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A RESPONSE SURFACE APPROACH  
TO THE COMBAT RESCUE AND  
SPECIAL OPERATIONS  
SIMULATION MODEL

THESIS

Steven Harris

Captain USAF

AFIT/GOR/ENS/89M-1

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**AIR FORCE INSTITUTE OF TECHNOLOGY**

Wright-Patterson Air Force Base, Ohio

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Presented to the Faculty of the School of Engineering  
of the Air Force Institute of Technology  
Air University  
in Partial Fulfillment of the  
Requirements for the Degree of  
Master of Science in Operations Research

Steven Harris B.A.

Captain USAF

March 1989

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## Preface

I would like to thank God and the following individuals for their support:

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Abstract

This thesis proposes a methodology for producing response surface metamodels to enhance the force sizing capability at Military Airlift Command. Output generated by the Combat Rescue and Special Operations Forces simulation model was used to develop the sets of predictive response equations. The methodology produced statistically good predictive metamodels using a Box and Behnken fractional factorial. Multivariate techniques were used to reduce the dimensionality of the responses modeled by the simulation model to further enhance the decision making process on force sizing issues.

*Keywords: Response surface methodology,  
simulation model, Computer program,*

## I. PROBLEM FORMULATION

### Introduction

➤ Currently Air Force special mission aircraft capability is measured using Headquarters Military Airlift Commands Combat Rescue And Special Operations Forces (CRASOF) simulation model. This model measures capability in terms of the number of successful rescue and special operations sorties successfully flown by assigned aircraft. The special missions used to determine a given force structure capability for any scenario are the airlift support provided for; infiltration, exfiltration and the resupply of special forces, combat rescue of downed aircrews, and refueling of special mission aircraft.

The analysis process used during force sizing exercises involves specifying types and numbers of aircraft and making several simulation runs using the CRASOF simulation model to determine the mission capability of each of the separate force sizes. On the basis of the simulation output and certain constraints e.g., budgetary constraints, the different force structures are rank ordered in terms of preference. This entails loading separate data files for each run, compiling the output into a usable format, and briefing results.

### Research Problem

The CRASOF analysis process is very time consuming. Problems occur when computer processing time is not available, and questions on capability of proposed force sizes are not answered in an expeditious way.

### Research Question

Given the output data generated by CRASOF, is there a method which when used in the force sizing analysis process expedites the analysis process?

### Scope and Limitations

This research will demonstrate the utility of using response surface metamodels to enhance the force sizing analysis process at Hq MAC. The research conducted will use unclassified scenarios from the CRASOF simulation model to generate the required data.

The research conducted will not attempt to generate concrete solutions to various force sizing issues. The unclassified response surfaces resulting from this research will be used to demonstrate the utility of using response surface methodology in conjunction with CRASOF at Hq MAC.

### Research Methodology

The second chapter is a literature review of current methods used for response surface derivations.

The third chapter provides an overview of how the simulation model CRASOF is structured. The variety of uses for CRASOF are then discussed and finally a summary of how the CRASOF simulation model has been validated.

Chapter four presents the response surface design and the methods used to verify the response surfaces adequacy. An explanation of the scenario data used and the set up of the experimental design is given also. Relevant factors are evaluated in detail using several of the methods expanded on in the literature review.

The fifth chapter goes into further analysis of the input factors and output factors combined and evaluated from a multivariate point of view. Factor Analysis methodology is used.

Chapter six consolidates the results of chapters four and five and presents individual results pertaining to the validity of the response surfaces generated in this research. In addition insights brought out by the multivariate analysis are presented.

Chapter seven summarizes the objectives of the research and the insights resulting from the research. Recommendations for the use of metamodels with CRASOF are made and recommendations for further study are presented.

## II. Literature Review

### Scope

The goal of this research is to demonstrate the utility of using a combined modeling approach for force sizing analysis. The combined modeling approach is the use of any analytic auxiliary model, metamodel, which is used to aid in the interpretation of a more detailed model (Freidman, 1988;p939).

### Organization

This literature review includes a brief overview of what response surface methodology is. The discussion will cover some of the more current research in response surface methodology applied to simulation analysis. The next topic discussed will be the use of experimental design in metamodel building. An overview of different techniques available for the verification and validation of response surface models is then examined. The conclusion will tie together the aspects of the discussion applicable to this research.

### Discussion

Experimental Design. Before a metamodel can be computed, attention should be focused on the collection of data from the simulation model. Data is collected over several runs of the simulation by varying the values of inputs and then observing the corresponding responses. Experimental design is used to methodically change the value of inputs to gain as much insight as possible about the sensitivity of responses to input changes (Kleijnen 1987;259).

Key Terms. Two basic terms associated with the design of experiments are factor and level. The inputs to a simulation program are called factors in the experiment. Factors include parameters, variables, and behavioral relationships that can

change during or before the running of a simulation. Parameter changes in CRASOF can be associated with changing the theater of operation that is modeled. The variables for the purpose of this research are the types of aircraft used in each theater scenario. These inputs are also called independent factors. The simulation output used as the measure of capability, number of successful missions, is the response or dependent factor. Behavioral relationship factors for CRASOF are the ways in which the aircraft prioritize the completion of the different mission types..

The values of a factor over the runs of a simulation are called the levels of the factor. The number of factor levels is important in determining the number of simulation runs required to extract information on response sensitivity. For an experimental design with number of levels,  $L$ , greater than or equal to 2 and number of factors,  $K$ , greater than or equal to 2, the number of runs is equal to  $L^K$ . The number of levels greater than or equal to 2 generates a readily apparent problem. The problem is "...the exponential growth in the number of runs as the number of factors  $K$  grows," (Kleijnen, 1987; 259). If the number of factors is small, then the number of runs required is manageable (Law and Kelton, 1982; 377). Once the number of factors  $K$  begins to grow the use of various techniques in design of experiments can reduce the number of runs.

Design Approaches. There are three distinguishable approaches to the design of experiments; one factor at a time, all factor level combinations, and specially selected combinations (Kleijnen, 1987; 260).

The one factor at a time approach involves holding all but one of the factors at a base value and the other factor is then varied at different levels. This strategy is repeated to examine each of the input factors one at a time. If the number of factors is greater than 2 this approach can be very inefficient (Law and

Kelton, 1982; 372).

The second approach is the full factorial or all factor level combination method. This method requires many more combinations than does the one factor at a time method. Two benefits result from the use of full factorials (Kleijnen, 1987; 269). As the number of runs increases, the variance,  $\sigma^2$ , decreases dramatically. This is not the case in the first approach where variance remains constant. The second benefit is the effectiveness in using a full factorial. The first approach results in only the estimation of the  $K + 1$  factor effects. Using the full factorial, interaction effects are also estimated. Full factorials are excellent for use if the key factors are unknown and the research is attempting to find significant factor effects.

If certain interactions are known to be insignificant, then the incomplete or fractional factorial approach can be used. The fractional factorial has the same efficiency as the full factorial (Kleijnen, 1987; 270). A key point to remember when using fractional factorials is to use the correct design when estimating effects. Factor effects can be confounded or unseparable from other effects giving misleading results. To avoid this problem, fractional designs with specified resolution are used to insure no confounding of effects of interest. The resolution,  $R$ , of an experiment with  $p$  factors is the number of effect types not confounded with any other effects having  $R-p$  factors (Smith and Mauro, 1984; 255). An example would be a  $2^{8-4}$  resolution 4 design where  $R$  equals 4, and  $p$  equals 8. Any effect with 8 minus 4 factors will not be confounded with any other effect with less than 4 factors.

Design Planning. When designing a simulation experiment the assumptions made prior to initial simulation runs are crucial

to the experimental design (Steinberg and Hunter, 1984; 77). It is important to evaluate the sensitivity of the experimental design to the assumptions made prior to design creation. The term used to describe this sensitivity is robustness. Assumptions in experimental design are necessary when uncertainty exists as to the structure of the true response model. Steinberg and Hunter (1984) suggest three types of designs that can provide insight into model building when no clues exist concerning the structure of the model.

The first design is a model-robust design. Box and Draper (1959) state that model-robust designs focus on minimum average mean square error as it relates to the bias of a proposed model. The minimum biased design tends to make the analysis robust or insensitive to inaccuracies in the proposed response model (Steinberg and Hunter, 1984; 77).

When considering the error term of the response model, the assumption is that the error term is independent and identically distributed (Draper and Smith, 1981; 23). Error-robust designs deal with misjudgement in the assumptions about the error distribution. Box and Draper (1975) suggest ways in which robustness to error assumptions can be made.

If the assumptions made are reasonably valid and the goal is to search through models until an acceptable model is found, then model-sensitive or non-robust designs are required. The search for an appropriate model is done by "... highlighting the uncertainties and inaccuracies in order to modify or refine the proposed model," (Steinberg and Hunter, 1984; 78). The key assumption made in this research is that a proposed experimental design matrix with responses can be adequately described as

$$\text{response} = \text{model} + \text{error}.$$

Model-sensitive designs are appropriate when searching for the best predictive model. The ability to produce sensitivity in

response variables through changes in input factor levels is a key component of response surface analysis (Kleijnen, 1987; 261).

Response Surface Methodology. Response surface methodology or regression analysis, is a statistical tool which uses the interaction between two or more quantitative variables, so that one variable can be predicted based on the value of the other(s) (Neter, 1974;p21). There are two concepts that are basic to response models:

- (1) A tendency for the dependent variable,  $Y$ , to vary with the independent variable(s),  $X_i$ , in a statistical way,
- (2) A scattering of observed values of  $Y$  around the curve of statistical relationship (Neter, 1974;p21).

The relationship between the dependent and independent variables is denoted by,

$$Y = B_0 + B_i X + \varepsilon_i \quad (1.1)$$

where,  $Y$  is the dependent variable of interest

$X$  is the set of known constant values of the independent variables

$B_0$  and  $B_i$  is the set of parameters

$\varepsilon_i$  is the true error or deviation in the regression model

( $\varepsilon_i$  is assumed to be independent, normal random variables, with mean equal to zero and constant variance  $\sigma^2$ )

(Box and Draper, 1981; 9).

Given that the data is readily available, through simulation, the only unknowns are the  $B_0$ ,  $B_i$ , and  $\varepsilon_i$ . A good way to determine estimates  $b_i$ 's of the  $B_i$ 's is to use the method of least squares (Draper, 1981;p8). The method of least squares evaluates the deviation of  $Y$  from its expected value,  $E(Y)$ ,

$$Y - (B_0 + B_i X) = \hat{\varepsilon}_i \quad \text{for, } i = 1 \dots n \quad (1.2)$$

Taking the sums of the squared deviations from the true model,

$$S = \sum (\hat{\varepsilon}_i^2). \quad (1.3)$$

The best values for  $b_0$  and  $b_i$  are those values which minimizes the value of  $S$ , the sum of the squared deviations. Once the estimators  $b=(b_0, b_1, \dots, b_n)$  have been computed, the regression equation

$$E(Y) = Y = B_0 + B_i X \quad (1.5)$$

can be estimated by the parameters  $b$  in the least squares regression equation,

$$\hat{Y} = b_0 + b_i x_i. \quad (1.5)$$

$\hat{Y}$  is denoted as the fitted or predicted value of the independent variable  $Y_i$  based on the estimators  $b_0$  and  $b_i$  for a given set of  $x_i$ . The response equation, 1.5, is then evaluated in several ways to determine its accuracy and applicability for its derived use (Draper and Smith, 1981; 17).

Applications. Response surface methodology has been used in a number of studies in recent years covering a broad spectrum of topics including manpower issues and force structure procurement issues. Several specific topics are covered here to give an idea of the capability of response surface methodology to enhance the analysis process when correctly applied.

Kraus (1986), in a thesis that upgraded the capability of CRASOF to handled more realistic scenarios, used response surface analysis in his analysis of the new simulation model. Three basing options were studied on the basis of analysis of eight response variables. How well each basing option met the mission priorities was the measure of effectiveness. The goal was to find a maximizing function of basing locations for each of the three theater scenarios modeled.

McKoy (1988), used response surface methodology to help develop goals for a goal programming problem that dealt with manning issues for helicopter pilots. Response surface methodology produced equations from simulation data that were interpreted as policy variables. The policy variables were later

used in a goal programming optimization program.

Percich (1987), applied response surface methodology to a manpower issue that dealt with strategic airlift pilots. Percich developed two response surfaces. Then using techniques described later in this research he was able to produce an analytic submodel that replicated the results produced by the simulation model which produced the original data. Further reading on other than military uses of response surface methodology can be found in Draper (1981; 691-692).

Verification. When response surface methodology is applied to simulation output data to produce a metamodel, a model of the output from another model (Freidman and Pressman, 1988; 939), close attention must be paid to the validity and adequacy of the metamodel. A key point to remember when dealing with metamodels is "the metamodel supplements, not replaces, the decision model by simplifying the sensitivity calculations "(Blanning, 1974: 37). Since the objective of this research is demonstrating the utility of response surface metamodels applied to CRASOF, the following review covers aspects of checking the adequacy and validity of metamodels as predictors of simulation models.

Metamodel adequacy checking or model verification involves checking for lack of fit, residual analysis, and the determination of independent factors that influence the response (Montgomery and Peck, 1982; 42).

Lack of fit in a response equations is a significantly different value for the residual mean square error compared to a prior estimate of the true variance. A key component of lack of fit testing is to remember that the best fit does not always imply the best predictor. For example a metamodel may have been developed primarily for predicting new observations for a particular system, however, factors that were not known during metamodel building could play a significant role in the predicted

response. This could cause predictions of the misspecified model to be inaccurate and useless (Montgomery and Peck, 1982; 424). A lack of fit test can only be conducted if there are repeat observations made for a given input level or design point. When designing your experiment and you have available exact repeats the following four steps as outlined can be used for lack of fit testing (Draper and Smith, 1981; 40).

1. Fit the model, compute the usual anova table with regression and residual entries. Do not perform a F-test for overall regression yet.

2. Separate out the pure error and lack of fit sums of squares from the residuals. If no pure error check via residual plots instead.

3. Perform the F-test for lack of fit. If significant lack of fit is exhibited, go to 4a. If the lack of fit test is not significant, so that there is no reason to doubt the adequacy of the model go to 4b.

- 4a. Significant lack of fit. Stop the analysis of the model and seek ways to improve the model by examining residuals. At this point transformation and/or the addition of higher order terms may be needed. Do not carry out the F-test for overall regression, do not attempt to obtain confidence intervals. The assumptions on which these calculations are made are not true if there is lack of fit in the model fitted.

- 4b. No significant lack of fit. Recombine the pure error and lack of fit sum of squares into the residual, use the residual mean square as an estimate of variance,  $V(y)$ . Carry out F-test for overall regression, obtain confidence intervals for the true mean value of Y, evaluate R-square, and so on. Note the residuals should still be plotted and checked for peculiarities. (Draper and Smith, 1981; 40).

The next step in verification is residual checking. Residuals are defined as

$$e_i = Y_i - \hat{Y}_i \quad (1.6)$$

where  $i=1,2,\dots,n$  and  $Y_i$  is the response observed in your data and  $\hat{Y}_i$  is the value generated by using the regression equation fitted to the input data. This difference  $e_i$  is the amount of information not explained by the regression equation. Examining residuals will result in either rejecting or not rejecting the assumptions made about the metamodel. Two plots of  $e_i$  can be made that are applicable to this research;  $e_i$  vs  $\hat{Y}_i$ , and the overall plot which can be constructed as a normal or half-normal plot. Examination of residuals and comparison with known tendencies of plots of incorrect regressions will lead to reexamination of the metamodel or continuing on with your analysis.

Independent factors is another method of determining the adequacy of the metamodel is to examine the independent factors from your data set to find the best subset of factors. One way of examining these factors is the the use of Mallows  $C_p$  statistic (Draper and Smith, 1981;p175). The complete equation for Mallows statistic is

$$C_p = \text{RSS}_p / s^2 - (n-p) \quad (1.7)$$

where  $n$  is the number of observations taken. The  $C_p$  statistic is compared with  $p$  and the closer the ratio of  $C_p$  to  $p$  is to one, the better the metamodel with  $p$  parameters is. Another method of discerning the utility of a metamodel with the  $C_p$  statistic is to plot the  $C_p$  statistic for several metamodels against the  $E(C_p)=p$  line. This line can be used as a bench mark for tradeoffs in that the  $C_p$  statistic "... is an estimate of the overall sum of squares

of discrepancies, variance error plus bias error, of the fitted model from the true model" (Draper, 1981;p300). The tradeoff comes from being able to chose a biased metamodel that has a larger  $RSS_p$  where  $C_p$  is less than  $p$ , but an estimated variance error plus bias error smaller than the true models. Or a choice can be made for a metamodel with more parameters that fits better but has a larger variance error plus bias error than does the true model.

Another relevent method of independent factors analysis is stepwise regression in cunjunction with  $R^2$  analysis. Stepwise regression is accomplished by inserting variables into the regression equation and checking the inserted variables correlation with the output response. The higher the correlation the better the chance of the variable staying in the equation. The variable input is regressed on by the output variable and a F-test is done to check the significance of the input variable. If the F-test is significant the variable stays in the response equation. The next input variable with the highest correlation to the response, taking into account the input variable already regressed, is added to the equation and the F-test is conducted again. Also a  $R^2$  measure is taken which is the percentage of variation explained by the regression equation,  $R^2$  is equal to the (sum of squares due to regression)/(total sums of squares, corrected for the mean) or

$$R^2 = \frac{\sum(\hat{y}_i - \bar{Y})^2}{\sum(y_i - \bar{Y})^2} \quad (1.8)$$

This process continues until no other input variables can enter the regression equation and the process stops.

Validation. When the adequacy of the metamodel has been determined, the final process is determining the validity of the metamodel. A question that arises while checking metamodel validity is: "Are the conclusions drawn from this metamodel applicable only to the simulation model or, by extension, given the validity of the simulation model, may they be applied to the real-world system under study?" (Freidman, 1988;p940). One way to determine the answer to this question is to use new data and derive predicted responses using the metamodel, then compare these responses to those from the simulation model and make inferences about validity.

Here are two methods commonly used to validate models; analytical validation which is checking each part of the model, and synoptic validation which is insuring that an acceptable response is achieved for each of a set of inputs (Finlay and Forey, 1988; 935). Sargeant (1987) refers to synoptic validation as operational validation and discusses forms of operational validation. Some of the ways in which operational validation can take place are; (1) predictive validation where the model is used to forecast system behavior and comparisons are made to actual system behavior (simulation results), (2) face validity where people knowledgeable about the system under study determine whether the behavior is reasonable, (3) data splitting or historical data validation is setting aside some of the original data to build the metamodel and using the remaining observations to investigate the models predictive performance (Sargeant, 1987; 34). Any of the above methods can be used to accomplish validation. The best hedge against poor validation is the use of at least two of the validation approaches so that there is an overlapping of coverage in validation leading to the models acceptance. For the purposes of this research, the operational approach will be used. "Operational validity is primarily

concerned with determining that the model's output behavior has the accuracy required for for the model's intended use..." (Sargeant, 1987; 35). At least two sets of experimental data should be used in operational validation when comparing output from the metamodel and the system under study. Three basic approaches to comparison of the metamodel with the system model are;

- (1) graphs of the system behavior versus the metamodel behavior,
- (2) confidence intervals, and
- (3) hypothesis tests.

Summary. Mckoy (1988) employs a methodology which is appropriate for use in handling the verfication portion of this research. The methodology he uses is taken from Bauer (1988) and is listed at figure 1.

