# Recognizing Common Patterns of Software Acquisition Failures

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# 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

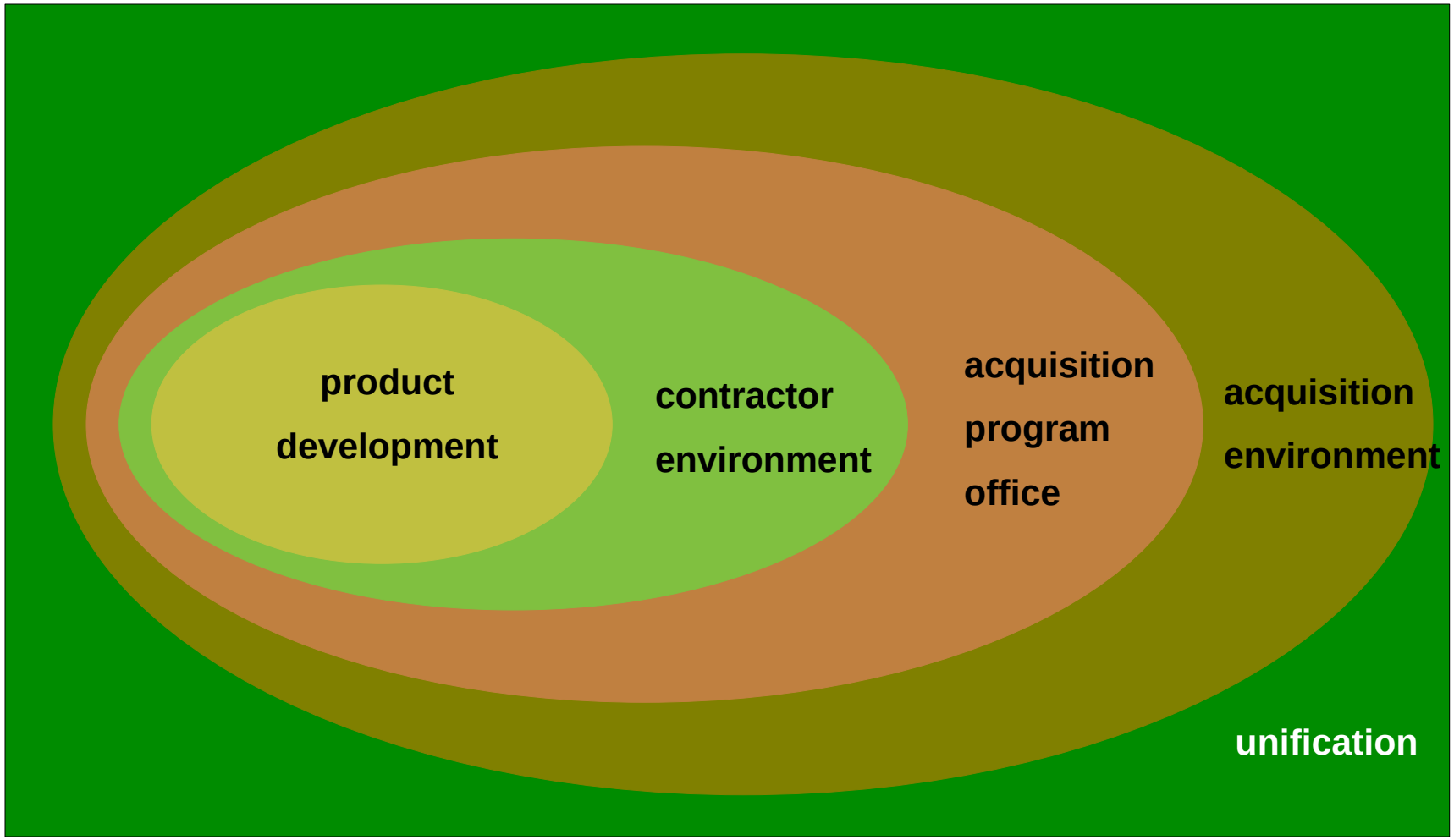
# Aerospace "Bell-Ringing" Research



- **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





# 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



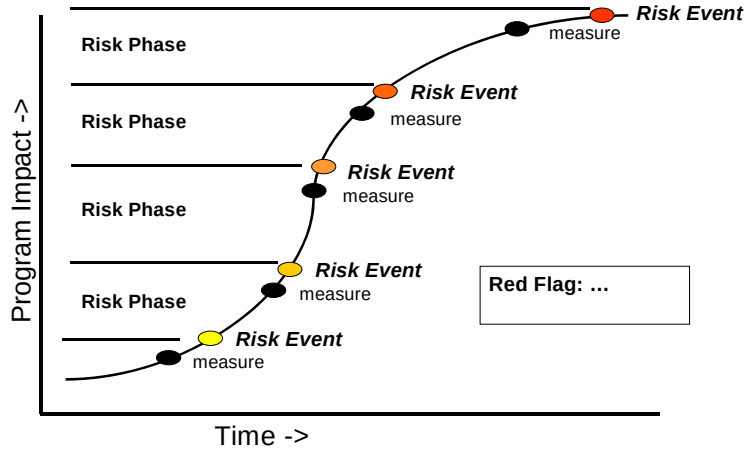
## Problem:

- 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

## Example:




## 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

# The Approach for Defining Early Warning Indicators and Thresholds for the Failure Profiles



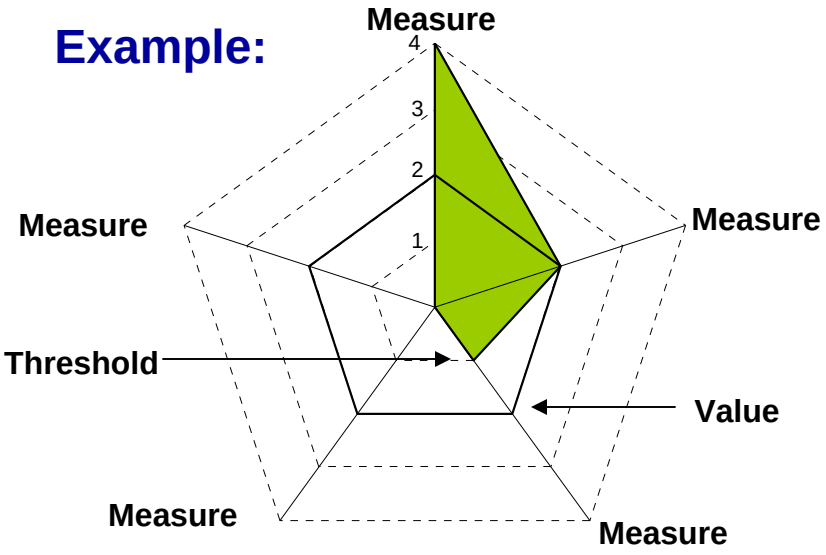
## Problem:

- 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

## Example:




## 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!*

# 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.

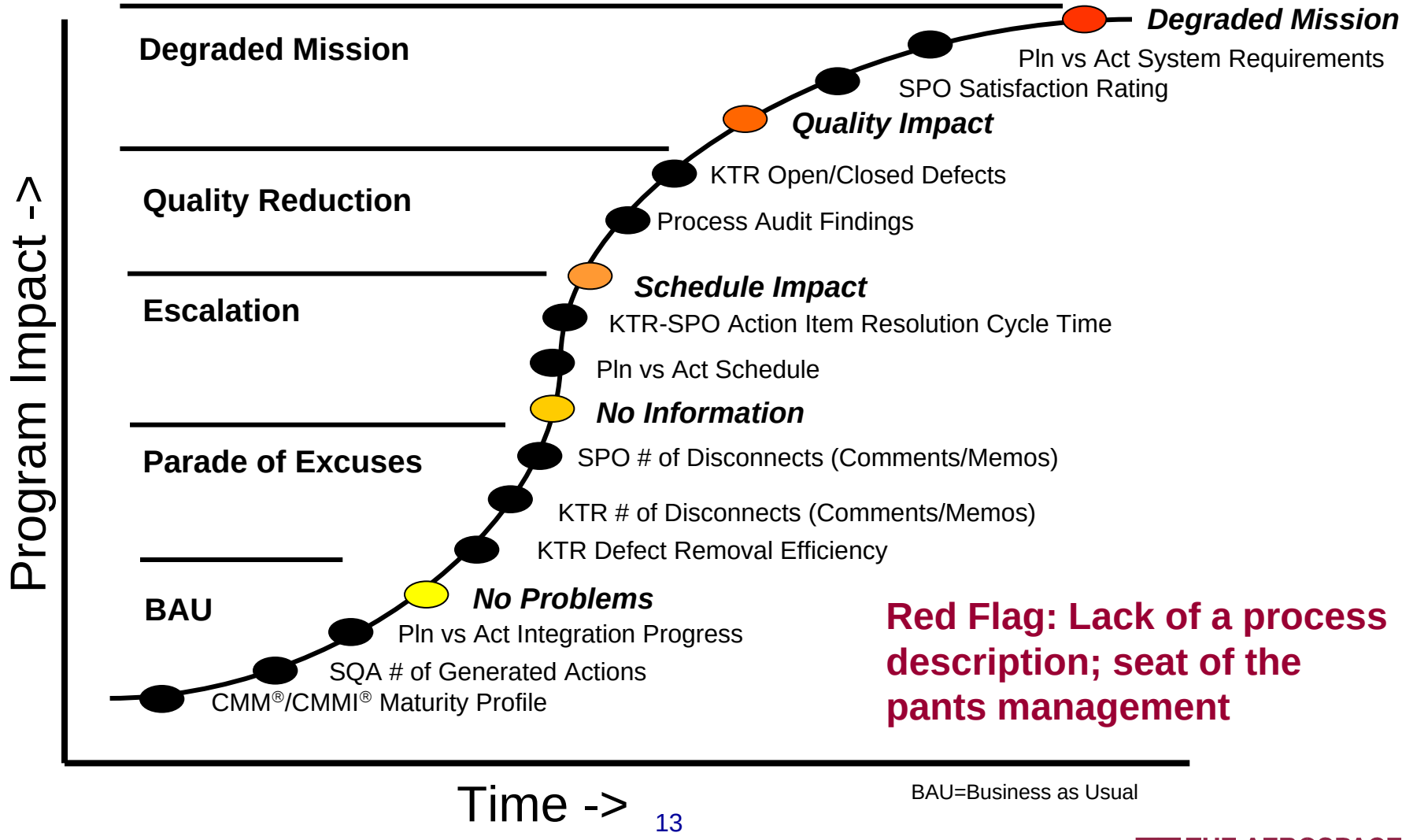
**Red Flag: Lack of a process description; seat of the pants management**

## 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





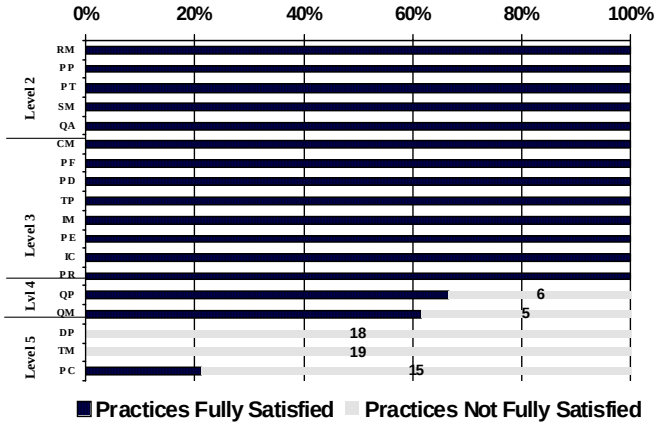

**Red Flag: Lack of a process description; seat of the pants management**

BAU=Business as Usual

# Critical Indicator Set
# Inattention to Mission Success



Dec Assessment Against the CMM for S/W Key Practices

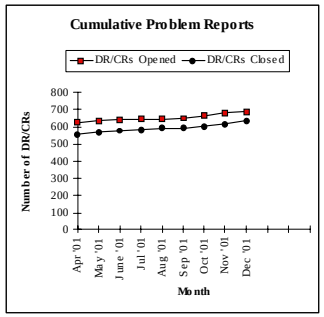


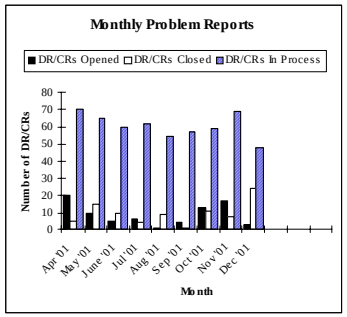

| KPs | Change + | Change - |
|---|---|---|
| 12 | | |
| 25 | 0 | 0 |
| 24 | 0 | 0 |
| 22 | | |
| 17 | | |
| 21 | | |
| 16 | 0 | 0 |
| 11 | 0 | 0 |
| 16 | | |
| 19 | 0 | 0 |
| 20 | | |
| 17 | | |
| 9 | | |
| 18 | | |
| 13 | | |
| 18 | | |
| 19 | | |
| 19 | | |

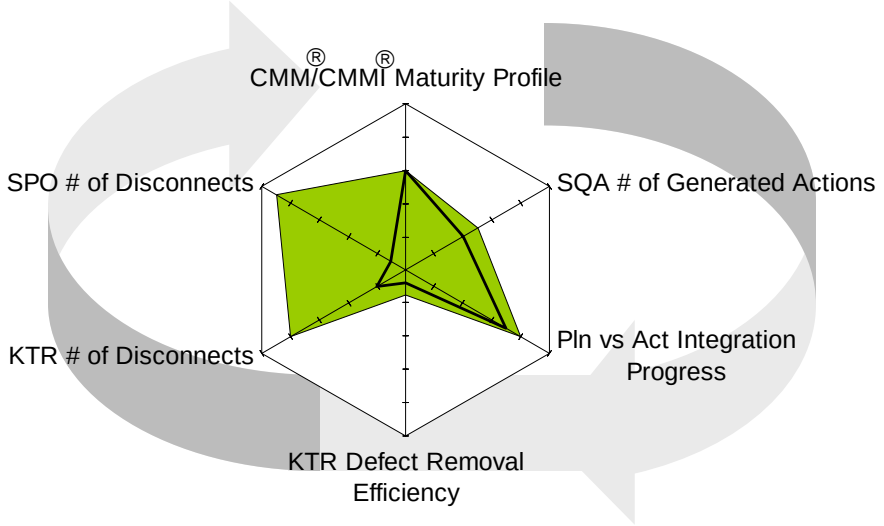
- CMM®/CMMI® Maturity Profile Less than Level 3[1] indicates a lack of consistent process
  **EXAMPLE: All Level 3 KPA's are satisfied at 100% = Level 3 Compliance**
- KTR Defect Removal Efficiency <85%[2] closure rate indicates defect accumulation
  **EXAMPLE: Cum. Closed Defects/Cum. Defects = Defect Closure Rate (636/684 = 93%) represents a a reasonable closure rate**

