Extending CMMI Level 4/5 Organizational Metrics Beyond Software Development

CMMI Technology Conference and User Group
Denver, Colorado
14-17 November 2005

Linda Brooks
Northrop Grumman Corporation
Topics

- The Challenge
- The Pitfalls
- Background
- Proposed Approach
- Northrop Grumman Mission Systems Case Studies
- Summary
The Challenge

Extending organizational metrics beyond software development to achieve CMMI Levels 4/5 requires breaking new ground.

Few examples exist for project types such as systems engineering (SE), operations and maintenance (O&M), services, hardware development.

A repeatable process for developing such metrics that avoids typical pitfalls is needed.
5 Major Pitfalls

1. Getting the cart before the horse - business needs not driving metrics definition
2. Not taking advantage of in-house and/or industry experience
3. Industry or in-house examples implemented organization wide without evaluating needs and/or impact
4. Insufficient stakeholder buy-in
5. Cost of collecting the metrics greater than the benefits to be derived
Northrop Grumman Mission Systems

- A leading global integrator of complex systems
  - Based on information technology and systems engineering expertise
  - Integrated solutions: architecture, development and sustainment
- Over $5B 2004 Revenue
- 18,000+ Employees
- Diverse business base
  - 300 locations in 20 countries, 50 states
  - 2,000 active contracts and task orders
### CMMI Organizational Metrics Support Meeting Business Needs

- **Leverage organization historical data to ensure accurate estimates for new work**
  - Level 3: Historical data is the foundation for cost credibility and accuracy
- **Understand process performance to enable more effective management**
  - Level 4: Statistical process control – a means for understanding performance
- **Improve process performance to increase competitive edge**
  - Level 5: Improvement activities based on accurate measures

<table>
<thead>
<tr>
<th>Level</th>
<th>Process Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Optimizing</td>
<td>Causal Analysis and Resolution</td>
</tr>
<tr>
<td></td>
<td>Organizational Innovation and Deployment</td>
</tr>
<tr>
<td>4 Quantitatively Managed</td>
<td>Quantitative Project Management</td>
</tr>
<tr>
<td></td>
<td>Organizational Process Performance</td>
</tr>
<tr>
<td>3 Defined</td>
<td>Requirements Development</td>
</tr>
<tr>
<td></td>
<td>Technical Solution</td>
</tr>
<tr>
<td></td>
<td>Product Integration</td>
</tr>
<tr>
<td></td>
<td>Verification</td>
</tr>
<tr>
<td></td>
<td>Validation</td>
</tr>
<tr>
<td></td>
<td>Organizational Process Focus</td>
</tr>
<tr>
<td></td>
<td>Organizational Process Definition</td>
</tr>
<tr>
<td></td>
<td>Organizational Training</td>
</tr>
<tr>
<td></td>
<td>Risk Management</td>
</tr>
<tr>
<td></td>
<td>Integrated Project Management (for IPPD*)</td>
</tr>
<tr>
<td></td>
<td>Integrated Teaming*</td>
</tr>
<tr>
<td></td>
<td>Integrated Supplier Management**</td>
</tr>
<tr>
<td></td>
<td>Decision Analysis and Resolution</td>
</tr>
<tr>
<td></td>
<td>Organizational Environment for Integration*</td>
</tr>
<tr>
<td>2 Managed</td>
<td>Requirements Management</td>
</tr>
<tr>
<td></td>
<td>Project Planning</td>
</tr>
<tr>
<td></td>
<td>Project Monitoring and Control</td>
</tr>
<tr>
<td></td>
<td>Supplier Agreement Management</td>
</tr>
<tr>
<td></td>
<td>Measurement and Analysis</td>
</tr>
<tr>
<td></td>
<td>Process and Product Quality Assurance</td>
</tr>
<tr>
<td></td>
<td>Configuration Management</td>
</tr>
<tr>
<td>1 Performed</td>
<td></td>
</tr>
</tbody>
</table>
Supporting Infrastructure

**Mature metrics collection**
- Metrics repository
- Organization Metrics Manual
- Established organization baselines & models
- Established collection process

**Engineering Process Group**
- Provides stakeholder input
- Metrics/QM working group

**Six Sigma/Lean**
- Structure for improvement
- Tools & methods

**CMMI Level 5**
- Mature processes
- Structure for sharing best practices
Standard Metric Development Process Overview

- Starts when the metric sponsor identifies a business need
- A Metric Development Project Lead is appointed to lead the process
- The standard process ensures:
  - Metric development is integrated into the annual overall organizational metrics planning;
  - The relationship and effect on the organizational standard processes is considered;
  - All stakeholders are kept informed and can provide inputs;
  - Results are documented and appropriate approvals are obtained.
Step 1 – Business Need & Plan

