SEER-SEM + CMMI = High Maturity
Software Cost Estimation

2008 SEER User Conference
Redondo Beach, CA

April 8-10, 2008

Richard L. W. Welch, PhD
Associate Technical Fellow
Northrop Grumman Integrated Systems
Topics

- 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

Andreas R. Felschow
SEI Authorized Lead Appraiser
The Process Company, LLC

Kevin M. Cotherman
SEI CMMI Lead Appraiser
The Process Company, LLC

Major Software-Intensive Programs
- E-8C Joint STARS
- E-4D Advanced Hawkeye
- E/A-18G Growler
- KC-45A Tanker
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 confound the accuracy of the proposal with management track record during project execution
  - 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 in the CMMI

- **“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
Project Management Basics

**PP - Establish Estimates**
- Determining
  - What’s in/what’s out
  - SW sizing
  - SW estimate

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

**PP - Obtain Commitment**
- Herding the cats
  - System/Software/Test

**QPM - Statistical Performance**

**OPP - Baselines & Models**

**PP = Project Planning**
**QPM = Quantitative Project Management**
**OPP = Organizational Process Performance**
“Closed Loop” Estimating

IPM Define & Use the Project’s Process

• Estimating the process defines the process
• The estimate depends on the process baseline, closing the estimating loop

IPM Work with Committed Team Mates

• SW Cost Working Group
• SW Process Management Team

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

QPM - Quantitatively Manage Processes

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 - Statistically Manage Subprocesses

OPP - Establish 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
Principles

- 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

- Avoid the Lake Wobegon syndrome
  - Using parametric tools credibly to ensure cost realism and reasonableness

- Ensure executability
  - Execution risk – do you think about it? Your management and your Customer do
  - Specific risk items will be in the Customer’s evaluation of Most Probable Cost. Addressing them is your choice
  - Ditto for your Customer’s other concerns
  - Know how your Customer scores an estimate

- Justify, justify, justify reuse
  - Establish the pedigree and substantiate the choice
No Rogues

Follow a Defined Estimating Process

- SW Sizing procedure
  - Allowable methods
  - Counting rules
  - Reuse sizing
  - Checklists
- SW Estimation procedure
  - SW Cost Working Group
  - Parametric size-based estimate
    - SEER-SEM is our preferred tool
  - Discrete methods for other costs
- SW Estimating reference manual
- Discipline review & approval

*Ill-defined processes introduce risk and justify estimate plus-ups.*

---

Copyright 2005 Northrop Grumman Corporation
One Is Better Than Many
Software Cost Working Group (SCWG)

SW Cost Working Group
- Responsible to produce a unified & integrated 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

One team → one model
Two Is Better Than One
Independent Estimates of 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)
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
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?
Execution Risk

- 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.
Customer Risk Items

- Specific allowances in the estimate
  - SW growth
    - Holchin, Popp studies
    - Planned vs. unplanned growth
  - Build currency with incremental development
  - Maintenance of the SW baseline before final system delivery
  - Multi-site development
  - Security

### Other Customer Concerns

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

<table>
<thead>
<tr>
<th>CMMI Process Areas</th>
<th>Prime</th>
<th>Subs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements Management</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Project Planning</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Project Monitoring &amp; Control</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Supplier Agreement Management</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Measurement &amp; Analysis</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Product &amp; Process Quality Assurance</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Configuration Management</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CMMI Process Areas</th>
<th>Prime</th>
<th>Subs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements Development</td>
<td>✓</td>
<td>(2)</td>
</tr>
<tr>
<td>Technical Solution</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Product Integration</td>
<td>✓</td>
<td>(3)</td>
</tr>
<tr>
<td>Verification</td>
<td>✓</td>
<td>(3)</td>
</tr>
<tr>
<td>Validation</td>
<td>✓</td>
<td>(3)</td>
</tr>
<tr>
<td>Organizational Process Focus</td>
<td>✓</td>
<td>(4)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CMMI Process Areas</th>
<th>Prime</th>
<th>Subs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organizational Process Definition</td>
<td>✓</td>
<td>(4)</td>
</tr>
<tr>
<td>Organizational Training</td>
<td>✓</td>
<td>(4)</td>
</tr>
<tr>
<td>Integrated Project Management for IPPD</td>
<td>✓</td>
<td>(1)</td>
</tr>
<tr>
<td>Risk Management</td>
<td>✓</td>
<td>(1)</td>
</tr>
<tr>
<td>Integrated Teaming</td>
<td>✓</td>
<td>(1)</td>
</tr>
<tr>
<td>Integrated Supplier Management</td>
<td>✓</td>
<td>(4)</td>
</tr>
<tr>
<td>Decision Analysis &amp; Resolution</td>
<td>✓</td>
<td>(1)</td>
</tr>
<tr>
<td>Organizational Environment for Integration</td>
<td>✓</td>
<td>(4)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CMMI Process Areas</th>
<th>Prime</th>
<th>Subs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organizational Process Performance</td>
<td>✓</td>
<td>(5)</td>
</tr>
<tr>
<td>Quantitative Project Management</td>
<td>✓</td>
<td>(5)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CMMI Process Areas</th>
<th>Prime</th>
<th>Subs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organizational Innovation &amp; Deployment</td>
<td>✓</td>
<td>(5)</td>
</tr>
<tr>
<td>Causal Analysis &amp; Resolution</td>
<td>✓</td>
<td>(5)</td>
</tr>
</tbody>
</table>

**Notes:**

1. Subcontractor internal processes and IPT operations integrate with prime’s processes.
2. System requirements are allocated by prime; subcontractors develop requirements at the configuration item (CI) level.
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.
4. Subcontractors follow their own CMMI-compliant business processes.
5. Prime is responsible team’s process control and optimization.
Use SPC to 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
**Know How Your Customer Scores an Estimate**

- They reward reality-based estimating
  - Model tuning with historical data
  - Reuse justification

<table>
<thead>
<tr>
<th>Color</th>
<th>Description</th>
</tr>
</thead>
<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>
</tr>
</tbody>
</table>
| Yellow| Estimate **not well correlated to, or substantiated** 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. |
| Green | Estimate supported by **relevant** comparable data from "similar programs" and/or **validated parametric** estimating systems. |
| Blue/| Estimate supported by **relevant** comparable data from "multiple similar programs." |
| Green | |
| Blue  | Estimate supported by **production experience** and/or **cost trend data for "multiple programs."** |

Source: ESC Training material

*"In God we trust, all others bring data"*  
*W. Edwards Deming*
Justify, Justify, Justify Reuse

- Establish the pedigree
  - Source
  - Reuse checklists & evaluation criteria ratings

- Substantiate the choice
  - SW reuse worksheets
  - Reuse %ages
  - SW assurance reports
  - Pre-award integration in the project’s System Integration Lab

Don’t neglect COTS software & hardware.
Summary

- CMMI goals and practices should shape your engineering estimating process
- Estimates should be planned and managed like projects
- SEER-SEM is key to cost realism and reasonableness
  - Tune the model to your process performance models and baselines
- Ensure your estimate is executable
  - Use SEER-SEM’s capabilities and your process performance models and baselines to achieve the desired confidence level
- SW reuse must be justified
QUESTIONS

Richard L. W. Welch, PhD
Northrop Grumman Corporation
(321) 951-5072
Rick.Welch@ngc.com