Paladin Drives Forward To CMMI® Maturity Level 5

The Paladin M109A6 Self-propelled Howitzer

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Topics, In Order of Presentation

- U.S. Army RDECOM-ARDEC, FCS&TD, AFCS and the SWE
- The Paladin System Software Development & Maintenance Projects
- A Typical Paladin Project's Business Objective Summary
- Paladin's One Best Way
- The Paladin Process Optimization Life Cycle
- Using CAR to Establish & Optimize A Statistically Managed Process
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- Picking Up Where Deming Left Off
- Queuing Systems
- Service Process Capability Measurement Paladin's One Best Way
- Paladin Pilot CAR Study
- Centering and Statistically Managing A Service Process
- Quantitative Methods For CMMI® Maturity Level 5 Paladin's One Best Way
- Paladin Pilot CAR Study: Results & Observations
- Using Quantitative Information as a Basis For Decision Analysis & Resolution
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- Paladin Drives Forward To CMMI® Maturity Level 5

Armament Research, Development & Engineering Center (ARDEC)
Fire Control Systems & Technology Directorate (FCS&TD)

Vision …

Recognized foremost provider of fire control and related technologies that transform the battlefield and secure the homeland.

Mission …

- ☑ Deliver total life cycle hardware & software engineering solutions for weapon systems control, automated test systems and homeland defense
- ☑ Rapidly incorporate and field emerging hardware and software technologies into sustainable fire control products
- ☑ Provide customers with fire control and related domain expertise
- ☑ Provide sustainment engineering for fielded fire control systems

Artillery Fire Control Systems (AFCS)

Fire Control Systems & Technology Directorate (FCS&TD)
U.S. Army Research, Development & Engineering Command –
Armament Research, Development & Engineering Center (RDECOM-ARDEC)

- The RDECOM-ARDEC Software Enterprise (SWE) consists of the software elements of the FCS&TD, including AFCS, and the Software Quality Groups of the Quality Engineering & System Assurance Directorate (QESA).
- The SWE adopted the Staged Representation of the CMMI® SE/SW/SS Model for Systems Engineering, Software Engineering, and Supplier Sourcing as part of a formal process improvement initiative.
- The SWE achieved a CMMI® maturity level 3 in 2002.
- SWE projects include:
  - Software Development Projects
    - Paladin Software V7, Block 2, Block 3
    - M1A1 Abrams
    - Mortar Fire Control System (MFCS) Heavy
    - Lightweight Handheld Mortar Ballistic Computer
  - Service/Infrastructure Projects
    - Process Engineering Group
    - Process Assurance
    - Organizational Support Environment
    - Configuration Mgmt/Library System Mgmt
  - Acquisition Projects
    - Towed Artillery Digitization (TAD) Block 1A
    - Excalibur XM982
    - CROWS
    - IMS
    - XM29 Rifle (OICW)
    - Virtual Trainers
    - MICAD
    - NSD-A(SPIDER)

The Paladin System Software Development & Maintenance Projects

- **The M109A6 Paladin Self-propelled Howitzer is the U.S. Army's most advanced artillery system.**
- **The Paladin system has advanced navigation capabilities and an on-board capability to determine accurate ballistic firing solutions for a bourgeoning array of special purpose artillery munitions. These capabilities, among others, provide for military commanders a powerful capability to emplace the Paladin system quickly and begin engaging a variety of enemy targets in a matter of seconds.**
- **Currently, the Paladin system is fielded in Iraq where it has made an outstanding contribution to efforts in Operation Iraqi Freedom.**
- **AFCS Paladin projects are system software development and maintenance projects for the Paladin Self-propelled Howitzer. Several Paladin projects are usually in progress simultaneously.**
- **Paladin's Lessons Learned will be helpful to any project seeking attainment of higher maturity levels.**

A Typical Paladin Project's Business Objective Summary

a. Improve Customer Satisfaction

a-1) Provide desired new functionality.

a-2) Maintain and support baseline versions and upgrades.

b. Improve Predictability, Consistency and Quality, of our Services and Products

b-1) Maintain an excellent* outgoing quality level.

c. Maintain and Enhance our Core Competencies

c-1) Perform in accordance with recognized quality standards.**

c-2) Improve performance through staged growth IAW CMMI®.

d. Increase Productivity & Reduce Cycle Time

d-1) Adopt statistical management for key processes (IAW the CAR Plan)

e. Improve our Competitive Advantage

e-1) Achieve progressively improved levels of CMMI® appraisal.

*** An excellent outgoing quality level is one that meets software release standards specified in the Software Test Plan.**
**** Recognized quality standards include practices outlined in the organizationally adopted CMMI® model and SWE policies and procedures.**

Organizational Objectives (a to e)
Project Objectives (a-1 to e-1)

Paladin's One Best Way

For Paladin to drive forward to CMMI® maturity level 5, we needed to formulate a process optimization roadmap.

