Recognizing Common Patterns of Software Acquisition Failures

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  - Marilee Wheaton, General Manager, Systems Engineering Division
Outline

• **Background**
  - History of the Research Project
  - The Framework for Software Acquisition Early Warning Indicators

• **Software Acquisition Failure Profiles**
  - Research Approach
  - Example Failure Profiles

• **Lessons Learned and Conclusions**

• **Backup Charts**
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

• In 2001, 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 Framework for Software Acquisition
Early Warning Indicators

product development

contractor environment

acquisition program office

acquisition environment

unification
The Framework Factors

- **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

- **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

- **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

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

- **Unification** – Influences from the interrelationships among the first four factors, such as customer satisfaction, communication and agreements
Research Project Second Phase

- **Research project second phase:** Use the framework containing the factors adversely influencing the success of software-intensive system acquisition to define the “bell-ringing” criteria

- **Approach:**
  - Identify a set of well documented failure themes
  - Develop scenarios of failure, based on failure themes, using the framework
  - Define a failure profile for each scenario, using the indicators from the framework
  - Establish thresholds for the early warning indicators based on documented industry experience and known cases of failures

- **The early warning indicators and their thresholds for the set of failure profiles constitute the “bell-ringing” criteria**
The Approach for Defining Failure Profiles Using the Framework

**Problem:**
- Failure themes are well documented
- Need to pick measures that are early indicators of failure

**Approach:**
- Develop a scenario of failure based on a failure theme, using the framework
- Identify early warning indicator measures from the framework

**Definitions:**
- **Risk Phase** – A period of time during which a set of conditions leading to a risk event emerges
- **Red Flag** – An early warning signal that identifies potential entry into a particular failure scenario
- **Risk Event** – An indicator that, once triggered, identifies a higher likelihood that the specific profile is occurring
- **Measure** – A quantitative indicator that leads to a risk event

**Example:**

![Diagram illustrating the approach with risk phases, risk events, and measures over time.](image_url)
The Approach for Defining Early Warning Indicators and Thresholds for the Failure Profiles

**Problem:**
- No single factor causes program failure
- Patterns of failure have been observed and documented
- Attention to only a single factor often causes program failures

**Approach:**
- Use early warning indicators as the early evidence of potential failure
- Establish thresholds based on documented industry experience and known cases of failure

**Definitions:**
- **Radar Chart** - Provides a general target area defined by early warning indicators
- **Measure** - Represents a specific early warning indicator from the framework that has been identified as applicable to this failure profile
- **Threshold** - A value of the measure that should not be breached without appropriate action being taken
- **Value** – Actual value of the measure for the program under examination
Some Identified Failure Themes

✓ Inattention to Mission Success – Mission, What Mission?

✓ Cost Constrained Environment – Where’s the Money?

✓ Schedule Compression - And Then a Miracle Occurred

✓ Requirements Creep – IKIWISI

✓ Funding Volatility – You Want Us to Re-Plan Again?!?

✓ Overcommitted SPO – Everybody Wants Something NOW!

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Inattention to Mission Success

Mission, What Mission?

Description:
The inattention to mission success is usually manifested as a lack of quality during system design and development or as a disregard for meeting the system performance requirements placed on contract. The actual occurrence of mission success then comes as a surprise. It is more likely this scenario ends in mission failure. This scenario is most likely to occur in an organization with low process maturity.

Red Flag: Lack of a process description; seat of the pants management

Scenario Summary:
• Lack of well defined processes
• Business as usual until integration
• Defect counts escalate
• Progress falls behind; schedule slips are discovered; milestone slips are encountered
• Technical questions go unanswered
• Rework and action item activities overwhelm forward progress
• High priority action item responses become normal
• Degraded mission becomes a possibility
• Customer dissatisfaction rampant
• Degraded mission becomes a reality
Inattention to Mission Success Profile Indicators

