

AD-A044 078

AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCHO--ETC F/G 15/5  
A COMPARATIVE ANALYSIS OF THE D041 SINGLE MOVING AVERAGE AND OT--ETC(U)  
JUN 77 J S BRANTLEY; D E LOREMAN  
AFIT-LSSR-7-77A

UNCLASSIFIED

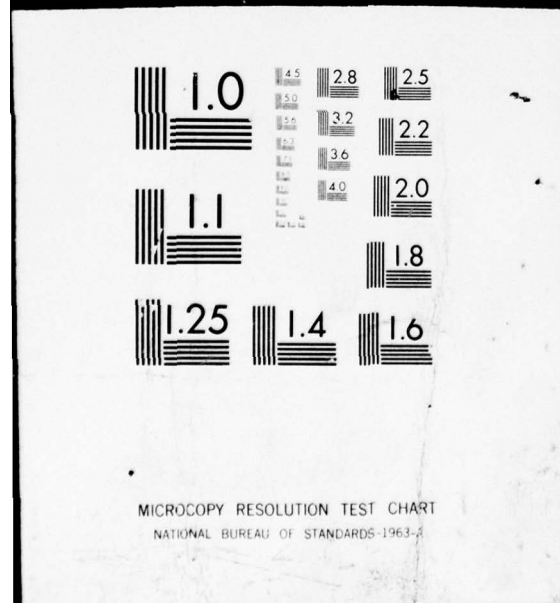
NL

1 OF 2  
AD  
A044 078



The table consists of 13 columns and 6 rows of microfilm frames. The first row contains a title page with a logo, followed by 12 frames of text. The second row contains 12 frames of text. The third row contains 12 frames of text. The fourth row contains 12 frames of text, with the last two frames showing bar charts. The fifth row contains 12 frames of text, with the last two frames showing bar charts. The sixth row contains 12 frames of text.

044 07



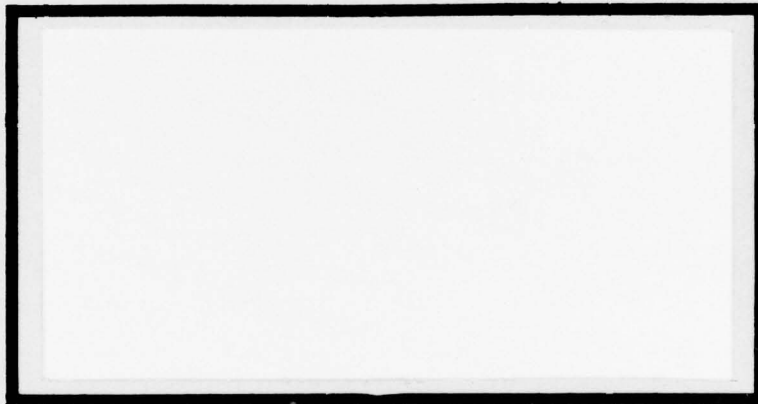
MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

AD A 044078

3



COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION



UNITED STATES AIR FORCE  
 AIR UNIVERSITY  
 AIR FORCE INSTITUTE OF TECHNOLOGY  
 Wright-Patterson Air Force Base, Ohio

AD No. \_\_\_\_\_  
 DDC FILE COPY

DISTRIBUTION STATEMENT A  
 Approved for public release;  
 Distribution Unlimited

DDC  
 RECEIVED  
 SEP 14 1977  
 RECEIVED  
 B

A COMPARATIVE ANALYSIS OF THE  
D041 SINGLE MOVING AVERAGE AND  
OTHER TIME SERIES ANALYSIS  
FORECASTING TECHNIQUES

Jim S. Brantley, Captain, USAF  
Donald E. Loreman, Captain, USAF

LSSR 7-77A

DDC  
RECEIVED  
SEP 14 1977  
RECEIVED  
B

DISTRIBUTION STATEMENT A  
Approved for public release;  
Distribution Unlimited

See 1473

The contents of the document are technically accurate, and no sensitive items, detrimental ideas, or deliterious information are contained therein. Furthermore, the views expressed in the document are those of the author and do not necessarily reflect the views of the School of Systems and Logistics, the Air University, the United States Air Force, or the Department of Defense.

## AFIT RESEARCH ASSESSMENT

The purpose of this questionnaire is to determine the potential for current and future applications of AFIT thesis research. Please return completed questionnaires to: AFIT/SLGR (Thesis Feedback), Wright-Patterson AFB, Ohio 45433.

1. Did this research contribute to a current Air Force project?

- a. Yes                      b. No

2. Do you believe this research topic is significant enough that it would have been researched (or contracted) by your organization or another agency if AFIT had not researched it?

- a. Yes                      b. No

3. The benefits of AFIT research can often be expressed by the equivalent value that your agency received by virtue of AFIT performing the research. Can you estimate what this research would have cost if it had been accomplished under contract or if it had been done in-house in terms of man-power and/or dollars?

a. Man-years \_\_\_\_\_ \$ \_\_\_\_\_ (Contract).

b. Man-years \_\_\_\_\_ \$ \_\_\_\_\_ (In-house).

4. Often it is not possible to attach equivalent dollar values to research, although the results of the research may, in fact, be important. Whether or not you were able to establish an equivalent value for this research (3 above), what is your estimate of its significance?

- a. Highly Significant      b. Significant      c. Slightly Significant      d. Of No Significance

5. Comments:

\_\_\_\_\_  
Name and Grade

\_\_\_\_\_  
Position

\_\_\_\_\_  
Organization

\_\_\_\_\_  
Location

OFFICIAL BUSINESS  
PENALTY FOR PRIVATE USE, \$300

AFIT/LSGR (Lt Col Barndt)  
Wright-Patterson AFB, OH 45433

AU FORM 6  
JUL 74 6

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

14

AFIT REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: LSSR-7-77A; 2. GOVT ACCESSION NO.; 3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): A COMPARATIVE ANALYSIS OF THE D041 SINGLE MOVING AVERAGE AND OTHER TIME SERIES ANALYSIS FORECASTING TECHNIQUES; 5. TYPE OF REPORT & PERIOD COVERED: Master's Thesis; 5. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): Jim S./ Brantley, Captain, USAF; Donald E./ Loreman, Captain, USAF; 8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS: Graduate Education Division, School of Systems and Logistics, Air Force Institute of Technology, WPAFB, OH; 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS: Department of Research and Administrative Management (LSGR), AFIT/LSGR, WPAFB, OH 45433; 12. REPORT DATE: June 1977; 13. NUMBER OF PAGES: 99; 15. SECURITY CLASS. (of this report): UNCLASSIFIED

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office); 15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES: APPROVED FOR PUBLIC RELEASE AFR 190-17. JERRAL F. GUESS, CAPT, USAF, Director of Information

19. KEY WORDS (Continue on reverse side if necessary and identify by block number): FORECASTING, TIME SERIES ANALYSIS, EXPONENTIAL SMOOTHING, REPARABLE GENERATIONS, D041 SYSTEM

20. ABSTRACT (Continue on reverse side if necessary and identify by block number): Thesis Chairman: John M. Pearson, Major, USAF

This thesis examines the forecasting technique used in the Air Force Logistics Command D041 reparable asset management system. The process of retrieving usable data from the D041 Data Bank is described in some detail, including computer problems and potential pitfalls. It was hypothesized that the mean of the absolute values of the D041 forecast error was equal to zero. This hypothesis could not be rejected, but the results are questionable because, after the fact forecasts were used. It was further hypothesized that another time series forecasting technique (exponential smoothing) would also yield an error distribution with a mean of zero. This hypothesis could not be rejected; however, the variances for the exponential smoothing forecast error distributions were less than the D041 forecast error distributions for all four lead times examined (one, two, three and four quarters).

ACCESSION for

NTIS  Write Section  
DDC  Buff Section  
UNANNOUNCED   
JUSTIFICATION \_\_\_\_\_

BY \_\_\_\_\_  
DISTRIBUTION/AVAILABILITY CODES  
Dist. \_\_\_\_\_ or SP.COM

A 23

D42

LSSR 7-77A

A COMPARATIVE ANALYSIS OF THE D041 SINGLE MOVING AVERAGE  
AND OTHER TIME SERIES ANALYSIS FORECASTING TECHNIQUES

A Thesis

Presented to the Faculty of the School of Systems and Logistics  
of the Air Force Institute of Technology  
Air University

In Partial Fulfillment of the Requirements for the  
Degree of Master of Science in Logistics Management

By

Jim S. Brantley, BS  
Captain, USAF

Donald E. Loreman, BA  
Captain, USAF

June 1977

Approved for public release;  
distribution unlimited

This thesis, written by

Captain Jim S. Brantley

and

Captain Donald E. Loreman

has been accepted by the undersigned on behalf of the  
faculty of the School of Systems and Logistics in partial  
fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

DATE: 15 June 1977

  
COMMITTEE CHAIRMAN

#### ACKNOWLEDGEMENT

The authors wish to express appreciation to Major J. M. Pearson for his able assistance as our Faculty Advisor and to the staff and faculty, School of Systems and Logistics, Air Force Institute of Technology, for their help in this research effort. An additional note of recognition is due Phyllis Reynolds for her professionalism in typing this thesis.

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS . . . . .	iii
LIST OF TABLES . . . . .	vi
LIST OF FIGURES . . . . .	vii
Chapter	
I. INTRODUCTION . . . . .	1
Background . . . . .	1
Statement of the Problem . . . . .	2
AFLC Forecasting System . . . . .	3
Research Justification . . . . .	4
Areas of Investigation . . . . .	12
Research Question . . . . .	13
Research Hypotheses . . . . .	13
II. RESEARCH METHODOLOGY . . . . .	14
Population of Interest . . . . .	14
Definition of Variables . . . . .	15
Data Requirements . . . . .	16
Data Collection . . . . .	16
Research Approach . . . . .	18
Testing the First Research Hypothesis . . . . .	18
Testing the Second Research Hypothesis . . . . .	22
List of Assumptions . . . . .	23
List of Limitations . . . . .	23

Chapter	Page
III. FINDINGS AND ANALYSIS . . . . .	24
The D041 Forecasting Method . . . . .	24
The TCAST Forecasting Method . . . . .	24
Comparison of the Two Forecasting Methods . .	25
IV. CONCLUSIONS AND RECOMMENDATIONS . . . . .	28
Conclusions . . . . .	28
Recommendations . . . . .	29
APPENDICES . . . . .	30
A. D041 DATA BANK DATA RETRIEVAL . . . . .	31
B. TIME SERIES FORECASTING DATA PREPARATION . . .	53
C. STATISTICS COMPUTATION . . . . .	64
D. RESULTS OF THE STATISTICAL HYPOTHESIS TESTS . .	90
SELECTED BIBLIOGRAPHY . . . . .	95
A. REFERENCES CITED . . . . .	96
B. RELATED SOURCES . . . . .	97

LIST OF TABLES

Table	Page
2.1 Significant Variables . . . . .	17
2.2 Example Determination of Forecast Errors for $\tau=1$ and $\tau=2$ . . . . .	21
3.1 Characteristics of TCAST Forecasts . . . . .	26
A.1 D041 Data . . . . .	51
A.2 Data After Preparation . . . . .	52
A.3 Computed D041 Forecast Error . . . . .	54
B.1 TCAST Data for Lead Time One . . . . .	60
B.2 TCAST Data for Lead Time Two . . . . .	61
B.3 TCAST Data for Lead Time Three . . . . .	62
B.4 TCAST Data for Lead Time Four . . . . .	63
D.1 D041 Hypothesis Test Results . . . . .	92
D.2 TCAST Hypothesis Test Results . . . . .	93
D.3 Forecasting Method Comparison Hypothesis Test Results . . . . .	94

LIST OF FIGURES

Figure	Page
A.1 FSN/MSN Conversion Program . . . . .	38
A.2 FSN Selection Program . . . . .	40
A.3 OFM Demand Data Retrieval Program . . . . .	42
A.4 Past Program/Reparable Generation Data Retrieval Program . . . . .	45
A.5 Data Preparation Program . . . . .	48
A.6 D041 Forecast Error Computation Program . . . . .	53
C.1 Statistics Computations for D041 Forecasts in Lead Time One . . . . .	66
C.2 Statistics Computations for D041 Forecasts in Lead Time Two . . . . .	67
C.3 Statistics Computations for D041 Forecasts in Lead Time Three . . . . .	68
C.4 Statistics Computations for D041 Forecasts in Lead Time Four . . . . .	69
C.5 Statistics Computations for TCAST Forecasts in Lead Time One . . . . .	70
C.6 Statistics Computations for TCAST Forecasts in Lead Time Two . . . . .	71
C.7 Statistics Computations for TCAST Forecasts in Lead Time Three . . . . .	72
C.8 Statistics Computations for TCAST Forecasts in Lead Time Four . . . . .	73
C.9 D041 Error Distribution for Lead Time 1 . . . . .	74
C.10 D041 Error Distribution for Lead Time 2 . . . . .	75
C.11 D041 Error Distribution for Lead Time 3 . . . . .	76

Figure	Page
C.12 D041 Error Distribution for Lead Time 4 . . . .	77
C.13 TCAST Error Distribution for Lead Time 1 . . . .	78
C.14 TCAST Error Distribution for Lead Time 2 . . . .	79
C.15 TCAST Error Distribution for Lead Time 3 . . . .	80
C.16 TCAST Error Distribution for Lead Time 4 . . . .	81
C.17 D041 Error Over Time for Lead Time 1 . . . . .	82
C.18 D041 Error Over Time for Lead Time 2 . . . . .	83
C.19 D041 Error Over Time for Lead Time 3 . . . . .	84
C.20 D041 Error Over Time for Lead Time 4 . . . . .	85
C.21 TCAST Error Over Time for Lead Time 1 . . . . .	86
C.22 TCAST Error Over Time for Lead Time 2 . . . . .	87
C.23 TCAST Error Over Time for Lead Time 3 . . . . .	88
C.24 TCAST Error Over Time for Lead Time 4 . . . . .	89

## CHAPTER I

### INTRODUCTION

#### Background

During the past fifteen years, much outside pressure--Congressional and taxpayer--has been placed on the Department of Defense to improve the management of its materiel acquisition system as well as other resource expenditure programs. This pressure, combined with the aggressiveness of individuals involved in the materiel systems, has generated many innovative techniques to improve the support of our weapons systems (1:22-23). As a result, the focus has been on obtaining the maximum national defense for minimum dollar expenditure; a goal to be achieved through the effective use of national resources.

The management of the Air Force portion of these national responses is the responsibility of the Air Force Logistics Command (AFLC), which ". . . must maintain the ability to replenish base stock levels through a constant flow of recoverable materiel to and from our global deployed Air Force units [12:2-2]." The materiel support system required to accomplish this mission involves the management of 1.8 million line items worth approximately 9 billion dollars (7:34).

### Statement of the Problem

Forecasting for and acquiring spare parts is an important facet of the materiel support system. Forecasts are used to develop dependable systems and to formulate decisions concerning the technical and economic feasibility of retaining a system in use (4:15-16). The economics of spiraling prices and austere budgets make reliable estimates, or forecasts, especially critical. The exponential acceleration of spares cost provides sufficient justification for basing requirements computations upon the best available forecasting methodology (1:22). As new data sources become available, as improvements are made in forecasting techniques, as added insight of needs is received, and as other uses for planning factors are considered, current forecasting methods require modification or complete change. Forecasting is an evolutionary, dynamic process, and the method which served well yesterday may not continue to be the best method for use today (8:351-358). Operating systems managers in Headquarters AFLC suspect that the forecasting technique incorporated in the AFLC materiel support system is biased, i.e., the expected value of the forecast error is not zero. The problems analyzed in this research are to determine the bias of the current AFLC forecasting technique and to compare this bias to that of other selected forecasting methods.

### AFLC Forecasting System

The Air Force Logistics Command manages spares according to the provisions of the Recoverable Consumption Item Requirements System (D041), a computer based inventory control system (12:1-1). In this context, spares are defined as recoverable items coded with an Expendability-Recoverability-Reparability-Code (ERRC) of XD, which indicates that the spare is reparable at the base or depot level when necessary. Spares constantly move through a cycle of transactions from the supply activity's warehouse, to installation on an end item, to removal from a higher assembly after failure, through a repair facility, and then back to the supply activity ready for reissue once again. Spares stockage, after initial procurement with the weapon system, is based primarily on past demands or reparable generations. Information concerning these reparable generations at both base and depot level is accumulated and consolidated through the Air Force Recoverable Asset Management System. This data is input to the D041 System to provide the data base which is used to produce the forecasts. These forecast computations are made monthly, for quarterly periods. The initial quarter identifies specific items requiring buy, repair, termination and disposal actions (12:1-1). The second quarterly computation (FY-2) is used for adjusting previously initiated item actions, updating workload projections for annual negotiation, buy

actions in process, termination and disposal (12:1-1). The third quarterly computation (FY-3) is used to develop budget requests and update logistic actions in process (12:1-2). The fourth quarterly computation (FY-4) is used to update logistics actions in process, initiate new actions, and provide data input into other systems (12:1-2).

Forecasts are made in the form of a reparable generation rate, which provides a basis for the requirements computation performed by the item managers. The computations combine the forecast with other asset availability data to determine actual requirements. These requirements are further modified by subjective external factors called additives (5).

The intricacy and subjectivity of the requirements computation procedures are beyond the scope of the proposed research effort. This research focused only upon the statistical model incorporated in the D041 System used to forecast reparable generations. Consequently, the only variables considered were the data points, or actual reparable generations and the resulting forecasts.

#### Research Justification

A number of sophisticated statistical forecasting techniques are available, but time series analysis seems to be the most promising for forecasting demand data. Time

series analysis is based upon the concept that a sequence of observations composing a time series is one realization of jointly distributed random variables. The past history of the time series is thus used to provide information about the mechanism which describes its evolution through time, and the mechanism derived is used to forecast the future (1:18-19).

The procedural forecasting instructions outlined in current Air Force directives are descriptive translations of the basic mathematical forecasting models used to predict future requirements. Little management attention is given to the forecasting technique unless significant disparities exist between forecasts and reparable generations. The tendency, even then, is to modify the forecasts rather than to question the validity of the technique generating the forecasts (6). The effectiveness of the AFLC spares support system depends upon the accuracy of forecasts; therefore, it is imperative that the most accurate forecasting techniques available be used. The system currently in use (D041) depends primarily on one of the simplest statistical techniques available--the weighted moving average, specifically a twenty-four month moving average (12). Its effectiveness must be determined and compared to that of other forecasting techniques if the Air Force is to operate an efficient logistics system.

The moving average technique smooths fluctuations in time series and is applied to trend lines as well as seasonal and cyclical variations. Smoothing takes place by fitting a straight line to successive groups of  $n$  years by the method of least squares (13:337). However, when  $n$  is 24 months, a straight line may not adequately fit. A parabola may perhaps be the best fit in the least-squares sense (13:861). The moving average technique also assumes that successive observations are statistically independent, i.e., assuming this year's reparable generations are independent of last year's generations, but usually this is not true (13:865). This technique assumes that the data are stationary (data mean and variance do not change over time) and that the data are not autocorrelated (independent of previous time periods). The moving average technique is simple, and easy to use because of its straightforward calculations. In formula form, the predicted value of reparable generations,  $\hat{g}_t$ , for period  $t$  (made in period  $t-1$ ) is  $g_{t-1}$  such that the average for time  $t+1$  is:

$$\hat{g}_{t+1} = g_{t-1} + \frac{1}{n} (g_t - g_{t-n}) \quad (\text{Equation 1})$$

where:

$\hat{g}_{t+1}$  is the forecast reparable generations for period  $t+1$ ,

$n$  is the number of periods,  
 $t$  is the time period,  
 $g_t$  is the actual reparable generation in period  
 $t$ , and  
 $g_{t-n}$  is the actual reparable generations in period  
 $t-n$ .

The error associated with this forecast is the difference between the forecast value and the actual demand value. With the simple moving average forecasting technique the forecast error is small, but its standard deviation is greater than the standard deviation of the actual data (11:4). The moving average technique merely smoothes out the fluctuations in the data by "moving" the arithmetic mean value through the time series (10:234). This technique reacts slowly to sudden changes in the data and is ineffective if the data is erratic. If a step change in demand occurs, the moving average takes  $n$  periods (the moving average base) to level off at the new demand (11:5). However, in the case of continuously increasing demand, estimated demand responds slowly and always underestimates actual demand. When this occurs, the forecast becomes more biased (11:4); that is, the absolute value of the expected value of the error increases. The forecast lags behind the trend in demand, and the amount of lag depends on the number of periods in the forecast. Alterations are then required to offset the bias in the moving

average forecast causing yet another problem. The "corrected" level often overshoots the actual demand and does not return to the mean. The moving average technique is not easily adapted to adjust for forecasting over long periods, nor does it allow for averaging over arbitrarily varying time periods (11:6).

Application of the moving average technique to time series data requires data with a characteristically linear function and a definite rhythmic pattern of fluctuation which repeats periodically (10:234).