It was concluded that the basis of this formulation must, of necessity, comprise a strategy that:

- **Improves the utilization of model-based quantitative methods;**
- **Efficiently satisfies multiple Specific Practices (SP's) across multiple projects (when appropriate); and**
- **Considers behavioral aspects of operating with the people in the system.**

For Paladin, it was found that the "One Best Way" of satisfying our strategic intent was an approach called Process Enrichment℠.

Paladin's One Best Way

Process Enrichment's
Statistical Process Enrichment℠ (SPE) Methodology*

- ☐ Design of experiment
  - Data collection
- ☐ Information generation
  - Task relationships
  - Performance measurements
  - Process Statistics (Capability)
  - Resource utilization/availability
- ☐ Formation of strategic objectives
  - Customer service objectives
  - Process Objectives
  - Economic policy
- ☐ Process Optimization
  - Service Product Specification
  - Process re-engineering
  - Work Simplification
  - Job Enrichment
- ☐ Process Assessment
  - Process Audit
  - Long-term effects of strategy
  - Customer satisfaction evaluation
  - Scheduling critical points for reassessment

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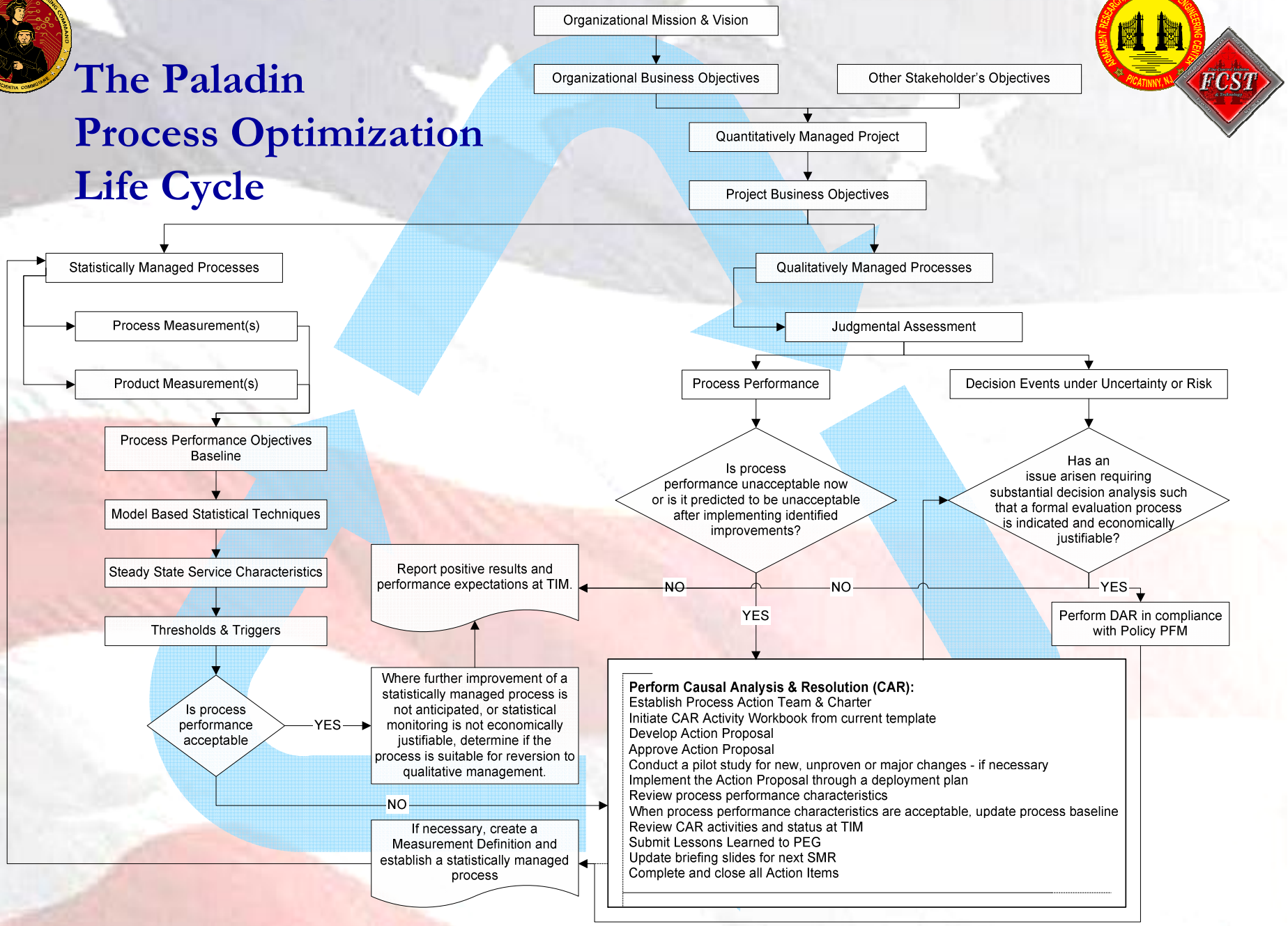
The Paladin Process Optimization Life Cycle



