U.S. ARMY

Center for Army Analysis

# PLANNING ARMY RECAPITALIZATION INVESTMENT STRATEGIES

JUNE 2002

CENTER FOR ARMY ANALYSIS
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| REPORT DOCUMENTATION PAGE | | | Form Approved OMB No. 074-0188 |
|---|---|---|---|
| Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503 | | | |
| **1. AGENCY USE ONLY (Leave blank)** | **2. REPORT DATE** June 2002 | **3. REPORT TYPE AND DATES COVERED** Final, Dec 2001-June 2002 | |
| **4. TITLE AND SUBTITLE** PLANNING ARMY RECAPITALIZATION INVESTMENT STRATEGIES | | | **5. FUNDING NUMBER** |
| **6. AUTHOR** LTC Allen C. East | | | |
| **7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)** **Center for Army Analysis** **6001 Goethals Road** **Fort Belvoir, VA 22060-5230** | | | **8. PERFORMING ORGANIZATION REPORT NUMBER** |
| **9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)** Army G8 ATTN: DAPR-FD 600 Army Pentagon, Rm 1E1037 Washington, D.C. 20310-0600 | | | **10. SPONSORING / MONITORING AGENCY REPORT NUMBER** |
| **11. SUPPLEMENTARY NOTES** | | | |
| **12a. DISTRIBUTION / AVAILABILITY STATEMENT** Approved for public release, dissemination unlimited | | | **12b. DISTRIBUTION CODE** A |

The Army's overall recapitalization requirement of $59 B as determined by the half-life metric far exceeds the $35 B currently programmed over the next 10 years. The Defense Planning Guidance (DPG) 2003-07 directs the Services to make a more detailed assessment of recapitalization needs and to report optimum recapitalization rates. Planning Army Recapitalization Investment Strategies (PARIS) is what the Center for Army Analysis (CAA) used to determine these rates. A basic question with aging equipment is at what point is it cost-effective to recapitalize rather than pay increased operations and maintenance costs. Based on a fleet management model developed for this project, PARIS develops a strategy that minimizes fleet ownership costs of a set of Army fleets using a mixed integer program. The PARIS approach provides the Army with a more robust way of determining recapitalization quantities than using the less defensible half-life approach. The result is a more efficient and analytically defendable use of programmed dollars.

| **14. SUBJECT TERMS** Recapitalization, investment strategy, linear program, Defense Planning Guidance | | | **15. NUMBER OF PAGES** |
|---|---|---|---|
| | | | **16. PRICE CODE** |
| **17. SECURITY CLASSIFICATION OF REPORT** UNCLASSIFIED | **18. SECURITY CLASSIFICATION OF THIS PAGE** UNCLASSIFIED | **19. SECURITY CLASSIFICATION OF ABSTRACT** UNCLASSIFIED | **20. LIMITATION OF ABSTRACT** SAR |

**NSN 7540-01-280-5500**
**Standard Form 298**

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# PLANNING ARMY RECAPITALIZATION INVESTMENT STRATEGIES

## SUMMARY

**THE PROJECT PURPOSE** is to determine optimum recapitalization rates for a set of Army fleets during their life cycles, generally 25-30 years. Recapitalization is the process of rebuilding a system to "like new" condition.

**THE PROJECT SPONSOR** is the Army G8 (DAPR-FD), Headquarters, Department of the Army.

**THE PROJECT OBJECTIVES** were to:

**(1)** Develop a fleet management model that the Army can use to plan and budget recapitalization of existing fleets and the procurement of new fleets.

**(2)** Determine when operation and maintenance age escalation makes recapitalization cost-effective.

**(3)** Develop a linear program that determines optimal recapitalization quantities that are cost effective investment strategies for the Army.

**(4)** Compare the PARIS-generated solution to the Vice Chief of Staff (Army) approved recapitalization program.

**THE SCOPE OF THE PROJECT:** Consider twenty Army fleets in three categories. Tier 1 includes twelve legacy fleets, tier 2 includes six legacy to objective force fleets, and tier 3 includes two new/future systems.

**THE MAIN ASSUMPTIONS:**

**(1)** Recapitalization, in general, reduces operations and maintenance costs and extends equipment service life.

**(2)** Operation and maintenance costs increase as equipment ages.

**THE PRINCIPAL FINDINGS** are that:

**(1)** Recapitalization is generally cost-effective when three conditions exist:

(a) Recapitalization is of limited duration within the life cycle of the fleet.

(b) When the average annual system operation and maintenance cost real growth is greater than two percent.

(c) When the ratio of the system's annual operation and maintenance cost to the system's recapitalization cost is greater than five percent.

**(2)** Using the PARIS model, a more cost-effective program requiring $32 B for recapitalization was developed.

**THE PRINCIPAL RECOMMENDATIONS** are that:

**(1)** The Army use the fleet management model to better plan for future recapitalization and procurement of new fleets.

**(2)** The Army use the PARIS methodology to determine cost-effective recapitalization investment strategies instead of using the current half-life metric.

**(3)** The Army more thoroughly research and collect operation and maintenance (O&M) cost data by system age.

**THE PROJECT EFFORT** was conducted by LTC Allen C. East, Resource Analysis Division, Center for Army Analysis (CAA).

**COMMENTS AND QUESTIONS** may be sent to the Director, Center for Army Analysis, ATTN: CSCA-RA, 6001 Goethals Road, Suite 102, Fort Belvoir, VA 22060-5230.

## CONTENTS

Page



## FIGURES

# 1 INTRODUCTION

## 1.1 Background

In 2001, senior military leaders informed the United States Congress that aging equipment was becoming an increasing burden on operation and maintenance (O&M) budgets. The Services proposed that equipment recapitalization was necessary to avoid a budgetary crisis. Recapitalization, or recap, is the process of rebuilding a piece of equipment to "like-new" condition. Because of the high cost of recap, the Office of the Secretary of Defense (OSD) required the Services, in the Defense Planning Guidance (DPG) 2003-07 released in December 2001, to review their recap programs and determine optimum recap rates by February 2002. The Army G8 tasked CAA to provide an analytical solution to the DPG question on recap rates. Planning Army Recapitalization Investment Strategies (PARIS) is the methodology that CAA developed and used to determine optimum recap rates.

## 1.2 Purpose

The purpose is to determine optimum recap rates for a set of Army fleets during their life cycles, generally 25-30 years.

## 1.3 Key Assumptions

The key assumptions for this project are:

(1) Operation and Maintenance (O&M) costs increase as equipment ages; this is what we define as age escalation. The Army does not have detailed data supporting system-specific O&M age escalation factors. A December 2001 U.S. Army Materiel Systems Analysis Activity (AMSAA) report showed inconclusive O&M age escalation for selected tanks and trucks. An August 2001 Congressional Budget Office (CBO) paper estimates that spending on O&M for aircraft increases by 1 percent to 3 percent for every additional year of age after adjusting for inflation. PARIS initially assumes a 3% annual O&M age escalation rate and then provides sensitivity analysis across a range of O&M age escalation factors for each system to determine the impact on recap quantities.

(2) Recapitalization, in general, reduces O&M costs and extends service life. Since the Army does not maintain this type of data and FY02 is the base-line year for this report, PARIS assumes that recap of aged equipment reduces O&M costs to the FY02 annual O&M cost. For example, if the FY02 system annual O&M cost is \$100 K, a 15 year old system would have an annual O&M cost of $100(1+.03)^{(15-1)}$ = \$151 K. If we recap a 15 year old system, it becomes age 1 and has an O&M cost of \$100 K, saving \$51 K in O&M for the first year after the vehicle is recapped. The system's annual O&M cost then continues to escalate as the recapped equipment ages.

## 1.4 Key Limitation

Recapitalization may increase system readiness and capability. These potential recap benefits are not included in the PARIS study since these factors are not readily quantifiable and arguably subjective. PARIS considers recap from a cost-effectiveness perspective. On a case-by-case basis, decision-makers may want to consider increasing recap quantities beyond what is determined to be cost-effective to meet certain mission requirements.

## 1.5 Scope

The scope of this report includes three tiers of twenty systems presented in Figure 1. The sponsor of the project, the Army G8, determined what Army vehicles and systems to include in PARIS. Except for the Paladin, all of the tier 1 and tier 2 vehicles and systems have recap programs approved by the Vice Chief of Staff (Army) (VCSA) as of December 2001. This report provides a comparison of the current recap programs to the PARIS solution. The inclusion of tier 3 (new / future systems) will allow the Army to plan and budget for recap early in a new system's life-cycle.

- **Tier 1 (Legacy) (12 fleets)**
  - **Abrams Tank**
  - **Apache Helicopter**
  - **Bradley Fighting Vehicle**
  - **Multiple Launch Rocket System (MLRS)**
  - **M88 Recovery Vehicle**
  - **Armored Vehicle Launched Bridge (AVLB)**
  - **M9 Armored Combat Earthmover (ACE)**
  - **Small Earth Excavator (SEE)**
  - **Electronic Shops**
  - **Field Artillery Ammunition Supply Vehicle (FAASV)**
  - **M113 Infantry Carrier**
  - **Paladin 155mm SP Artillery**
- **Tier 2 (Legacy to Objective Force) (6 fleets)**
  - **UH-60 Blackhawk Helicopter**
  - **CH-47 Chinook Helicopter**
  - **Heavy Expanded Mobility Tactical Truck (HEMTT)**
  - **High Mobility Artillery Rocket System (HIMARS)**
  - **Firefinder field artillery radar**
  - **High Mobility Multipurpose Wheeled Vehicle (HMMWV)**
- **Tier 3 (New / Future Systems) (2 fleets)**
  - **RAH-66 Comanche Helicopter**
  - **Stryker Armored Vehicle**

**Figure 1. Fleets considered**

## 1.6 General Methodology

The general methodology for this project can be divided into three phases:

(1) Data collection and verification.

(2) Run linear program for each system to find a solution that minimizes the cost to own a fleet.

(3) Conduct sensitivity analysis.

The Army Cost and Economic Analysis Center (CEAC) provided all of the input cost data and the staff synchronization officers from the Army G8 provided system inventory and recap information. The input data is described in detail in Chapter 4. Data collection and verification takes a significant amount of time because of the number and variety of systems and amount of data required for each system. Once the data has been collected and verified for accuracy, the linear program is run for each system to determine the minimum cost solution using the initial data. The linear program is discussed in Chapter 4. After the initial linear program has run successfully, the input parameters are changed to see how sensitive the solution is to minor changes in the data. Results are then tabulated and reported in Chapter 6.

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# 2 DEFINITIONS

## 2.1 What is Optimum?

The DPG tasked the services to provide “optimum” recap rates. OSD did not provide a definition of optimum, thus giving the Services flexibility to create their definition. PARIS defines optimum as minimizing fleet ownership costs over the life-cycle of the fleet. Fleet ownership costs are what the Army pays to own and operate a fleet. Specifically, fleet ownership costs are O&M costs plus recap costs. Since the equipment is already in the Army inventory, procurement, research, development, test, and evaluation (RDT&E) costs are sunk costs and not considered a part of the fleet ownership costs.

OWNERSHIP COSTS = O&M COSTS + RECAP COSTS

## 2.2 What is Cost-Effective?

Cost-effective means that the cost of the recap program plus the reduced fleet O&M costs are lower than the fleet O&M costs without recap over the life-cycle of the fleet. To be considered cost effective, a recap program must pay for itself in reduced fleet O&M costs. PARIS optimally determines the most cost-effective solution by using a mixed integer program to calculate when recap should occur and at what quantities to minimize fleet ownership costs. It is possible that the minimum cost solution will not include a recap program.