In summary, the moving average is simple to compute and has merit if the basic assumptions have been met, but it has a serious disadvantage in that it responds slowly to changes in the demand pattern (11:6). Data at the beginning of a series are lost. Moving averages may generate cycles or other movements which are not present in the original data. Moving averages are affected by extreme values (11:6). A method of averaging that allows for an easy change of the series length and overcomes the effects of extreme values should be used. Further support for discontinuing the use of the simple moving average was found in the Predictive Techniques Study, Phase I: "Comparison of Some Forecast Methods" done by M. D. Lum, L. L. Blair and J. R. Stuart. They used generated data and concluded that the 24 month single item moving average for items with long-term exponential or linear trend was the worst of all

methods tested, and that double exponential smoothing with specified constants using Brown's tracking signal (an out-of-control signal that indicated the difference between the forecast and new datum has become significantly larger than one would expect by chance) ranked best for the items with exponential trends. The study also recommended that efforts be made to investigate applications of other techniques, and that real data be used in the future studies. A more reliable method for forecasting appears to be necessary and a search for this method has led statisticians to the exponential smoothing technique (9:iii-v).

Exponential smoothing uses the fundamental idea that any new estimate of demand is related to the previous estimate corrected for new information. Like the simple moving average, exponential smoothing also assumes stationarity and independence. The estimating equation is:

$$\text{New Estimate} = \theta(\text{New Demand}) + (1-\theta)(\text{Old Estimate})$$

(Equation 2)

where  $0 < \theta < 1$  is the smoothing constant. Small values of the smoothing constant ( $\theta$ ) can be used to place heavier emphasis on demands from the distant past and little weight on more recent demands. Conversely, larger values of  $\theta$  can be used so that the distant past has little effect on the forecast (11:7). By varying  $\theta$ , the item's demand history can be increased or decreased in importance

for making forecasts, and the method can be repeated using as many different thetas as desired. Overall, when the smoothing constant is small, the function behaves like the average of a large amount of past data, and therefore the variance of the estimate is small. When the smoothing constant is large the function will respond rapidly to changes in the pattern. The advantages of exponential smoothing are simplicity, ease of calculations, minimal data requirements once the forecasting method has been developed, simple control procedures for the forecasts; and the straightforward manner in which data enter the forecast (11:8). Therefore, if forecasting is performed several times, over many items, exponential smoothing can be routinely accomplished. For unexpected sudden changes in the demand pattern, the estimator is unbiased in the long run; but for steadily increasing demands the estimator is biased because the forecast lags behind the demand (11:9).

Double exponential smoothing is similar to single exponential smoothing and the conclusions can be extended to any order of smoothing. The single smoothed value of the data will increase to the value of theta in response to the data input, while the response of the double smoothed value is theta squared ( $\theta^2$ ). The order of smoothing is based on the choice of the degree of the polynomial

model that is to represent the data and the subsequent selection of a smoothing constant for the respective order.

This smoothing constant controls the number of past observations that have any effect on the forecast. Flexibility of changing the constant should be considered to obtain stable forecasts from stable processes and forecasts that respond rapidly when the value of any coefficient appears to have changed greatly (11:9). Two values should be selected for the smoothing constant: one for stable conditions and a higher value for conditions of rapid change. A small value includes many observations; but for larger values, only recent data are included. With the higher order models, more coefficients must be estimated. Since more coefficients are needed, the number of past observations should also be increased to insure better coefficient estimators by using as many data points as necessary to satisfy the degrees of freedom requirement for the model.

The moving average method does not attempt to assess rate-of-change in the data points as a function of time. In other words, the technique only estimates the current level of a factor without regard for whether that factor is increasing or decreasing, making no attempts to adjust for trends. The forecasts with the moving average are always the same, regardless of the forecast lead time (number of time periods into the future for which the

current forecast is being made). Thus the moving average forecasts straight ahead. In contrast, the exponential smoothing method estimates both the current level of a factor and the current linear rate-of-change for the same order. Forecasts made are a linear function of the forecast lead time using these estimates. Exponential smoothing attempts to account for and to follow trends, and it can follow the direction of these trends by forecasting upwards, downwards or straight ahead (9:9-10).

Headquarters AFLC suggests that the double exponential smoothing method should be analyzed for possible AFLC use (5) and that the present D041 prediction method should also be compared against other more currently developed predictive techniques (6).

This thesis continues the research conducted by Captain Bruce R. Christensen and Mr. Gene J. Schroeder, who used simulated models (2:Ch.1) to conclude that the expected value of the distribution of forecast errors presently found in the D041 System was not zero (3:Ch.1-3). Their recommendation was to incorporate actual D041 data into the investigation of the bias produced by the single moving average forecast and other techniques such as time series analysis (3:37).

#### Areas of Investigation

There are two areas of investigation that provide the objectives for the proposed research:

1. To determine if the D041 System forecasts are biased.

2. To calculate, review and compare the forecast error of time series analysis methods to that of the D041 System to determine which of the techniques is the best, in terms of minimum error, to forecast failures of spare parts.

#### Research Question

What forecasting technique should the D041 inventory management system use to provide the most accurate forecasts?

#### Research Hypotheses

1. The use of the weighted moving average technique leads to biased forecasts in the AFLC material support system.

2. The use of the time series analysis technique leads to forecasts with significantly less bias than that of the D041 System.

## CHAPTER II

### RESEARCH METHODOLOGY

#### Population of Interest

This research focused upon the characteristics of the D041 forecasting technique, the technique currently used to create quarterly forecasts for 125,000 recoverable items in the Air Force inventory. Of these 125,000 items, approximately 45,000 items are forecast subjectively by the responsible item manager, rather than by the D041 System based on past demands (5). These items are excluded from consideration since they do not typify the statistical technique used in the D041. The population was further limited to the nine Federal Stock Classes listed below:

1560	Aircraft Structural
1615	Helicopter Components
1630	Wheel and Brake Components
2915	Engine Components
5841	Airborne Radar
5865	Electronic Countermeasure
5905	Resistors
5910	Capacitors
6615	Airborne Gyros

The selection of these classes was based upon the past history of inaccurate forecasts and consequential problems as recommended by Ms. Anita Clevenger of AFLC (5). Class 1560, Aircraft Structural, was specifically selected because of its stable demand pattern. The population was further limited by the requirement for eight years data necessary to examine the performance of the techniques over an adequate time period.

#### Definition of Variables

Within the D041 forecasting environment, approximately 20 variables interact to influence the requirements computation for spares. Examination of most of these variables is beyond the scope of this research. With the focus on the performance of the forecasting technique itself, only the following variables were considered (5):

1. Base reparable generations, i.e., the number of failures.
2. Organizational Field Maintenance (OFM) demand rate, i.e., the predicted ratio of future reparable generations to the predicted number of flying hours.
3. Operational Program, i.e., the number of flying hours for the spare in question.
4. Projected Operational Program, i.e., the number of flying hours forecast for future periods.

### Data Requirements

Data used in this research consisted of 31 quarters of forecast data and 35 quarters of actual reparable generations for a single Master Stock Number (MSN). To obtain this data, three elements of data were collected for each of 31 MSNs over the time period FY 69-2 to FY 77-4. These data elements, as shown in Table 2.1, consist of the OFM demand rate, the base reparable generations and the past operational program. To obtain a forecast of units demanded, the OFM demand rate is multiplied by the projected operational program. However, the forecasts provided by AFLC were obtained by multiplying the OFM demand rate by the past operational program (e.g., actual hours flown). This data, then, does not reflect the actual D041 forecasts and, hence, any conclusions drawn concerning the biasedness of these forecasts is of questionable significance.

### Data Collection

The required data was available from the D041 Tape Library (5). Computer programs had to be written to extract the required information from the D041 tapes and transfer it to a data file in the CREATE System. Appendix A describes this data retrieval in detail. Master Stock Numbers were initially selected according to the following edit criteria:

TABLE 2.1  
SIGNIFICANT VARIABLES

Description of Variable	Data Source	Units of Data Measurement	Value Level	Measurement Scale
Base Repairable Generation	D041 Data Library	To nearest Unit	Discrete Infinite	Ratio
Organization Field Maintenance Demand Rate	D041 Data Library	To four decimal points	Discrete Infinite	Ratio
Past Operational Program	D041 Data Library	To nearest unit	Discrete Infinite	Ratio

1. Element is in one of the 9 classes previously defined.
2. Element is coded XD.
3. Element is forecast by the D041 Sytem, not by the IM.

The initial computer run resulted in 500 MSNs (Classes 1615, 1630, 2915, 5841, and 6615). Subsequent runs against the above edit criteria reduced the usable data to 31 MSNs, all in class 6615.

#### Research Approach

The stated purposes of this research are to analyze the performances of different techniques used for forecasting reparable generations and to compare their accurateness. The basic approach was: (1) to compare the D041 single moving average forecast with actual reparable generations for the same time period to determine the forecast bias, and (2) to compare the two methods (D041, and time series analysis) with each other to determine which technique offered the least amount of bias.

#### Testing the First Research Hypothesis

The first research hypothesis was: The use of the weighted moving average technique leads to biased forecasts in the AFLC materiel support system. This is to say that the expected value of the forecast error presently found

in the D041 System is significantly different than zero. The hypothesis may then be stated as:

$$H_0: E(e_\tau) = 0$$

$$H_1: E(e_\tau) \neq 0$$

where:

$E(e_\tau)$  is the expected value of the forecast error, for fixed lead time  $\tau$ .

Each D041 forecast from quarter five (FY 70-2) to quarter 34 (FY 77-3) was compared to the actual reparable generations for quarter six (FY 70-3) to quarter 35 (FY 77-4). The forecast error associated with each time period, for each Master Stock Number was calculated as:

$$e_\tau(t) = \hat{g}_\tau(t) - g(t) \quad (\text{Equation 5})$$

where:

$e_\tau(t)$  is the error term associated with  $(t)$ , a lead time of  $\tau$ ,

$\hat{g}_\tau(t)$  is the forecast for period  $t$  made  $\tau$  periods earlier, and

$g(t)$  is the actual reparable generations in period  $t$ .

The final data pattern consisted of four error distributions (one for lead times of 1, 2, 3, and 4 quarters) for each Master Stock Number. The data points were the error  $[e_\tau(t)]$  values for  $t = 1, 2, 3, \dots, \tau$  for a fixed lead time,  $\tau$ .

Table 2.2 should clarify the explanation of forecasts made for various time periods for lead times one and two (3:20).

The first research hypothesis was designed to determine if the D041 forecasting method is biased. The expected value of each error distribution for a fixed lead time was calculated according to

$$E(e_{\tau}) = \sum_{t=1}^n [\hat{g}_{\tau}(t) - g(t)] \quad (\text{Equation 6})$$

where:

$E(e_{\tau})$  is the expected value of the forecast error made for lead time  $\tau$ ,

$\hat{g}_{\tau}(t)$  is the forecast reparable generations for period  $t$  with lead time  $\tau$ ,

$g(t)$  is the actual reparable generation in period  $t$ , and

$n$  is the number of data points in the distribution.

The hypothesis was then tested for each error distribution. Rejection of the null hypothesis means that the D041 forecast technique is biased (13).

A computer program was written to compute the forecast errors, and an SL library program (SIMFIT) was used to determine the statistic properties of these errors.

TABLE 2.2  
 EXAMPLE DETERMINATION OF FORECAST ERRORS FOR  $\tau=1$  AND  $\tau=2$

Lead Time $\tau$	Month						
	1	2	3	4	5	6	7
1	$\hat{g}_1(2)$	$\hat{g}_1(3)$	$\hat{g}_1(4)$	$\hat{g}_1(5)$	$\hat{g}_1(6)$	$\hat{g}_1(7)$	$\hat{g}_1(3)$
		$g(2)$	$g(3)$	$g(4)$	$g(5)$	$g(6)$	$g(7)$
2	$\hat{g}_2(3)$	$\hat{g}_2(4)$	$\hat{g}_2(5)$	$\hat{g}_2(6)$	$\hat{g}_2(7)$	$\hat{g}_2(8)$	$\hat{g}_2(9)$
			$g(3)$	$g(4)$	$g(5)$	$g(6)$	$g(7)$

NOTE:  $\hat{g}_\tau(t)$  is the  $\tau$ -period forecast for the month  $t$  made in month  $t-\tau$ .

$g(t)$  is the actual number of generations for month  $t$ .

The one-month forecast error for month 2 is  $e_1(2) = \hat{g}_1(2) - g(2)$ .

The one-month forecast error for month 3 is  $e_2(3) = \hat{g}_2(3) - g(3)$ .

### Testing the Second Research Hypothesis

The second hypothesis states: Use of the time series analysis techniques leads to forecasts with significantly less bias than that of the D041 System. To obtain a basis for comparison, forecasts were made from the same data base and lead times using SL library program TCAST. These forecasts were compared to the actual reparable generations for the period and the resulting errors were calculated according to Equation 5. The expected value for each distribution was then calculated according to Equation 6 and tested with the following hypothesis:

$$H_0: E(e_{\tau}) = 0$$

$$H_1: E(e_{\tau}) \neq 0$$

As with the first hypothesis, SL library program SIMFIT was used to compute the statistical properties of these errors. If the statistical test resulted in the rejection of the null hypothesis, it was inferred that the tested forecasting technique was biased. Conversely, if the null hypothesis could not be rejected, the inference was that the tested forecasting technique is not biased.

The expected values of the error distributions obtained from the two forecasting techniques were tested for significant statistical difference according to the following hypothesis:

$$H_0: |E(e_\tau)|_{D041} < |E(e_\tau)|_{TCAST}$$

$$H_1: |E(e_\tau)|_{D041} \geq |E(e_\tau)|_{TCAST}$$

If the statistical test results in the rejection of the null hypothesis, the time series (TCAST) forecasting technique is inferred to be more accurate than the D041 technique. Conversely, if the null hypothesis cannot be rejected, the inference is that there is no significant difference between the techniques.

#### List of Assumptions

1. The D041 forecasting procedures have been applied consistently through the period of time examined by this research.
2. The error terms for a specific lead time are statistically independent.
3. Forecasting errors are normally distributed.

#### List of Limitations

The research was limited to the forecasting techniques as applied to a subset of repairable items. Extrapolation to forecasting for other non-repairable items may require additional research.

## CHAPTER III

### FINDINGS AND ANALYSIS

#### The D041 Forecasting Method

The D041 forecasting method was investigated to determine if the forecast was biased. The forecast error distributions and their statistics were computed by computer programs for lead times of one, two, three, and four quarters (refer to Table D.1). For this particular MSN (661500735893), the null hypothesis could not be rejected at any reasonable confidence level for any of the four lead times examined, inferring that the D041 forecasting technique is unbiased for these data.

The graph plots (Figures C.9 through C.12) show the error distribution to approximate rather flat normal curves which are in fact very close to uniform distribution curves.

#### The TCAST Forecasting Method

The exponential smoothing forecasting method (TCAST) was investigated to determine if it produced forecasts which were biased. The distribution of forecast errors and its statistics were computed for lead times of one, two, three, and four (refer to Table D.2).

The TCAST model was optimized for each forecast made. Nearly 72 percent of the 102 forecasts made were

optimized with third order exponential smoothing, which takes into account the quadratic rate of change in the single exponentially smoothed average. Third order exponential smoothing normally results in more responsive forecasting than first or second order.

Similarly, larger alpha (smoothing constant) values usually result in more responsive forecasting, but in these data, 86 percent of the 102 forecasts were optimized with smoothing constants of .1 or .2 (refer to Table 3.1).

The null hypothesis could not be rejected at any reasonable level of confidence for any of the lead times of one, two, or three, inferring that the TCAST method of forecasting is unbiased for these data. However, for a lead time of four quarters, the null hypothesis could be rejected with 87 percent confidence, inferring that the TCAST method of forecasting, for a lead time of four quarters, is biased for these data.

The graph plots (Figures C.13 through C.16) of the error distributions approximate rather flat normal curves which are, in fact, very close to uniform distribution curves.

#### Comparison of the Two Forecasting Methods

The statistics of the D041 and the TCAST forecasting methods were compared to determine if the TCAST method offered less bias than the D041. The null hypothesis could

TABLE 3.1  
 CHARACTERISTICS OF TCAST FORECASTS

Lead Time	Smoothing Constants								Type Smoothing	
	.1	.2	.3	.4	.5	.6	.8	1	2	4
1	12	11	2			1	1	5	7	15
2	20	4	1	1				2	4	20
3		20	1	1	1			4	5	16
4	4	17	1	1			3	1	1	22
Totals	36	52	5	3	1	1	4	12	17	73

not be rejected with any reasonable confidence for any of the four lead times, inferring that there is no statistically significant difference in the expected values of the forecast errors for these two methods.

For all four lead times, the D041 forecasting method produced positive mean error values, inferring a somewhat consistent tendency to over-forecast. However, the TCAST method produced negative forecast error means for lead times one, three and four, inferring a tendency to under-forecast.

## CHAPTER IV

### CONCLUSIONS AND RECOMMENDATIONS

#### Conclusions

The first research hypothesis stated that the use of the weighted moving average forecasting technique by the AFLC material support system led to biased forecasts. Because of the nature of the forecasts provided by AFLC, no conclusions can be reached concerning the biasedness of the D041 forecasting technique.

The second research hypothesis stated that the use of time series analysis technique would lead to significantly more accurate forecasts. Again, no firm conclusions can be stated regarding differences in accuracy between the two techniques. However, the TCAST forecasts were statistically unbiased and made no use of "after the fact" information as did the D041 forecasts. Also, the variance of the distribution of forecast errors for the TCAST technique was substantially less than the variance associated with the distribution of forecast errors for D041. This smaller variance means that the risk associated with using the TCAST forecast is less than that associated with using the D041 method.

### Recommendations

Recommendations for further research include the following:

1. Research should be conducted using a larger variety of items. The data needed for this research is available in AFIT/CREATE Library under permanent D041 file.

2. The future program forecasting procedures and their ramifications should be studied. The projected flying hours (future program) are a driving force in the calculations to determine how many repairable assets of a given type will be required.

3. The Box and Jenkins forecasting technique should be investigated as a possible better forecasting method. This method should be compared to both the D041 results and the exponential smoothing time series results in this thesis.

4. The thesis results obtained from generated data by Captain Bruce Christensen and Mr. Gene Schroeder should be compared to the results of this thesis and any other techniques studied using real data.

APPENDICES

APPENDIX A

D041 DATA BANK DATA RETRIEVAL

The Current D041 Data Bank consists of approximately 330 magnetic tapes containing a staggering volume of historical information. It is in fact this volume which greatly complicates actual usage of the available data. In order to ferret out the bits of information pertinent to the issue at hand, hours of computer time were consumed in a computer search through the information.

In acquiring the data for this research effort, much time was dedicated to locating a knowledgeable person to explain system access procedures. Ms. Anita Clevenger of the Policy and Systems Division, HQ AFLC and Ms. Virginia Thomas of the CREATE Application Support Group were able to jointly and cooperatively furnish the required guidance. Ms. Thomas can furnish copies of the quarterly D041 Data Bank control ledger and the file format for each record.

The first set of problems encountered involving learning the use of tapes. A set of permanent tapes was secured through the use of System NEWTAPE. In order to preclude confusion and the inadvertent destruction (write-over) of one of the data tapes, a control log was used. For each program run the numbers and labels of the tapes read from, and written to, were recorded in this control log. A CARDIN NOSLEW control card was used immediately

prior to defining the "write to" tape in order to suppress any carriage control format instruction and therefore to obtain accurate "read" and "write" actions. Some of the D041 tapes are in marginal condition, which occasionally caused a run to abort with an irrecoverable input error. In each case, running the same program again after requesting special assistance of the operator resulted in a satisfactory run. Should this have failed, Ms. Thomas could have requested the reconstruction of the defective tape.

Program design incorporated the minimum number of tapes for each single run because of the limited number of tape drives (14) available on the CREATE System. If a single run required more than three tape drives, some delay was experienced. Several smaller runs rather than one large one were preferred.

In this research effort, the basic programming approach was to run the program against the first available data to arbitrarily select 900 Master Stock Numbers (MSNs) according to certain criteria, and write them to a data tape. The next run read these MSNs from the data tape, read through the next quarter's data tapes until the MSNs and desired list of information matched, and then wrote all of that information to another data tape. The following run read that information, read the next quarter's information, and wrote all the desired information to a third data tape. In other words, all the desired

information was transferred back and forth through each consecutive run. From this, it is obvious that runs had to be made in sequence. From discussions with the computer operator, it was learned that a CARDIN MSG1 control card could be used to instruct the operator to run that program only after the completion of a previous run. Therefore, an entire series of runs could be entered at one time. Preparing the runs in sequence led to the fact that prior to quarter 74-3, only first and third quarter data was retained in the Data Bank. After 74-3, data was retained for each quarter.

Beginning with quarter 75-4, MSNs became National Stock Numbers (NSNs) including the "00" (e.g., 6615003147504). Prior to 75-4 MSNs were really Federal Stock Numbers (FSNs) without the 00 (e.g., 66153147504). In order to make this transition in the series of runs, a conversion program was written to read the information already collected from a data bank and write it back to another data tape, inserting the 00 with a format statement. See Figure A.1 for a copy of this program.

In order to retrieve the data necessary for this research, three specific pieces of information were required, for each quarter, for an unknown number of MSNs. The OFM demand rate is available on the 01 record; the base reparable generations are available from the 03 record; and the past program is available from the 11 record.

