Creating Acquisition Insight Through Measurement

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  - Michael Zambrana, USAF Space and Missile Systems Center (SMC), Directorate of Systems Engineering
Outline

• Background
  ❖ History of the “Bell Ringing” Initiative
  ❖ Overview of the Framework for Software Acquisition Early Warning Indicators

• The Acquisition Program Office
  ❖ Overview and characteristics
  ❖ Metrics for monitoring its own work
  ❖ Metrics for understanding the constraints on the contractor
  ❖ Selecting a balanced metrics set

• Conclusions
History of the “Bell-Ringing” Initiative

• Beginning in 1999, failures in high-profile acquisition reform programs began to emerge at SMC
  - Performance deficiencies, extensive software defects
  - Large, unanticipated cost and schedule overruns
• Extent and severity of software-related problems were not understood until late in the development life cycle
• One SMC System Program Director expressed the desire to have a set of “bell-ringing criteria”
  - Early warning indicators of actual or potential problems in one or more factors that influence success of software-intensive system acquisitions
  - Signal the need for additional management attention to the influencing factors
Aerospace “Bell-Ringing” Research

• Aerospace began a research project to develop a comprehensive set of “bell-ringing criteria”
• Factors adversely influencing the success of software-intensive system acquisition were determined to extend far beyond those controlled by the contractor’s software development teams
• Research project first phase: Define a Framework for identifying and classifying these factors
  - Framework to define the relationships and interactions of the factors
  - Framework to include quantitative indicators derived from the factors
    - These indicators to provide foundation for satisfying the realistic information needs of the acquisition manager
The Approach for Defining the Framework for Software Acquisition Early Warning Indicators

Problem:
- Needed a simple way to model systemic influences and factors
- Needed to be able to express Cause (influence) and Effect (factors)
- Needed an intuitive information presentation method

Approach:
- Ishikawa Diagrams selected for
  - Ease of use
  - Automated tools
  - Low training needs

Definitions:
- **Problem Statement** - A statement of the problem—usually provided in terms of a necessary improvement
- **Factor** - Possible causes of the problem
- **Sub-factor** - The lower level factors of the subset problem
- **Influence** - Measurable feature of the factor or sub-factor

Example:

```
Problem Statement
\[\text{Influence} \rightarrow \text{Sub-factor} \rightarrow \text{Factor}\]
```

The problem statement is interconnected with factors and sub-factors, illustrating the cause-and-effect relationships.
1. Acquisition Environment – Influences from acquisition-related organizations external to the SPO, including acquisition management, user/operator, independent test and certification, interfacing system, support, and Government provider (e.g., GOTS, GFE/GFI, facilities) organizations

2. Acquisition Program Office – Influences from the SPO itself, including everyone from the SPO director down through the lowest level personnel, plus Aerospace, other FFRDCs and SETA contractors that support the SPO

3. Contractor Environment – Influences from contractor team organizations external to contractor team’s engineering organizations, including corporate and program management, quality assurance/software quality assurance, contracts, scheduling, and organizational process improvement groups

4. Product Development – Influences from contractor team engineering organizations, including systems engineering, software engineering, specialty engineering, test organizations, and configuration management

5. Unification – Influences from the interrelationships among the first four factors, such as customer satisfaction, communication and agreements
The Unique Role of the SPO

**SPO External Influences**
- Line Management Organizations
- External Technology Organizations
- Government Maintenance Organizations
- Staff Organizations
- Certification Organizations
- User Organizations
- Acquisition Management Organizations
- Interfacing System Organizations

**SPO**

**Contractor & Contractor External Influences**
- Product Development Organization
- Shared Resources Organizations
- Line Management Organizations
- Process Improvement Organizations
- Quality Assurance Organizations
- Policy Making Organizations

**Organizations**
- Government
- Technology
- Line Management
- Staff
- User
- Line
- Shared Resources
- Process Improvement
- Quality Assurance
- Policy Making
Example Products of the Acquisition Program Office

- System Requirements
  - Draft System Specification (DSS), Technical Requirements Document (TRD), System Performance Specification (SPS)
- Interface Requirements
  - Interface Requirements Specification (IRS), Interface Control Document (ICD)
- Acquisition Products
  - Request for Proposal (RFP) Package
  - Acquisition Strategy Briefing
  - Program Milestone/Key Decision Point (KDP) Briefing, Integrated Program Summary (IPS)
- Test and Evaluation (T&E) Products
  - Test and Evaluation Master Plan (TEMP)
- Cost and Schedule Products
  - Cost Analysis Requirements Document (CARD)
  - Program Schedule
- Other Products
  - Trade Studies (e.g., Architecture Studies)
  - Management Reports
  - Processes, Training
Software Measurement and Acquisition Management

