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THESIS

FORECASTING 5"/54 CALIBER NON-COMBAT EXPENDITURE REQUIREMENTS FOR SURFACE COMBATANTS OF THE U.S. PACIFIC FLEET

by

Steven R. Rasmussen

September, 1995

Thesis Advisor: Robert R. Read

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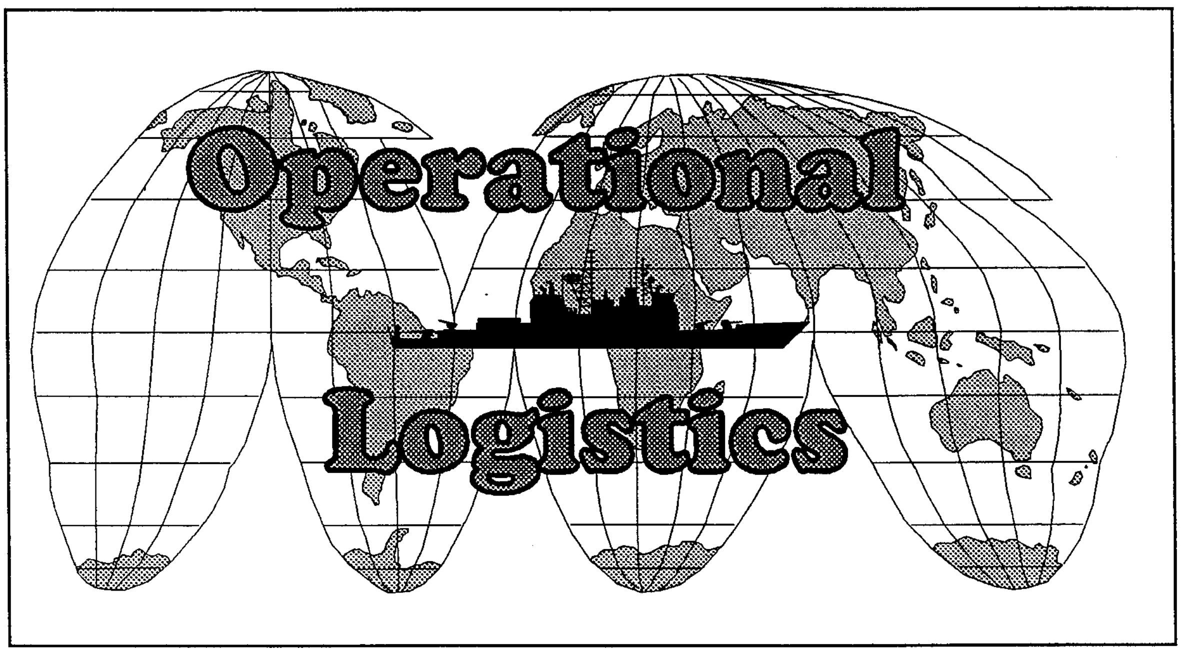
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This thesis applies data analysis and casual forecasting methods to the problem of predicting 5"/54 caliber gun ammunition non-combat expenditure requirements (NCERs) for U.S. Pacific Fleet surface combatants. The NCER is the amount of ammunition required for non-combat purposes for a given fiscal year. Current methodology does not consider past expenditure data when predicting future requirements and significantly overestimates them. The author takes advantage of the fact that similar ship types follow an identical notional training cycle between overseas deployments leading to distinct expenditure patterns. This thesis shows that improvements to current NCER determination procedures can be achieved using historical consumption data as a function of ship type and relative position in the interdeployment training cycle. The results include a significant reduction in requirements overestimation and more accurate annual ammunition planning factors.

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FORECASTING 5"/54 CALIBER NON-COMBAT EXPENDITURE REQUIREMENTS FOR SURFACE COMBATANTS OF THE U.S. PACIFIC FLEET

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Submitted in partial fulfillment
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ABSTRACT

This thesis applies data analysis and casual forecasting methods to the problem of predicting 5"/54 caliber gun ammunition non-combat expenditure requirements (NCERs) for U.S. Pacific Fleet surface combatants. The NCER is the amount of ammunition required for non-combat purposes for a given fiscal year. Current methodology does not consider past expenditure data when predicting future requirements and significantly overestimates them. The author takes advantage of the fact that similar ship types follow an identical notional training cycle between overseas deployments leading to distinct expenditure patterns. This thesis shows that improvements to current NCER determination procedures can be achieved using historical consumption data as a function of ship type and relative position in the interdeployment training cycle. The results include a significant reduction in requirements overestimation and more accurate annual ammunition planning factors.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAW	Anti-Aircraft Warfare
ASUW	Anti-Surface Warfare
BL-P	Blank, Loaded, and Plugged Training Projectile
CAIMS	Conventional Ammunition Integrated Management System
CART	Command Assessment of Readiness and Training
CG-47	Ticonderoga Class Guided Missile Cruiser
CHOP	Change Operational Control
CINC	Commander-in-Chief
CINCPACFLT	Commander-in-Chief, U.S. Pacific Fleet, Pearl Harbor, HI
CLF	Combat Logistics Force
CNO	Chief of Naval Operations
COMTHIRDFLT	Commander, U.S. Third Fleet
CSA	Combat Systems Assessment
CVT	Controlled Variable Time Fuse
DD	Spruance Class Destroyer
DDG-51	Arleigh Burke Class Guided Missile Destroyer
DDG-993	Kidd Class Guided Missile Destroyer
FLTEX	Fleet Exercise
FSC	Full Service Charge
FY	Fiscal Year
HE	High Explosive Projectile
IG	Department of Defense Inspector General
ILLUM	Illumination Projectile
ISE	Independent Steaming Exercises
LHA	Tarawa Class Amphibious Assault Ship
MSLEX	Missile Exercise
MT	Mechanical Time Fuse
NALC	Naval Ammunition Logistics Code
NCEA	Non-combat Expenditure Allocation
NCER	Non-combat Expenditure Requirements
NNOR	Non-nuclear Ordnance Requirements Review
NOC	Naval Ordnance Center
NSFS	Naval Surface Fire Support
OPCON	Operational Control
OPPE	Operational Propulsion Plant Examination
OR	Operations Research
PD	Point Detonating Fuse
PMA	Primary Mission Area
Puff	Target Practice Smoke Puff Projectile
SURFPAC	Commander Naval Surface Force, U.S. Pacific Fleet
TSTA	Tailored Ships Training Availability
TYCOM	Type Commander
VT	Variable Time Fuse

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EXECUTIVE SUMMARY

U. S. Navy surface combatants expend gun ammunition every day conducting training exercises designed to improve crew and gun system proficiency. These exercises are elements of the interdeployment training cycle designed to ensure high states of readiness for deploying ships.

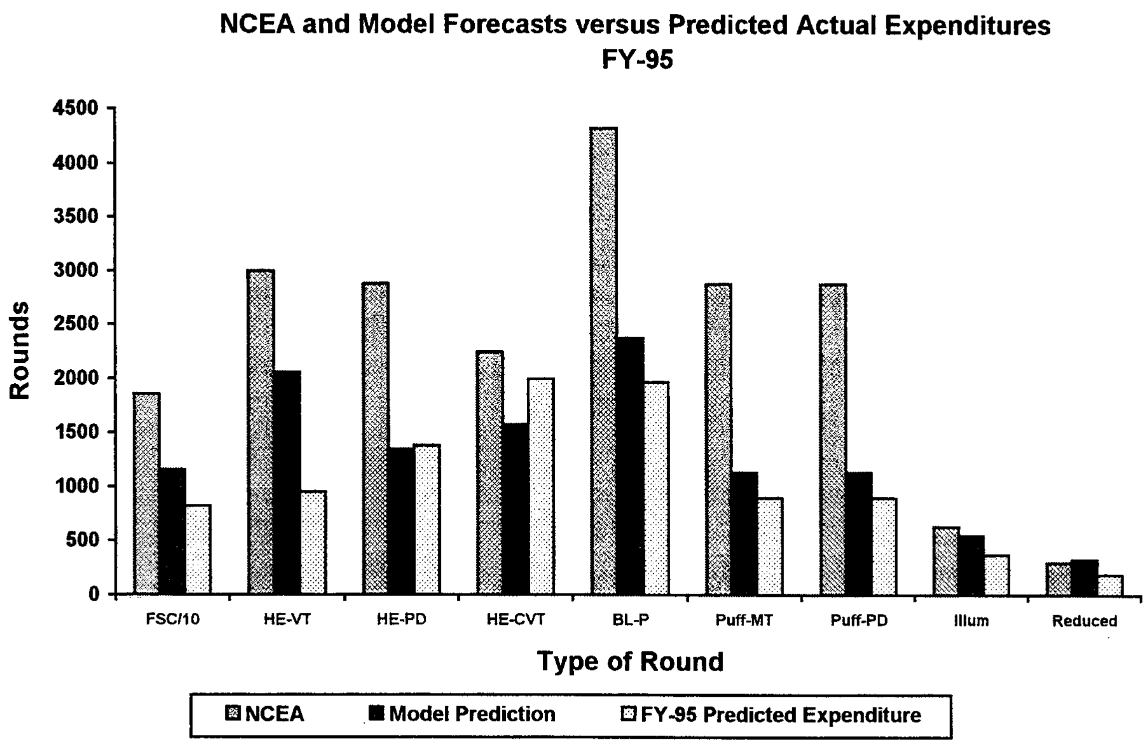
At some point, planners must predict the amount of ammunition required for training by the fleet for the upcoming fiscal year. These estimates, known as the non-combat expenditure requirements (NCER), are currently severely overestimated. This is not surprising since no scientific methodology is currently being used to predict these numbers.

Current NCER methodology does not consider past expenditure patterns or future ship schedules in predicting fiscal year requirements, and fleet ammunition requirements appear to be educated guesses. Subsequent distribution of the approved non-combat expenditure allocation (NCEA) is done using a fair-share policy with no regard for a ships schedule. A ship entering the shipyard receives the exact same allocation as one beginning a deployment or one entering the height of the training cycle. Furthermore, the fleetwide NCEA was significantly overestimated in FY-94 only to be increased by approximately 15% for FY-95. Yearly expenditures have been dropping since at least FY-92, and this action suggests that past expenditure data is not being considered in the decision making process.

This thesis identifies one alternative method to the current requirements determination procedures. Data analysis and casual forecasting methods are applied to the problem of predicting 5"/54 caliber gun ammunition non-combat expenditure requirements (NCER) for U.S. Pacific Fleet surface combatants. This is possible due to the fact that similar ship types follow the same notional training cycle between deployments.

Raw expenditure data from the Conventional Ammunition Integrated Management System (CAIMS) was used after extensive validation. Twelve-month demand distributions were developed based on the interdeployment training cycle for nine ammunition classes. The data points were generated by taking all possible occurrences of the random 12-month window on the training cycle. After outlier processing, fitted equations were transferred to a simple spreadsheet to form the forecasting model. The inputs to the model are *ship type* and *months before deployment*, and the output is the expected fiscal year requirements for each ammunition family. Standard deviations are also calculated to aid the decision maker.

This thesis shows that improvements to current NCER determination procedures can be achieved using historical consumption data as a function of ship type and relative position in a ships interdeployment training cycle for 5"/54 caliber ammunition. FY-92 through FY-94 data was analyzed and used to predict FY-95 requirements. The results summarized in the graph below include a significant reduction in requirements overestimation and more accurate ammunition planning factors than are currently available. Based on FY-95 expenditures, these improvements to the NCER determination process may immediately result in an estimated 30% reduction in initial procurement costs per year as well as save time and money currently spent to manage, inspect, track, and store excess ordnance.



This graph depicts the potential savings that can be achieved due to decreased overestimation of the fleet NCER using the model presented in this thesis. The leftmost bar in each series is the NCEA -- the current prediction. The middle bar is the model's prediction, and the rightmost bar is the estimated FY-95 actual expenditures. (Note: The first series, FSC, is divided by 10 to allow it to fit on this graph.)

I. INTRODUCTION

A. *THE RESEARCH PROBLEM*

U.S. Navy surface combatants expend gun ammunition every day conducting training exercises designed to improve crew and gun system proficiency. Specific exercises requirements are listed in the Navy's Surface Force Training Manual. [Ref. 1] This consolidated training document dictates the specific exercises that must be satisfactorily completed by each type of ship during the standard training cycle to maintain acceptable levels of readiness. Individual exercises require various types and quantities of ammunition and are conducted at various times in a ships interdeployment training cycle.

Like many cycles, there exist periods of high and low expenditures that are a function of many factors including ship type and number of months remaining in the interdeployment training cycle.

The cost of all 5"/54 caliber rounds expended for training and non-combat operations in the Pacific Fleet is in excess of ten million dollars per fiscal year. Consequently, the logistics system which supports the interdeployment training cycle deserves to be managed effectively to reduce inefficiencies, save money, and ensure that a strong support system exists in the future. Unfortunately, very little quantitative analysis takes place to improve this complicated process. Specifically, no concrete analysis is presently being applied to accurately predict the non-combat requirements of ammunition needed to maintain fleet readiness at acceptable levels.

The result of this lack of analysis is significant overestimation of non-combat ammunition expenditure requirements each fiscal year.

B. OVERVIEW

This thesis applies data analysis and casual forecasting methods to the problem of predicting non-combat expenditure requirements (NCERs) of naval gun ammunition for surface combatants of the U.S. Pacific Fleet. Improvements to current NCER determination procedures are achieved using historical consumption data as a function of ship type and relative position in the interdeployment training cycle resulting in less overestimation and more accurate predictions than are currently available.

Chapter II of this thesis provides pertinent background information about the Navy, its conventional ammunition management program, and the interdeployment training cycle, that drive the expenditure of ammunition. Chapter III provides the motivation for this thesis based on the author's experience tour. Chapter IV formally states the problem, Chapter V discusses the sources of data gathered for this study, Chapter VI discusses the methodology and data analysis, and Chapter VII discusses results, conclusions, and suggestions for further study.

Appendices are included that document specifics including the rather extensive data validation procedure, ammunition family groupings, outlier statistics, NCER forecasting graphs, forecast standard deviations, and the FY-95 NCER forecast worksheet.

C. SCOPE

This thesis will analyze the non-combat expenditure data of Pacific Fleet cruisers and destroyers expending 5"/54 caliber ammunition. Smaller rounds of ammunition are relatively inexpensive and difficult to manage, and larger munitions (i.e., missiles) are tracked extremely closely and do not present as large a potential for improvement. Amphibious assault ships, Arleigh Burke class destroyers, and nuclear cruisers will be mentioned briefly but are not analyzed due to the relatively small numbers of these ships compared to the study group and due to the small amounts of data they represent.

II. BACKGROUND INFORMATION

This chapter provides background information necessary for a basic understanding of the nature of this problem. Those familiar with the U.S. Navy and the interdeployment training cycle may skip this chapter with no loss of continuity.

A. U.S. NAVY SHIPS

U.S. Navy ships are divided into ship types according to their design and primary mission area (PMAs). Ship types are further divided into classes, named after the lead ship of the class. The ships with primary missions containing the word "warfare" are considered to be surface combatants, while those having the primary mission of support are considered to be combat logistics force (CLF) ships. A partial listing of some ship types, primary mission areas, ship classes, and class names appears in Table 1.

Ship Type	Primary Mission Area	Ship Class	Class Name
Aircraft Carrier	Strike Warfare	CVN-68	Nimitz
Amphibious Assault Ship	Amphibious Warfare	LHA-1	Tarawa
Destroyer	Anti-Submarine Warfare	DD-963	Spruance
Fleet Oiler	Combat Logistics	AO-177	Cimarron
Guided Missile Cruiser	Anti-Air Warfare	CG-47	Ticonderoga
Guided Missile Destroyer	Anti-Air Warfare	DDG-51	Arleigh Burke
Guided Missile Destroyer	Anti-Air Warfare	DDG-993	Kidd
Guided Missile Frigate	Anti-Air Warfare	FFG-7	Oliver Hazard Perry

Table 1. Partial Listing of Ships by type, PMA, class, and name.

Upon commissioning, U.S. Navy ships are assigned to the Atlantic or the Pacific Fleet and begin a continuous cycle of maintenance and training to ensure combat proficiency for routine deployments and crisis response to global contingencies.

B. PACIFIC FLEET TRAINING ORGANIZATION

The Commander-in-Chief, Pacific Fleet (CINCPACFLT), has primary responsibility for the tactical training of naval forces to be provided to the Unified Commander. Ships joining the Pacific Fleet are initially assigned to the Commander, Naval Surface Force Pacific (SURFPAC). Under CINCPACFLT's tactical training strategy, PMA tactical training is executed by SURFPAC in the initial phases of the training cycle. Once a ship is trained and equipped, it will change operational control (CHOP) to one of the numbered fleets, the Third, Fifth, or Seventh. Ships are normally assigned to the Third Fleet for operations near the West coast of the U.S., and CHOP to the Seventh Fleet for operations in the Western Pacific/Indian Ocean, or the Fifth Fleet for operations in the Arabian Gulf.