The first run selected the initial set of (in this case) Federal Stock Numbers: 100 in each of five classes. The only other criteria were a requirement for existing data in the first quarter (70-2) and a computer made forecast for that quarter (card column 090 of the 01 record should be blank). An "E" in that card column would indicate a manipulated forecast. The program (Figure A.2) was run against the 01 record in quarter 70-2, which consisted of three tapes. These tapes appeared to be in stock number sequence. Results were 500 Federal Stock Numbers and the associated OFM demand rate for that quarter. This information was then written to a tape which in turn provided the basis for the run against the next quarter's data.

These runs against quarter 71-1 and subsequent quarters were made with the program in Figure A.3, which is the final run against quarter 77-4. This series of runs retrieved the OFM demand rate for each of the stock numbers remaining in the data sample. Since stock numbers were eliminated when no data was found or when a manual forecast was made, the number of stock numbers in the sample rapidly decreased from 500 to 46 with the final run.

With the demand rate data in hand, the next runs were made against the 03 and 11 records to obtain the past program and reparable generations data. The records show in the D041 Data Bank Control Ledger as only the 03 record, but the 03 through 11 records are carried on those tapes.

Sequence appears to be by Air Logistics Center, then stock number, then record type. Since eight quarters of data are carried on each quarter's records, it was necessary only to run against the 71-1, the 72-3, the 74-3, the 76-3 and the 77-4 tapes to obtain a full set of data for the stock numbers in the data sample. A sample of the program can be seen in Figure A-4.

Programming logic for this series was similar to that used for obtaining the OFM demand data. The end results were 22 quarters of OFM demand data (because of the missing quarters) on one tape and 35 quarters of past program and reparable generation data on the second tape. To mesh them together, compute the forecast and write all the data to a permanent data file, another program was written (Figure A.5). As the data was read from the tapes prior to adjusting, the quarters did not match. The data for a sample MSN appeared as in Table A.1. The missing OFM demand rates were filled in by straight line averaging the nearest actual demand rates. The limitations of this step were recognized, but it was deemed more valuable to compute the statistics for a larger sample of error points than to rely on strictly actual available data. Since no demand rates were available for the first four quarters (FY 69-2 through FY 70-1) no forecasts were analyzed for those quarters.

The end result of this program run was a usable stream of 35 quarters of data. The full data file for all 31 remaining stock numbers is established as a permanent file under the name D041. This file is accessible for other potential uses. The data for the stock number examined in this research is tabulated in Table A.2.

The actual data points to be examined in this research were the errors of the forecast. A computer program (Figure A.6) to read the D041 data (forecast and reparable generations) and compute the forecast errors for lead times one, two, three, and four (Table A.3) was accordingly written.

Time became one of the largest problems in obtaining this data file. The programs themselves normally required 15 to 35 minutes of computer time each. When this requirement is combined with the tape drive requirements and sequencing requirements, a data retrieval project becomes a formidable task requiring a significant number of calendar days to complete. The situation is complicated by computer down-time and the fact that jobs this large are only run at night and on weekends. Once the tape and formats were identified, writing and running the set of programs in this appendix required approximately six weeks of continuous daily runs.

```

1000C      FIGURE A.1 FSN/MSN CONVERSION PROGRAM
1010C
1020C
1030C#N,R(SL)
1040C:IDENT:WP1190,AFITSL 77A BRANTLEY LOREMAN
1050C:OPTION:FORTRAN,NOMAP
1060C:FORTY:NFORM,NLNO
1070C
1080C PROGRAM FSN/MSN CONVERSION
1090C
1100C THIS PROGRAM CONVERTS FEDERAL STOCK NUMBERS TO
1110C NATIONAL STOCK NUMBERS.
1120C
1130 CHARACTER FIIN*11(70),FN*11,DC*1
1140 INTEGER FSC(70),CLASS,Q,QT,QTR
1150 DIMENSION OFMDR(70,14)
1160C
1170C READ IN THE VALUES FOR THE TOTAL NUMBER OF MSN.
1180C
1190 READ 800,NUM
1200 800 FORMAT (V)
1210C
1220C SET THE QUARTER NUMBER BEFORE EACH RUN.
1230C
1240 Q=14
1250 DO 1120 J=1,NUM
1260C
1270C READ THE MSN AND DEMAND DATA FROM THE DATA TAPE.
1280C
1290 READ (16,1000,END=1220) FSC(J),FIIN(J)
1300 1000 FORMAT (I4,A11)
1310 DO 1090 QTR=1,Q-1
1320 READ (16,1010,END=1220) OFMDR(J,QTR)
1330 1010 FORMAT (F6.4)
1340 1090 CONTINUE
1350 1120 CONTINUE
1360C
1370C NOW PRINT THE NSN'S AND WRITE THEM TO TAPE.
1380C CONVERSION IS DONE BY FORMATTING IN A 00.
1390C THE NEXT RUN WILL INCLUDE THE 00 IN ITS READ FORMAT
1400C (A11) , COMPENSATED FOR WITH A 2X AFTER THE FIIN.
1410C
1420 1220 ITP=NUM
1430 DO 1250 J=1,ITP
1440 PRINT 1230,FSC(J),FIIN(J)
1450 1230 FORMAT (1X,I4,1X,2H00,1X,A11)
1460 WRITE (17,1240,END=1270) FSC(J),FIIN(J)
1470 1240 FORMAT (I4,2H00,A11)
1480 DO 1248 QTR=1,13
1490 PRINT 1245,OFMDR(J,QTR)
1500 1245 FORMAT (11X,F6.4)
1510 WRITE (17,1247,END=1270) OFMDR(J,QTR)
1520 1247 FORMAT (F6.4)
1530 1248 CONTINUE

```

1540 1250 CONTINUE  
1550 PRINT 1260, NUM  
1560 1260 FORMAT (//IX,41H THE NUMBER OF STOCK NUMBERS  
1570& REMAINING IS ,12) .  
1580 1270 CONTINUE  
1590 C  
1600 STOP  
1610 END  
1620s:EXECUTE  
1630s:LIMITS:5,15K  
1640s:DATA:I\*  
1650 52  
1660s:TAPE:16,X1D,,71988,,DATAFILE2  
1670s:FFILE:17,NOSLEW  
1680s:TAPE:17,A1D,,71870,,DATAFILE1/RING  
1690s:ENDJOB

```

1000C          FIGURE A.2 FSN SELECTION PROGRAM
1010C
1020C
1030C#AN,R(SL)
1040s:IDENT:WP1190,AFITSL 77A BRANTLEY LOREMAN
1050s:OPTION:FORTAN,NOMAP
1060s:FORTY:NFORM,NLNO
1070C
1080C PROGRAM SELECT
1090C
1100C PROGRAM SELECTS 100 FEDERAL STOCK NUMBERS IN
1110C CLASSES 1530,1615,1630,2915,5841,5865,5905,5910,
1120C AND 6615 FROM THE DATA BANK AT AFLC.
1130C
1140C TO BE RUN AGAINST THE 70-2 RECORD.
1150C
1160 CHARACTER FN*11,FIIN*11,DRC*1
1170 INTEGER FSC,CLASS,CLAS(9)/1530,1615,1630,
1180&2915,5841,5865,5905,5910,6615/
1190 DIMENSION IPT(9),FSC(9,100),FIIN (9,100),OFMDR(9,100)
1200C
1210C INITIALIZE THE TAPE DEVICE TO BE READ FROM.
1220C
1230 INT=13
1240 DO 1230 KS=1,120000
1250 GO TO 5
1260C
1270C INCREMENT THE TAPE DEVICE AND DETERMINE IF ALL THE
1280C TAPES HAVE BEEN READ.
1290C
1300 999 INT=INT+1
1310 IF (INT.GT.14) GO TO 1240
1320C
1330C READ THE FEDERAL STOCK CLASS,FIIN, DEMAND RATE,
1340C AND DEMAND RATE CODE FROM THE TAPE. THE FSC AND
1350C THE FIIN ARE SEPARATED IN ORDER TO COMPARE THE
1360C CLASSES.
1370C
1380 5 READ (INT,1000,END=999) CLASS,FN,DR,DRC
1390 1000 FORMAT (4X,I4,A11,65X,F5.0,A1)
1400C
1410C DIVIDE THE DEMAND RATE BY 10000 IN ORDER TO PLACE
1420C THE DECIMAL POINT IN THE PROPER PLACE.
1430C
1440 DR=DR/10000.
1450C
1460C DISCARD THE ITEM IF THE DEMAND CODE IS E.
1470C
1480 1050 IF (DRC.EQ.'E') GO TO 1230
1490C
1500C DETERMINE IF THE CLASS IS ONE OF THE WINE DESIRED.
1510C IF THERE ARE ALREADY 100 ITEMS SAVED IN THAT CLASS.
1520C READ ANOTHER NUMBER. OTHERWISE SAVE THE FSC, FIIN,
1530C AND DEMAND RATE.

```

```

1540C
1550 IP=0
1560 DO 1125 J=1,9
1570 IF (CLASS.EQ.CLAS(J)) IP=J
1580 1125 CONTINUE
1590 IF (IP.EQ.J) GO TO 5
1600 IF (IPT(IP).EQ.100) GO TO 5
1610 IPT(IP)=IPT(IP)+1
1620 FSC(IP,IPT(IP))=CLASS
1630 FIIN(IP,IPT(IP))=FN
1640 OFMDR(IP,IPT(IP))=DR
1650 IFL=0
1660C
1670C DETERMINE THE TOTAL NUMBER OF DATA POINTS COLLECTED.
1680C IF 900 HAVE BEEN COLLECTED PRINT THEM AND WRITE
1690C THEM TO A TAPE.
1700C
1710 DO 1225 J=1,9
1720 IFL=IFL+IPT(J)
1730 IF (IFL.GE.900) GO TO 1240
1740 1225 CONTINUE
1750 1230 CONTINUE
1760 1240 DO 1260 I=1,9
1770 IF (FSC(I,J).EQ.0) GO TO 1260
1780 DO 1257 J=1,100
1790 IF (FSC(I,J).EQ.0) GO TO 1260
1800 PRINT 1250,FSC(I,J),FIIN(I,J),OFMDR(I,J)
1810 1250 FORMAT (1X,I4,1X,A11,2X,F6.4)
1820 WRITE (16,1255,END=1230) FSC(I,J),FIIN(I,J),OFMDR(I,J)
1830 1255 FORMAT (I4,A11,F6.4)
1840 1257 CONTINUE
1850 1260 CONTINUE
1860 1270 CONTINUE
1870 1280 CONTINUE
1880C
1890 STOP
1900 END
1910$:EXECUTE
1920$:LIMITS:40
1930$:TAPE:13,X1D,,70460,,70-2 DDB01
1940$:TAPE:14,X2D,,70363,,70-2 DDB01
1950$:FFILE:16,NOSLEN
1960$:TAPE:16,A1D,,73671,,MSNDATA/RING
1970$:ENDJOB

```

```

1000C FIGURE A.3 OFM DEMAND DATA RETRIEVAL PROGRAM
1010C
1020C
1030##N,R(SL)
1040s:IDENT:AP1190,AFITSL 77A BRANTLEY LOREMAN
1050s:MSG1:MUST BE RUN AFTER SNUMB 0506T PLEASE
1060s:OPTION:FORTAN,NOMAP
1070s:FORTY:NFORM,ILNO
1080C
1090C PROGRAM DEMAND
1100C
1110C THIS PROGRAM SEARCHES THROUGH EACH QUARTER'S DATA
1120C TO RECORD THE OFM DEMAND RATE.
1130C
1140 CHARACTER FIIN*(11(54),FN*11,DC*1
1150 INTEGER FSC(54),CLASS,Q,QI,QTR
1160 DIMENSION OFMDR(52,22)
1170C
1180C READ IN THE VALUES FOR THE TOTAL NUMBER OF MSN
1190C IN EACH CLASS.
1200C
1210 READ 800,NUM
1220 800 FORMAT (V)
1230C
1240C SET THE QUARTER NUMBER BEFORE EACH RUN.
1250C
1260 Q=22
1270C
1280C INITIALIZE THE TAPE DEVICE TO BE READ FROM IN
1290C THE D041 DATA BANK.
1300C
1310 INT=13
1320C
1330C SET THE VALUE FOR THE VARIABLE REPRESENTING THE
1340C LAST TAPE DEVICE IN THE DATA BANK TO BE READ FROM
1350C ON THIS RUN.
1360C
1370 IEN=13
1380C
1390C INITIALIZE THE DEMAND DATA APRAYH TO -1. IN ORDER
1400C TO PROVIDE INDICATORS FOR DETERMINING WHICH MSN
1410C WERE NOT MATCHED.
1420C
1430 DO 1120 J=1,NUM
1440 OFMDR (J,Q)=-1.
1450C
1460C READ THE MSN AND DEMAND DATA FROM THE DATA TAPE.
1470C
1480 READ (16,1000,END=1220) FSC(J),FIIN(J)
1490 1000 FORMAT (I4,A11)
1500 DO 1090 QTR=1,Q-1
1510 READ (16,1010,END=1220) OFMDR(J,QTR)
1520 1010 FORMAT (F6.4)
1530 1090 CONTINUE

```

```

1540 1120 CONTINUE
1550C
1560C SEARCH THRU THIS QUARTER'S DATA AND READ THE FSC,
1570C FIIN, OFM DEMAND RATE, AND DEMAND CODE.
1580C
1590 DO 1210 INDX=1,120000
1600 GO TO 1129
1610C
1620C DETERMINE IF THE LAST AVAILABLE TAPE HAS BEEN READ.
1630C
1640 1125 INT=INT+1
1650 IF (INT.GT.IEN) GO TO 1220
1660 1129 READ (INT,1130,END=1125) CLASS,FN,DR,DC
1670 1130 FORMAT (4X,I4,A11,65X,F5.0,A1)
1680C
1690C MATCH THE ITEM READ TO THE BASIC DATA LIST
1700C PREVIOUSLY SAVED. IF THE STOCK NUMBERS MATCH,
1710C INCREMENT THE COUNTER (KNTR) TO TRACK THE NUMBER
1720C OF DATA POINTS AND RECORD THE DEMAND DATA. IF THE
1730C STOCK NUMBER READ DOESN'T MATCH ANY IN THE DATA
1740C LIST, READ ANOTHER NUMBER.
1750C
1760 IF (CLASS.NE.6615) GO TO 1210
1770 DO 1165 J=1,NUM
1780 IF (FN.NE.FIIN(J)) GO TO 1165
1790 KNTR=KNTR+1
1800C
1810C IF THE DEMAND CODE IS E, DO NOT SAVE DEMAND DATA.
1820C OTHERWISE, SAVE THE DEMAND DATA.
1830C
1840 IF (DC.NE.'E') GO TO 1160
1850 GO TO 1210
1860 1160 OFMDR(J,0)=DR/10000.
1870 IF (KNTR.LT.NUM) GO TO 1210
1880 GO TO 1220
1890 1165 CONTINUE
1900C
1910 1210 CONTINUE
1920C
1930C UPDATE THE FILE. FIND EACH MSN WITH DEMAND DATA
1940C STILL EQUAL TO -1. AND ELIMINATE IT BY ADJUSTING
1950C THE FIINS FROM THAT POINT ON. THEN DECREMENT THE
1960C NUMBER OF MSN'S REMAINING IN THAT CLASS AND ADJUST
1970C ALL THE DEMAND DATA COLLECTED THUS FAR TO MAINTAIN
1980C ALIGNMENT.
1990C
2000C PRINT THE DATA AND WRITE IT BACK TO THE TAPE.
2010C
2020 1220 ITP=NUM
2030 DO 1250 J=1,ITP
2040 PRINT 1230,FSC(J),FIIN(J)
2050 1230 FORMAT (1X,I4,1X,A11)
2060 WRITE (17,1240,END=1270) FSC(J),FIIN(J)
2070 1240 FORMAT (I4,A11)

```

```
2080 DO 1243 QTR=1,0
2090 PRINT 1245,OFMDR(J,QTR)
2100 1245 FORMAT (11X,F6.4)
2110 WRITE (17,1247,END=1270) OFMDR(J,QTR)
2120 1247 FORMAT (F6.4)
2130 1248 CONTINUE
2140 GO TO 1250
2150 1250 CONTINUE
2160 PRINT 1260, NUM
2170C 1260 FORMAT (//1X,41HTHE NUMBER OF STOCK NUMBERS
2180& REMAINING IS ,12)
2190 1270 CONTINUE
2200C
2210 STOP
2220 END
2230s:EXECUTE
2240s:LIMITS:37,15K
2250s:DATA:I*
2260 51
2270s:TAPE:13,X1D,,73512,,77-4 DDB01
2280s:TAPE:16,X2D,,73739,,DATAFILE7
2290s:FFILE:17,NOSLEN
2300s:TAPE:17,A1D,,70846,,DATAFILES/RING
2310s:ENDJOB
```

```

1000C FIGURE A.4 PAST PROGRAM/REPARABLE GENERATION
1010C DATA RETRIEVAL PROGRAM
1020C
1030C
1040 #S,R(SL) : ,8,16
1050s:MSG1:MUST BE RUN AFTER SNJMB M163T PLEASE
1060s:IDENT:WP1190,AFITSL 77A BRANTLEY LOREMAN
1070s:OPTION:FORTRAN,NOMAP
1080s:FORTY:NFORM,JLNO
1090C
1100C PROGRAM PAST PROGRAM/REPARABLE GENERATION
1110C
1120C THIS PROGRAM SEARCHES THROUGH EACH QUARTER'S DATA
1130C TO RECORD THE PAST OPERATIONAL PROGRAM AND
1140C REPARABLE GENERATIONS FOR EACH MSN IN THE DATA
1150C LIST.
1160C
1170 CHARACTER FIIN*11(46),FN*11,DUMMY*5(24)
1180 DIMENSION PSTPRG(46,35),RPGN(46,35),OFMDR(46,35),
1190&FRCST(46,35)
1200 DIMENSION PSTPRG(46,35),RPGN(46,35),RGPP(24),RGPPC(8)
1210C
1220C INITIALIZE THE TAPE DEVICE TO BE READ FROM IN THE
1230C DATA BANK.
1240C
1250 INT=12
1260C
1270C SET THE VALUE FOR THE VARIABLE REPRESENTING THE
1280C LAST TAPE DEVICE IN THE DATA BANK TO BE READ FROM
1290C ON THIS RUN.
1300C
1310 IF (PSTPRG(I,J).EQ.-1..OR.RPGN(I,J).EQ.-1.)
1320&MSN(I)='0'
1330 IEN=12
1340C
1350C READ IN THE QUARTER AND NUMBER OF MSN.
1360C
1370 Q=35
1380 NUM=46
1390C
1400C INITIALIZE THE PAST PROGRAM OR REPARABLE GENERATION
1410C TO -1. TO PROVIDE INDICATORS FOR UNMATCHED MSN'S.
1420C
1430 DO 1280 NSN=1,46
1440 DO 1120 J=1,NUM
1450 OFMDR(NSN,36-I)=OFMDR(NSN,23-I)
1460 RPGN(J,Q)=-1.
1470C
1480 OFMDR(NSN,22-I)=(OFMDR(NSN,23-I)+OFMDR(NSN,21-I))/2.
1490C
1500 OFMDR(NSN,7)=OFMDR(NSN,5)=(OFMDR(NSN,8)+
1510&OFMDR(NSN,5))/2.
1520 1000 FORMAT (I4,A11)
1530 OFMDR(NSN,5)=OFMDR(NSN,1)

```

```

1540 READ (16,1010,END=4000)PSTPRG(J,K),RPGN(J,K)
1550 OFMDR(NSN,K)=.9999
1560 1110 CONTINUE
1570 FRCST(NSN,J)=OFMDR(NSN,J)*PSTPRG(NSN,J+1)
1580 I=NSN
1590 IF (MSN(I).EQ.'J') GO TO 1280
1600C
1610C
1620 DO 1490 INDX=1,250000
1630 GO TO 1140
1640C
1650C DETERMINE IF THE LAST AVAILABLE TAPE HAS BEEN READ.
1660C
1670 1135 INT=INT+1
1680 IF (INT.GT.IEN) GO TO 3000
1690 1140 READ (INT,1170,END=1135)RT,CLASS,FN,(DUMMY(IMNTH
1700),IMNTH=1,24)
1710 1170 FORMAT (I2,2X,I4,A11,2X,24A5)
1720 IF (CLASS-6615) 1140,1171,1140
1730 1171 GO TO (1140,1140,1200,1140,1140,1140,1140,1140,
1740&1140,1140,1200),RT
1750C
1760C MATCH THE ITEM READ TO THE BASIC DATA LIST
1770C PREVIOUSLY SAVED. IF THE STOCK NUMBERS MATCH,
1780C INCREMENT THE COUNTER (KNTR) TO TRACK THE NUMBER
1790C OF DATA POINTS. IF THE STOCK NUMBER READ DOESN'T
1800C MATCH ANY IN THE DATA LIST, READ ANOTHER NUMBER.
1810C
1820 1200 DO 1470 J=1,NUM
1830 IF (FN.NE.FIIN(J)) GO TO 1470
1840 KNTR=KNTR+1
1850C
1860C SEPARATE THE MONTHLY DATA INTO QUARTERS BY ADDING
1870C THE APPROPRIATE MONTHLY DATA TOGETHER.
1880C
1890 MQ=-2
1900 DO 1468 QTR=Q-4,0
1910 RGPPQ(QTR)=0.
1920 MQ=MQ+3
1930 DO 1460 MNTH=MQ,MQ+2
1940 IF (DUMMY(MNTH).EQ.'*****') GO TO 1140
1950 DECODE (DUMMY(MNTH),1453)RGPP(MNTH)
1960 1453 FORMAT(F5.0)
1970 RGPPQ(QTR)=RGPPQ(QTR)+RGPP(MNTH)
1980 1460 CONTINUE
1990 IF (RT.NE.03) GO TO 1465
2000 RPGN(J,QTR)=RGPPQ(QTR)
2010 GO TO 1468
2020 1465 PSTPRG(J,QTR)=RGPPQ(QTR)
2030 1468 CONTINUE
2040 IF(KNTR.LT.2*NUM) GO TO 1140
2050 GO TO 3000
2060 1470 CONTINUE
2070 1490 CONTINUE