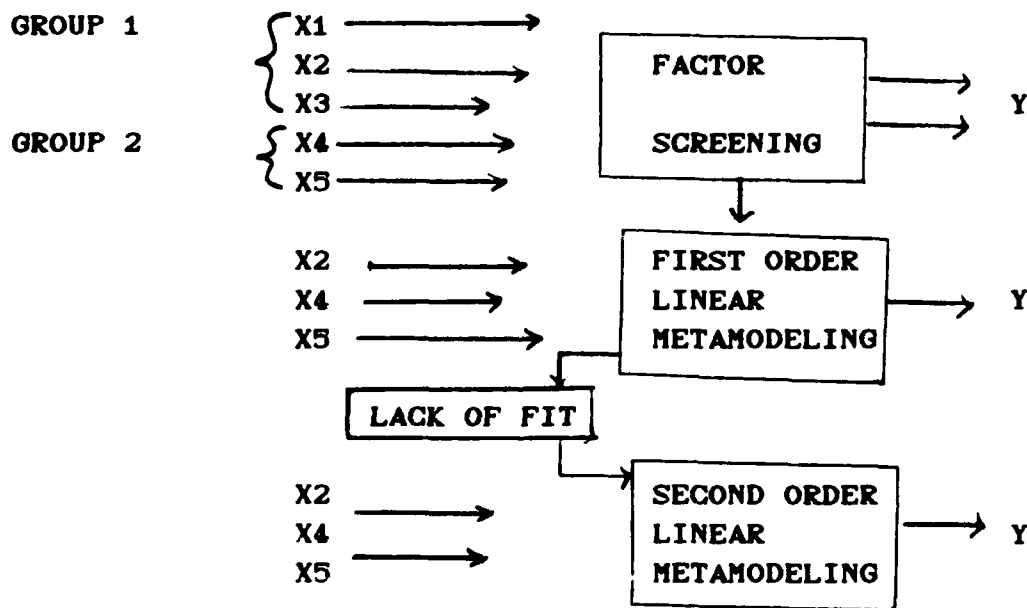


Figure 2-1 Meta Modeling Building  
Bauer (1988)

This method incorporates using stepwise regression to accomplish screening of significant factors out of the input data. Because

simulation data is used for input data, replications can be generated by manipulating the random number seeds when running the simulation. The replications built into the model design can be used to conduct lack of fit tests. The stepwise regression program which is accomplished using the Statistical Analysis System (SAS), will also conduct lack of fit tests and compute  $R^2$ . SAS also computes residuals for performing the residual plots. Independent factors will also be analyzed using multivariate techniques discussed in chapter five. The validation phase will be accomplished using graphical and predictive analysis.

### III. Current Implementation

#### Introduction

This chapter will provide a brief history of CRASOF and its previous uses. The discussion will expand on the structure and flow of the CRASOF simulation code, input data files and output data files.

#### Model Variations

The CRASOF simulation model was developed over a period from 1983 to 1984 under the direction of Hq MAC/XPS. The original simulation model was developed to study aircraft tanker refueling requirements for special mission aircraft. The model developers, while meticulous in their development of the air refueling logic, decided to make the simulation model flexible enough to answer other airlift questions (Kraus, 1986; 26).

After the models development and acceptance for use in performing the tanker force requirement study, the model was used to accomplish the Combat Rescue and Air Force Special Operations Force Minimum Risk Forces Study for Hq MAC/XP in 1985 and 1986. During this time period the model was coded using FORTRAN and Simulation for Alternative Modeling, SLAM. The CRASOF simulation model used at that time was set up to operate forces from one basing location at a time which lead to certain assumptions having to be made to account for the co-location of aircraft assets.

Kraus (1986) completed a thesis study that revised CRASOF to operate as a multi-basing type simulation. The new version more realistically represented the scenarios under study. This new version of CRASOF was used at Hq MAC/CAAG until 1987. With the ability to distribute aircraft within a given scenario, CRASOF was considered a more reliable or valid simulation model. However, with the development of the multi-basing mode, the run time for

CRASOF increased dramatically which slowed down the analysis process of providing accurate yet timely information to decision makers.

In 1987 work was begun to recode the multi-basing mode version of CRASOF to FORTRAN using SIMLIB. SIMLIB is based on the concept of linked storage allocation, which makes it easier to manipulate records (Law and Kelton, 1982; 65). The programming changes made to CRASOF, were made to make the program more versatile from a hardware perspective in that it could now be used on stand alone personal computers with sufficient memory. The data files read by the SIMLIB subroutines give analysts using CRASOF the ability to manipulate aircraft forces during the actual run time of the simulation (Neimeyer, 1987). Even though the set-up time for CRASOF simulations runs was reduced, total run time was still at an undesirable level for short notice analysis work (Neimeyer, 1987).

### Model Structure

The source code for CRASOF is primarily used to call the different SIMLIB subroutines and input files as well as the user written subroutines.

Program Code. Once the SIMLIB subroutines are initialized, the user written subroutines take over to simulate the scenario desired. The user written subroutines can be divided into four sets of subroutines; flying operations figure 3-1, mission generation figure 3-2, statistic manipulation figure 3-3, and scenario environment figure 3-4.

| SUBROUTINE | USE                                                                  |
|------------|----------------------------------------------------------------------|
| Search     | Look for best aircraft/tanker for the mission.                       |
| Plane      | Finds closest base with correct mission aircraft.                    |
| Gofly      | Assigns aircrew and handles report of mission from start to finish.  |
| Seize      | Allocates additional resources required for a mission.               |
| Losses     | Identifies aircraft attrition.                                       |
| Arspot     | Determines additional refuelings required after tanker is in the air |
| Artank     | Sets up refueling schedule for primary aircraft assigned a mission.  |
| Lastar     | Computes distance flown by aircraft and amount of fuel remaining.    |

Figure 3-1, Flying Operations.

| SUBROUTINE | USE                                                                 |
|------------|---------------------------------------------------------------------|
| Newmsn     | New mission arrival at start of day.                                |
| Addmsn     | Missions generated from prior missions.                             |
| Makecr     | generates missions caused by attrition of special mission aircraft. |
| Flyem      | Execute missions scheduled.                                         |

Figure 3-2, Mission Generation.

| SUBROUTINE | USE                                                             |
|------------|-----------------------------------------------------------------|
| Flush      | Attempt made to satisfy all missions built up in the queues.    |
| Stat       | Statistics collected on all aspects of a mission.               |
| Release    | Releases crews and aircraft after mission completion and maint. |
| Begday     | Beginning of statistics for a given day.                        |
| Endday     | End of day statistics for a given day                           |

Figure 3-3, Statistic Collection

| SUBROUTINE | USE                                                       |
|------------|-----------------------------------------------------------|
| Wxdelay    | Check for weather delay at takeoff.                       |
| Wmabort    | Check for weather while inflight also mechanical failure. |

Figure 3-4, Scenario Environment.

Model Inputs. CRASOF can simulate winter or summer conditions for a given scenario. The theaters that can be modeled with CRASOF are Europe, the Pacific, and Centcom. The initialization data for CRASOF is located in four separate

input data files. To keep this research unclassified, fictitious force sizes were used and located at basing locations within the theaters without reference to actual wartime basing locations.

The first input data file, BASERXX.DAT, is used for bedding down aircraft resources. This data provides longitude and latitude coordinates for basing. The number of aircraft and aircrews per base are also listed. In addition the simulation run time, number of replications and mid-simulation aircraft changes are controlled from this file.

The second input data file, AREAXX.dat, provides theater unique information on mission priorities for the selected theater. Information on special operations and combat rescue ground missions are held in this file. The file stores probabilities used to determine when mission generation will take place. Mission planning information is also held here. This information is based on historical data and is held constant over all simulation runs.

The third data file is ACFTXX.DAT. This data file handles all information on the attributes of each of the aircraft types. A maximum of ten aircraft types can be modeled at once using this data file. Sixty-two attributes are listed to describe the capabilities of each of the aircraft types.

The last data input file used by CRASOF is the climate controlling file, CLIMXX.DAT. This file lists probabilities for ceiling levels, turbulances, visibility, wind, and precipitation. The probabilities are set for individual basing locations and regional areas that cover several bases.

The primary inputs used as factors for the model are the number of each type aircraft. The number of different aircraft used is five. This hypothetical force is shown in figure 3-5.

| VARIABLE NAME | AIRCRAFT TYPE |
|---------------|---------------|
| X1            | Tilt-roter    |
| X2            | Rotary wing   |
| X3            | Fixed wing    |
| X4            | Rotary wing   |
| X5            | Tanker        |

Figure 3-5 Aircraft Types.

Model Outputs. After completion of a simulation run, statistics are written to an output file. This file holds information on the five measures of capability for each scenario. The five measures are number of successful completions of; infiltration, exfiltration, resupply, combat rescue and refueling missions. Information is also broken out by aircraft type. Figure 3-6 shows the label assignment of each of the five model outputs, and figure 3-7 shows the general flow of the model.

| VARIABLE NAME | DESCRIPTION    |
|---------------|----------------|
| Y1            | Infiltrations  |
| Y2            | Exfiltrations  |
| Y3            | Resupplies     |
| Y4            | Combat Rescues |
| Y5            | Refuelings     |

Figure 3-6 Response Types.

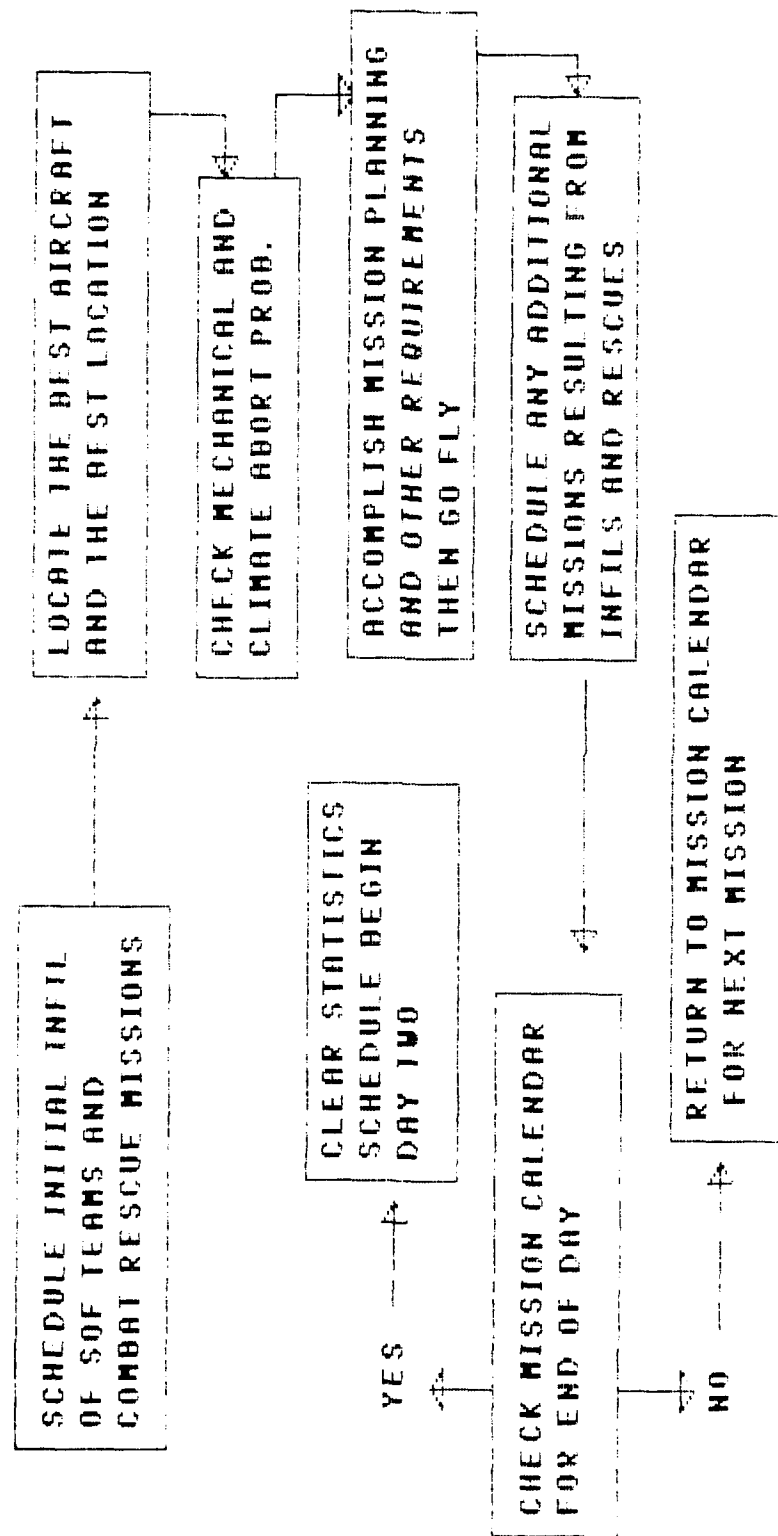


Figure 3-7. CRASOF Flow

## SUMMARY

The CRASOF program with its subroutines and data files is well laid out and easy to manipulate. The acceptance of CRASOF as a valid tool for modeling special mission force requirements, has continued through revisions and upgrades using two different simulation languages. The actual program code and data files are not shown in this study due to their length and a desire of Hq MAC/AGS to control the distribution of the CRASOF programming code. If further information on or a copy of CRASOF is desired, The original code is located at Hq MAC/AGS, Scott AFB, Illinois.

#### IV. RESPONSE SURFACE DESIGNS

##### Introduction

The force size modeled in each theater is a hypothetical force mix of aircraft to avoid classification of this research. The types of aircraft are listed and described in table 3-5. The time duration for each run of the simulation is sixty days. The climate data is set for summer conditions. Aircraft configurations are listed in appendix A. Each run of the simulation produces five output responses, which are listed in appendix B.

##### Experimental Design

The design used in each theater is a three level, five factor, fractional factorial (Box and Behnken, 1960; 455). The three levels were chosen to insure that the linear and second order terms would be estimated without being confounded with each other. It is assumed that all terms above the second order are insignificant i.e., the  $(X_1, X_2, X_3)$  interaction. Orthogonal blocking is used in the design matrix. The orthogonal blocks refer to the columns of the design matrix being perpendicular so that the collinearity between inputs is zero. The orthogonality "...minimizes the variance of the estimates of regression coefficients," (Box and Behnken, 1960; 457). Center design points (inputs values set to mean value for all inputs) are included in the design matrix to produce replicated runs for testing for lack of fit in the derived regression equations. The center points also eliminate the singularity in the design matrix (Box and Behnken, 1960; 464). The design is listed in tables 4-1(a) and 4-1(b), and is the same for the three theaters modeled in this research.

Table 4-1(a) First Orthogonal Block

| RUN | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ |
|-----|-------|-------|-------|-------|-------|
| 1   | -1    | -1    | 0     | 0     | 0     |
| 2   | 1     | -1    | 0     | 0     | 0     |
| 3   | -1    | 1     | 0     | 0     | 0     |
| 4   | 1     | 1     | 0     | 0     | 0     |
| 5   | 0     | 0     | -1    | -1    | 0     |
| 6   | 0     | 0     | 1     | -1    | 0     |
| 7   | 0     | 0     | -1    | 1     | 0     |
| 8   | 0     | 0     | 1     | 1     | 0     |
| 9   | 0     | -1    | 0     | 0     | -1    |
| 10  | 0     | 1     | 0     | 0     | -1    |
| 11  | 0     | -1    | 0     | 0     | 1     |
| 12  | 0     | 1     | 0     | 0     | 1     |
| 13  | -1    | 0     | -1    | 0     | 0     |
| 14  | 1     | 0     | -1    | 0     | 0     |
| 15  | -1    | 0     | 1     | 0     | 0     |
| 16  | 1     | 0     | 1     | 0     | 0     |
| 17  | 0     | 0     | 0     | -1    | -1    |
| 18  | 0     | 0     | 0     | 1     | -1    |
| 19  | 0     | 0     | 0     | -1    | 1     |
| 20  | 0     | 0     | 0     | 1     | 1     |
| 21  | 0     | 0     | 0     | 0     | 0     |
| 22  | 0     | 0     | 0     | 0     | 0     |
| 23  | 0     | 0     | 0     | 0     | 0     |

Table 4-1(b) Second Orthogonal Block

| RUN | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ |
|-----|-------|-------|-------|-------|-------|
| 24  | 0     | -1    | -1    | 0     | 0     |
| 25  | 0     | 1     | -1    | 0     | 0     |
| 26  | 0     | -1    | 1     | 0     | 0     |
| 27  | 0     | 1     | 1     | 0     | 0     |
| 28  | -1    | 0     | 0     | -1    | 0     |
| 29  | 1     | 0     | 0     | -1    | 0     |
| 30  | -1    | 0     | 0     | 1     | 0     |
| 31  | 1     | 0     | 0     | 1     | 0     |
| 32  | 0     | 0     | -1    | 0     | -1    |
| 33  | 0     | 0     | 1     | 0     | -1    |
| 34  | 0     | 0     | -1    | 0     | 1     |
| 35  | 0     | 0     | 1     | 0     | 1     |
| 36  | -1    | 0     | 0     | 0     | -1    |
| 37  | 1     | 0     | 0     | 0     | -1    |
| 38  | -1    | 0     | 0     | 0     | 1     |
| 39  | 1     | 0     | 0     | 0     | 1     |
| 40  | 0     | -1    | 0     | -1    | 0     |
| 41  | 0     | 1     | 0     | -1    | 0     |
| 42  | 0     | -1    | 0     | 1     | 0     |
| 43  | 0     | 1     | 0     | 1     | 0     |
| 44  | 0     | 0     | 0     | 0     | 0     |
| 45  | 0     | 0     | 0     | 0     | 0     |
| 46  | 0     | 0     | 0     | 0     | 0     |

## European Theater

Scenario Input Data. The number of aircraft modeled covers a range of values feasible for the European theater. Table 4-2 lists aircraft type and the range of values for each aircraft.

Table 4-2 Uncoded European Force Size

| A/C Type       | Low | Median | High |
|----------------|-----|--------|------|
| X <sub>1</sub> | 10  | 20     | 30   |
| X <sub>2</sub> | 10  | 15     | 20   |
| X <sub>3</sub> | 15  | 20     | 25   |
| X <sub>4</sub> | 15  | 20     | 25   |
| X <sub>5</sub> | 10  | 15     | 20   |

The number of aircraft input per run has been standardized to the values -1, 0, 1 for low, median, and high input values respectively. The conversion equations used for standardizing the number of aircraft input per simulation run are

$$X_1 = ( \xi_1 - 20 ) + 10 \quad (4-1)$$

$$X_2 = ( \xi_2 - 15 ) + 5 \quad (4-2)$$

$$X_3 = ( \xi_3 - 20 ) + 5 \quad (4-3)$$

$$X_4 = ( \xi_4 - 20 ) + 5 \quad (4-4)$$

$$X_5 = ( \xi_5 - 15 ) + 5 \quad (4-5)$$

where  $\xi_i$ , for  $i = 1$  to  $5$ , is the original uncoded value for the corresponding  $X_i$ . The coded values are listed below in table 4-3.

Table 4-3 Coded European Force Size

| A/C Type       | Low | Median | High |
|----------------|-----|--------|------|
| X <sub>1</sub> | -1  | 0      | 1    |
| X <sub>2</sub> | -1  | 0      | 1    |
| X <sub>3</sub> | -1  | 0      | 1    |
| X <sub>4</sub> | -1  | 0      | 1    |
| X <sub>5</sub> | -1  | 0      | 1    |

Aircraft capabilities for each aircraft type are listed in appendix A. The output matrix of responses computed by the design inputs are also in appendix B.

Relevant Factors. The SAS statistical package for stepwise regression produced all of the following equations with standard error in parentheses.