Degraded Mission
- Pln vs Act System Requirements
- SPO Satisfaction Rating
- KTR Open/Closed Defects
- Process Audit Findings
- KTR-SPO Action Item Resolution Cycle Time
- Pln vs Act Schedule
- SPO # of Disconnects (Comments/Memos)
- KTR # of Disconnects (Comments/Memos)
- KTR Defect Removal Efficiency

Quality Impact
- No Problems
- Pln vs Act Integration Progress
- SQA # of Generated Actions
- CMM®/CMMI® Maturity Profile

Schedule Impact
- No Information
- BAU

Escalation
- Parade of Excuses

Program Impact ->

BAU = Business as Usual

Red Flag: Lack of a process description; seat of the pants management

*CMM and CMMI are registered in the U.S. Patent and Trademark Office by Carnegie Mellon University
Critical Indicator Set
Inattention to Mission Success

- **CMM®/CMMI® Maturity Profile** Less than Level 3 indicates a lack of consistent process
  EXAMPLE: All Level 3 KPA’s are satisfied at 100% = Level 3 Compliance

- **KTR Defect Removal Efficiency** <85% closure rate indicates defect accumulation
  EXAMPLE: Cum. Closed Defects/Cum. Defects = Defect Closure Rate (636/684 = 93%) represents a reasonable closure rate

Flight Software Problem Report Tracking

- Cumulative Problem Reports
- Monthly Problem Reports

CMM/CMMI® Maturity Profile

SQA # of Generated Actions

Pln vs Act Integration Progress

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Cost Constrained Environment

Where’s the Money?

Description:
Expectations of developing required capability with insufficient funding. The Government funding profile is most often severely constrained in the early years (we always have more money later, never now!), which is the time when meaningful risk reduction needs to be done. The effect of this situation is witnessed in the contractor team, which promises to develop the capability within the required funding profile with no hope of succeeding.

Red Flag: Unrealistic software cost estimates

Scenario Summary:
- Unrealistic SW cost estimates, requiring high SW productivity goals
- Use of “Streamlined” SW processes, resulting in erosion of quality
- Milestones slip as uncompleted work and rework builds up
- Management pressure for unpaid overtime, resulting in morale problems and staff turnover
- SW size growth and rework issues result in SW build progress problems
- Increase in cost; EAC exceeds contract funds
- Descoped contract; requirements deleted or deferred to stay within funding profile
Cost Constrained Environment Profile Indicators

SW ACQ FAILURE PROFILES

Contract Descoping

Cost Increase

Milestone Slip

Quality Reduction

Cost Constraints

Time ->

Program Impact ->

Contract Descoping

Cost Impact

Milestone Impact

Quality Impact

Cost Constraint Impact

- KTR Effort Performing Ind. Audits
- SPO Satisfaction Rating
- DoD-KTR Cost Estimation # of Disconnects
- SW Product Size/Cost Estimation Assumptions
- Contract Dollar Profile

Red Flag: Unrealistic software cost estimates
Critical Indicator Set
Cost Constrained Environment

Basic Estimate (Data Extracted from SEER-SEM™ Run)

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<th>Value</th>
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<tr>
<td>Effective Technology Metric</td>
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</tr>
<tr>
<td>Probability – Effort</td>
<td>50.00%</td>
</tr>
<tr>
<td>Probability – Schedule</td>
<td>50.00%</td>
</tr>
<tr>
<td>Estimate/Staffing Constraints</td>
<td>Min Time/None</td>
</tr>
</tbody>
</table>

- **SW Product Size/Cost Estimation**
  - **Assumptions:** <80% estimation confidence level indicates high likelihood of not succeeding
    - **EXAMPLE:** Software Cost Estimation Confidence Level = 50%

- **SQA to Development Effort Ratio <5%**
  - Indicates inadequate QA staffing
    - **EXAMPLE:** QA staffing level remains at a constant 7% rate throughout the life of the project. This rate should vary as the effort expended on the project varies.
Schedule Compression
And Then a Miracle Occurred

Description:
Expectations of too much capability in insufficient time. The effect of this situation is most often witnessed in the contractor team, which, under duress, promises the capability. However, even when they know they cannot deliver on time, they may be hoping for a miracle.