```

```
2080 3000 DO 3500 J=1,NUM
2090 PRINT 3010, FSC(J),FIIN(J)
2100 3010 FORMAT (/,I4,IX,A11)
2110 WRITE (17,3020,END=4000) FSC(J),FIIN(J)
2120 3020 FORMAT (I4,A11)
2130 DO 3200 QTR=1,Q
2140 PRINT 3100, PSTPRG(J,QTR),RPGN(J,QTR)
2150 3100 FORMAT (11X,F7.0,5X,F7.0)
2160 WRITE (17,3120,END=4000) PSTPRG (J,QTR),RPGN(J,QTR)
2170 3120 FORMAT (F7.0,F7.0)
2180 3200 CONTINUE
2190 3500 CONTINUE
2200 4000 CONTINUE
2210 STOP
2220 END
2230s:EXECUTE
2240s:LIMITS:60,40K
2250s:TAPE:12,X1D,,71943,,77-4 DDB03
2260s:TAPE:16,X2D,,76210,,DATAFILE5
2270s:FFILE:17,NOSLEW
2280s:TAPE:17,A1D,,73613,,DATAFILE9/RING
2290s:ENDJOB
```

```

1000C      FIGURE A.5 DATA PREPARATION PROGRAM
1010C
1020C
1030##N,R(SL)
1040S:IDENT:WP1190, AFIT/SL 77A BRANTLEY LOREMAN
1050S:OPTION:FORTRAN,NOMAP
1060S:FORTY:NFORM,NLNO
1070C
1080C PROGRAM DATA PREPARATION
1090C
1100C THIS PROGRAM READS THE MASTER STOCK NUMBER, OFM
1110C DEMAND RATE, BASE REPARABLE GENERATIONS, AND PAST
1120C PROGRAM INFORMATION FROM THE FILE AND PERFORMS
1130C CALCULATIONS NECESSARY TO TRANSFORM THEM INTO A
1140C DATA STREAM FOR ANALYSIS.
1150C
1160 CHARACTER FIIN*11(46),MSN1*15(46)
1170 INTEGER FSC(46)
1180 DIMENSION PSTPRG(46,35),RPGN(46,35),OFMDR(46,35),
1190&FRCST(46,35)
1200C
1210C READ THE MSN, PAST PROGRAM, AND REPARABLE
1220C GENERATION DATA FROM THE DATA TAPE.
1230C
1240 DO 1040 I=1,46
1250 READ (12,1000,END=4000) FSC(I),FIIN(I)
1260 1000 FORMAT (I4,A11)
1270 DO 1030 J=1,35
1280 READ (12,1010,END=4000) PSTPRG(I,J),RPGN(I,J)
1290 1010 FORMAT (2F7.0)
1300C
1310C IF PAST PROGRAM OR REPARABLE GENERATION INFORMATION
1320C IS NOT AVAILABLE (EQUALS -1.) THEN SET THAT FSC
1330C EQUAL TO ZERO.
1340C
1350 IF (PSTPRG(I,J).EQ.-1..OR.RPGN(I,J).EQ.-1.)FSC(I)=0
1360 1030 CONTINUE
1370 1040 CONTINUE
1380 DO 1080 L=1,46
1390C
1400C READ THE MSN AND OFM DEMAND DATA FROM THE DATA TAPE.
1410C
1420 READ (13,1050,END=4000) MSN1(L)
1430 1050 FORMAT (A15)
1440 DO 1070 K=1,22
1450 READ (13,1060,END=4000) OFMDR(L,K)
1460 1060 FORMAT (F6.4)
1470 1070 CONTINUE
1480 1080 CONTINUE
1490C
1500C FOLLOWING SEGMENT OF PROGRAM MESHES THE 22 QUARTERS
1510C OF OFM DEMAND DATA WITH THE 35 QUARTERS OF PAST
1520C PROGRAM AND REPARABLE GENERATION DATA.
1530C MISSING QUARTERS OF OFM DEMAND DATA WERE SIMULATED

```

```

1540C BY STRAIGHTLINE AVERAGING THE VALUES ON EITHER SIDE.
1550C FORECASTS WERE THEN COMPUTED BY MULTIPLYING THE OFM
1560C DEMAND RATE BY THE PAST PROGRAM OF THE NEXT QUARTER.
1570C
1580 DO 1280 NSN=1,46
1590 DO 1100 I=1,14
1600 OFMDR(NSN,36-I)=OFMDR(NSN,23-I)
1610 1100 CONTINUE
1620 JK=0
1630 DO 1200 I=1,13,2
1640 JK=JK+1
1650 OFMDR(NSN,22-I)=(OFMDR(NSN,10-JK)+OFMDR(NSN,
1660&9-JK))/2.
1670 IND=(22-I-5)/2
1680 OFMDR(NSN,21-I)=OFMDR(NSN,IND)
1690 1200 CONTINUE
1700 OFMDR(NSN,7)=(OFMDR(NSN,2)+OFMDR(NSN,1))/2.
1710 OFMDR(NSN,6)=OFMDR(NSN,7)
1720 OFMDR(NSN,5)=OFMDR(NSN,1)
1730 DO 1205 K=1,4
1740 OFMDR(NSN,K)=.9999
1750 1205 CONTINUE
1760 DO 1210 J=5,34
1770 FRCST(NSN,J)=OFMDR(NSN,J)*PSTPRG(NSN,J+1)
1780 1210 CONTINUE
1790 I=NSN
1800C
1810C PRINT AND WRITE TO A PERMANENT FILE THE NSN,OFM
1820C DEMAND RATE, PAST PROGRAM, FORECAST, AND REPARABLE
1830C GENERATIONS FOR EACH QUARTER.
1840C IF THE FSC EQUALS 0 (NO VALID DATA), THEN SKIP IT.
1850C
1860 IF (FSC(I).EQ.0) GO TO 1280
1870 PRINT 1230, FSC(I),FIIN(I)
1880 1230 FORMAT (//,10X,3HNSN,2X,I4,A11,/)
1890 WRITE (17,1240) FSC(I),FIIN(I)
1900 1240 FORMAT (I4,A11)
1910 PRINT 1245
1920 1245 FORMAT (24X,4HPAST,20X,9HREPARABLE,/,1X,
1930&7HQUARTER,5X,5HOFMDR,5X,7HPROGRAM,5X,3HFORECAST,
1940&5X,11HGENERATIONS,/)
1950 DO 1270 J=1,35
1960 PRINT 1250,J,OFMDR(I,J),PSTPRG(I,J),FRCST(I,J),
1970&RPGN(I,J)
1980 1250 FORMAT (4X,I2,6X,F6.4,5X,F6.0,5X,F8.4,8X,F6.0)
1990 WRITE (17,1260) J,OFMDR(I,J),PSTPRG(I,J),FRCST(I,J),
2000&RPGN(I,J)
2010 1260 FORMAT (I2,2X,F6.4,2X,F6.0,2X,F8.4,2X,F6.0)
2020 1270 CONTINUE
2030 1230 CONTINUE
2040 4000 CONTINUE
2050 STOP
2060 END
2070$ :EXECUTE

```

2080\$:LIMITS:01,30K  
2090\$:TAPE:12,X1D,,73613,,DATAFILE9  
2100\$:TAPE:13,X2D,,73146,,DATAFILE6  
2110\$:FFILE:17,NOSLEW  
2120\$:PRMFL:17,H,S,77A34/D041  
2130\$:ENDJOB

TABLE A.1

D041 DATA

Quarter	OFM Demand Rate	Past Program	Reparable Generations
1. 69-2	*	1016	28
2. 69-3	*	936	25
3. 69-4	*	914	23
4. 70-1	*	861	30
5. 70-2	.0336	816	24
6. 70-3	*	791	21
7. 70-4	*	693	32
8. 71-1	.0314	571	24
9. 71-2	*	580	22
10. 71-3	.0357	621	33
11. 71-4	*	548	21
12. 72-1	.0380	479	17
13. 72-2	*	497	32
14. 72-3	.0433	533	15
15. 72-4	*	502	17
16. 73-1	.0424	493	24
17. 73-2	*	577	17
18. 73-3	.0367	809	16
19. 73-4	*	928	27
20. 74-1	.0301	981	11
21. 74-2	*	663	14
22. 74-3	.0243	652	10
23. 74-4	.0235	435	11
24. 75-1	.0218	285	10
25. 75-2	.0213	364	10
26. 75-3	.0222	383	11
27. 75-4	.0202	392	7
28. 76-1	.0247	384	15
29. 76-2	.0266	342	12
30. 76-3	.0283	379	8
31. 76-4	.0293	384	15
32. 77-1	.0300	342	12
33. 77-2	.0339	379	8
34. 77-3	.0335	335	11
35. 77-4	.0357	324	13

\*Indicates missing data.

TABLE A.2  
DATA AFTER PREPARATION

MSN 6615000735893

QUARTER	OFMDR	PAST PROGRAM	FORECAST	REPARABLE GENERATIONS
1	0.9999	1016.	0.	28.
2	0.9999	936.	0.	25.
3	0.9999	914.	0.	23.
4	0.9999	861.	0.	30.
5	0.0336	816.	26.5776	24.
6	0.0325	791.	22.5225	21.
7	0.0325	693.	18.5575	32.
8	0.0314	571.	18.2120	24.
9	0.0336	580.	20.8346	22.
10	0.0357	621.	19.5636	33.
11	0.0369	548.	17.6512	21.
12	0.0380	479.	18.8860	17.
13	0.0407	497.	21.6665	32.
14	0.0433	533.	21.7366	15.
15	0.0429	502.	21.1251	17.
16	0.0424	493.	24.4648	24.
17	0.0396	577.	31.9960	17.
18	0.0367	809.	34.0576	16.
19	0.0334	928.	32.7654	27.
20	0.0301	981.	19.9563	11.
21	0.0272	663.	17.7344	14.
22	0.0243	652.	10.5705	10.
23	0.0235	435.	6.6975	11.
24	0.0218	285.	7.9352	10.
25	0.0213	364.	8.1579	10.
26	0.0222	383.	8.7024	11.
27	0.0202	392.	7.7568	7.
28	0.0247	384.	8.4474	15.
29	0.0266	342.	10.0814	12.
30	0.0283	379.	10.8672	8.
31	0.0293	384.	10.0206	15.
32	0.0300	342.	11.3700	12.
33	0.0339	379.	11.3565	8.
34	0.0335	335.	10.8540	11.
35	0.0357	324.	0.	13.

```

1000C FIGURE A.6 D041 FORECAST ERROR COMPUTATION PROGRAM
1010C
1020C
1030C THIS PROGRAM ANALYZES THE D041 DATA AND COMPUTES
1040C THE ERROR ASSOCIATED WITH EACH FORECAST THROUGH
1050C LEAD TIMES ONE, TWO, THREE, AND FOUR.
1060C
1070 CHARACTER MSN*13
1080 DIMENSION FRCST(35),RPGN(35),ERRD041(40,4)
1090C
1100C READ FROM A FILE THE MASTER STOCK NUMBER, FORECAST,
1110C REPARABLE GENERATIONS FOR EACH QUARTER.
1120C
1130 CALL ATTACH(16,"77A84/DATD041;",0,1,,)
1140 READ (16,900) LN,MSN
1150 900 FORMAT (V)
1160 DO 1000 I=1,35
1170 READ (16,900) LN,FRCST(I),RPGN(I)
1180 1000 CONTINUE
1190 DO 1100 I=5,34
1200 DO 1090 J=1,4
1210 IND=I+J
1220 IF (IND.GT.35) GO TO 1080
1230 ERRD041(I,J)=FRCST(I)-RPGN(IND)
1240 GO TO 1090
1250 1080 CONTINUE
1260 1090 CONTINUE
1270 1100 CONTINUE
1280 PRINT 1110
1290 1110 FORMAT (34X,"TABLE A.3",//,24X,
1300,"COMPUTED D041 FORECAST ERROR"////)
1310 PRINT 1120
1320 1120 FORMAT (21X,4(2X,3HLEADTIME))
1330 PRINT 1130
1340 1130 FORMAT (27X,1H1,9X,1H2,9X,1H3,9X,1H4)
1350 PRINT 1135
1360 1135 FORMAT (15X,7HQUARTER,3X,5HERROR,3(5X,5HERROR),//)
1370 DO 1160 I=5,34
1380 PRINT 1140, I,ERRD041(I,1),ERRD041(I,2),
1390,ERRD041(I,3),ERRD041(I,4)
1400 1140 FORMAT (18X,I2,4(4X,F6.1),/)
1410 1150 CONTINUE
1420 1160 CONTINUE
1430 STOP
1440 END

```

TABLE A.3  
COMPUTED D341 FORECAST ERROR

QUARTER	LEADTIME	LEADTIME	LEADTIME	LEADTIME
	1 ERROR	2 ERROR	3 ERROR	4 ERROR
5	5.6	-5.4	2.6	4.6
6	-9.5	-1.5	0.5	-10.5
7	-5.4	-3.4	-14.4	-2.4
8	-3.8	-14.8	-2.8	1.2
9	-12.2	-0.2	3.8	-11.2
10	-1.4	2.6	-12.4	4.6
11	0.7	-14.3	2.7	0.7
12	-13.1	3.9	1.9	-5.1
13	6.7	4.7	-2.3	4.7
14	4.7	-2.3	4.7	5.7
15	-2.9	4.1	5.1	-5.9
16	7.5	8.5	-2.5	13.5
17	16.0	5.0	21.0	13.0
18	7.1	23.1	20.1	24.1
19	21.8	18.8	22.8	21.8
20	6.0	10.0	9.0	10.0
21	7.7	6.7	7.7	7.7
22	-0.4	0.6	0.6	-0.4
23	-3.3	-3.3	-4.3	-0.3
24	-2.1	-3.1	0.9	-7.1
25	-2.8	1.2	-6.8	-3.9
26	1.7	-6.3	-3.3	0.7
27	-7.2	-4.2	-0.2	-7.2
28	-3.6	0.4	-6.6	-3.6
29	2.1	-4.9	-1.9	2.1
30	-4.1	-1.1	2.9	-0.1
31	-2.0	2.0	-1.0	-3.0
32	3.4	0.4	-1.6	0.
33	0.4	-1.6	0.	0.
34	-2.1	0.	0.	0.

APPENDIX B  
TIME SERIES FORECASTING DATA PREPARATION

The forecasting method used was that of the Honeywell Corporation TCAST computer program in the AFIT CREATE Library. This program reviews the exhibited characteristics of a variable and describes its behavior by performing an intrinsic analysis on discrete data. In the analysis each data point is split into base series, trends, seasonal, cyclical and erratic components. Base series are known historical data values which are considered constant over given periods of time; trend refers to the long-term growth or decay of the system; seasonal refers to regular annually recurring periodic fluctuations which are predictable; cyclical is a wave-like fluctuation about a trend which is not constant nor predictable; erratic refers to the unexplained or random variation that occurs for unknown reasons. After the analysis on each data component the results are combined and the forecasting model developed generates a forecast.

The forecast generation followed five objectives:

1. Evaluated trends in the historical data.
2. Dampened the erratic variations.
3. Responded to true changes in the physical process as they occurred.
4. Projected trends in future time periods.

5. Used program generated optimum forecast parameters to accomplish the previous four objectives.

A "signal," the deterministic part of the time series, consists of the long-term trend, cyclic and seasonal effects and this signal is separate from the random variation. This signal and the random variation projections are used together to determine a future process value. Logically these steps were followed to develop a signal:

1. Display the data and visually determine any obvious characteristics.
2. Remove any apparent growth or decay trends.
3. Remove any significant cyclical components.
4. Evaluate the residual trends of the original corrected data and determine their type and order of growth or decay.
5. Fit the residual trends to an appropriate program method: exponential smoothing.
6. Forecast for the future period using the appropriate programmed time series forecast model.
7. Continue to update the model as new data becomes available.

As updating continues various alphas are selected within the TCAST Program to give the smallest mean absolute deviation (MAD) of the forecast errors for each smoothing type. Generally, alphas will be between .01 and .3 for first

order smoothing and .3 to one for second or third order smoothing. After smoothing has been accomplished the residual left is due to random variations and these would produce errors in any forecast model.

Forecasts for this study were generated by truncating the TCAST program through the use of ASK function. Accordingly, all extraneous data was sent to a file dump while only the forecast information was asked for on the teletype, thereby decreasing the actual time for the teletype operation of TCAST. The actual operation of TCAST was easily accomplished by following the instructions that can be obtained from AFIT/CREATE Library.

The forecasts generated were obtained by using the first eight data points to establish a computational base for the first forecast, with additional data items input to continue forecasting into future periods. Forecasts were generated for lead times (number of periods in the future being forecasted) of one, two, three and four. Specifically, for lead time one, forecasts began in the ninth quarter and continued to the 35th quarter; for lead time two, forecasts began in the tenth quarter and continued to the thirty-fifth; for lead time three; forecasts began in the eleventh quarter and continued to the thirty-fifth quarter; and for lead time four forecasts began in the twelfth quarter and continued to the thirty-fifth quarter. One complete TCAST run had to be made for

each needed forecast; i.e., the first run included the first eight data points to form the data base to forecast for the ninth period, the second run included the data base plus the influence of the ninth periods actual usage to forecast for the tenth period, and so forth. Each run continued to regenerate forecast for the past periods for which a forecast had already been extracted but these were disregarded and only the last period forecasted on each run was extracted.

After the forecasts were obtained for each quarter the type smoothing (first order, second order, or third order) was recorded, as was the alpha (optimal weighted value). Following this the actual repairable generations were subtracted from the forecasted values and this difference represented the error for each quarter. The error was rounded to one decimal place and both positive and negative values were obtained. (See Figure B.1 through B.4.) These differences represented the error distributions data base.

TABLE B.1

## TCAST DATA FOR LEAD TIME ONE

Qtr.	Order Smoothing	Smoothing Constant	Forecast	Reparable Generations	Forecast Error
8	3	.2	25.453	24	
9	2	.8	19.429	22	3.5
10	1	.3	27.253	33	-13.6
11	3	.1	24.953	21	6.3
12	3	.1	22.370	17	8.0
13	1	.1	26.092	32	-9.6
14	3	.1	21.706	15	11.1
15	3	.1	19.830	17	4.7
16	1	.2	22.536	24	-4.2
17	3	.1	18.911	17	5.5
18	3	.1	17.407	16	2.9
19	3	.1	19.550	27	-9.6
20	3	.1	16.516	11	8.6
21	3	.1	15.026	14	2.5
22	3	.2	10.008	10	5.0
23	3	.2	8.8349	11	-1.0
24	3	.2	7.8006	10	-1.2
25	2	.2	8.6828	10	-2.2
26	2	.2	8.6299	11	-2.3
27	3	.1	6.7158	7	1.6
28	2	.2	9.3022	15	-8.3
29	1	.6	12.156	12	-2.7
30	3	.1	7.2936	8	4.2
31	2	.2	10.514	15	-7.7
32	2	.3	12.162	12	-1.5
33	2	.2	9.3827	8	4.2
34	1	.2	7.7847	11	-1.6
35				15	-5.2

TABLE B.2

## TCAST DATA FOR LEAD TIME TWO

Qtr.	Order Smoothing	Smoothing Constant	Forecast	Reparable Generations	Forecast Error
9	1	.3	25.985		
10	3	.1	24.098	33	-7.0
11	3	.1	26.659	21	3.9
12	3	.1	24.756	17	9.7
13	3	.1	21.929	32	-7.3
14	3	.1	24.652	15	6.9
15	3	.1	21.242	17	7.7
16	3	.1	19.211	24	2.8
17	3	.1	19.950	17	2.2
18	3	.1	18.281	16	4.0
19	3	.1	16.672	27	-8.7
20	3	.1	19.081	11	5.7
21	3	.1	15.781	14	5.1
22	3	.1	14.195	10	5.8
23	3	.1	11.684	11	3.2
24	3	.1	10.096	10	1.7
25	3	.1	8.5976	10	.1
26	3	.1	7.5072	11	-2.4
27	3	.1	7.0772	7	.5
28	3	.1	5.5248	15	-7.9
29	3	.1	7.0390	12	-6.5
30	2	.2	9.2174	8	-1.0
31	2	.2	7.9214	15	-5.8
32	2	.2	10.175	12	-4.1
33	2	.2	10.491	8	2.2
34	1	.4	9.6932	11	-.5
35				13	-3.3

TABLE B.3

## TCAST DATA FOR LEAD TIME THREE

Qtr.	Order Smoothing	Smoothing Constant	Forecast	Reparable Generations	Forecast Error
10	2	.5	25.117		
11	1	.8	22.638	21	4.1
12	2	.2	27.594	17	5.6
13	3	.2	23.838	32	-4.4
14	3	.2	17.109	15	8.8
15	3	.2	26.159	17	.1
16	3	.2	17.179	24	2.2
17	3	.2	13.819	17	.2
18	3	.2	18.207	16	-2.2
19	3	.2	15.177	27	-2.2
20	3	.2	12.870	11	4.2
21	3	.2	21.246	14	-1.1
22	3	.2	12.779	10	11.2
23	3	.2	10.619	11	1.8
24	3	.2	6.3872	10	.6
25	3	.2	5.2920	10	-3.6
26	3	.2	4.3943	11	-5.7
27	3	.2	4.4559	7	-2.6
28	3	.2	5.8945	15	-10.5
29	2	.2	5.1863	12	-6.1
30	2	.2	8.0304	8	-2.8
31	2	.2	8.6894	15	-7.0
32	1	.8	8.8621	12	-3.3
33	1	.8	13.772	8	.9
34	1	.4	10.338	11	2.8
35				13	-2.7

TABLE B.4

## TCAST DATA FOR LEAD TIME FOUR

Qtr.	Order Smoothing	Smoothing Constant	Forecast	Reparable Generations	Forecast Error
11	3	.3	8.0450		
12	3	.3	18.625	17	-9.0
13	3	.2	30.163	32	-13.4
14	3	.2	23.476	15	15.2
15	3	.2	15.709	17	6.5
16	3	.2	26.359	24	-8.3
17	3	.2	15.927	17	9.4
18	3	.2	12.164	16	- .1
19	3	.2	17.436	27	-14.8
20	3	.1	16.967	11	6.4
21	3	.2	11.475	14	3.0
22	3	.1	18.112	10	1.5
23	3	.2	11.548	11	7.1
24	3	.2	9.1894	10	1.5
25	3	.2	4.4506	10	- .8
26	3	.2	3.4062	11	-6.6
27	3	.2	2.5908	7	-3.6
28	3	.2	2.8846	15	-12.4
29	3	.2	4.7567	12	-9.1
30	3	.2	2.5082	8	-3.2
31	3	.1	5.0361	15	-12.5
32	3	.1	5.5723	12	-7.0
33	2	.2	6.7258	8	-2.4
34	1	.4	8.5262	11	-4.3
35				13	-4.5

APPENDIX C  
STATISTICS COMPUTATION

The statistics for the error distributions were computed using the LSS/SIMFIT program. The program fitted the error data points to an internally determined distribution type, and then provided the type distribution derived and the statistics as shown in Figures C.1 through C.8. These statistics were then used to perform Student's t tests on the null hypotheses.