Response One. The response equation derived for the infiltration missions was

$$\begin{aligned} \text{INFILS} = & 717.0588 + 43.8125X_2 + 23.3125X_3 + 17.375X_5 - 13.4804X_2^2 \\ & (2.00) \quad (3.4) \quad (3.4) \quad (3.4) \quad (4.25) \\ & - 15.5637X_5^2 \quad (4.25) \end{aligned} \quad (4-6)$$

The alpha level used for entering and removing parameters during the stepwise regression was set to the SAS default value of 0.15. The regression analysis of variance for response one follows:

|       | DF | Sum Squares | Mean Square | F     | Prob>F |
|-------|----|-------------|-------------|-------|--------|
| Model | 5  | 48005.4253  | 9601.0851   | 51.91 | 0.0001 |
| Error |    |             |             |       |        |
| pure  | 5  | 824.8333    | 164.9667    | 1.139 |        |

|           |    |            |          |               |               |
|-----------|----|------------|----------|---------------|---------------|
| lack/fit  | 35 | 6573.6545  | 187.8187 |               |               |
| total     | 40 | 7398.4878  | 184.9622 |               |               |
| Total     | 45 | 55403.9131 |          |               |               |
|           |    | B-value    | STD Err  | II Sum Square | F Prob>F      |
| Intercept |    | 717.0588   |          |               |               |
| b1        |    | 43.8125    | 3.4000   | 30712.5625    | 166.05 0.0001 |
| b2        |    | 23.3125    | 3.4000   | 8695.5625     | 47.01 0.0001  |
| b3        |    | 17.375     | 3.4000   | 4830.2500     | 26.11 0.0001  |
| b4        |    | -13.4804   | 4.2584   | 1853.5339     | 10.02 0.0030  |
| b5        |    | -15.5637   | 4.2584   | 2470.7414     | 13.36 0.0007  |

The multiple correlation coefficient,  $R^2$ , equals 0.87. A break-out of the partial  $R^2$  and model  $R^2$  is given for each variable that was included in the regression equation.

|         |               |             |
|---------|---------------|-------------|
|         | Partial $R^2$ | Model $R^2$ |
| $X_2$   | 0.5543        | 0.5543      |
| $X_3$   | 0.1569        | 0.7113      |
| $X_5$   | 0.0872        | 0.7985      |
| $X_5^2$ | 0.0345        | 0.8330      |
| $X_2^2$ | 0.0335        | 0.8665      |

The F-Statistic for the lack of fit test was 1.139 and the F-value for 35 and 5 degrees of freedom is approximately 9.33. Since 1.139 is less than 9.33 there is no significant statistical lack of fit for response equation 4-6. The lack of fit and pure errors can be recombined into total error (Box and Draper, 1981; 41). The total error,  $s^2 = 184.96$ , can be used as an estimate of the variance,  $\sigma^2$ , for an overall regression significance F-test and as an estimate of model variance  $s^2 = 184.96$ . The F-statistic for the proposed model should be at least 4 times as large as the f-value found in statistical tables to be considered a good

predictive model, (Box and Draper, 1981; 93). The F-statistic is 51.91 and the F-value from tables is 3.51 at the 99% confidence level. The difference between the two F values is large enough to accept the proposed model as a good predictor of response one.

The final test of adequacy for response equation one is the examination of residual plots. The plot used was a plot of residuals against the predicted values of the response equation. No peculiar patterns showed up in the plot. A list containing residuals, predicted values and residual plots is located in appendix D. A plot of the residuals exhibits no significant peculiar patterns.

Response Two. The response equation produced for exfiltration missions was

$$\begin{aligned} \text{EXFILS} = & 351.5588 + 48.125X_2 + 23.375X_3 + 18.0625X_5 - 15.0637X_2^2 \\ & (1.81) \quad (3.08) \quad (3.08) \quad (3.08) \quad (3.86) \\ & - 15.4804X_5^2 \quad (4-7) \\ & (3.86) \end{aligned}$$

The adequacy tests for response equation EXFILS were performed similar to the first response and showed EXFILS to be a good predictive equation.

Response Three. The response equation produced for resupply missions was

$$\begin{aligned} \text{RESUPPLY} = & 773.1275 - 22.625X_1 + 87.0X_2 + 145.6875X_3 - 49.3125X_5 \\ & (8.51) \quad (14.45) \quad (14.45) \quad (14.45) \quad (14.45) \\ & + 77.8480X_3^2 + 30.8480X_5^2 \quad (4-8) \\ & (18.09) \quad (18.09) \end{aligned}$$

The F test for lack of fit and full regression were insignificant so the predicted model is a good one.

Response Four. The response equation produced for combat rescue missions was

$$\text{RESCUES} = 89.03 + 4.6875X_1 + 3.25X_3 \quad (4-9)$$

(0.21)    (0.77)        (0.77)

The adequacy tests for response  $Y_4$  showed it to be a good predictive equation although the  $R^2$  value was only 0.56. This fact was counteracted by the relative smallness of residual values.

Response Five. The response equation produced for refueling missions was

$$\begin{aligned} \text{REFUELS} = & 279.1190 - 18.125X_1 + 86.5625X_2 - 16X_3 + 14.125X_5 \\ & (2.59) \quad (4.21) \quad (4.21) \quad (4.21) \quad (4.21) \\ & + 30.2262X_1^2 + 11.4762X_2^2 + 16.1429X_4^2 \quad (4-10) \\ & (5.35) \quad (5.35) \quad (5.35) \end{aligned}$$

### Pacific Theater

Scenario Input Data. The number of aircraft modeled covers a range of values feasible for the Pacific theater. Table 4-5 lists aircraft type and the range of values for each aircraft.

Table 4-4 Uncoded Pacific Force Size

| A/C Type | Low | Median | High |
|----------|-----|--------|------|
| $X_1$    | 10  | 20     | 30   |
| $X_2$    | 5   | 10     | 15   |
| $X_3$    | 5   | 15     | 25   |
| $X_4$    | 10  | 20     | 30   |
| $X_5$    | 15  | 25     | 35   |

The number of aircraft input per run has been standardized to the values -1, 0, 1 for low, median, and high input values respectively. The conversion equations used for standardizing the number of aircraft input per simulation run are

$$X_1 = ( \xi_1 - 20 ) + 10 \quad (4-11)$$

$$X_2 = ( \xi_2 - 10 ) + 5 \quad (4-12)$$

$$X_3 = ( \xi_3 - 15 ) + 10 \quad (4-13)$$

$$X_4 = ( \xi_4 - 20 ) + 10 \quad (4-14)$$

$$X_5 = ( \xi_5 - 25 ) + 10 \quad (4-15)$$

were  $\xi_i$ , for  $i = 1$  to  $5$ , is the original uncoded value for the corresponding  $X_i$ . The coded values are listed in table 4-3.

Table 4-5 Coded Pacific Force Size

| A/C Type | Low | Median | High |
|----------|-----|--------|------|
| $X_1$    | -1  | 0      | 1    |
| $X_2$    | -1  | 0      | 1    |
| $X_3$    | -1  | 0      | 1    |
| $X_4$    | -1  | 0      | 1    |
| $X_5$    | -1  | 0      | 1    |

Aircraft capabilities for each aircraft type are the same as those for the European forces listed in appendix A. The output matrix of responses derived by the design are listed in appendix B.

#### Relevant Factors

Response One. The quadratic equation derived for infiltration missions was

$$\begin{aligned} \text{INFILS} = & 177.9118 + 24.5625X_2 + 1.8125X_3 + 3.0625X_5 - 17.6127X_2^2 \\ & (0.512) \quad (1.21) \quad (1.21) \quad (1.21) \quad (1.52) \\ & - 3.9461X_5^2 \quad (4-16) \\ & (1.52) \end{aligned}$$

The adequacy tests for the first response INFILS showed it to be a good predictor.

Response Two. The response equation produced for exfiltration missions was

$$\begin{aligned} \text{EXFILS} = & 55.8431 + 12.75X_2 + 1.937X_6 - 8.1912X_2^2 \\ & (0.49) \quad (0.83) \quad (0.83) \quad (1.05) \\ & - 3.1078X_6^2 \quad (4-17) \\ & (1.05) \end{aligned}$$

The adequacy test showed no statistical problems with the predictor equation.

Response Three. The third response equation for resupply missions was

$$\begin{aligned} \text{RESUPPLYS} = & 98.3043 + 38.25X_2 \quad (4-18) \\ & (1.75) \quad (2.25) \end{aligned}$$

The adequacy tests showed this equation to be a good predictor.

Response Four. The fourth response equation for combat rescue missions was

$$\begin{aligned} \text{RESCUES} = & 261.4902 + 46.625X_2 - 3.875X_6 - 11.3922X_2^2 \\ & (1.02) \quad (1.71) \quad (1.71) \quad (2.15) \\ & + 4.1078X_6^2 \quad (4-19) \\ & (2.15) \end{aligned}$$

Once again the the adequacy tests gave strong indication that the response equation is a good predictor equation.

Response Five. The fifth response equation for refueling missions was

$$\begin{aligned} \text{REFUELS} = & 241.2353 + 94.4375X_2 + 13.0625X_6 - 27.3382X_2^2 \\ & (1.99) \quad (3.39) \quad (3.39) \quad (4.25) \\ & - 11.3382X_6^2 \quad (4-20) \\ & (4.25) \end{aligned}$$

The adequacy tests showed this equation to be a good predictor.

Centcom Theater

Scenario Input Data. The number of aircraft modeled covers a range of values feasible for the CENTCOM theater. Table 4-6 lists aircraft type and the range of values for each aircraft.

Table 4-6 Uncoded Centcom Force Size

| A/C Type | Low | Median | High |
|----------|-----|--------|------|
| $X_1$    | 10  | 20     | 30   |
| $X_2$    | 5   | 10     | 15   |
| $X_3$    | 5   | 15     | 25   |
| $X_4$    | 10  | 20     | 30   |
| $X_5$    | 15  | 25     | 35   |

The number of aircraft input per run has been standardized to the values -1, 0, 1 for low, median, and high input values respectively. The conversion equations used for standardizing the number of aircraft input per simulation run are

$$X_1 = ( \xi_1 - 15 ) + 10 \quad (4-21)$$

$$X_2 = ( \xi_2 - 10 ) + 5 \quad (4-22)$$

$$X_3 = ( \xi_3 - 15 ) + 5 \quad (4-23)$$

$$X_4 = ( \xi_4 - 10 ) + 5 \quad (4-24)$$

$$X_5 = ( \xi_5 - 10 ) + 5 \quad (4-25)$$

where  $\xi_i$ , for  $i = 1$  to 5, is the original uncoded value for the corresponding  $X_i$ . The coded values are listed in table 4-7.

Table 4-7 Coded CENTCOM Force Size

| A/C Type       | Low | Median | High |
|----------------|-----|--------|------|
| X <sub>1</sub> | -1  | 0      | 1    |
| X <sub>2</sub> | -1  | 0      | 1    |
| X <sub>3</sub> | -1  | 0      | 1    |
| X <sub>4</sub> | -1  | 0      | 1    |
| X <sub>5</sub> | -1  | 0      | 1    |

Aircraft capabilities for each aircraft type are similar to those for the European forces. The exceptions are variations in capability for the tilt-roter, (X1), and fixed wing transport, (X3), listed in appendix A. The output matrix of responses derived by the design are listed in appendix B.

#### Relevant Factors

Response One. The stepwise regression procedure produced the following quadratic equation for infiltration missions

$$\text{INFILS} = 151.5667 + 21.375X_1 - 21.9417X_1^2 \quad (4-26)$$

(0.74)      (1.25)      (1.25)

The adequacy tests for the first response had no statistical peculiarities and indications are that the response equation is a good predictive model.

Response Two. The response equation produced for exfiltration missions was

$$\text{EXFILS} = 136.9333 + 37X_1 - 37.9333X_1^2 \quad (4-27)$$

(1.29)      (2.18)      (2.70)

The adequacy tests for the second response again revealed no peculiarities, indications are that it is a good predictive model.

Response Three. The response for resupply missions was

$$\text{RESUPPLYS} = 1.7333 - 29.9375X_1 - 2.9375X_3 + 28.4542X_1^2 \quad (4-28)$$

(0.41)      (0.69)      (0.69)      (0.85)

The adequacy tests for the third response gave indications that the surface is a good predictive model.

Response Four. The response equation produced for combat rescue missions was

$$\text{RESCUES} = 77.9667 + 24.0625X_1 - 24.9042X_1^2 \quad (4-29)$$

(0.43)      (0.74)      (0.91)

The adequacy tests for the forth response gave indications that it is a good predictive model.

Response Five. The response equation produced for refueling missions was

$$\text{REFUELS} = 271.8333 + 64.125X_1 - 66.4583X_1^2 \quad (4-30)$$

(1.86)      (3.16)      (3.92)

The adequacy tests for the fifth response showed no statistical indications that it is not a good predictive model.

## V. MULTIVARIATE ANALYSIS

### Introduction

In the preceding chapter, response surface equations were derived to predict the number of missions accomplished in each theater of operation. The purpose of this chapter is to reduce the dimensionality of the predicted five responses for each theater based on related mission types. If related missions or dimensions are present, then mission capability indexes, MCI's, can be generated to compare force sizes. The MCI can be used to maximize the utility of the predictive response equations.

Principal component analysis was used initially to get a preliminary idea of the dimensionality present in each of the theaters response data. The principal components analysis reduced the number of variables under study, in this case the five responses. The smaller set of new variables can be described by linear combinations of the original variables while maintaining as much of the variance of the original data as possible (Dillon and Goldstein, 1984; 24). The number resulting from the linear combination of simulated or predicted data can be compared against a baseline force size index to determine whether a new force size produces more capability.

Factor analysis is the next step used in the multivariate analysis of the derived response equations. Factor analysis using the principal component procedure was applied to the original response data to confirm the dimensionality proposed in the principal components analysis. The factor analysis provides an indicator of qualitative communalities present in the responses that make up each derived factor or dimension (Dillon and Goldstein, 1984; 60). Factor analysis can also

extract quantitative differences in the response data however, this is not done in this research due to the common units of measure used to describe the responses and mission capability indexes.

### Results

Europe. The eigenvalues and corresponding variance explained from the original response data by the eigenvalues are listed in table 5-1.

Table 5-1 Europe Eigenvalues

|        | Eigenvalue | Proportion | Cumulative |
|--------|------------|------------|------------|
| *PRIN1 | 16808.9    | 0.775895   | 0.77590    |
| *PRIN2 | 4090.7     | 0.188828   | 0.96472    |
| PRIN3  | 729.2      | 0.033659   | 0.99838    |
| PRIN4  | 28.0       | 0.001291   | 0.99967    |
| PRIN5  | 7.1        | 0.000327   | 1.00000    |

The table reveals that approximately 96.5 percent of the variance in the Europe response data can be explained by the first two principal components, PRIN1 and PRIN2, and the corresponding eigenvalues. The eigenvectors PRIN1 and PRIN2 are those linear combinations of response variables that will generate a value that explains 96.5 percent of the variance for a set of responses. The linear combinations that describe the principal components are listed below.

$$\begin{aligned} \text{PRIN1} = & 0.172330Y_1 + 0.18852642Y_2 + 0.955799Y_3 + 0.026358Y_4 \\ & + 0.143227Y_5 \end{aligned} \quad (5-1)$$

$$\text{PRIN2} = 0.323799Y_1 + 0.35877842Y_2 - 0.255051Y_3 + 0.015521Y_4 + 0.837341Y_5 \quad (5-2)$$

Where  $Y_1$  = INFILS,  $Y_2$  = EXFILS,  $Y_3$  = RESUPPLY,  $Y_4$  = RESCUES, and  $Y_5$  = REFUELS. The assumption made here is that there are two underlying dimensions being explained by the five original responses in the European theater.

The factor analysis was used to confirm the existence of two dimensions in the European theater. The factor pattern generated in table 5-2 shows that infiltrations, exfiltrations, resupplies, and combat rescues are loaded most heavily on the first factor. The fifth response, refuelings, is most heavily loaded on factor2.

Table 5-2 Europe Factor Pattern

|       | FACTOR1 | FACTOR2  | FACTOR3  | FACTOR4  | FACTOR5  |
|-------|---------|----------|----------|----------|----------|
| $Y_1$ | 0.63674 | 0.59022  | 0.48561  | -0.10154 | 0.00873  |
| $Y_2$ | 0.66256 | 0.62203  | 0.40444  | 0.10194  | -0.01132 |
| $Y_3$ | 0.99096 | -0.13045 | -0.03118 | -0.00069 | -0.00036 |
| $Y_4$ | 0.75262 | 0.21864  | 0.06920  | 0.22420  | 0.57507  |
| $Y_5$ | 0.31780 | 0.91658  | -0.24261 | -0.00477 | -0.00002 |

A varimax rotation was conducted, however when the rotation was complete the factor pattern spread out the responses over four factors. This was uninterpretable for the European theater since it meant that the responses were independent of each other which is not the case for infils, exfils, and resupplies. The mission capability indexes that can be formed from the factor analysis are Primary Mission Activities, PMA, and Support Mission Activities, SMA. The PMA responses are infiltration, exfiltration, resupply, and combat rescue missions. The SMA response is air refuelings.

generated to support the primary missions.

Pacific. The eigenvalues and corresponding variance explained by the eigenvalues are listed in table 5-3.

Table 5-3 Pacific Eigenvalues

|        | Eigenvalue | Proportion | Cumulative |
|--------|------------|------------|------------|
| *PRIN1 | 5214.14    | 0.95946    | 0.95946    |
| PRIN2  | 110.96     | 0.020418   | 0.97988    |
| PRIN3  | 83.16      | 0.015302   | 0.99518    |
| PRIN4  | 18.98      | 0.003492   | 0.99867    |
| PRIN5  | 7.2        | 0.001327   | 1.00000    |

The table reveals that approximately 96 percent of the variance in the Pacific response data can be explained by the first principal component, PRIN1, and the corresponding eigenvalue. The eigenvector PRIN1 is the linear combination of response variables that will generate a value that explains 96 percent of the variance for a set of responses. The linear combination that describes the principal component is listed in equation 5-3.

$$\begin{aligned} \text{PRIN1} = & 0.227769Y_1 + 0.117571Y_2 + 0.32077Y_3 + 0.384769Y_4 \\ & + 0.826652Y_5 \end{aligned} \quad (5-3)$$

Where  $Y_1$  = INFILS,  $Y_2$  = EXFILS,  $Y_3$  = RESUPPLY,  $Y_4$  = RESCUES, and  $Y_5$  = REFUELS. The assumption made here is that there is one underlying dimension being explained by the five original responses in the Pacific theater.

The factor analysis is used here to confirm the existence of one dimension in the Pacific theater. The factor pattern in table 5-4 shows that infiltrations, exfiltrations, resupplies, combat rescues, and refuelings, are most heavily loaded on

the first factor.

Table 5-4 Pacific Factor Pattern

|                | FACTOR1 | FACTOR2  | FACTOR3  | FACTOR4  | FACTOR5  |
|----------------|---------|----------|----------|----------|----------|
| Y <sub>1</sub> | 0.93308 | -0.21922 | 0.20968  | 0.18949  | -0.03778 |
| Y <sub>2</sub> | 0.91884 | -0.25170 | 0.11259  | 0.05099  | 0.27768  |
| Y <sub>3</sub> | 0.94633 | 0.14797  | -0.27412 | 0.08576  | 0.00804  |
| Y <sub>4</sub> | 0.94830 | 0.27228  | 0.16293  | -0.00109 | 0.00605  |
| Y <sub>5</sub> | 0.99751 | -0.06222 | -0.01311 | -0.02986 | -0.00569 |

The factor pattern was not rotated here because all factors were loaded on the first factor. The mission capability index that can be formed from the factor analysis is Special Mission Activities, SMA. The SMA responses are infiltration, exfiltration, resupply, combat rescue, and refueling missions.

Centcom. The eigenvalues and corresponding variance explained by the eigenvalues are listed in table 5-5.

Table 5-5 Centcom Eigenvalues

|        | Eigenvalue | Proportion | Cumulative |
|--------|------------|------------|------------|
| *PRIN1 | 4649.95    | 0.988316   | 0.98832    |
| PRIN2  | 43.16      | 0.009174   | 0.99749    |
| PRIN3  | 7.37       | 0.001566   | 0.99906    |
| PRIN4  | 3.80       | 0.000807   | 0.99986    |
| PRIN5  | 0.64       | 0.000136   | 1.00000    |

The table reveals that approximately 98.8 percent of the variance in the Centcom response data can be explained by the first principal component, PRIN1, and the corresponding eigenvalue. The eigenvector PRIN1 is the linear combination of response

variables that will generate a value that explains 98.8 percent of the variance for a set of responses. The linear combination that describes the principal component is listed in equation 5-4..

$$\begin{aligned} \text{PRIN1} = & 0.0250760Y_1 + 0.436507Y_2 - 0.322881Y_3 + 0.274746Y_4 \\ & + 0.752890Y_5 \end{aligned} \quad (5-4)$$

Where  $Y_1$  = INFILS,  $Y_2$  = EXFILS,  $Y_3$  = RESUPPLY,  $Y_4$  = RESCUES, and  $Y_5$  = REFUELS. The assumption made here is that there is one underlying dimension being explained by the five original responses in the Centcom theater.

The factor analysis is used here to confirm the existence of one dimension in the Centcom theater. The factor pattern in table 5-6 shows that infiltrations, exfiltrations, resupplies, combat rescues, and refuelings, are most heavily loaded on the first factor. The factor pattern was not rotated because all factors were again loaded on the first factor.

