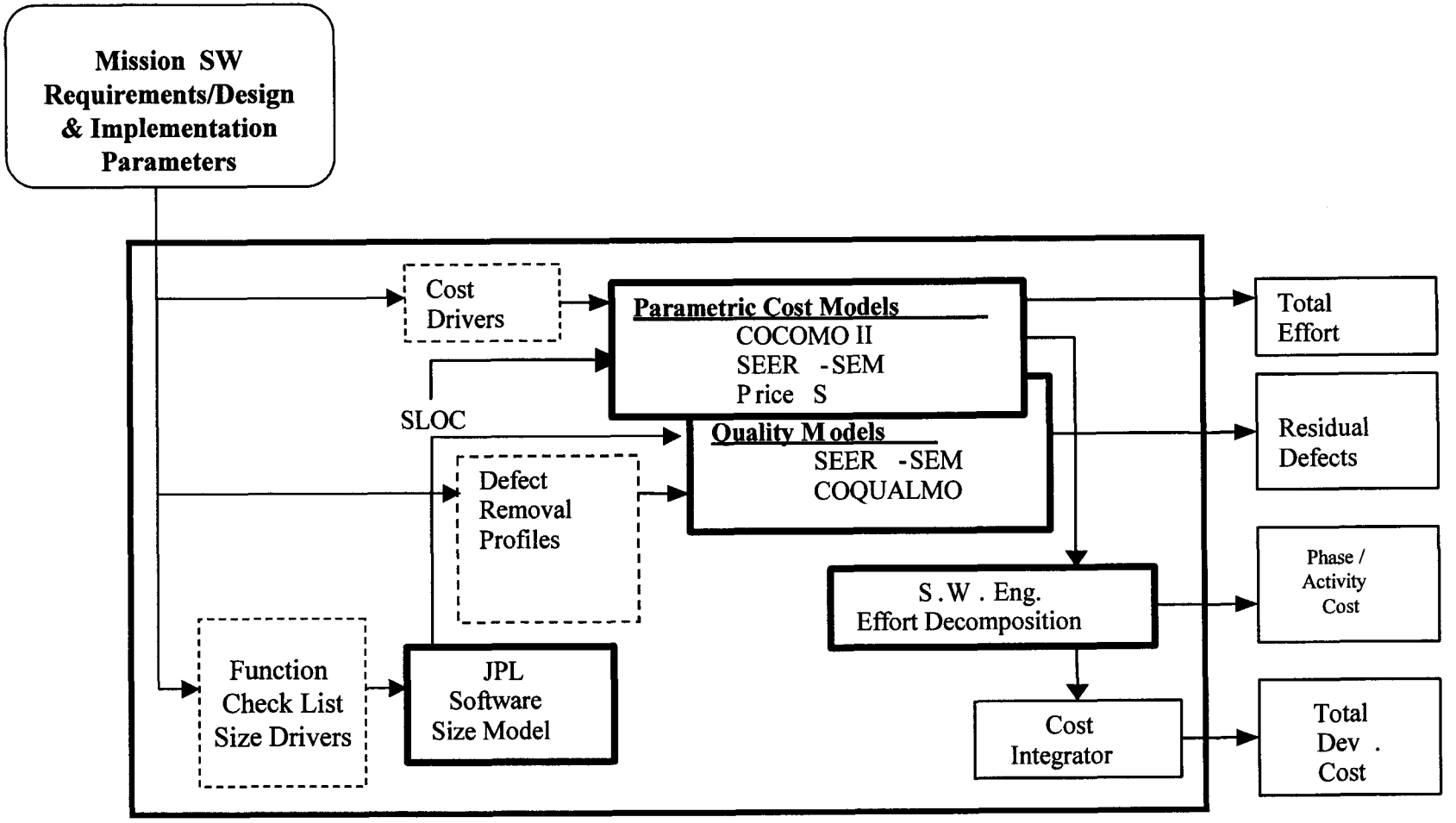
- Maintain objectivity
- Plan for change (it will happen)
- Use a comprehensive WBS
- Provide multiple estimates
- Incorporate Uncertainty and Risk
- Maintain history
  - Easier updates
  - Learn from your own history