Using CAR to Establish & Optimize A Statistically Managed Process

- **Each Paladin project maintains a (CAR) Plan.**

> ***"Causal analysis may also be performed on problems unrelated to defects. For example, causal analysis may be used to improve quality attributes such as cycle time." (CMMI®)***

- **Paladin's Pilot CAR Study**

"Optimize service process efficiency in processing PA Audit questionnaires"

- **CAR 1 – *Establish A Statistically Managed Process***
  - ***Establish a CAR Activity Workbook***
    - **Serves as a container to document issues, actions and findings of CAR activities**
  - ***Develop a Measurement Definition***
    - **Describes the measurement method, data collection, and decisions supporting achievement of operational results**
- **CAR 2 – *Optimize Process Centering***

Quantitative Methods For CMMI® Maturity Level 5

- **Some quantitative methods aren't designed for maturity level 5 process improvements.**

> ***"In quality control in manufacturing, the answer, "No, this is not a constant-cause system," leads to a hunt for an assignable cause of variation, and an attempt to remove it, if possible. The answer, "Yes, this is a constant-cause system," leads to leaving the process alone, making no effort to hunt for causes of variation." (Grant & Leavenworth)***

> ***"Removing a special cause of process variation does not change the underlying subprocess. It addresses an error in the way the subprocess is being executed." (CMMI®)***

> ***"At maturity level 5, processes are concerned with addressing common causes of process variation and changing the process (that is, shifting the mean of the process performance) to improve process performance…" (CMMI®)***

Picking Up Where Deming Left Off

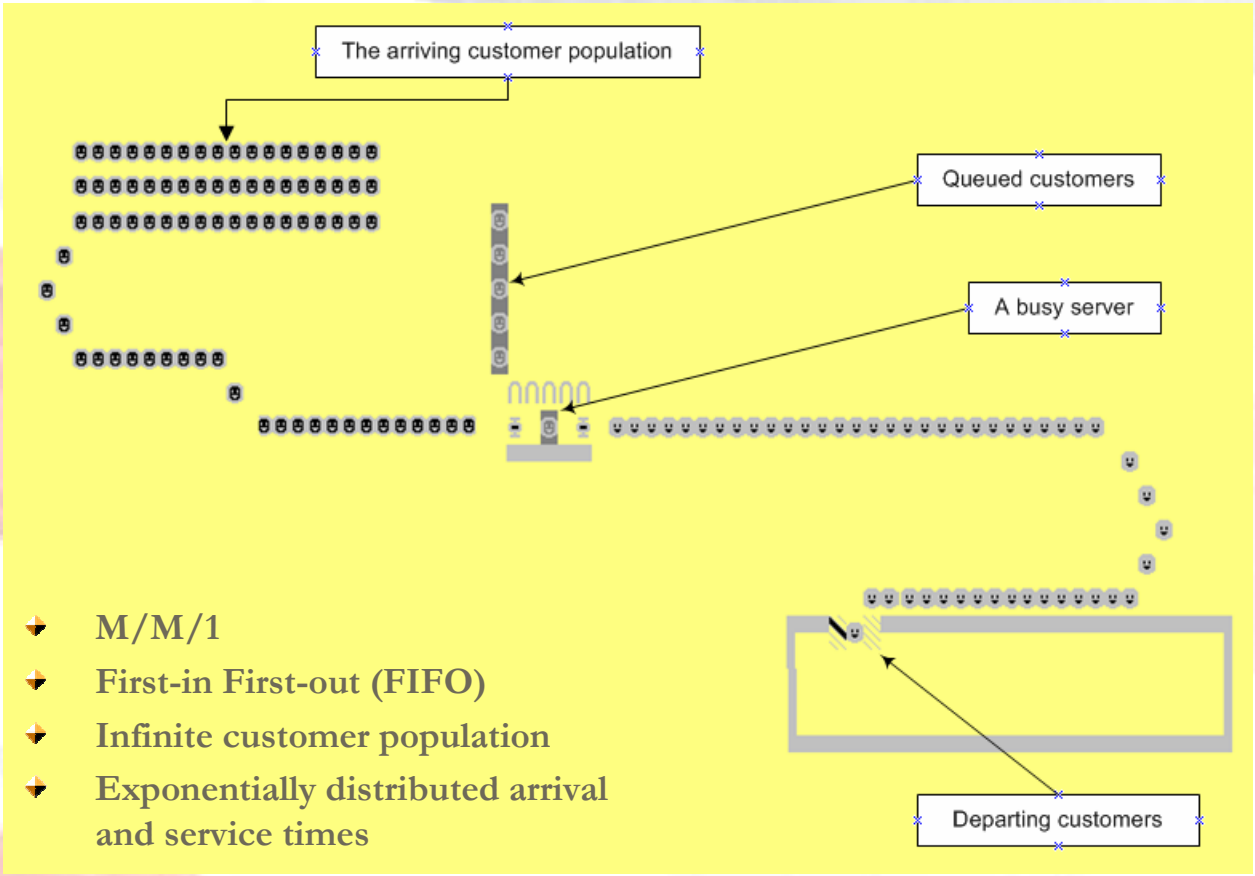
Quantitative Methods For CMMI® Maturity Level 5