The SIMFIT Program gave the uniform distribution as the predominate distribution fitting the data (smallest maximum error) for five of the eight error distributions. However, the histogram provided by SIMFIT empirically displayed the data in symmetrical form. The normal distribution's maximum error was larger than the Uniform's, however, in testing for the Uniform the larger errors were not sufficient to reject the Uniform distribution at the 90 percent confidence level. But since empirical evidence must be weighted more heavily than theoretical, the normal distribution was accepted as being the predominant distribution, which supported the previous assumption that the forecast error was normally distributed. This can be more clearly seen in the graphs in Figures C.9 through C.16.

The slightly larger variance of the D041 forecasts can be easily seen in the graphs (Figure C.17 through C.24) which plot the forecast error over time.

THIS IS THE ERROR DISTRIBUTION

SAMPLE STATISTICS

NUMBER OF VALUES IN LIMITS = 30.000  
MINIMUM VALUE OF ALL DATA = -13.100  
MAXIMUM VALUE OF ALL DATA = 21.800  
MODE OF DATA = -3.750  
ARITHMETIC MEAN = 0.517  
STD. DEVIATION = 7.476  
VARIANCE = 55.897  
VARIANCE / MEAN = 108.188

ESTIMATED SAMPLE MOMENTS ABOUT THE MEAN:

3 276.4  
4 0.1167E 05

A3 0.696

IF A3 IS EQUAL TO ZERO, THE DISTRIBUTION IS SYMMETRICAL

A4 0.997

IF A4 IS NEGATIVE DISTRIBUTION HAS A FLAT TOP

IF A4 IS ZERO, DISTRIBUTION IS ALMOST NORMAL

IF A4 IS POSITIVE, DISTRIBUTION HAS A HIGH PEAK.

IF ANY PROBABILITY FUNCTIONS DO NOT FIT DATA  
SUGGEST THAT YOU TRY THE FOLLOWING VALUES

AMEN = -13.1000  
WIDTH = 3.8778  
NCELLS = 9

Figure C.1. Statistics Computations for D041  
Forecasts in Lead Time One

THIS IS THE ERROR DISTRIBUTION

SAMPLE STATISTICS

NUMBER OF VALUES IN LIMITS = 29.000  
MINIMUM VALUE OF ALL DATA = -14.800  
MAXIMUM VALUE OF ALL DATA = 23.100  
MODE OF DATA = 0.750  
ARITHMETIC MEAN = 0.883  
STD. DEVIATION = 7.908  
VARIANCE = 62.536  
VARIANCE / MEAN = 70.842

ESTIMATED SAMPLE MOMENTS ABOUT THE MEAN:

3 335.3  
4 0.1654E 05

A3 0.715

IF A3 IS EQUAL TO ZERO, THE DISTRIBUTION IS SYMMETRICAL

A4 1.536

IF A4 IS NEGATIVE DISTRIBUTION HAS A FLAT TOP

IF A4 IS ZERO, DISTRIBUTION IS ALMOST NORMAL

IF A4 IS POSITIVE, DISTRIBUTION HAS A HIGH PEAK.

IF ANY PROBABILITY FUNCTIONS DO NOT FIT DATA  
SUGGEST THAT YOU TRY THE FOLLOWING VALUES

AMEN = -14.8000  
WIDTH = 4.3563  
NCELLS= 9

Figure C.2. Statistics Computations for D041  
Forecasts in Lead Time Two

THIS IS THE ERROR DISTRIBUTION

SAMPLE STATISTICS

NUMBER OF VALUES IN LIMITS = 28.000  
MINIMUM VALUE OF ALL DATA = -14.400  
MAXIMUM VALUE OF ALL DATA = 22.800  
MODE OF DATA = 0.750  
ARITHMETIC MEAN = 1.650  
STD. DEVIATION = 8.662  
VARIANCE = 75.031  
VARIANCE / MEAN = 45.473

ESTIMATED SAMPLE MOMENTS ABOUT THE MEAN:

3 534.1  
4 0.2067E 05

A3 0.868

IF A3 IS EQUAL TO ZERO, THE DISTRIBUTION IS SYMMETRICAL

A4 0.949

IF A4 IS NEGATIVE DISTRIBUTION HAS A FLAT TOP

IF A4 IS ZERO, DISTRIBUTION IS ALMOST NORMAL

IF A4 IS POSITIVE, DISTRIBUTION HAS A HIGH PEAK.

IF ANY PROBABILITY FUNCTIONS DO NOT FIT DATA  
SUGGEST THAT YOU TRY THE FOLLOWING VALUES

AMEN = -14.4000  
WIDTH = 4.4286  
NCELLS= 8

Figure C.3. Statistics Computations for D041  
Forecasts in Lead Time Three

THIS IS THE ERROR DISTRIBUTION

SAMPLE STATISTICS

NUMBER OF VALUES IN LIMITS = 27.000  
MINIMUM VALUE OF ALL DATA = -11.200  
MAXIMUM VALUE OF ALL DATA = 24.100  
MODE OF DATA = 0.750  
ARITHMETIC MEAN = 2.178  
STD. DEVIATION = 9.069  
VARIANCE = 82.248  
VARIANCE / MEAN = 37.767

ESTIMATED SAMPLE MOMENTS ABOUT THE MEAN:

3 614.0  
4 0.2026E 05

A3 0.871

IF A3 IS EQUAL TO ZERO, THE DISTRIBUTION IS SYMMETRICAL

A4 0.230

IF A4 IS NEGATIVE DISTRIBUTION HAS A FLAT TOP

IF A4 IS ZERO, DISTRIBUTION IS ALMOST NORMAL

IF A4 IS POSITIVE, DISTRIBUTION HAS A HIGH PEAK.

IF ANY PROBABILITY FUNCTIONS DO NOT FIT DATA  
SUGGEST THAT YOU TRY THE FOLLOWING VALUES

AMEN = -11.2000  
WIDTH = 4.3580  
NCELLS= 8

Figure C.4. Statistics Computations for D041  
Forecasts in Lead Time Four

THIS IS THE ERROR DISTRIBUTION

SAMPLE STATISTICS

NUMBER OF VALUES IN LIMITS = 27.000  
MINIMUM VALUE OF ALL DATA = -13.600  
MAXIMUM VALUE OF ALL DATA = 11.100  
MODE OF DATA = 5.250  
ARITHMETIC MEAN = -0.096  
STD. DEVIATION = 6.231  
VARIANCE = 38.827  
VARIANCE / MEAN = -403.207

ESTIMATED SAMPLE MOMENTS ABOUT THE MEAN:

3 -70.11  
4 3299.

A3 -0.307

IF A3 IS EQUAL TO ZERO, THE DISTRIBUTION IS SYMMETRICAL

A4 -0.640

IF A4 IS NEGATIVE DISTRIBUTION HAS A FLAT TOP

IF A4 IS ZERO, DISTRIBUTION IS ALMOST NORMAL

IF A4 IS POSITIVE, DISTRIBUTION HAS A HIGH PEAK.

IF ANY PROBABILITY FUNCTIONS DO NOT FIT DATA  
SUGGEST THAT YOU TRY THE FOLLOWING VALUES

AMEN = -13.6000  
WIDTH = 3.0494  
NCELLS= 8

Figure C.5. Statistics Computations for TCAST  
Forecasts in Lead Time one

THIS IS THE ERROR DISTRIBUTION

SAMPLE STATISTICS

NUMBER OF VALUES IN LIMITS = 26.000  
MINIMUM VALUE OF ALL DATA = -8.700  
MAXIMUM VALUE OF ALL DATA = 9.700  
MODE OF DATA = 0.750  
ARITHMETIC MEAN = 0.269  
STD. DEVIATION = 5.308  
VARIANCE = 28.174  
VARIANCE / MEAN = 104.647

ESTIMATED SAMPLE MOMENTS ABOUT THE MEAN:

3 -24.13  
4 1415.

A3 -0.171

IF A3 IS EQUAL TO ZERO, THE DISTRIBUTION IS SYMMETRICAL

A4 -1.072

IF A4 IS NEGATIVE DISTRIBUTION HAS A FLAT TOP

IF A4 IS ZERO, DISTRIBUTION IS ALMOST NORMAL

IF A4 IS POSITIVE, DISTRIBUTION HAS A HIGH PEAK.

IF ANY PROBABILITY FUNCTIONS DO NOT FIT DATA  
SUGGEST THAT YOU TRY THE FOLLOWING VALUES

AMEV = -8.7000  
WIDTH = 2.3590  
NCELLS= 8

Figure C.6. Statistics Computations for TCAST  
Forecasts in Lead Time Two

THIS IS THE ERROR DISTRIBUTION

SAMPLE STATISTICS

NUMBER OF VALUES IN LIMITS = 25.000  
MINIMUM VALUE OF ALL DATA = -10.500  
MAXIMUM VALUE OF ALL DATA = 11.200  
MODE OF DATA = 0.750  
ARITHMETIC MEAN = -0.516  
STD. DEVIATION = 5.231  
VARIANCE = 27.363  
VARIANCE / MEAN = -53.029

ESTIMATED SAMPLE MOMENTS ABOUT THE MEAN:

3 26.82  
4 1903.

A3 0.199

IF A3 IS EQUAL TO ZERO, THE DISTRIBUTION IS SYMMETRICAL

A4 -0.242

IF A4 IS NEGATIVE DISTRIBUTION HAS A FLAT TOP

IF A4 IS ZERO, DISTRIBUTION IS ALMOST NORMAL

IF A4 IS POSITIVE, DISTRIBUTION HAS A HIGH PEAK.

IF ANY PROBABILITY FUNCTIONS DO NOT FIT DATA  
SUGGEST THAT YOU TRY THE FOLLOWING VALUES

AMEN = -10.5000  
WIDTH = 2.8933  
NCELLS= 8

Figure C.7. Statistics Computations for TCAST  
Forecasts in Lead Time Three

THIS IS THE ERROR DISTRIBUTION

SAMPLE STATISTICS

NUMBER OF VALUES IN LIMITS = 24.000  
MINIMUM VALUE OF ALL DATA = -14.800  
MAXIMUM VALUE OF ALL DATA = 15.200  
MODE OF DATA = -8.250  
ARITHMETIC MEAN = -2.558  
STD. DEVIATION = 7.834  
VARIANCE = 61.376  
VARIANCE / MEAN = -23.991

ESTIMATED SAMPLE MOMENTS ABOUT THE MEAN:

3 168.8  
4 8503.

A3 0.374

IF A3 IS EQUAL TO ZERO, THE DISTRIBUTION IS SYMMETPICAL

A4 -0.542

IF A4 IS NEGATIVE DISTRIBUTION HAS A FLAT TOP

IF A4 IS ZERO, DISTRIBUTION IS ALMOST NORMAL

IF A4 IS POSITIVE, DISTRIBUTION HAS A HIGH PEAK.