Table 5-6 Centcom Factor Pattern

|       | FACTOR1  | FACTOR2  | FACTOR3  | FACTOR4  | FACTOR5  |
|-------|----------|----------|----------|----------|----------|
| $Y_1$ | 0.99107  | 0.06054  | 0.11500  | -0.01009 | 0.02815  |
| $Y_2$ | 0.99625  | 0.05911  | -0.05733 | -0.02351 | 0.01223  |
| $Y_3$ | -0.96949 | 0.24219  | -0.00822 | 0.03691  | 0.00212  |
| $Y_4$ | 0.98856  | -0.12177 | -0.02704 | 0.08373  | 0.01376  |
| $Y_5$ | 0.99928  | 0.03560  | 0.00853  | 0.00484  | -0.00873 |

The mission capability index that can be formed from the factor analysis in Centcom is Special Mission Activities, SMA. The SMA responses are infiltration, exfiltration, resupply, combat rescue, and refueling missions. The fact that the  $Y_3$ , RESUPPLY, response operates in the opposite direction to the other responses is addressed in the results section.

Summary. The capability indexes generated by the multivariate analysis can be used to compare the aggregate capability generated by proposed force sizes. This comparison is made by reducing the dimensionality of the original five responses into some smaller set of variables while maintaining the maximum amount of variance present in the original data. A demonstration of how the capability indexes can be used is presented in the following chapter.

## VI. ANALYSIS RESULTS

### Introduction

This chapter summarizes and validates the response surface equations generated in this research. The mission capability indexes derived previously are implemented to provide an example of how they might be used in force sizing analysis. The relevant input factors for each theater and any peculiarities noted in the analysis are also discussed.

Predictive validation was used by comparing the predicted responses against the simulated responses. The second validation step used was to graphically compare the predicted responses with the simulated responses. A determination is then made as to any significant departure in the patterns formed by the plotted points. It should be noted that the significance of variation in the compared patterns is a judgement decision made by the analyst and decision makers. The mission capability indexes will also compare predicted values against simulated values. This will be done to determine the aggregate worth of each force size and whether or not the indexes for the simulated results parallel the indexes for the predicted results.

### Response Equation Validation

To conduct the response surface validation, two proposed force sizes are compared in each theater. The same force sizes were used in each theater and are listed in table 6-1. The only difference is found in the capability of aircraft types X1 and X3 for Centcom, where upgrades have been made to account for the increased threats assumed by the analyst in Centcom. The upgrades are the ability to operate in threat type one for X1 and air refueling capability for X3.

Table 6-1 Proposed Forces

| Aircraft    |    | Force One | Force Two |
|-------------|----|-----------|-----------|
| tilt-roter  | X1 | 17        | 25        |
| helicopter1 | X2 | 21        | 15        |
| transport   | X3 | 30        | 20        |
| helicopter2 | X4 | 15        | 15        |
| tanker      | X5 | 20        | 20        |

Europe. The response equations for Europe are:

$$\begin{aligned} \text{INFILS} = & 717.0588 + 43.8125X_2 + 23.3125X_3 + 17.375X_5 - 13.4804X_2^2 \\ & - 15.5637X_5^2 \end{aligned} \quad (4-11)$$

$$\begin{aligned} \text{EXFILS} = & 351.5588 + 48.125X_2 + 23.375X_3 + 18.0625X_5 - 15.0637X_2^2 \\ & - 15.4804X_5^2 \end{aligned} \quad (4-12)$$

$$\begin{aligned} \text{RESUPPLYS} = & 773.1275 - 22.625X_1 + 87.0X_2 + 145.6875X_3 - 49.3125X_5 \\ & + 77.8480X_3^2 + 30.8480X_5^2 \end{aligned} \quad (4-13)$$

$$\text{RESCUES} = 89.03 + 4.6875X_1 + 3.25X_3 \quad (4-14)$$

$$\begin{aligned} \text{REFUELS} = & 279.1190 - 18.125X_1 + 86.5625X_2 - 16X_3 + 14.125X_5 \\ & + 30.2262X_1^2 + 11.4762X_2^2 + 16.1429X_4^2 \end{aligned} \quad (4-15)$$

The simulated response values for the two proposed force sizes are found in table 6-2.

**Table 6-2 Europe Simulated and Predicted Results**

| RESPONSE | FORCE 1 |       |      | FORCE 2 |       |       |
|----------|---------|-------|------|---------|-------|-------|
|          | SIMUL.  | PRED. | DIF  | SIMUL.  | PRED. | DIF   |
| INFILS   | 839     | 799   | 0.04 | 724     | 719   | 0.007 |
| EXFILS   | 474     | 437   | 0.08 | 358     | 354   | 0.01  |
| RESUPPLY | 1238    | 1455  | 0.17 | 816     | 743   | 0.09  |
| RESCUE   | 102     | 94    | 0.08 | 90      | 91    | 0.01  |
| REFUEL   | 381     | 406   | 0.07 | 291     | 308   | 0.06  |

The differences between the predicted and simulated results are plotted in Appendix E. The percentage difference in simulated and predicted responses are all statistically insignificant. It is apparent from the plots that the same trends resulting from the simulated data are mirrored by the predicted responses. In addition, the mission capability indexes follow a similar trend in that the predicted indexes mirror the simulated indexes.

The PMA and SMA indexes for each predicted and simulated force size are listed in table 6-3.

**Table 6-3 Mission Capability Indexes**

|           | PMA     |         | SMA     |         |
|-----------|---------|---------|---------|---------|
|           | FORCE 1 | FORCE 2 | FORCE 1 | FORCE 2 |
| SIMULATED | 1564    | 1016    | 447     | 400     |
| PREDICTED | 1671    | 947     | 386     | 430     |

The capability index PMA for force one is greater than force two for both the simulated and predictive models. In the second dimension SMA of the data the simulated index for force one is greater than force two. However, for the predicted model, the SMA

index values are reversed. This discrepancy can be directly attributed to the large number of resupply missions predicted by the response surface for RESUPPLYS. The large difference between the predicted and simulated resupply missions is tolerable in light of the large number of resupply missions accomplished.

Pacific. The response equations for the Pacific are:

$$\begin{aligned} \text{INFILS} = & 177.9118 + 24.5625X_2 + 1.8125X_3 + 3.0625X_5 - 17.6127X_2^2 \\ & - 3.9461X_5^2 \quad (4-16) \end{aligned}$$

$$\begin{aligned} \text{EXFILS} = & 55.8431 + 12.75X_2 + 1.937X_5 - 8.1912X_2^2 \\ & - 3.1078X_5^2 \quad (4-17) \end{aligned}$$

$$\text{RESUPPLYS} = 98.3043 + 38.25X_2 \quad (4-18)$$

$$\begin{aligned} \text{RESCUES} = & 261.4902 + 46.625X_2 - 3.875X_5 - 11.3922X_2^2 \\ & + 4.1078X_5^2 \quad (4-19) \end{aligned}$$

$$\begin{aligned} \text{REFUELS} = & 241.2353 + 94.4375X_2 + 13.0625X_5 - 27.3382X_2^2 \\ & - 11.3382X_5^2 \quad (4-20) \\ & (4.25) \end{aligned}$$

The simulated and predicted response values for the two proposed force sizes are found in table 6-4.

Table 6-4 Pacific Simulated and Predicted Results

| RESPONSE  | FORCE 1 |       |      | FORCE 2 |       |      |
|-----------|---------|-------|------|---------|-------|------|
|           | SIMUL.  | PRED. | DIF. | SIMUL.  | PRED. | DIF. |
| INFILS    | 186     | 147   | 0.20 | 185     | 183   | 0.01 |
| EXFILS    | 57      | 43    | 0.24 | 60      | 59    | 0.02 |
| RESUPPLYS | 148     | 182   | 0.23 | 132     | 137   | 0.04 |
| RESCUES   | 299     | 317   | 0.06 | 295     | 302   | 0.02 |
| REFUELS   | 310     | 319   | 0.03 | 293     | 219   | 0.25 |

The differences between the predicted and simulated results are plotted in Appendix E. The verification tests which indicated that the response equations were good predictors are validated by the identical trends indicated by the plots for the Pacific hypothetical force sizes.

The PMA index comparison for the predicted and simulated force sizes are listed in table 6-5.

Table 6-5 Mission Capability Indexes

|           |     |     |
|-----------|-----|-----|
| SIMULATED | 468 | 447 |
| PREDICTED | 483 | 456 |

The capability index PMA for force one is greater than force two for both the simulated and predictive models.

Centcom. The response equations for the Centcom are:

$$\text{INFILS} = 151.5667 + 21.375X_1 - 21.9417X_1^2 \quad (4-26)$$

$$\text{EXFILS} = 136.9333 + 37X_1 - 37.9333X_1^2 \quad (4-27)$$

$$\text{RESUPPLYS} = 1.7333 - 29.9375X_1 - 2.9375X_3 + 28.4542X_1^2 \quad (4-28)$$

$$\text{RESCUES} = 77.9667 + 24.0625X_1 - 24.9042X_1^2 \quad (4-29)$$

$$\text{REFUELS} = 271.8333 + 64.125X_1 - 66.4583X_1^2 \quad (4-30)$$

The simulated and predicted response values for the two proposed force sizes are found in table 6-6.

Table 6-6 Centcom Simulated and Predicted Results

| RESPONSE  | FORCE 1 |       |      | FORCE 2 |       |      |
|-----------|---------|-------|------|---------|-------|------|
|           | SIMUL.  | PRED. | DIF. | SIMUL.  | PRED. | DIF. |
| INFILS    | 151     | 143   | 0.05 | 151     | 157   | 0.04 |
| EXFILS    | 136     | 122   | 0.10 | 136     | 146   | 0.07 |
| RESUPPLYS | 0       | 9     | *    | 0       | 21    | *    |
| RESCUES   | 77      | 69    | 0.10 | 79      | 84    | 0.06 |
| REFUELS   | 269     | 247   | 0.08 | 269     | 287   | 0.07 |

The differences between the predicted and simulated results are plotted in Appendix E. The graphical analysis shows similar trends for the Centcom simulated and predicted force capability.

The SMA index for the predicted and simulated force size are listed in table 6-7.

Table 6-7 Centcom Mission Capability Index

|           | FORCE 1 | FORCE 2 |
|-----------|---------|---------|
| SIMULATED | 321     | 321     |
| PREDICTED | 291     | 335     |

The capability index for force one is the same for the simulated force sizes. However, the SMA index for the predictive force 2 was greater than force 1. This is attributed to the priority assigned to the completion of missions by aircraft types. The most relevant aircraft in Centcom is X1, the modified tilt-rotor. Examination of the simulation output showed that when the number of X1 aircraft increased significantly the overall number of primary missions accomplished by X1 increased. This freed up other aircraft primarily X3, the tanker transport, to do resupply missions. Going from 17 to 25 aircraft reflects this assumption in the predicted index but not in the simulated index.

## VII. SUMMARY

### Introduction

This chapter summarizes the research completed, observations noted during the research process, and then makes recommendations for using the results and additional research.

### Summary of Research

The objective of this research was to explore the feasibility of using response surface metamodels in conjunction with CRASOF. The goal was to enhance the force sizing capability at Headquarters Military Airlift Command. This research was accomplished by applying multiple regression analysis to simulated output data to form metamodels that predicted the output responses generated by CRASOF. Indexes were also derived which reduced the dimensionality of the responses that enhanced the comparison of different force sizes. The response metamodels combined with the mission capability indexes showed enormous potential for expediting answers to decision makers on whether further detailed study of proposed force sizes are warranted.

### Observations

The utility of this research was in describing the methodology to use on real-world special mission force sizes. Given real world force structures, the methodology described in this research can easily be applied to produce metamodels to supplement future CRASOF force sizing exercises. The relevant aircraft described in each theater can also help in determining the driving forces necessary for mission success in each of the given theaters.

## Recommendations

This research suggests a methodology appropriate for use in force sizing analysis. The metamodels can be used to minimize start up time when simulation runs are the only method of determining force capability. The metamodels only expose trends in the output data and are not meant to supplant CRASOF, only supplement it. Caution should be taken to avoid labeling metamodel predictions as exact capability.

## Future Research

Several indications in the research showed that the resupply mission had negative impact on the dimensionality in the high threat Centcom theater of operation. An assumption was made that this was due to the lower priority placed on resupply missions. Consequently, when a resupply was accomplished it took away resources from higher priority missions that could have been done. Future research could focus in on the priorities assigned to the missions to determine if priority of mission has a significant impact across the spectrum of theaters.

Another possible area for research is to investigate the confidence intervals for which the predicted equations are statistically valid using the classified input data located at Hq MAC. This study could also examine extrapolating responses from inputs that are outside the design points low and high settings.

There are a number of other topics that can be investigated using CRASOF. The inputs to the model, i.e., the settings which describe the theater climate are easily manipulated with a text editor. Investigation into affects on mission capability resulting from manipulation of various inputs might yield additional insight into factors affecting mission capability in the special missions environment.

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# APPENDIX A: Aircraft Input Capability

## AIRCRAFT CHARACTERISTICS (3X,A25,3X,5F9.0):

NOTE: ITEM 2, CAPABILITY/REQUIREMENTS ENTRY CODE FOLLOWS

- 0 - CAPABILITY MODE FOR ACFT & CREW
- 1 - REQUIREMENT MODE FOR ACFT; CAPABILITY MODE FOR CREW
- 2 - CAPABILITY MODE FOR ACFT; REQUIREMENT MODE FOR CREW
- 3 - REQUIREMENT MODE FOR ACFT & CREW

| ITEM#                         | X1       | AIRCRAFT TYPES |          |         |          | X2       |
|-------------------------------|----------|----------------|----------|---------|----------|----------|
|                               |          | N/A            | N/A      | N/A     | N/A      |          |
| 1 NOT USED                    | .00      | .00            | .00      | .12     | .00      | .00      |
| 2 CAP/REQ'T V1-3; SEE NOTE)   | .00      | .00            | .00      | .00     | .00      | .00      |
| 3 THREAT TYPE (1-3)           | 1.00     | 2.00           | 2.00     | 3.00    | 2.00     | 2.00     |
| 4 1ST PRIORITY MSN (1-5)      | 2.00     | 4.00           | 4.00     | 4.00    | 2.00     | 2.00     |
| 5 2ND PRIORITY MISSION #      | 1.00     | .00            | .00      | .00     | 1.00     | 1.00     |
| 6 3RD PRIORITY MISSION #      | 3.00     | .00            | .00      | .00     | 3.00     | 3.00     |
| 7 4TH PRIORITY MISSION #      | 4.00     | .00            | .00      | .00     | 4.00     | 4.00     |
| 8 5TH PRIORITY MISSION #      | .00      | .00            | .00      | .00     | .00      | .00      |
| 9 NOT USED                    | .00      | .00            | .00      | .00     | .00      | .00      |
| 10 NOT USED                   | .00      | .00            | .00      | .00     | .00      | .00      |
| 11 NOT USED                   | .00      | .00            | .00      | .00     | .00      | .00      |
| 12 NOT USED                   | .00      | .00            | .00      | .00     | .00      | .00      |
| 13 NOT USED                   | .00      | .00            | .00      | .00     | .00      | .00      |
| 14 ATTRITION RATE (%)         | .10      | .10            | .10      | .10     | .10      | .10      |
| 15 MECH AIR ABORT (%)         | .00      | .00            | .00      | .00     | .00      | .00      |
| 16 UTE RATE (HRS/DAY/ACFT)    | 3.00     | 2.20           | 2.00     | 1.68    | 2.33     | 2.33     |
| 17 SURGE RATE (HRS/DAY/ACFT)  | .00      | .00            | .00      | .00     | .00      | .00      |
| 18 DAYS CAN SUSTAIN SURGE     | .00      | .00            | .00      | .00     | .00      | .00      |
| 19 MISSION EFFECTIVENESS (%)  | 95.00    | 95.00          | 95.00    | 95.00   | 95.00    | 95.00    |
| 20 MISSION CAPABLE RATE (%)   | 72.00    | 77.50          | 58.50    | 64.50   | 58.50    | 58.50    |
| 21 CRASH HAS SURVIVORS (%)    | 75.00    | 75.00          | 75.00    | 75.00   | 75.00    | 75.00    |
| 22 VTOL CAPABLE (Y=1,N=0)     | 1.00     | 1.00           | 1.00     | 1.00    | 1.00     | 1.00     |
| 23 AVG CRUISE (KTAS)          | 220.00   | 120.00         | 120.00   | 120.00  | 120.00   | 120.00   |
| 24 UNREFUELED RADIUS (NM)     | 600.00   | 300.00         | 285.00   | 290.00  | 290.00   | 290.00   |
| 25 REFUEL INFIGHT(Y=1,N=0)    | 1.00     | 1.00           | 1.00     | 1.00    | 1.00     | 1.00     |
| 26 REQ'D A/R TRACK (NM)       | 100.00   | 30.00          | 30.00    | 30.00   | 30.00    | 30.00    |
| 27 RADII BEFORE A/R (0.5-2.0) | 1.50     | 1.25           | 1.25     | 1.25    | 1.25     | 1.25     |
| 28 BURN RATE (LBS/HR)         | 2300.00  | 1200.00        | 2200.00  | 1200.00 | 2200.00  | 2200.00  |
| 29 MAX FUEL (LBS)             | 16500.00 | 6000.00        | 11800.00 | 6500.00 | 11800.00 | 11800.00 |

|                               |        |        |        |        |        |
|-------------------------------|--------|--------|--------|--------|--------|
| 30 BURN LBS FUEL BEFORE A/R   | .00    | .00    | .00    | .00    | .00    |
| 31 DISTANCE FROM FOL (NM)     | .00    | .00    | .00    | .00    | .00    |
| 32 NOT USED                   | .00    | .00    | .00    | .00    | .00    |
| 33 MAX FLY HRS W/O AUGMENTING | 9.00   | 10.00  | 10.00  | 10.00  | 10.00  |
| 34 CREW RATIO                 | 2.00   | 1.50   | 1.50   | 1.25   | 1.50   |
| 35 AVG ACFT TURN TIME (HRS)   | 1.00   | 1.00   | 2.00   | 1.00   | 2.00   |
| 36 TAKEOFF CEILING MIN (FT)   | .00    | 300.00 | 300.00 | 300.00 | .00    |
| 37 TAKEOFF VIS MIN (SM)       | .12    | 1.00   | 1.00   | 1.00   | .00    |
| 38 ACFT #1 MSN CEILING MIN    | 100.00 | 300.00 | 300.00 | 300.00 | 100.00 |
| 39 ACFT #1 MSN VIS MIN        | .25    | 1.00   | 1.00   | 1.00   | .25    |
| 40 ACFT #1 MSN WIND MAX       | 45.00  | 45.00  | 45.00  | 60.00  | 45.00  |
| 41 RAIN CNX #1 MSN (Y=1,N=0)  | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   |
| 42 TURB CNX                   |        |        |        |        |        |
| 43 ACFT #2 MSN CEILING MIN    | .00    | 300.00 | 300.00 | 300.00 | 100.00 |
| 44 ACFT #2 MSN VIS MIN        | .00    | 1.00   | 1.00   | 1.00   | .25    |
| 5 ACFT #2 MSN WIND MAX        | 45.00  | 45.00  | 45.00  | 60.00  | 45.00  |
| 6 RAIN CNX #2 MSN (Y=1,N=0)   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   |
| 7 TURB CNX #2 MSN (Y=1,N=0)   | .00    | 1.00   | 1.00   | 1.00   | .00    |
| 8 ACFT #3 MSN CEILING MIN     | 100.00 | 300.00 | 300.00 | 300.00 | .00    |
| 9 ACFT #3 MSN VIS MIN         | .25    | 1.00   | 1.00   | 1.00   | .00    |
| 0 ACFT #3 MSN WIND MAX        | 45.00  | 45.00  | 45.00  | 60.00  | 45.00  |
| 1 RAIN CNX #3 MSN (Y=1,N=0)   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   |
| 2 TURB CNX #3 MSN (Y=1,N=0)   | .00    | 1.00   | 1.00   | 1.00   | .00    |
| 3 ACFT #4 MSN CEILING MIN     | 100.00 | 300.00 | 300.00 | 300.00 | 100.00 |
| 4 ACFT #4 MSN VIS MIN         | .25    | 1.00   | 1.00   | 1.00   | .25    |
| 5 ACFT #4 MSN WIND MAX        | 45.00  | 45.00  | 45.00  | 60.00  | 45.00  |
| 6 RAIN CNX #4 MSN (Y=1,N=0)   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   |
| 7 TURB CNX #4 MSN (Y=1,N=0)   | .00    | 1.00   | 1.00   | 1.00   | .00    |
| 8 ACFT #5 MSN CEILING MIN     | 100.00 | 300.00 | 300.00 | 300.00 | 100.00 |
| 9 ACFT #5 MSN VIS MIN         | .25    | 1.00   | 1.00   | 1.00   | .25    |
| 0 ACFT #5 MSN WIND MAX        | 45.00  | 45.00  | 45.00  | 60.00  | 45.00  |
| 1 RAIN CNX #5 MSN (Y=1,N=0)   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   |
| 2 TURB CNX #5 MSN (Y=1,N=0)   | .00    | 1.00   | 1.00   | 1.00   | .00    |