There are currently 106 surface ships in the Pacific Fleet, 38 of which expend 5"/54 caliber ammunition. The classes and numbers of these ships are displayed in Table 2. For the purposes of this thesis, the CG-47 class guided missile cruisers and DDG-993 class guided missile destroyers are grouped into one subset and the DD-963 class destroyers make up the other subset. The

DDG-51s, LHA-1s and the CGNs are not studied in detail, so this thesis applies to 30 of the 38 ships mentioned above.

Ship Class	Number of Ships	5" Guns per Ship
CG-47	13	2
DD-963	15	2
DDG-51*	3	1
DDG-993	2	2
LHA-1	3	2
CGN	2	2

*Table 2. Pacific Fleet Surface Combatants Expending 5"/54 Caliber Ammunition. The * indicates that 2.5 DDG-51s will join the U.S. Fleet each year.*

C. SURFACE COMBATANT TRAINING CYCLES

1. Readiness Indicators

Ships are required to deploy combat ready, and the Navy has developed a system of assigning a readiness indicator to each ship. This indicator is called mission rating, or "M-rating," and is based on the ability of a ship to perform its primary mission. The M-rating reflects many factors including equipment readiness, completed exercises, and crew training. M-ratings are briefly summarized in Table 3.

Readiness	M-Rating
Combat Ready	M1
Mostly Ready	M2
Partially Ready	M3
Not Ready	M4

Table 3. Readiness Level Description and Corresponding Mission Rating.

2. Notional Training Cycles

A notional schedule for the execution of interdeployment training has been established for each ship class, and all ships analyzed in this thesis follow the same basic notional schedule shown in Figure 1.

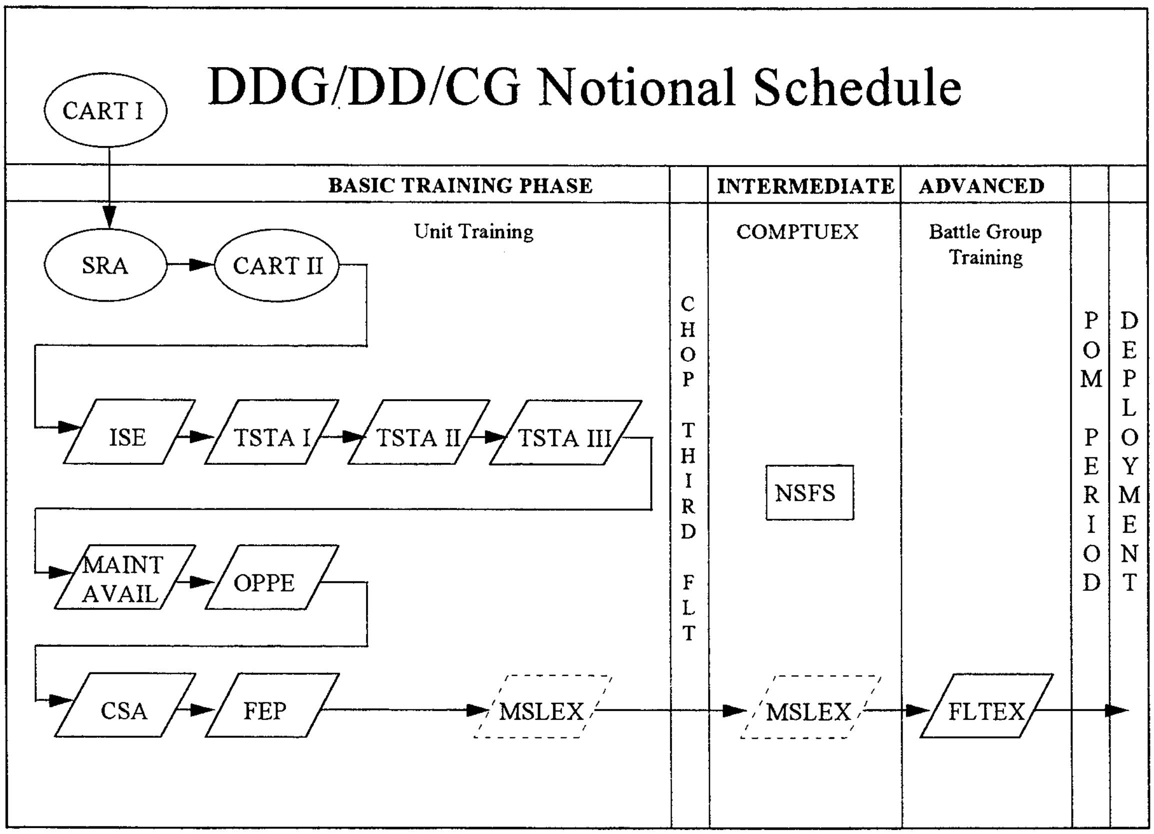


Figure 1. Taken from the Navy Tactical Training Manual [Ref. 2] combining the three ship types. The majority of the expenditures occur during ISE, TSTAs, CSA, and NSFS.

There are three main phases of training depicted in Figure 1 which include the basic, intermediate, and advanced phases. The Surface Force

Training Manual describes these phases in detail, but a summary of each phase is provided below for the reader's benefit:

- **Basic Training**. The focus of the basic training phase is on unit-level training emphasizing basic command and control, weapons employment, mobility and warfare specialty. After a nominal three month maintenance availability (SRA) or other longer overhaul period, each ship commences the interdeployment training cycle that will prepare it for its next deployment. First, each ship's commanding officer conducts a Command Assessment of Readiness and Training (CART II). The CART serves to validate and identify the specific training required during the upcoming interdeployment training cycle. This results in each ship having similar but different exercises scheduled for completion during Tailored Ship's Training Availabilities (TSTAs). Additional requirements of the basic phase include a Combat Systems Assessment (CSA), an Operational Propulsion Plant Examination (OPPE), and other maintenance availabilities as required. A Final Evaluation Period (FEP) is conducted at the end of the basic phase to evaluate the ship's readiness to proceed to the next level of training. A ship is expected to be substantially ready (M2) in all mission areas upon completion of the basic phase, and the notional training schedule is adapted by the ship's commanding officer and the ISIC to ensure this happens.
- **Intermediate Training**. The focus of the intermediate training phase is on warfare team training in support of the Composite Warfare Commander

(CWC) organization. During this phase, ships are under the operational control (OPCON) of their numbered fleet commander (i.e., COMTHIRDFLT) and begin to develop warfare skills in coordination with other ships while maintaining their own warfare proficiency. A Missile Exercise (MSLEX) and a Naval Surface Fire Support (NSFS) qualification, if required, is normally conducted during this phase representing high gun ammunition expenditures.

- **Advanced Training**. The focus of the advanced training phase is on coordinated battle group warfare skills. This phase is conducted by fleet commanders and includes war gaming and a Fleet Exercise (FLTEX) involving the entire battle group. After completion of the advanced training phase, a ship is ready to deploy (M1) and must maintain proficiency by completing repetitive exercises. Repetitive exercises are not as logistically demanding as the work-up exercises discussed above (i.e., not as much ammunition is required, a specific range or target is not required, and certain training services are not required for completion).

D. NAVY GUN AMMUNITION

1. Navy Ammunition Logistics Codes (NALCs)

All ammunition is described by a noun name and a four-digit Navy Ammunition Logistics Code (NALC). There are over 5000 NALCs used to describe different types of ammunition and ordnance components. Approximately 50 NALCs pertain specifically to 5"/54 caliber ammunition and all start with the letter "D" (i.e., D304, D324, and D326 for Full Service Charges). [Ref. 3]

2. Expenditure Patterns

Surface gun ammunition is expended to support a number of warfare areas and exercises. Normally, a five round pre-action calibration (PAC) fire will take place to ensure proper system operation prior to the exercise itself. The PAC fire normally uses D349 (BL-P) since this is an inexpensive and non-explosive round.

Different types of exercises include anti-air warfare (AAW), anti-surface warfare (ASUW), and Naval Surface Fire Support (NSFS). During these exercises, combatants shoot various types of ammunition at towed surface and air targets as well as ground targets. Specific exercise details and ammunition requirements can be found in Fleet Exercise Publications (i.e., FXP-2 and FXP-3).

Commanding Officers at sea frequently exercise the right to conduct additional training to enhance gun crew proficiency. These additional exercises are varied creating significant variance in the yearly expenditures for different ships.

E. THE NAVY'S AMMUNITION MANAGEMENT SYSTEM

The Navy's conventional ammunition management system is diverse, complex, and not without flaws. Its mission is to provide ammunition to naval units when needed. Structural inefficiencies exist at all levels which can be improved upon, but it is well beyond the scope of this thesis to attempt to overhaul this system. A basic understanding, however, is required to comprehend the problem.

1. Non-Nuclear Ordnance Requirements (NNOR)

For conventional gun ammunition, total Navy objectives are set by the Chief of Naval Operations (CNO) as a result of annual requirements reviews. These reviews, including the Non-nuclear Ordnance Requirements (NNOR) process, are high-level calculations based on models of expected world contingencies. Ammunition requirements generated by these studies determine war reserve levels and combat ship fill allowances as well as initiate ammunition procurement plans and inventory policy. The war reserve and ship fill figures are classified information and will be considered fixed for the purpose of this thesis.

2. Non-Combat Expenditure Allocations (NCEA)

The ordnance fired every day for fleet training and exercises is allocated to each ship yearly by its respective type commander (TYCOM) as a Non-combat Expenditure Allocation (NCEA). For the Pacific Fleet, SURFPAC is the TYCOM for all surface combatants. A ship is allowed to expend this NCEA for training and completion of required exercises, and must request an NCEA augment by naval message to expend a higher level of ammunition. As one would suspect, not all of the available ammunition is allocated, and the TYCOM maintains a reserve level to allocate in the event of extreme circumstances and NCEA augment requests.

3. Non-Combat Expenditure Requirements (NCER)

For 5"/54 caliber ammunition, the sum of all of the NCEAs for all ships comprises the fleet's Non-combat Expenditure Requirements (NCER) which are provided as inputs to the FLTCINC and passed to the CNO (See Figure 2). The CNO, in turn, modifies these requirements as necessary taking into account current assets and budgetary constraints. The CNO then allocates the fleet NCEA to the FLTCINC for further distribution to the type commander. The NCEA number is also forwarded to Naval Sea Systems Command (NAVSEA) by the CNO for procurement action.

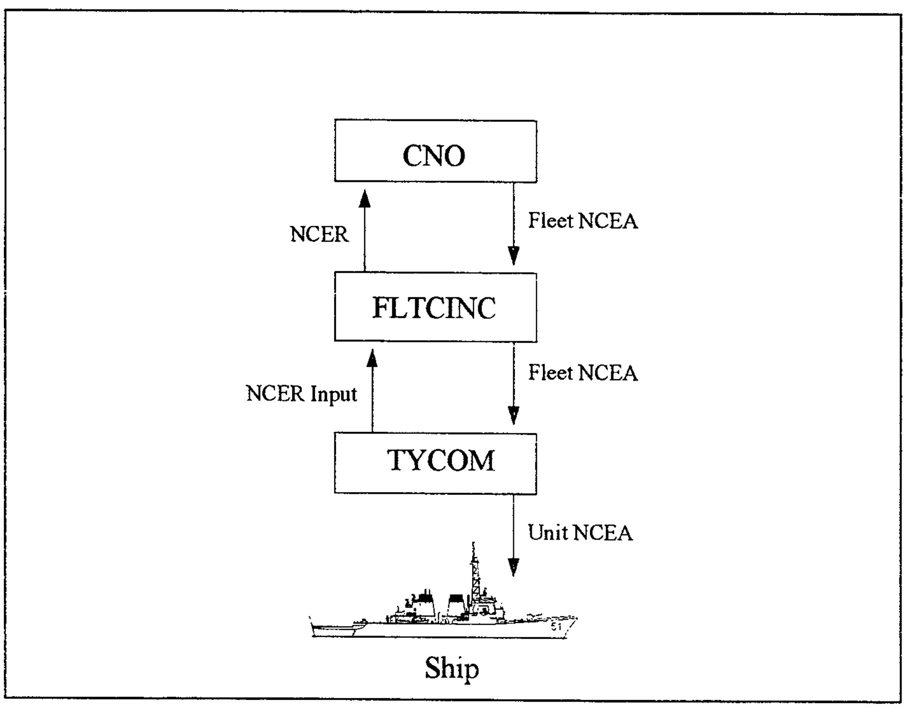


Figure 2. Flow of NCER inputs and subsequent NCEA.

Once SURFPAC receives the fleet allocation (NCEA), it is then distributed to all ships in a yearly notice. [Ref. 4] Ideally, at the beginning of a new fiscal year, each type commander would conduct an analysis of past ammunition expenditures and compare them to each ships planned schedule to determine the best NCEAs to assign for the next fiscal year. However, at present this or any other formal analysis does not appear to be happening. Instead, trial and error estimation reinforced by "fleet experience" appear to be the guiding principles resulting in all ships receiving the same allocation of ammunition regardless of their upcoming schedule.

III. THESIS MOTIVATION

A. *MOTIVATION*

A 1983 audit by the Department of Defense Inspector General found that many fleet commander procedures were contrary to effective management of ammunition. [Ref. 5] Rather than base the NCER on actual training needs, the NCER was based solely on aggregated historical expenditure. What the entire fleet expended the past fiscal year was generally considered a good approximation for the next year's requirements. Consequently, NCEAs were distributed to ships with no regard for the ship's schedule or type of ship.

Compounding the problem, consumption of ammunition was monitored at the fleet vice the unit level -- allowing certain ships to expend over twice their allowance without alerting the fleet commander to the problem.

Similar inefficiencies still exist today in this complicated system. The author was exposed to related discrepancies while on experience tour at COMNAVSURFPAC in San Diego, CA. One senior officer in the fleet requirements branch commented that the Navy's ammunition system is "broken" and any studies that could be done to help the system would be beneficial – starting at the ground level. A clear understanding that the NCER determination process was complex and confusing existed resulting in NCEAs being assigned to individual ships using a fair-share policy. Data analysis is not done currently due to the complexity of the problem. The fleet NCEA allocated to SURFPAC by the CNO and CINCPACFLT is simply divided by the number of 5"/54 caliber barrels in the fleet and then appropriately apportioned to each ship's NCEA.

As a means for resolving different ships' requirements, squadron/group commanders are authorized to redistribute NCEAs as they deem necessary to ships under their command, but this practice will not be a viable solution in the future. The latest fleet organization calls for the entire squadron/group of ships to deploy together in the same battle group. This will result in all of their training cycles being synchronized and all of their requirements being very similar (either high or low). This will place even more importance on the ammunition requirements determination process in the future.

B. PAST NCER REQUIREMENTS METHODOLOGY

The last known attempt at 5"/54 caliber fleet level NCER methodology was promulgated by the CNO's office in October 1991. [Ref. 6] This confidential notice, entitled "NCER Methodology," listed planning factors for determining each ship's expected expenditures based on the major exercises the ship was to participate in during the next fiscal year. These categories included exercises such as type commander exercises (TYPEX), independent steaming exercises (ISE), Naval Surface Fire Support (NSFS), spotter services, refresher training, and fleet exercises (FLTEX).

By knowing each ships detailed schedule, a decision maker could use these planning factors to estimate the ammunition requirements for the next fiscal year. This system, however, failed due to the inaccuracy of these estimates. Each estimate was generally too high for each individual ship which became amplified and caused gross overestimation when aggregated to the fleet level.

Factors such as target availability, system casualties, and range availability all affect the final quantity of ammunition expended to complete an exercise. These factors generally force each ship to expend less ammunition than planned. The formal NCER methodology appears to have been discontinued.

C. CURRENT NCER DETERMINATION PROCESS

The current NCER process at the fleet level does not consider deployment cycle, ship type, maintenance schedules, or any other of a number of factors affecting the expenditure of ammunition. Every ship with two guns is assumed to require the same amount of ammunition. This policy may be inefficient, but it ensures that all ships feel equally important. Furthermore, it is easy to apply and much easier to justify than other methods.

As discussed in the previous chapter and depicted in Figure 1, a notional training cycle exists for each ship. This interdeployment training cycle is normally 18-21 months in duration with some variation. Deployment data for the ships studied in this thesis yields the mean cycle times displayed in Table 4.

Ship Class	Mean	Standard Deviation
CG-47/DDG-993	17.5	5.0
DD-963	21.3	8.3

Table 4. Mean Interdeployment Cycle Times (in months).

The author speculates that the older DD-963 class ships spend a few extra months between deployments taking advantage of maintenance availabilities, but has no evidence to support this.

The difficulty associated with predicting the proper NCEA for a particular ship is that this number is based on the fiscal year and the training cycle is not. Therefore, the 12-month fiscal year window associated with the NCEA falls randomly onto the 18-21 month cycle. For this reason, fiscal year expenditures (corresponding to NCEA) will always be a random variable.

Figure 3 shows the actual expenditures of Full Service Charges versus the predictions (NCEA) for all Pacific Fleet ships over the past 4 fiscal years to illustrate the problems with current methodology.