"I should estimate that in my experience most troubles and most possibilities for improvement add up to proportions something like this:
94% belong to the system (responsibility of management)
6% special."

(Deming)

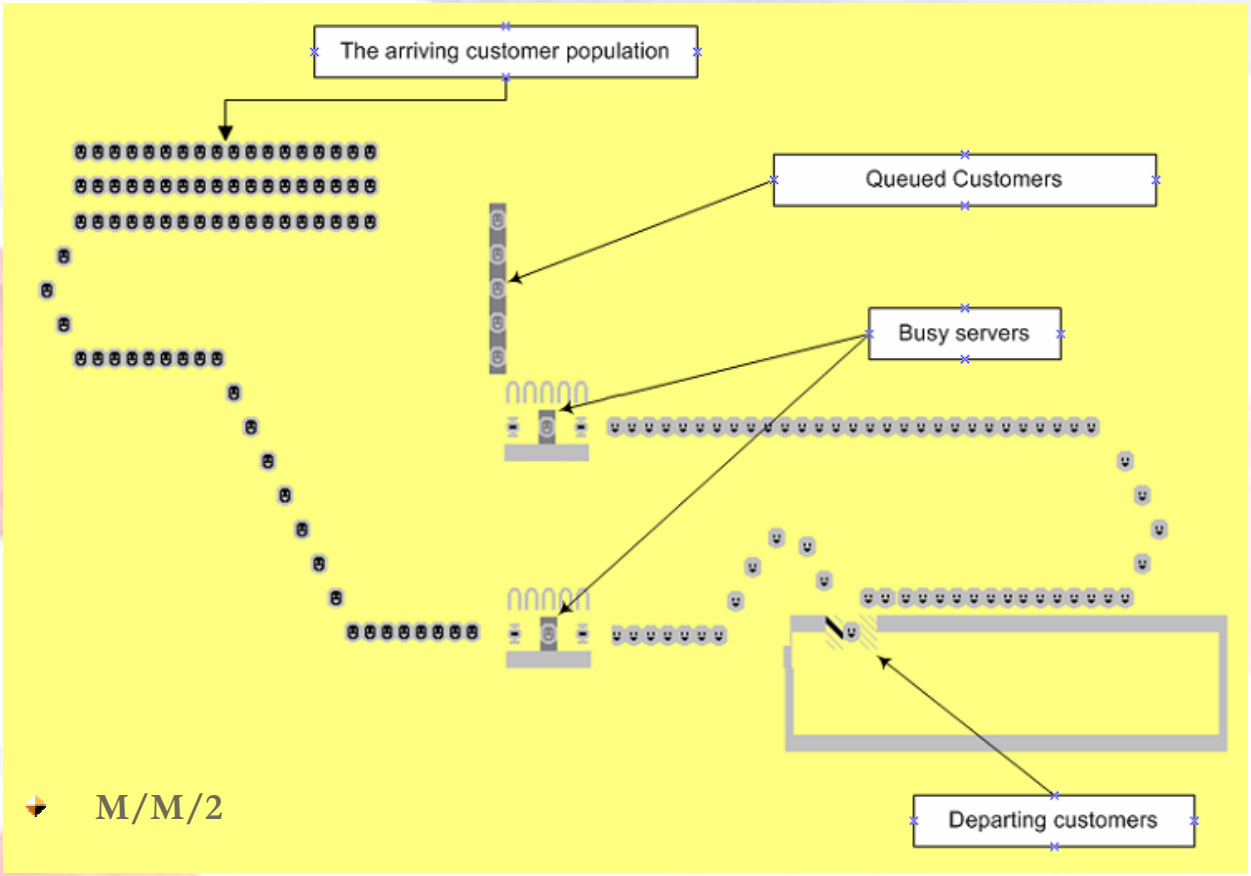
The Process Enrichment philosophy speaks of managing the architecture of a process, as it relates to its capability, in a sustained manner, to meet process objectives, as meeting the need to achieve performance that "assures the longevity of your business."