#### AIRCRAFT TYPES

| ITEM#                      | X3   | N/A  | X4   | X5   | N/A  |
|----------------------------|------|------|------|------|------|
| 1 NOT USED                 | .00  | .00  | .00  | .00  | .00  |
| 2 CAP/REQ'T (0-3; SEE NOTE | .00  | .00  | .00  | .00  | .00  |
| 3 THREAT TYPE (1-3)        | 1.00 | 1.00 | 2.00 | 2.00 | 1.00 |
| 4 1ST PRIORITY MSN (1-5)   | 1.00 | 2.00 | 2.00 | 5.00 | 1.00 |
| 5 2ND PRIORITY MISSION #   | 3.00 | 1.00 | 1.00 | .00  | 3.00 |
| 6 3RD PRIORITY MISSION #   | .00  | 3.00 | 3.00 | .00  | 5.00 |
| 7 4TH PRIORITY MISSION #   | .00  | 4.00 | 4.00 | .00  | .00  |

|                               |          |          |         |          |          |
|-------------------------------|----------|----------|---------|----------|----------|
| 8 5TH PRIORITY MISSION #      | .00      | .00      | .00     | .00      | .00      |
| 9 NOT USED                    | .00      | .00      | .00     | .00      | .00      |
| 10 NOT USED                   | .00      | .00      | .00     | .00      | .00      |
| 11 NOT USED                   | .00      | .00      | .00     | .00      | .00      |
| 12 NOT USED                   | .00      | .00      | .00     | .00      | .00      |
| 13 NOT USED                   | .00      | .00      | .00     | .00      | .00      |
| 14 ATTRITION RATE (%)         | .10      | .10      | .10     | .10      | .10      |
| 15 MECH AIR ABORT (%)         | .43      | .00      | .00     | 2.44     | .43      |
| 16 UTE RATE (HRS/DAY/ACFT)    | 3.00     | 2.33     | 2.20    | 2.80     | 3.00     |
| 17 SURGE RATE (HRS/DAY/ACFT)  | .00      | .00      | .00     | .00      | .00      |
| 18 DAYS CAN SUSTAIN SURGE     | .00      | .00      | .00     | .00      | .00      |
| 19 MISSION EFFECTIVENESS (%)  | 95.00    | 95.00    | 95.00   | 95.00    | 95.00    |
| 20 MISSION CAPABLE RATE (%)   | 61.50    | 58.50    | 77.50   | 64.50    | 61.50    |
| 21 CRASH HAS SURVIVORS (%)    | 15.00    | 75.00    | 75.00   | 15.00    | 15.00    |
| 22 VTOL CAPABLE (Y=1,N=0)     | .00      | 1.00     | 1.00    | .00      | .00      |
| 23 AVG CRUISE (KTAS)          | 220.00   | 120.00   | 120.00  | 220.00   | 220.00   |
| 24 UNREFUELED RADIUS (NM)     | 950.00   | 290.00   | 300.00  | 1350.00  | 950.00   |
| 25 REFUEL INFLIGHT(Y=1,N=0)   | .00      | 1.00     | 1.00    | .00      | .00      |
| 26 REQ'D A/R TRACK (NM)       | .00      | 30.00    | 30.00   | .00      | .00      |
| 27 RADII BEFORE A/R (0.5-2.0) | .00      | 1.25     | 1.25    | .00      | .00      |
| 28 BURN RATE (LBS/HR)         | 6000.00  | 2200.00  | 1200.00 | 6000.00  | 6000.00  |
| 29 MAX FUEL (LBS)             | 59000.00 | 11800.00 | 6000.00 | 82000.00 | 59000.00 |
| 30 BURN LBS FUEL BEFORE A/R   | .00      | .00      | .00     | .00      | .00      |
| 31 DISTANCE FROM FOL (NM)     | .00      | .00      | .00     | .00      | .00      |
| 32 NOT USED                   |          |          |         |          |          |
| 33 MAX FLY HRS W/O AUGMENTING | 9.00     | 10.00    | 10.00   | 9.00     | 9.00     |
| 34 CREW RATIO                 | 1.50     | 1.50     | 1.50    | 1.50     | 1.50     |
| 35 AVG ACFT TURN TIME (HRS)   | 1.50     | 2.00     | 1.00    | 1.50     | 1.50     |
| 6 TAKEOFF CEILING MIN (FT)    | .00      | .00      | 300.00  | .00      | .00      |
| 7 TAKEOFF VIS MIN (SM)        | .30      | .00      | 1.00    | .30      | .30      |
| 8 ACFT #1 MSN CEILING MIN     | .00      | 100.00   | 300.00  | .00      | .00      |
| 9 ACFT #1 MSN VIS MIN         | .00      | .25      | 1.00    | 1.00     | .00      |
| 0 ACFT #1 MSN WIND MAX        | 60.00    | 45.00    | 45.00   | 60.00    | 60.00    |
| 1 RAIN CNX #1 MSN (Y=1,N=0)   | 1.00     | 1.00     | 1.00    | 1.00     | 1.00     |
| 2 TURB CNX #1 MSN (Y=1,N=0)   | 1.00     | .00      | 1.00    | 1.00     | 1.00     |
| 3 ACFT #2 MSN CEILING MIN     | .00      | 100.00   | 300.00  | .00      | .00      |
| 4 ACFT #2 MSN VIS MIN         | .00      | .25      | 1.00    | .00      | .00      |
| 5 ACFT #2 MSN WIND MAX        | 60.00    | 45.00    | 45.00   | 60.00    | 60.00    |
| 6 RAIN CNX #2 MSN (Y=1,N=0)   | 1.00     | 1.00     | 1.00    | 1.00     | 1.00     |
| 7 TURB CNX #2 MSN (Y=1,N=0)   | 1.00     | .00      | 1.00    | 1.00     | 1.00     |
| 8 ACFT #3 MSN CEILING MIN     | 500.00   | .00      | 300.00  | .00      | .00      |
| 9 ACFT #3 MSN VIS MIN         | 1.00     | .00      | 1.00    | .00      | 1.00     |
| 0 ACFT #3 MSN WIND MAX        | 60.00    | 45.00    | 45.00   | 60.00    | 60.00    |

|   |      |        |                 |        |        |        |       |       |
|---|------|--------|-----------------|--------|--------|--------|-------|-------|
| 1 | RAIN | CNX #3 | MSN (Y=1,N=0)   | 1.00   | 1.00   | 1.00   | 1.00  | 1.00  |
| 2 | TURB | CNX #3 | MSN (Y=1,N=0)   | 1.00   | .00    | 1.00   | 1.00  | 1.00  |
| 3 | ACFT | #4     | MSN CEILING MIN | 500.00 | 100.00 | 300.00 | .00   | .00   |
| 4 | ACFT | #4     | MSN VIS MIN     | 1.00   | .25    | 1.00   | .00   | .00   |
| 5 | ACFT | #4     | MSN WIND MAX    | 60.00  | 45.00  | 45.00  | 60.00 | 60.00 |
| 6 | RAIN | CNX #4 | MSN (Y=1,N=0)   | 1.00   | 1.00   | 1.00   | 1.00  | 1.00  |
| 7 | TURB | CNX #4 | MSN (Y=1,N=0)   | 1.00   | .00    | 1.00   | 1.00  | 1.00  |
| 8 | ACFT | #5     | MSN CEILING MIN | .00    | 100.00 | 300.00 | .00   | .00   |
| 9 | ACFT | #5     | MSN VIS MIN     | .00    | .25    | 1.00   | .00   | .00   |
| 0 | ACFT | #5     | MSN WIND MAX    | 60.00  | 45.00  | 45.00  | 60.00 | 60.00 |
| 1 | RAIN | CNX #5 | MSN (Y=1,N=0)   | 1.00   | 1.00   | 1.00   | 1.00  | 1.00  |
| 2 | TURB | CNX #5 | MSN (Y=1,N=0)   | 1.00   | .00    | 1.00   | 1.00  | 1.00  |

# APPENDIX B:

## Europe Response Matrix and Box Benhken Fractional Factorial Design

Y1= INFILTRATION Y2= EXFILTRATION Y3= RESUPPLY Y4= RESCUE Y5= REFUEL

| Y1  | Y2  | Y3   | Y4  | Y5  | mu | X1 | X2 | X3 | X4 | X5 |
|-----|-----|------|-----|-----|----|----|----|----|----|----|
| 655 | 291 | 785  | 86  | 266 | 1  | -1 | -1 | 0  | 0  | 0  |
| 657 | 285 | 742  | 86  | 196 | 1  | 1  | -1 | 0  | 0  | 0  |
| 758 | 397 | 917  | 95  | 400 | 1  | -1 | 1  | 0  | 0  | 0  |
| 755 | 389 | 893  | 93  | 385 | 1  | 1  | 1  | 0  | 0  | 0  |
| 679 | 311 | 740  | 87  | 308 | 1  | 0  | 0  | -1 | -1 | 0  |
| 762 | 389 | 1016 | 91  | 285 | 1  | 0  | 0  | 1  | -1 | 0  |
| 662 | 328 | 706  | 87  | 314 | 1  | 0  | 0  | -1 | 1  | 0  |
| 738 | 377 | 1055 | 90  | 284 | 1  | 0  | 0  | 1  | 1  | 0  |
| 640 | 273 | 754  | 86  | 197 | 1  | 0  | -1 | 0  | 0  | -1 |
| 699 | 337 | 978  | 99  | 324 | 1  | 0  | 1  | 0  | 0  | -1 |
| 669 | 296 | 757  | 85  | 208 | 1  | 0  | -1 | 0  | 0  | 1  |
| 770 | 407 | 852  | 97  | 413 | 1  | 0  | 1  | 0  | 0  | 1  |
| 692 | 324 | 698  | 85  | 342 | 1  | -1 | 0  | -1 | 0  | 0  |
| 697 | 324 | 667  | 88  | 314 | 1  | 1  | 0  | -1 | 0  | 0  |
| 750 | 383 | 969  | 94  | 315 | 1  | -1 | 0  | 1  | 0  | 0  |
| 746 | 385 | 897  | 93  | 294 | 1  | 1  | 0  | 1  | 0  | 0  |
| 693 | 323 | 927  | 93  | 283 | 1  | 0  | 0  | 0  | -1 | -1 |
| 699 | 321 | 941  | 89  | 278 | 1  | 0  | 0  | 0  | 1  | -1 |
| 711 | 343 | 776  | 90  | 286 | 1  | 0  | 0  | 0  | -1 | 1  |
| 729 | 361 | 737  | 91  | 296 | 1  | 0  | 0  | 0  | 1  | 1  |
| 709 | 347 | 757  | 92  | 304 | 1  | 0  | 0  | 0  | 0  | 0  |
| 703 | 327 | 728  | 86  | 257 | 1  | 0  | 0  | 0  | 0  | 0  |
| 720 | 339 | 719  | 80  | 266 | 1  | 0  | 0  | 0  | 0  | 0  |
| 650 | 278 | 580  | 83  | 211 | 1  | 0  | -1 | -1 | 0  | 0  |
| 731 | 366 | 844  | 89  | 409 | 1  | 0  | 1  | -1 | 0  | 0  |
| 671 | 298 | 995  | 88  | 189 | 1  | 0  | -1 | 1  | 0  | 0  |
| 769 | 401 | 1082 | 100 | 349 | 1  | 0  | 1  | 1  | 0  | 0  |
| 717 | 362 | 858  | 91  | 320 | 1  | -1 | 0  | 0  | -1 | 0  |
| 728 | 368 | 774  | 90  | 291 | 1  | 1  | 0  | 0  | -1 | 0  |
| 714 | 358 | 860  | 90  | 363 | 1  | -1 | 0  | 0  | 1  | 0  |
| 723 | 359 | 793  | 93  | 295 | 1  | 1  | 0  | 0  | 1  | 0  |
| 676 | 308 | 796  | 87  | 293 | 1  | 0  | 0  | -1 | 0  | -1 |
| 697 | 343 | 1041 | 93  | 257 | 1  | 0  | 0  | 1  | 0  | -1 |
| 708 | 345 | 673  | 87  | 310 | 1  | 0  | 0  | -1 | 0  | 1  |
| 735 | 382 | 980  | 96  | 272 | 1  | 0  | 0  | 1  | 0  | 1  |
| 685 | 311 | 773  | 86  | 314 | 1  | -1 | 0  | 0  | 0  | -1 |
| 657 | 298 | 772  | 91  | 289 | 1  | 1  | 0  | 0  | 0  | -1 |

|     |     |     |    |     |   |    |    |   |    |   |
|-----|-----|-----|----|-----|---|----|----|---|----|---|
| 703 | 340 | 729 | 85 | 355 | 1 | -1 | 0  | 0 | 0  | 1 |
| 699 | 329 | 689 | 87 | 321 | 1 | 1  | 0  | 0 | 0  | 1 |
| 646 | 274 | 563 | 83 | 225 | 1 | 0  | -1 | 0 | -1 | 0 |
| 735 | 376 | 806 | 90 | 437 | 1 | 0  | 1  | 0 | -1 | 0 |
| 659 | 281 | 605 | 80 | 233 | 1 | 0  | -1 | 0 | 1  | 0 |
| 731 | 373 | 801 | 89 | 393 | 1 | 0  | 1  | 0 | 1  | 0 |
| 725 | 353 | 750 | 82 | 279 | 1 | 0  | 0  | 0 | 0  | 0 |
| 735 | 361 | 755 | 91 | 269 | 1 | 0  | 0  | 0 | 0  | 0 |
| 733 | 362 | 773 | 94 | 276 | 1 | 0  | 0  | 0 | 0  | 0 |

Pacific Response Matrix with Box and Behnken Design

| Y1  | Y2 | Y3  | Y4  | Y5  | MU | X1 | X2 | X3 | X4 | X5 |
|-----|----|-----|-----|-----|----|----|----|----|----|----|
| 131 | 37 | 56  | 204 | 117 | 1  | -1 | -1 | 0  | 0  | 0  |
| 128 | 34 | 65  | 203 | 115 | 1  | 1  | -1 | 0  | 0  | 0  |
| 185 | 61 | 142 | 304 | 321 | 1  | -1 | 1  | 0  | 0  | 0  |
| 187 | 60 | 149 | 298 | 322 | 1  | 1  | 1  | 0  | 0  | 0  |
| 178 | 57 | 97  | 261 | 243 | 1  | 0  | 0  | -1 | -1 | 0  |
| 176 | 56 | 94  | 262 | 239 | 1  | 0  | 0  | 1  | -1 | 0  |
| 177 | 57 | 97  | 263 | 239 | 1  | 0  | 0  | -1 | 1  | 0  |
| 178 | 58 | 95  | 261 | 239 | 1  | 0  | 0  | 1  | 1  | 0  |
| 131 | 30 | 65  | 208 | 112 | 1  | 0  | -1 | 0  | 0  | -1 |
| 169 | 54 | 109 | 284 | 232 | 1  | 0  | 1  | 0  | 0  | -1 |
| 134 | 33 | 57  | 202 | 119 | 1  | 0  | -1 | 0  | 0  | 1  |
| 187 | 61 | 144 | 310 | 336 | 1  | 0  | 1  | 0  | 0  | 1  |
| 176 | 53 | 87  | 263 | 228 | 1  | -1 | 0  | -1 | 0  | 0  |
| 178 | 54 | 101 | 258 | 241 | 1  | 1  | 0  | -1 | 0  | 0  |
| 179 | 53 | 99  | 259 | 234 | 1  | -1 | 0  | 1  | 0  | 0  |
| 179 | 58 | 95  | 265 | 239 | 1  | 1  | 0  | 1  | 0  | 0  |
| 174 | 47 | 109 | 275 | 223 | 1  | 0  | 0  | 0  | -1 | -1 |
| 171 | 52 | 100 | 276 | 223 | 1  | 0  | 0  | 0  | 1  | -1 |
| 177 | 55 | 96  | 262 | 240 | 1  | 0  | 0  | 0  | -1 | 1  |
| 174 | 54 | 94  | 261 | 235 | 1  | 0  | 0  | 0  | 1  | 1  |
| 173 | 56 | 103 | 254 | 235 | 1  | 0  | 0  | 0  | 0  | 0  |
| 158 | 47 | 85  | 276 | 218 | 1  | 0  | 0  | 0  | 0  | 0  |
| 180 | 65 | 112 | 252 | 260 | 1  | 0  | 0  | 0  | 0  | 0  |
| 135 | 36 | 64  | 208 | 118 | 1  | 0  | -1 | -1 | 0  | 0  |
| 185 | 61 | 137 | 295 | 310 | 1  | 0  | 1  | -1 | 0  | 0  |
| 141 | 31 | 60  | 205 | 118 | 1  | 0  | -1 | 1  | 0  | 0  |
| 185 | 60 | 137 | 293 | 302 | 1  | 0  | 1  | 1  | 0  | 0  |
| 180 | 49 | 97  | 259 | 230 | 1  | -1 | 0  | 0  | -1 | 0  |
| 176 | 51 | 97  | 259 | 233 | 1  | 1  | 0  | 0  | -1 | 0  |

|     |    |     |     |     |   |    |    |    |    |    |
|-----|----|-----|-----|-----|---|----|----|----|----|----|
| 185 | 53 | 90  | 266 | 235 | 1 | -1 | 0  | 0  | 1  | 0  |
| 177 | 57 | 98  | 261 | 239 | 1 | 1  | 0  | 0  | 1  | 0  |
| 169 | 51 | 94  | 268 | 212 | 1 | 0  | 0  | -1 | 0  | -1 |
| 175 | 48 | 93  | 280 | 218 | 1 | 0  | 0  | 1  | 0  | -1 |
| 167 | 53 | 91  | 267 | 225 | 1 | 0  | 0  | -1 | 0  | 1  |
| 181 | 54 | 96  | 260 | 242 | 1 | 0  | 0  | 1  | 0  | 1  |
| 170 | 54 | 94  | 270 | 230 | 1 | -1 | 0  | 0  | 0  | -1 |
| 173 | 54 | 93  | 272 | 230 | 1 | 1  | 0  | 0  | 0  | -1 |
| 180 | 55 | 96  | 253 | 243 | 1 | -1 | 0  | 0  | 0  | 1  |
| 181 | 56 | 103 | 256 | 249 | 1 | 1  | 0  | 0  | 0  | 1  |
| 139 | 38 | 61  | 201 | 118 | 1 | 0  | -1 | 0  | -1 | 0  |
| 187 | 61 | 138 | 302 | 312 | 1 | 0  | 1  | 0  | -1 | 0  |
| 139 | 34 | 59  | 205 | 116 | 1 | 0  | -1 | 0  | 1  | 0  |
| 186 | 59 | 143 | 296 | 309 | 1 | 0  | 1  | 0  | 1  | 0  |
| 183 | 57 | 101 | 245 | 268 | 1 | 0  | 0  | 0  | 0  | 0  |
| 180 | 59 | 136 | 273 | 258 | 1 | 0  | 0  | 0  | 0  | 0  |
| 185 | 65 | 93  | 257 | 253 | 1 | 0  | 0  | 0  | 0  | 0  |