Recommended Estimation Process

Use two or more people to develop cost estimates



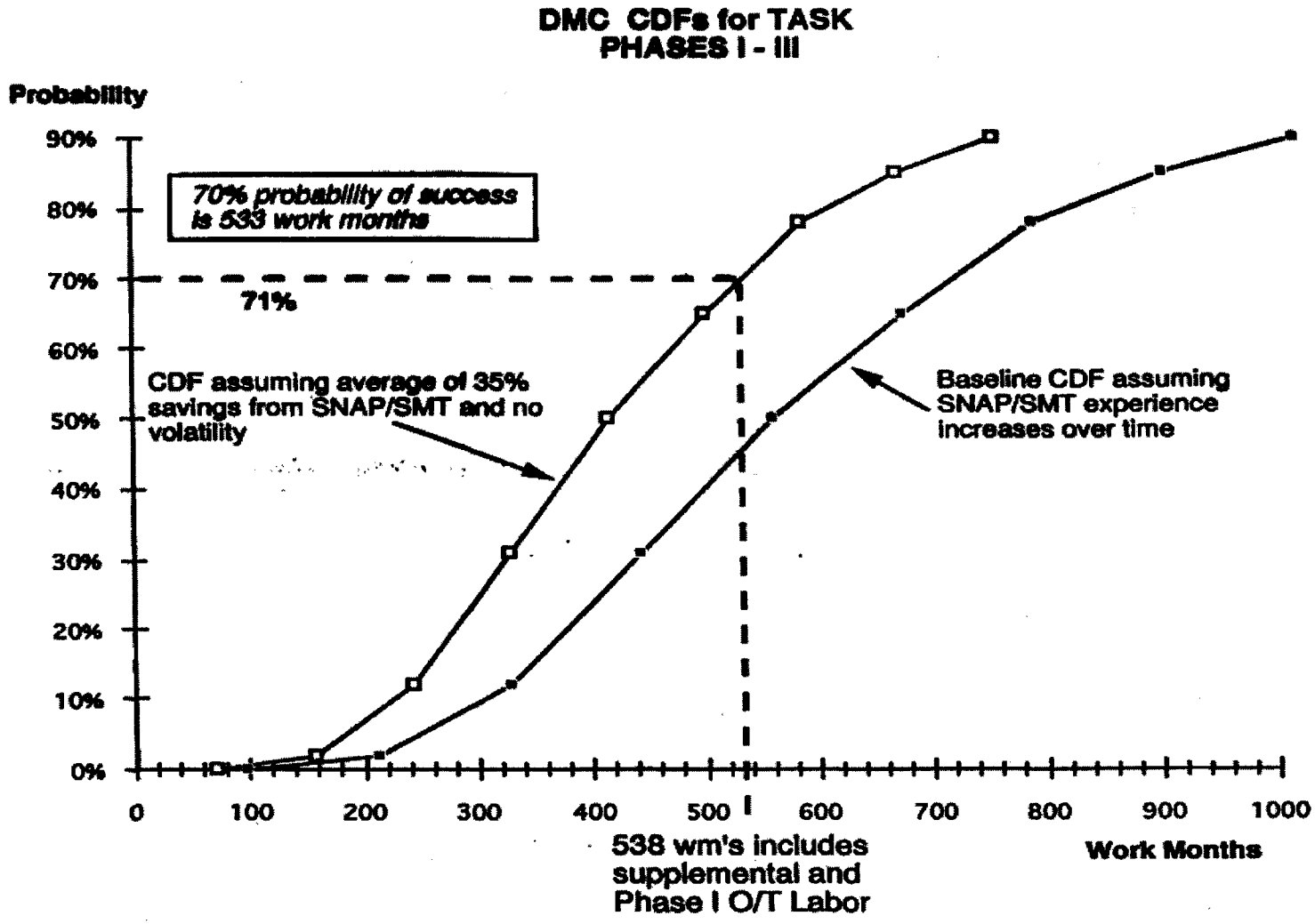
Cost & Quality Engineering Model Overview



