Using Cost Models to Capture Project Risk: A Knowledge-Based Approach

Dr. Ricardo Valerdi
Massachusetts Institute of Technology
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[rvalerdi@mit.edu]
We Share A Goal: Enterprise Excellence
1. **Systems engineering** can be the blessing or the curse
   - Resource estimation methods are being developed

2. **Technology maturity and requirements stability** are controllable risks
   - Cost models help understand this relationship

3. **People** risks are often underestimated
   - Experience and capability are not interchangeable

4. By the **time** the risk is identified, it’s too late!
   - Need leading indicators (not lagging indicators)
Cost Commitment on Projects

Constructive Systems Engineering
Cost Model

- # Requirements
- # Interfaces
- # Scenarios
- # Algorithms
- 3 Adj. Factors

Size
Drivers

Effort
Multipliers

Application factors
8 factors
Team factors
6 factors

3 Adj. Factors
Calibration

COSYSMO

Effort

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Systems Engineering Processes

- **Acquisition and Supply**
  - Supply Process
  - Acquisition Process

- **Technical Management**
  - Planning Process
  - Assessment Process
  - Control Process

- **System Design**
  - Requirements Definition Process
  - Solution Definition Process

- **Product Realization**
  - Implementation Process
  - Transition to Use Process

- **Technical Evaluation**
  - Systems Analysis Process
  - Requirements Validation Process
  - System Verification Process
  - End Products Validation Process
<table>
<thead>
<tr>
<th>Company</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boeing</td>
<td><strong>Integrated Defense Systems (Seal Beach, CA)</strong></td>
</tr>
<tr>
<td>Raytheon</td>
<td><strong>Intelligence &amp; Information Systems (Garland, TX)</strong></td>
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<tr>
<td>Northrop Grumman</td>
<td><strong>Mission Systems (Redondo Beach, CA)</strong></td>
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<tr>
<td>Lockheed Martin</td>
<td><strong>Transportation &amp; Security Solutions (Rockville, MD)</strong></td>
</tr>
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<td></td>
<td><strong>Integrated Systems &amp; Solutions (Valley Forge, PA)</strong></td>
</tr>
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<td></td>
<td><strong>Systems Integration (Owego, NY)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Aeronautics (Marietta, GA)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Maritime Systems &amp; Sensors (Manassas, VA; Baltimore, MD; Syracuse, NY)</strong></td>
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<tr>
<td>General Dynamics</td>
<td><strong>Maritime Digital Systems/AIS (Pittsfield, MA)</strong></td>
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<td></td>
<td><strong>Surveillance &amp; Reconnaissance Systems/AIS (Bloomington, MN)</strong></td>
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<tr>
<td>BAE Systems</td>
<td><strong>National Security Solutions/ISS (San Diego, CA)</strong></td>
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<td></td>
<td><strong>Information &amp; Electronic Warfare Systems (Nashua, NH)</strong></td>
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<td>SAIC</td>
<td><strong>Army Transformation (Orlando, FL)</strong></td>
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<td></td>
<td><strong>Integrated Data Solutions &amp; Analysis (McLean, VA)</strong></td>
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<tr>
<td>L-3 Communications</td>
<td><strong>Greenville, TX</strong></td>
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</tbody>
</table>
Traditional Cost and Schedule Risk Estimation

Determine Sources of Risk
- Risk Taxonomy
- Organizational Lessons Learned

Assess/Estimate Possible Risk Impacts
- Ranges of Values of Size, Productivity, & Other Parameters

Estimate Cost & Schedule Risks
- Ranges of Cost & Schedule Values & Probabilities