Flight Software Problem Report Tracking

| Year | 2001 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Month | Apr '01 | May '01 | June '01 | Jul '01 | Aug '01 | Sep '01 | Oct '01 | Nov '01 | Dec '01 |
| Activity | | | | | | | | | |
| Cumulative DR/CRs | 625 | 635 | 640 | 646 | 647 | 651 | 664 | 681 | 684 |
| Cumulative DR/CRs Closed | 555 | 570 | 580 | 584 | 593 | 594 | 605 | 612 | 636 |
| | | | | | | | | | |
| DR/CRs Opened This Month | 20 | 10 | 5 | 6 | 1 | 4 | 13 | 17 | 3 |
| DR/CRs Closed This Month | 5 | 15 | 10 | 4 | 9 | 1 | 11 | 7 | 24 |
| DR/CRs In Process | 70 | 65 | 60 | 62 | 54 | 57 | 59 | 69 | 48 |



# 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**

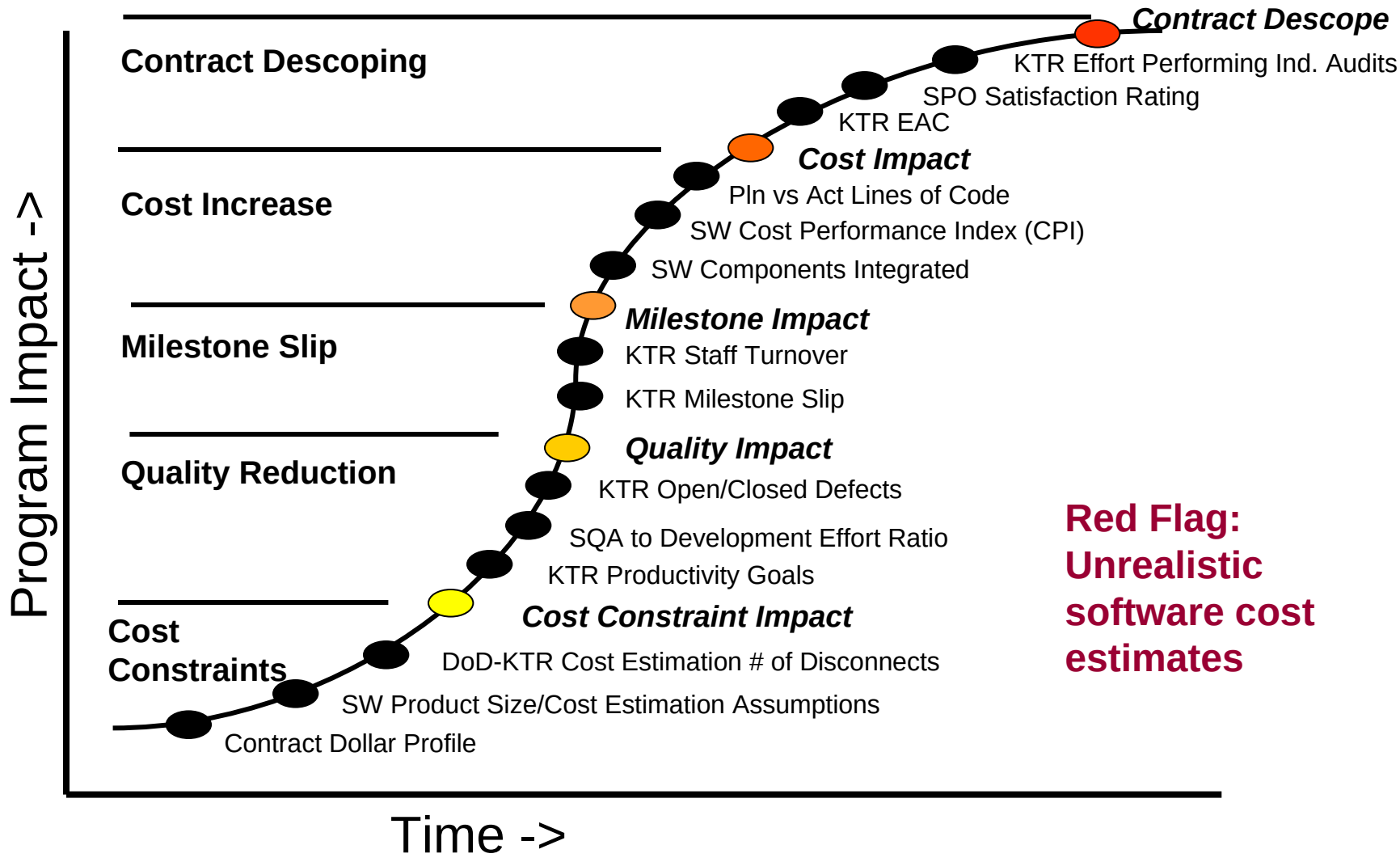
**Red Flag: Unrealistic software cost estimates**

## 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





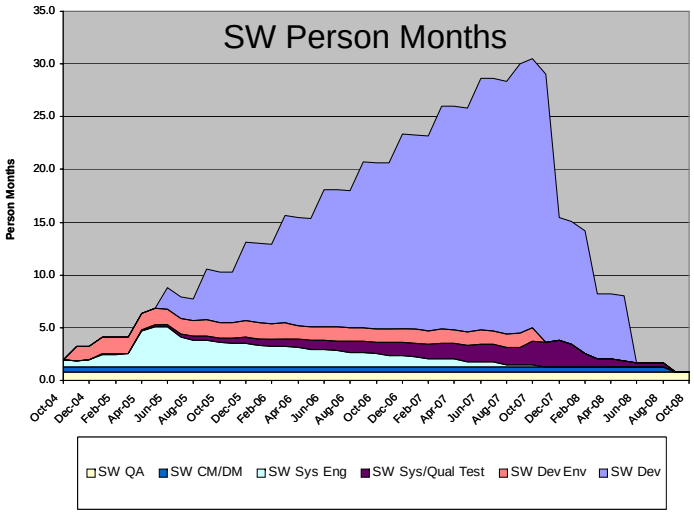
# Critical Indicator Set
# Cost Constrained Environment

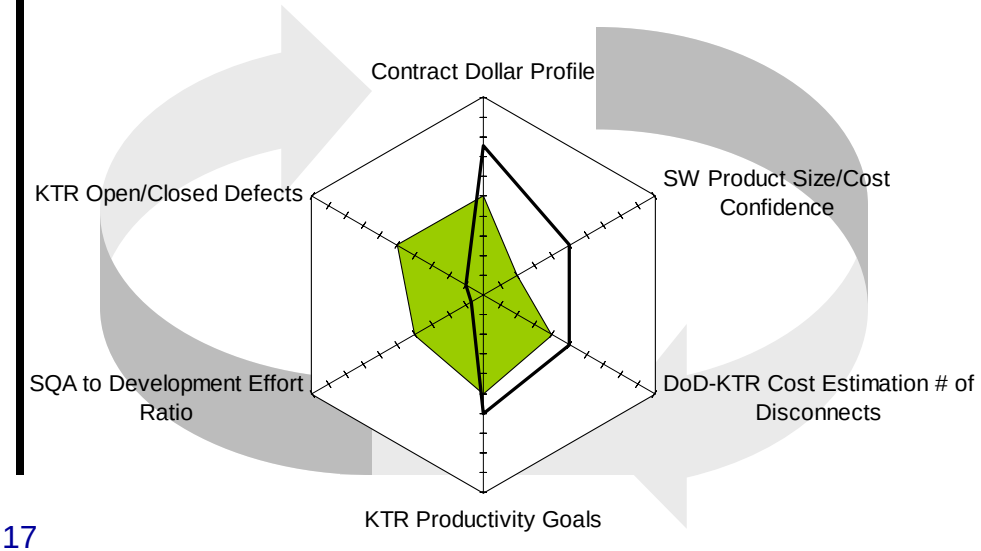


Basic Estimate (Data Extracted from SEER-SEM™ Run)

| | Input Summary |
|---|---|
| Effective Size | 16,500 |
| Effective Lines Only | 0 |
| Effective Functions Only | 194 |
| Total Size | 21,800 |
| Total Lines Only | 0 |
| Total Functions Only | 194 |
| Complexity (input) | Nom |
| Basic Technology Metric | 6,590.8 |
| Effective Technology Metric | 3,225.1 |
| Probability - Effort | 50.00% |
| Probability - Schedule | 50.00% |
| Estimate/Staffing Constraints | Min Time/None |