Red Flag: Justification for higher than expected productivity estimates; unrealistic software schedules

Scenario Summary:
• Reduced processes, especially quality-enhancing processes
• Rapid staffing ramp-up not achieved
• Quality is compromised from the beginning due to these reductions
• Morale suffers, further affecting productivity
• Milestones slip as reduced productivity and rework show up
• More personnel are added, further reducing productivity
• Cost increases are experienced
• Schedule slip is experienced
• Finally, a contract breach occurs
SW ACQ FAILURE PROFILES

Schedule Compression Profile Indicators

- Contract Breach
- Schedule Slip
- Schedule Impact
- Cost Impact
- Quality Impact
- Milestone Impact
- Milestone Slip
- Milestone
- Cost Increase
- Quality Reduction
- Schedule Slip
- Contract Breach

Red Flag: Justification for higher than expected productivity estimates, unrealistic software schedules

Time ->

Program Impact ->
Critical Indicator Set
Schedule Compression

- **KTR Effort Performing Peer Reviews**: Percent of development effort spent performing peer reviews <5% indicates insufficient time spent in defect identification.
  
  **EXAMPLE**: COQ varies from month to month. Six out of the twelve months COQ calculations are between 0% and 4%. PR Hours/Dev. Hours = COQ (20/(4.8*166)=2.5% for AUG COQ).

- **KTR Pln vs Act Staff Level**: Variations in staff ±7% from the plan over 3 consecutive months indicate inadequate staff planning.
  
  **EXAMPLE**: For Feb/Mar/Apr actual was less than planned staff level by more than 7%. Planned – Actual/Planned x 100 (e.g., 5.8-3.5/5.8X100 = 39%).

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**Peer Review Preparation & Review Hours**

**Plan vs Actual Staffing**

**KTR Effort Performing Peer Review**

**SPO Effort Performing Peer Review**

**Open/Closed Defects**

**KTR Pln vs Act Staff Level**
Research Lessons Learned and Conclusions

• The research team found it necessary to establish a common framework for communication and decision making
  ❖ The framework reflects consensus on a common set of terminology and mental models
• The research was beneficial in putting measurement in the program execution context
  ❖ Quantified mental models on how programs execute
• The payoff for a program will be recognizing and acting on the early parts of the failure profiles
  ❖ The later parts of all of the failure profiles look remarkably alike (“Death March”)
• Nearly all failure profiles showed a degradation of product quality!
  ❖ Programs need to pay very close attention to leading indicators of quality problems
• SPOs need to collect metrics on themselves
  ❖ Many leading indicators of failure show up first in the SPO
Future Research??

• Most troubled programs are on several different failure profiles concurrently
  ❖ How can we address the interaction among the failure profiles?

• Failure profiles provide a mechanism for recognizing when a program is beginning to proceed down a known failure scenario
  ❖ What actions can a program take to get off a failure profile early enough to make a difference?
  ❖ At what point on the failure profile is it too late to recover?
Backup Charts

- **Failure Profiles**
  - Requirements Creep
  - Funding Volatility
  - Overcommitted SPO

- **End Notes**
- **Contact Information**
- **Acronym List**
Requirements Creep
IKIWISI

Description:
Requirements creep describes the activity of evolving the system to be what the user/customer/SPO desires it to be. This most often is witnessed during the development of an unprecedented system applying new technology. As the system definition evolves, the technical knowledge of the people involved also increases, providing opportunities for “improvement” in the initial system vision.