Management

Acquisition Management Process

Acquirer

Information Products

Contractor

Development Management Process

Acquisition Measurement Process

CDRL Requirements

Information Needs

Development Measurement Process

CDRL Items

Information Products
Acquisition Program Office Subfactors and Influences

2.1 Resources and Cost Sub-Factor
- Financial Performance
- Environment & Support
- Personnel Effort

2.2 Process Performance Sub-Factor
- Process Efficiency
- Process Effectiveness
- Process Compliance
- Product Quality
- Maintainability
- Functional Correctness

2.3 Size and Stability Sub-Factor
- Process
- Product
- Cost
- Schedule
- System Performance
- Process Performance
- Product Assurance Level
- Technology Effectiveness

2.4 Schedule and Progress Sub-Factor
- Milestone Completion
- Critical Path Performance
- Work Progress
- Evolutionary Capability
- Schedule and Progress

2.5 Product Quality Sub-Factor
- Constraints Sub-Factor

2.6 Constraints Sub-Factor

Acquisition Program Office Influences
Acquisition Program Office Subfactors

• **Resources and Cost** - Included are the program-specific personnel resources responsible for performing the work within this factor and the Acquisition Program Office infrastructure, facilities and other resources required to execute the program.

• **Process Performance** - processes used by the organizations and functions in the Acquisition Program Office factor to perform the work and produce the products for which they are responsible.

• **Size and Stability** - addresses the size and stability of the processes used and of the products produced by the organizations and functions in the Acquisition Program Office factor.

• **Schedule and Progress** - addresses the schedule and progress of the work performed by the organizations and functions in the Acquisition Program Office factor.

• **Product Quality** - addresses the quality of the products produced by the organizations and functions in the Acquisition Program Office factor.

• **Constraints** - addresses the various constraints imposed by the organizations and functions in the Acquisition Program Office factor on all types of work (engineering, management, support) being performed by the contractor on the program.
## Acquisition Program Office Influences and Example Metrics - 1

<table>
<thead>
<tr>
<th>Subfactor</th>
<th>Influence (Issue)</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resources &amp; Cost</td>
<td>Personnel Effort</td>
<td>Staff Level</td>
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<tr>
<td></td>
<td></td>
<td>Effort</td>
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<td></td>
<td></td>
<td>Staff Turnover</td>
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<td></td>
<td></td>
<td>Overload</td>
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<td></td>
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<td>Unplanned Tasking</td>
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<tr>
<td>Financial Performance</td>
<td>Budget</td>
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<tr>
<td></td>
<td>Cost</td>
<td></td>
</tr>
<tr>
<td>Environment &amp; Support</td>
<td>Quantity Needed/Available</td>
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<tr>
<td></td>
<td>Time Needed/Available</td>
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<tr>
<td></td>
<td>Fidelity &amp; Quality of Resources</td>
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<td>Time Used</td>
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## Acquisition Program Office Influences and Example Metrics - 2

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<th>Subfactor</th>
<th>Influence (Issue)</th>
<th>Metric</th>
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<tr>
<td>Process Performance</td>
<td>Process Compliance</td>
<td>Reference Maturity Profile</td>
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<td>Process Audit Findings</td>
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<td>Process Efficiency</td>
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<td>Productivity</td>
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<td>Cycle Time</td>
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<td>Process Effectiveness</td>
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<td>Defects Contained</td>
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<tr>
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<td>Defects Escaped</td>
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<td></td>
<td></td>
<td>Rework Effort</td>
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<td>Size and Stability</td>
<td>Processes</td>
<td>Process Size</td>
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<td>Process Changes</td>
</tr>
<tr>
<td></td>
<td>Products</td>
<td>Product Size</td>
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<td></td>
<td></td>
<td>Product Changes</td>
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## Acquisition Program Office Influences and Example Metrics - 3

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<th>Subfactor</th>
<th>Influence (Issue)</th>
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<tr>
<td>Schedule and Progress</td>
<td>Milestone Completion</td>
<td>Milestone Dates</td>
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<td>Schedule Compression Ration</td>
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<tr>
<td></td>
<td>Critical Path Performance</td>
<td>Slack Time</td>
</tr>
<tr>
<td></td>
<td>Work Progress</td>
<td>Requirements Traced/Untraced</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Action Items Opened/Closed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Change Requests Opened/Closed</td>
</tr>
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<td></td>
<td>Evolutionary Capability</td>
<td>Capabilities Fielded</td>
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<tr>
<td></td>
<td></td>
<td>Interfaces Integrated</td>
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<tr>
<td>Product Quality</td>
<td>Maintainability</td>
<td>Complexity</td>
</tr>
<tr>
<td></td>
<td>Functional Correctness</td>
<td>Defects</td>
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<td>Age of Defects</td>
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<td></td>
<td></td>
<td>Completeness</td>
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<tr>
<td></td>
<td></td>
<td>Estimating Accuracy</td>
</tr>
</tbody>
</table>
Interaction among Acquisition Program Office Subfactors and Influences

