High Maturity System/Software Cost Estimation

November 14, 2007

Richard L. W. Welch, PhD
Northrop Grumman Integrated Systems
- Who we are
- State of the industry
  - Our track record
- Key relationships between CMMI goals and practices and high maturity cost estimating behaviors
- Practical advice on implementing high maturity behaviors
- Summary

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What Is Achievable?

- Industry record is dismal
  - 2006 Chaos Report
    - 46% of projects are "challenged" with cost or schedule overruns or requirements gaps
    - 19% of projects fail
  - Barry Boehm’s data indicate a ± 50% proposal accuracy is common

What Is Achievable?

- Root cause analysis is difficult to establish
  - End-of-job actuals are confounded with the project management track record
  - Credit, or blame, must be shared

- Our track record
  - Seven major SW development projects completed 1998-2007
    - Median SW cost performance index (CPI) = 102%
    - All projects completed on schedule with schedule performance index (SPI) = 100%
  - As-delivered SW quality at six-sigma levels
Key Relationships

Mapping of CMMI Goals/Practices to Key Estimating Behaviors
Getting Started

Generic Practices

- “Must-win” estimating efforts
  - Are planned and managed like projects
  - Follow a defined process
  - Are executed by a team of product & estimating specialists

- All relevant IPTs, engineering disciplines, and other stakeholders must commit to the estimate
  - Identify & involve (with mutual agreement)
  - Monitor & control
  - Objectively evaluate
  - Review status with higher management
The Basics

PP SG 1 Establish Estimates
- Determining
  - What's in/what's out
  - SW sizing
  - SW estimate

PP SG 2 Develop Project Plan
- Ensuring executability
  - Schedule & staffing
  - Risk reducers
  - Reuse plan
  - SW build plan

PP SG 3 Obtain Commitment
- Herding the cats
  - System/Software/Test

QPM SG 2 Statistical Performance

OPP SG 1 Baselines & Models

PP = Project Planning
QPM = Quantitative Project Management
OPP = Organizational Process Performance
"Closed Loop" Estimating

- IPM SG 1 Getting to a Defined Process
  - Estimating the process defines the process
  - The estimate depends on the process baseline, closing the estimating loop

- IPM SG 2 & 3 Working with Committed Team Mates
  - SW Cost Working Group
  - SW Process Management Team

SAM SG 1 Supplier Agreements

IPM = Integrated Project Management
SAM = Supplier Agreement Management
Using Maturity to Your Advantage

QPM SG 1 The Quantitatively Defined Process

Expanding the definition of process
- Estimating with knowledge of process variance in SW size, cost, schedule, staffing, etc.
- Confidence/risk predictions
- Monte Carlo validation
- Life Cycle Cost optimization

QPM SG 2 Statistical Management

OPP SG 1 Performance Baselines & Models

- Providing a high maturity infrastructure
- Enabling history & risk based estimating

QPM = Quantitative Project Management
OPP = Organizational Process Performance
Practical Advice

How a High Maturity Organization Approaches System/Software Cost Estimation
- No rogues
  - *We don't need no stinking process!*

- Manage the estimate
  - One is better than many
  - Who's on First?
  - Two is better than one

- Parametric tools work
  - How do you use them credibly?

- Ensure executability
  - Think about execution risk. Your management and your Customer do
  - Risk items will be in the Customer's evaluation of Most Probable Cost. Addressing them in the bid is up to you
  - Know how your Customer scores an estimate
  - Avoid the Lake Wobegon syndrome. You need cost realism and reasonableness

- Justify, justify, justify reuse
  - Establish the pedigree and substantiate the choice
Follow a Defined Estimating Process

- **SW Sizing procedure**
  - Allowable methods
  - Counting rules
  - Reuse sizing
  - Checklists

- **SW Estimation procedure**
  - SW Cost Working Group
  - Parametric Model for size-based components
  - Discrete methods for other costs

- **Discipline review & approval**

*Ill-defined processes introduce risk and justify estimate plus-ups.*
One Is Better Than Many

Software Cost Working Group (SCWG)

Our SCWG anticipates the SW Process Management Team that will oversee and manage the development after contract award.