- SW Product Size/Cost Estimation Assumptions: <80%[3] estimation confidence level indicates high likelihood of not succeeding
  **EXAMPLE: Software Cost Estimation Confidence Level = 50%**
- SQA to Development Effort Ratio <5%[4] 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.**






SEER-SEM is a Trademark of Galorath, Inc.

# 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.**

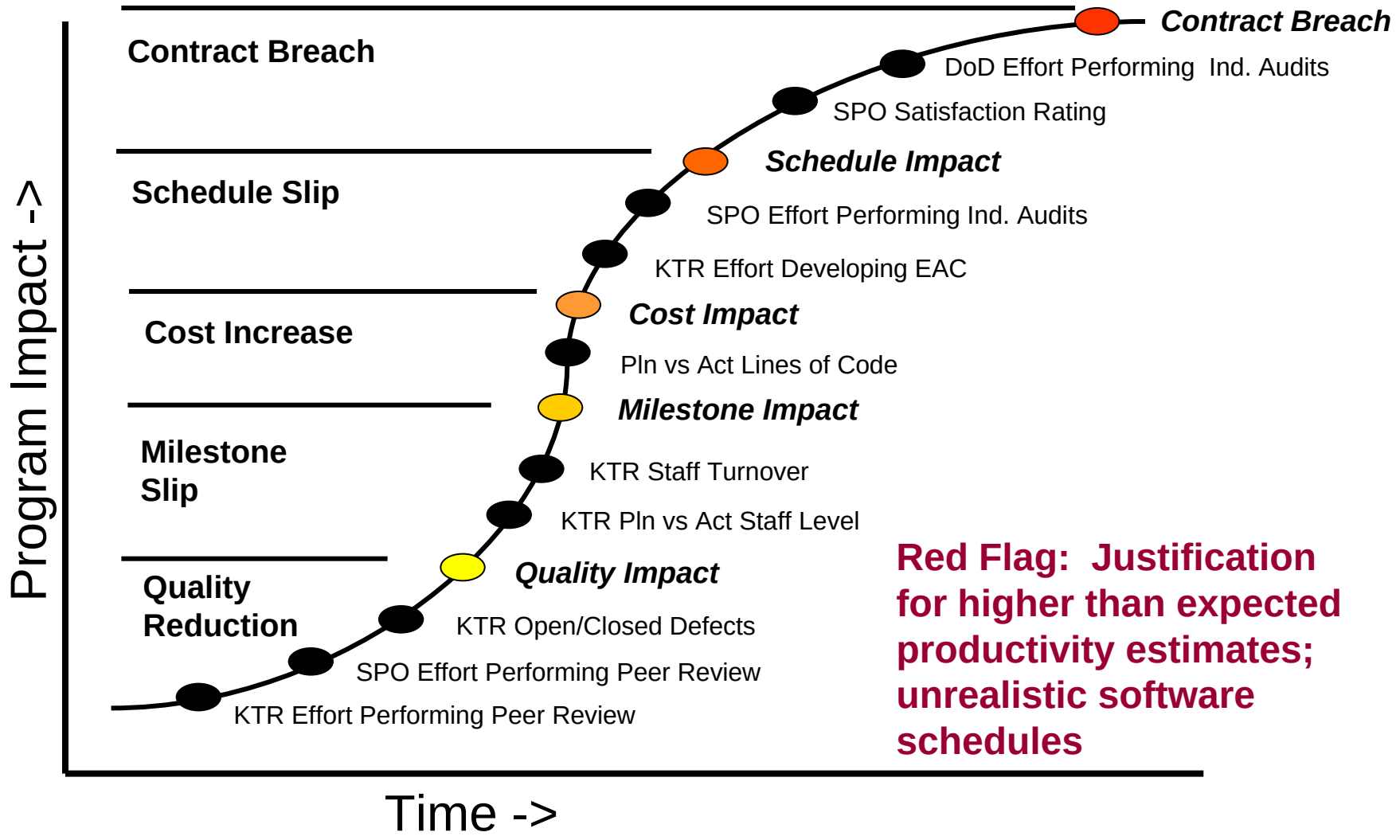
**Red Flag: Justification for higher than expected productivity estimates; unrealistic software schedules**