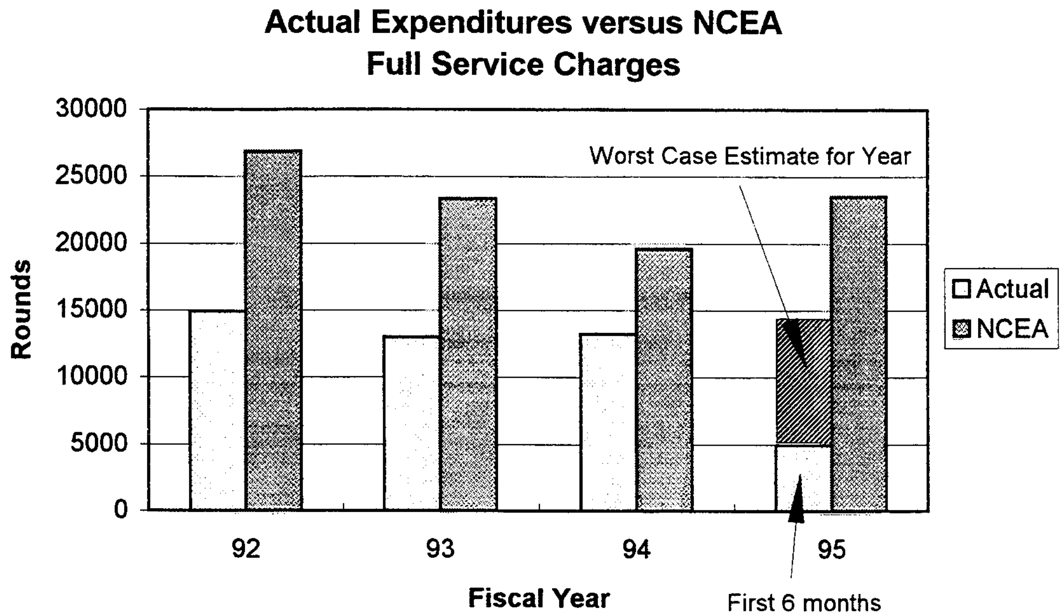


Figure 3. Actual Expenditures versus NCEA for Full Service Charges (FY 92-95). Expenditures for the first six months of FY-95 were almost 5000 rounds. Using the worst, and unlikely, case of a 200 % increase in expenditures the last half of the year still shows significant overestimation.

Figure 3 clearly shows the overestimation taking place on the order of six to ten thousand rounds per year. The decreasing NCEA figures seemed to be converging to actual expenditure levels from FY 92-94, but FY-95 will certainly be the worst prediction of all. There is no way to justify an increase in FY-95 requirements if past expenditure data is taken into account. Obviously, no learning curve exists, NCEA forecasts are simply guesswork, and this problem requires an analytical study to improve the process.

Six of the nine ammunition families have consistently been overestimated in the past 3 fiscal years. Of the remaining three, HE-PD and HE-CVT were underestimated in FY-92 and 93 and overestimated in FY-94, and Reduced Charges were the reverse of this. All of the NCEAs have been raised for FY-95, which causes substantial overestimation. This results in high inputs leading to the procurement of excessive 5"/54 caliber ammunition which will need to be stored and maintained until it can be used.

D. FURTHER MOTIVATION

Members of the SURFPAC ordnance shop feel that this problem is too complex to model and none of them have the time required to undertake such a project. These two factors make this an ideal thesis opportunity.

IV. PROBLEM STATEMENT

The goal of this thesis is to apply basic OR analysis techniques to readily available data to improve the 5"/54 caliber NCER determination process for Pacific Fleet surface combatants. The development of planning factors and the reduction of fleetwide overestimation can only improve the Navy's vast conventional ammunition management system.

To this end, the following assumptions were made:

- Current readiness levels are acceptable. In fact, surface ship combat readiness levels are the highest they have been in decades.

- The CAIMS data used in this thesis is accurate after the procedures described in Appendix A are applied. This readily available data was not without peculiarities and required significant validation before it was usable.

- Better NCEA estimates at the fleet level will improve the Navy's overall ammunition program.

The system is too large for this thesis alone to fix. However, this thesis does show that all ships do not expend the same amount of ammunition over a fiscal year and that historical data can be used to improve the requirements determination process for future fiscal years.

V. DATA

A. CAIMS EXPENDITURE DATA

Most of the data used in this thesis comes from the Conventional Ammunition Integrated Management System (CAIMS) database at the Naval Ordnance Center (NOC) in Mechanicsburg, Pennsylvania. CAIMS is basically an accounting system and it is generally not revered by analysts as a good source of accurate information on ammunition expenditures and real-time on-hand quantities. Despite these perceived shortfalls, CAIMS accuracy is considerably high (about 98%), and there are CAIMS terminals at SURFPAC which facilitate easy access to this data for the analyst or decision maker.

All ammunition transactions are reported to CAIMS within 24-48 hours of occurring. Examples of transactions that are reported include: training expenditures, operational expenditures, ammunition transfers, and losses or gains of ammunition due to clerical errors. There is no way of backdating transactions, so CAIMS records these transactions as they are received. This results in many difficulties in analyzing the raw data. For example, if a ship expended 35 rounds of BL-P ammunition for training in July 1994, the following could happen:

First, the ship actually expends 35 rounds of D341 (BL-P projectiles) and 35 rounds of D326 (Full Service Charges), but accidentally reports 25 rounds of each with a typographical error reporting D324 instead of D326. Lines 1 and 2 of Figure 4 would be generated and recorded in the CAIMS database. Second, this same ship submits a correction in July of 1994 resulting in the data in lines 3-5. Line 3 corrects the D324 typographical error, line 4 correctly reports the actual expenditure of D326, and line 5 reports the expenditure of the additional 10 rounds of D341.

Transaction #	Date	NALC	Family	Qty	Reason
Originally Reported Transactions:					
1	May 94	D324	FSC	25	Training
2	May 94	D341	BL-P	25	Training
Follow-up Correction Transactions:					
3	July 94	D324	FSC	-25	Clerical Error
4	July 94	D326	FSC	35	Clerical Error
5	July 94	D341	BL-P	10	Training

Figure 4. Sample CAIMS data.

Obviously, this data is not useable in this form. A manual interpretation of the reported data is required to transform these transactions into actual expenditure data. Note that the analyst must be careful not to misinterpret the data. In this case, one could mistakenly deduce that 25 rounds of BL-P was expended in May and 10 rounds of the same ammunition expended in July. For this reason, painstaking reviews of each ships reported expenditures is necessary to accurately piece together the actual expenditures. Specific procedures used to validate the data for this thesis are detailed in Appendix A.

It is interesting to note that while the data from FY 92-94 contained a small percentage of negative entries, FY-95 data contained none. A representative at NOC reported that no major changes had taken place in the database, and that the reports must have simply been formatted differently. It appears that analyses similar to this can be done with increasing ease in the future.

B. CAIMS NCEA DATA

The NCEA data from the CAIMS database included all fiscal year initial NCEA figures from FY 92-95 as well as each augmentations given throughout the year. The number of augments requested was considerably low meaning that current predictions satisfy almost all of the ships in the Pacific Fleet.

C. DEPLOYMENT DATES/EMPLOYMENT SCHEDULES

The Operations Department at SURFPAC (N-3) is responsible for all Pacific Fleet surface ship schedules. Current software in use contains data on every major exercise or event a ship participates in, but only the deployment dates were considered for this thesis.

D. COMMISSIONING/DECOMMISIONING DATES

Commissioning and decommissioning information was received from the Public Affairs Officer at SURFPAC and was used as a basis for omitting recently commissioned ships.

E. OVERHAUL/MAJOR MAINTENANCE DATES

Major maintenance availability dates, completed and scheduled, are available through the Supervisor of Shipbuilding (SUPSHIP) for each ships' respective region. A majority of the ships in this thesis are covered by SUPSHIP San Diego, but approximately seven are not. This data is incomplete and is not incorporated into this thesis.

F. OTHER DATA

Other sources of data are listed in the bibliography and include ship names, NALC information, and ammunition families. This data was used to classify ships and make the data more easily manageable.

VI. METHODOLOGY AND ANALYSIS

A. DATA COLLECTION AND ORGANIZATION

There were 27 NALCs represented in the data set that were placed into the nine categories of NCEA issued by SURFPAC. Although the NCEA is established for a single NALC, there are many NALCs in similar "families" of ammunition that may be substituted. The families of ammunition and the groupings are listed in Appendix B. Family groupings for this thesis were made based on the NALC manual [Ref. 3] and the SURFPAC cross reference list. [Ref. 4] The costs of each round expressed in 1995 dollars is also included in Appendix B.

B. METHODOLOGY

Expenditure data was downloaded onto floppy disks and imported into Microsoft Excel 5.0 for validation, organization, and analysis. Microsoft Excel 5.0 proved to be invaluable as a tool for all aspects of the data analysis including list processing, automatic summary tables, and curve fitting. The following phases of analysis occurred:

1. Twelve-Month Moving Windows of Historical Expenditures

The data was organized onto a timeline with the deployment dates superimposed onto the data. Twelve-month moving "windows" were placed at every possible month between deployments ensuring that no deployment months were included in the fiscal year window. This procedure was used to produce the data series of random yearly expenditures used for the forecasts. The sums of the expenditures in each 12-month window form data points for the forecasting graphs in Appendix D. The data in each series is highly correlated and interdependent, so each series was treated as a set of data.

2. Outlier Determination

Data series containing all zero entries were assumed to be unusual and were deleted. Additionally, data series with points lying outside 2 standard errors were carefully examined and considered for deletion. Equation 1 was used to calculate standard error about the mean, or the unbiased estimator of the population standard deviation. This gave the widest acceptance region to allow more of the data to be included.

$$StdError = \sqrt{\frac{(x_i - \mu)^2}{n-2}}$$

Equation 1. Standard Error Equation. (where n= number of data points in each time slot, μ = mean of each time slot, and x_i = data points in each time slot.)

It is usually true that 95% of the data points will lie within two standard errors of the mean. [Ref. 7] Those falling outside of this range were considered as possible outlying points. Each outlying point was considered individually taking into account the other data points in the series. If it was determined that the data series was not representative of the overall data or if unusual expenditure patterns were discovered, that entire data series was deleted. The results of eliminating the outliers is summarized in Appendix C.

3. Fitted Historical Demand Curves

The data was split into two groups, DDs and CGs, and plotted using *months before deployment* as the independent variable and *yearly expenditures* as the dependent variable. Sixth order polynomial equations were fit to this data and used for casual forecasting. The resulting 18 graphs are included in Appendix D. Note that the polynomial equation fit through the data lies very close to the mean of the expenditures in each time slot. The standard deviations for each time period are listed in Appendix E.

4. NCEA/NCER Forecast Worksheet

The equations of each of the 18 sets of data were transferred to a Microsoft Excel Worksheet to assist the decision maker in quick and easy determination of baseline NCEAs and a fleet NCER. The number of months until the next deployment is simply inserted into the shaded column, and forecasts for each family of ammunition are calculated using the fitted equations. Model results are summarized at the bottom and compared to the actual NCEA and actual expenditures. The run for FY-95 is contained in Appendix F. The *months before deployment* input field and corresponding meanings are listed in Figure 5.

Field Entry	Meaning
-20	Ship is 20 or more months before deployment at start of FY
-19	Ship is 19 months before deployment at start of FY
:	:
0	Ship begins deployment at start of FY
:	:
5	Ship is in its sixth month of deployment at start of FY
6	Ship has been back from deployment for one month at start of FY
:	:
14	Ship has been back from deployment for nine months at start of FY

Figure 5. Months Before Deployment field used in model.

VII. RESULTS, CONCLUSIONS, AND FURTHER STUDY

A. RESULTS

The results of this thesis are summarized below in Figure 6.

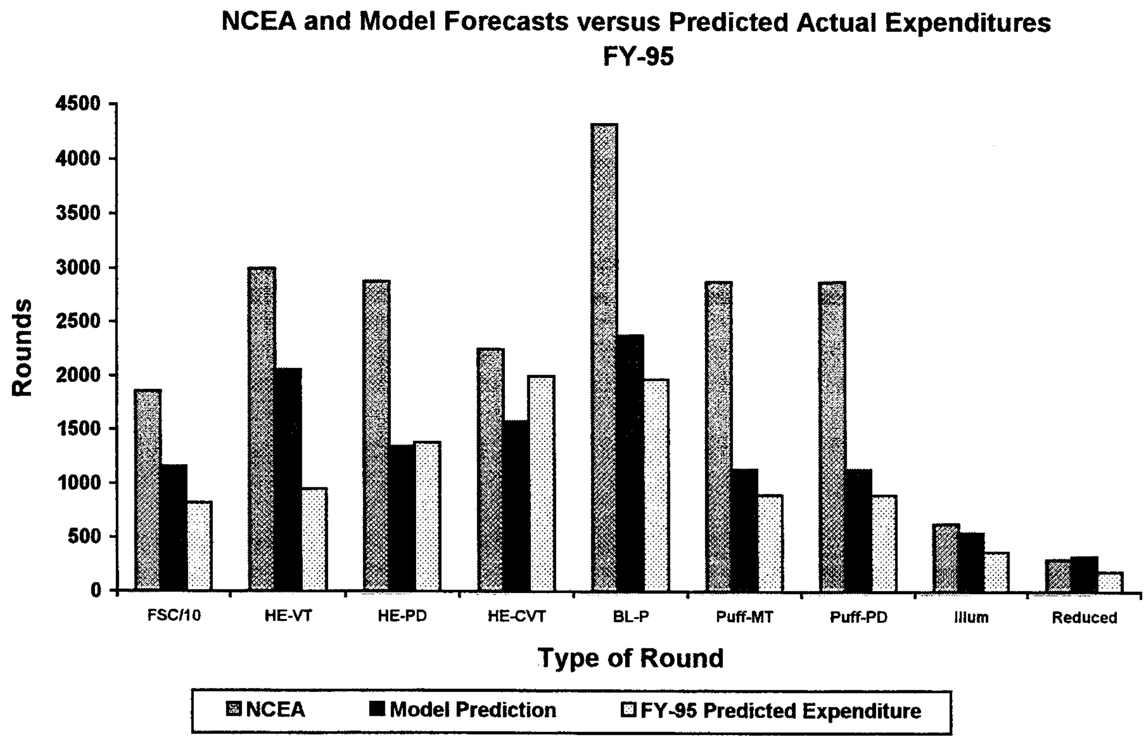


Figure 6. This graph depicts the savings achieved using the model in this thesis. The leftmost bar in each series is the NCEA -- the current prediction. The middle bar is the model's prediction, and the rightmost bar is the estimated FY-95 actual expenditures. (Note: The first category of ordnance, FSC, is divided by 10 to allow it to fit on this graph.)

In most cases, the tallest bar in each ammunition family is the FY-95 NCEA issued by SURFPAC. The next highest bar in each family is the prediction using the fitted historical demand curves in this thesis. (Note the significant reduction in NCER.) The shortest bar indicates the expected actual

FY-95 expenditures which were predicted using linear regression on the first eight months of data for FY-95. (In order to fit all nine categories of ordnance onto one graph, the figures in the first series, FSC, were divided by ten.)

One can clearly see that the model estimations are much less overestimated than those calculated using the current methodology. Thus, using past expenditure data is definitely a viable method of predicting future expenditures. How accurate this model is in determining actual FY-95 expenditures can only be determined at the end of this fiscal year, but the preliminary results are promising.

B. CONCLUSION

This thesis has demonstrated the power of a simple OR study in determining NCER levels for surface combatants of the U.S. Pacific Fleet. A vast improvement over the current methodology, this process has clearly shown that all ships are not created equal and that fiscal year expenditures vary sharply with ship type and location in the interdeployment training cycle. (LHAs expend far less ammunition than the ships studied in this thesis and possess even greater room for improvement since they are treated the same as a cruiser or destroyer.)

Future augment requests will be expected to increase in number under this system due the lower NCEAs initially being assigned to each ship, but the benefits of accurately predicting fleet NCER levels far outweigh the inconvenience of transmitting an NCEA augment request.

For FY-95, the cost of the initially allocated rounds was in excess of 15 million dollars. The cost of the model requirements for the same year was roughly 10 million dollars – a significant reduction. It may not be possible to save 5 million dollars each fiscal year using data analysis on 5"/54 caliber ammunition, but this thesis certainly proves the concept that vast improvements can be made in this area by applying some simple data analysis techniques. Not only will the initial procurement costs be reduced, but later costs of inspection, maintenance and storage of excess ammunition will be saved as well.

C. FURTHER STUDY

Inefficiencies exist throughout the conventional ammunition management system which deserve analytical study. This thesis scratched the surface of a huge problem. Further study could include validating this model against the actual FY-95 data and incorporating this data into a new and improved model – possibly using more independent variables to obtain higher resolution. These additional data variables could include major maintenance schedules, NSFS qualification dates, nature of the next deployment, and operational commander.

The reader is reminded that CAIMS does not provide clean data to work with, and any future work will depend on the ability to accurately extract the actual expenditures from the reported transactions. Some other source of operational data is desired by operational commanders as well as analysts, but currently does not exist.

APPENDIX A. CAIMS DATA VALIDATION PROCEDURE

As stated in previous chapters of this thesis, Conventional Ammunition Integrated Management System (CAIMS) data may not be a timely and reliable source of data for most applications. CAIMS is, however an accurate accounting trail of all transactions. By using careful and often tedious reconstruction techniques, this data can be transformed into a useful form. To remain focused on the task at hand, a consistent policy was developed and used. This Appendix details the procedures used by the author to validate the data used in this thesis.