Centcom Response Matrix with Box and Behnken Fractional Factorial

| Y1  | Y2  | Y3 | Y4 | Y5  | mu | X1 | X2 | X3 | X4 | X5 |
|-----|-----|----|----|-----|----|----|----|----|----|----|
| 111 | 61  | 64 | 26 | 143 | 1  | -1 | -1 | 0  | 0  | 0  |
| 151 | 136 | 0  | 77 | 268 | 1  | 1  | -1 | 0  | 0  | 0  |
| 111 | 56  | 64 | 32 | 140 | 1  | -1 | 1  | 0  | 0  | 0  |
| 151 | 136 | 0  | 77 | 268 | 1  | 1  | 1  | 0  | 0  | 0  |
| 151 | 136 | 5  | 77 | 272 | 1  | 0  | 0  | -1 | -1 | 0  |
| 151 | 136 | 0  | 79 | 269 | 1  | 0  | 0  | 1  | -1 | 0  |
| 148 | 133 | 11 | 77 | 268 | 1  | 0  | 0  | -1 | 1  | 0  |
| 151 | 136 | 0  | 77 | 270 | 1  | 0  | 0  | 1  | 1  | 0  |
| 151 | 136 | 0  | 77 | 270 | 1  | 0  | -1 | 0  | 0  | -1 |
| 151 | 136 | 1  | 77 | 270 | 1  | 0  | 1  | 0  | 0  | -1 |
| 151 | 136 | 0  | 78 | 269 | 1  | 0  | -1 | 0  | 0  | 1  |
| 151 | 136 | 0  | 78 | 269 | 1  | 0  | 1  | 0  | 0  | 1  |
| 109 | 64  | 59 | 28 | 141 | 1  | -1 | 0  | -1 | 0  | 0  |
| 151 | 136 | 0  | 77 | 271 | 1  | 1  | 0  | -1 | 0  | 0  |
| 109 | 56  | 51 | 33 | 135 | 1  | -1 | 0  | 1  | 0  | 0  |
| 151 | 136 | 0  | 77 | 270 | 1  | 1  | 0  | 1  | 0  | 0  |
| 151 | 136 | 0  | 78 | 270 | 1  | 0  | 0  | 0  | -1 | -1 |
| 151 | 136 | 0  | 77 | 270 | 1  | 0  | 0  | 0  | 1  | -1 |
| 151 | 136 | 0  | 80 | 270 | 1  | 0  | 0  | 0  | -1 | 1  |
| 151 | 136 | 0  | 77 | 268 | 1  | 0  | 0  | 0  | 1  | 1  |
| 151 | 136 | 1  | 79 | 272 | 1  | 0  | 0  | 0  | 0  | 0  |
| 158 | 140 | 3  | 77 | 282 | 1  | 0  | 0  | 0  | 0  | 0  |

|     |     |    |    |     |   |    |    |    |    |    |
|-----|-----|----|----|-----|---|----|----|----|----|----|
| 164 | 146 | 3  | 76 | 290 | 1 | 0  | 0  | 0  | 0  | 0  |
| 151 | 136 | 4  | 78 | 271 | 1 | 0  | -1 | -1 | 0  | 0  |
| 151 | 136 | 5  | 80 | 271 | 1 | 0  | 1  | -1 | 0  | 0  |
| 151 | 136 | 0  | 77 | 270 | 1 | 0  | -1 | 1  | 0  | 0  |
| 151 | 136 | 0  | 77 | 270 | 1 | 0  | 1  | 1  | 0  | 0  |
| 108 | 62  | 61 | 27 | 141 | 1 | -1 | 0  | 0  | -1 | 0  |
| 151 | 136 | 0  | 78 | 269 | 1 | 1  | 0  | 0  | -1 | 0  |
| 106 | 70  | 54 | 30 | 147 | 1 | -1 | 0  | 0  | 1  | 0  |
| 151 | 136 | 0  | 78 | 269 | 1 | 1  | 0  | 0  | 1  | 0  |
| 151 | 136 | 9  | 73 | 270 | 1 | 0  | 0  | -1 | 0  | -1 |
| 151 | 136 | 1  | 77 | 270 | 1 | 0  | 0  | 1  | 0  | -1 |
| 151 | 136 | 6  | 78 | 272 | 1 | 0  | 0  | -1 | 0  | 1  |
| 151 | 136 | 0  | 77 | 270 | 1 | 0  | 0  | 1  | 0  | 1  |
| 108 | 56  | 68 | 26 | 137 | 1 | -1 | 0  | 0  | 0  | -1 |
| 151 | 136 | 2  | 76 | 271 | 1 | 1  | 0  | 0  | 0  | -1 |
| 104 | 71  | 60 | 30 | 146 | 1 | -1 | 0  | 0  | 0  | 1  |
| 151 | 136 | 0  | 77 | 270 | 1 | 1  | 0  | 0  | 0  | 1  |
| 151 | 136 | 1  | 77 | 270 | 1 | 0  | -1 | 0  | -1 | 0  |
| 151 | 136 | 1  | 79 | 271 | 1 | 0  | 1  | 0  | -1 | 0  |
| 151 | 136 | 0  | 77 | 270 | 1 | 0  | -1 | 0  | 1  | 0  |
| 151 | 136 | 1  | 76 | 270 | 1 | 0  | 1  | 0  | 1  | 0  |
| 147 | 122 | 0  | 76 | 255 | 1 | 0  | 0  | 0  | 0  | 0  |
| 133 | 118 | 0  | 79 | 236 | 1 | 0  | 0  | 0  | 0  | 0  |
| 173 | 185 | 0  | 94 | 340 | 1 | 0  | 0  | 0  | 0  | 0  |

# APPENDIX C: Multiple Regression ANOVA Tables

## ----- REGRESSION ANALYSIS -----

HEADER DATA FOR: B:EUR LABEL:

NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

## ----- EUROPE INFILTRATION (Y1) REGRESSION -----

| INDEX            | NAME | MEAN        | STD. DEV. |
|------------------|------|-------------|-----------|
| 1                | x2   | .0000       | .5963     |
| 2                | x3   | 7.60870E-16 | .5963     |
| 3                | x5   | 3.39130E-15 | .5963     |
| 4                | x2s  | .3478       | .4815     |
| 5                | x5s  | .3478       | .4815     |
| DEP. VAR.: infil |      | 706.9565    | 35.0884   |

DEPENDENT VARIABLE: infil

| VAR.     | REGRESS COEFF | STD. ERROR | T(DF= 40) | PROB.  | PART r^2 |
|----------|---------------|------------|-----------|--------|----------|
| x2       | 43.8125       | 3.4000     | 12.886    | .00000 | .8059    |
| x3       | 23.3125       | 3.4000     | 6.857     | .00000 | .5403    |
| x5       | 17.3750       | 3.4000     | 5.110     | .00001 | .3950    |
| x2s      | -13.4804      | 4.2584     | -3.166    | .00296 | .2003    |
| x5s      | -15.5637      | 4.2584     | -3.655    | .00074 | .2503    |
| CONSTANT | 717.0588      |            |           |        |          |

STD. ERROR OF EST. = 13.6001

ADJUSTED R SQUARED = .8498

R SQUARED = .8665

MULTIPLE R = .9308

## ANALYSIS OF VARIANCE TABLE

| SOURCE      | SUM OF SQUARES | D.F. | MEAN SQUARE | F RATIO | PROB.    |
|-------------|----------------|------|-------------|---------|----------|
| REGRESSION  | 48005.4253     | 5    | 9601.0851   | 51.908  | .000E+00 |
| RESIDUAL    | 7398.4877      | 40   | 184.9622    |         |          |
| LACK OF FIT | 6573.6544      | 35   | 187.8187    | 1.14    |          |
| PURE ERR    | 824.8333       | 5    | 164.9667    |         |          |
| TOTAL       | 55403.9130     | 45   |             |         |          |

----- REGRESSION ANALYSIS -----

HEADER DATA FOR: B:EUR LABEL:  
 NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

-----  
 EUROPE EXFILTRATION (Y2) REGRESSION

| INDEX      | NAME  | MEAN        | STD. DEV. |
|------------|-------|-------------|-----------|
| 1          | x2    | .0000       | .5963     |
| 2          | x3    | 7.60870E-16 | .5963     |
| 3          | x5    | 3.39130E-15 | .5963     |
| 4          | x2s   | .3478       | .4815     |
| 5          | x5s   | .3478       | .4815     |
| DEP. VAR.: | exfil | 340.9348    | 36.8905   |

-----  
 DEPENDENT VARIABLE: exfil

| VAR.     | REGRESS COEFF | STD. ERROR | T(DF= 40) | PROB.  | PART r^2 |
|----------|---------------|------------|-----------|--------|----------|
| x2       | 48.1250       | 3.0832     | 15.609    | .00000 | .8590    |
| x3       | 23.3750       | 3.0832     | 7.581     | .00000 | .5897    |
| x5       | 18.0625       | 3.0832     | 5.858     | .00000 | .4618    |
| x2s      | -15.0637      | 3.8615     | -3.901    | .00036 | .2756    |
| x5s      | -15.4804      | 3.8615     | -4.009    | .00026 | .2866    |
| CONSTANT | 351.5588      |            |           |        |          |

STD. ERROR OF EST. = 12.3327

ADJUSTED R SQUARED = .8882

R SQUARED = .9007

MULTIPLE R = .9490

ANALYSIS OF VARIANCE TABLE

| SOURCE     | SUM OF SQUARES | D.F. | MEAN SQUARE | F RATIO | PROB.    |
|------------|----------------|------|-------------|---------|----------|
| REGRESSION | 55157.0041     | 5    | 11031.4008  | 72.530  | .000E+00 |
| RESIDUAL   | 6083.8002      | 40   | 152.0950    |         |          |
| LACK FIT   | 5170.9669      | 35   | 147.7419    | 0.809   |          |
| PURE ERROR | 912.8333       | 5    | 182.5667    |         |          |
| TOTAL      | 61240.8043     | 45   |             |         |          |

----- REGRESSION ANALYSIS -----

HEADER DATA FOR: B:EUR LABEL:  
 NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

-----  
 EUROPE RESUPPLY (Y3) REGRESSION

| INDEX            | NAME | MEAN        | STD. DEV. |
|------------------|------|-------------|-----------|
| 1                | x1   | 1.69565E-15 | .5963     |
| 2                | x2   | .0000       | .5963     |
| 3                | x3   | 7.60870E-16 | .5963     |
| 4                | x5   | 3.39130E-15 | .5963     |
| 5                | x3s  | .3478       | .4815     |
| 6                | x5s  | .3478       | .4815     |
| DEP. VAR.: resup |      | 810.9348    | 125.0483  |

-----  
 DEPENDENT VARIABLE: resup

| VAR.     | REGRESS COEFF | STD. ERROR | T(DF= 39) | PROB.  | PART R^2 |
|----------|---------------|------------|-----------|--------|----------|
| x1       | -22.6250      | 14.4459    | -1.566    | .12538 | .0592    |
| x2       | 87.0000       | 14.4459    | 6.022     | .00000 | .4819    |
| x3       | 145.6875      | 14.4459    | 10.085    | .00000 | .7228    |
| x5       | -49.3125      | 14.4459    | -3.414    | .00151 | .2300    |
| x3s      | 77.8480       | 18.0928    | 4.303     | .00011 | .3219    |
| x5s      | 30.8480       | 18.0928    | 1.705     | .09615 | .0694    |
| CONSTANT | 773.1275      |            |           |        |          |

STD. ERROR OF EST. = 57.7837

ADJUSTED R SQUARED = .7865

R SQUARED = .8149

MULTIPLE R = .9027

ANALYSIS OF VARIANCE TABLE

| SOURCE     | SUM OF SQUARES | D.F. | MEAN SQUARE | F RATIO | PROB.     |
|------------|----------------|------|-------------|---------|-----------|
| REGRESSION | 573449.6107    | 6    | 95574.9351  | 28.624  | 7.700E-13 |
| RESIDUAL   | 130219.1936    | 39   | 3338.9537   |         |           |
| LACK FIT   | 128225.1936    | 34   | 3771.3292   | 9.46    |           |
| PURE       | 1994.0000      | 5    | 398.8000    |         |           |
| TOTAL      | 703668.8043    | 45   |             |         |           |

----- REGRESSION ANALYSIS -----

HEADER DATA FOR: B:EUR LABEL:  
 NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

-----  
 EUROPE RESCUE (Y4) REGRESSION

| INDEX            | NAME | MEAN        | STD. DEV. |
|------------------|------|-------------|-----------|
| 1                | x2   | .0000       | .5963     |
| 2                | x3   | 7.60870E-16 | .5963     |
| DEP. VAR.: rescu |      | 89.3043     | 4.5405    |

-----  
 DEPENDENT VARIABLE: rescu

| VAR.     | REGRESS COEFF | STD. ERROR | T(DF= 43) | PROB.  | PART r^2 |
|----------|---------------|------------|-----------|--------|----------|
| x2       | 4.6875        | .7693      | 6.093     | .00000 | .4634    |
| x3       | 3.2500        | .7693      | 4.225     | .00012 | .2933    |
| CONSTANT |               | 89.3043    |           |        |          |

STD. ERROR OF EST. = 3.0772

ADJUSTED R SQUARED = .5407  
 R SQUARED = .5611  
 MULTIPLE R = .7491

ANALYSIS OF VARIANCE TABLE

| SOURCE     | SUM OF SQUARES | D.F. | MEAN SQUARE | F RATIO | PROB.     |
|------------|----------------|------|-------------|---------|-----------|
| REGRESSION | 520.5625       | 2    | 260.2813    | 27.487  | 2.045E-08 |
| RESIDUAL   | 407.1766       | 43   | 9.4692      |         |           |
| LACK FIT   | 243.6766       | 38   | 6.4125      | 0.196   |           |
| PURE ERR   | 163.5000       | 5    | 32.7000     |         |           |
| TOTAL      | 927.7391       | 45   |             |         |           |

----- REGRESSION ANALYSIS -----

HEADER DATA FOR: B:EUR LABEL:  
 NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

-----  
 EUROPE REFUELING (Y5) REGRESSION

| INDEX             | NAME | MEAN        | STD. DEV. |
|-------------------|------|-------------|-----------|
| 1                 | x1   | 1.69565E-15 | .5963     |
| 2                 | x2   | .0000       | .5963     |
| 3                 | x3   | 7.60870E-16 | .5963     |
| 4                 | x5   | 3.39130E-15 | .5963     |
| 5                 | x1s  | .3478       | .4815     |
| 6                 | x2s  | .3478       | .4815     |
| 7                 | x4s  | .3478       | .4815     |
| DEP. VAR.: refuel |      | 299.2391    | 58.4295   |

DEPENDENT VARIABLE: refuel

| VAR.     | REGRESS COEFF | STD. ERROR | T(DF= 38) | PROB.  | PART r^2 |
|----------|---------------|------------|-----------|--------|----------|
| x1       | -18.1250      | 4.2074     | -4.308    | .00011 | .3281    |
| x2       | 86.5625       | 4.2074     | 20.574    | .00000 | .9176    |
| x3       | -16.0000      | 4.2074     | -3.803    | .00050 | .2757    |
| x5       | 14.1250       | 4.2074     | 3.357     | .00180 | .2287    |
| x1s      | 30.2262       | 5.3536     | 5.646     | .00000 | .4562    |
| x2s      | 11.4762       | 5.3536     | 2.144     | .03852 | .1079    |
| x4s      | 16.1429       | 5.3536     | 3.015     | .00456 | .1931    |
| CONSTANT | 279.1190      |            |           |        |          |

STD. ERROR OF EST. = 16.8297

ADJUSTED R SQUARED = .9170

R SQUARED = .9299

MULTIPLE R = .9643

ANALYSIS OF VARIANCE TABLE

| SOURCE     | SUM OF SQUARES | D.F. | MEAN SQUARE | F RATIO | PROB.     |
|------------|----------------|------|-------------|---------|-----------|
| REGRESSION | 142867.2416    | 7    | 20409.6059  | 72.058  | 1.700E-13 |
| RESIDUAL   | 10763.1280     | 38   | 283.2402    |         |           |
| LACK FIT   | 9464.2947      | 33   | 286.7968    | 1.104   |           |
| PURE ERR   | 1298.8333      | 5    | 259.7667    |         |           |
| TOTAL      | 153630.3696    | 45   |             |         |           |

----- REGRESSION ANALYSIS -----

HEADER DATA FOR: C:PAC LABEL:  
 NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

-----  
 PACIFIC INFILTRATION (Y1) REGRESSION

| INDEX            | NAME | MEAN        | STD. DEV. |
|------------------|------|-------------|-----------|
| 1                | x2   | .0000       | .5963     |
| 2                | x3   | 7.60870E-16 | .5963     |
| 3                | x5   | 3.39130E-15 | .5963     |
| 4                | x2s  | .3478       | .4815     |
| 5                | x5s  | .3478       | .4815     |
| DEP. VAR.: infil |      | 170.4130    | 17.6265   |

-----  
 DEPENDENT VARIABLE: Y1

| VAR.              | REGRESS COEFF | STD. ERROR | T(DF=40) | PROB.  | PARTIAL r^2 |
|-------------------|---------------|------------|----------|--------|-------------|
| x2                | 24.5625       | 1.2142     | 20.229   | .00000 | .9110       |
| x3                | 1.8125        | 1.2142     | 1.493    | .14336 | .0528       |
| x5                | 3.0625        | 1.2142     | 2.522    | .01575 | .1372       |
| x2s               | -17.6127      | 1.5208     | -11.582  | .00000 | .7703       |
| x5s               | -3.9461       | 1.5208     | -2.595   | .01317 | .1441       |
| CONSTANT 177.9118 |               |            |          |        |             |

STD. ERROR OF EST. = 4.8569

ADJUSTED R SQUARED = .9241

R SQUARED = .9325

MULTIPLE R = .9657

ANALYSIS OF VARIANCE TABLE

| SOURCE      | SUM OF SQUARES | D.F. | MEAN SQUARE | F RATIO | PROB.     |
|-------------|----------------|------|-------------|---------|-----------|
| REGRESSION  | 13037.5652     | 5    | 2607.5130   | 110.536 | 3.000E-14 |
| RESIDUAL    | 943.5870       | 40   | 23.5897     |         |           |
| LACK OF FIT | 450.0870       | 35   | 12.8596     | 0.130   |           |
| PURE ERROR  | 493.5000       | 5    | 98.7000     |         |           |
| TOTAL       | 13981.1522     | 45   |             |         |           |

----- REGRESSION ANALYSIS -----

HEADER DATA FOR: C:PAC LABEL:  
 NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

-----  
 PACIFIC EXFILTRATION (Y2) REGRESSION

| INDEX            | NAME | MEAN        | STD. DEV. |
|------------------|------|-------------|-----------|
| 1                | x2   | .0000       | .5963     |
| 2                | x5   | 3.39130E-15 | .5963     |
| 3                | x2s  | .3478       | .4#5      |
| 4                | x5s  | .3478       | .4815     |
| DEP. VAR.: exfil |      | 51.9130     | 9.2396    |

-----  
 DEPENDENT VARIABLE: Y2

| VAR.     | REGRESS COEFF | STD. ERROR | T(DF=41) | PROB.  | PARTIAL r^2 |
|----------|---------------|------------|----------|--------|-------------|
| x2       | 12.7500       | .8368      | 15.236   | .00000 | .8499       |
| x5       | 1.9375        | .8368      | 2.315    | .02568 | .1156       |
| x2       | -8.1912       | 1.0481     | -7.816   | .00000 | .5984       |
| x5s      | -3.1078       | 1.0481     | -2.965   | .00502 | .1766       |
| CONSTANT | 55.8431       |            |          |        |             |

STD. ERROR OF EST. = 3.3473

ADJUSTED R SQUARED = .8688  
 R SQUARED = .8804  
 MULTIPLE R = .9383

ANALYSIS OF VARIANCE TABLE

| SOURCE      | SUM OF SQUARES | D.F. | MEAN SQUARE | F RATIO | PROB.    |
|-------------|----------------|------|-------------|---------|----------|
| REGRESSION  | 3382.2833      | 4    | 845.5708    | 75.470  | .000E+00 |
| RESIDUAL    | 459.3689       | 41   | 11.2041     |         |          |
| LACK OF FIT | 234.5356       | 36   | 6.5149      | 0.145   |          |
| PURE ERROR  | 224.8333       | 5    | 44.9667     |         |          |
| TOTAL       | 3841.6522      | 45   |             |         |          |

----- REGRESSION ANALYSIS -----

HEADER DATA FOR: C:PAC LABEL:  
NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

-----  
PACIFIC RESUPPLY (Y3) REGRESSION

| INDEX      | NAME  | MEAN    | STD. DEV. |
|------------|-------|---------|-----------|
| 1          | x2    | .0000   | .5963     |
| DEP. VAR.: | resup | 98.3043 | 24.4766   |