- Responsible to produce a unified & integrated system/software cost model for the project
- Rules of engagements for team members
- Review of software technical and mgmt metrics reported by each team member
- Review of software estimates reported by each team member
- Review of cost modeling parameters reported by each team member
- Coordination & communication among the SCWG members to ensure mgmt commitment by all
- SW process issues
- SW estimation risk
- Issue and monitor estimating actions

Team Mate

Team Mate

Team Mate

Team Mate
Two Is Better Than One

Independent Estimates

- **SW Sizing**
  - Good: multiple, independent reviews of all size estimates by the SCWG and third party team of experts
  - Better: independent estimates with the same technique (with reviews)
  - Best: independent estimates with different techniques (with reviews)

- **SW Estimation** addressed on next slide
Tools Work

- Very accurate – when properly calibrated & used
- Know your Customer preference

**Key PRICE S Input Parameters**
- Platform
- Management Complexity
- Internal & External Integration
- Utilization
- Schedule Constraints
- Language & Productivity Factors
- Application Factors
- COTS & Furnished CSCI Data
- Risk Parameters

**Key SEER-SEM Input Parameters**
- Experience/Capabilities
- Development Support Environment
- Development Environment Complexity
- Schedule & Staff Constraints
- Product Development Requirements
- Reusability
- Target Environment
- Confidence Level (50%-80%)

**Government Funding & Events**
- WBS, Software Build Plan, and Software Reuse

**System Description**
- TRD Requirements
- Derived Requirements
- Baseline Solution
- CAIV Constraints

**Software BOE**
- WBS, Schedule, Effort by Labor Category
- Teammate Quotes

**Risk-Adjusted Estimation Model**
- Demonstrated Performance
- Software Schedule
- Validated Effort & Schedule
- Design-to-Cost Constraints

Recognize that your bid defines the project's process.
- 50/50 bids do not always make the most sense
  - If you are bidding mean performance, you are almost certainly not at 50/50 anyway
  - Management or Customer direction
- 80/20, 90/10, or other bid strategies require process performance baselines that capture statistical variation in the process
- Commercial parametric tools do offer these capabilities
  - Variable Risk/Confidence settings for parameters & estimates
  - Monte Carlo risk analyses

Air Force policy is to estimate and fund programs to a high (80-90%) confidence. That is to say, programs are to be estimated and funded so that the total program costs for any given program would be less than the budget 80-90% of the time. Also, program milestones and program completion should meet the planned schedule 80-90% of the time.

Sources: US Air Force Software Management Guidebook, V0.9, December 2004. SEER-SEM screenshot on this page is from Galorath’s “Regional Tactical Simulation” example.
Ensure Executability

- **Functional discipline reviews**
  - Estimation methodology
  - Process, metrics & performance baselines
  - Indirect & other non-project commitments
- **Non-Advocate Review (NAR)**
  - Ensure program is executable within cost and schedule proposed and do not expose the company to unacceptable risk
  - Is the program executable?
- **Independent Cost Evaluation (ICE)**
  - Independent, objective evaluation of proposed costs, designed to assess the reasonableness of the bases of estimates (BOEs) cost risks associated with program execution, and the resultant financial impacts
  - Is the cost realistic?
Risk Items

- Specific allowances in estimate
  - SW growth
    - Holchin, Popp studies
    - Planned vs. unplanned growth
  - Build currency with incremental development
  - Maintenance of the SW baseline between completion of software integration & test and final system delivery to the Customer
- Multi-site development
  - Multiple Site Development in SEER-SEM
  - Management Complexity (CPLXM) in Price
- Security requirements

Other Customer Concerns

- Customer funding profile
- Compatibility of detailed SW Build Plan with availability of all hardware, software, and lab components
  - Traceability of the SW Build Plan to the IMS
- CMMI maturity of all system/software sites that are part of the development team
- Managing the development team to have one unified system/software development process
# Alignment of Processes with Subs