Step 1: Resolve any obvious errors.

All data was tabulated and displayed by month on a timeline from December 1990 through May 95. Obvious accounting errors, account adjustments, and error correction transactions were located and resolved. For example, if a ship reported expending 96 rounds of a highly specialized type of ammunition in one month without expending any charges or practice ammunition in that month, it was assumed that this was an account adjustment and not an expenditure for training.

Step 2: Resolve negative entries.

All negative entries that remained after step one (55 of about 5100) were analyzed to find out what transaction they were used to correct. In most instances, the errors were obvious and correction was simple. In others, the errors could not be found. Fortunately, none of the ships studied in this thesis had unresolvable errors.

Step 3: Ensure projectile/charge ratio equals one for each month.

Once all obvious errors were resolved, all expenditures were broken down into projectiles and charges which are expended in a 1:1 ratio. To resolve differing ratios, the assumption was made that the projectile reports were correct and that the charges could be redistributed based on projectile expenditures. This turned out to be a reasonable assumption with the following results.

	Projectiles	Charges	Total
Raw Data	69,853	69,367	138,683
Data after Validation	68,768	68,768	137,597
Percent Change from Raw Data	1.53%	0.864%	0.783%

Table 5. Effect of Validation on Raw Data.

One can see from Table 5 that very little change in the total numbers of rounds expended occurred. Expenditures were simply redistributed month-to-month to recreate the actual expenditures based on the audit trail. On an individual ship basis, only seven of the 30 ships used for forecasts had changes in the FSC expenditures of one percent or more with the worst being 3.25%. (See Table 6). None had significant changes in other expenditures.

Command Name	Ship Type	Orig. Total	Validated	Change	% Change
ANTIETAM	CG	4229	4226	-3	-0.07
BUNKER HILL	CG	3180	3179	-1	-0.03
CHANCELLORSVILLE	CG	1999	2022	23	1.15
CHOSIN	CG	3839	3846	7	0.18
COWPENS	CG	3096	3115	19	0.61
LAKE CHAMPLAIN	CG	3640	3646	6	0.16
LAKE ERIE	CG	1123	1151	28	2.49
MOBILE BAY	CG	3862	3811	-51	-1.32
PRINCETON	CG	3025	3025	0	0.00
SHILOH	CG	2599	2600	1	0.04
VALLEY FORGE	CG	2216	2213	-3	-0.14
VINCENNES	CG	2698	2686	-12	-0.44
CALLAGHAN	DDG	2673	2760	87	3.25
CHANDLER	DDG	3257	3212	-45	-1.38
CUSHING	DD	2707	2691	-16	-0.59
DAVID R. RAY	DD	3456	3437	-19	-0.55
ELLIOT	DD	3217	3195	-22	-0.68
FIFE	DD	1817	1815	-2	-0.11
FLETCHER	DD	3848	3849	1	0.03
HARRY W. HILL	DD	2412	2415	3	0.12
HEWITT	DD	3213	3213	0	0.00
INGERSOLL	DD	1846	1846	0	0.00
JOHN YOUNG	DD	2458	2423	-35	-1.42
KINKAID	DD	2360	2354	-6	-0.25
LEFTWICH	DD	2812	2812	0	0.00
MERRILL	DD	2432	2430	-2	-0.08
O'BRIEN	DD	1866	1882	16	0.86
OLDENDORF	DD	2026	2029	3	0.15
PAUL F. FOSTER	DD	2694	2752	58	2.15

Table 6. Effect of validation procedure on Full Service Charges. Seven of 30 ships were altered by more than 1 percent with the worst being 3.25 percent.

APPENDIX B. AMMUNITION FAMILIES

NALC	Ammunition Name	Family	Unit Cost (Dollars)
D349	BL-P	BL-P	232.07
D341*	BL-P, HIFRAG	BL-P	496.00
D326*	Full Service Charge (Poly)	FSC	317.40
D324	Full Service Charge (Cork)	FSC	317.40
D304	Full Service Charge (Cork)	FSC	317.40
D803	HE-CVT, MK 158-0 (Prox.)	HE-CVT	551.40
D350	HE-CVT, MK41	HE-CVT	492.50
D346*	HE-CVT, HIFRAG	HE-CVT	737.00
D295	HE-CVT	HE-CVT	492.50
D343*	HE-PD/D, HIFRAG	HE-PD	920.00
D340	HE-MT/PD, MK 82-0	HE-PD	1,027.00
D339	HC, w/PDF, Delay	HE-PD	303.00
D338	HE-MT/PD, MK 115-0	HE-PD	802.50
D330	HE-PD, w/MK30 Fuse	HE-PD	492.50
D320	HC, w/PDF (Non-Delay)	HE-PD	492.50
D319	AAC	HE-PD	802.50
D354*	Illumination, MK 91-0	ILLUM	1,866.92
D353	Illumination, MK 48 or MK 88	ILLUM	925.00
D351	PUFF-MT/PD, MK 120-0	PUFF-MT	524.00
D291*	TP Smoke, Puff w/MTF	PUFF-MT	270.00
D290*	TP Smoke, Puff w/PDF	PUFF-PD	307.00
D297*	Reduced Charge	Reduced	274.09
D334*	VT-NF, Non Self-Destructing	VT	572.50
D333	VT-NF Self-Destructing	VT	572.50
D332	VT, Non Self-Destructing	VT	697.50
D331	VT, Self-Destructing	VT	697.50

* indicates NCEA established for this NALC. Others in family are interchangeable.

APPENDIX C. OUTLIER STATISTICS

Ammunition Family	Number of Data Series Deleted	Number of Outlying Points	Percent of Data Thrown Out
FSC	1	2	3.1
VT	1	4	4.8
Puff-MT	2 (1)	6	10.4
Puff-PD	3 (4)	12	24.4
BL-P	0	9	0.0
HE-PD	2 (3)	18	26.9
HE-CVT	1 (1)	14	5.1
Reduced	1	13	10.6
Illumination	2	13	6.8

Table 7. CG-47/DDG-993 Outlier Statistics for 449 data points.
( ) denotes series of all zero entries deleted.

Ammunition Family	Number of Data Series Deleted	Number of Outlying Points	Percent of Data Thrown Out
FSC	2	12	12.8
VT	2	18	8.7
Puff-MT	2	11	10.9
Puff-PD	2	24	19.8
BL-P	1	13	6.3
HE-PD	3	15	9.6
HE-CVT	1 (2)	20	5.2
Reduced	3	10	15.5
Illumination	2	16	5.7

Table 8. DD-963 Outlier Statistics for 458 data points.
( ) denotes series of all zero entries deleted.

APPENDIX D. NCER FORECASTING GRAPHS

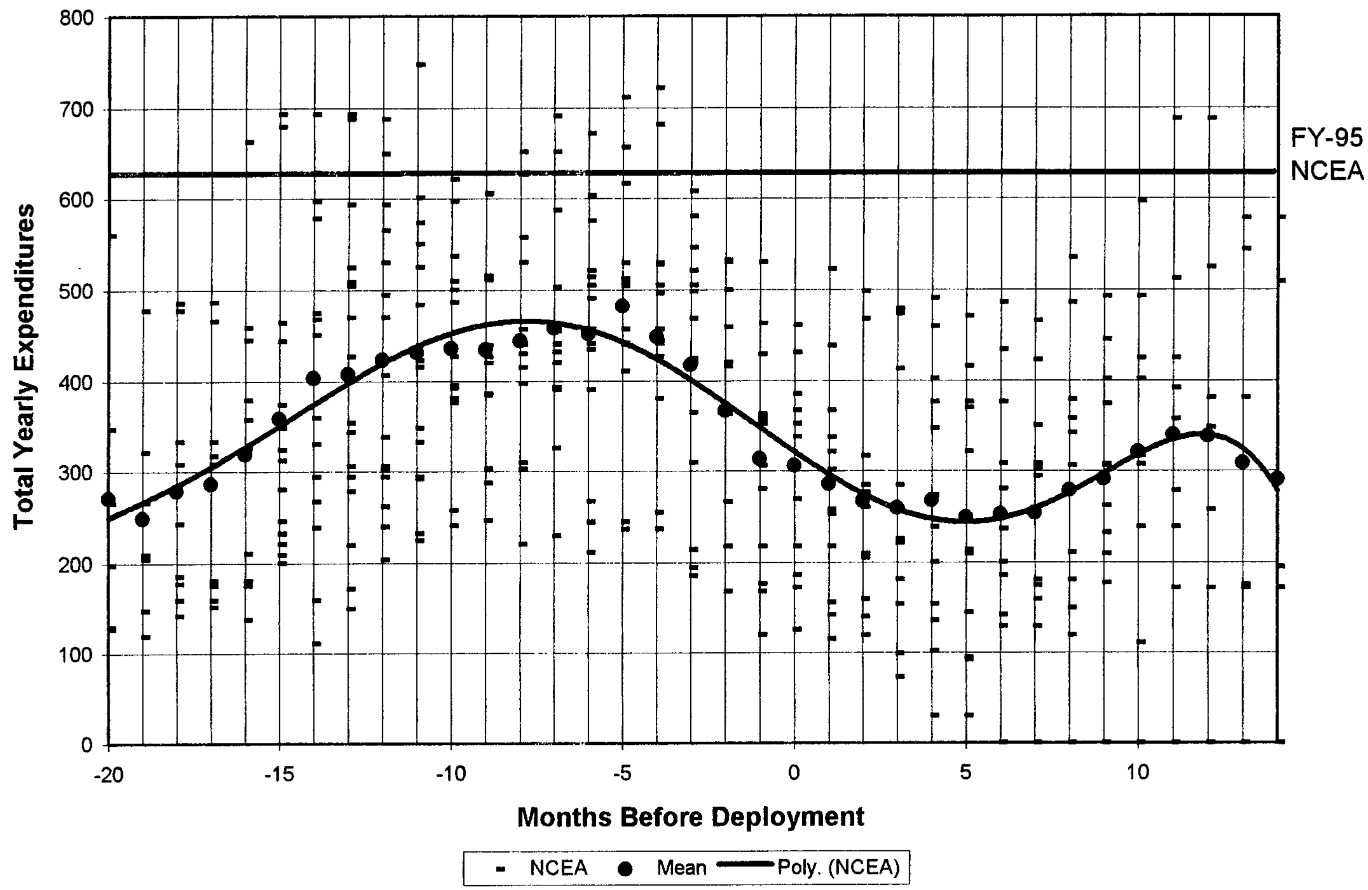
The next 18 graphs contain the raw 12-month sums of expenditures for each ammunition and ship type. The first nine graphs are for destroyers and the last nine graphs are for the cruisers. *Months before deployment* is the independent variable for each ship type and is entered as described in Figure 7. The solid dots show the mean for each time slot, or the expected value of expenditures for a ship in that position in the interdeployment training cycle.

The polynomial equation fit through the data is this model's prediction of the NCER for a particular ship for next fiscal year. (Note that Appendix E lists standard deviations for each time slot if a different final figure is desired by the decision maker.) The straight line depicts the FY-95 NCEA assigned by SURFPAC. This is higher in most cases. The sinusoidal shape of the fitted curves clearly shows the dynamic nature of expenditure requirements throughout the interdeployment training cycle.

DD-963 NCEA FORECAST CURVE
Full Service Charges

$$y = -0.000020809x^6 - 0.000829821x^5 - 0.000191887x^4 + 0.279410594x^3 + 0.858491147x^2 - 26.323144364x + 321.877875378$$

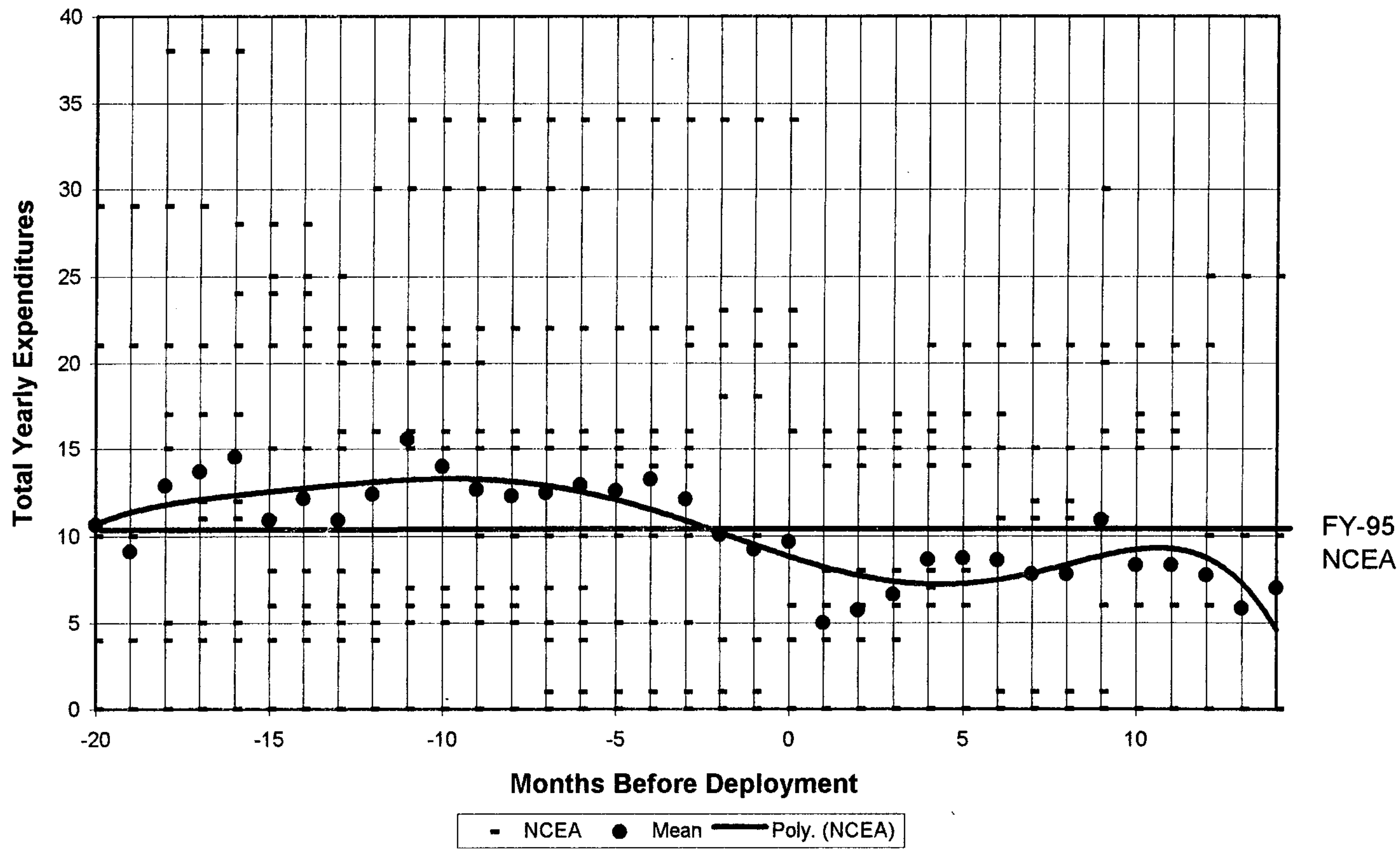
$$R^2 = 0.215151425$$



DD-963 NCEA FORECAST CURVE
Reduced Charges

$$y = -0.000000801x^6 - 0.000027331x^5 - 0.000023020x^4 + 0.007165361x^3 + 0.034315528x^2 - 0.646148266x + 8.859934745$$