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# 3 COMPARING METRICS

## 3.1 Half-Life Metric

A generally accepted metric to determine recap quantities is the half-life metric. Simply stated, the idea is to keep the average age of a fleet at half its service life. For example, if a vehicle has an estimated 20-year service life, the goal is to keep the average age of all the vehicles in the fleet at 10 years. Using this method, it is fairly straightforward to calculate recap quantities because the Army maintains data on equipment inventory by age. However, the half-life method has two significant limitations. Half-life is an arbitrary metric. Why set the fleet age goal at half-life? Why not keep the average age of the fleets at another level, say 60% of its service life? Additionally, half-life does not consider cost impacts. Using this method, the Army needs $59 B over the next 10 years to keep its fleets at their half-lives (Figure 2). Currently, $35 B dollars are programmed over the same time period, an apparent $24 B short fall. It becomes apparent that half-life is infeasible to attain from a budgetary perspective. The PARIS methodology allows the Army to move away from the half-life metric by determining feasible, cost-effective recap quantities.

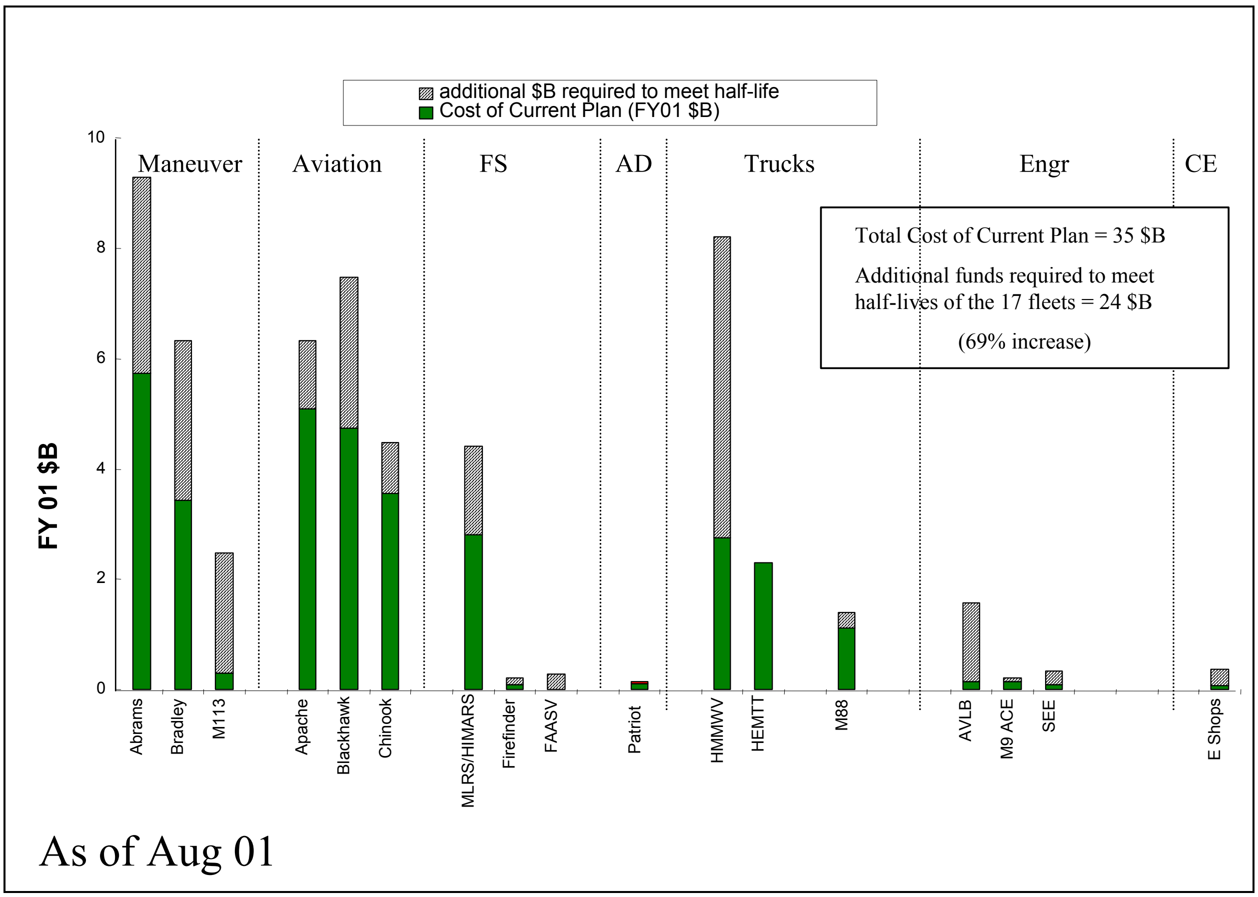


**Figure 2. Half-Life Metric Costs**

## 3.2 Fleet Management Model

The fleet management model in Figure 3 was developed within PARIS to depict how different Army fleets could be managed efficiently using one concept. Each fleet goes through three phases: procure, utilize, retire. During the utilization phase, each fleet arrives at a decision point --should the fleet be recapped? If so, when and what percentage of the fleet should the Army recap? The PARIS methodology proposes that recap occur only if it is cost-effective within the service life of the fleet. With or without recap, the fleet is retired as it reaches the end of its service life. The procurement of the new fleet is timed with the retirement of the old fleet. Currently, Army fleets are being utilized beyond their service life and recap dollars compete for procurement dollars.

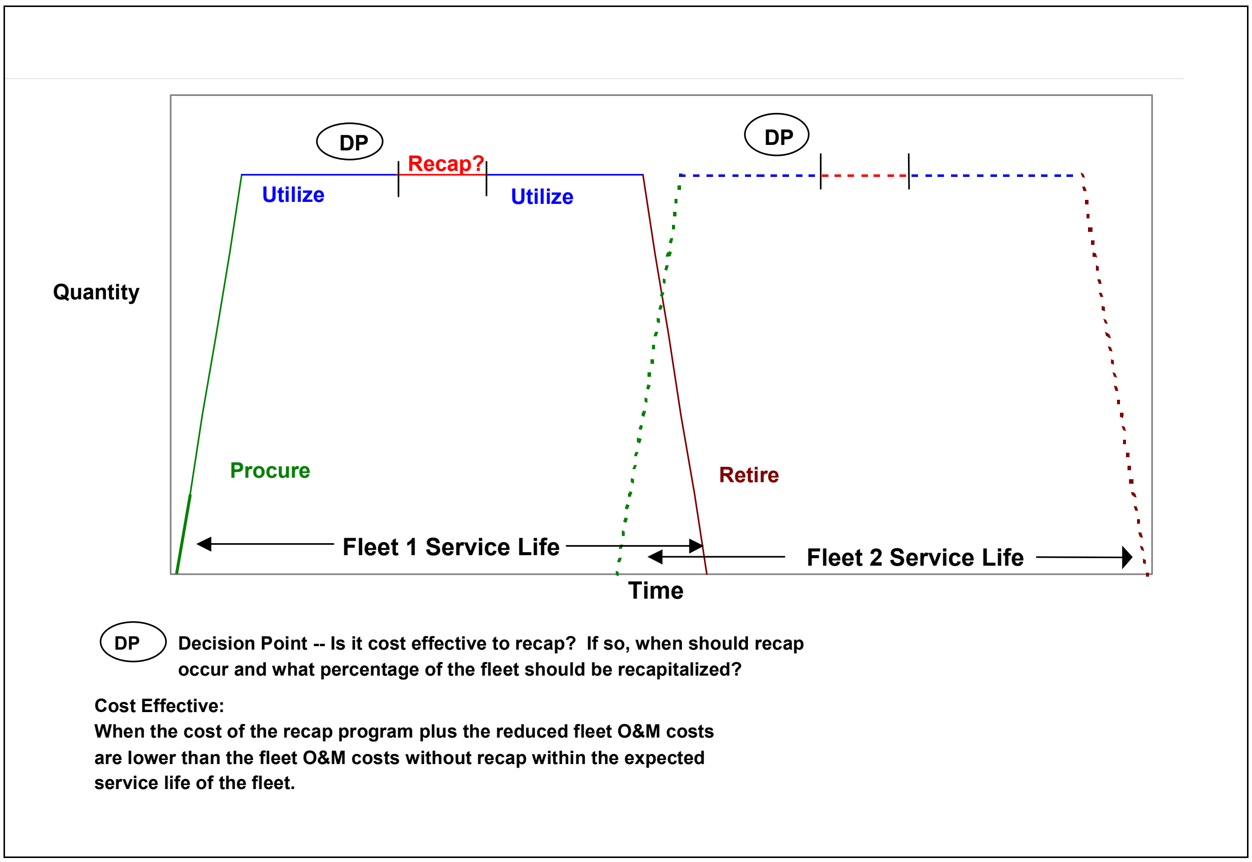


**Figure 3. Fleet Management Model**

The decision to recap should not compete with the decision to procure new equipment because procurement is a necessity that should be planned to occur near the end of the life-cycle of the existing fleet. From an investment perspective, the decision to recap should be based on whether or not recap is a cost-effective strategy within the current fleet's life-cycle. Decision-makers should ask if recap will lower fleet ownership costs of the existing fleet. For example, in the current budget process, decision-makers are under the impression that they have to decide whether to recap a vehicle or procure a new one. The questions should be -- will recap extend the life of the fleet and pay for itself, or should the Army retire the current fleet and procure a new one? This approach will allow the Army to better manage its fleets.

# 4 MODEL OVERVIEW

## 4.1 Introduction

The PARIS model is a mixed integer linear program that uses the data inputs listed in the next section for each fleet to determine a minimum-cost solution to own each fleet considered in the scope of the analysis, taking into consideration the capacity of the industrial base to recap systems and Army transformation goals. The model is run five times for each system, corresponding to the range of O&M age escalation of 2% to 4%, at .5% increments. Since there are 20 fleets in the analysis, this corresponds to 100 runs of the linear program. Using the GAMS c-plex solver, each run of the linear program solves in seconds. The most time consuming elements of the PARIS model are the collection and review of the input data.

## 4.2 Data Inputs

The sources and data inputs required for PARIS are listed in Figure 4. The fleet inventory by system age is the start point for this analysis. It is the current age distribution of a fleet and is simply a count of system quantities by how old they are. For example, 150 tanks are 15 years old, 125 tanks are 14 years old, 100 tanks are 13 years old, etc. The Army G8 provides this data.

The Army Cost and Economic Analysis Center (CEAC) provides the per-system annual O&M cost in FY02 constant dollars. This data input indicates how much the Army spends, on average, to operate and maintain a system on an annual basis. For example, the annual O&M cost for the UH-60 Blackhawk helicopter is $512K.

The annual system O&M age escalation factor is the percentage the O&M cost increases for every year a system ages, not including inflation. The assumption is that the system is more expensive to maintain as it gets older. As previously mentioned, PARIS determines optimal recap quantities using a range of 2% to 4% age escalation factors based upon a Congressional Budget Office paper that estimates that 3% is not unreasonable.

Program managers provide the system recap budget estimates in FY02 constant dollars. This data input provides an estimate of the cost to recap each system. A key factor is the ratio of the annual system O&M cost to the system recap cost. As this ratio increases, it is more likely that a recap program will be cost effective.

The annual real discount rates adjust future year dollars into today’s dollars for a consistent comparison across all years. Without this adjustment, future year savings and recap quantities would be overstated. The current discount rate provided by the Office of Management and Budget (OMB) is 3.2% for every year.

The Army G8 provides the maximum annual recap quantities for each system. This data input insures that the industrial base can meet the recap quantities determined in the PARIS solution.

- **Fleet inventory by system age (as of FY02)**
  **(Source: Army G8)**
- **Per system annual O&M cost (FY02 constant dollars)**
  **(Source: Army Cost and Economic Analysis Center)(CEAC)**
- **Annual system O&M age escalation (percent)**
  **(Source: CBO Paper)**
- **Per system recap budget estimates (FY02 constant dollars)**
  **(Source: Program Managers)**
- **Annual real discount rates (percent). These rates discount futur e year dollars into today's dollars for a consistent comparison across all year s.**
  **(Source: OMB)**
- **Maximum annual recap quantities (system/year)**
  **(Source: Army G8)**
- **Estimated annual fleet quantity changes based on transformation (system/year) (Source: Army G8)**

**Figure 4. Data Inputs**

The Army G8 provides the estimated annual fleet quantity changes based upon transformation. This data input takes into account that certain fleets are being reduced over time. For example, there are approximately 6000 Bradleys in the inventory today. However, in 20 years there will be far fewer Bradleys because of the Army transformation. PARIS determines recap quantities taking into account the proposed inventory reduction in legacy fleets over time.