### 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**

# Schedule Compression Profile Indicators

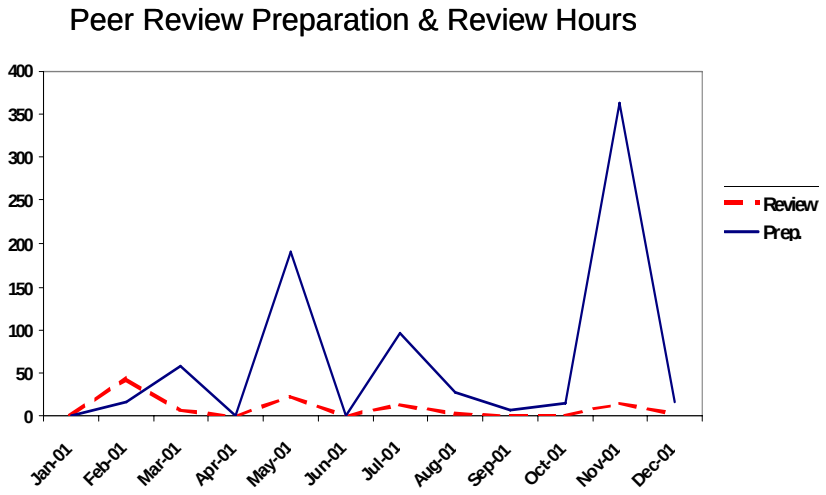




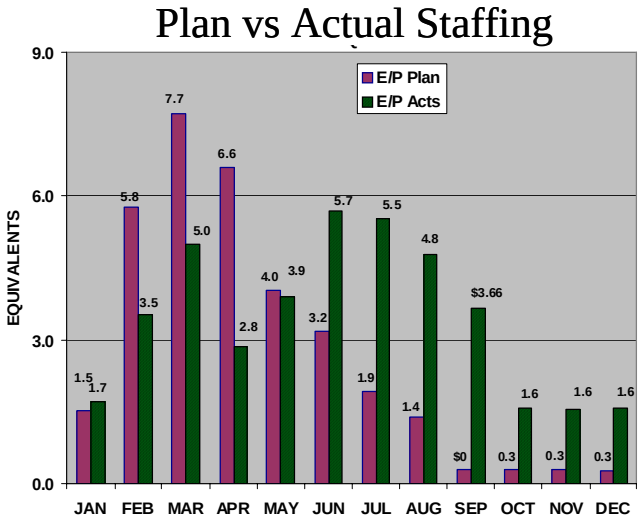

**Red Flag: Justification for higher than expected productivity estimates; unrealistic software schedules**

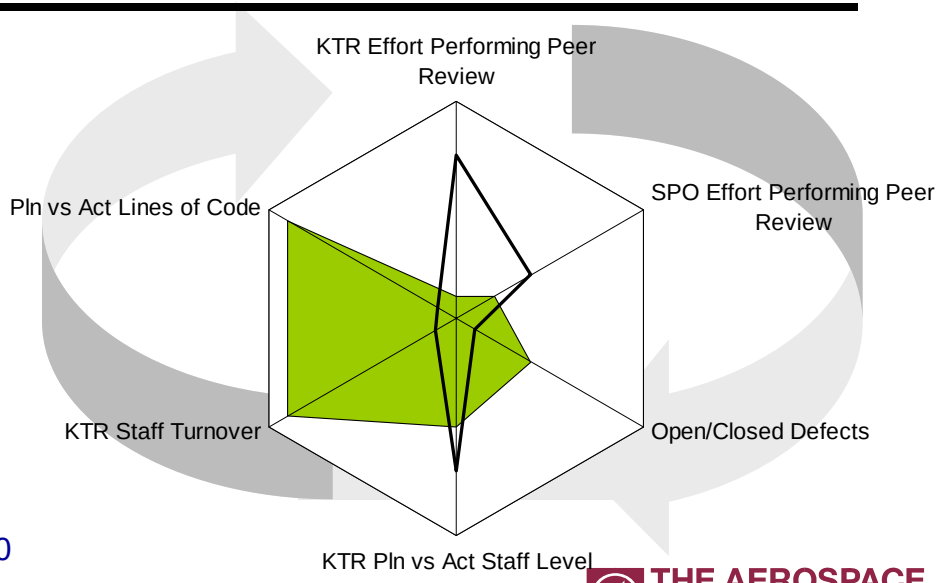
# Critical Indicator Set
# Schedule Compression






- KTR Effort Performing Peer Reviews Percent of development effort spent performing peer reviews <5%[9] 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%[10] 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%)**



# 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.**

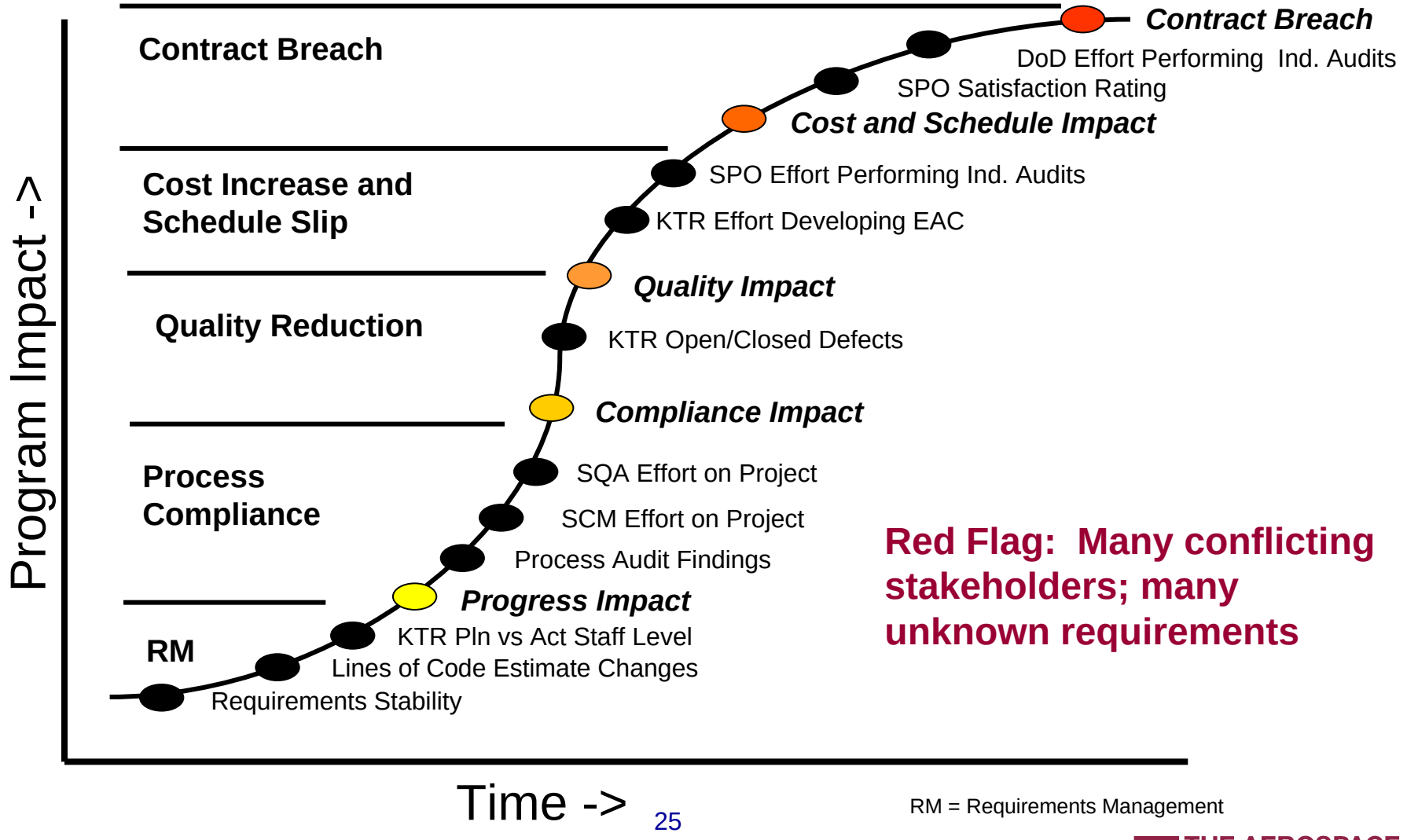
**Red Flag: Many conflicting stakeholders; many unknown requirements**

### 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





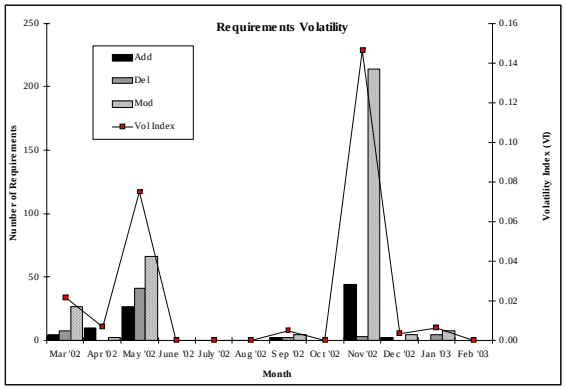

**Red Flag: Many conflicting stakeholders; many unknown requirements**

RM = Requirements Management

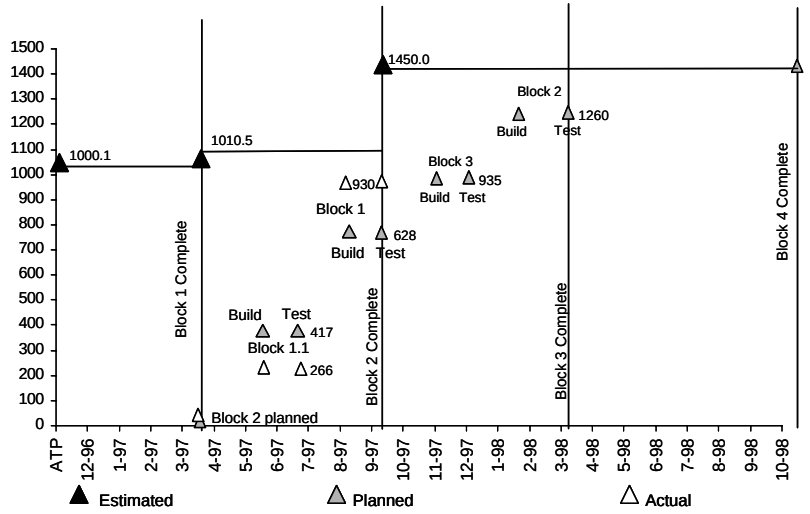
# Critical Indicator Set
# Requirements Creep Profile