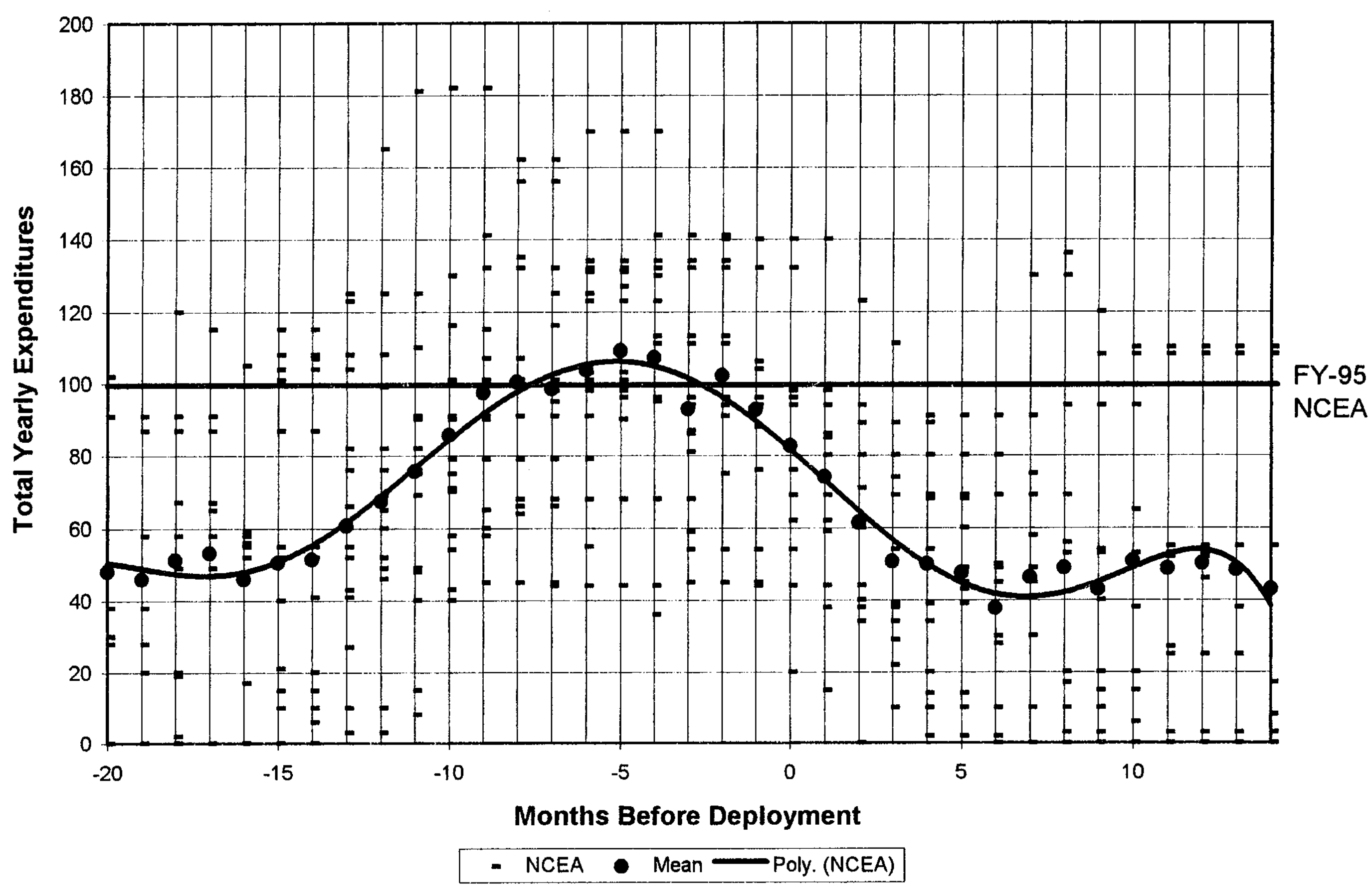
$$R^2 = 0.051789030$$



DD-963 NCEA FORECAST CURVE
HE-VT Projectiles

$$y = -0.000009365x^6 - 0.000268944x^5 + 0.002487577x^4 + 0.091654224x^3 - 0.305167049x^2 - 8.239899458x + 81.785926316$$

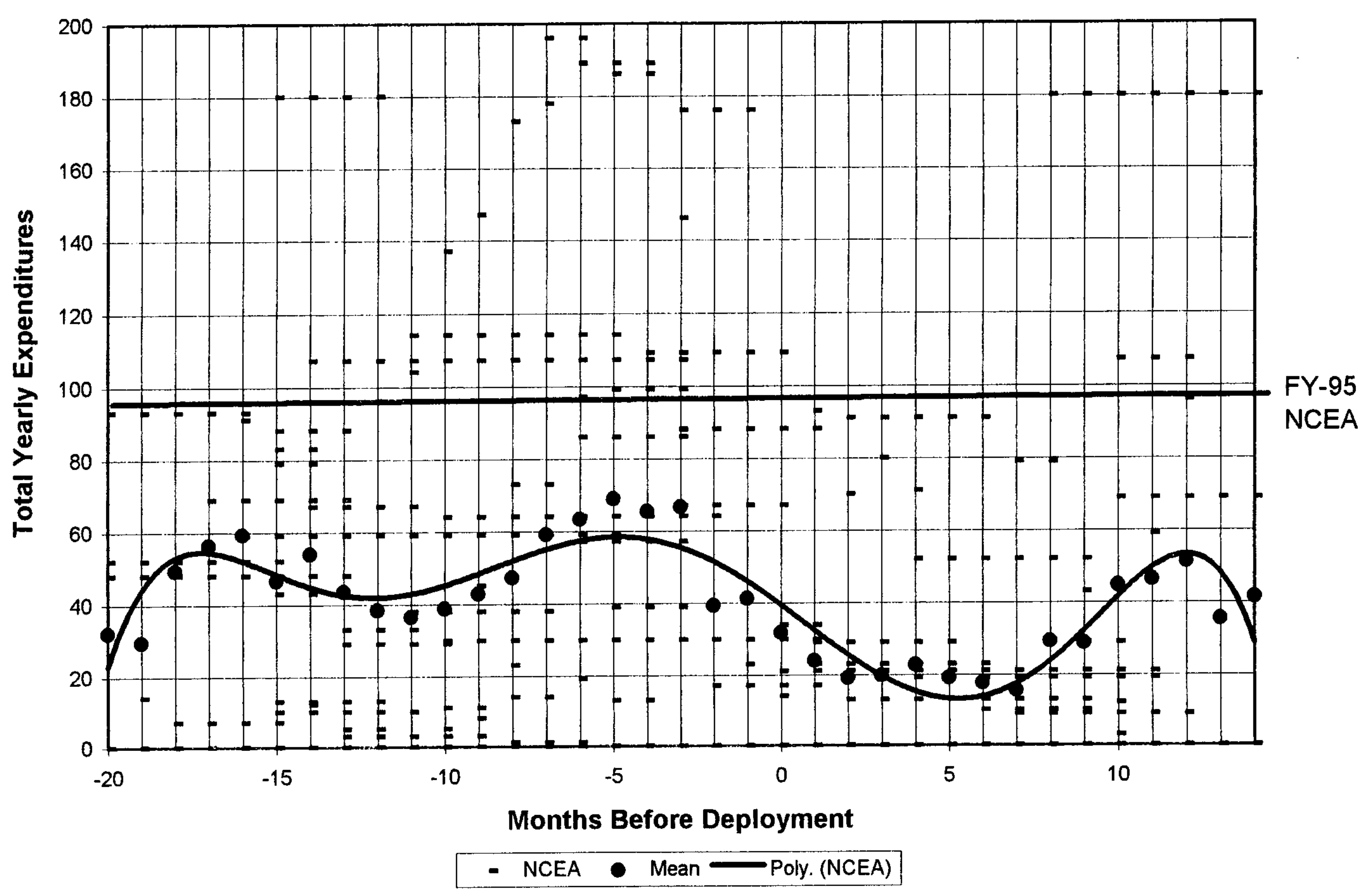
$$R^2 = 0.275210347$$



DD-963 NCEA FORECAST CURVE
HE-PD Projectiles

$$y = -0.000017885x^6 - 0.000361977x^5 + 0.004747369x^4 + 0.103035532x^3 - 0.256963817x^2 - 6.859282956x + 39.577195387$$

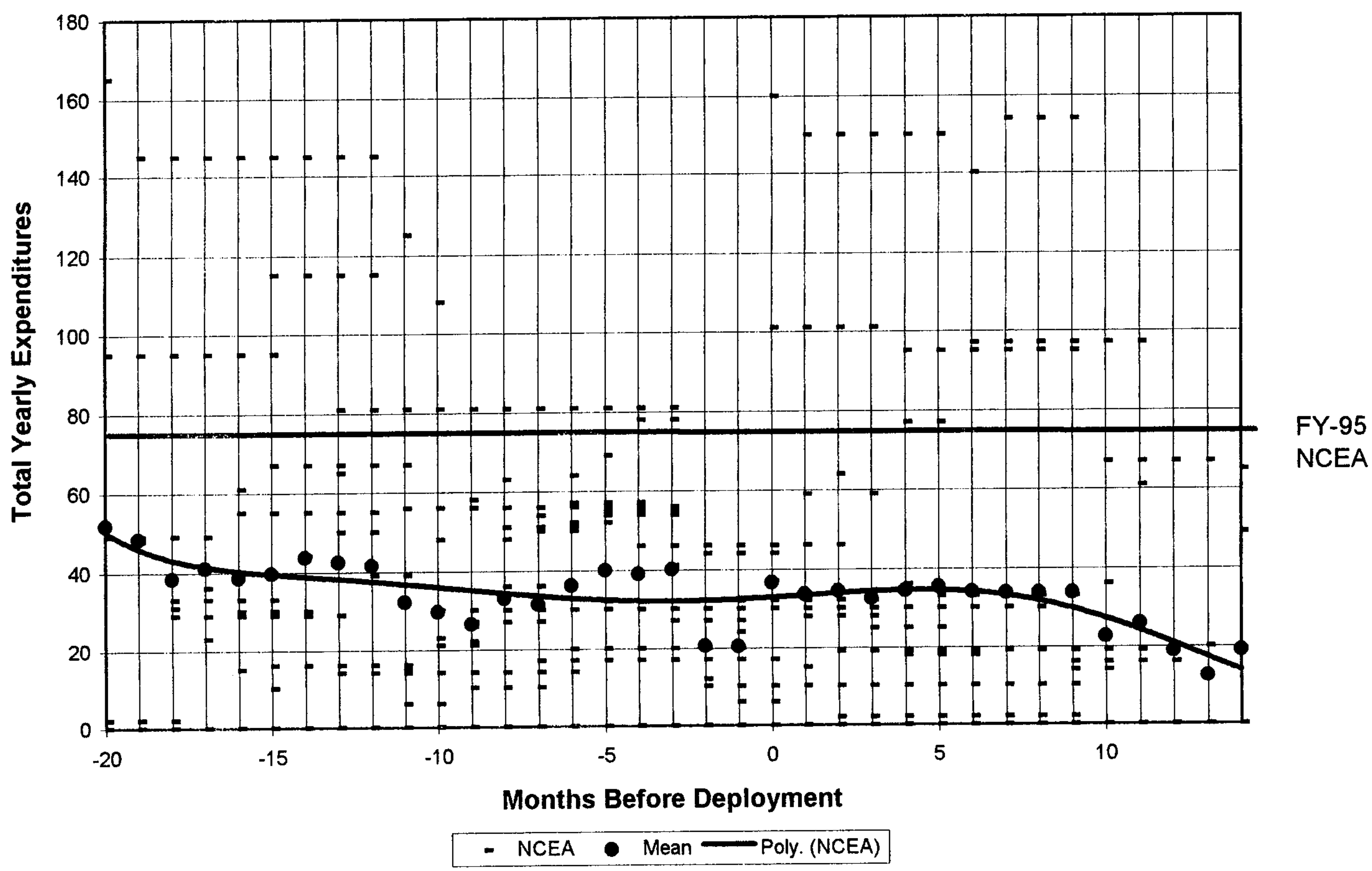
$$R^2 = 0.068765777$$



DD-963 NCEA FORECAST CURVE
HE-CVT Projectiles

$$y = 0.000001567x^6 + 0.000021828x^5 - 0.000683958x^4 - 0.011229289x^3 + 0.040592013x^2 + 0.475657655x + 32.888271815$$

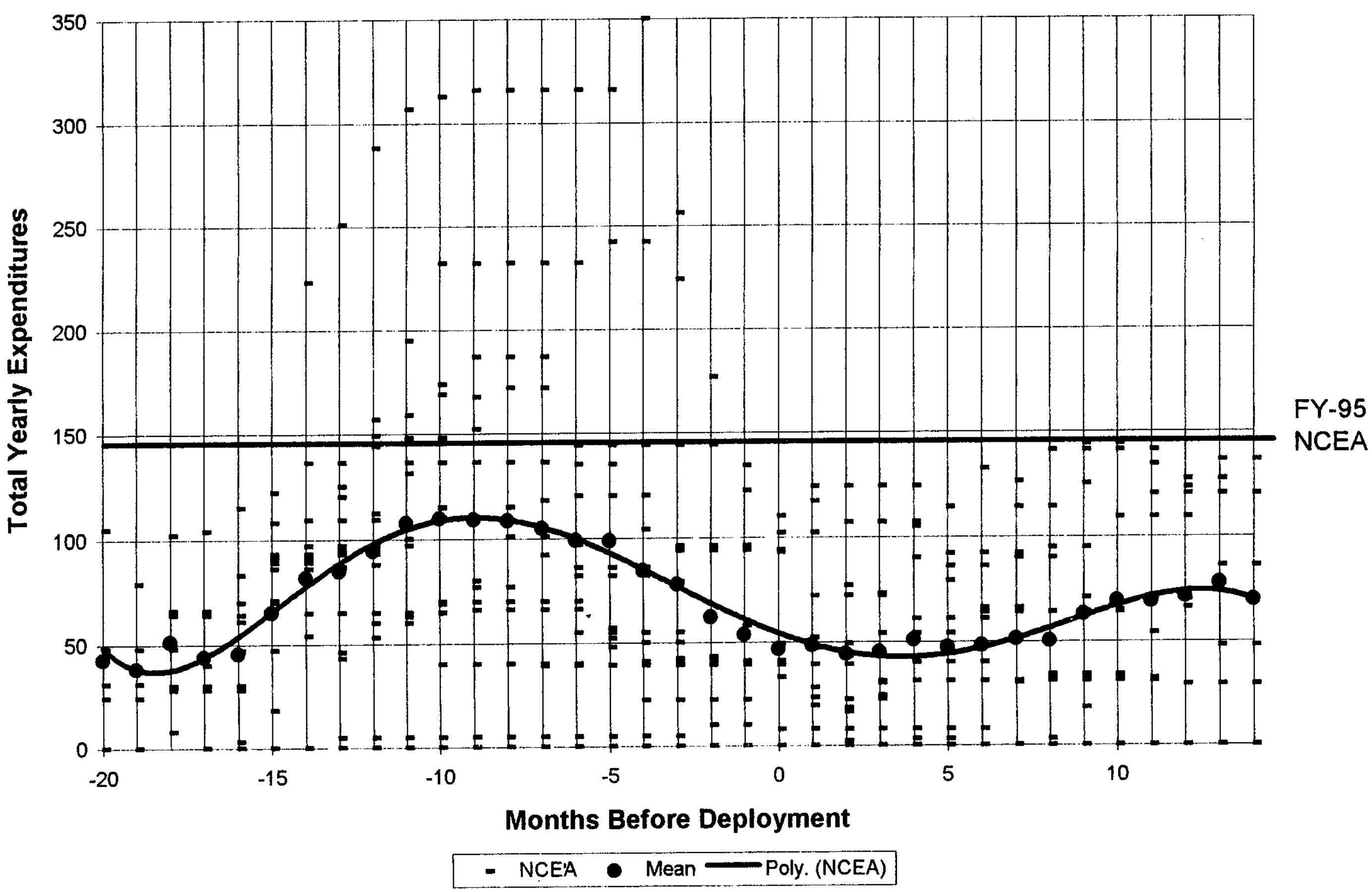
$$R^2 = 0.021220089$$



DD-963 NCEA FORECAST CURVE
BL-P Projectiles

$$y = 0.000003807x^6 - 0.000109664x^5 - 0.003589289x^4 + 0.051340218x^3 + 0.656288315x^2 - 6.112647908x + 54.482376834$$