## 4.3 Formulation

PARIS is a mixed integer programming model. Below is the model formulation.

Indices:

$s$ – systems

$y$ – years

$a$ – age

Integer Variables:

$x_{s,y}$ = number of system $s$ to recap in year $y$

$I_{s,a,y}$ = inventory of system $s$ of age $a$ in year $y$

$r_{s,a,y}$ = number of system $s$ of age $a$ to retire in year $y$

Data:

$c_{s,y}$ = cost to recap system $s$ in year $y$

$o_{s,a}$ = annual O & M cost for system $s$ of age $a$

$S_{s,a}$ = number of system $s$ of age a in the Army inventory in year 1

$u_{s,y}$ = upper limit on number of system $s$ that can be recapped in year $y$

$d_y$ = the amount the force changes in year $y$

$f_y$ = the fleet size in year $y$

Objective function:

$$\text{Minimize Ownership Cost} = \sum_{s}\sum_{a}\sum_{y}\left(c_{s,y}x_{s,y} + o_{s,a}I_{s,a,y}\right)$$

The objective function minimizes ownership cost. Ownership cost is defined as the sum of the system recap costs and the system O&M costs. The decision variable is how many systems to recap each year. A nice feature of the solution is that the PARIS model not only determines recap quantities, but it also determines a recap timeframe during the system's life cycle. Additionally, the model may contain a solution with zero recap quantities if it is not cost-effective to recap.

Constraints:

$$I_{s,a,y} = S_{s,a}, \text{ when } y = 1, \forall s, a \qquad (1)$$

Constraint 1 insures that the system starting inventory equals the inventory variable for the first year. It is important to have an accurate starting value for the inventory variable because it is used in the objective function and three of the constraints.

$$x_{s,y} < u_{s,y}, \forall s, y \qquad (2)$$

Constraint 2 insures that the recap quantities the model is solving for are less than or equal to the upper recap limit of the industrial base. This constraint insures that the recap solution is feasible with regard to the production capacity in the industrial base.

$$r_{s,a,y+1} \le I_{s,a,y}, \forall s, a, y \qquad (3)$$

Constraint 3 insures that the model does not retire more systems than are in the inventory. For the purpose of this model, systems are retired for two reasons. First, as transformation dictates, systems are retired to meet force structure reductions. Second, as systems are recapped, an “old” system is retired and a “new” system starts at age 1. This represents the assumption that recap returns a system to “like new ” condition. An interesting feature of the model is that it will always retire the oldest systems first because it is trying to minimize cost and the oldest systems have the highest O&M cost. We do not have to force the model to retire the older systems first. The fact that the model retires older systems first is representative of the cascade effect of systems to the Guard and Reserve. Active Army systems are eventually transferred to the Guard and Reserve. The Guard and Reserve then retire their oldest equipment to make room for the recently received Active Army systems; this is known as the cascade effect and represents how older systems are retired first.

$$I_{s,a+1,y+1} = I_{s,a,y} + x_{s,y} - r_{s,a,y+1}, \forall s, a, y \qquad (4)$$

Constraint 4 is a balance equation. This constraint ensures that next year’s inventory is equal to what was in the inventory the year before plus what has been recapped minus what has been retired.

$$\sum_{s} x_{s,y-1} - \sum_{s}\sum_{a} r_{s,a,y} = d_y, \forall y \qquad (5)$$

Constraint 5 takes into account force transformation changes. If the system is being reduced due to transformation, then this constraint allows the model to retire more systems than it recaps to meet the reduced force structure.

$$\sum_{s}\sum_{a} I_{s,a,y} = f_y, \forall y \qquad (6)$$

Constraint 6 ensures that the sum of the inventory for a given year equals the fleet size for a given year.

The linear program solves for recap quantities that minimize ownership cost while meeting the six constraints. This is what we refer to as optimal recap quantities.

# 5 SYSTEM EXAMPLES

## 5.1 Introduction

As discussed in the project scope in Section 1.5, the analysis was categorized into three tiers. This chapter illustrates the input data and results of the linear program for one fleet in each tier. Each fleet must be analyzed from the perspective of where it is on the fleet management model.

## 5.2 Tier 1 Example – Bradley Fighting Vehicle

Figure 5 lists the Bradley fighting vehicle data input. There are currently 6,710 Bradleys in the Army inventory. It costs the Army approximately $180K annually to operate and maintain each Bradley. The current budget estimate to recapitalize each Bradley is $1.7 M. The ratio of the annual O&M cost to the recap cost is 180/1700, or 11%. In general, values of this ratio greater than 5%, combined with an annual O&M age escalation of 3%, indicate that a recap program during the system's life-cycle will be cost effective.

BRADLEY FIGHTING VEHICLE DATA INPUT

FY02 inventory= 6710 systems

Per system annual O&M cost = $179.603 K (FY02 constant dollars)

Annual system O&M age escalation = 3%

Per system recap budget estimate = $1.683 M (FY02 constant dollars)

Annual real discount rate  = 3.2%

Maximum annual recap quantity = 300 systems

Transformation quantity changes = -3560 systems thru FY26

**Figure 5. Bradley Data Input**

In the case of the Bradley, even with a reduction of 3560 Bradleys by FY26 due to Army transformation, it is cost effective to recap 300 Bradleys each year for 10 years from 2002 until 2011, for a total of 3000 Bradley's recapped. This represents 45% of the initial Bradley inventory. There are two major factors that make the Bradley recap program cost effective starting in FY02. First, the Bradley has a high O&M cost-to-recap cost ratio of 11%. Second, like many of the fleets in the Army, the Bradley fleet is advanced in age, with hundreds of Bradleys 18-22 years old. These older Bradleys are cost effective to recapitalize because we have assumed a 2-4% O&M age escalation.

The graph in Figure 6 illustrates that fleet ownership costs are initially higher because of the investment in the recap program from 2002 until 2011. The recap program realizes dividends in lower fleet ownership costs from 2012 through 2026 because of the lower O&M costs provided by the recap program in earlier years.

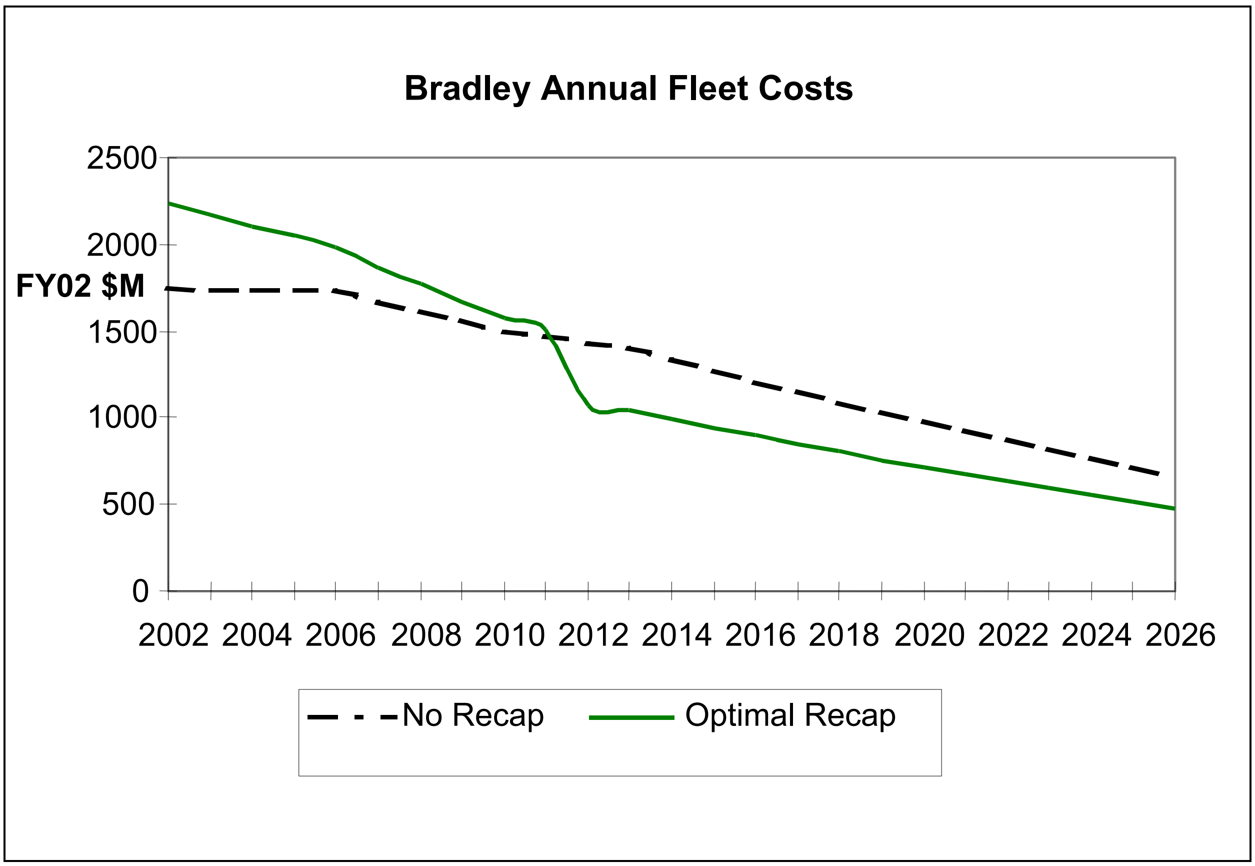


**Figure 6. Bradley Annual Costs**

Because the recap program returns each Bradley to "like new" condition, each Bradley that is recapped returns to age 1 and saves the Army additional O&M costs that an older Bradley would have incurred. The initial investment in recapping 3000 Bradleys for a total cost of $5 B over 10 years actually pays for itself in lower O&M costs over the life-cycle of the fleet. These savings have been discounted by 3.2% each year. Without discounting these future year savings, the recap program would inaccurately realize even more savings and the solution would increase the recap quantities. Bradley fleet ownership costs decrease over time because of the decrease in Bradley quantities due to the Army transformation.

The graph in Figure 7 shows that the Bradley recap program pays for itself during the life-cycle of the fleet. The cumulative fleet ownership cost with a recap program is lower than without a recap program. The break-even point occurs in 2019, with $1.7 B saved by 2026. A point worth making is that the Bradley recap program is not a tremendous cost-saver, but it *is* cost-effective and provides a reasonable justification for the recap program. Keeping in mind that the Army primarily recaps equipment for capability and readiness reasons, it is an even better investment strategy if the recap program is also cost-effective. Decision-makers should be informed that a recap program requires an upfront investment that will pay immediate dividends in enhanced capability and readiness and then additional dividends of reduced O&M costs in the second half of the system's life-cycle.