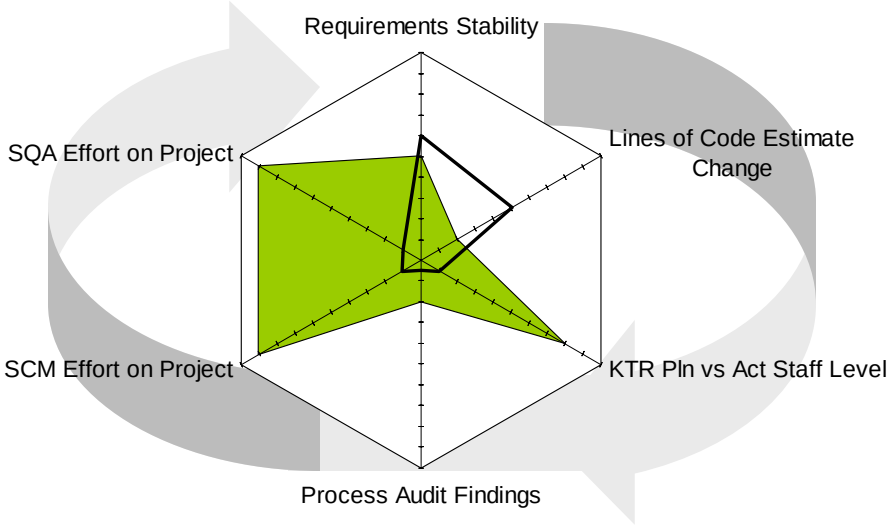


| Year | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Mar '02 | Apr '02 | May '02 | June '02 | July '02 | Aug '02 | Sep '02 | Oct '02 | Nov '02 | Dec '02 | Jan '03 | Feb '03 |
| Activity | | | | | | | | | | | | |
| Total Active Requirements | 1791 | 1788 | 1798 | 1784 | 1784 | 1784 | 1784 | 1784 | 1784 | 1825 | 1827 | 1823 |
| Added (A) | 5 | 10 | 27 | 0 | 0 | 0 | 2 | 0 | 44 | 2 | 0 | 0 |
| Deleted (D) | 8 | 0 | 41 | 0 | 0 | 0 | 2 | 0 | 3 | 0 | 4 | 0 |
| Modified (M) | 26 | 2 | 66 | 0 | 0 | 0 | 5 | 0 | 214 | 4 | 8 | 0 |
| VI =(A+ D+M)/Total | 0.02 | 0.01 | 0.07 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 0.15 | 0.00 | 0.01 | 0.00 |




- Requirements Stability >1%[7] 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%[8] necessitates project rescope
  **EXAMPLE: New SLOC Estimate-Old 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

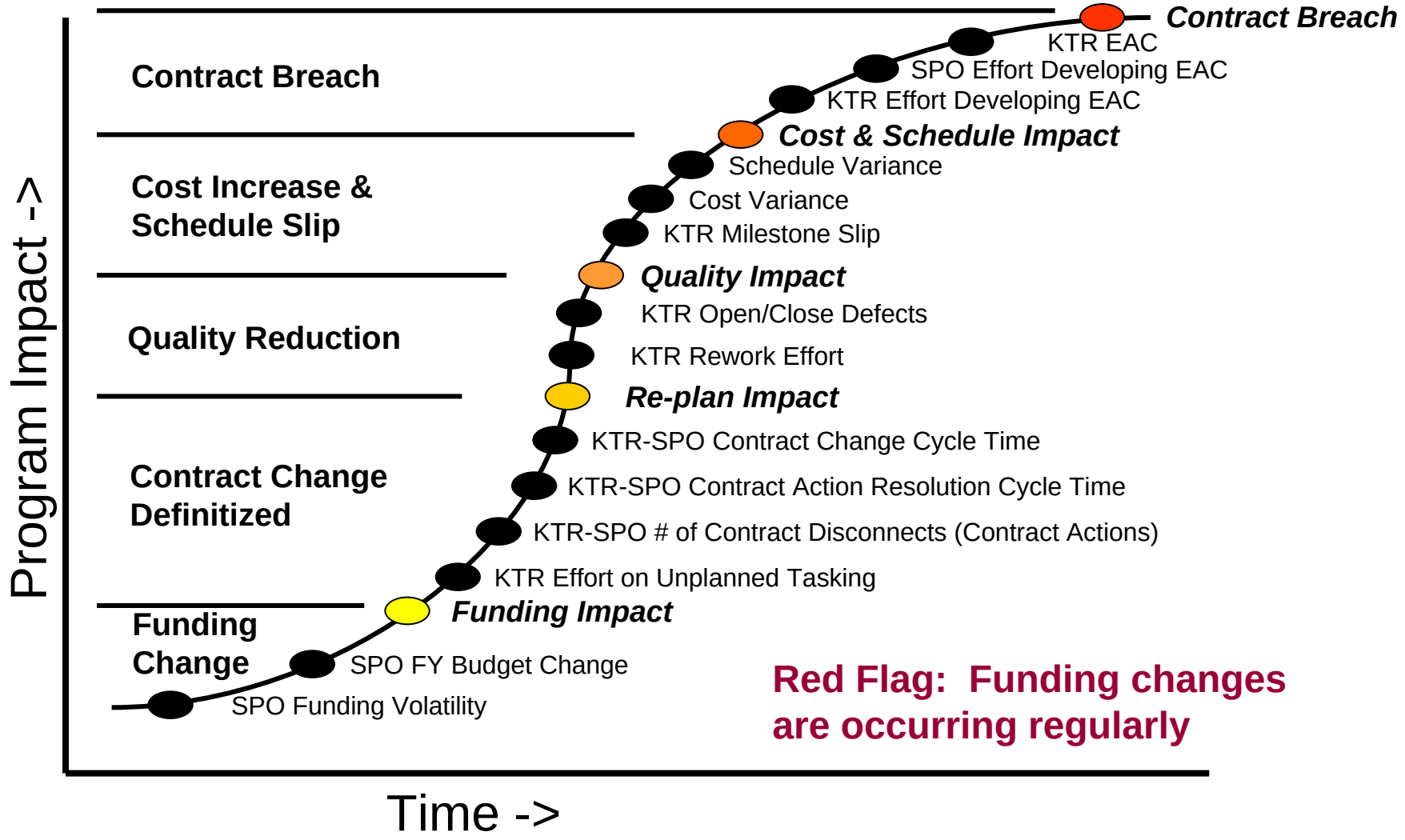
**Red Flag: Funding changes are occurring regularly**