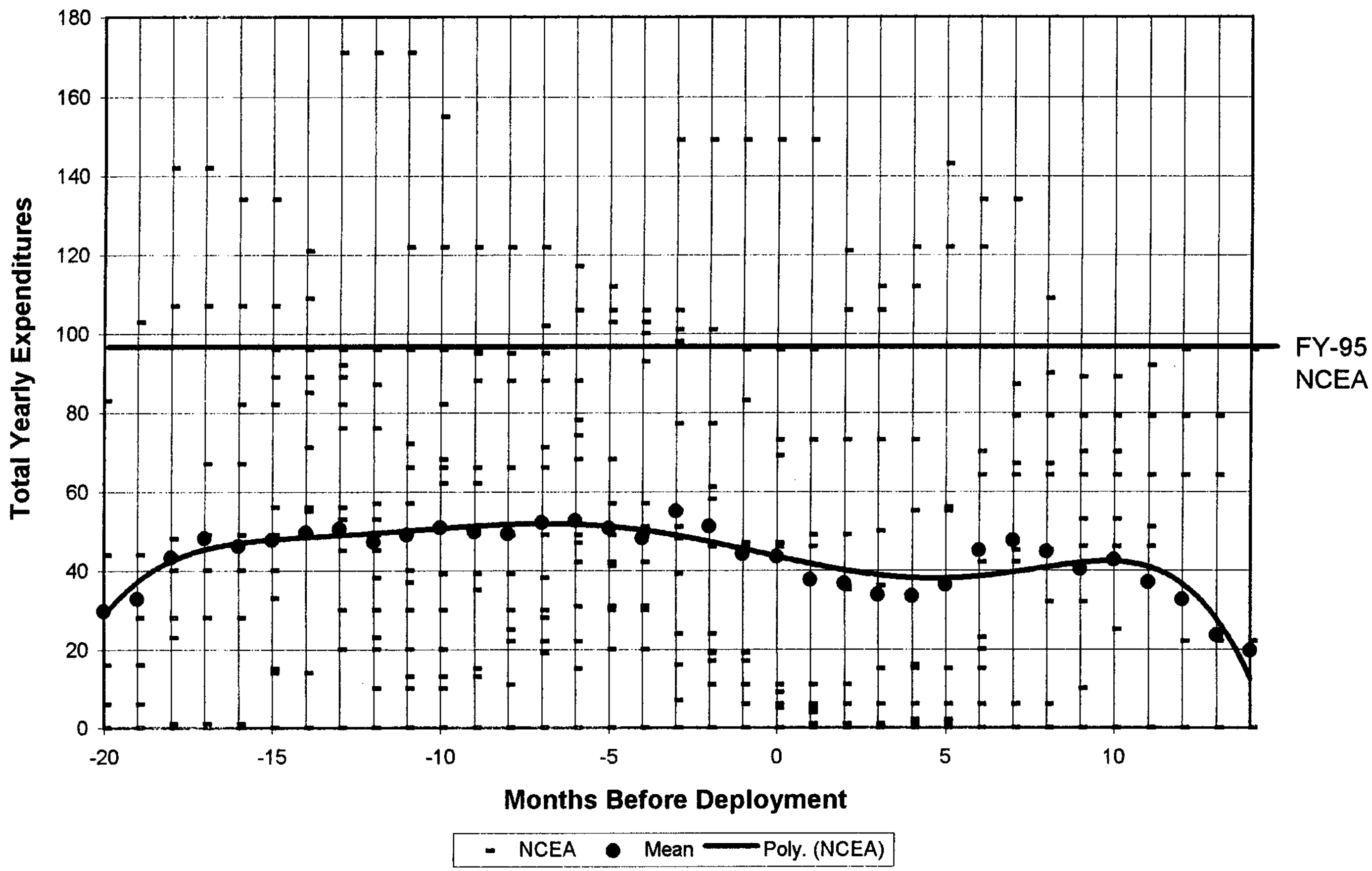
$$R^2 = 0.126093429$$



DD-963 NCEA FORECAST CURVE
Puff-MT Projectiles

$$y = -0.000004882x^6 - 0.000122940x^5 + 0.000448820x^4 + 0.027453702x^3 + 0.032965681x^2 - 1.937480508x + 43.575659252$$

$$R^2 = 0.026918210$$

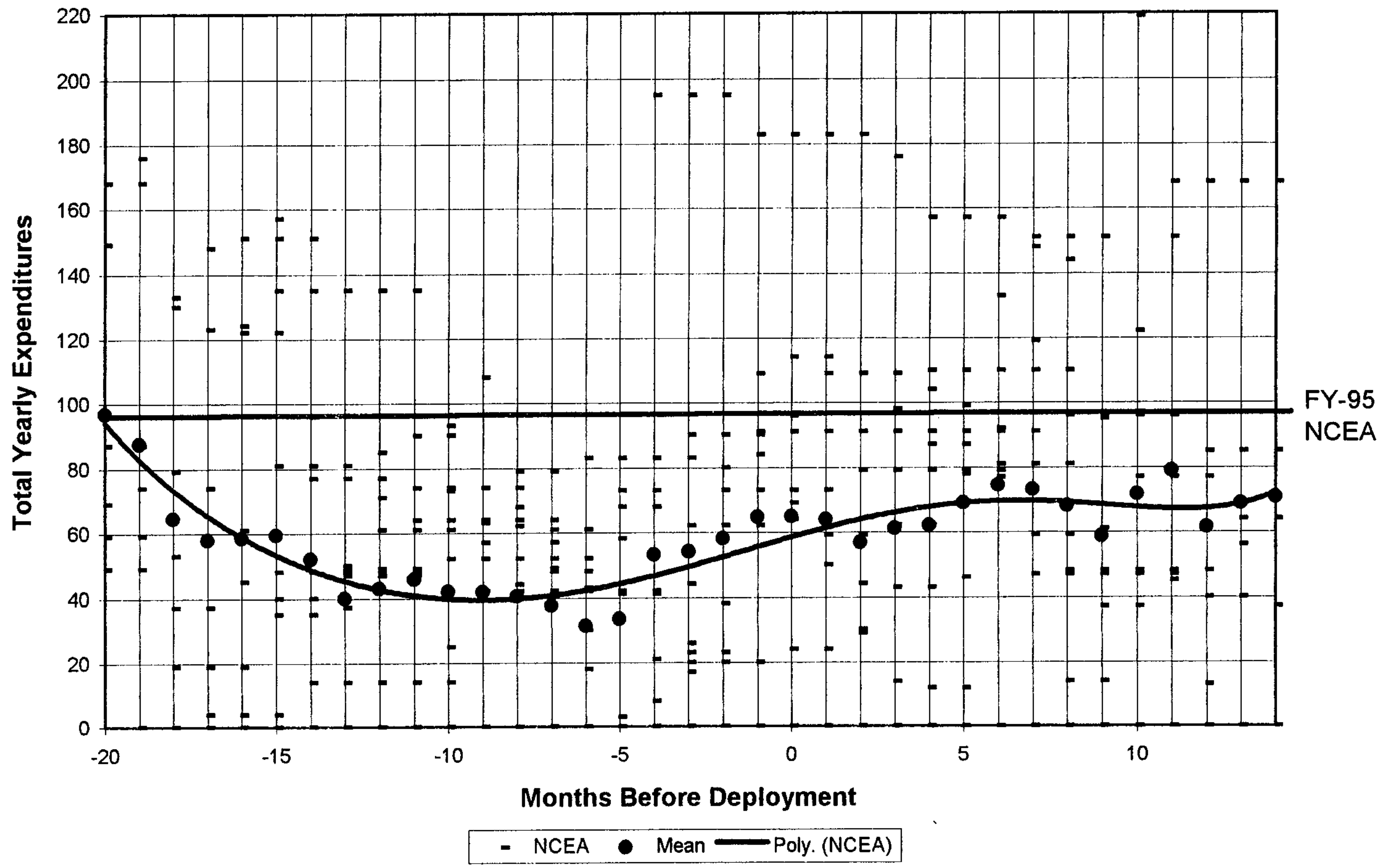


DD-963 NCEA FORECAST CURVE

Puff-PD Projectiles

$$y = 0.000001433x^6 + 0.000049492x^5 + 0.000187080x^4 - 0.020501075x^3 - 0.081319738x^2 + 2.954221143x + 58.548361275$$

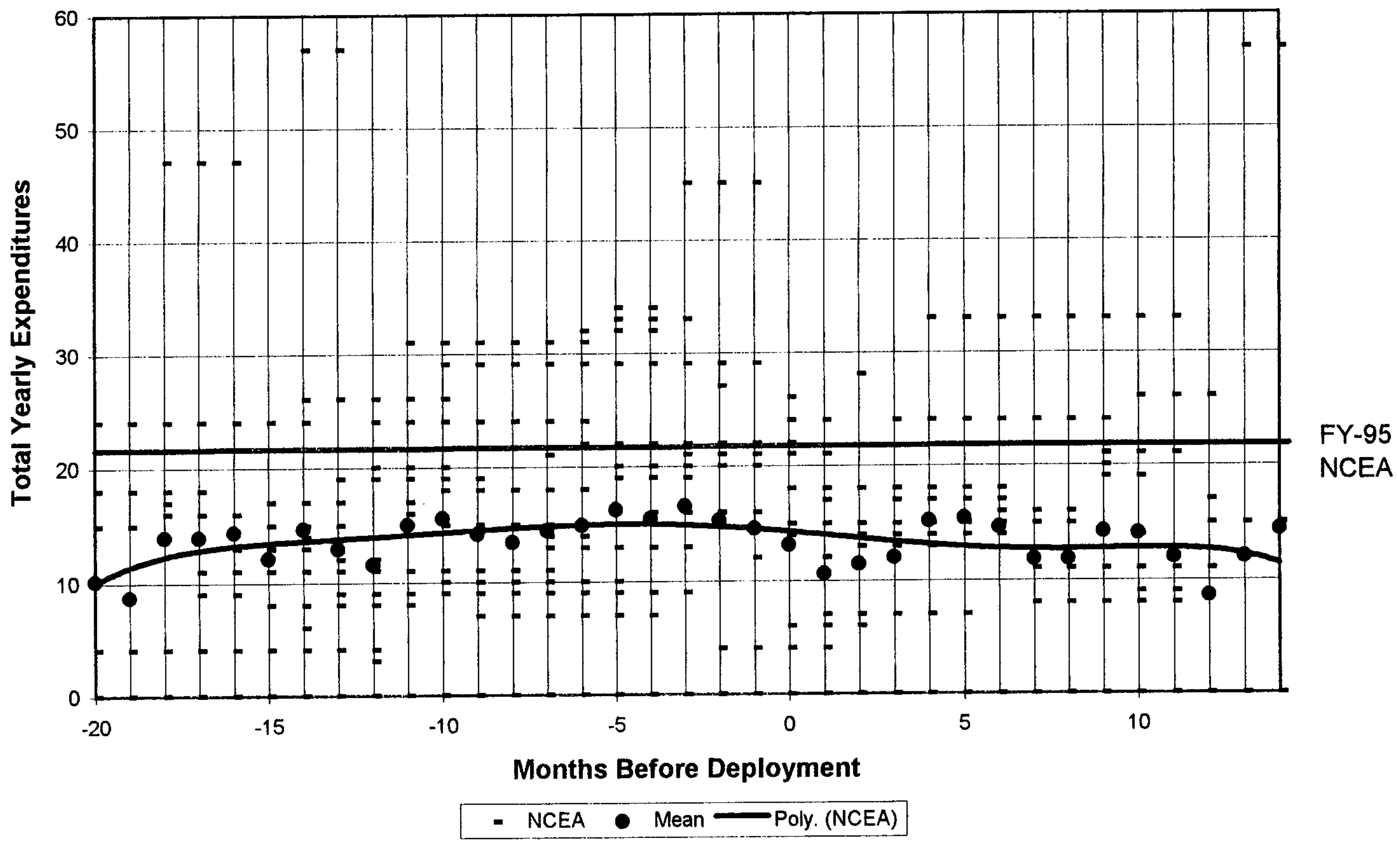
$$R^2 = 0.066737929$$



DD-963 NCEA FORECAST CURVE
Illumination Projectiles

$$y = -0.000000553x^6 - 0.000010264x^5 + 0.000147095x^4 + 0.003009671x^3 - 0.016723940x^2 - 0.275067502x + 14.331974055$$

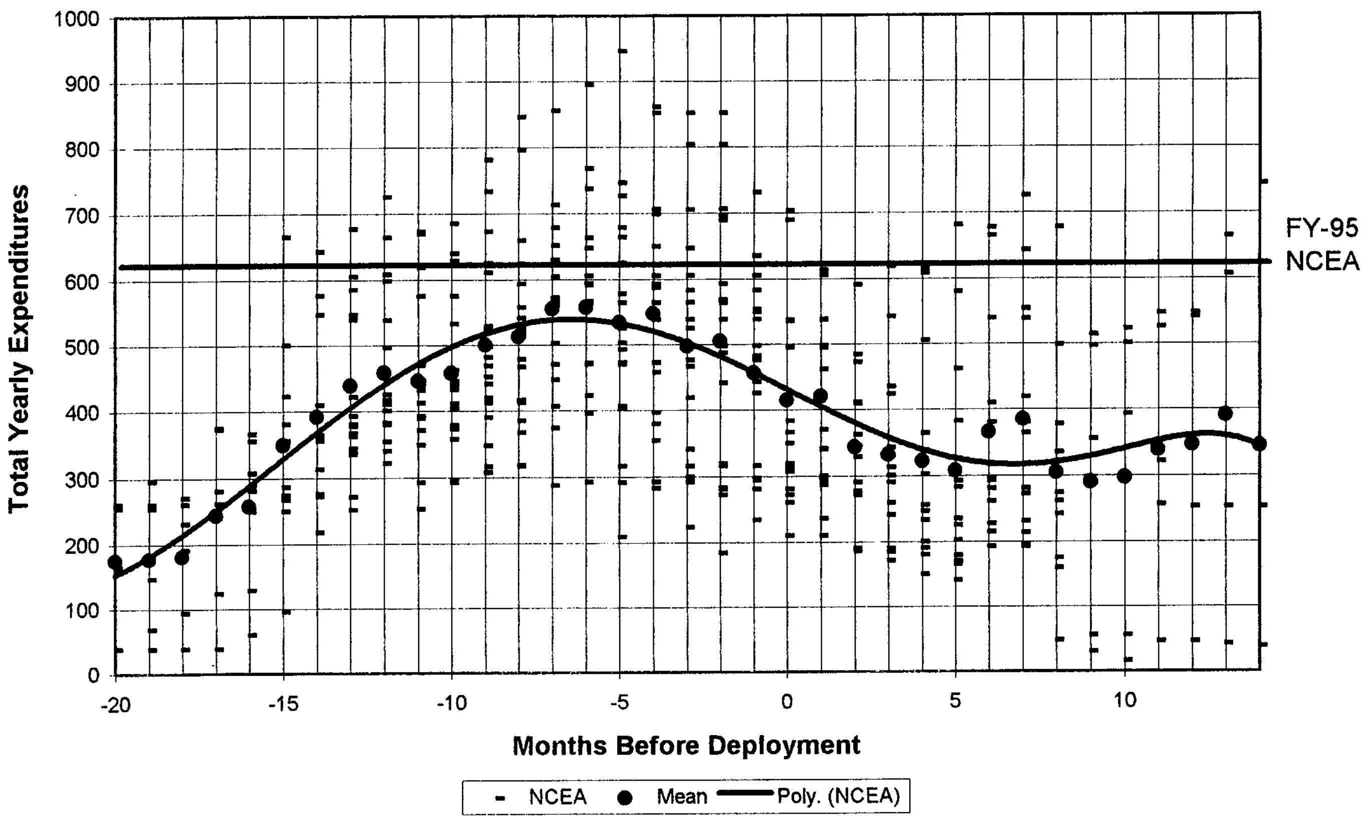
$$R^2 = 0.008453808$$



CG-47/DDG-993 NCEA FORECAST CURVE
Full Service Charges

$$y = -0.0000132100x^6 - 0.0005720230x^5 + 0.0011910392x^4 + 0.2418407132x^3 - 0.1149237379x^2 - 26.2992494038x + 431.7166100855$$

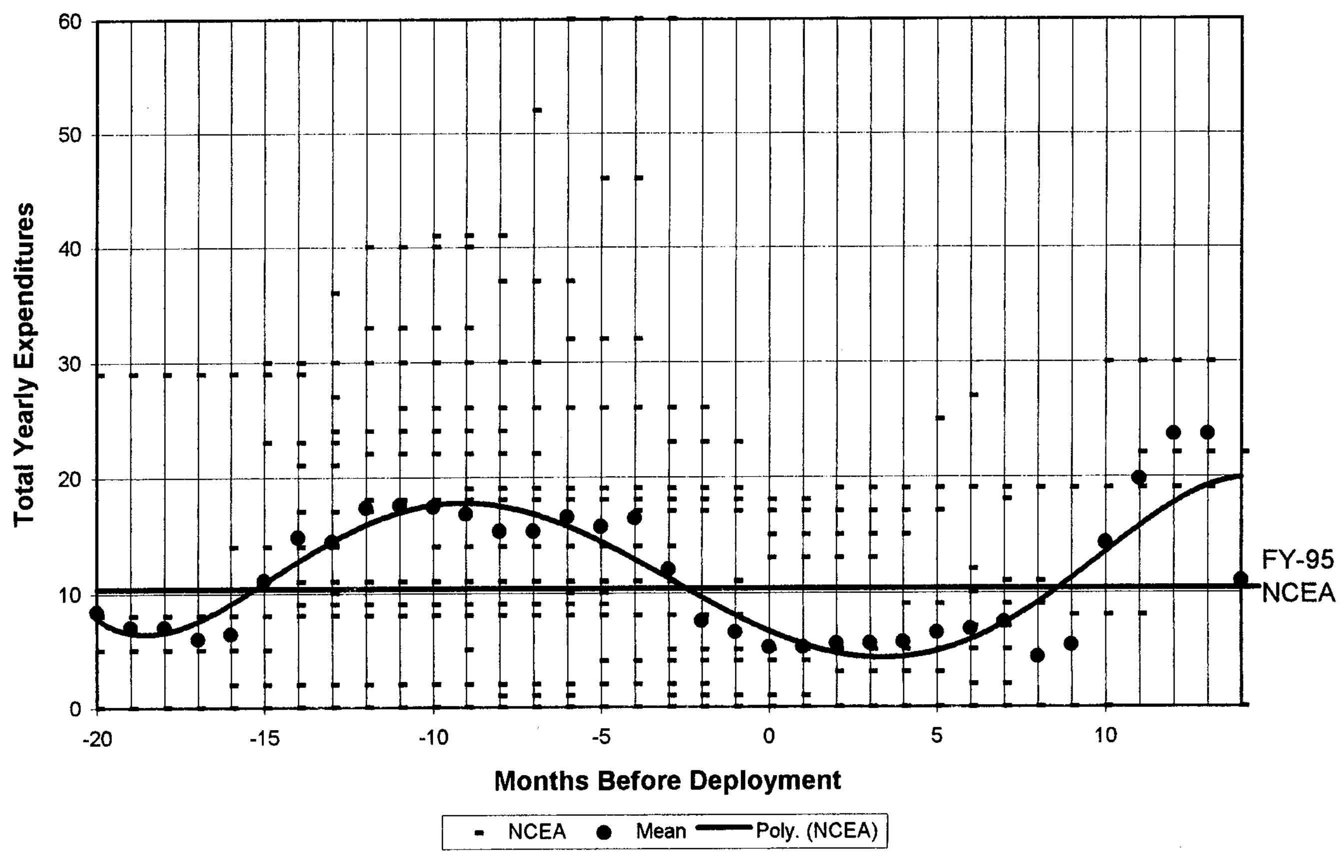
$$R^2 = 0.2781612001$$



CG-47/DDG-993 NCEA FORECAST CURVE
Reduced Charges

$$y = 0.0000000849x^6 - 0.0000306761x^5 - 0.0004366862x^4 + 0.0138518872x^3 + 0.1315078258x^2 - 1.2831036802x + 6.6587009785$$