A Single-Server Single-Stage Queuing System



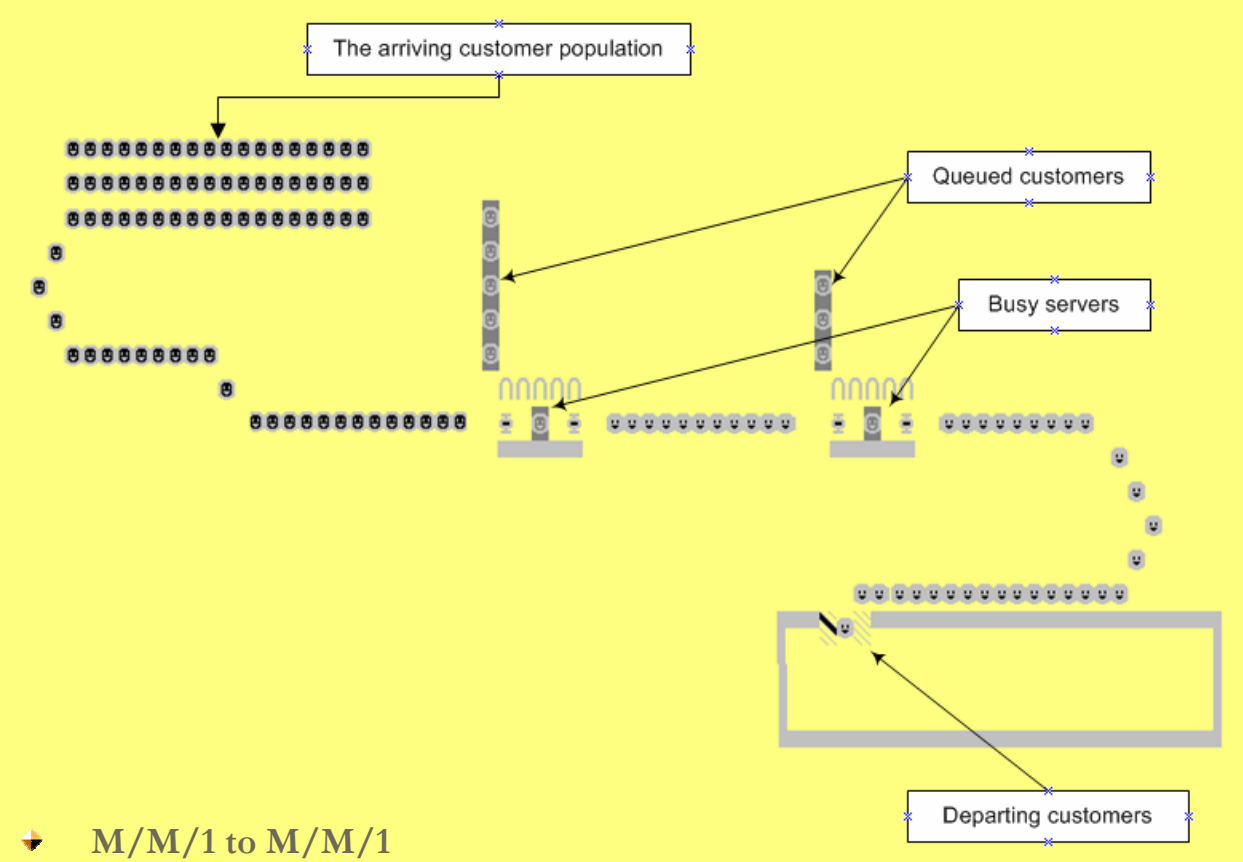
- M/M/1
- First-in First-out (FIFO)
- Infinite customer population
- Exponentially distributed arrival and service times

A Multiple-Server Single-Stage Queuing System



- M/M/2

A Single-Server Multiple-Stage Queuing System



- M/M/1 to M/M/1

Service Process Capability Measurement Paladin's One Best Way

- *"…statistical control implies monitoring capability as well as stability." (CMMI®)*
- *An "essential element of quantitative management is understanding the nature and extent of the variation experienced in process performance, and recognizing when the project's actual performance may not be adequate to achieve the project's quality and process-performance objectives." (CMMI®)*

As the preceding slides have shown, service processes are characterized by an interplay of multiple transactions and processes - most notably an arrival process and a service process.

Queuing analysis is a quantitative method that uses arrival rates and service rates to calculate a broad spectrum of process performance characteristics encapsulating service process capability.

As the following slides will demonstrate, this capability of queuing analysis to provide several managerially useful process performance statistics concurrently is unparalleled by any other quantitative method in our experience on Paladin.