Size & Stability
- Product
- Process
- Process Effectiveness
- Process Efficiency
- Process Compliance

Resources & Cost
- Personnel Effort
- Financial Performance
- Environment & Support

Product Quality
- Functional Correctness
- Maintainability

Schedule & Progress
- Work Progress
- Critical Path Performance
- Evolutionary Capability
- Milestone Completion

Process Performance
- Process Performance

Environment & Support
- Environment & Support

Process
- Process

Financial Performance
- Financial Performance

Evolutionary Capability
- Evolutionary Capability
Acquisition Program Office Metrics: Cost and Schedule Performance Indexes

Compare actual work accomplished on a project to the original plan, and track cost and schedule performance for the work completed

• ANALYSIS MODEL –
  - CPI and SPI are plotted over time to show trends.
  - Indices greater than 1.0 indicate under cost (CPI) and ahead of schedule (SPI).
  - Indices less than 1.0 indicate over cost (CPI) and behind schedule (SPI).

• DECISION CRITERIA –
  - CPI and SPI at the cumulative level are an indication of the health of the program.
  - Values less than 0.9 are an indication that there are problems that should be addressed.
  - The overall trends should be reviewed. Several months of declining values are an indicator that there are issues that should be addressed.

SPO SPI and CPI

Framework
Factor: Acquisition Program Office
Subfactor: Resources and Cost
Influence: Financial Performance
Metric: Cost
Acquisition Program Office Metric: Unplanned Tasking Effort

Compare actual effort against the original plan, and track variance due to unplanned tasking.

- **ANALYSIS MODEL** –
  - Cumulative effort (planned staff-hours, actual staff-hours on planned work and on unplanned tasking) is plotted over time to show trends.
  - The actual effort spent on unplanned tasking should stay within the decision criteria.

- **DECISION CRITERIA** –
  - Effort at the cumulative level is an indication of the health of the program.
  - More than 10% of planned effort spent on unplanned tasking indicates a dilution of effort on planned program tasks.
  - The overall trends should be reviewed. An adverse trend over 3 months is an indicator that there are issues that should be addressed.

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**Framework**
Factor: Acquisition Program Office
Subfactor: Resources and Cost
Influence: Personnel Effort
Metric: Unplanned Tasking
Acquisition Program Office Metric: Action Items Opened/Closed

Understand the magnitude of the impact of the SPO work backlog by tracking action item status

• ANALYSIS MODEL –
  - Action items are plotted over time to show trends
  - Bar chart shows the magnitude of the action items opened and closed each week; line chart indicates the cumulative open and closed action items from week to week
  - Action item closure rates should remain consistent over course of program in order to prevent SPO communication backlog

• DECISION CRITERIA –
  - Open action item buildup is an indication of management overload, leading to a lack of communication with the contractor.
  - A closure rate of less than 85% is generally an indicator of SPO overload.
  - Consistent information exchange backlog leads to continual discovery and rediscovery of the same issues.

Framework
Factor: Acquisition Program Office
Subfactor: Schedule and Progress
Influence: Work Progress
Metric: Action Items Open/Closed
The Reality of Contracting Constraints
# Acquisition Program Office Constraints

## Subfactor - 1

<table>
<thead>
<tr>
<th>Influence (Issue)</th>
<th>Example Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Contract Dollars Profile</td>
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<tr>
<td></td>
<td>Fiscal Year Dollar Profile</td>
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<tr>
<td></td>
<td>Volatility</td>
</tr>
<tr>
<td>Schedule</td>
<td>Fixed Milestone Dates</td>
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<tr>
<td></td>
<td>Volatility</td>
</tr>
<tr>
<td>System Performance</td>
<td>Timing</td>
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<td></td>
<td>Accuracy</td>
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<td></td>
<td>Reliability/Availability</td>
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<td></td>
<td>Maintainability</td>
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<td></td>
<td>Program Specific QPRs</td>
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<tr>
<td></td>
<td>Volatility</td>
</tr>
<tr>
<td>Process Performance</td>
<td>CMM/CMMI Goals</td>
</tr>
<tr>
<td></td>
<td>Processes</td>
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<tr>
<td></td>
<td>Volatility</td>
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## Acquisition Program Office Constraints
### Subfactor - 2