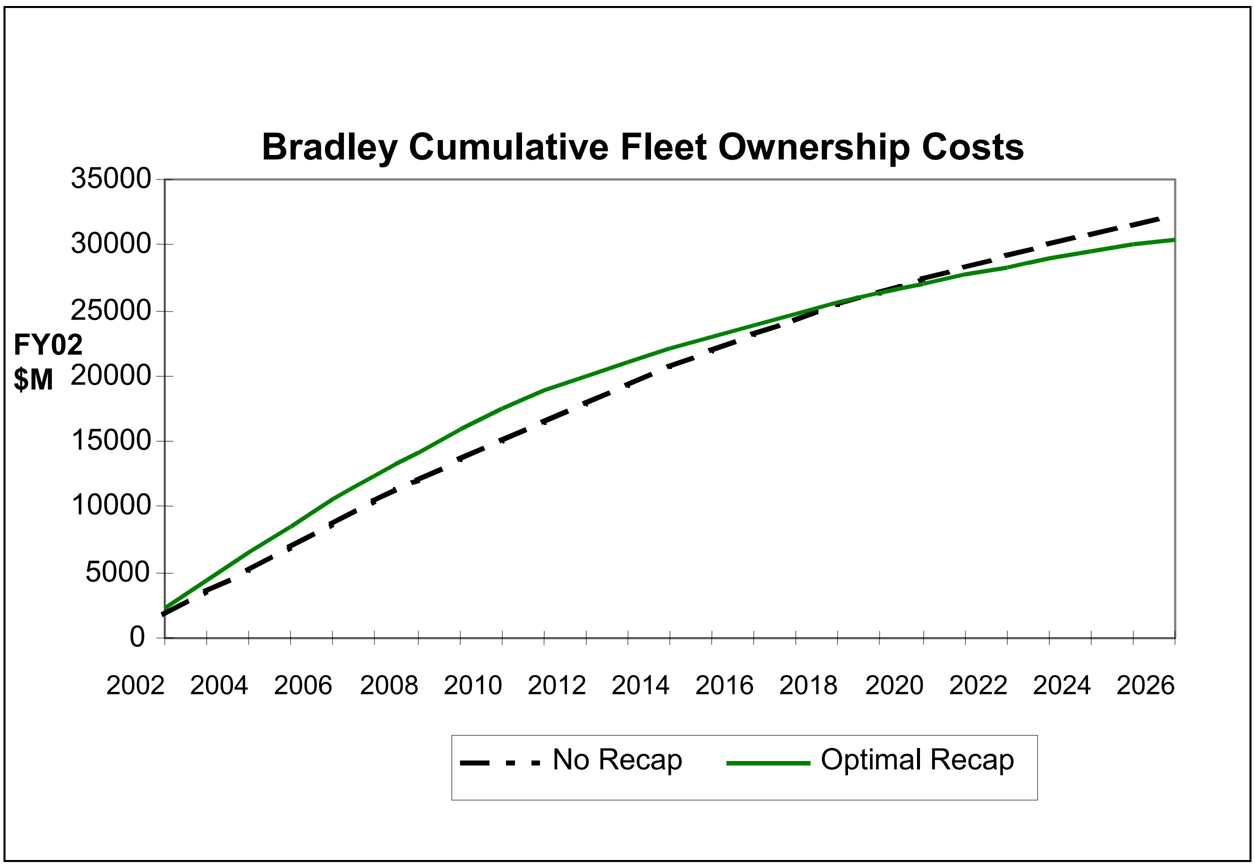


**Figure 7. Bradley Cumulative Costs**

Assuming a 3% O&M age escalation, the optimal Bradley recap program is 300 Bradleys per year from 2002-2011, for a total of 3000 Bradleys. The bar chart in Figure 8 illustrates that the Bradley recap program should be of limited duration, in this case 10 years.

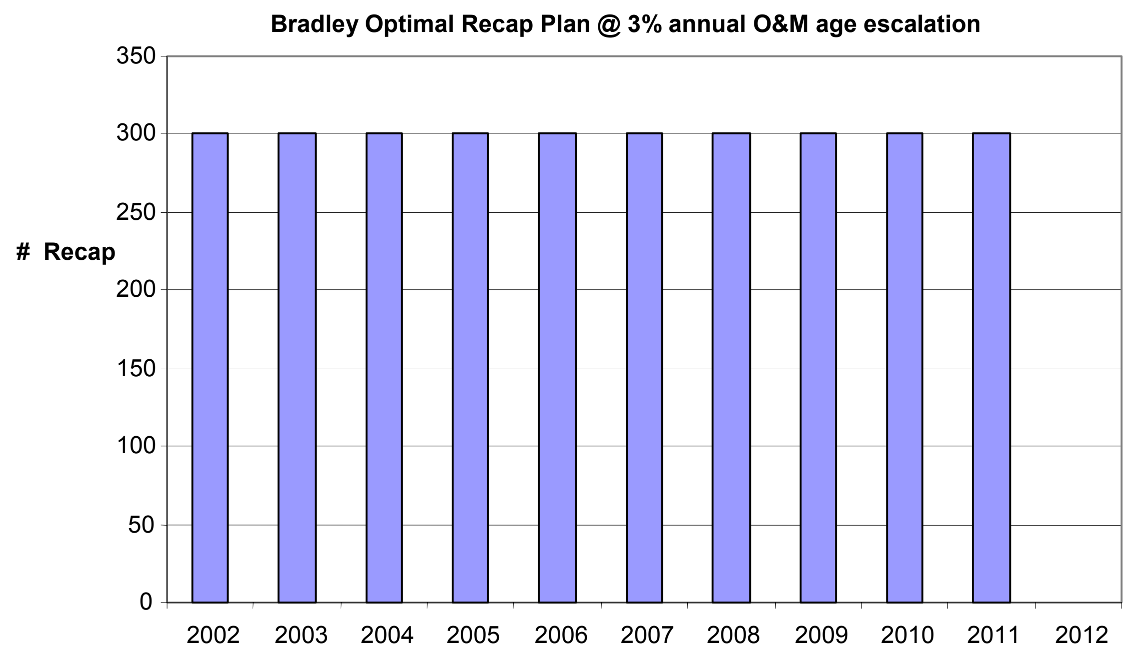


**Figure 8. Bradley Optimal Recap Plan**

If we relax the 300 per year recap limit constraint, then the recap program will be shorter in duration. The output of the linear program indicates that the Bradley should be recapped from 2002 until 2011. After 2011, it is no longer cost-effective to recap the Bradley because it is on the second half of the fleet management model and further investment in recap will not result in lower fleet ownership costs.

Sensitivity to different O&M age escalation factors is depicted in Figure 9. This figure shows the optimal quantities for Bradley recap for each age escalation factor using recap costs of $1.25M and $1.7M per system. It is interesting to note that if the O&M age escalation factor is actually 2%, then a Bradley recap program is not cost-effective unless the system recap cost is reduced from $1.7 M to $1.25 M. Thus, if we fix the O&M age escalation factor, we can determine what the recap cost should be in order for the program to be cost-effective. This feature of the model can be used to assist in determining how much the Army should spend to recap a system. If the Bradley recap cost is reduced to $1.25 M, then it is cost-effective to recap 1000 Bradleys if the O&M age escalation factor is 2%.

The average of the optimal solutions at different O&M age escalation factors is called the optimal average. The optimal average is 2528 Bradleys recapped. The current VCSA approved plan is to recap 2665 Bradleys. The optimal average is close to the current plan.

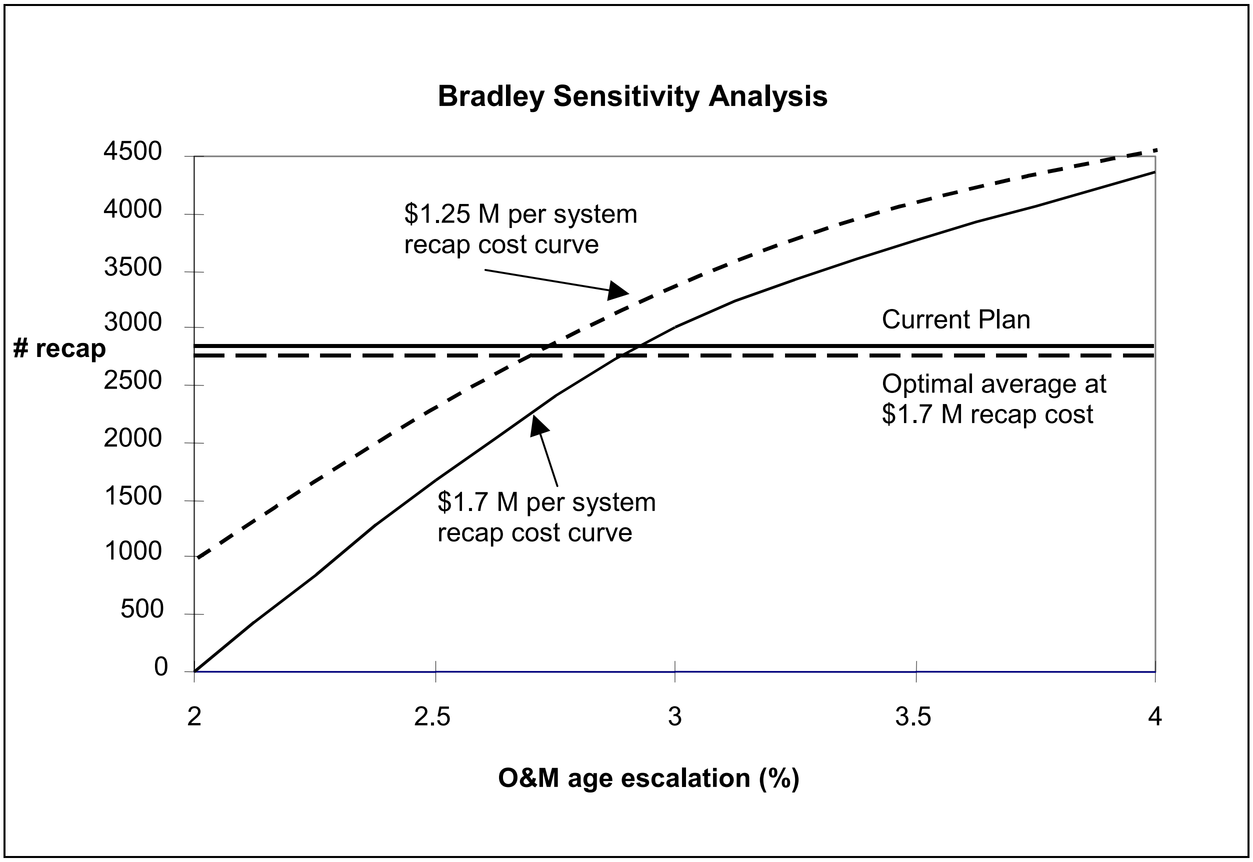


**Figure 9. Bradley Sensitivity Analysis**

## 5.3 Tier 2 Example – High Mobility Multi-purpose Wheeled Vehicle

We will also refer to the High Mobility Multi-purpose Wheeled Vehicle (HMMWV) as the humvee. Figure 10 lists the humvee data input. There are currently 103,455 humvees in the Army inventory. It costs the Army approximately $2.7 K annually to operate and maintain each humvee. The current budget estimate to recapitalize each humvee is $25 K. The ratio of the annual O&M cost to the recap cost is 2.7/25, or 11%. Similar to the Bradley, the humvee has a

HUMVEE DATA INPUT

FY02 inventory= 103,455 systems

Per system annual O&M cost = $2.71 K (FY02 constant dollars)

Annual system O&M age escalation = 2.5%

Per system recap budget estimate = $25 K (FY02 constant dollars)

Annual real discount rate = 3.2%

Maximum annual recap quantity = 3000 systems

Transformation quantity changes = 0

**Figure 10. Humvee Data Input**

high O&M cost-to-recap cost ratio. This means that a recap program is likely to be cost-effective at relatively low O&M age escalation factors. However, unlike the Bradley, the humvee is a Tier 2 (Legacy to Objective Force) system with no planned reductions at this time in the humvee inventory due to transformation. In fact, the humvee inventory may grow even larger because of new equipment that uses the humvee chassis. Because the humvee will be in the Army inventory for the objective force, we need to carefully manage the existing fleet and properly time the procurement of the next fleet.

Assuming that the current humvee fleet will remain until FY26, Figure 11 shows how an investment in a recap program of 27,000 humvees from FY06-FY14 will require an initial investment that will start realizing savings in ownership costs in FY15.