Paladin Pilot CAR Study

"Optimize service process efficiency in processing PA Audit questionnaires"

☑ Design of experiment
☑ Information generation

Key service process characteristics:

- Service quality (cycle time)
- Economically optimal number of servers
- Economically optimal service rate
- Server utilization

Model:

- M/M/S Queuing System
- Process capability and variation is described by the steady state values of process performance parameters of the M/M/S model - driven by demand for service, λ , and the service rate, μ, of an average server.
- Threshold limits for process characteristics are established based on the assessed risk of not meeting process objectives. Operation within threshold limits towards the direction of improvement is the objective for each process characteristic.
- Common cause variation is regulated by management decisions regarding process architecture and the service product offering. Special causes of variation are prevented or mitigated by contingency plans driven by threshold values.
- Economic optimization is based on equal waiting costs and service costs

Documentation:

- A Measurement Definition was developed.
- A CAR Activity Workbook was established to record facts, figures, analysis, and conclusions.
- Technical Interchange Meeting (TIM) Read Aheads and Senior Mgmt. Reviews are used to communicate process performance

Implementation Note:

- Since the audit process affects all Paladin projects, one queuing study will provide audit artifacts satisfying Specific Practices for all Paladin projects.

Paladin Pilot CAR Study

"Optimize service process efficiency in processing PA Audit questionnaires"

☑ Formation of strategic objectives

Expected Process Performance Characteristics

Characteristic	Actual Value	Threshold	Units
Arrival Rate (λ)	0.023715	>= 00.04	Audits/ Workday
Inter-arrival time ($1/\lambda$)	42.166667	<= 25	Workdays
Service Rate (μ)	0.094340	<= 00.05	Audits/ Workday
Service Time ($1/\mu$)	10.5999999	>= 20.00	Workdays
Server Utilization (ρ)	0.251383 * 100 = 25	>= 35	%
Length in system (L_S)	0.335797	>= 00.60	Audits
Length in queue (L_Q)	0.084414	>= 00.12	Audits
Length in busy queue (L_B)	0.335797	>= 00.60	Audits
Wait in system (Cycle Time) (W_S)	14.159451	>= 25	Workdays /Audit
Wait in queue (W_Q)	3.559451	>= 6	Workdays /Audit
Wait in busy queue (W_B)	14.159451	>= 25	Workdays /Audit
Variance, Std-Dev., of length in system	0.449, 0.66974	>= 00.60, >= 00.90	
Variance, Std-Dev., of wait in system	200, 14.159	>= 275, >= 25	
Probability of no arrivals to system (P_0)	0.748617 * 100 = 75	<= 40	%
Probability of busy system (P_B)	0.251383 * 100 = 25	>= 45	%

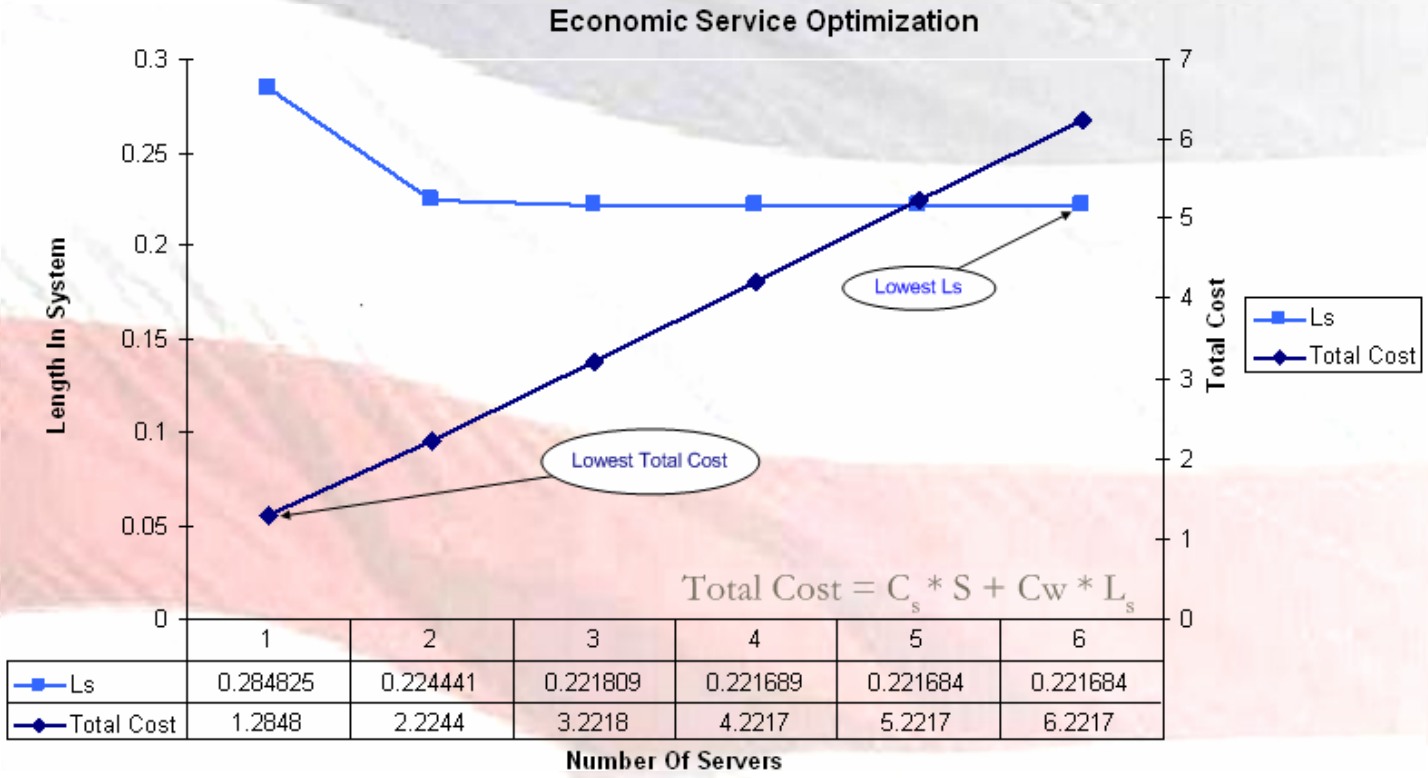
Economically Optimal Process Performance Values