-----  
DEPENDENT VARIABLE: Y3

| VAR.     | REGRESS COEFF | STD. ERROR | T(DF= 44) | PROB.  |
|----------|---------------|------------|-----------|--------|
| x2       | 38.2500       | 2.2458     | 17.032    | .00000 |
| CONSTANT | 98.3043       |            |           |        |

STD. ERROR OF EST. = 8.9832

r SQUARED = .8683

r = .9318

ANALYSIS OF VARIANCE TABLE

| SOURCE      | SUM OF SQUARES | D.F. | MEAN SQUARE | F RATIO | PROB.    |
|-------------|----------------|------|-------------|---------|----------|
| REGRESSION  | 23409.0000     | 1    | 23409.0000  | 290.079 | .000E+00 |
| RESIDUAL    | 3550.7391      | 44   | 80.6986     |         |          |
| LACK OF FIT | 1976.7361      | 39   | 50.6855     | 0.161   |          |
| PURE ERROR  | 1574.0000      | 5    | 314.8000    |         |          |
| TOTAL       | 26959.7391     | 45   |             |         |          |

----- REGRESSION ANALYSIS -----

HEADER DATA FOR: C:PAC LABEL:  
 NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

-----  
 PACIFIC RESCUE (Y4) REGRESSION

| INDEX      | NAME  | MEAN        | STD. DEV. |
|------------|-------|-------------|-----------|
| 1          | x2    | .0000       | .5963     |
| 2          | x5    | 3.39130E-15 | .5963     |
| 3          | x2s   | .3478       | .4815     |
| 4          | x5s   | .3478       | .4815     |
| DEP. VAR.: | rescu | 258.9565    | 29.2984   |

-----  
 DEPENDENT VARIABLE: RESCUE

| VAR.     | REGRESS COEFF | STD. ERROR | T(DF=41) | PROB.  | PARTIAL r^2 |
|----------|---------------|------------|----------|--------|-------------|
| x2       | 46.6250       | 1.7146     | 27.193   | .00000 | .9475       |
| x5       | -3.8750       | 1.7146     | -2.260   | .02920 | .1108       |
| x2s      | -11.3922      | 2.1475     | -5.305   | .00000 | .4070       |
| x5s      | 4.1078        | 2.1475     | 1.913    | .06277 | .0819       |
| CONSTANT | 261.4902      |            |          |        |             |

STD. ERROR OF EST. = 6.8585

ADJUSTED R SQUARED = .9452  
 R SQUARED = .9501  
 MULTIPLE R = .9747

ANALYSIS OF VARIANCE TABLE

| SOURCE      | SUM OF SQUARES | D.F. | MEAN SQUARE | F RATIO | PROB.    |
|-------------|----------------|------|-------------|---------|----------|
| REGRESSION  | 36699.3150     | 4    | 9174.8288   | 195.047 | .000E+00 |
| RESIDUAL    | 1928.5980      | 41   | 47.0390     |         |          |
| LACK OF FIT | 1171.098       | 36   | 32.5305     | 0.215   |          |
| PURE ERROR  | 757.5000       | 5    | 151.5000    |         |          |
| TOTAL       | 38627.9130     | 45   |             |         |          |

----- REGRESSION ANALYSIS -----

HEADER DATA FOR: C:PAC LABEL:  
 NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

-----  
 PACIFIC REFUELING (Y5) REGRESSION

| INDEX            | NAME | MEAN        | STD. DEV. |
|------------------|------|-------------|-----------|
| 1                | x2   | .0000       | .5963     |
| 2                | x5   | 3.39130E-15 | .5963     |
| 3                | x2s  | .3478       | .4815     |
| 4                | x5s  | .3478       | .4815     |
| DEP. VAR.: refue |      | 227.7826    | 59.8405   |

-----  
 DEPENDENT VARIABLE: REFUEL

| VAR.                         | REGRESS COEFF | STD. ERROR | T(DF=41) | PROB.  | PARTIAL r^2 |
|------------------------------|---------------|------------|----------|--------|-------------|
| x2                           | 94.4375       | 3.3914     | 27.847   | .00000 | .9498       |
| x5                           | 13.0625       | 3.3914     | 3.852    | .00040 | .2657       |
| x2s                          | -27.3382      | 4.2475     | -6.436   | .00000 | .5026       |
| x5s                          | -11.3382      | 4.2475     | -2.669   | .01084 | .1481       |
| CONSTANT                     |               | 241.2353   |          |        |             |
| STD. ERROR OF EST. = 13.5654 |               |            |          |        |             |

ADJUSTED R SQUARED = .9486  
 R SQUARED = .9532  
 MULTIPLE R = .9763

ANALYSIS OF VARIANCE TABLE

| SOURCE     | SUM OF SQUARES | D.F. | MEAN SQUAR. | F RATIO | PROB.    |
|------------|----------------|------|-------------|---------|----------|
| REGRESSION | 153594.9805    | 4    | 38398.7451  | 208.665 | .000E+00 |
| RESIDUAL   | 7544.8456      | 41   | 184.0206    |         |          |
| TOTAL      | 161139.8261    | 45   |             |         |          |

----- REGRESSION ANALYSIS -----

HEADER DATA FOR: C:CENT LABEL:  
 NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

-----  
 CENTCOM INFILTRATION (Y1) REGRESSION

| INDEX            | NAME | MEAN        | STD. DEV. |
|------------------|------|-------------|-----------|
| 1                | X1   | 1.69565E-15 | .5963     |
| 2                | x1s  | .3478       | .4815     |
| DEP. VAR.: INFIL |      | 143.9348    | 17.2658   |

-----  
 DEPENDENT VARIABLE: INFIL

| VAR.     | REGRESS COEFF | STD. ERROR | T(DF=43) | PROB.  | PARTIAL r^2 |
|----------|---------------|------------|----------|--------|-------------|
| X1       | 21.3750       | 1.2534     | 17.054   | .00000 | .8712       |
| x1s      | -21.9417      | 1.5521     | -14.137  | .00000 | .8229       |
| CONSTANT | 151.5667      |            |          |        |             |

STD. ERROR OF EST. = 5.0136

ADJUSTED R SQUARED = .9157  
 R SQUARED = .9194  
 MULTIPLE R = .9589

ANALYSIS OF VARIANCE TABLE

| SOURCE     | SUM OF SQUARES | D.F. | MEAN SQ   | F RATIO | PROB.    |
|------------|----------------|------|-----------|---------|----------|
| REGRESSION | 12333.9377     | 2    | 6166.9688 | 245.340 | .000E+00 |
| RESIDUAL   | 1080.8667      | 43   | 25.1364   |         |          |
| LACK FIT   | 105.5334       | 38   | 2.7772    | 0.014   |          |
| PURE ERR   | 975.3333       | 5    | 195.0667  |         |          |
| TOTAL      | 13414.8043     | 45   |           |         |          |

----- REGRESSION ANALYSIS -----

HEADER DATA FOR: C:CENT LABEL:  
 NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

-----  
 CENTCOM EXFILTRATION (Y2) REGRESSION

| INDEX      | NAME  | MEAN        | STD. DEV. |
|------------|-------|-------------|-----------|
| 1          | X1    | 1.69565E-15 | .5963     |
| 2          | x1s   | .3478       | .4815     |
| DEP. VAR.: | EXFIL | 123.7391    | 29.8875   |

-----  
 DEPENDENT VARIABLE: EXFILS

| VAR.     | REGRESS COEFF | STD. ERROR | T(DF=43) | PROB.  | PARTIAL r <sup>2</sup> |
|----------|---------------|------------|----------|--------|------------------------|
| X1       | 37.0000       | 2.1827     | 16.951   | .00000 | .8698                  |
| x1s      | -37.9333      | 2.7028     | -14.035  | .00000 | .8208                  |
| CONSTANT | 136.9333      |            |          |        |                        |

STD. ERROR OF EST. = 8.7309

ADJUSTED R SQUARED = .9147  
 R SQUARED = .9185  
 MULTIPLE R = .9584

ANALYSIS OF VARIANCE TABLE

| SOURCE     | SUM OF SQUARES | D.F. | MEAN SQUARE | F RATIO | PROB.    |
|------------|----------------|------|-------------|---------|----------|
| REGRESSION | 36919.0029     | 2    | 18459.5014  | 242.157 | .000E+00 |
| RESIDUAL   | 3277.8667      | 43   | 76.2295     |         |          |
| LACK FIT   | 401.0334       | 38   | 10.5535     | 0.018   |          |
| PURE ERR   | 2876.8333      | 5    | 575.3667    |         |          |
| TOTAL      | 40196.8696     | 45   |             |         |          |

----- REGRESSION ANALYSIS -----

HEADER DATA FOR: A:CENT LABEL:  
 NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

-----  
 CENTCOM RESUPPLY (Y3) REGRESSION

| INDEX               | NAME | MEAN        | STD. DEV. |
|---------------------|------|-------------|-----------|
| 1                   | X1   | 1.69565E-15 | .5963     |
| 2                   | X3   | 7.60870E-16 | .5963     |
| 3                   | x1s  | .3478       | .4815     |
| DEP. VAR.: RESUPPLY |      | 11.6304     | 22.7277   |

-----  
 DEPENDENT VARIABLE: RESUPPLY

| VAR.     | REGRESS  | COEFF | STD. ERROR | T(DF=42) | PROB.  | PARTIAL r^2 |
|----------|----------|-------|------------|----------|--------|-------------|
| X1       | -29.9375 |       | .6881      | -43.508  | .00000 | .9783       |
| X3       | -2.9375  |       | .6881      | -4.269   | .00011 | .3026       |
| x1s      | 28.4542  |       | .8521      | 33.395   | .00000 | .9637       |
| CONSTANT |          |       | 1.7333     |          |        |             |

STD. ERROR OF EST. = 2.7524

ADJUSTED R SQUARED = .9853

R SQUARED = .9863

MULTIPLE R = .9931

ANALYSIS OF VARIANCE TABLE

| SOURCE     | SUM OF SQUARES | D.F. | MEAN SQ   | F RATIO  | PROB.    |
|------------|----------------|------|-----------|----------|----------|
| REGRESSION | 22926.5382     | 3    | 7642.1794 | 1008.776 | .000E+00 |
| RESIDUAL   | 318.1792       | 42   | 7.5757    |          |          |
| LACK FIT   | 307.3459       | 37   | 8.3066    | 3.834    |          |
| PURE ERR   | 10.8333        | 5    | 2.1667    |          |          |
| TOTAL      | 23244.7174     | 45   |           |          |          |

----- REGRESSION ANALYSIS -----

HEADER DATA FOR: B:CENT LABEL:  
 NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

-----  
 CENTCOM RESCUE (Y4) REGRESSION

| INDEX      | NAME   | MEAN        | STD. DEV. |
|------------|--------|-------------|-----------|
| 1          | X1     | 1.69565E-15 | .5963     |
| 2          | x1s    | .3478       | .4815     |
| DEP. VAR.: | RESCUE | 69.3043     | 18.9196   |

-----  
 DEPENDENT VARIABLE: RESCUE

| VAR.     | REGRESS COEFF | STD. ERROR | T(DF=43) | PROB.  | PARTIAL r^2 |
|----------|---------------|------------|----------|--------|-------------|
| X1       | 24.0625       | .7352      | 32.731   | .00000 | .9614       |
| x1s      | -24.9042      | .9103      | -27.357  | .00000 | .9457       |
| CONSTANT |               | 77.9667    |          |        |             |

STD. ERROR OF EST. = 2.9407

ADJUSTED R SQUARED = .9758  
 R SQUARED = .9769  
 MULTIPLE R = .9884

ANALYSIS OF VARIANCE TABLE

| SOURCE     | SUM OF SQUARES | D.F. | MEAN SQ   | F RATIO | PROB.    |
|------------|----------------|------|-----------|---------|----------|
| REGRESSION | 15735.8975     | 2    | 7867.9487 | 909.854 | .000E+00 |
| RESIDUAL   | 371.8417       | 43   | 8.6475    |         |          |
| LACK FIT   | 133.0084       | 38   | 3.5002    | 0.073   |          |
| PURE ERR   | 238.8333       | 5    | 47.7667   |         |          |
| TOTAL      | 16107.7391     | 45   |           |         |          |

----- REGRESSION ANALYSIS -----

HEADER DATA FOR: B:CENT LABEL:  
 NUMBER OF CASES: 46 NUMBER OF VARIABLES: 16

-----  
 CENTCOM REFUELING (Y5) REGRESSION

| INDEX      | NAME   | MEAN        | STD. DEV. |
|------------|--------|-------------|-----------|
| 1          | X1     | 1.69565E-15 | .5963     |
| 2          | x1s    | .3478       | .4815     |
| DEP. VAR.: | REFUEL | 248.7174    | 51.3717   |

-----  
 DEPENDENT VARIABLE: REFUEL

| VAR.     | REGRESS COEFF | STD. ERROR | T(DF=43) | PROB.  | PARTIAL R^2 |
|----------|---------------|------------|----------|--------|-------------|
| X1       | 64.1250       | 3.1617     | 20.282   | .00000 | .9054       |
| x1s      | -66.4583      | 3.9151     | -16.975  | .00000 | .8701       |
| CONSTANT | 271.8333      |            |          |        |             |

STD. ERROR OF EST. = 12.6470

ADJUSTED R SQUARED = .9394

R SQUARED = .9421

MULTIPLE R = .9706

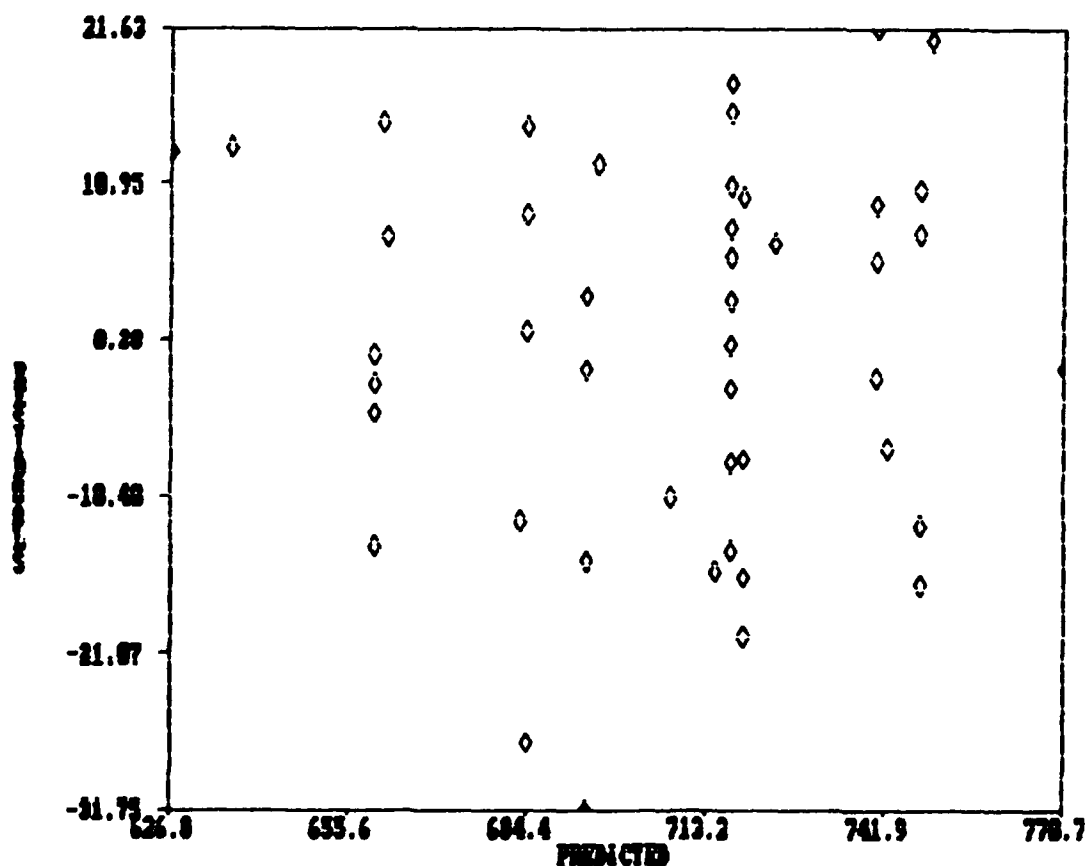
ANALYSIS OF VARIANCE TABLE

| SOURCE     | SUM OF SQUARES | D.F. | MEAN SQ    | F RATIO | PROB.    |
|------------|----------------|------|------------|---------|----------|
| REGRESSION | 111879.6594    | 2    | 55939.8297 | 349.743 | .000E+00 |
| RESIDUAL   | 6877.6667      | 43   | 159.9457   |         |          |
| LACK FIT   | 552.8334       | 38   | 14.5482    | 0.012   |          |
| PURE ERR   | 6324.8333      | 5    | 1264.9667  |         |          |
| TOTAL      | 118757.3261    | 45   |            |         |          |

# APPENDIX D: Europe Infil Residuals

| RUN | OBSR | PREDICT | RESIDUAL | RUN | OBSR | PREDICT | RESIDUAL |
|-----|------|---------|----------|-----|------|---------|----------|
| 1   | 655  | 659.766 | -4.7660  | 24  | 650  | 636.453 | 13.5470  |
| 2   | 657  | 659.766 | -2.7660  | 25  | 731  | 724.078 | 6.9220   |
| 3   | 758  | 747.391 | 10.6090  | 26  | 671  | 683.078 | -12.0780 |
| 4   | 755  | 747.391 | 7.6090   | 27  | 769  | 770.703 | -1.7030  |
| 5   | 679  | 693.746 | -14.7460 | 28  | 717  | 717.059 | -0.0590  |
| 6   | 762  | 740.371 | 21.6290  | 29  | 728  | 717.059 | 10.9410  |
| 7   | 662  | 693.746 | -31.7460 | 30  | 714  | 717.059 | -3.0590  |
| 8   | 738  | 740.371 | -2.3710  | 31  | 723  | 717.059 | 5.9410   |
| 9   | 640  | 626.827 | 13.1730  | 32  | 676  | 660.808 | 15.1920  |
| 10  | 699  | 714.452 | -15.4520 | 33  | 697  | 707.433 | -10.4330 |
| 11  | 669  | 661.577 | 7.4230   | 34  | 708  | 695.558 | 12.4420  |
| 12  | 770  | 749.202 | 20.7980  | 35  | 735  | 742.183 | -7.1830  |
| 13  | 692  | 693.746 | -1.7460  | 36  | 685  | 684.12  | 0.8800   |
| 14  | 697  | 693.746 | 3.2540   | 37  | 657  | 684.12  | -27.1200 |
| 15  | 750  | 740.371 | 9.6290   | 38  | 703  | 718.87  | -15.8700 |
| 16  | 746  | 740.371 | 5.6290   | 39  | 699  | 718.87  | -19.8700 |
| 17  | 693  | 684.12  | 8.8800   | 40  | 646  | 659.766 | -13.7660 |
| 18  | 699  | 684.12  | 14.8800  | 41  | 735  | 747.391 | -12.3910 |
| 19  | 711  | 718.87  | -7.8700  | 42  | 659  | 659.766 | -0.7660  |
| 20  | 729  | 718.87  | 10.1300  | 43  | 731  | 747.391 | -16.3910 |
| 21  | 709  | 717.059 | -8.0590  | 44  | 725  | 717.059 | 7.9410   |
| 22  | 703  | 717.059 | -14.0590 | 45  | 735  | 717.059 | 17.9410  |
| 23  | 720  | 717.059 | 2.9410   | 46  | 733  | 717.059 | 15.9410  |