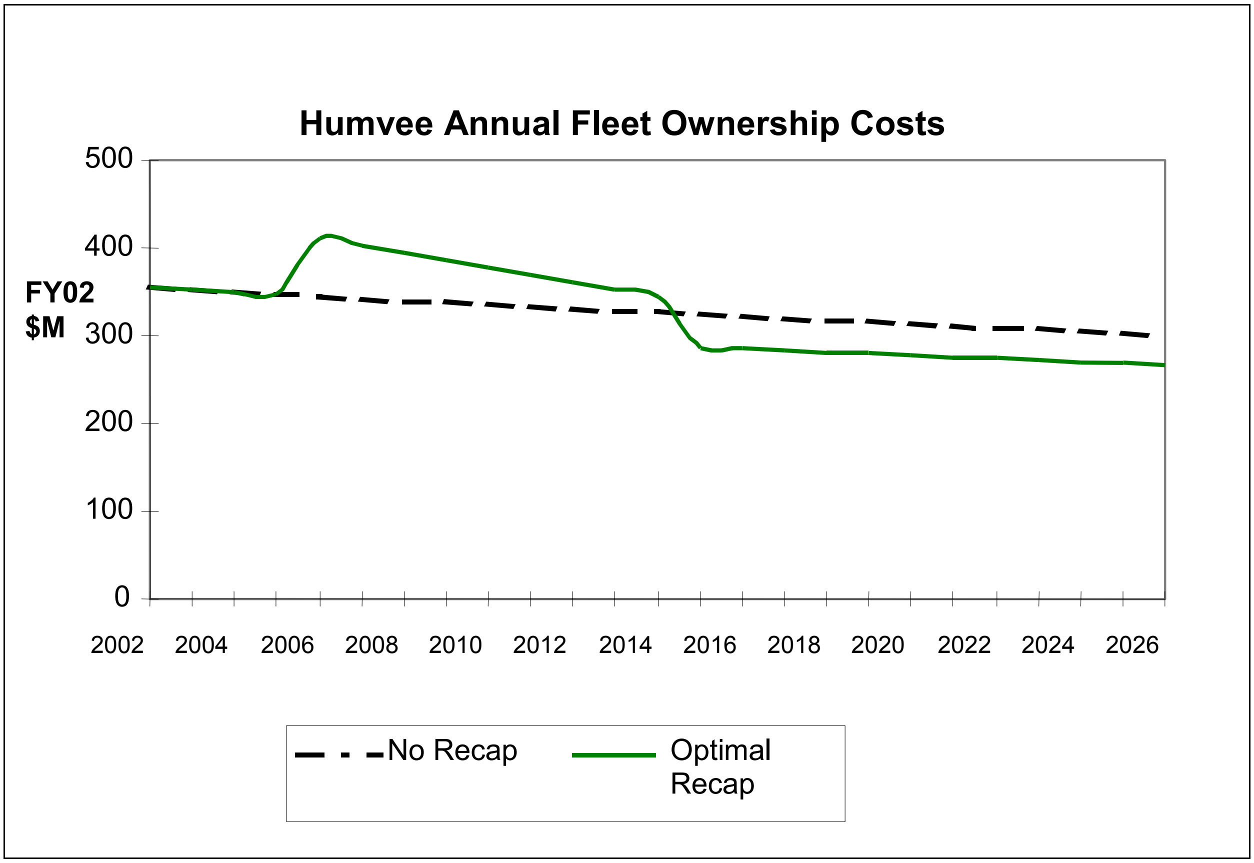


**Figure 11. Humvee Annual Costs**

The graph in Figure 12 shows that the humvee recap program pays for itself during the life-cycle of the humvee fleet. The cumulative fleet ownership cost with a recap program is lower than without a recap program. The break-even point occurs in 2023, with $57 M saved by 2026. Although $57M is not a significant savings when the cumulative cost is $8 B, the point is that the investment of $675 M in recap of 27,000 vehicles will be recovered in reduced O&M costs during the humvee's life-cycle. The $675 M investment in humvee recap will pay for itself and save an additional $57 M while also improving system capability and readiness.

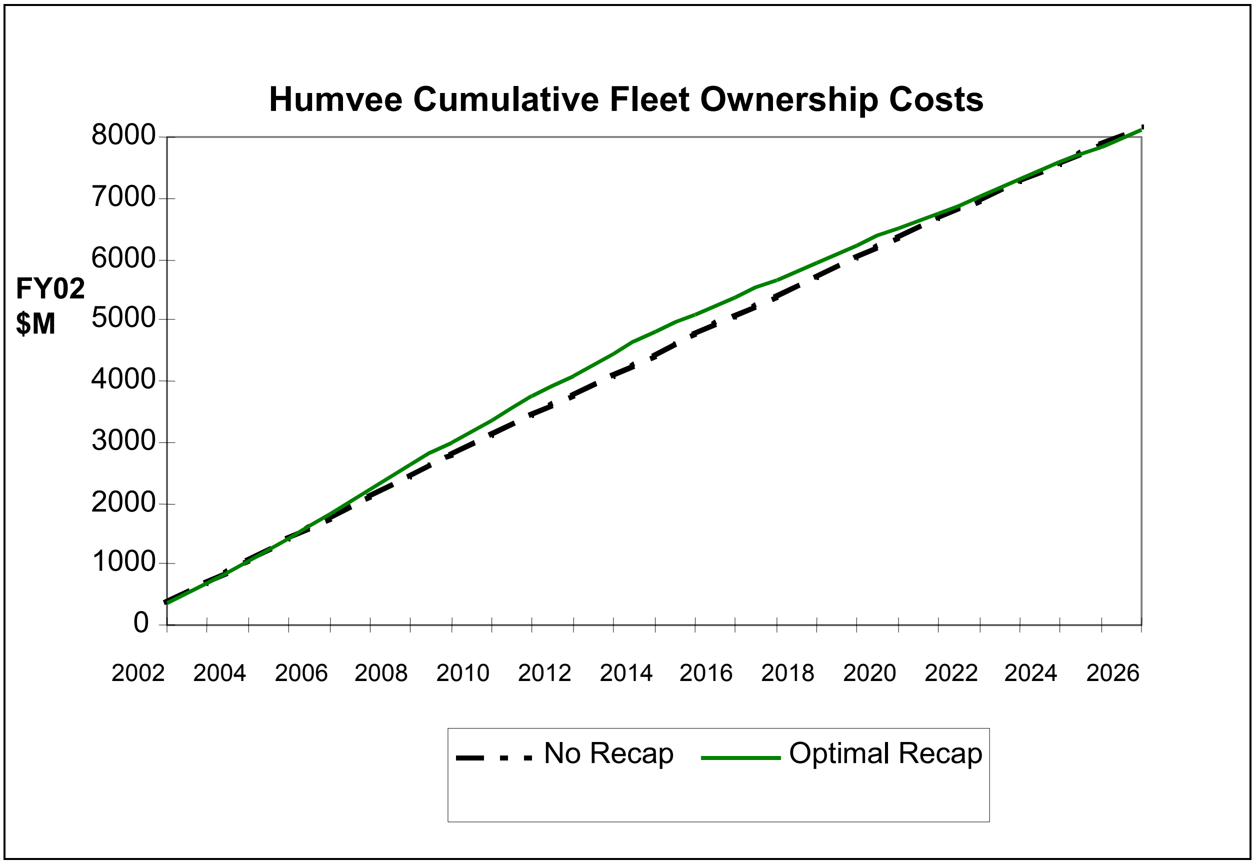


**Figure 12. Humvee Fleet Cumulative Costs**

Assuming a 2.5% O&M age escalation, the optimal humvee recap program is 3000 humvees per year from 2006-2014, for a total of 27,000 humvees, or 26% of the fleet (Figure 13). The current plan is to recap 4,372 humvees, or 4% of the fleet, and procure 17,017 humvees by 2009. The sum of the humvee recap and the planned new procurement is 21,389; this seems fairly close to the 27,000 optimal plan. However, the 17,017 new humvees are not replacements for the older humvees, rather, these vehicles are *additions* to the current force structure. Thus, there will only be 4,372 older vehicles recapped and the humvee fleet will continue to be more expensive to operate and maintain under the current plan than with a recap program of 27,000.

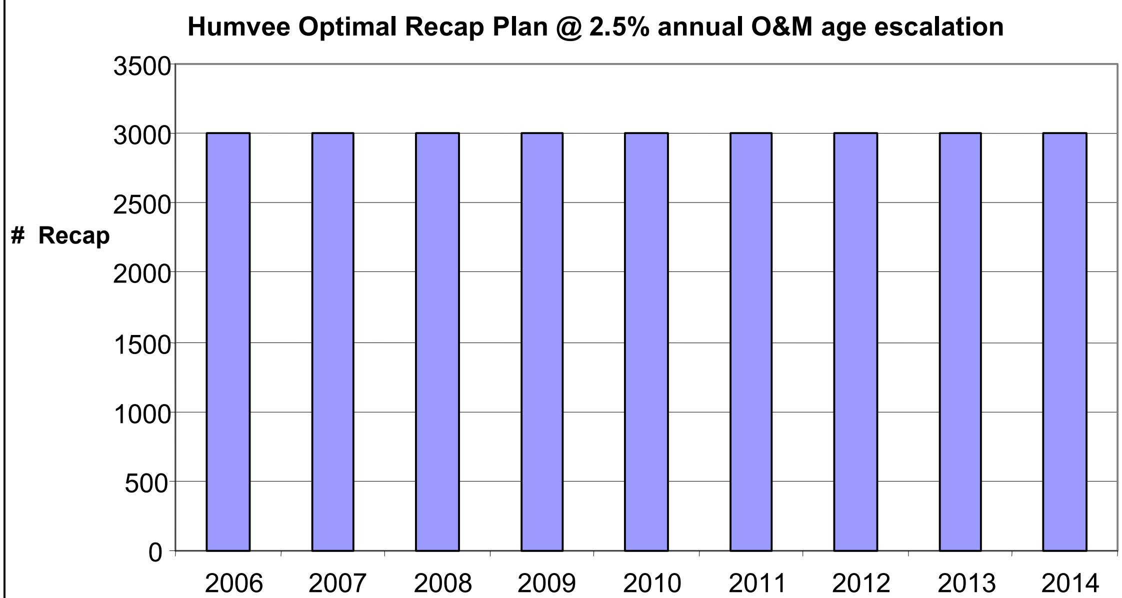


**Figure 13. Humvee Optimal Recap Plan**

Sensitivity to different O&M age escalation factors is depicted in Figure 14. As in the Bradley example, model runs were done using two different recap costs, $25 K and $35 K for each age escalation factor. The optimal average across different O&M age escalation factors for the $25 K recap cost is 39,000 humvees. The sensitivity curve in Figure 14 shows that if the O&M age escalation is greater than 2% then a recap program is cost-effective and the current plan to recap 4,372 humvees is too low. If the recap cost remains at $25K per system, then decision-makers may want to consider increasing the humvee recap program to a range from 27,000 to 51,000 vehicles, corresponding to an O&M age escalation factor between 2.5 and 3%. Because of the low $25 K cost to recap a humvee, it will be cost-effective to recap a large portion of the fleet. If the recap cost increases to $35 K per system, then the optimal recap quantities decrease to the $35 K recap dotted line shown in Figure 14.