Characteristic	Actual Value	Threshold	Units
Optimal number of servers	1	> 1	Servers
Optimal Service Rate	0.177712	N/A	Audits/ Workday

Analysis: Current staffing of 1 server is economically optimal. All process performance characteristics are well within threshold limits.

Paladin Pilot CAR Study

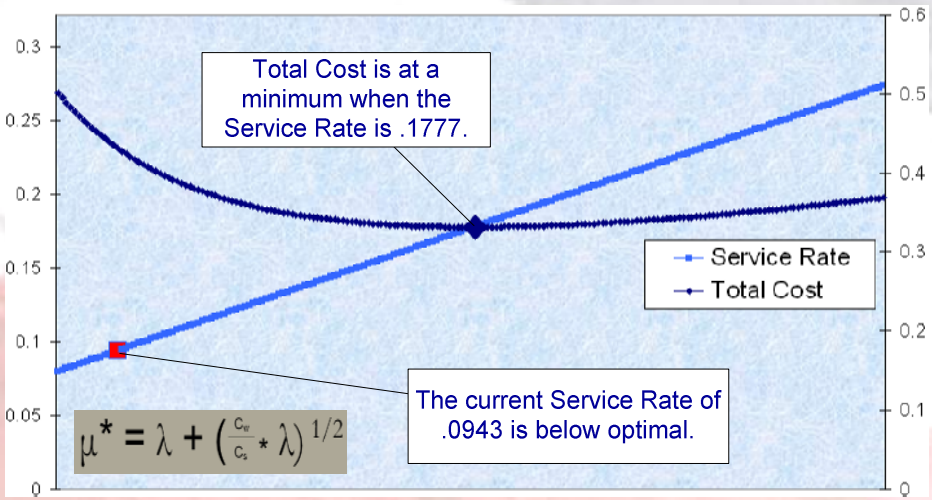
"Optimize service process efficiency in processing PA Audit questionnaires"



	1	2	3	4	5	6
Ls	0.284825	0.224441	0.221809	0.221689	0.221684	0.221684
Total Cost	1.2848	2.2244	3.2218	4.2217	5.2217	6.2217

Analysis: As more servers are added, Total Cost shows an almost linear growth. Length In System (Ls) declines sharply as a second server is added, but shows smaller improvements beyond two servers. The lowest, and therefore optimal, cost is achieved with one server - given the, historically derived, expected process performance characteristics. Staffing of 1 server is economically optimal.

Centering and Statistically Managing A Service Process



☑ Process Optimization

For service processes, the concept of centering involves identifying the best qualitative and quantitative position for the service process to achieve, in the steady state, in order to satisfy process goals – of which several are usually present.

The optimal number of servers cannot usually provide the optimal service rate because the optimal number of servers is an integer value. The optimal service rate is derived as shown in the figure above. This value, shows the direction of improvement for the service rate from the current value.

A quantitative process objective is set to meet this optimal service rate. If necessary, process centering requires re-engineering the process to match the optimal service rate or to satisfy qualitative process needs.

Quantitative Methods For CMMI® Maturity Level 5 Paladin's One Best Way

- **"Critical criteria for selecting statistical management measures include the following:**
  - **Controllable (e.g., can a measure's values be changed by changing how the subprocess is implemented?)**
  - **Adequate performance indicator (e.g., is the measure a good indicator of how well the subprocess is performing relative to the objectives of interest?)" (CMMI®)**
- **The goal of quantitative methods for service processes is for them to support the manageability of the service process. There is a strong correlation between the parameters monitored in a queuing study and the parameters management is interested in controlling. For example, the parameter values monitored will change in a quantifiable manner as the number of servers change, as the duration of service changes and as the demand for service changes.**
- **Assuming that a valid queuing study was performed, a rich variety of managerially-useful process performance characteristic values will have been determined. As has been seen, the model readily facilitates construction of "what if" models that indicate process performance under a variety of scenarios.**