## 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

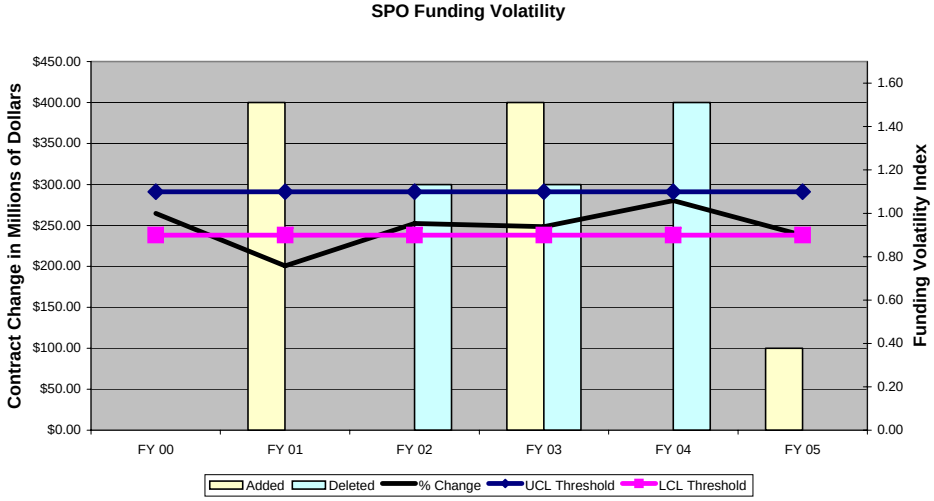





**Red Flag: Funding changes are occurring regularly**

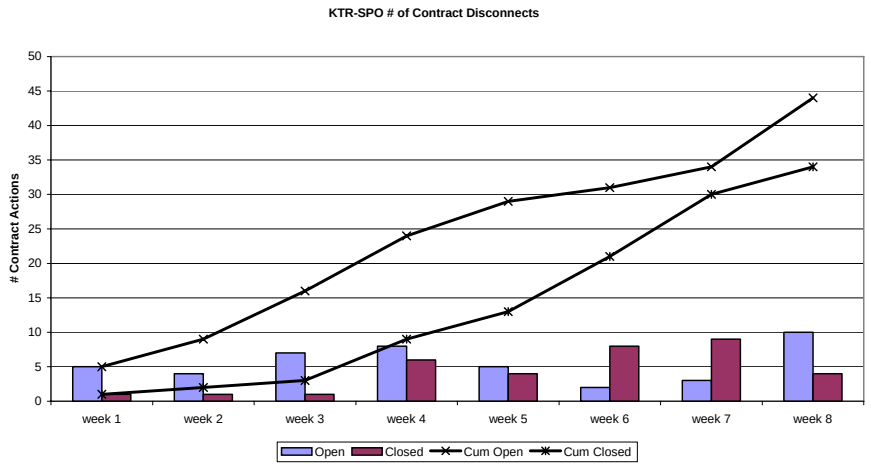
# Critical Indicator Set
# Funding Volatility

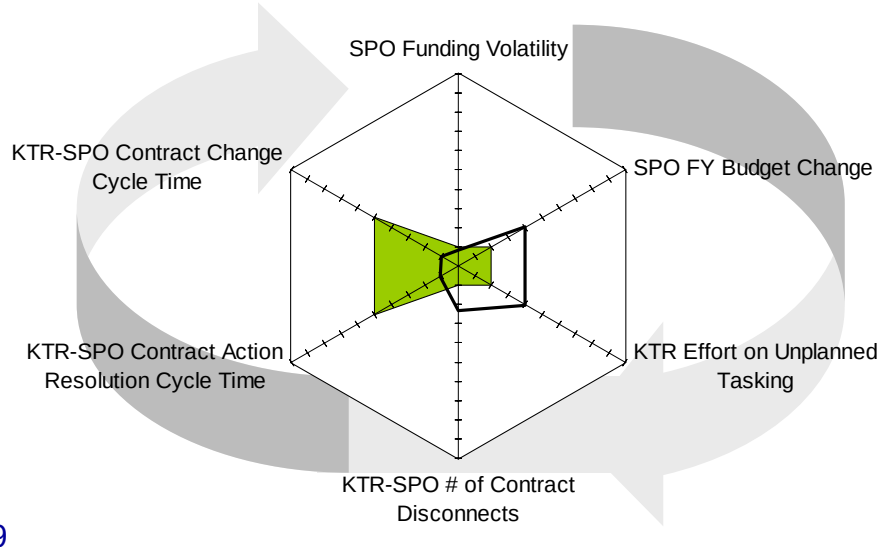





- SPO Funding Volatility ±10%[5] volatility indicates funding instability causing continual scope, cost, schedule re-planning
  **EXAMPLE: Funding Volatility Index indicates regular annual change. While the magnitude of the change mostly remains within the 10% threshold, this profile may still explain instability in the program.**

- KTR-SPO # of Contract Disconnects <85%[6] closure rate indicates inadequate closure rate
  **EXAMPLE: Cum. Closed/Cum. Opened = Action Closure Rate ( 34/44 = 77%)**



# 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.**

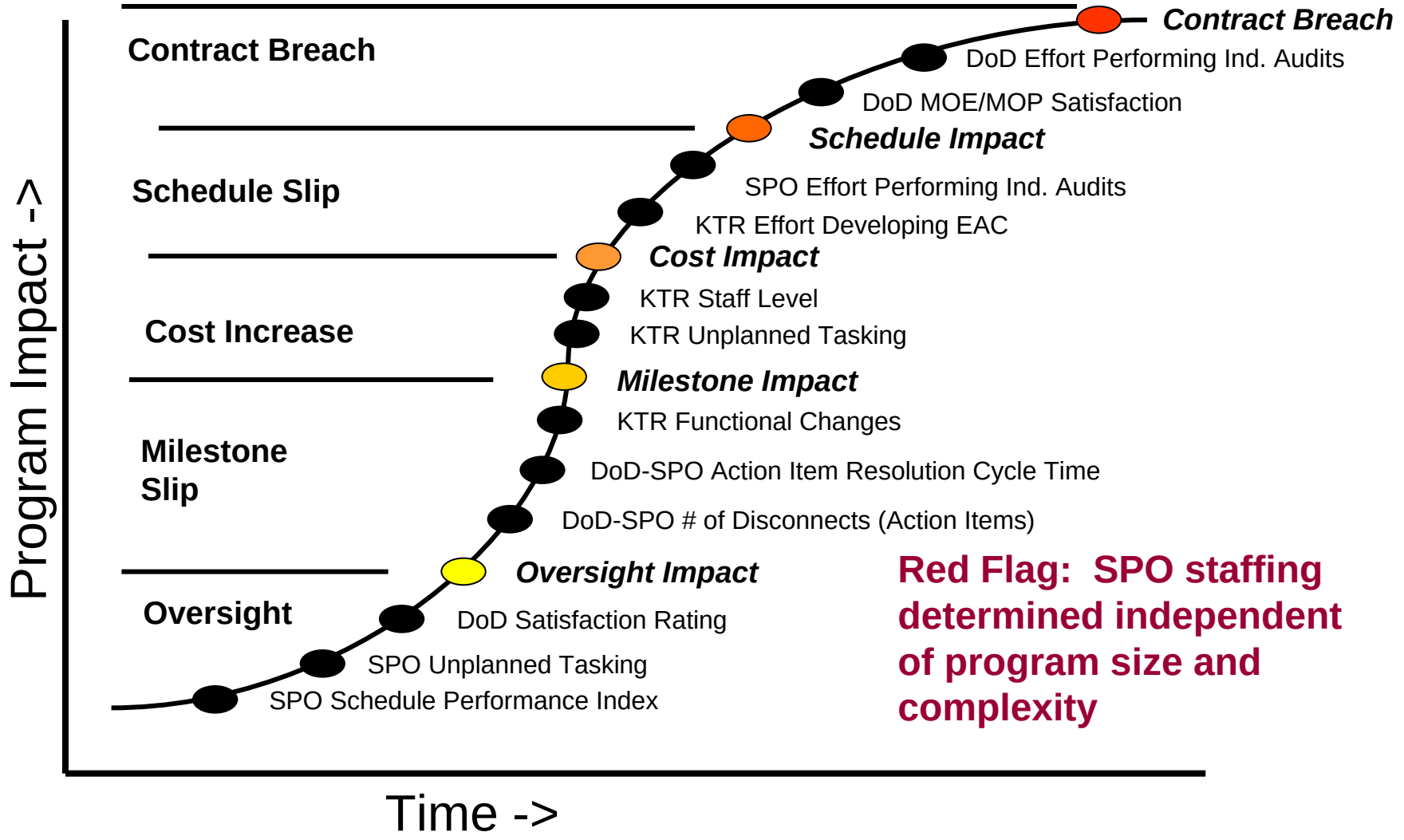
**Red Flag: SPO staffing determined independent of program size and complexity**

