What is Cost-Risk?

presented to
NASA RISK MANAGEMENT CONFERENCE
6 DEC 05

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OUTLINE

• What is Cost-Risk?
• Common Definition
• Cost Estimator Definition
  – Assessment
    • Cost Estimating Relationship (CER) Risk
    • Cost Driving Parameter Risk
    • Key Engineering Parameter Performance (KEPP) Risk
    • Correlation Risk
  – Analysis
    • Convolution (e.g., analytic; monte carlo)
Common Definition

• “The potential for final costs to exceed the target cost”
• …something like that anyway
Cost Estimator’s Definition

• “Cost-risk is composed of five elements:
  – CER Risk
  – Input Parameter Risk
  – Key Engineering Parameter Performance (KEPP) Risk
  – Correlation Risk
  – Convolution of Distributions

• These type of risks are intended to be “known unknowns”
Cost-Risk Assessment & Analysis

• Assessment
  1. **Cost model risk**
     • Cost estimators handle this
  2. **Input parameter risk**
     • Engineering assessment needed
  3. **Key Engineering Parameter Performance (KEPP) risk**
     • Engineering assessment needed
     • 3 WBS element risk profiles (pessimistic, optimistic & reference) evaluated in terms of cost-risk drivers
  4. **Correlation risk**
     • Engineering/cost estimator assessment needed

• Analysis
  – Convolve all distributions for “S”-curve (CDF)
Cost-Risk Assessment

1. Cost model risk
   - Accomplished in ESAS FY 06-11 cost-risk

2. Input parameter risk
   - Accomplished in ESAS FY 06-11 cost-risk
Cost Model and Input Parameter Risk

Cost Quantification

\[ \text{Cost} = a + bX^c \]

Input variable

Historical data point

Cost estimating relationship

Standard percent error bounds

CER

\[ \text{Cost} = a + bX^c \]

THE AEROSPACE CORPORATION
3. **Key Engineering Parameter Performance (KEPP) risk**

- A Key Engineering Performance Parameter is a technical or operational parameter that can be described as a requirement

- **Partially** Accomplished in ESAS FY 06-11 cost-risk

  - Adds cost-risk impacts due to TRL, Design/Engineering, Integration, Requirements Stability, Complexity, etc., risks
  - Relative Risk Weighting process & NAFCOM can capture these risks
Key Engineering Performance Parameters\(^1\) (KEPP) Examples

- KEPPs for new electronic component for a S/C
  - Dynamic load resistance
  - Operating voltage
  - Power regulation
  - Radiation resistance
  - Emissivity
  - Component mass
  - Operating temperature range
  - Operating efficiency

- KEPPs for a Laser/Amplifier Transmitter
  - Wave front sensing
  - Wave generation
  - Mirror coatings and gratings
  - Autonomous resonator alignment
  - Bore sighting
  - Electrical power generation

\(^1\)The Technology Puzzle: Quantitative Methods for Developing Advanced Aerospace Technology; Liam Sarsfield (RAND)
### RRW Implemented in Excel
(Degree System’s KEPPs Impacted by Cost-Risk Drivers in each Scenario)

#### COST-RISK DRIVERS

<table>
<thead>
<tr>
<th>TRL</th>
<th>Des/Eng</th>
<th>Schedule</th>
<th>Integration</th>
<th>Regts Stab</th>
<th>Risk Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pessimistic</td>
<td>0.048</td>
<td>0.111</td>
<td>0.058</td>
<td>0.049</td>
<td>0.345</td>
</tr>
<tr>
<td>Reference</td>
<td>0.020</td>
<td>0.027</td>
<td>0.026</td>
<td>0.016</td>
<td>0.102</td>
</tr>
<tr>
<td>Optimistic</td>
<td>0.014</td>
<td>0.023</td>
<td>0.007</td>
<td>0.016</td>
<td>0.071</td>
</tr>
</tbody>
</table>

#### Intensities

- Very High: 0.397, 0.370, 0.385, 0.442, 0.534
- High: 0.240, 0.220, 0.262, 0.243, 0.216
- Moderately High: 0.139, 0.150, 0.171, 0.142, 0.094
- Moderate: 0.099, 0.089, 0.078, 0.081, 0.070
- Moderately Low: 0.070, 0.075, 0.049, 0.047, 0.044
- Low: 0.033, 0.054, 0.034, 0.026, 0.026
- Very Low: 0.022, 0.042, 0.021, 0.019, 0.016

#### Ratio Scale
- Pess/Reference Ratio: 3.4
- Opt/Reference Ratio: 0.7
Cost-Risk Assessment
(cont)

4. Correlation risk
   – Accomplished in ESAS
CORRELATION

• What is Correlation?\(^2\)
  – A measure of association between two variables
  – It measures how strongly the variables are related, or change, with each other

• Engineers and CRM specialists can assist cost estimators in identifying and quantifying correlation between WBS elements or systems

\(^2\) www.statlets.com/usermanual/glossary.htm
Correlation

- Dr. Stephen Book (MCR) plotted the theoretical underestimation of percent total cost standard deviation (y-axis) when correlation (x-axis) is assumed to be zero rather than its true value, $\rho$.
  - In cost estimates we would underestimate % SD ~60%-80% if we ignored correlation and it was actually 0.2

From: 1999 Cost Risk Analysis Seminar, Manhattan Beach, CA
Cost-Risk Analysis

• Analysis
  – Convolve all distributions for “S”-curve (CDF)
Cost-Risk Analysis: Convolution

**CORRELATED SUBSYSTEM & SYSTEM COST DISTRIBUTIONS:**

- RPE
- CER, Parameter Input, and KEPP Cost-Risk Distributions

**SUMMARY COST DISTRIBUTIONS:**

- BELL CURVE
- "S"-CURVE

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\[ \sum_{\text{RPE}} \text{cost} \]

\[ \sum_{\text{RPE}} \text{density} \]