IF ANY PROBABILITY FUNCTIONS DO NOT FIT DATA  
SUGGEST THAT YOU TRY THE FOLLOWING VALUES

AMEN = -14.8000  
WIDTH = 4.1667  
NCELLS= 7

Figure C.8. Statistics Computations for TCAST  
Forecasts in Lead Time Four

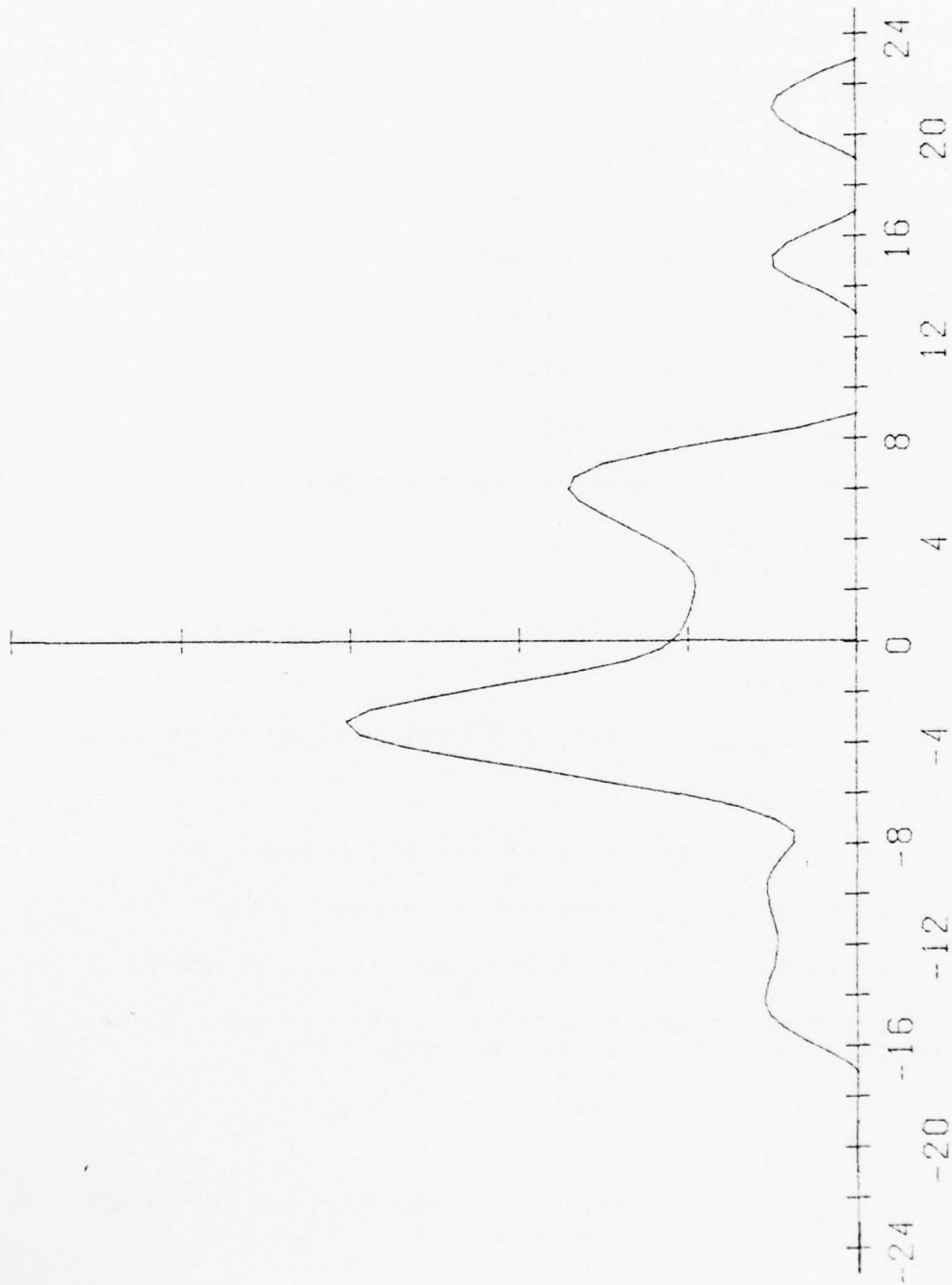


FIGURE C.9 D041 ERROR DISTRIBUTION FOR LEAD TIME 1

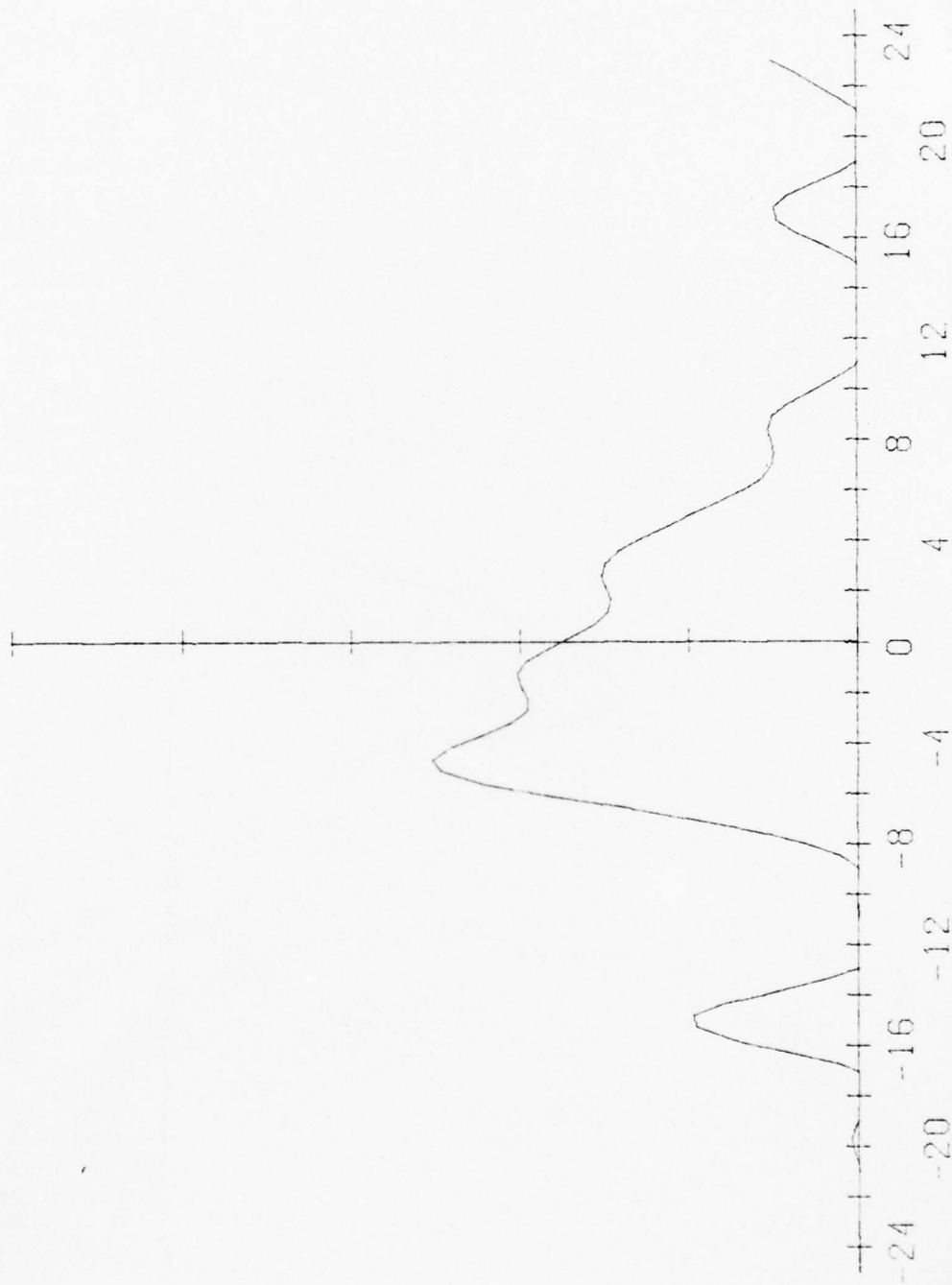


FIGURE C-10 D041 ERROR DISTRIBUTION FOR LEAD TIME 2

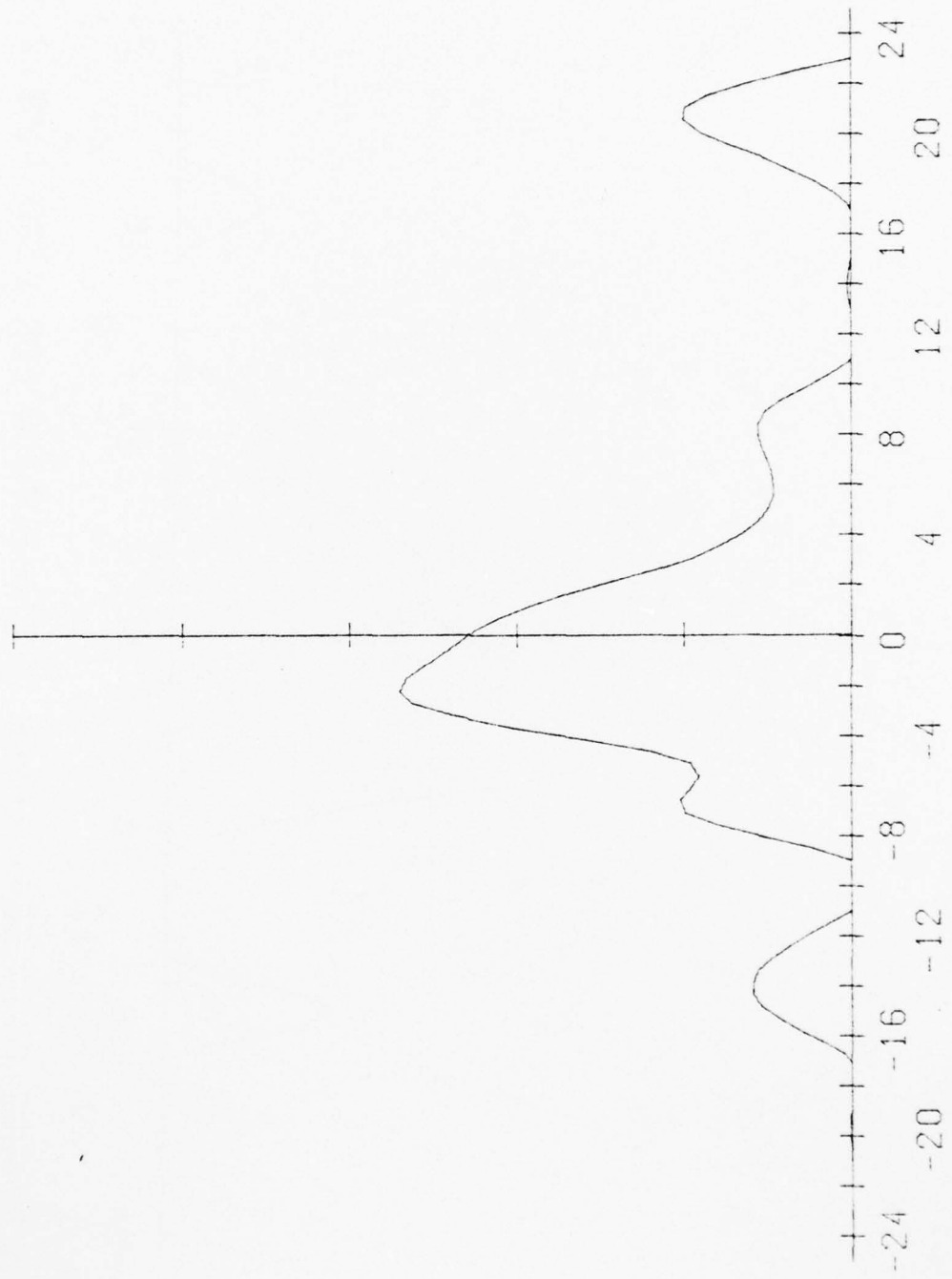


FIGURE C.11 D041 ERROR DISTRIBUTION FOR LEAD TIME 3

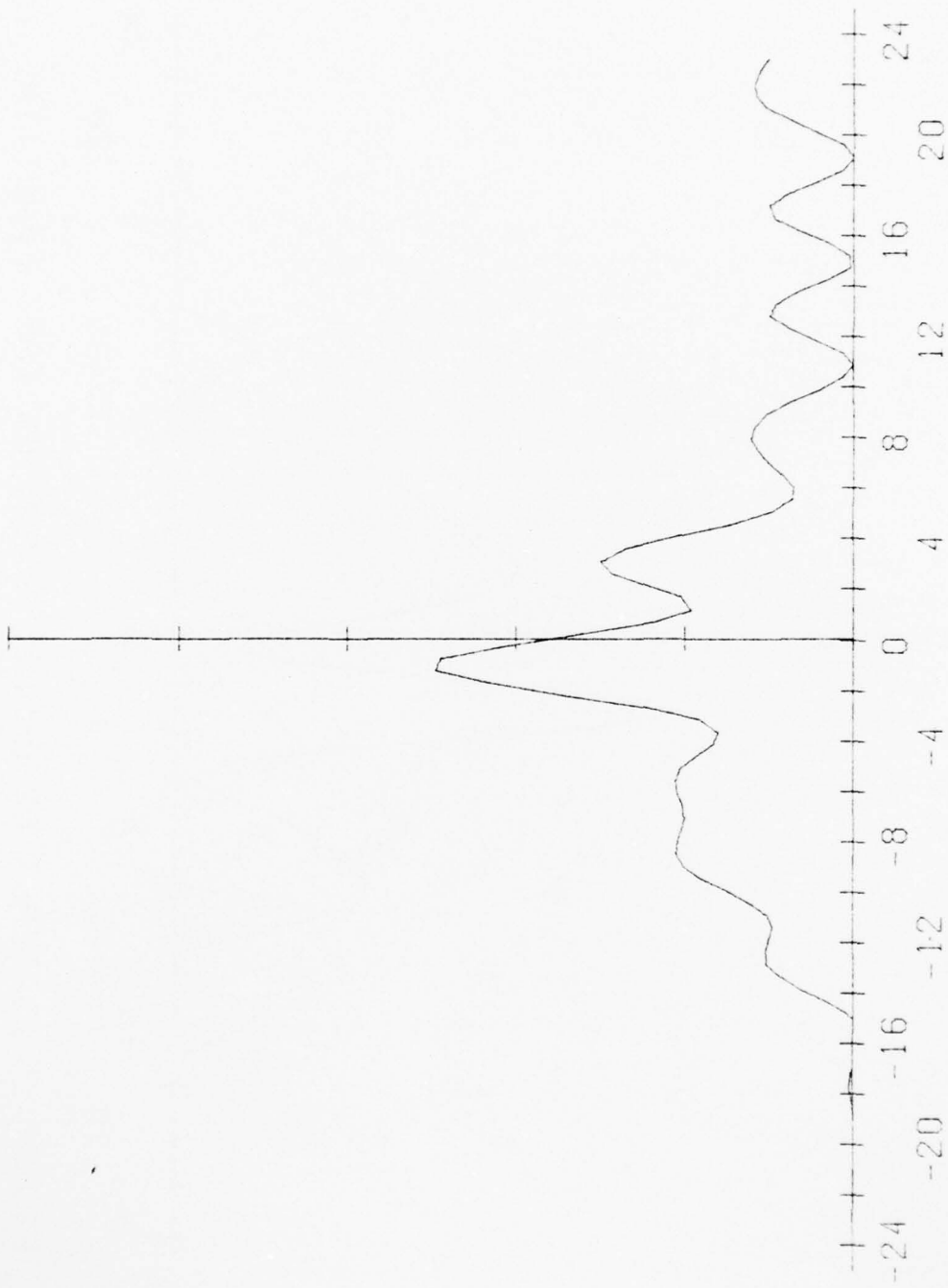


FIGURE C.12 D041 ERROR DISTRIBUTION FOR LEAD TIME 4

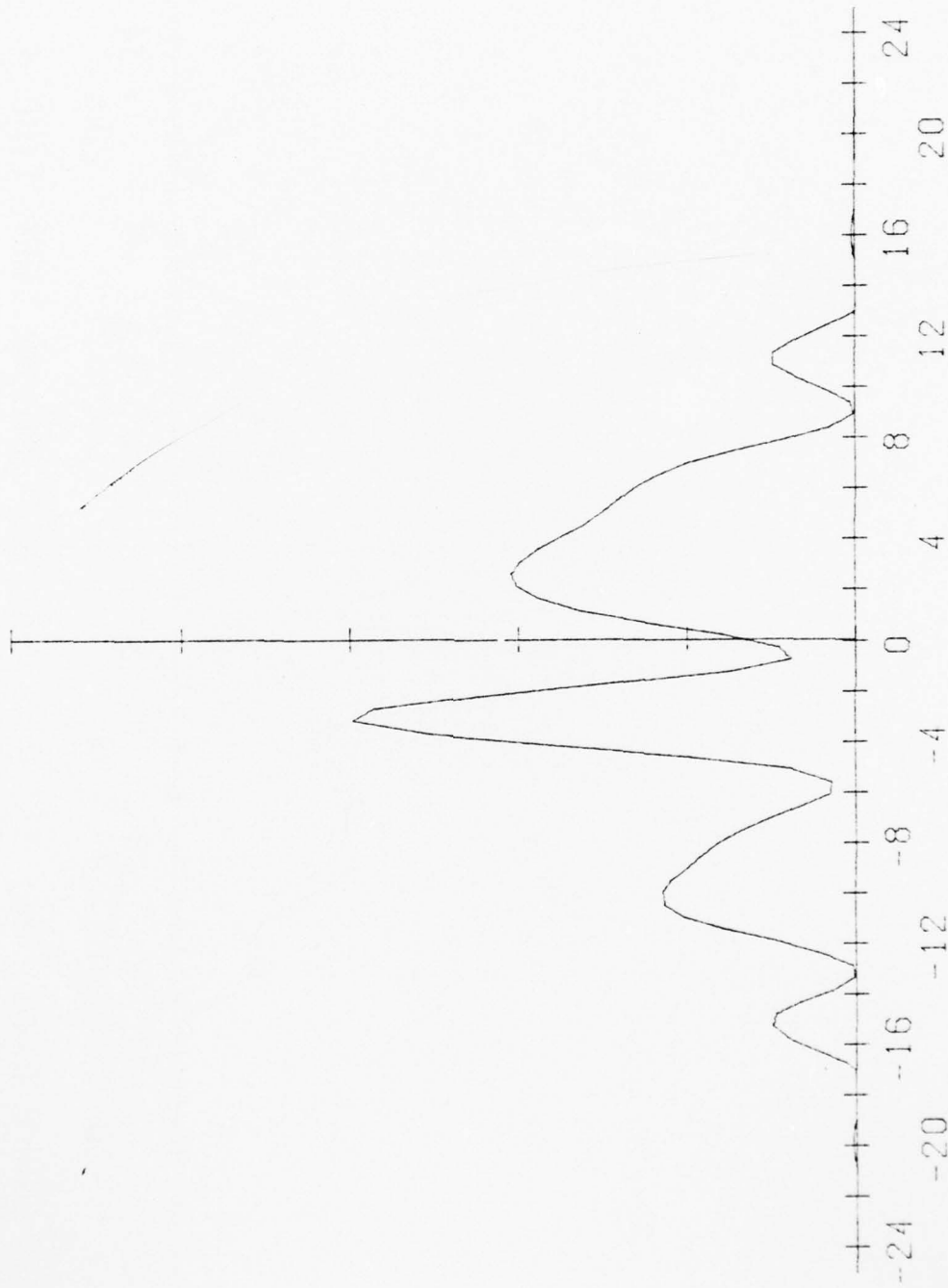


FIGURE C-13 1CAST ERROR DISTRIBUTION FOR LEAD TIME 1

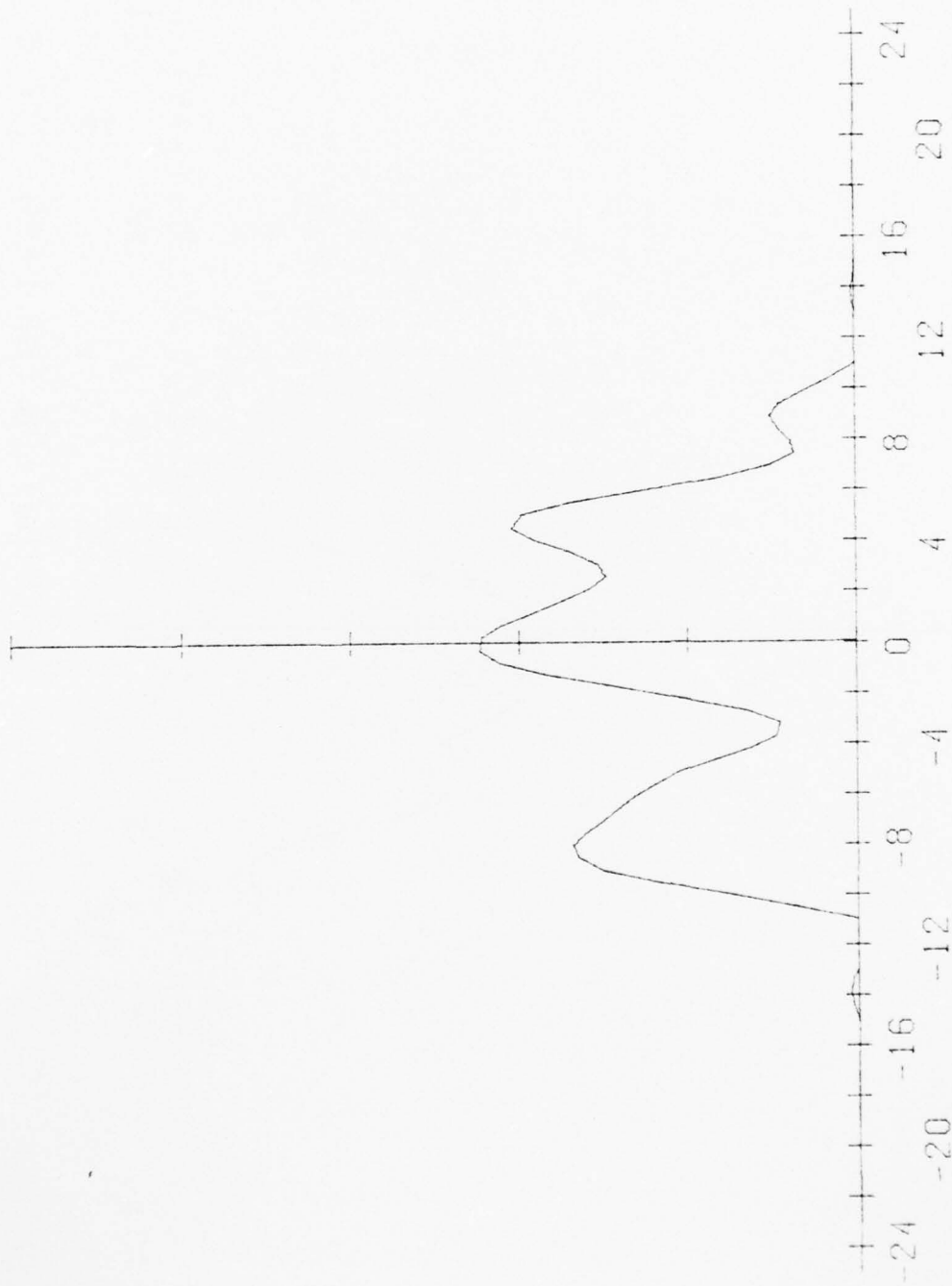


FIGURE C.14 TCAS ERROR DISTRIBUTION FOR LEAD TIME 2

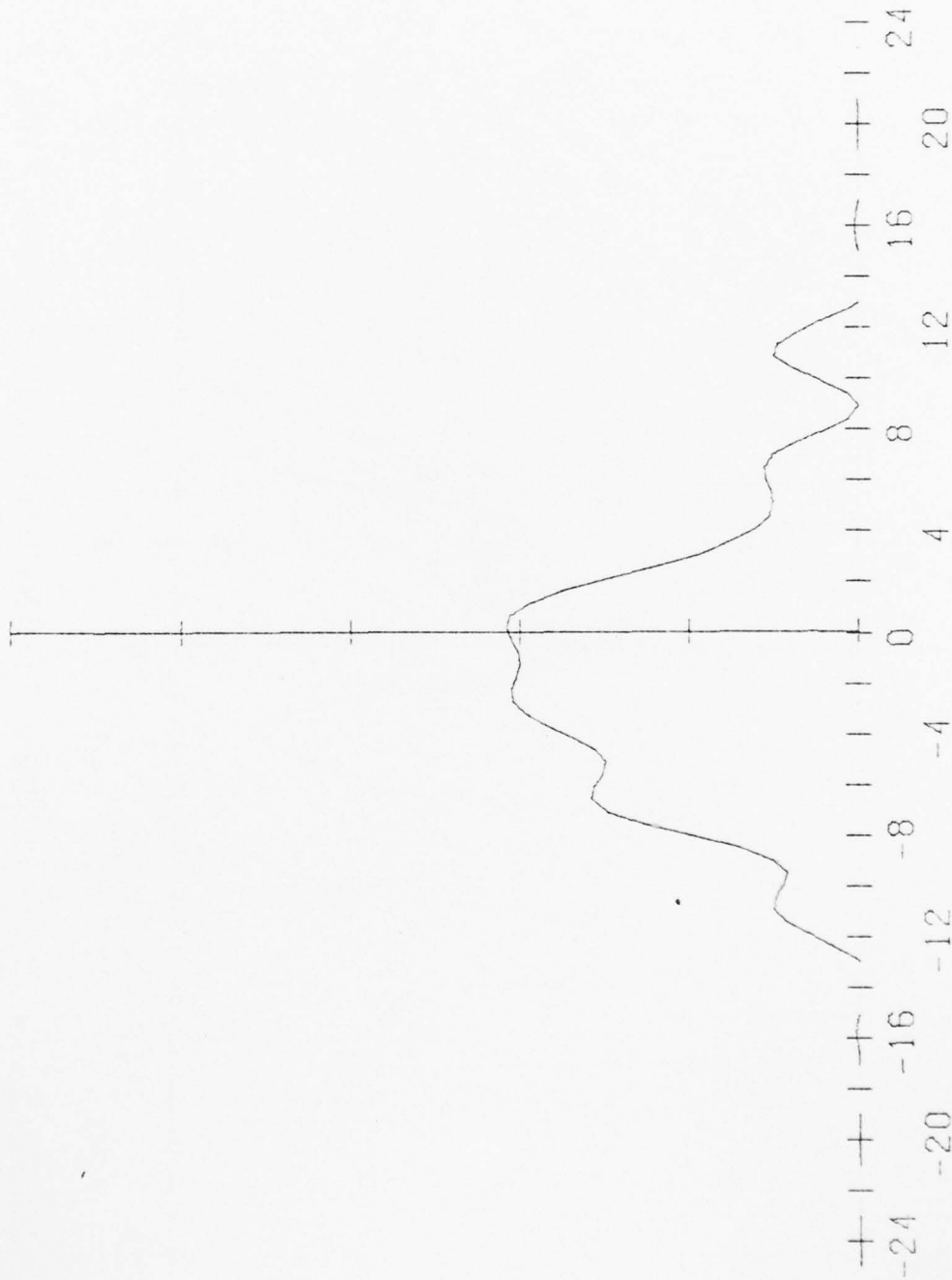


FIGURE C.15 TCAS ERROR DISTRIBUTION FOR LEAD TIME 3

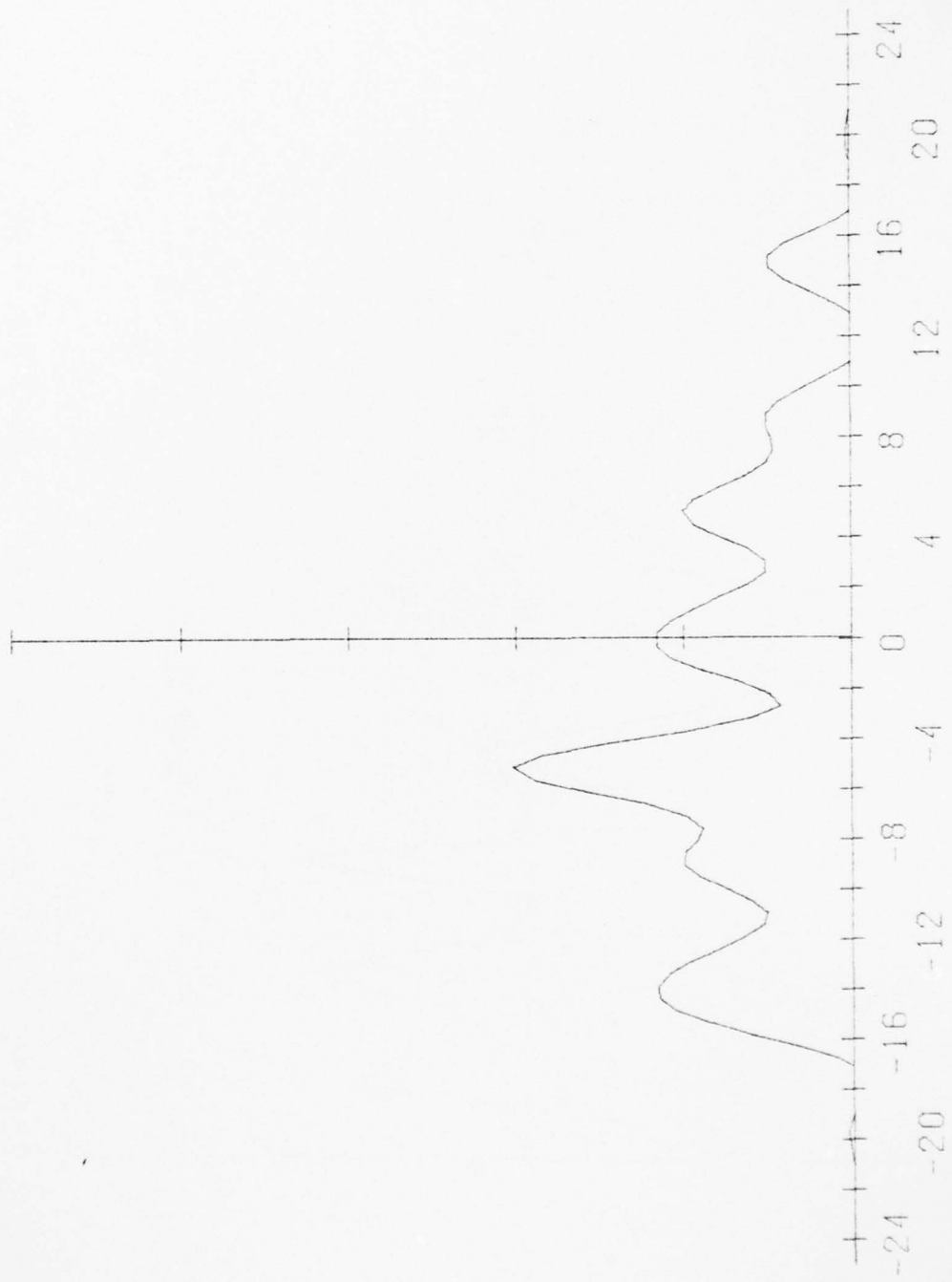


FIGURE C-16 TCAS ERROR DISTRIBUTION FOR LEAD TIME 4

AD-A044 078

AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SHO--ETC F/G 15/5  
A COMPARATIVE ANALYSIS OF THE D041 SINGLE MOVING AVERAGE AND OT--ETC(U)  
JUN 77 J S BRANTLEY, D E LOREMAN