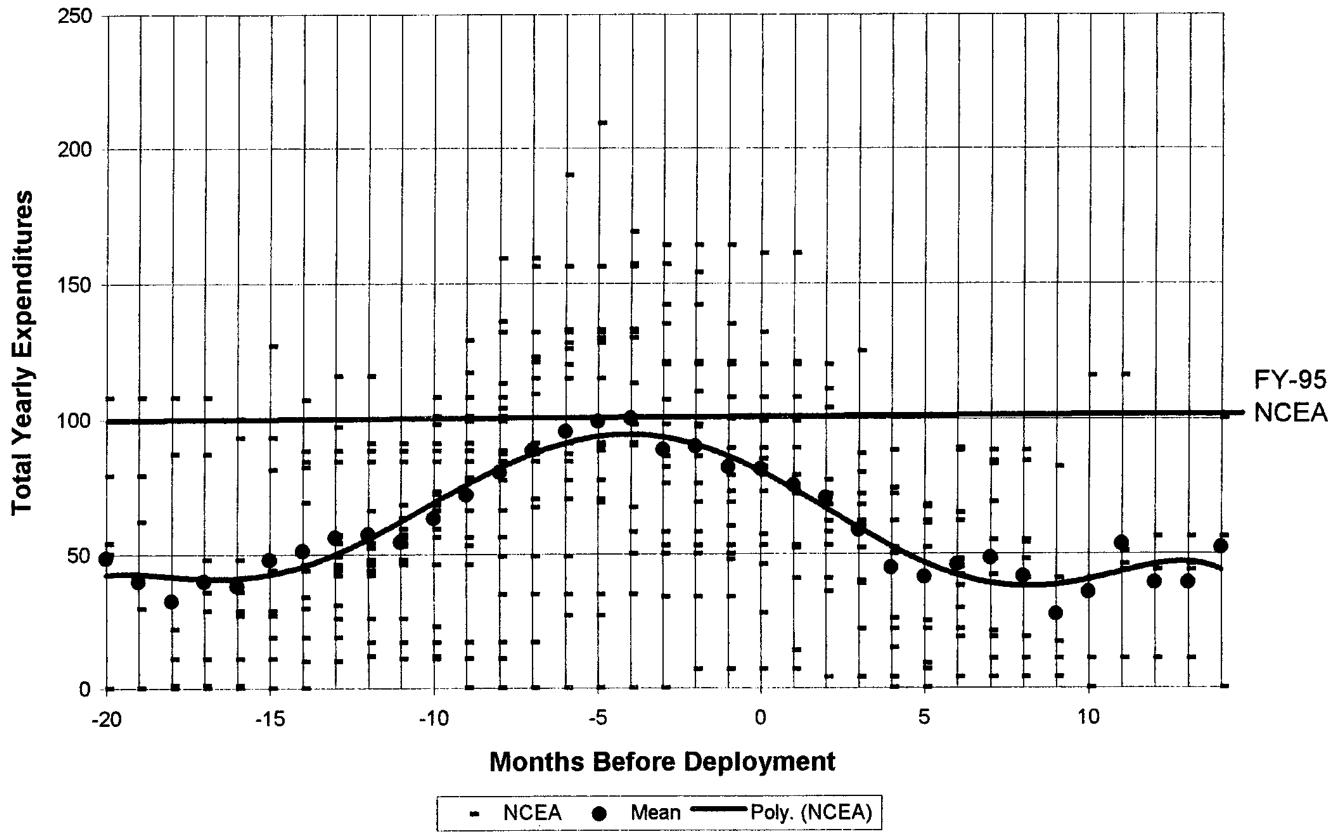
$$R^2 = 0.1491180391$$

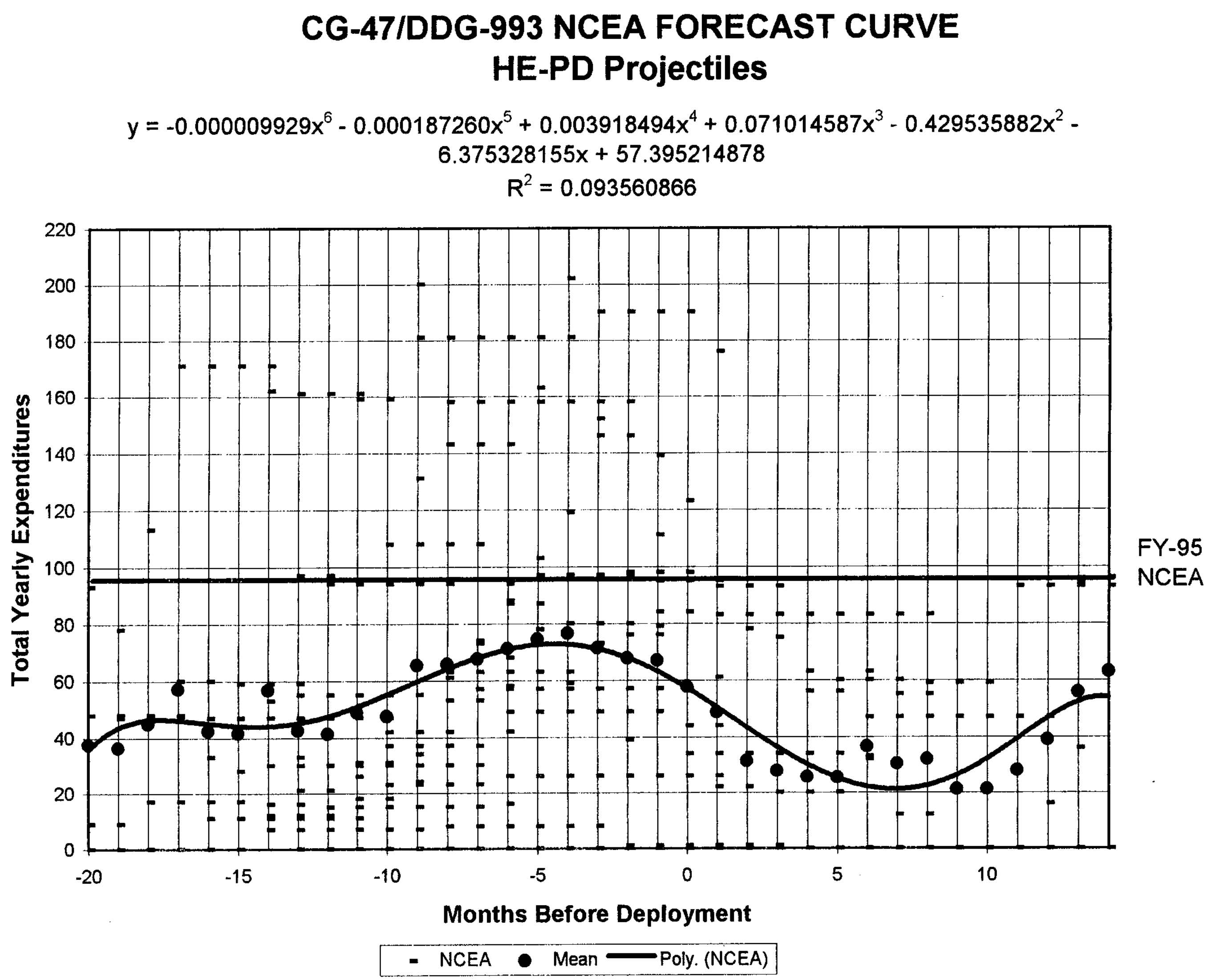


CG-47/DDG-993 NCEA FORECAST CURVE
HE-VT Projectiles

$$y = -0.000007474x^6 - 0.000171142x^5 + 0.003008452x^4 + 0.064789941x^3 - 0.485018588x^2 - 6.178830334x + 80.542296550$$

$$R^2 = 0.225072025$$

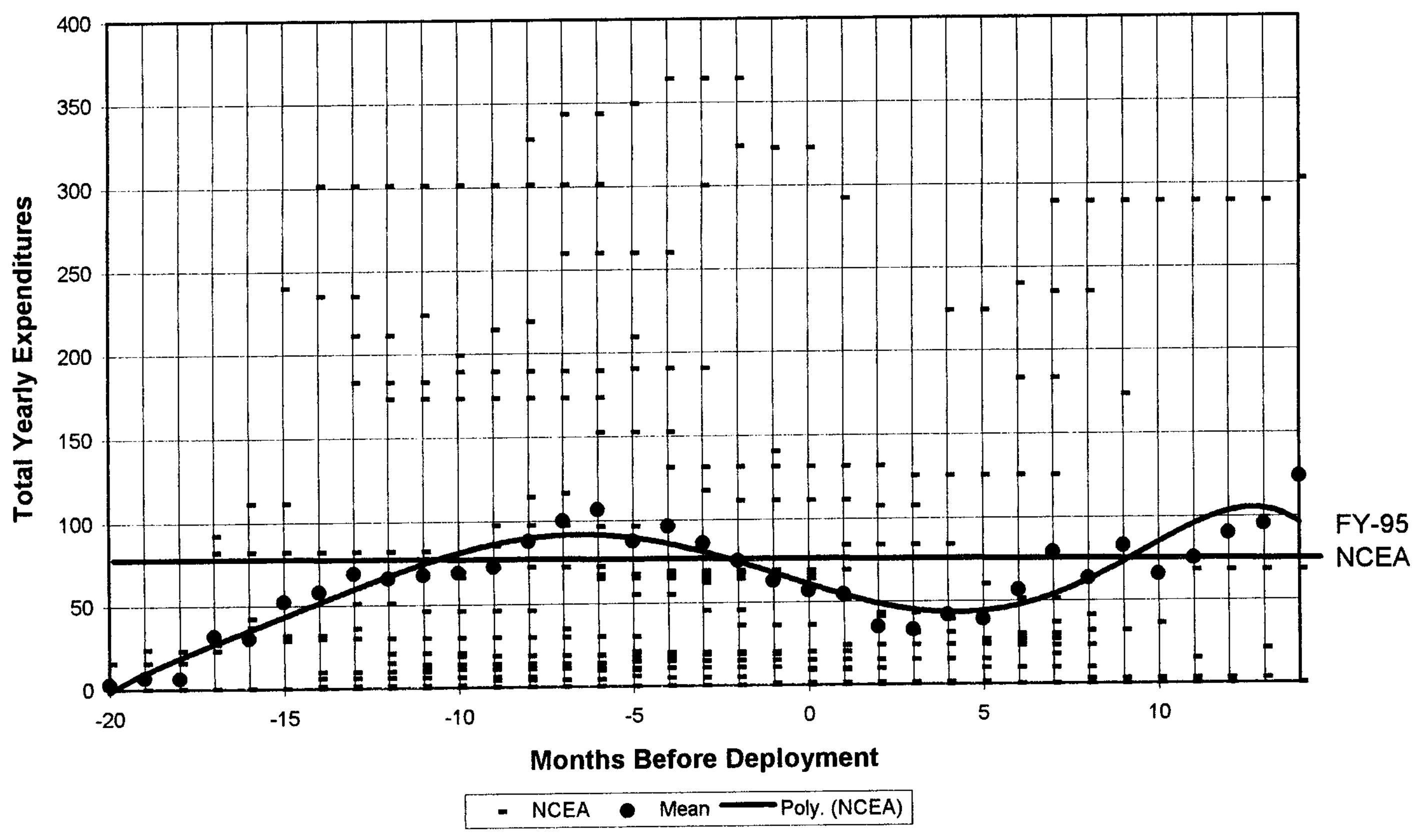



CG-47/DDG-993 NCEA FORECAST CURVE
HE-PD Projectiles
y = -0.000009929x^6 - 0.000187260x^5 + 0.003918494x^4 + 0.071014587x^3 - 0.429535882x^2 - 6.375328155x + 57.395214878
R^2 = 0.093560866
Total Yearly Expenditures
220
200
180
160
140
120
100
80
60
40
20
0
-20
-15
-10
-5
0
5
10
Months Before Deployment
FY-95
NCEA
NCEA
Mean
Poly. (NCEA)

CG-47/DDG-993 NCEA FORECAST CURVE
HE-CVT Projectiles

$y = -0.0000087427x^6 - 0.0002833498x^5 + 0.0009928940x^4 + 0.0984358203x^3 + 0.2063270831x^2 - 6.8212638638x + 61.0728350837$

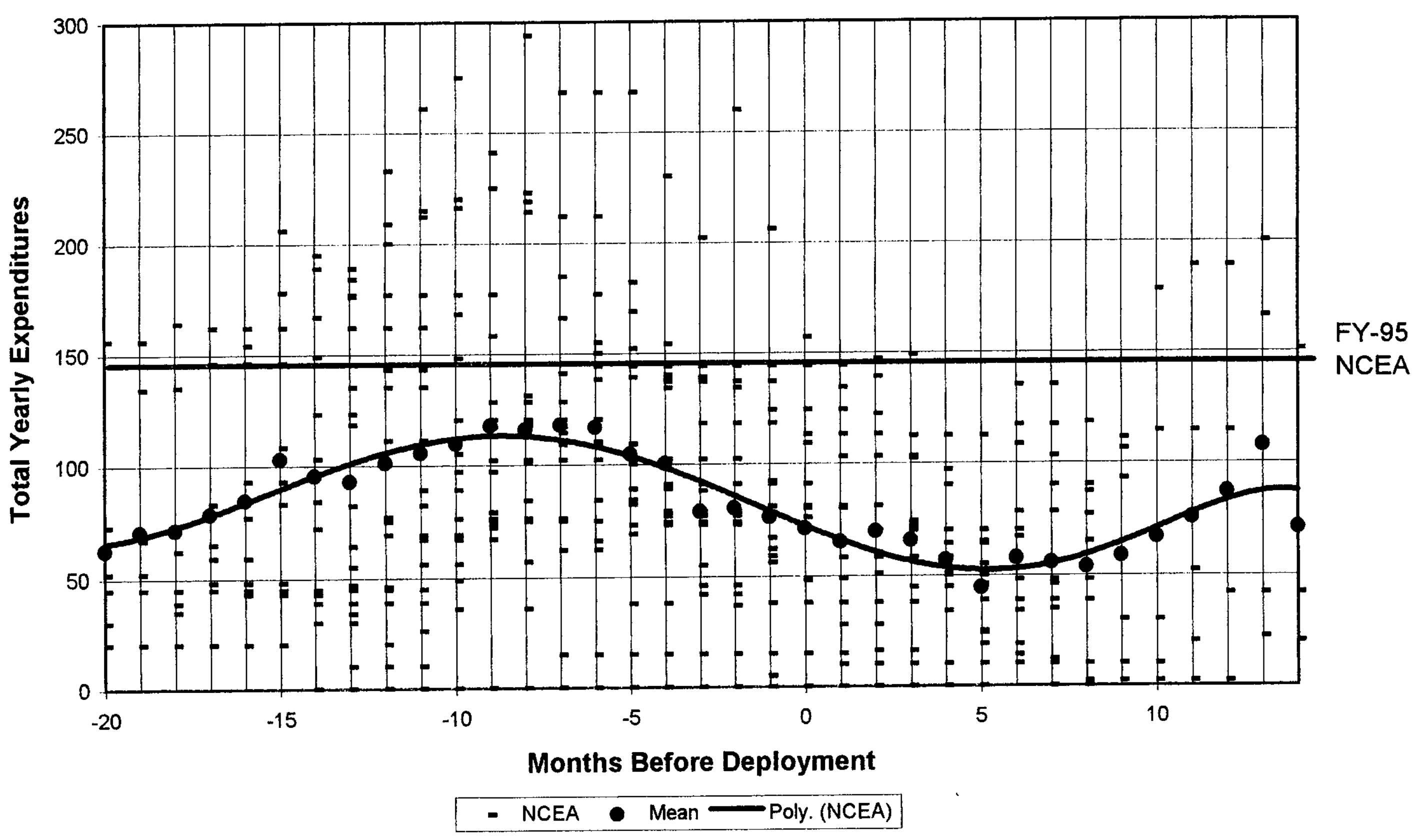
$R^2 = 0.0568347381$



CG-47/DDG-993 NCEA FORECAST CURVE
BL-P Projectiles

$$y = -0.0000026377x^6 - 0.0001356846x^5 - 0.0001868114x^4 + 0.0582733850x^3 + 0.2342517068x^2 - 6.5148740851x + 72.4302209655$$