**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





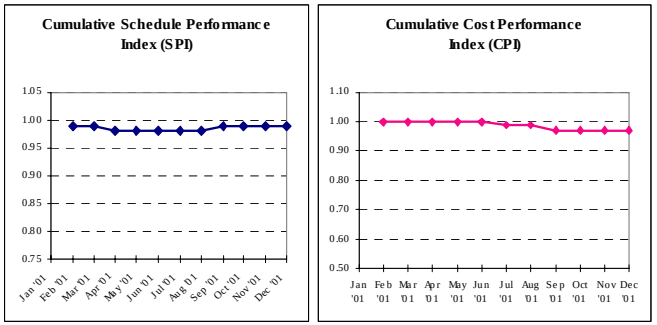

**Red Flag: SPO staffing determined independent of program size and complexity**

# Critical Indicator Set
# Overcommitted SPO

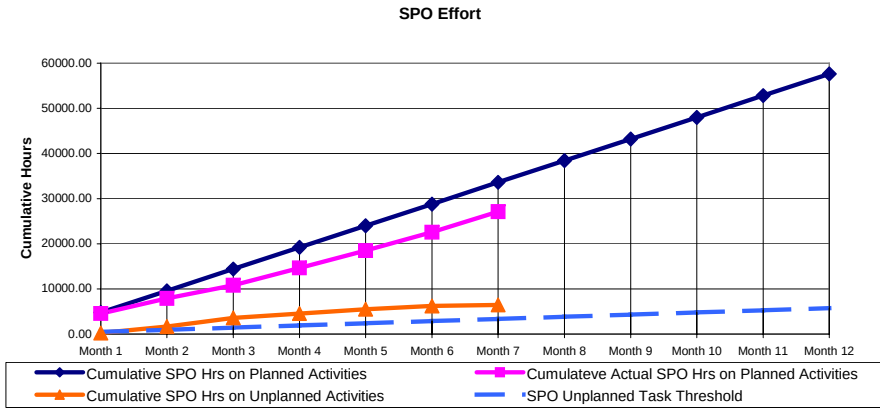


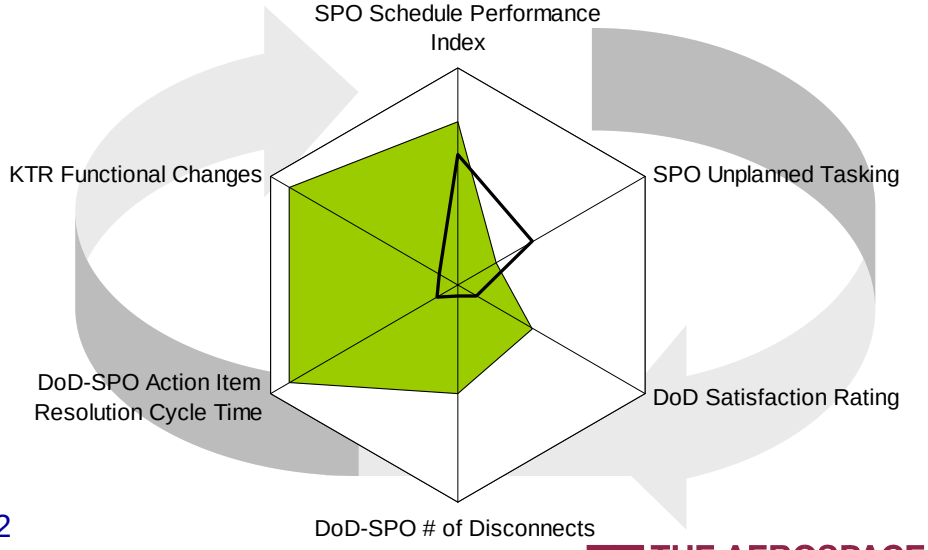
SPO SPI and CPI

| Year | 2001 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Jan '01 | Feb '01 | Mar '01 | Apr '01 | May '01 | Jun '01 | Jul '01 | Aug '01 | Sep '01 | Oct '01 | Nov '01 | Dec '01 |
| Activity | | | | | | | | | | | | |
| Cumulative SPI | | 0.99 | 0.99 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.99 | 0.99 | 0.99 | 0.99 |
| Monthly SPI | | 1.00 | 0.90 | 0.61 | 0.76 | 0.76 | 0.57 | 0.75 | 0.93 | 0.93 | 1.00 | 1.00 |
| Cumulative CPI | | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.99 | 0.99 | 0.97 | 0.97 | 0.97 | 0.97 |
| Monthly CPI | | 1.13 | 1.26 | 0.97 | 1.15 | 0.96 | 0.82 | 0.82 | 0.69 | 0.69 | 0.70 | 0.70 |




- 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**



# End Notes

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# Acronyms and Abbreviations - 1



| | |
|---|---|
| ACQ | Acquisition |
| ACT | Actual |
| ACTS | Actuals |
| BAU | Business as Usual |
| CM | Configuration Management |
| CMM® | Capability Maturity Model® |
| CMMI® | Capability Maturity Model® IntegrationSM |
| COQ | Cost of Quality |
| CPI | Cost Performance Index |
| CR | Change Request |
| C/SCSC | Cost/Schedule Control System Criteria |
| CUM | Cumulative |
| DEV | Development |
| DM | Data Management |
| DoD | Department of Defense |
| DR | Discrepancy Report |
| EAC | Estimate at Completion |
| ENG | Engineering |
| ENV | Environment |
| E/P | Equivalent People |
| FFRDC | Federally Funded Research and Development Center |
| FY | Fiscal Year |
| GFE | Government Furnished Equipment |
| GFI | Government Furnished Information |
| GOTS | Government Off the Shelf |
| HRS | Hours |

# Acronyms and Abbreviations - 2



| | |
|---|---|
| IEEE | Institute of Electrical and Electronics Engineers |
| IKIWISI | I Know It When I See It |
| IND | Independent |
| KPA | Key Process Area |
| KTR | Contractor |
| LCL | Lower Control Limit |
| MOE | Measure of Effectiveness |
| MOIE | Mission Oriented Investigation and Experimentation |
| MOP | Measure of Performance |
| PR | Peer Review |
| QA | Quality Assurance |
| Qual | Qualification |
| RM | Requirements Management |
| SCM | Software Configuration Management |
| SETA | Systems Engineering and Technical Assistance |
| SLOC | Source Lines of Code |
| SMC | Space and Missile Systems Center |
| SPI | Schedule Performance Index |
| SPO | System Program Office |
| SQA | Software Quality Assurance |
| SW | Software |
| SYS | System |
| S/W | Software |
| UCL | Upper Control Limit |
| U.S. | United States |
| USAF | United States Air Force |
| vs. | Versus |