Red Flag: Many conflicting stakeholders; many unknown requirements

Scenario Summary:
• Increasing requirements and requirements changes
• Increase in code estimates
• Additional personnel needs cannot be met due to unavailability
• Quality activities are reduced in an attempt to make up schedule
• Milestone slips occur as reduced productivity and rework show up
• More personnel are added, further reducing productivity
• Cost increases are experienced
• Schedule slip is experienced
• Finally, a contract breach occurs
Requirements Creep Profile Indicators

Program Impact -> Time ->

- **Contract Breach**
- **Cost Increase and Schedule Slip**
- **Quality Reduction**
- **Process Compliance**
- **Progress Impact**

Red Flag: Many conflicting stakeholders; many unknown requirements

RM = Requirements Management
Critical Indicator Set
Requirements Creep Profile

- Requirements Stability >1% per month of unstable requirements for 3 consecutive months indicative of an unstable project
  **EXAMPLE:** Volatility Index indicates unstable condition for Mar/Apr/May

- Lines of Code Estimate Changes Growth in SLOC estimate is >20% necessitates project rescope
  **EXAMPLE:** New SLOC Estimate - Old SLOC Estimate = Lines of Code Estimate Changes (1450-1000.1/1000.1 = 45%)
Funding Volatility
You Want Us to Re-Plan Again?!

Description:
Changing political climate often causes program funding volatility from year to year. Most often this is manifested in funding reductions with no corresponding change in requirements. This environment causes continual re-planning and may cause an otherwise successful program to spend its time estimating and negotiating contract changes rather than performing contract work.

Red Flag: Funding changes are occurring regularly

Scenario Summary:
• Funding change requires re-plan
• Re-plan requires KTR senior staff
• Re-plan coordination takes time
• KTR re-plan is optimistic
• KTR senior staff loss increases defects
• Re-plan breakage causes rework
• Re-plan schedule cannot be met
• Cost increases are experienced
• Schedule slip is experienced
• Finally, a contract breach occurs
Funding Volatility Profile Indicators

**Contract Breach**
- Cost Increase & Schedule Slip
- Quality Reduction
- Contract Change Definitized

**Cost & Schedule Impact**
- Quality Impact
  - KTR Open/Close Defects
  - KTR Rework Effort
- Re-plan Impact
  - KTR-SPO Contract Change Cycle Time
  - KTR-SPO Contract Action Resolution Cycle Time
  - KTR-SPO # of Contract Disconnects (Contract Actions)
  - KTR Effort on Unplanned Tasking

**Funding Impact**
- Funding Change
  - SPO FY Budget Change
  - SPO Funding Volatility

**Red Flag:** Funding changes are occurring regularly
**Critical Indicator Set**

**Funding Volatility**

- **SPO Funding Volatility** $\pm 10\%$ volatility indicates funding instability causing continual scope, cost, schedule re-planning.

  **EXAMPLE:** Funding Volatility Index indicates regular annual change. While the magnitude of the change mostly remains within the 10% threshold, this profile may still explain instability in the program.

- **KTR-SPO # of Contract Disconnects** $<85\%$ closure rate indicates inadequate closure rate.

  **EXAMPLE:** Cum. Closed/Cum. Opened = Action Closure Rate ($34/44 = 77\%$)

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**Additional Diagrams:**

- SPO Funding Volatility
- KTR-SPO Contract Change Cycle Time
- SPO FY Budget Change
- KTR Effort on Unplanned Tasking
- KTR-SPO # of Contract Disconnects
Overcommitted SPO
Everybody Wants Something NOW!

Description:
Too few people to get the job completed. This is most often witnessed in the Acquisition Program Office which must manage the changing system requirements, the contractor, and the effects of the acquisition environment. While the buck often stops here, the ball rarely does.

Red Flag: SPO staffing determined independent of program size and complexity

Scenario Summary:
• Constant “High Priority” external tasking dilutes attention to contractor
• Late discovery of implementation not meeting user expectations
• Extensive contractor and user coordination required to define an acceptable product
• Assumptions used to redefine product are inadequate due to unaccounted for rework
• More personnel and overtime are used to complete rework and makeup milestone slips
• Cost increases are experienced
• Schedule slip is experienced
• Finally, a contract breach occurs
Overcommitted SPO Profile Indicators