Paladin Pilot CAR Study

"Optimize service process efficiency in processing PA Audit questionnaires"

Results and Observations:

- **Service process efficiency was economically optimized based on demand for service, economic criteria, process capability, and project needs.**
- **Sub-optimal performance can be prevented because mitigation or contingency actions are established.**
- **The queuing model provides a means to quantitatively predict the impact on performance of architectural or service level changes to the service process.**
- **Four organizational level and three project level goals are, to varying extents, satisfied by this measurement system**
- **Queuing analysis constitutes a, model-based, predictive, statistically robust, quantitative method that served well in CMMI® maturity level 5 appraisals.**
- **Process performance data used for this measurement system provides an excellent source of descriptive sampling information which, if found necessary, would provide the foundation for process simulation.**

Using Quantitative Information as a Basis for Decision Analysis and Resolution (DAR)

Dear Project Leader,

Now there are only 8 working days till the audit due date.
The service rate for this process shows a Wait in system (Cycle Time) = 14.159451 workdays.
The planned method of completing this audit, using a single server, is no longer feasible.
There are 3 alternative solutions that should be considered, based on established contingency plans defined in the Measurement Definition…:

1) **Postpone the Audit delivery by 7 days and continue with a single server (audit preparer).**
2) **Add 1 server (a total of two servers) for the following effect:**
   Wait in system . . . . . Ws is calculated to be 10.770101*
   and postpone the audit by 3 days.
3) **Add 2 servers (a total of three servers) for the following effect:**
   Wait in system . . . . . Ws is calculated to be 10.608624
   and postpone the audit by 3 days.
   Obviously adding additional servers beyond 2 is a fruitless proposition.
4) **Make provisions for an overtime effort.**

Please let me know your view on this at your earliest opportunity.
Regards…

(* Note that the primary message is that the audit can't be done in 8 days.
Use of steady state results to estimate the transient state results is probably a good idea.)

Artifacts Generated For One Statistically Managed Process Paladin's One Best Way

- **Measurement Plan (updated only)**
  - Describes the Project's measurement commitments including "Statistically Managed Processes"
- **Measurement Report**
  - A measurement and analysis report on monthly quantitative performance indicators
- **CAR Activity Workbook**
  - Serves as a container to document issues, actions and findings of CAR activities
- **Measurement Definition – Processing PA Audit Questionnaires**
  - Describes the measurement method, data collection, and decisions supporting achievement of operational results.
- **Technical Interchange Meeting (TIM) Read Ahead**
  - A functional area's report containing process performance info. discussed at bi-weekly meetings
- **Senior Management Review**
  - A quarterly status review meeting
- **Upload CAR Activity Workbook to Measurement Repository**
  - A Web based repository for sharing measurement information across projects
- **RE Request For Audit.msg**
  - An e-mail, presenting alternative solutions to the project leader on how to proceed in a circumstance where the proposed schedule for an audit couldn't be met – based on an established threshold.

Specific Practices Satisfied By One Statistically Managed Process Paladin's One Best Way

☑ Process Assessment

1. **DAR SP 1.2 Establish Evaluation Criteria**
2. **DAR SP 1.3 Identify Alternative Solutions**
3. **DAR SP 1.4 Select Evaluation Methods**
4. **DAR SP 1.5 Evaluate Alternatives**
5. **DAR SP 1.6 Select Solutions**
6. **QPM SP 2.1 Select Measures and Analytic Techniques**
7. **QPM SP 2.2 Apply Statistical Methods to Understand Variation**
8. **QPM SP 2.3 Monitor Performance of the Selected Subprocesses**
9. **QPM SP 2.4 Record Statistical Management Data**
10. **CAR SP 1.1 Select Defect Data for Analysis**
11. **CAR SP 1.2 Analyze Causes**
12. **CAR SP 2.1 Implement the Action Proposals**
13. **CAR SP 2.2 Evaluate the Effect of Changes**
14. **CAR SP 2.3 Record Data**

Paladin Drives Forward To CMMI® Maturity Level 5

- As Paladin's presentation demonstrates, ARDEC's AFCS is progressing from CMMI® maturity level 3 to maturity level 5.
- Paladin's One Best Way produced results that were useful and succeeded in motivating project members. Optimization is now an accepted and ongoing precept of project planning.
- Paladin's accomplishments in CMMI, and evident process improvements, were recognized and appreciated by customers.
- The Acting Director of ARDEC recognized Paladin's efforts towards CMMI® maturity level 5 as leading the way when he stated:

"Paladin proved it could be done."

Dialog

Notes

For more information about:

- ARDEC visit: http://www.pica.army.mil/PicatinnyPublic/index.asp
- Or contact Victor Elias at the:

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  (973) 724-2439

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