UNCLASSIFIED

AFIT-LSSR-7-77A

NL

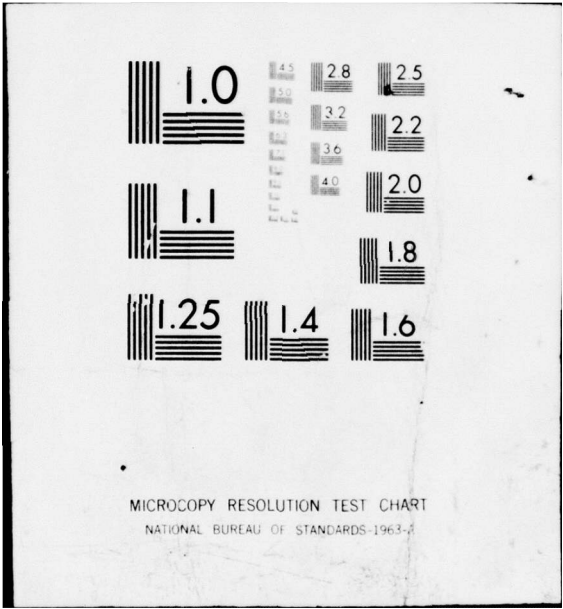
2 OF 2  
AD  
A044 078



END  
DATE  
FILMED

9-77

DDC



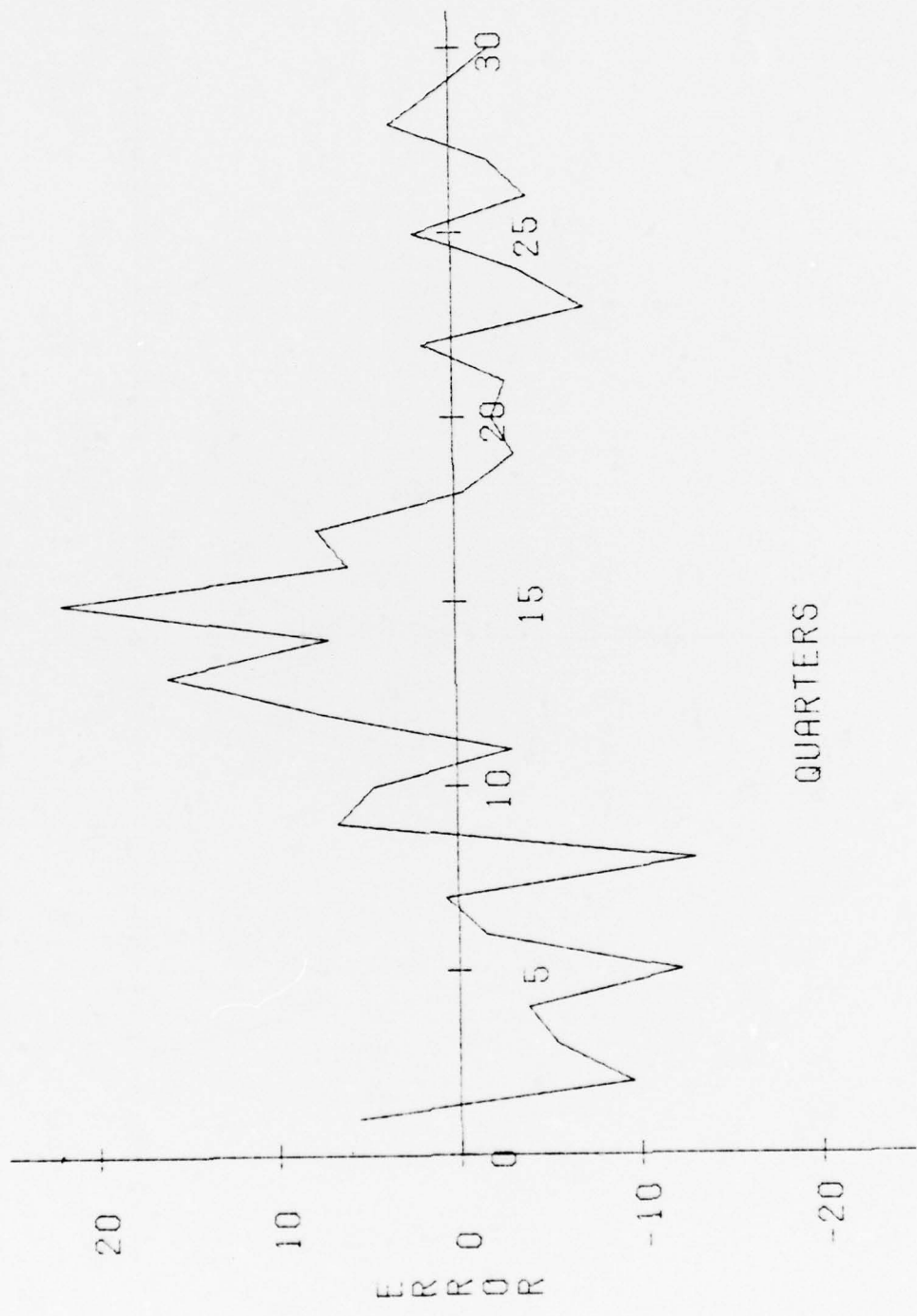


FIGURE C-17 D041 ERROR OVER TIME FOR LEAD TIME 1

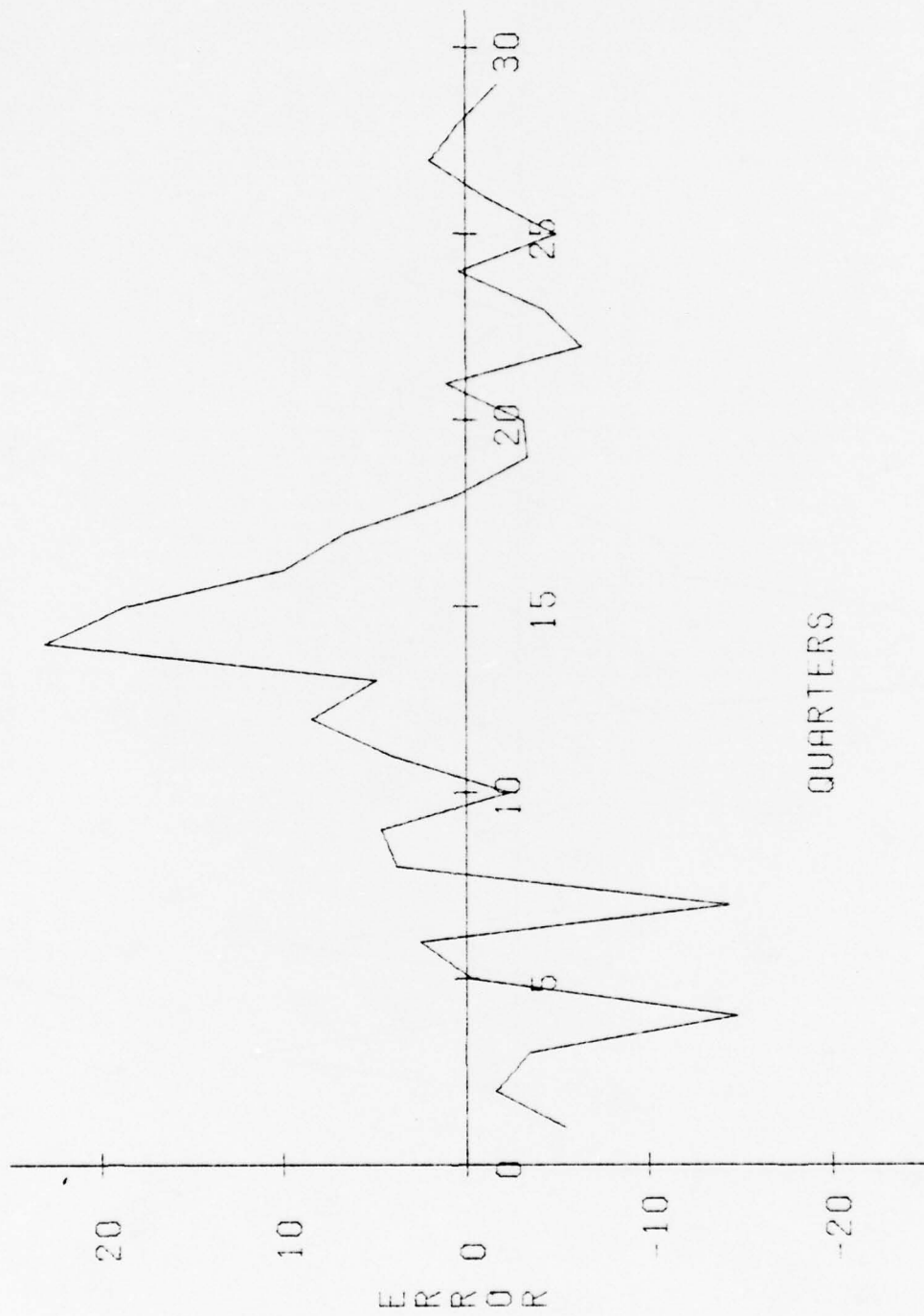


FIGURE C-18 D041 ERROR OVER TIME FOR LEAD TIME 2

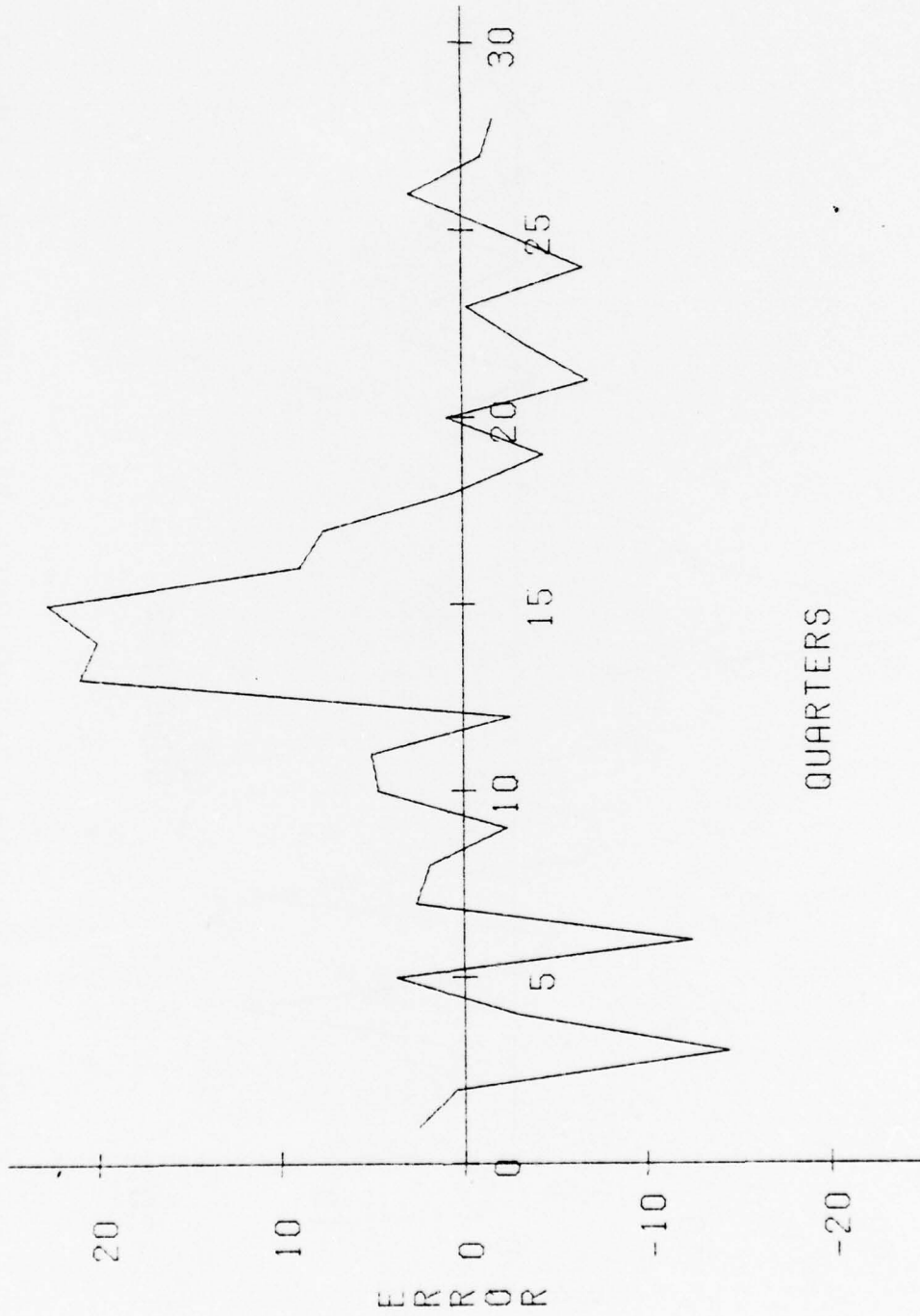


FIGURE C.19 D041 ERROR OVER TIME FOR LEAD TIME 3

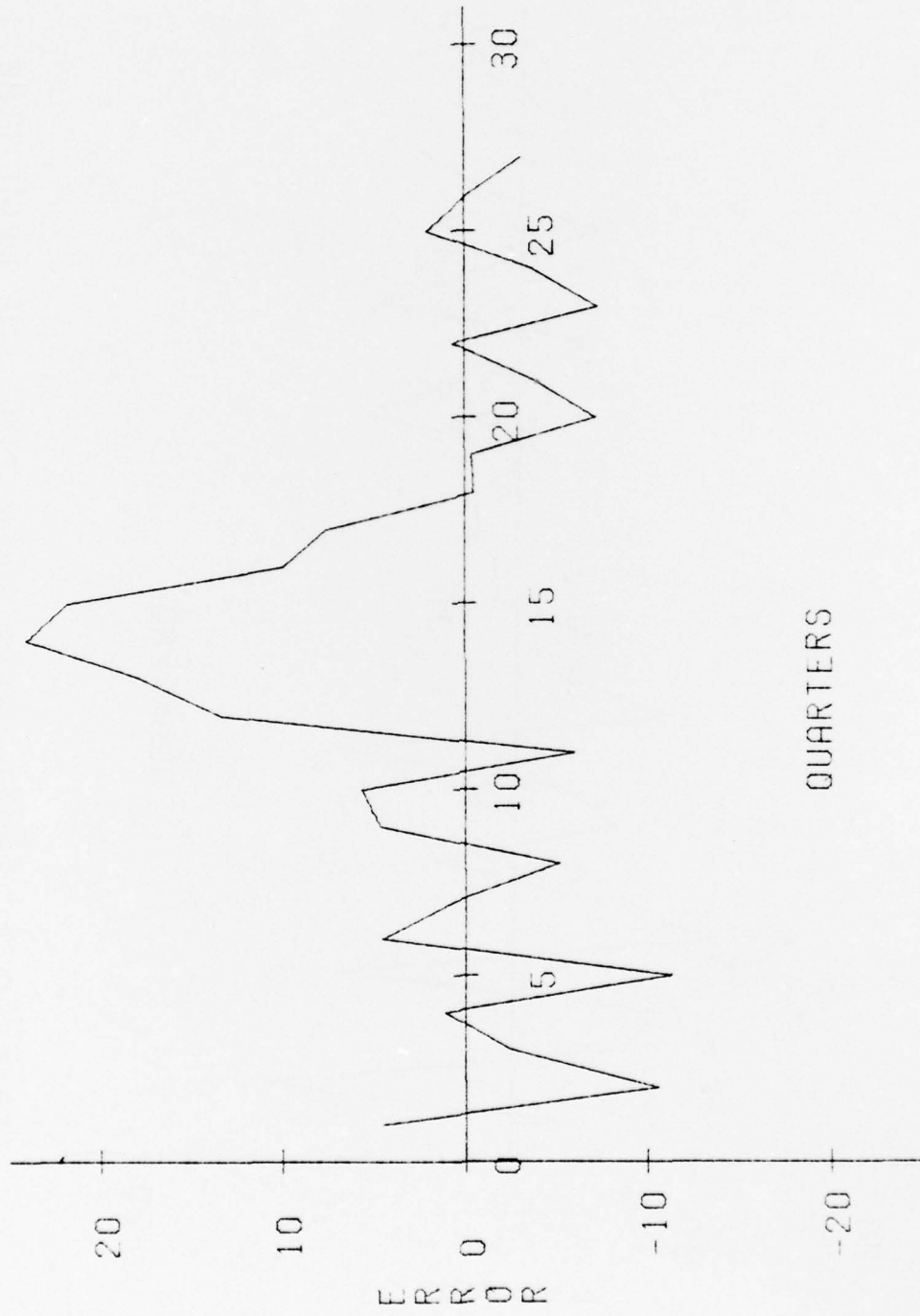


FIGURE C.20 D041 ERROR OVER TIME FOR LEAD TIME 4

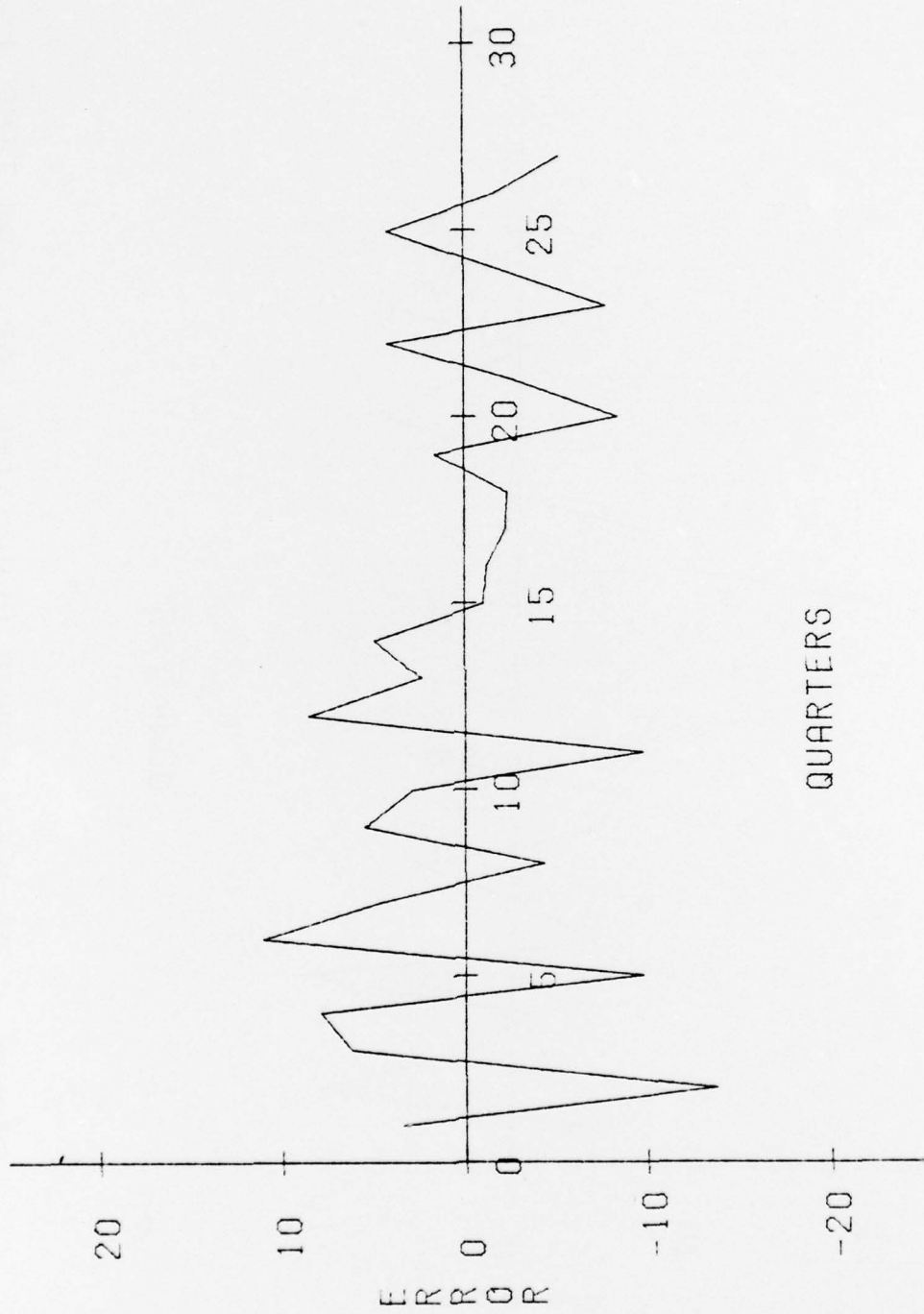


FIGURE C.21 TCAS ERROR OVER TIME FOR LEAD TIME 1

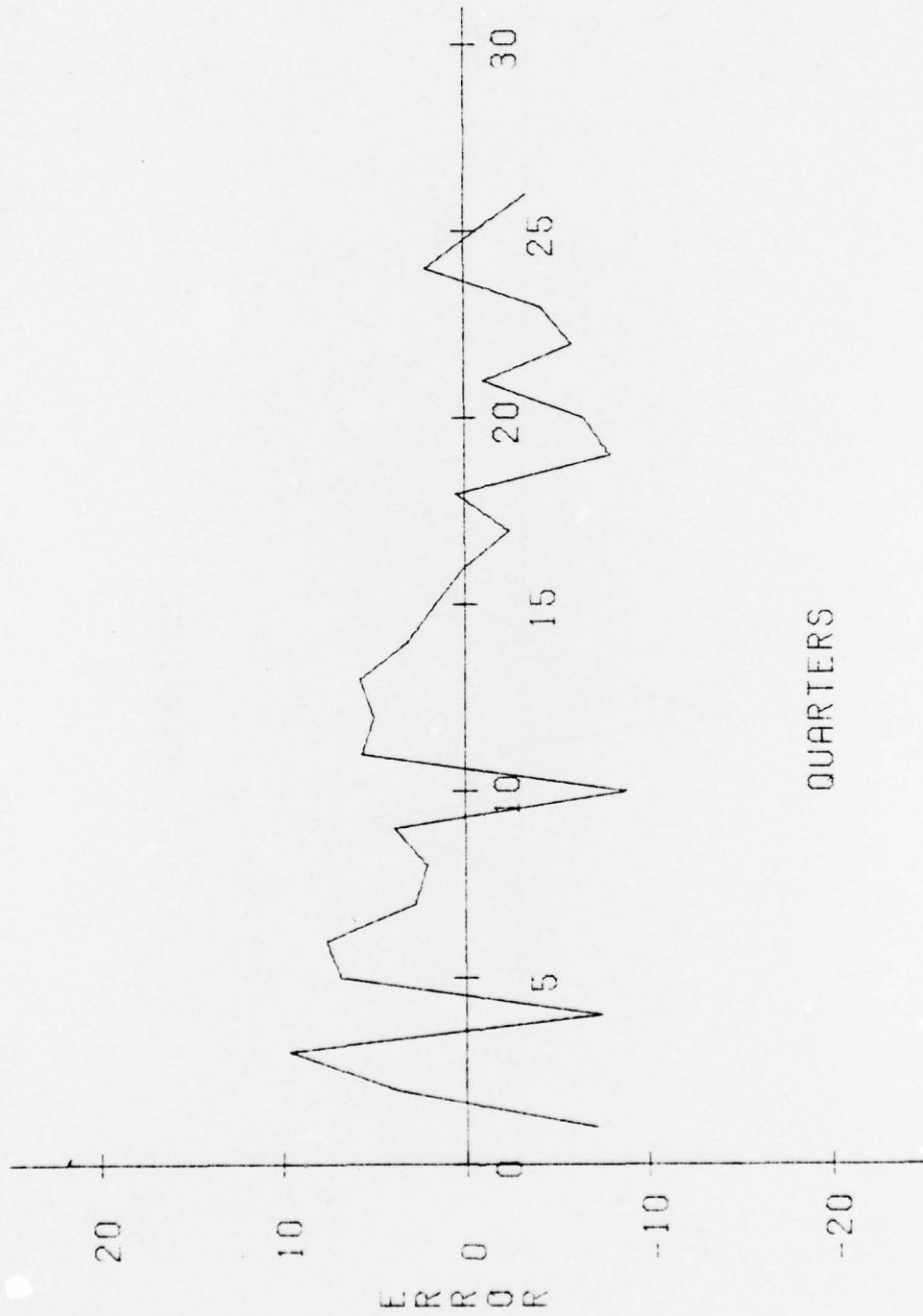


FIGURE C-22 TCAST ERROR OVER TIME FOR LEAD TIME 2

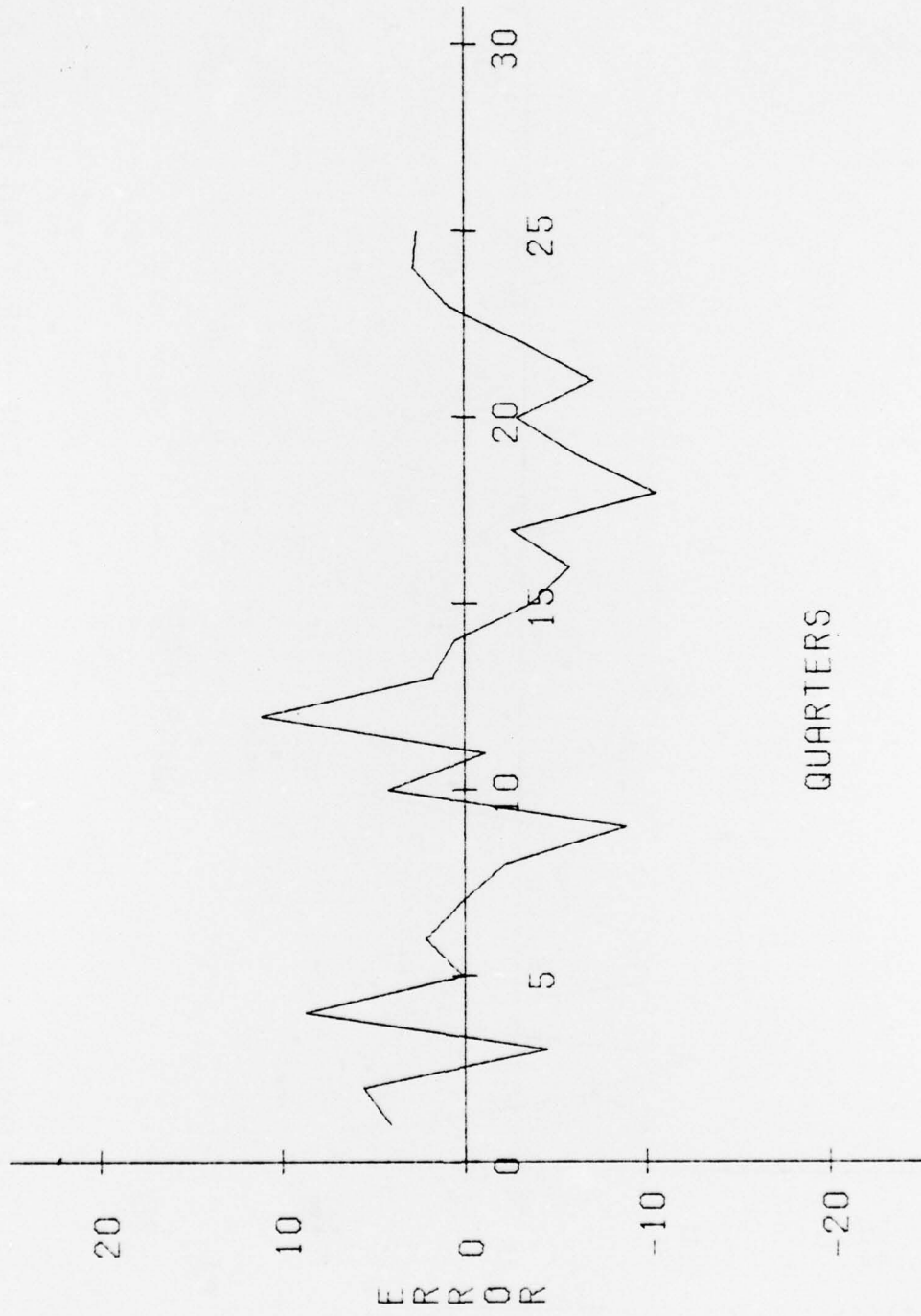


FIGURE C.23 TCAS ERROR OVER TIME FOR LEAD TIME 3

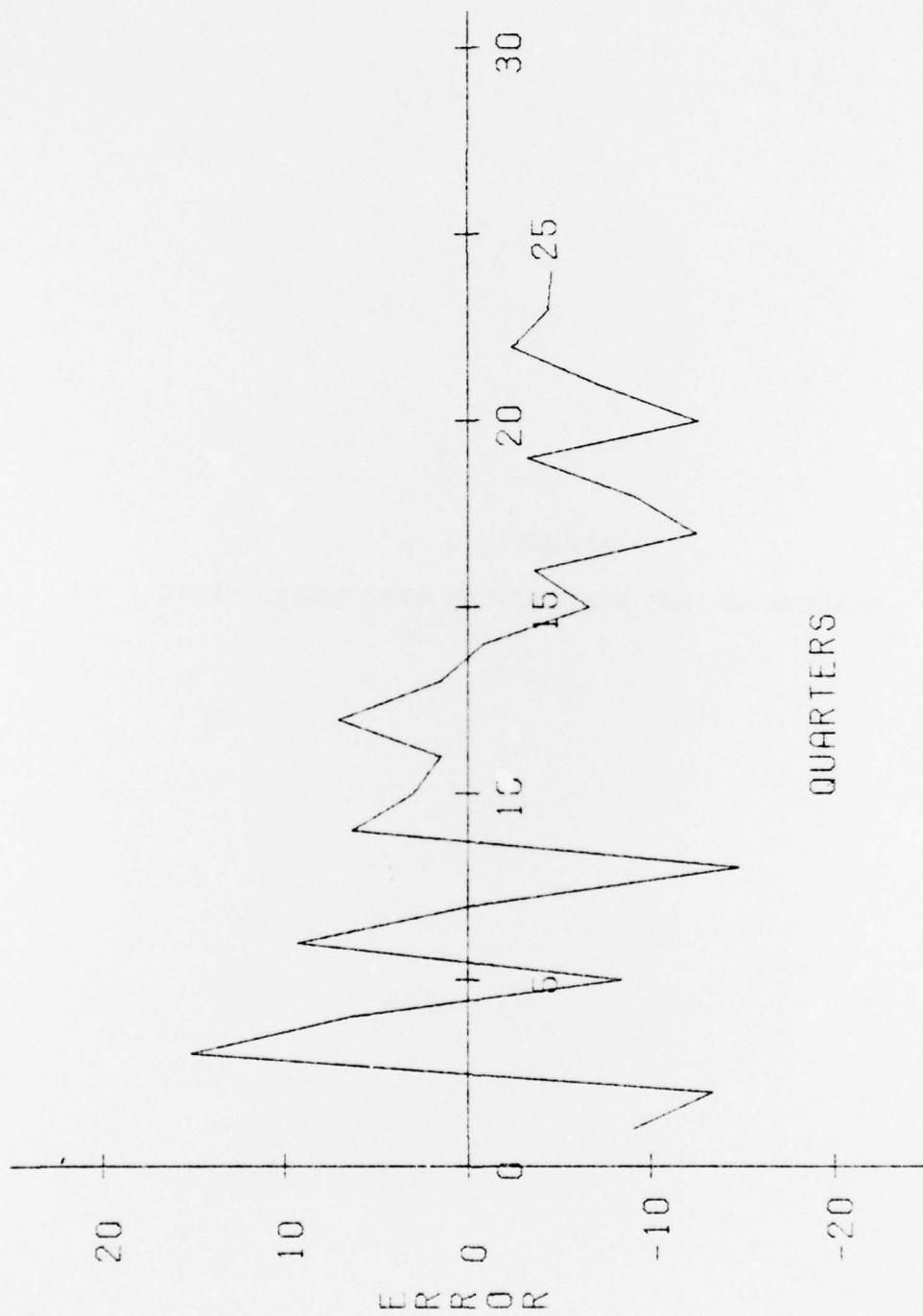


FIGURE C.24 TCAS ERROR OVER TIME FOR LEAD TIME 4

APPENDIX D  
RESULTS OF THE STATISTICAL HYPOTHESIS TESTS

This appendix tabulates (see Tables D.1, D.2, and D.3) the following information used in, and resulting from, the statistical hypotheses test:

1. The mean forecast error for each error distribution.
2. The variance of each distribution.
3. The standard deviation for difference between the means for each lead time.
4. The standard error of the difference between the means for each lead time.
5. The number of observations for each distribution.
6. The Student t Test Statistic computed as follows:
  - a. For the D041 and TCAST error distribution;  
$$t = \frac{\text{distribution means} - \text{hypothesized mean}}{\text{distribution standard deviation}}$$
  - b. For the comparison of the two methods;  
$$t = \frac{\text{difference between error distribution mean}}{\text{standard error of the difference between the means}}$$
7. The confidence level at which the null hypothesis could be rejected.

TABLE D.1  
D041 HYPOTHESIS TEST RESULTS

Lead Time	Mean Error	Variance	Standard Deviation	Number of Observations	Test Statistic	Confidence Level for Rejecting $H_0$
1	.517	55.897	7.476	30	.379	.32
2	.883	62.536	7.908	29	.601	.44
3	1.650	75.031	8.662	28	1.008	.69
4	2.178	82.248	9.669	27	1.248	.78

TABLE D.2

## TCAST HYPOTHESIS TEST RESULTS

Lead Time	Mean Error	Variance	Standard Deviation	Number of Observations	Test Statistic	Confidence Level for Rejecting $H_0$
1	-.096	38.827	6.231	27	-.416	.32
2	.269	28.174	5.308	26	.258	.20
3	-.516	27.363	5.231	25	.493	.34
4	-2.558	61.376	7.834	24	-1.600	.87

TABLE D.3  
 FORECASTING METHOD COMPARISON HYPOTHESIS TEST RESULTS

Lead Time	Degree of Freedom	Standard Error of the Difference Between the Means	Test Statistic	Confidence Level for Rejecting $H_0$
1	55	1.865	.225	.18
2	53	1.871	.328	.25
3	51	2.032	.558	.42
4	49	2.440	-.156	.14

SELECTED BIBLIOGRAPHY

A. REFERENCES CITED

1. Belden, Colonel David L., and Ernest G. Cammack. National Security Management: Procurement. Washington, D.C.: Industrial College of the Armed Forces, 1973.
2. Box, George E. P., and Gwilym M. Jenkins. Time Series Analysis Forecasting and Control. San Francisco: Holden-Day, Inc., 1970.
3. Christensen, Captain Bruce R., USAF, and Gene J. Schroeder. "Comparative Analysis of D041 System and Time-Series Analysis Techniques for Forecasting Repairable Generations." Unpublished masters thesis, Air Force Institute of Technology, School of Systems and Logistics (AU), Wright-Patterson AFB, Ohio, 1976.
4. Clark, Charles T., and Lawrence L. Schkade. Statistical Methods for Business Decisions. Chicago: South-Western Publishing Company, 1969.
5. Clevenger, Anita. Inventory Management Specialist, Policy and System Division, HQ AFLC, Wright-Patterson AFB, Ohio. Personal interviews conducted intermittently from 11 August 1976 to present.
6. Cook, Marvin. Inventory Specialist, Policy and Systems Analysis Division, HQ AFLC, Wright-Patterson AFB, Ohio. Personal interviews conducted intermittently from 4 June 1976 to present.
7. DeLuca, Major General Joseph R. "Supply Support," Air University Review Magazine, July-August, 1969.