- Develop business need description
- Identify Metric Sponsor, Metric Development Project Lead, affected process owners, other stakeholders
- Establish initial schedule for each process step and identify resources
- Coordinate with the organization stakeholders for integration with organization priorities and plans
- Document results
Step 2 – Analysis & Initial Recommendations

- Assess and evaluate related in-house metrics use
- Assess and evaluate related industry metrics use
- Analyze fit related to meeting business needs
- Evaluate potential impact on policy/processes/projects
- Specify proposed metrics
- Evaluate cost vs. benefit
- Document results
Step 3 – Verification & Approval

- Obtain stakeholder input and verification of satisfaction of business needs
- Update plans and metrics definition as needed
- Prepare draft Change Request and supporting documentation
- Document results
- Obtain required organization/CCB approvals (provide documented process results to approval authorities)
Step 4 – Implementation & Evaluation

- Implement metrics collection
- Analyze results
- Prepare results for use
- Prepare recommendations for changes or needed actions
Metric Development Documentation Outline

Business Need and Plan (documents results of process step 1)
- Business need description
- Metric Sponsor, Metric Dev Project Lead, stakeholder identification
- Target/actual completion date and status for each process step

Analysis and Initial Recommendation (documents results of process step 2)
- In-house metrics assessment
- Industry metrics assessment
- Other analysis results
- Impact evaluation
- Definition of proposed metric(s)

Verification and Approval (documents results of process step 3)
- Record of stakeholder input and review
- Mapping to business needs
- Change Request to related documentation
- Record of required org/CCB approvals

Post Collection Analysis and Recommendations (documents results of process step 4)
- Summary of analysis results and recommendations
Northrop Grumman Mission Systems Case Studies

- O&M Metrics Example
- Systems Engineering Metrics Example
O&M Metrics Development Example
Step 1 Highlight – Business Needs

➢ Prediction of effort for new work requires productivity values for key O&M processes
  - Defect Correction
  - Small Enhancements
  - Help Desk Support
  - Operations Support

➢ Additional needs to provide the organization with more useful process performance baselines and/or models

Background goal to limit impact on projects and the organization collection system
Step 2 Highlight – Analysis: Sources & Eval

➤ **In-house metric sources**

- Projects A, B and C
  - Projects used defect related metrics similar to development projects for project specific baselines/models
  - Recommend expanding defect metrics to O&M project activities
- Metrics currently collected as part of the organization data collection
  - Potentially useful productivity measures could be computed from metrics already being collected
  - Need more data points

➤ **Industry metric sources considered**

- SEER-SEM and COCOMO cost models
  - Use to validate productivity values
Step 3 Highlight – Verification Against Business Needs

- **Prediction of effort for new work**
  - Currently collect potentially useful metrics to enable computation of needed productivity measures

- **Providing more useful organization process performance baselines/models**
  - Potentially this need will be met by the currently collected data and the addition of selected defect data
  - Analysis against productivities derived from existing data shows promise

### Productivity = Size/Effort

<table>
<thead>
<tr>
<th>Process</th>
<th>Potential Size Metric(s)</th>
<th>Effort Metric From Related Standard WBS Line Item(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Defect Correction</td>
<td># base code SLOC,</td>
<td>12.1.3 Software Defect Correction</td>
</tr>
<tr>
<td>Small SW Enhancements</td>
<td># base code SLOC, # base code SLOC affected, # SLOC added, # SLOC changed # SLOC deleted</td>
<td>12.1.6 Software Enhancements</td>
</tr>
<tr>
<td>Help Desk Support</td>
<td># sites supported, # users supported, # calls per week, # hours per week</td>
<td>12.1.9 Help Desk Support</td>
</tr>
</tbody>
</table>
Step 4 Highlight – Eval of Collected Data

Notional raw defect correction productivity data

<table>
<thead>
<tr>
<th>Proj</th>
<th>Duration in Months</th>
<th>Completion Date</th>
<th>Software Defect Correction Hrs</th>
<th>Software Defect Correction Hrs Annualized</th>
<th>Defect Correction SLOC Maintained</th>
<th>5W Maintenance Productivity (Base SLOC/ Hrs Annualized)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>3/16/2003</td>
<td>11139</td>
<td>11139</td>
<td>722000</td>
<td>65</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>3/17/2003</td>
<td>69065</td>
<td>69065</td>
<td>3169925</td>
<td>63</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>6/12/2003</td>
<td>44513</td>
<td>28303</td>
<td>1546525</td>
<td>56</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
<td>11/2/2003</td>
<td>29449</td>
<td>12092</td>
<td>1368481</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Check shows data to be normally distributed