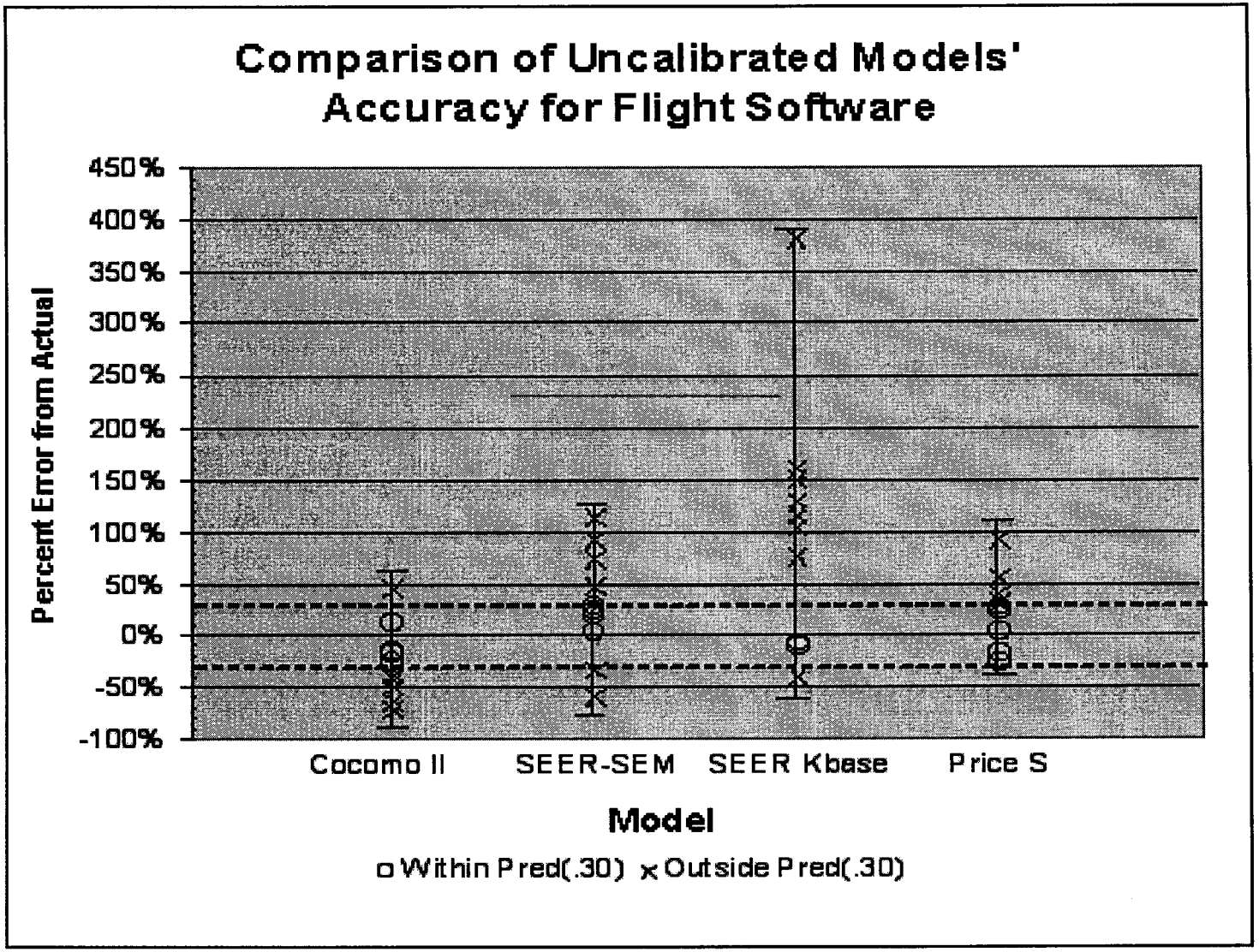
Incorporating Uncertainty

- After decomposing, recommend that a Low, Most Likely, and High estimate be provided along with the likelihood of observing a value outside of the range specified.
- This technique
  - captures the inherent uncertainty in the estimation process
  - can be applied to any estimation method
  - has been applied successfully on DSN software-intensive upgrade tasks for the past ten years
- Can recombine into a single cost distribution using functions built into most spreadsheets
  - distribution functions
  - random number generation

DSN Monitor & Control PDR Example (1)



Cost Model Validation & Calibration



Conclusion

- Based on your experience
  - What does not work for you?
  - What is missing?