Select Cost and Schedule

Risk Assessment

Management Decision

http://lean.mit.edu
Expert COSYSMO Operation

Integrated Estimation and Risk Analysis

Cost Estimate with Uncertainty Ranges

Risk Assessment
- Identification
- Analysis
- Prioritization

Risk Control
- Planning
- Monitoring

User Input

Size Drivers

Cost Drivers

Rule-Based Risk Heuristics

Cost Estimating Relationship


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## Initial Risk Conditions

| Category                                                                 | SIZE (REQ + INTF + ALG + OPSC) | RQMT | ARCH | LSVC | MIGR | TRSK | DOCU | INST | RECU | TEAM | PCAP | PEXP | PROC | SITE | TOOL |
|--------------------------------------------------------------------------|-------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| SIZE                                                                     | 21                            | 21   | 9    | 12   | 5    | 4    | 7    | 10   | 8    | 9    | 11   | 7    | 6    | 7    |      |
| Requirements Understanding                                               | 17                            | 9    | 7    | 8    | 3    | 5    | 9    | 5    | 10   | 8    | 5    | 4    | 1    |      |
| Architecture Understanding                                              | 9                             | 10   | 12   | 3    | 7    | 11   | 6    | 11   | 6    | 11   | 5    | 6    | 4    |      |
| Level of Service Requirements (theilities)                              | 9                             | 10   | 12   | 3    | 7    | 11   | 6    | 11   | 6    | 11   | 5    | 6    | 4    |      |
| Migration Complexity (legacy system considerations)                      | 8                             | 1    | 10   | 1    | 4    | 7    | 7    | 3    | 5    | 4    |      |      |      |      |
| Technology Risk (maturity of technology)                                | 2                             | 8    | 6    | 4    | 9    | 5    | 3    | 3    | 5    |      |      |      |      |      |
| Documentation match to life cycle needs                                 | 2                             | 3    | 4    | 4    | 2    | 6    | 2    | 3    |      |      |      |      |      |      |
| Number and Diversity of Installations or Platforms                       | 2                             | 3    | 4    | 4    | 2    | 6    | 2    | 3    |      |      |      |      |      |      |
| Number of Recursive Levels in the Design                                 | 1                             | 2    | 3    | 4    | 2    | 6    | 2    | 3    |      |      |      |      |      |      |
| Stakeholder Team Cohesion                                                | 7                             | 9    | 3    | 8    | 3    |      |      |      |      |      |      |      |      |      |
| Personnel/team capability                                                | 12                            |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Personnel Experience and Continuity                                      | 10                            | 8    | 3    |      |      |      |      |      |      |      |      |      |      |      |
| Process Capability                                                       | 10                            | 8    | 3    |      |      |      |      |      |      |      |      |      |      |      |
| Multisite Coordination                                                   | 10                            | 8    | 3    |      |      |      |      |      |      |      |      |      |      |      |
| Tool Support                                                             | 10                            | 8    | 3    |      |      |      |      |      |      |      |      |      |      |      |

Risk Network

Risk Categories  Risk Items  Mitigation Guidance Items

- **Product**
  - ARCH_RECU
  - **Prototype**
    - PRR = Σ RE

- **People**
  - ARCH_PCAP
  - **Hire**
    - PRR = Σ RE
  - ARCH_MIGR
  - Rescope
    - PRR = Σ RE

- **Platform**
  - RECU_PCAP
  - RE = Risk Exposure
  - PRR = Potential Risk Reduction

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Expert COSYSMO Inputs

http://csse.usc.edu/tools/ExpertCOSYSMO.php
### Systems Engineering Effort = 3635 Person-months

#### Effort Distribution (Person-Months)

<table>
<thead>
<tr>
<th>Phase / Activity</th>
<th>Conceptualize</th>
<th>Develop</th>
<th>Operational Test and Evaluation</th>
<th>Transition to Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition and Supply</td>
<td>71.3</td>
<td>129.8</td>
<td>33.1</td>
<td>20.4</td>
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<tr>
<td>Technical Management</td>
<td>136.0</td>
<td>234.9</td>
<td>154.5</td>
<td>92.7</td>
</tr>
<tr>
<td>System Design</td>
<td>370.9</td>
<td>436.3</td>
<td>185.4</td>
<td>98.2</td>
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<tr>
<td>Product Realization</td>
<td>70.9</td>
<td>163.6</td>
<td>174.5</td>
<td>136.3</td>
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<tr>
<td>Product Evaluation</td>
<td>202.9</td>
<td>304.3</td>
<td>450.9</td>
<td>169.1</td>
</tr>
</tbody>
</table>

#### Risk Summary

- **Product**: 60
- **Process**: 2
- **Personnel**: 20

#### Prioritized Risks

- **High**
  - requ_arch
  - requ_migr
  - requ_trsk
  - requ_team
- **Medium**
  - requ_serv
  - requ_oov
  - requ_tool
- **Low**
  - serv_migr
  - serv_trsk
  - serv_team
  - serv_pexp
  - serv_tool
  - migr_team
  - migr_migr
  - migr_trsk
  - migr_team
  - migr_tool
  - trsk_team
  - trsk_pexp
  - trsk_tool
## Risk Mitigation Guidance

The risk mitigation guidance below shows alternatives for consideration in specific project environments.

<table>
<thead>
<tr>
<th>Risk Severity</th>
<th>Description</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Requirements Understanding = Very Low and Architecture Understanding = Very Low</td>
<td>Subcontract, prioritize requirements, cancel project</td>
</tr>
<tr>
<td>High</td>
<td>Architecture Understanding = Very Low and Technology Risk = Very High</td>
<td>Early prototyping, trade studies, negotiation on priorities</td>
</tr>
<tr>
<td>High</td>
<td>Architecture Understanding = Very Low and Personnel Experience/Continuity = Very Low</td>
<td>Hire experts, establish educational benefits, conduct training</td>
</tr>
</tbody>
</table>
Risk Exposure Trends as Leading Indicators

- Risk burndown tracked as mitigation actions are executed and other changes occur
Publicly Available Resources

• U.S. General Accountability Office (http://gao.gov/)
  • Investigative arm of the U.S. Congress

• RAND Corporation (http://rand.org/)
  • Public think tank
  • “Managing Risk in USAF Force Planning”

• Defense Acquisition University (https://acc.dau.mil)
  • One of several U.S. Military Universities
  • “DoD Risk Management Guidebook “