Program Impact ->

- Contract Breach
- Schedule Slip
- Cost Increase
- Milestone Slip
- Oversight

Time ->

- Schedule Impact
  - DoD Effort Performing Ind. Audits
  - SPO Effort Performing Ind. Audits
  - KTR Effort Developing EAC

- Cost Impact
  - KTR Staff Level
  - KTR Unplanned Tasking

- Milestone Impact
  - KTR Functional Changes
  - DoD-SPO Action Item Resolution Cycle Time
  - DoD-SPO # of Disconnects (Action Items)

- Oversight Impact
  - DoD Satisfaction Rating
  - SPO Unplanned Tasking
  - SPO Schedule Performance Index

Red Flag: SPO staffing determined independent of program size and complexity
Critical Indicator Set
Overcommitted SPO

SPO Schedule Performance Index <0.90\(^5\) per month indicates significant deviation in SPO schedule performance

**EXAMPLE:** While the cumulative SPI (shown on chart) remains within the threshold boundary, the monthly SPI shows a significant dip during the Apr/May/Jun/Jul timeframe.

- SPO Unplanned Tasking >10\(^{11}\) of Cum. Planned effort indicates program management dilution

**EXAMPLE:** Cum. SPO effort spent on unplanned task >10% since Month 2

\[\text{Cumulative Hours} \]

- Cumulative SPO Hrs on Planned Activities
- Cumulative Actual SPO Hrs on Planned Activities
- Cumulative SPO Hrs on Unplanned Activities
- SPO Unplanned Task Threshold

\[\text{SPO Schedule Performance Index} \]

- KTR Functional Changes
- SPO Unplanned Tasking
- DoD-SPO Action Item Resolution Cycle Time
- DoD-SPO # of Disconnects

\[\text{DoD Satisfaction Rating} \]
## End Notes

6. Analogy to #4 for development.
11. Published source not yet identified.
Contact Information

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# Acronyms and Abbreviations - 1

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<th>Abbreviation</th>
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<tr>
<td>ACQ</td>
<td>Acquisition</td>
</tr>
<tr>
<td>ACT</td>
<td>Actual</td>
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<tr>
<td>ACTS</td>
<td>Actuals</td>
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<td>BAU</td>
<td>Business as Usual</td>
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<tr>
<td>CM</td>
<td>Configuration Management</td>
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<td>CMM®</td>
<td>Capability Maturity Model®</td>
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<td>CMMI®</td>
<td>Capability Maturity Model® Integration®</td>
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<td>COQ</td>
<td>Cost of Quality</td>
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<td>Cost Performance Index</td>
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<td>CR</td>
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<td>DEV</td>
<td>Development</td>
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<td>DM</td>
<td>Data Management</td>
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<td>Department of Defense</td>
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<td>DR</td>
<td>Discrepancy Report</td>
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<td>EAC</td>
<td>Estimate at Completion</td>
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<td>ENV</td>
<td>Environment</td>
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<td>E/P</td>
<td>Equivalent People</td>
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<tr>
<td>FFRDC</td>
<td>Federally Funded Research and Development Center</td>
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<tr>
<td>FY</td>
<td>Fiscal Year</td>
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<tr>
<td>GFE</td>
<td>Government Furnished Equipment</td>
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<td>GFI</td>
<td>Government Furnished Information</td>
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<td>GOTS</td>
<td>Government Off the Shelf</td>
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## Acronyms and Abbreviations - 2

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<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
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<td>IKIWISI</td>
<td>I Know It When I See It</td>
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<td>IND</td>
<td>Independent</td>
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<td>KPA</td>
<td>Key Process Area</td>
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<td>Contractor</td>
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<td>LCL</td>
<td>Lower Control Limit</td>
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<td>MOE</td>
<td>Measure of Effectiveness</td>
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<td>MOIE</td>
<td>Mission Oriented Investigation and Experimentation</td>
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<td>MOP</td>
<td>Measure of Performance</td>
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<td>PR</td>
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<td>Space and Missile Systems Center</td>
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<td>System Program Office</td>
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<td>Software Quality Assurance</td>
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