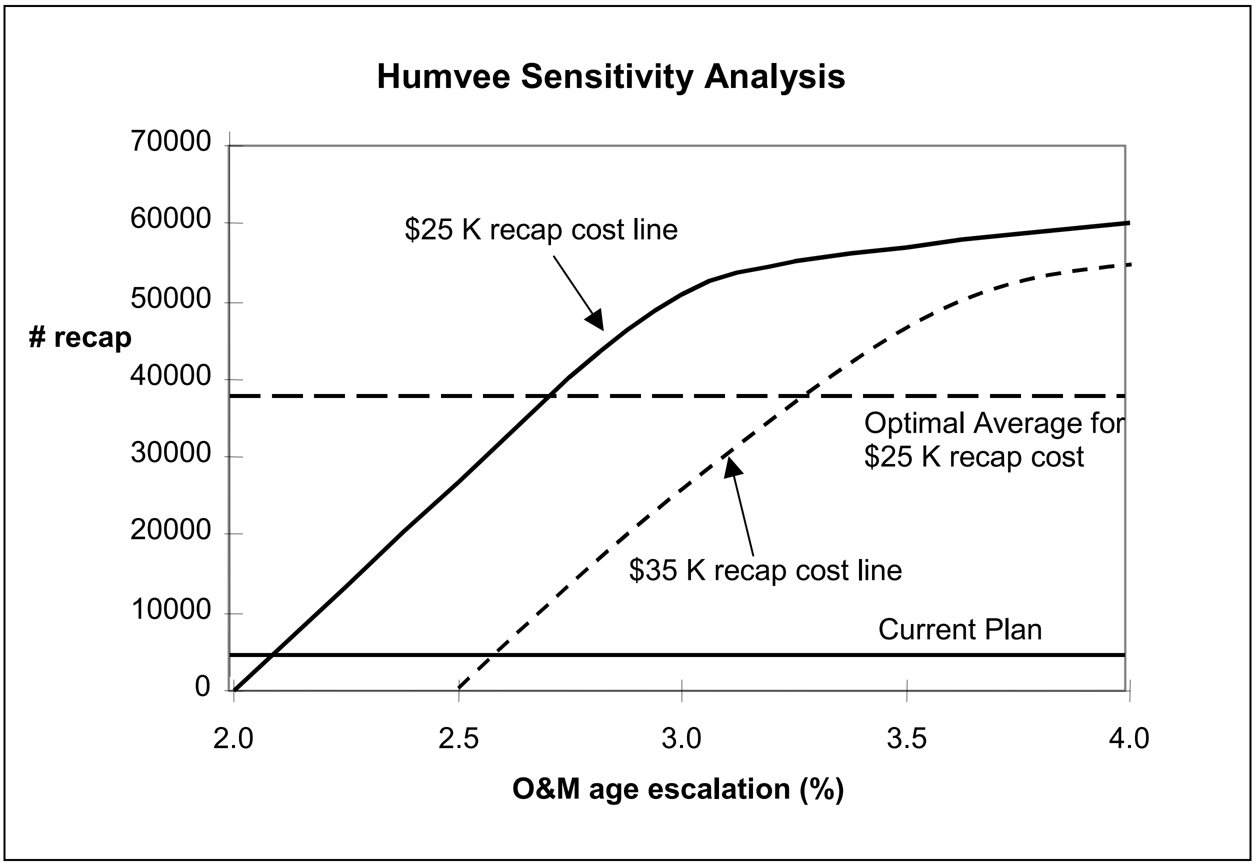


**Figure 14. Humvee Sensitivity Analysis**

## 5.4 Tier 3 Example -- Stryker

The Stryker armored vehicle data input is listed in Figure 15. The Army will procure 4,029 Strykers by 2009 and the vehicle will be in the Army inventory until approximately 2032 when the objective force is fully phased-in. The purpose of analyzing the tier 3 (new/future) systems is to determine under what parameters recap will be cost-effective and when it should be planned and budgeted. Proper planning of future recap requirements may alleviate last minute budget trade-offs among competing systems.

STRYKER DATA INPUT

FY09 inventory= 4029 systems

Per system annual O&M cost = $95.604 K (FY02 constant dollars)

Annual system O&M age escalation = 3.5%

Per system recap budget estimate = $637.36 K (FY02 constant dollars)

Annual real discount rate = 3.2%

Maximum annual recap quantity = 575 systems

Transformation quantity changes = -4029 systems FY26 -32

**Figure 15. Stryker Data Input**

A model of how the Stryker fleet can be managed is presented in Figure 16. After procuring 4,029 Strykers from 2002-09, the fleet enters the utilization phase in 2010, then enters the retirement phase in 2026. Under what conditions will a recap program be cost-effective?

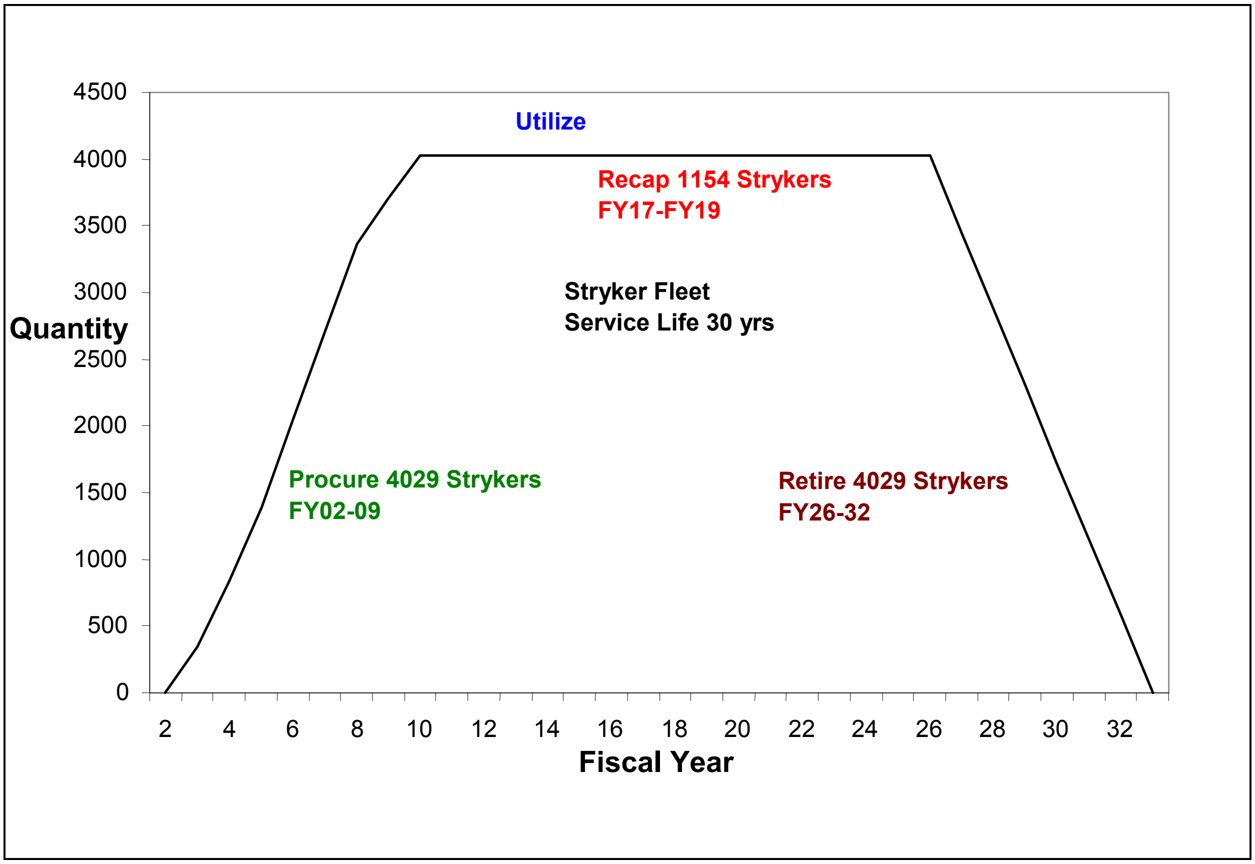


**Figure 16. Stryker Fleet Management Model**

Using the assumptions in Figure 15, it is cost-effective to recap 1154 Strykers, or 29% of the fleet, from 2017-2019. The approximate total cost of this program will be $735 M and will result in lower fleet ownership costs from 2020 to 2032 (Figure 17).

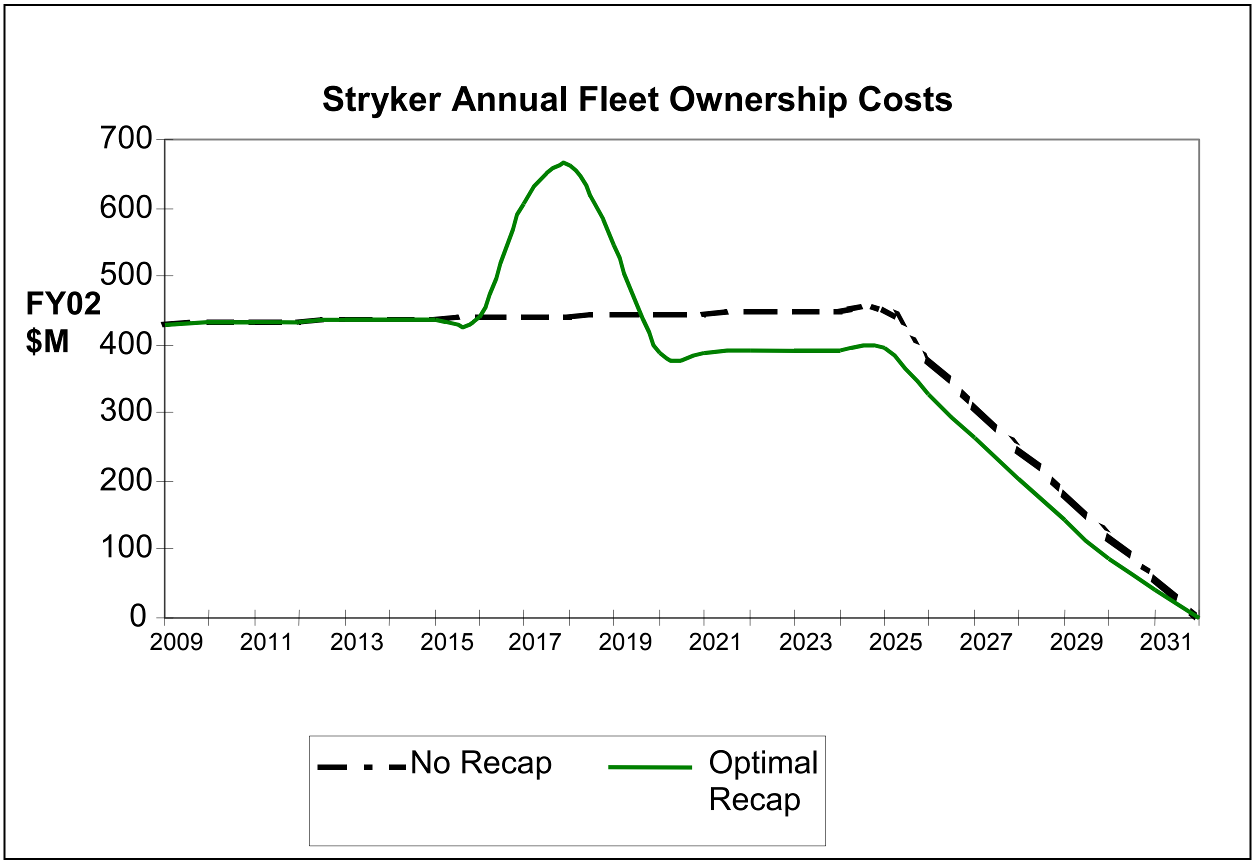


**Figure 17. Stryker Annual Costs**

The $735 M cost of the recap program will be recovered by 2032 and an additional $83 M saved in fleet ownership costs (Figure 18).