8. England, Wilbur G., and Michiel R. Leenders. Purchasing and Materials Management. Homewood, Illinois: Richard D. Irwin, Inc., 1975.
9. Lum, M. D., L. L. Blair, and J. R. Stuart. "Predictive Techniques Study, Phase I: Comparison of Some Forecast Methods." Operations Analysis Report No. 10, Operations Analysis Office, HQ AFLC, Wright-Patterson AFB, Ohio, 1970.

10. Mason, Robert D. Statistical Techniques in Business and Economics. Homewood, Illinois, 1967.
11. Sims, Robert L. "Routine Forecasting for Inventory Control." Technical Report SLTR 21-70, AFIT/SL, Wright-Patterson AFB, Ohio, 1970.
12. U.S. Department of the Air Force. AFLCM 57-3, Recoverable Consumption Item Requirements System (D041). Change 1, Appendix 4, 19 June 1973.
13. Yamane, Taro. Statistics: An Introductory Analysis. New York: Harper & Row, 1967.

#### B. RELATED SOURCES

- Brown, Robert Goodell. Smoothing, Forecasting and Prediction of Discrete Time Series. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1963.
- Burt, Lieutenant Colonel David N. "Acquisition: A Dynamic Process," Military Environment and Decision Making, Air War College, 1975.
- Carpenter, Lieutenant Colonel Gordon L. "Air Force Parts Control Program," Defense Industry Bulletin, Fall, 1971, pp. 26-29.
- Cody, Major General Joseph J. "The Changing Emphasis on Reliability," Supplement to the Air Force Policy Letter for Commanders, July, 1971, pp. 15-16.
- Feeney, G. J., J. W. Peterson, and C. C. Sherbrooke. "An Aggregate Base Stockage Policy for Recoverable Spare Parts." Unpublished Research Report No. RM-3644-PR, Rand Corporation, Santa Monica, California, 1963.
- Forrester, Jay M. Industrial Dynamics. Cambridge, Massachusetts: The M.I.T. Press, 1965.
- Garrett, Leonard J., and Milton Silver. Production Management Analysis. New York: Harcourt Brace and World, Inc., 1966.
- Herholz, Major Paul R., Jr. "Cost Estimating Techniques for Systems Acquisitions," Defense Industry Bulletin, December, 1970, pp. 16-19.

- Kast, Fremont E., and James E. Rosenzweig. Organization and Management. New York: McGraw-Hill Book Co., 1974.
- Laird, Melvin R. "Management in the Defense Department," Defense Industry Bulletin, April, 1970, pp. 43-66.
- Langtry, Colonel J. O., Australian Staff Corps. "The Impact of Socio-Political and Socio-Economic Trends on the Environment of the 1980's," Alternative Future Worlds. Air War College, 1975, pp. 10-11.
- Magee, John F., and David M. Boodman. Production Planning and Inventory Control. New York: McGraw-Hill, Inc., 1967.
- Meditch, J. S. Stochastic Optimal Linear Estimation and Control. New York: McGraw-Hill, Inc., 1969.
- Nelson, Charles R. Applied Time Series Analysis. San Francisco: Holden-Day, Inc., 1973.
- Niswonger, C. Rollin, and Phillip E. Fess. Accounting Principles. Cincinnati, Ohio: South-Western Publishing Company, 1973.
- Orr, Donald. "Demand Forecasts Using Process Models and Item Class Parameters: Application of Ancillary Variables." Unpublished research report no. 219, DRC Inventory Research Office, Frankford Arsenal, Pennsylvania, April, 1976.
- Pearson, Major John M. Assistant Professor of Operations Research, Air Force Institute of Technology, School of Systems and Logistics, Wright-Patterson Air Force Base, Ohio. Intermittent personal interviews, June 1976 to October 1976.
- Quade, E. S., and W. I. Boucher. Systems Analysis and Policy Planning: Applications in Defense. New York: American Elsevier Publishing Company, Inc., 1968.
- Reilly, David P. "Box-Jenkins for the Layman," Technical Paper, Celanese Corp., New York, N.Y., 1975.
- U.S. Department of the Air Force. Policies, Responsibilities, and Guidelines for Determining Materiel Requirements. AFM 57-1. Washington: Government Printing Office, 1972.

U.S. Department of the Air Force. Supply Management Reference Book. AFPAM 67-2. Washington: Government Printing Office, 1971.

U.S. Air Force Logistics Command. Determinants of Requirements of Initially Provisioned Items. AFLCR 57-27. Wright-Patterson AFB, Ohio, 1972.