<table>
<thead>
<tr>
<th>Influence (Issue)</th>
<th>Example Metrics</th>
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<tbody>
<tr>
<td>Product Assurance Level</td>
<td>Safety</td>
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<td></td>
<td>Security</td>
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<td></td>
<td>IV&amp;V</td>
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<tr>
<td></td>
<td>Quality</td>
</tr>
<tr>
<td></td>
<td>Volatility</td>
</tr>
<tr>
<td>Technology Effectiveness</td>
<td>Suitability</td>
</tr>
<tr>
<td></td>
<td>Readiness (TRL)</td>
</tr>
<tr>
<td></td>
<td>Volatility</td>
</tr>
</tbody>
</table>
Selecting a Balanced Set of Acquisition Program Office Metrics

• **Balance the metrics across the subfactors**
  - Resources and Cost
  - Process Performance
  - Size and Stability
  - Schedule and Progress
  - Product Quality
  - Constraints

• **Focus on:**
  - Areas of highest risk, and
  - Areas where meeting process improvement goals will provide the greatest benefit

• **Keep the number of Acquisition Program Office metrics small, especially initially**
  - Target 7 to 11 metrics at most

• **Techniques used for selecting development metrics are useful here as well (e.g., GQM, PSM)**
Example: Selecting a Balanced Set of Acquisition Program Office Metrics

• Metrics for managing the work of the Acquisition Program Office
  1. How is unplanned tasking affecting the program work? (Resources and Cost)
  2. Is the actual cost of the Acquisition Program Office work tracking to the plan? (Resources and Cost)
  3. What is the cycle time for responding to contractor requests for information? (Process Performance)
  4. How stable is the system requirements specification? (Size and Stability)
  5. What is the critical path for the Acquisition Program Office’s integration tasks? (Schedule and Progress)
  6. Is there a growing backlog of action items for which the Acquisition Program Office is responsible? (Schedule and Progress)
  7. How many defects have been identified in the released system requirements specification? (Product Quality)

• Metrics for understanding the driving constraints being placed on the contractor
  8. What is the readiness level of the critical technology being imposed?
  9. How volatile are the critical system performance parameters?
Conclusions

• This research effort has defined an integrated framework for software acquisition early warning indicators
  - Includes all participants in the acquisition and development environment, not just the contractor’s product development team
  - Addresses the full program life cycle
  - Aids in understanding the impact on mission success of all of the factors
  - Aids in identifying where corrective action is needed

• The framework provides a specific measurement perspective for the work of the Acquisition Program Office
  - Provides measures for the influences of the Acquisition Program Office, including its product and process performance
  - Provides a basis for measurement in an Acquisition Program Office process improvement effort
Past SSTC Papers on This Research

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# Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>CARD</td>
<td>Cost Analysis Requirements Document</td>
</tr>
<tr>
<td>CDRL</td>
<td>Contract Requirements Data List</td>
</tr>
<tr>
<td>CPI</td>
<td>Cost Performance Index</td>
</tr>
<tr>
<td>DSS</td>
<td>Draft System Specification</td>
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<tr>
<td>FFRDC</td>
<td>Federally Funded Research and Development Center</td>
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<tr>
<td>GFE</td>
<td>Government Furnished Equipment</td>
</tr>
<tr>
<td>GFI</td>
<td>Government Furnished Information</td>
</tr>
<tr>
<td>GOTG</td>
<td>Government Off the Shelf</td>
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<tr>
<td>GQM</td>
<td>Goal-Question-Metric</td>
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<tr>
<td>ICD</td>
<td>Interface Control Document</td>
</tr>
<tr>
<td>IPS</td>
<td>Integrated Program Summary</td>
</tr>
<tr>
<td>IRS</td>
<td>Interface Requirements Specification</td>
</tr>
<tr>
<td>KDP</td>
<td>Key Decision Point</td>
</tr>
<tr>
<td>MOIE</td>
<td>Mission Oriented Investigation and Experimentation</td>
</tr>
<tr>
<td>QPR</td>
<td>Quantitative Performance Requirement</td>
</tr>
<tr>
<td>PSM</td>
<td>Practical Software and System Measurement</td>
</tr>
<tr>
<td>RFP</td>
<td>Request for Proposal</td>
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<tr>
<td>SETA</td>
<td>Systems Engineering and Technical Assistance</td>
</tr>
<tr>
<td>SMC</td>
<td>Space and Missile Systems Center</td>
</tr>
<tr>
<td>SPI</td>
<td>Schedule Performance Index</td>
</tr>
<tr>
<td>SPO</td>
<td>System Program Office</td>
</tr>
<tr>
<td>SPS</td>
<td>System Performance Specification</td>
</tr>
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<td>T&amp;E</td>
<td>Test and Evaluation</td>
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<td>Test and Evaluation Master Plan</td>
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<td>Technical Requirements Document</td>
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<td>TRL</td>
<td>Technology Readiness Level</td>
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<td>USAF</td>
<td>United States Air Force</td>
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