Control chart shows in-control process

Productivity useful for estimating and as organization baseline data
Systems Engineering (SE) Metrics Development Example
Step 1 Highlight – Business Needs

- Prediction of effort for new work requires productivity values for key systems engineering processes
  - Architecture definition, Concept of Operations Development (including scenario and use case development)
  - Requirements Analysis (including system, software, and hardware)
  - Major Interface Definition
  - Performance Modeling

- Additional needs to provide the organization with useful process performance baselines and/or models

- Provide ability to support development and use of COSYSMO estimating model
Step 2 Highlight – Analysis: Sources & Eval

- **In-house metric sources considered & eval**
  - Division Six Sigma Project on System Sizing Cost Estimating Relationships
    - COSYSMO size measures fit primary needs for division and organization use
  - Projects A, B use of cycle-time and other metrics for key processes
    - Metrics too specific for organization use
  - Currently collected SE metrics
    - Need a few additions to support desired productivity calculations
  - SE metrics discussion with stakeholders

- **Industry metric sources considered**
  - USC/Industry COSYSMO SE cost model
  - INCOSE Systems Engineering Measurement Primer
  - Papers and Presentations
Step 2 Highlight – Analysis: Candidate Process Performance Metrics

Productivity = Size/Effort

<table>
<thead>
<tr>
<th>Process</th>
<th>Potential Size Metric(s)</th>
<th>Effort Metric From Related Standard WBS Line Item(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements Analysis</td>
<td># system reqs, # SW reqs, # HW reqs, # scenarios</td>
<td>2.3 System Requirements, 2.5 SW Requirements Analysis, 2.4 HW Requirements Analysis</td>
</tr>
<tr>
<td>Architecture/Concept of Operations</td>
<td># system reqs, # SW reqs, # HW reqs, # scenarios</td>
<td>2.6 Architecture Analysis/System Design, 2.8 Operations Concept Definition</td>
</tr>
<tr>
<td>Major Interface Definition</td>
<td># interfaces</td>
<td>2.7 Interface Definition</td>
</tr>
</tbody>
</table>
Step 2 Highlight – Analysis: Constructive Systems Engineering Cost Model (COSYSMO)

- Part of COCOMO Suite of models being developed under the guidance of Dr. Barry Boehm, the Director of the Center for Software Engineering at USC.
- Goal to more accurately estimate the time and effort associated with performing the system engineering tasks defined by ISO/IEC 15288.
- Development started in 2002, with industry (USC affiliates) and INCOSE involvement.
- 42 historical data points from 6 companies; 15 business units.
- Northrop Grumman participating in the development and submittal of history data.

*Used with permission of Dr. Barry Boehm*
Step 2 Highlight – Initial Recommendations

- Include the four COSYSMO size parameters, with difficulty level
- Add hardware requirements metrics
- Add collection of defect data for system requirements, hardware requirements and scenario/use case reviews
- Proposed Mods to the organization Standard WBS
  - Separate architecture, SW COTS assessment, HW COTS assessment
  - Separate performance modeling and life cycle cost analysis

**Modifications to the organization data collection, Metrics Manual and related documents**
Step 3 Highlight – Verification Against Business Needs

- **Prediction of effort for new work**
  - Size and accounting data already collected or identified for addition can potentially meet this need
  - COSYSMO should be of use as well

- **Development of organization process performance baselines/models**
  - Potentially this need will be met by the recommended data
  - Analysis against productivities derived from existing data shows promise

- **Support of COSYSMO development & use**
  - Existing plus new metrics support this
Step 4 Highlight – Eval of Collected Data

Notional raw system requirements productivity data

<table>
<thead>
<tr>
<th>Project</th>
<th># Sys Reqs</th>
<th>Hours</th>
<th>Hrs/Sys Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>464</td>
<td>365149</td>
<td>787</td>
</tr>
<tr>
<td>2</td>
<td>55</td>
<td>35663</td>
<td>648</td>
</tr>
<tr>
<td>3</td>
<td>164</td>
<td>143182</td>
<td>888</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Check shows data to be normally distributed

Control chart shows in-control process

Productivity useful for estimating and organization baseline data
Summary

A metrics development process should:

- Ensure business needs drive the process
- Take advantage of in-house and industry experience and best practices
- Include obtaining stakeholder input and buy-in
- Ensure benefits are worth the cost
- Include documentation and post-implementation evaluation