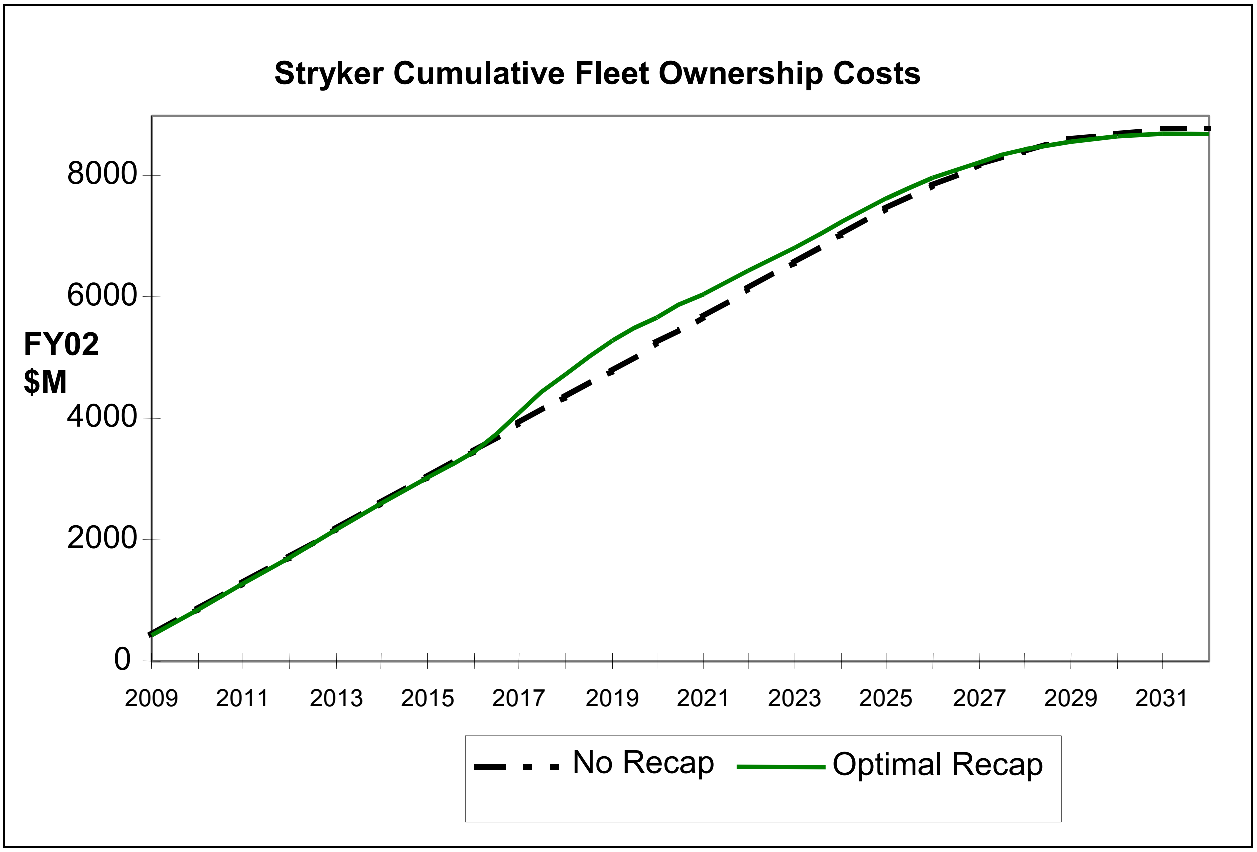


**Figure 18. Stryker Cumulative Costs**

Figure 19 shows the Stryker optimal recap plan assuming a 3.5% O&M age escalation factor. Since much of the input data for the Stryker is estimated, these input parameters should be reviewed as time progresses and the optimal recap program adjusted as required.

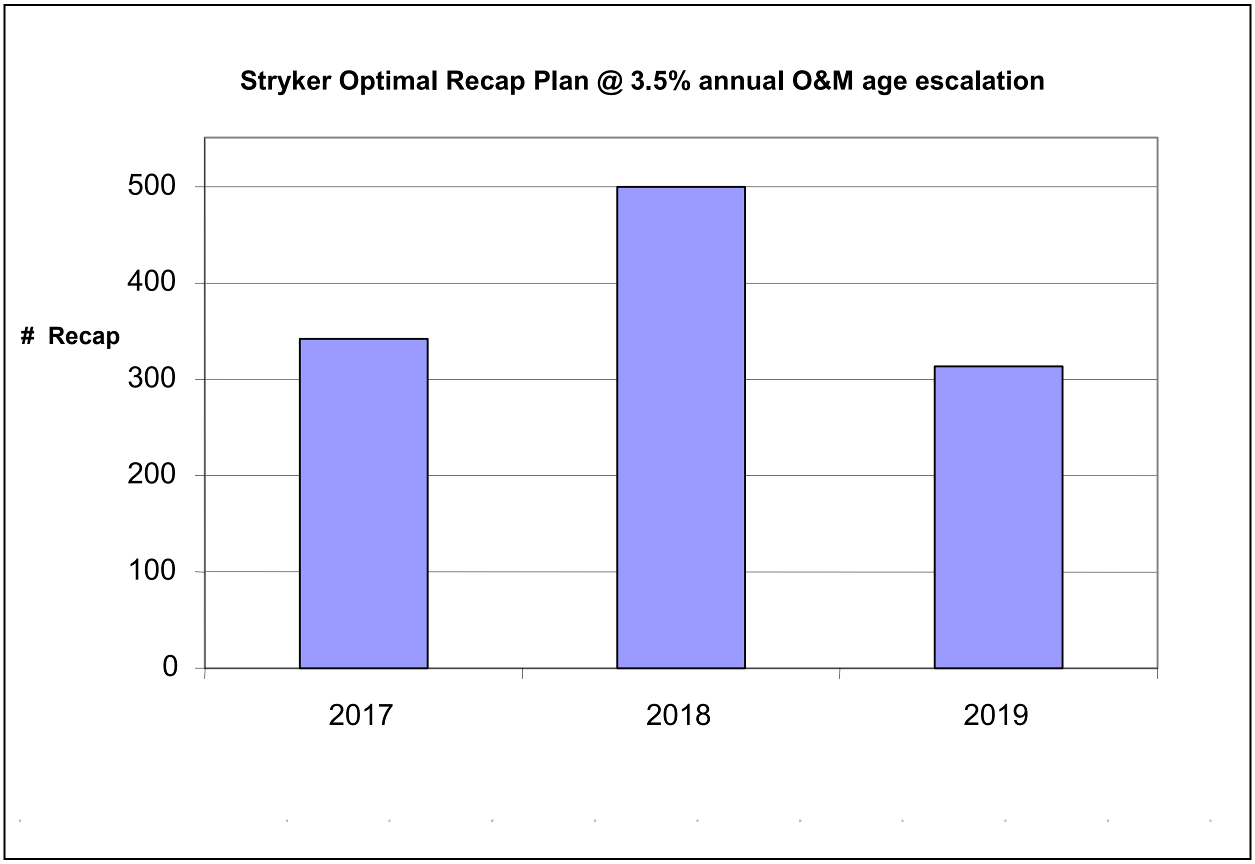


**Figure 19. Stryker Optimal Recap Plan**

Sensitivity to different O&M age escalation factors is shown in Figure 20. The optimal average across different O&M age escalation factors ranging from 2-4% is to recap 694 Strykers. The sensitivity curve in Figure 20 shows that the O&M age escalation factor must be greater than 2.5% for a recap program to be cost-effective. Additionally, if the Stryker is retired before 2032, the timeline to recover the recap program costs shortens, and it is less likely that a recap program will be cost-effective.

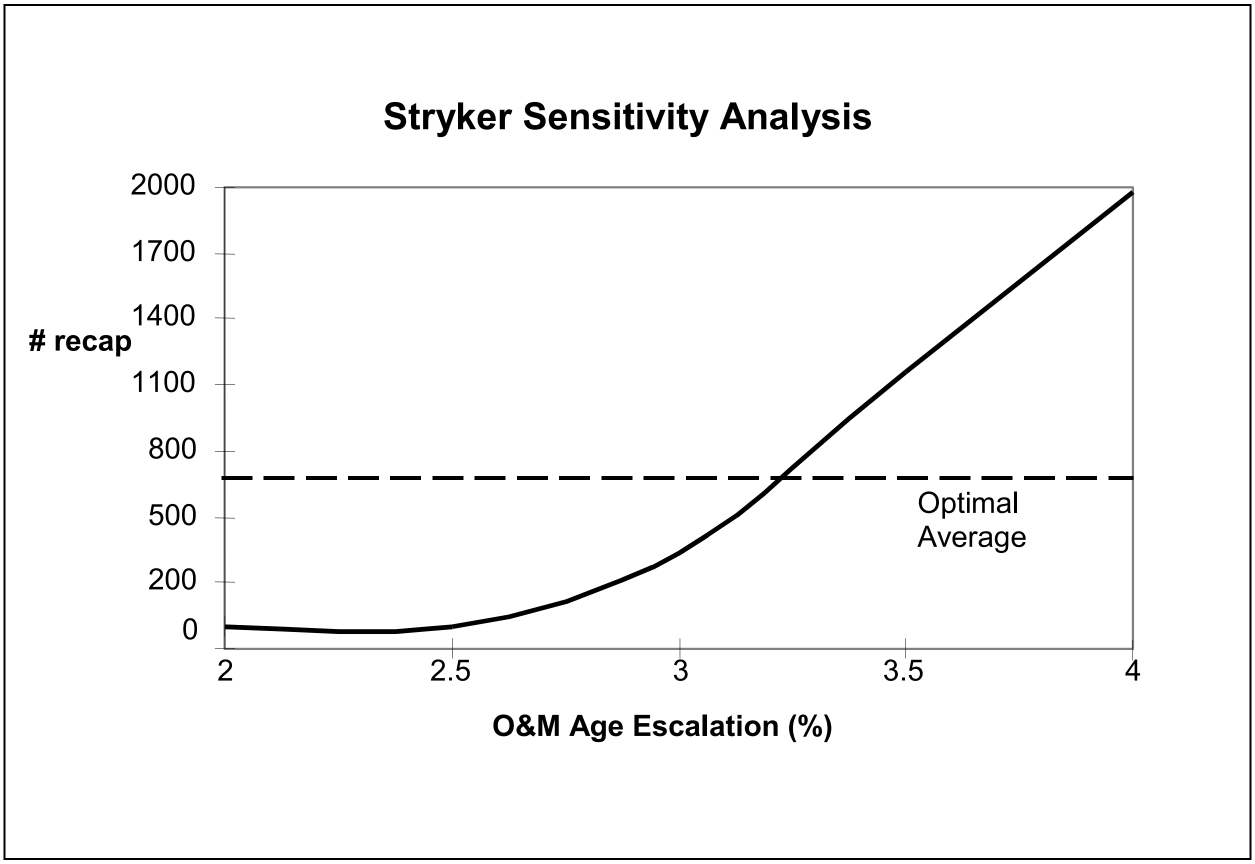


**Figure 20. Stryker Sensitivity Analysis**

# 6 SUMMARY

## 6.1 Optimal Average Plan vs. Current Plans

The optimal average plan was determined by minimizing fleet ownership costs across a range of *real* (net of inflation) O&M age escalation factors. The range is from 2% to 4% at 0.5 increments (2, 2.5, 3, 3.5, 4). The current plan was determined by meeting capabilities given funding constraints.