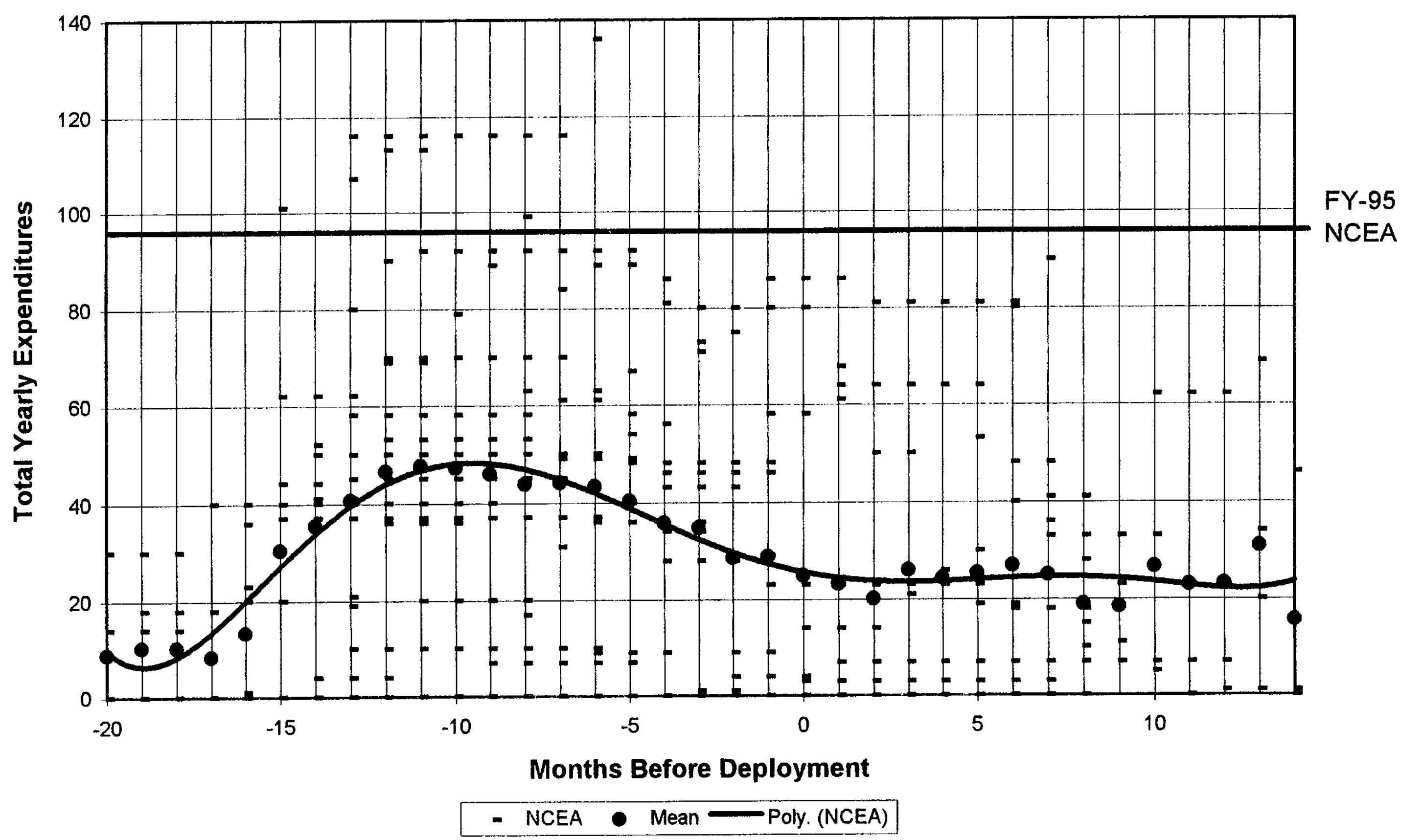
$$R^2 = 0.1125324112$$



CG-47/DDG-993 NCEA FORECAST CURVE
Puff-MT Projectiles

$$y = 0.0000048848x^6 + 0.0000321981x^5 - 0.0023399032x^4 - 0.0005709053x^3 + 0.2866650971x^2 - 1.4857585863x + 25.7023935177$$

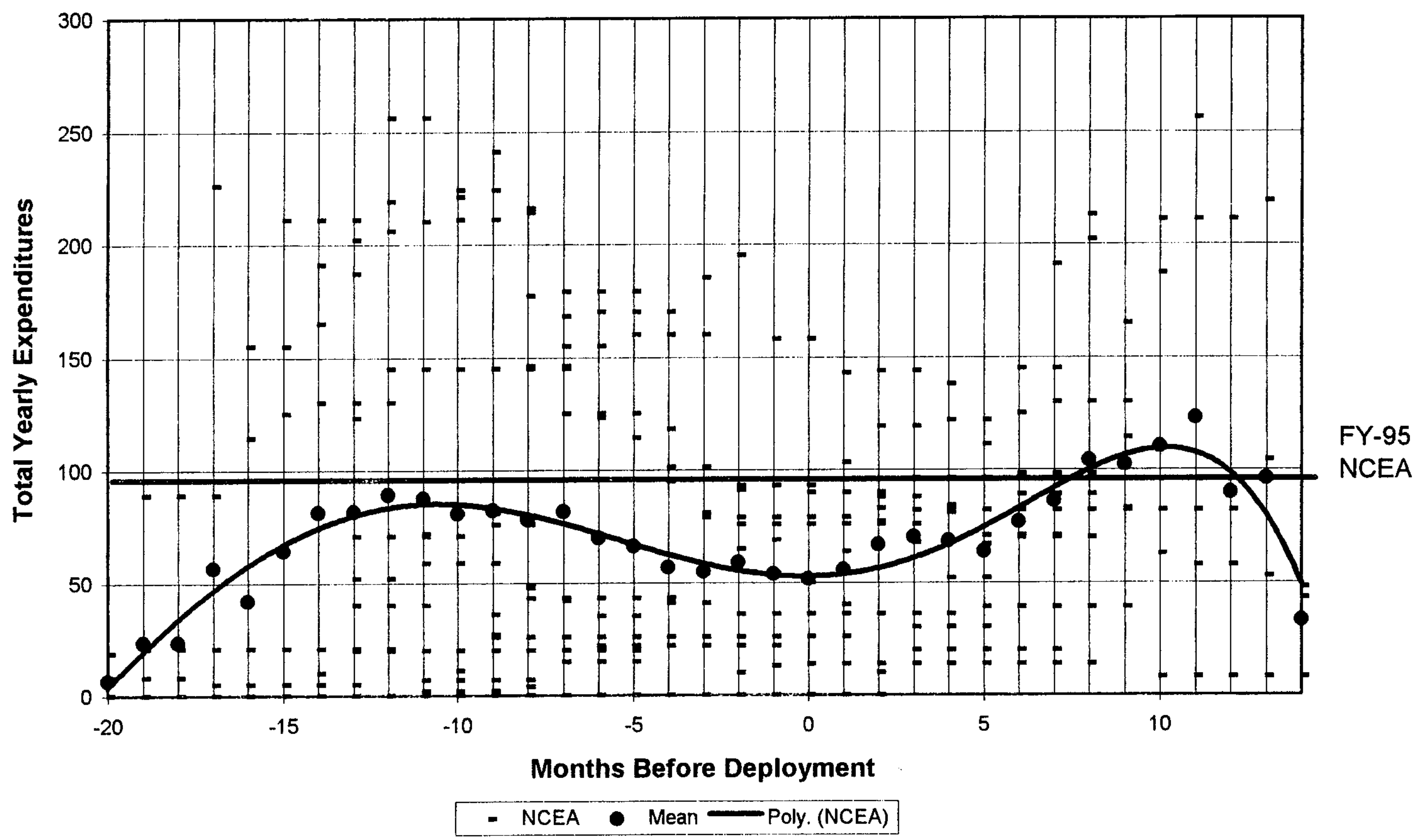
$$R^2 = 0.1087467723$$



CG-47/DDG-993 NCEA FORECAST CURVE
Puff-PD Projectiiles

$$y = -0.0000018226x^6 - 0.0001679227x^5 - 0.0035901449x^4 + 0.0275411687x^3 + 0.8199198906x^2 + 0.1429302288x + 52.9442494707$$

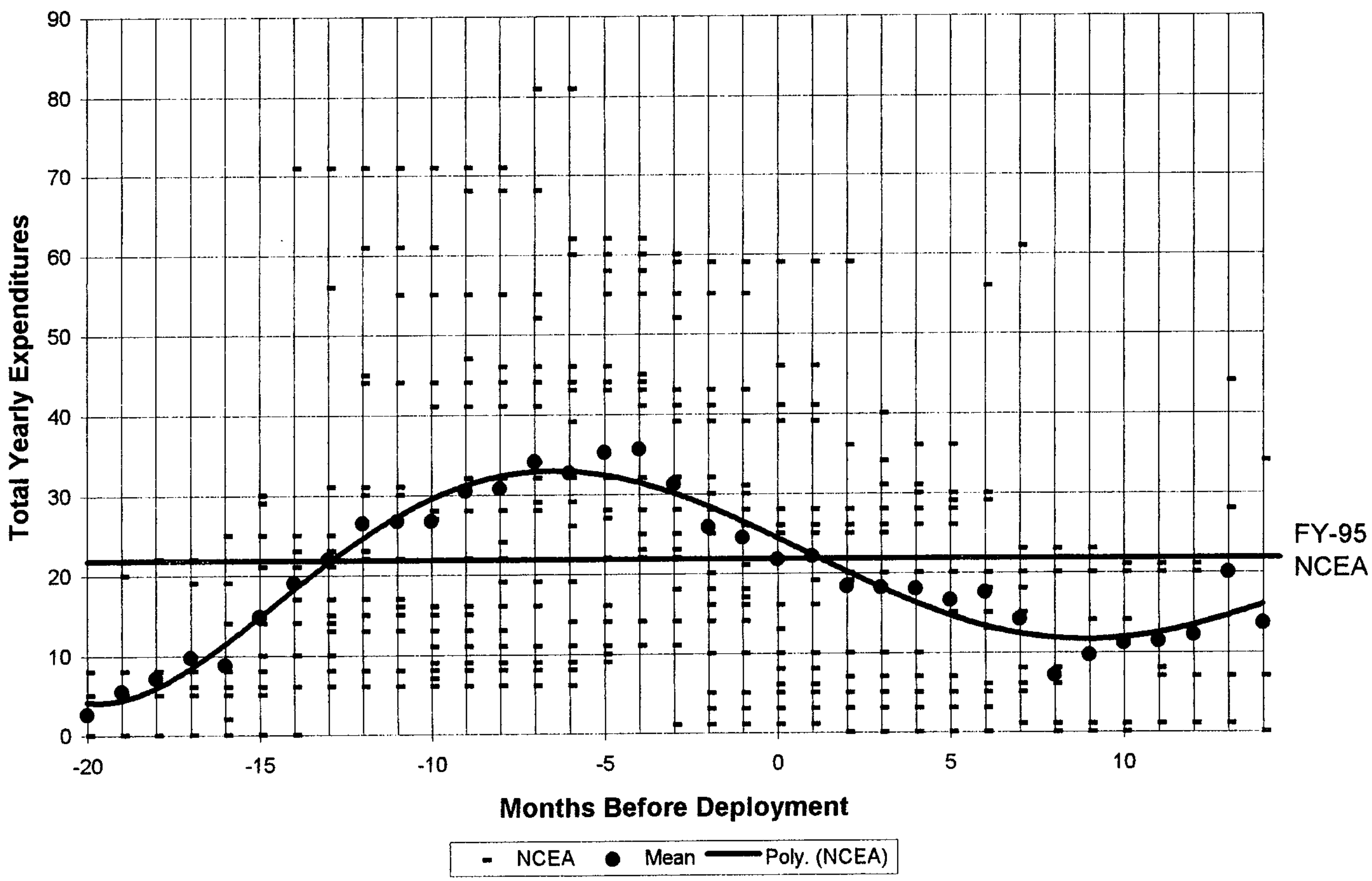
$$R^2 = 0.0752275427$$



CG-47/DDG-993 NCEA FORECAST CURVE
Illumination Projectiles

$$y = 0.000000063x^6 - 0.000020758x^5 - 0.000017005x^4 + 0.014469128x^3 - 0.036654098x^2 - 2.119092137x + 24.480803396$$

$$R^2 = 0.201943898$$



APPENDIX E. FORECAST CURVE STANDARD DEVIATIONS

		Early Training Phase (-20 to -13)	Work-up Training Phase (-12 to -1)	Deployment (0 to 5)	Post Deployment (6 to 14)
DD	FSC	162.4	137.1	130.5	171.0
	Reduced	11.1	10.6	7.8	8.7
	HE-VT	39.8	38.0	33.2	40.3
	HE-PD	60.3	53.6	29.9	50.5
	HE-CVT	46.6	28.9	43.2	40.0
	BL-P	47.6	81.6	39.8	49.6
	Puff-MT	47.6	41.3	44.5	38.4
	Puff-PD	44.2	42.2	52.8	53.8
	Illum.	54.1	10.7	8.8	12.6
CG	FSC	12.3	154.4	150.3	190.4
	Reduced	156.8	13.7	7.3	10.1
	HE-VT	36.6	43.0	37.0	30.2
	HE-PD	48.6	55.6	44.0	34.1
	HE-CVT	73.8	97.9	65.3	103.0
	BL-P	57.7	67.4	43.0	54.9
	Puff-MT	28.9	35.6	30.0	24.3
	Puff-PD	73.9	72.7	42.4	64.3
	Illum.	14.2	19.4	15.3	13.2

APPENDIX F. FY-95 NCER FORECAST WORKSHEET

Ship Name	Ship Type	Months to Deploy	FSC D326	Reduced D297	HE-VT D334	HE-PD D343	HE-CVT D346	BL-P D341	Puff-MT D291	Puff-PD D290	Illum D354
CUSHING	DD	-20	249	10	51	23	50	49	29	94	10
DAVID R. RAY	DD	0	322	9	82	40	33	54	44	59	14
ELLIOT	DD	-6	456	12	105	57	33	100	52	42	15
FIFE	DD	-10	452	13	84	45	36	109	51	40	14
FLETCHER	DD	9	297	9	45	32	30	62	42	69	13
HARRY W. HILL	DD	-9	461	13	92	48	35	110	51	39	15
HEWITT	DD	2	275	8	65	26	34	45	40	64	14
INGERSOLL	DD	-13	397	12	62	43	38	89	49	45	14
JOUNG YOUNG	DD	-19	266	11	49	44	46	38	37	83	11
KINKAID	DD	-1	349	9	90	46	32	61	46	56	15
LEFTWICH	DD	-20	249	10	51	23	50	49	29	94	10
MERRILL	DD	-7	463	13	102	55	34	105	52	41	15
O'BRIEN	DD	-20	249	10	51	23	50	49	29	94	10
OLDENDORF	DD	-13	397	12	62	43	38	89	49	45	14
PAUL F. FOSTER	DD	6	248	8	42	14	34	47	38	70	13
ANTIETAM	CG	8	320	9	38	23	64	59	25	100	12
BUNKER HILL	CG	-10	497	18	69	55	82	112	48	85	30
CHANCELLORSVILLE	CG	-6	539	16	91	71	92	108	42	72	33
CHOSIN	CG	-1	458	8	86	63	69	79	27	54	27
COWPENS	CG	4	340	4	53	30	44	54	24	67	16
LAKE CHAMPLAIN	CG	-3	503	11	93	71	82	92	33	59	30
LAKE ERIE	CG	-1	458	8	86	63	69	79	27	54	27
MOBILE BAY	CG	-10	497	18	69	55	82	112	48	85	30
PORT ROYAL	CG	-13	406	14	50	45	61	101	40	80	22
PRINCETON	CG	-6	539	16	91	71	92	108	42	72	33
SHILOH	CG	-19	181	7	43	44	11	69	6	19	4
VALLEY FORGE	CG	-2	482	10	90	68	76	86	30	56	28
VINCENNES	CG	4	340	4	53	30	44	54	24	67	16
CALLAGHAN	DDG	-13	406	14	50	45	61	101	40	80	22
CHANDLER	DDG	-11	471	17	62	51	76	109	47	85	27

	FSC D326	Reduced D297	HE-VT D334	HE-PD D343	HE-CVT D346	BL-P D341	Puff-MT D291	Puff-PD D290	Illum D354
1/2 Actual	**4047**	**85**	**440**	**590**	**1142**	**942**	**412**	**424**	**182**
2/3 Actual	**6015**	**130**	**668**	**1043**	**1373**	**1516**	**713**	**551**	**281**
Actual*	**8202**	**192**	**952**	**1385**	**1996**	**1972**	**897**	**816**	**375**
MODEL	**11567**	**333**	**2055**	**1348**	**1578**	**2379**	**1138**	**1970**	**552**
NCEA	**18540**	**300**	**3000**	**2880**	**2250**	**4320**	**2880**	**2880**	**630**

*Actual figure determined using linear regression on the first 8 months of the fiscal year.

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