<table>
<thead>
<tr>
<th>CMMI Process Areas</th>
<th>Prime</th>
<th>Subs</th>
<th>CMMI Process Areas</th>
<th>Prime</th>
<th>Subs</th>
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<tbody>
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<td><strong>Level 2</strong></td>
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<td><strong>Level 3 (continued)</strong></td>
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<tr>
<td>Requirements Management</td>
<td>✓</td>
<td>✓</td>
<td>Organizational Process Definition</td>
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<td>Project Planning</td>
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<td>Organizational Training</td>
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<td>Project Monitoring &amp; Control</td>
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<td>✓</td>
<td>Integrated Project Management for IPPD</td>
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<tr>
<td>Supplier Agreement Management</td>
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<td>Risk Management</td>
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<td>Measurement &amp; Analysis</td>
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<td>Integrated Teaming</td>
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<td>Product &amp; Process Quality Assurance</td>
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<td>Integrated Supplier Management</td>
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<td>Configuration Management</td>
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<td>Organizational Environment for</td>
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<td>Requirements Development</td>
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<td>Technical Solution</td>
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<td>Organizational Process Focus</td>
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<td>Notes:</td>
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<tr>
<td>(1) Subcontractor internal processes and IPT operations integrate with prime’s processes.</td>
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<td>(2) System requirements are allocated by prime; subcontractors develop requirements at the configuration item (CI) level.</td>
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<td>(3) All subcontractors integrate, verify and validate their products to the CI or subsystem level; this includes integration of software CIs into hardware CIs or line replaceable units (LRUs). Prime integrates, verifies and validates at the system level</td>
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<td>(4) Subcontractors follow their own CMMI-compliant business processes.</td>
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<td>(5) Prime is responsible team’s process control and optimization.</td>
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Your Advantage

- **Statistical process control (SPC)** reduces programmatic risk
  - Gives superior insight into average performance and variability of the controlled processes
  - Higher confidence estimates
  - Enhances predictability and stability in executing the job
  - Enables proactive process improvement to meet management or Customer performance targets
  - Removal of "common cause" variation from the process
Government BOE Scoring Criteria

<table>
<thead>
<tr>
<th>Color</th>
<th>Definition and Examples</th>
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<tbody>
<tr>
<td>Red</td>
<td>Estimate <strong>un-substantiated</strong> by supporting data. This definition includes un-supported engineering estimates and declarative statements (i.e., the xyz task will require three engineers for five months).</td>
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<tr>
<td>Yellow</td>
<td>Estimate <strong>not well correlated to, or substantiated</strong> by supporting data. In general, engineering estimates were based on the estimator’s experience and expertise is substantiated, the use of non-substantiated scaling factors, use of comparatives where relevance of comparative is not substantiated. Note: Past experience shows that engineering estimates receive no higher than yellow.</td>
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<tr>
<td>Green</td>
<td>Estimate supported by <strong>relevant</strong> comparable data from similar programs and/or <strong>validated parametric</strong> estimating systems.</td>
</tr>
<tr>
<td>Blue\Green</td>
<td>Estimate supported by <strong>relevant</strong> comparable data from multiple similar programs.</td>
</tr>
<tr>
<td>Blue</td>
<td>Estimate supported by <strong>production experience</strong> and/or <strong>cost trend data</strong> for “multiple programs.”</td>
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</table>

Source: ESC Training material
Avoid the Lake Wobegon Syndrome

- History matters – Customers will not accept forecasting an unrealized productivity improvement

"All the women are strong, all the men are good-looking, and all the children are above average"
Garrison Keillor
Justify, Justify, Justify Reuse

Establish the Pedigree

- Source
- Functionality provided
- Maturity & certifications
- In-house expertise
- Previous use
- Existing runtime & support environments
- Existing test procedures
- Portability
- Maintainability, reliability, quality

Don’t neglect COTS software & hardware.
Justify, Justify, Justify Reuse

Substantiate the Choice

- SW reuse checklists
- SW reuse worksheets
- Software Evaluation Assurance Lab (SEAL) reports
- Integration with other software in the project’s System Integration Lab
- CMMI goals and practices should be used to shape your engineering estimating process
- Estimates should be planned and managed like projects
- Parametric tools work
  - Tune them to your process performance models and baselines
- Estimate must be executable
  - Use your process performance models and baselines to achieve the desired confidence level
- SW reuse must be justified