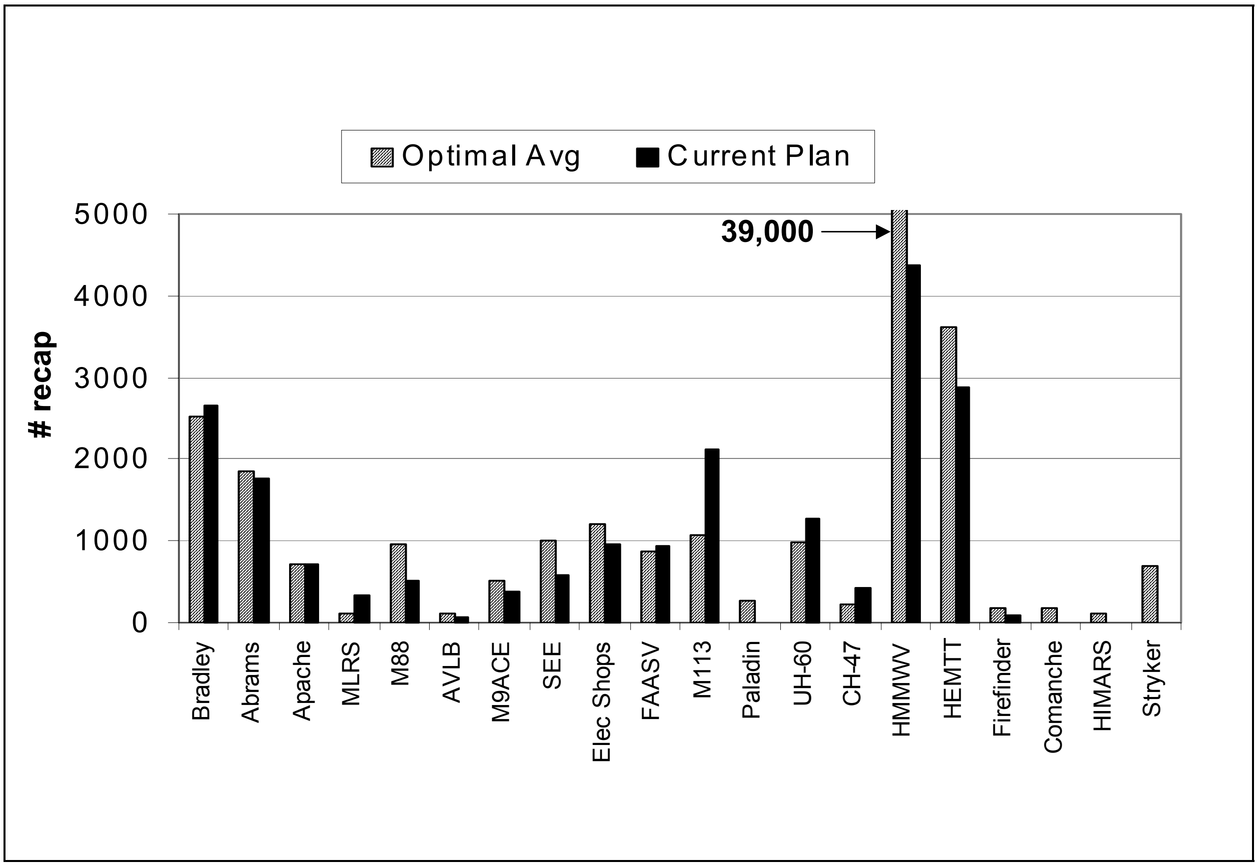


**Figure 21. Optimal Average vs. Current Recap Plans**

Figure 21 shows that many of the optimal plans are close to the current plans (Bradley, Abrams, Apache, AVLB, M9ACE, FAASV, Elec Shops, Firefinder). A few of the optimal plans are significantly greater than the current plans (M88, SEE, HMMWV, HEMTT) which means that the current plan, while still cost effective, could possibly be increased to further minimize fleet operating costs. Two of the optimal plans are significantly less than the current plan (MLRS, M113). This means that decision-makers may want to take a second look at these two programs from a cost-effectiveness point of view.

Although the UH60 and CH47 current plans are both somewhat greater than the optimal plans, this is not of concern because we expect to keep both of these aircraft for the objective force and need to keep the capability high. Additionally, aircraft may experience higher O&M age escalation, making the current plan cost effective at 3-4% age escalation.

The HMMWV current plan is significantly less than the optimal plan. There are approximately 103,455 HMMWVs in the Army inventory. The optimal average plan is 39,000. The current plan recapitalizes 4,372 HMMWVs, or 4% of the fleet. The HMMWV is discussed in more detail in Chapter 5.

The summary table in Figure 22 lists the input data, optimal plans at different O&M age escalation factors, optimal average plan, current plan, and costs for both plans for every system included in the study. The total cost of the optimal average plans is $32 B compared to the cost of $35 B for the current plan. As mentioned in Chapter 3, the cost to attain the half-life metric was $59 B. Not only is the half-life metric infeasible to budget, it is also not cost-effective. The PARIS solution of $32 B is cost-effective. Additionally, as systems and input data change, the PARIS model can be easily updated and re-run to provide quick analysis.

| | | FY02 $K | FY02 $K | | Upper | Recap quant at diff O&M Age Escalation | | | | | Optimal | Current | | Optimal | Current |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tier | System | Avg O&M Cost | Avg Recap Prog Est | # sys | Recap Limit | 2.0% | 2.5% | 3.0% | 3.5% | 4.0% | Avg | Plan | | Cost $M | Cost $M |
| 1 | Bradley | 179.603 | 1683 | 6710 | 300 | 0 | 1684 | 3000 | 3600 | 4357 | 2528 | 2665 | | 4255 | 4485.2 |
| 1 | Abrams | 224.65 | 3167 | 6745 | 300 | 0 | 0 | 1799 | 3521 | 3950 | 1854 | 1756 | | 5871.6 | 5561.3 |
| 1 | Apache | 1147.47 | 10800 | 909 | 150 | 171 | 807 | 821 | 821 | 909 | 706 | 704 | | 7622.6 | 7603.2 |
| 1 | MLRS | 97.564 | 2100 | 857 | 60 | 0 | 0 | 0 | 185 | 389 | 115 | 327 | | 241.08 | 686.7 |
| 1 | M88 | 117.99 | 2350 | 2391 | 100 | 0 | 741 | 1171 | 1441 | 1500 | 971 | 506 | | 2280.9 | 1189.1 |
| 1 | AVLB | 56.578 | 2808 | 719 | 100 | 0 | 0 | 0 | 252 | 342 | 119 | 77 | | 333.59 | 216.22 |
| 1 | M9ACE | 60.883 | 460 | 533 | 50 | 337 | 533 | 533 | 533 | 583 | 504 | 374 | | 231.75 | 172.04 |
| 1 | SEE | 11.59 | 135 | 1785 | 100 | 0 | 255 | 1265 | 1700 | 1785 | 1001 | 570 | | 135.14 | 76.95 |
| 1 | Elec Shops | 5.1 | 124 | 2786 | 150 | 0 | 987 | 1610 | 1610 | 1800 | 1201 | 957 | | 148.97 | 118.67 |
| 1 | FAASV | 31.997 | 239 | 927 | 75 | 664 | 789 | 921 | 927 | 1002 | 861 | 927 | | 205.68 | 221.55 |
| 1 | M113 | 13.567 | 288 | 14910 | 340 | 0 | 0 | 0 | 1642 | 3740 | 1076 | 2113 | | 310 | 608.54 |
| 1 | Paladin | 46.839 | 468.39 | 914 | 50 | 0 | 0 | 152 | 465 | 700 | 263 | 0 | | 123.37 | 0 |
| 2 | UH-60 | 512.415 | 5575 | 1421 | 100 | 293 | 809 | 1089 | 1276 | 1398 | 973 | 1278 | | 5424.5 | 7124.9 |
| 2 | CH-47 | 959.111 | 13700 | 431 | 45 | 0 | 28 | 232 | 374 | 431 | 213 | 431 | | 2918.1 | 5904.7 |
| 2 | HMMWV | 2.71 | 25 | 103455 | 3000 | 0 | 27000 | 51000 | 57000 | 60000 | 39000 | 4372 | | 975 | 109.3 |
| 2 | HEMTT | 10.754 | 189 | 12765 | 500 | 0 | 0 | 3565 | 6500 | 8027 | 3618 | 2877 | | 683.88 | 543.75 |
| 2 | Firefinder | 304.951 | 1200 | 145 | 10 | 145 | 150 | 170 | 185 | 195 | 169 | 92 | | 202.8 | 110.4 |
| 3 | Comanche | 478.171 | 3187.8 | 432 | 72 | 0 | 72 | 184 | 288 | 370 | 183 | NA | | | |
| 3 | HIMARS | 90.46 | 603.07 | 396 | 60 | 0 | 0 | 113 | 198 | 264 | 115 | NA | | | |
| 3 | Stryker | 95.604 | 637.36 | 4029 | 575 | 0 | 0 | 341 | 1154 | 1974 | 694 | NA | | | |
| | | | | | | | | | | | | | | 32 | 35 |
| | | | | | | | | | | | | | | $B | $B |

**Figure 22. Summary Table**

## 6.2 Findings

**THE PRINCIPAL FINDINGS** are that:

**(1)** Recapitalization is generally cost-effective when three conditions exist:

(a) Recap is of limited duration within the life cycle of the fleet.

(b) When the average annual system operation and maintenance cost real growth is greater than two percent.

(c) When the ratio of the system's annual operation and maintenance cost to the system's recapitalization cost is greater than five percent.

**(2)** Using the PARIS model, a more cost-effective program requiring $32 B for recap was developed.

Although simple, the use of the half-life metric to determine recap quantities has significant limitations. The combination of the fleet management model and the PARIS model offers a sound alternative to the half-life metric. The fleet management model portrays the fleet from procurement to retirement along a time horizon. The PARIS model then determines when and if it is cost-effective to recap the fleet during its life-cycle. Many of the current recap plans are cost-effective and only two should be reviewed from a cost-effectiveness standpoint.

The fleet management model provides a visual image of the life-cycle each fleet undergoes and allows the decision-maker to see where a fleet is on its particular life-cycle. The fleet management model indicates that there is a decision-point in the mid-point of each life-cycle where recap should be considered. The PARIS model then determines when and if recap is a cost-effective alternative.

This study examined the range of O&M age escalation necessary to support cost-effective recap programs and found that relatively low values of O&M age escalation combined with reasonable recap costs make recap a smart investment strategy.

## 6.3 Recommendations

**THE PRINCIPAL RECOMMENDATIONS** are that:

**(1)** The Army use the fleet management model to better plan for future recapitalization and procurement of new fleets.

**(2)** The Army use the PARIS model to determine cost-effective recapitalization investment strategies instead of using the current half-life metric.

**(3)** The Army more thoroughly research and collect operation and maintenance (O&M) cost data by system age.

Although PARIS has shown that relatively low values of O&M age escalation still result in cost-effective recap, the optimal solution can vary greatly even with small changes in the O&M age escalation factor. The Army should collect and study O&M age escalation factors for a wide variety of equipment. If it is determined that O&M age escalation does not exist, then recap should not be supported from a cost-effectiveness point of view. In this case, it would be less costly to pay O&M on each system instead of funding a recap program. However, if the Army finds that O&M age escalation does exist, then the PARIS methodology should be used to determine cost-effective recap quantities.

Army fleet management could be improved by using the fleet management model to depict the life-cycle of each fleet. Currently, Army fleets are utilized beyond their expected service life and recap is viewed as a fix instead of budgeting for new procurement. Using the fleet management model and the PARIS methodology, both recap and new procurement will work together to keep Army capability and readiness high while minimizing fleet ownership costs.

# APPENDIX A PROJECT CONTRIBUTORS

## 1. PROJECT TEAM

**a. Project Director:** LTC Allen C. East

**b. Team Members:** NA

**c. Other Contributors:**

## 2. PRODUCT REVIEWERS

LTC William Tarantino
LTC Robert Steinrauf
Ms. Linda Coblentz

## 3. EXTERNAL CONTRIBUTORS (If any)

Mr. Joe Gordon (CEAC)

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# APPENDIX B REQUEST FOR ANALYTICAL SUPPORT

**PART 1**

***Performing Division:*** RA ***Account Number:*** **2002091**

***Tasking:*** Verbal ***Mode (Contract-Yes/No):*** In-house

***Acronym:*** **PARIS**

***Title:*** Planning Army Recap Investment Strategies

***Start Date:*** 01-Jan-02 ***Estimated Completion Date:*** 01-May-02

***Requestor/Sponsor (i.e., DCSOPS):*** DCSPRO ***Sponsor Division:*** FDR

**Resource Estimates:** ***a. Estimated PSM:*** 5 ***b. Estimated Funds:*** $0.00

***c. Models to be Used:*** **FOREST**

***Description/Abstract:*** This study will develop a quantitative methodology to determine and report Army optimum recapitalization rates as directed by DPG 2003-07. The study will analyze selected major Army systems . A major objective of this analysis is to determine system recap rates that minimize total fleet operating costs.

***Study Director/POC Signature:*** *Original Signed* ***Phone#:*** 703-806-5391

***Study Director/POC:*** **LTC Allen East**

***If this Request is for an External Project expected to consume 6 PSM or more, Part 2 Information is Not Required. See Chap 3 of the Project Directors' Guide for preparation of a Formal Project Directive.***

**PART 2**

***Background:***

***Scope:***

***Issues:***

***Milestones:***

**Signatures** ***Division Chief Signature:*** *Original Signed and Dated* ***Date:***

***Division Chief Concurrence:***

***Sponsor Signature:*** *Original Signed and Dated* ***Date:***

***Sponsor Concurrence (COL/DA Div Chief/GO/SES):***

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