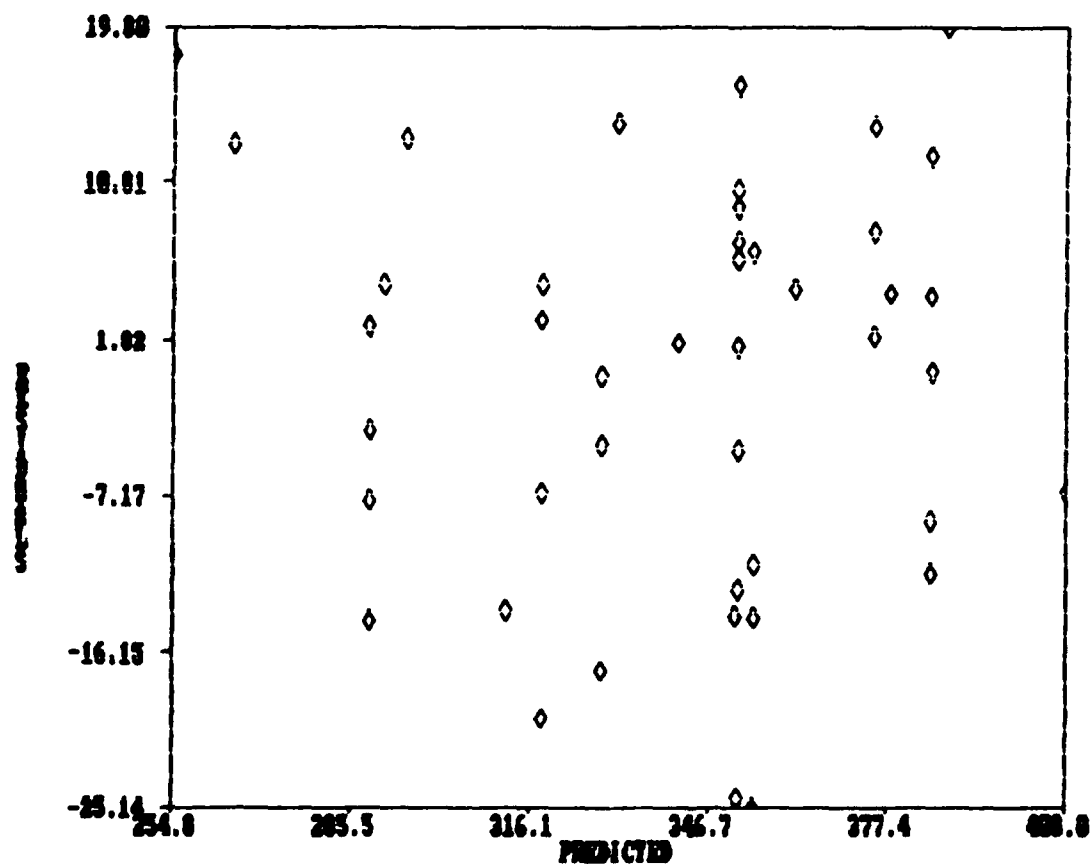
## EUROPE INFIL RESIDUAL PLOT



# Europe Exfil Residuals

| RUN | OBSR | PREDICT | RESIDUAL | RUN | OBSR | PREDICT | RESIDUAL |
|-----|------|---------|----------|-----|------|---------|----------|
| 1   | 291  | 288.37  | 2.6300   | 24  | 278  | 264.995 | 13.0050  |
| 2   | 285  | 288.37  | -3.3700  | 25  | 366  | 361.245 | 4.7550   |
| 3   | 397  | 384.62  | 12.3800  | 26  | 298  | 311.745 | -13.7450 |
| 4   | 389  | 384.62  | 4.3800   | 27  | 401  | 407.995 | -6.9950  |
| 5   | 311  | 328.184 | -17.1840 | 28  | 362  | 351.559 | 10.4410  |
| 6   | 389  | 374.934 | 14.0660  | 29  | 368  | 351.559 | 16.4410  |
| 7   | 328  | 328.184 | -0.1840  | 30  | 358  | 351.559 | 6.4410   |
| 8   | 377  | 374.934 | 2.0660   | 31  | 359  | 351.559 | 7.4410   |
| 9   | 273  | 254.827 | 18.1730  | 32  | 308  | 294.641 | 13.3590  |
| 10  | 337  | 351.077 | -14.0770 | 33  | 343  | 341.391 | 1.6090   |
| 11  | 296  | 290.952 | 5.0480   | 34  | 345  | 330.766 | 14.2340  |
| 12  | 407  | 387.202 | 19.7980  | 35  | 382  | 377.516 | 4.4840   |
| 13  | 324  | 328.184 | -4.1840  | 36  | 311  | 318.016 | -7.0160  |
| 14  | 324  | 328.184 | -4.1840  | 37  | 298  | 318.016 | -20.0160 |
| 15  | 383  | 374.934 | 8.0660   | 38  | 340  | 354.141 | -14.1410 |
| 16  | 385  | 384.934 | 0.0660   | 39  | 329  | 354.141 | -25.1410 |
| 17  | 323  | 318.016 | 4.9840   | 40  | 274  | 288.37  | -14.3700 |
| 18  | 321  | 318.016 | 2.9840   | 41  | 376  | 384.62  | -8.6200  |
| 19  | 343  | 354.141 | -11.1410 | 42  | 281  | 288.37  | -7.3700  |
| 20  | 361  | 354.141 | 6.8590   | 43  | 373  | 384.62  | -11.6200 |
| 21  | 347  | 351.559 | -4.5590  | 44  | 353  | 351.559 | 1.4410   |
| 22  | 327  | 351.559 | -24.5590 | 45  | 361  | 351.559 | 9.4410   |
| 23  | 339  | 351.559 | -12.5590 | 46  | 362  | 351.559 | 10.441   |

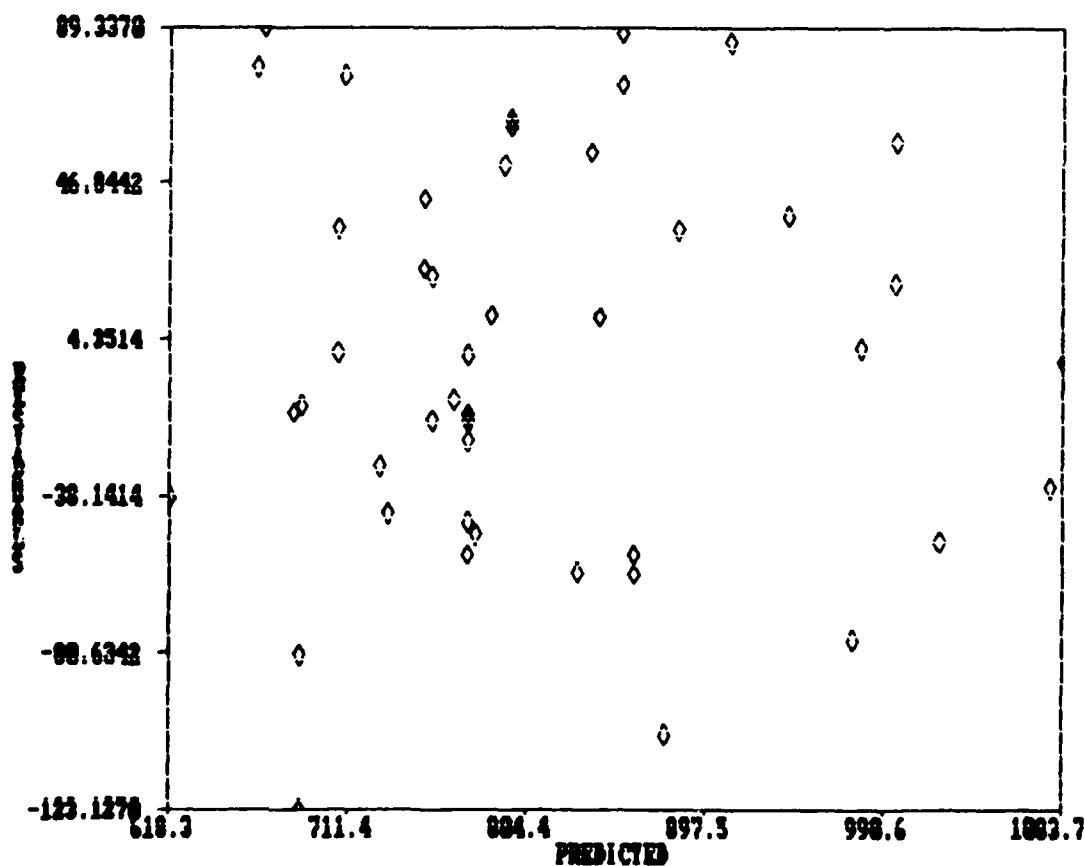
EUROPE EXFIL RESIDUAL PLOT



# Europe Resupply Residuals

| RUN | OBSR | PREDICT  | RESIDUAL | RUN | OBSR | PREDICT  | RESIDUAL   |
|-----|------|----------|----------|-----|------|----------|------------|
| 1   | 785  | 708.752  | 76.2480  | 24  | 580  | 618.288  | -38.2880   |
| 2   | 742  | 663.502  | 78.4980  | 25  | 844  | 792.288  | 51.7120    |
| 3   | 917  | 882.752  | 34.2480  | 26  | 995  | 909.663  | 85.3370    |
| 4   | 893  | 837.502  | 55.4980  | 27  | 1082 | 1083.663 | -1.6630    |
| 5   | 740  | 705.288  | 34.7120  | 28  | 858  | 795.752  | 62.2480    |
| 6   | 1016 | 996.663  | 19.3370  | 29  | 774  | 750.502  | 23.4980    |
| 7   | 706  | 705.288  | 0.7120   | 30  | 860  | 795.752  | 64.2480    |
| 8   | 1055 | 996.663  | 58.3370  | 31  | 793  | 750.502  | 42.4980    |
| 9   | 754  | 766.288  | -12.2880 | 32  | 796  | 785.449  | 10.5510    |
| 10  | 978  | 940.288  | 37.7120  | 33  | 1041 | 1076.824 | -35.8240   |
| 11  | 757  | 667.663  | 89.3370  | 34  | 673  | 686.824  | -13.8240   |
| 12  | 852  | 841.663  | 10.3370  | 35  | 980  | 978.199  | 1.8010     |
| 13  | 698  | 727.913  | -29.9130 | 36  | 773  | 875.913  | -102.9130  |
| 14  | 667  | 682.663  | -15.6630 | 37  | 772  | 830.663  | -58.6630   |
| 15  | 969  | 1019.288 | -50.2880 | 38  | 729  | 777.288  | -48.2880   |
| 16  | 897  | 974.038  | -77.0380 | 39  | 689  | 732.038  | -43.0380   |
| 17  | 927  | 853.288  | 73.7120  | 40  | 563  | 686.127  | -123.1270  |
| 18  | 941  | 853.288  | 87.7120  | 41  | 806  | 860.127  | -54.1270   |
| 19  | 776  | 754.663  | 21.3370  | 42  | 605  | 686.127  | -81.1270   |
| 20  | 737  | 754.663  | -17.6630 | 43  | 801  | 860.127  | -59.1270   |
| 21  | 757  | 773.127  | -16.1270 | 44  | 750  | 773.127  | -23.1270   |
| 22  | 728  | 773.127  | -45.1270 | 45  | 755  | 773.127  | -18.1270   |
| 23  | 719  | 773.127  | -54.1270 | 46  | 773  | 773.127  | -0.1269999 |

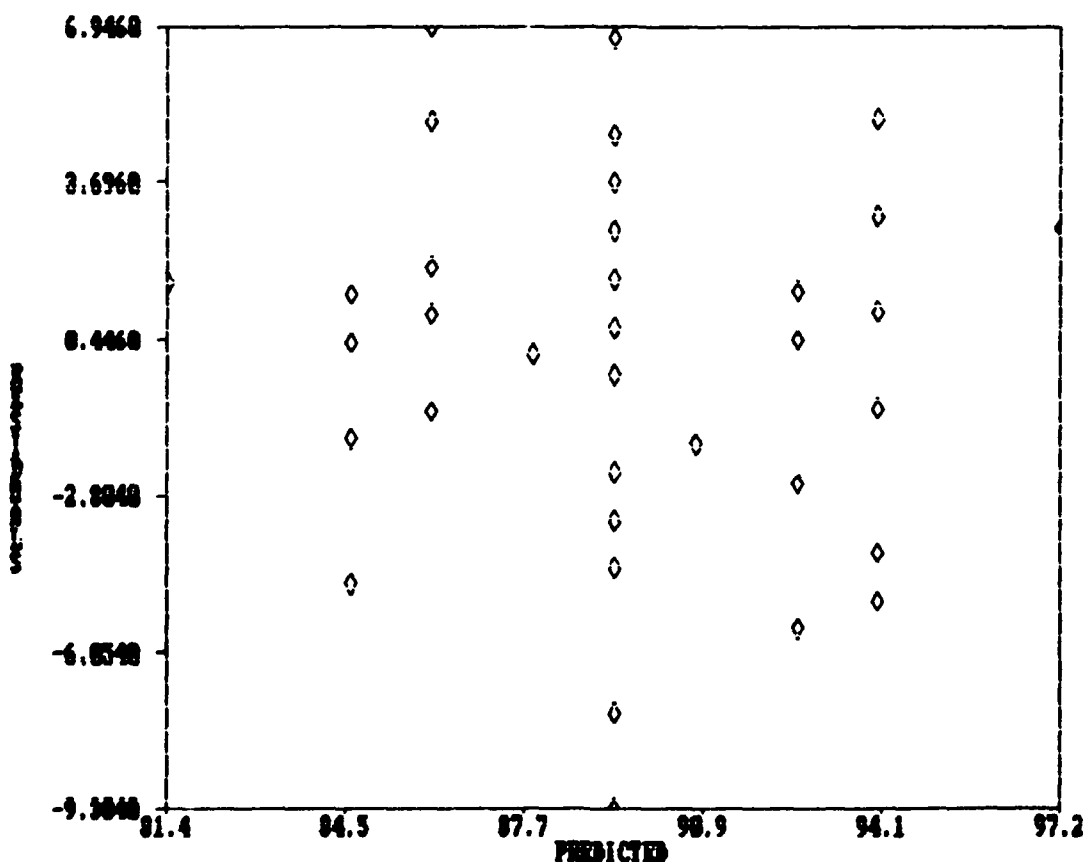
EUROPE RESUPPLY RESIDUAL PLOT



# Europe Rescue Residuals

| RUN | OBSR | PREDICT | RESIDUAL | RUN | OBSR | PREDICT | RESIDUAL |
|-----|------|---------|----------|-----|------|---------|----------|
| 1   | 86   | 84.617  | 1.3830   | 24  | 83   | 81.367  | 1.6330   |
| 2   | 86   | 84.617  | 1.3830   | 25  | 89   | 90.742  | -1.7420  |
| 3   | 95   | 93.992  | 1.0080   | 26  | 88   | 87.867  | 0.1330   |
| 4   | 95   | 93.992  | 1.0080   | 27  | 100  | 97.242  | 2.7580   |
| 5   | 93   | 93.992  | -0.9920  | 28  | 91   | 89.304  | 1.6960   |
| 6   | 91   | 86.054  | 4.9460   | 29  | 90   | 89.304  | 0.6960   |
| 7   | 87   | 86.054  | 0.9460   | 30  | 90   | 89.304  | 0.6960   |
| 8   | 90   | 92.554  | -2.5540  | 31  | 93   | 89.304  | 3.6960   |
| 9   | 86   | 84.617  | 1.3830   | 32  | 87   | 86.054  | 0.9460   |
| 10  | 99   | 93.992  | 5.0080   | 33  | 93   | 92.554  | 0.4460   |
| 11  | 85   | 84.617  | 0.3830   | 34  | 93   | 86.054  | 6.9460   |
| 12  | 97   | 93.992  | 3.0080   | 35  | 87   | 92.554  | -5.5540  |
| 13  | 85   | 86.054  | -1.0540  | 36  | 96   | 89.304  | 6.6960   |
| 14  | 88   | 86.054  | 1.9460   | 37  | 91   | 89.304  | 1.6960   |
| 15  | 94   | 92.554  | 1.4460   | 38  | 85   | 89.304  | -4.3040  |
| 16  | 93   | 92.554  | 0.4460   | 39  | 87   | 89.304  | -2.3040  |
| 17  | 93   | 89.304  | 3.6960   | 40  | 83   | 84.617  | -1.6170  |
| 18  | 89   | 89.304  | -0.3040  | 41  | 90   | 93.992  | -3.9920  |
| 19  | 90   | 89.304  | 0.6960   | 42  | 80   | 84.617  | -4.6170  |
| 20  | 91   | 89.304  | 1.6960   | 43  | 89   | 93.992  | -4.9920  |
| 21  | 92   | 89.304  | 2.6960   | 44  | 82   | 89.304  | -7.3040  |
| 22  | 86   | 89.304  | -3.3040  | 45  | 91   | 89.304  | 1.6960   |
| 23  | 80   | 89.304  | -9.3040  | 46  | 94   | 89.304  | 4.6960   |

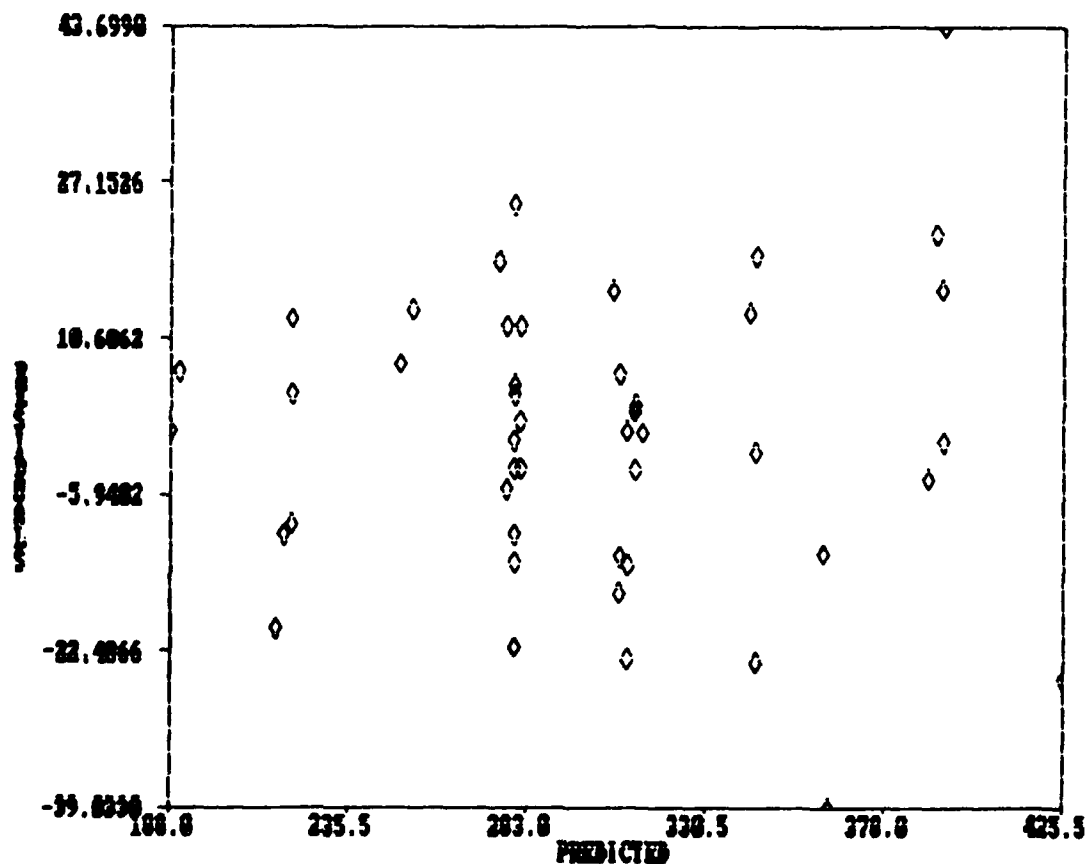
EUROPE RESCUE RESIDUAL PLOT



# Europe Refueling Residuals

| RUN | OBSR | PREDICT | RESIDUAL | RUN | OBSR | PREDICT | RESIDUAL |
|-----|------|---------|----------|-----|------|---------|----------|
| 1   | 266  | 252.384 | 13.6160  | 24  | 211  | 220.033 | -9.0330  |
| 2   | 196  | 216.134 | -20.1340 | 25  | 409  | 393.158 | 15.8420  |
| 3   | 400  | 425.509 | -25.5090 | 26  | 189  | 188.033 | 0.9670   |
| 4   | 385  | 389.259 | -4.2590  | 27  | 349  | 361.158 | -12.1580 |
| 5   | 308  | 311.262 | -3.2620  | 28  | 320  | 343.613 | -23.6130 |
| 6   | 285  | 279.262 | 5.7380   | 29  | 291  | 307.363 | -16.3630 |
| 7   | 314  | 311.262 | 2.7380   | 30  | 363  | 343.613 | 19.3870  |
| 8   | 284  | 279.262 | 4.7380   | 31  | 295  | 307.363 | -12.3630 |
| 9   | 197  | 189.908 | 7.0920   | 32  | 293  | 280.994 | 12.0060  |
| 10  | 324  | 363.033 | -39.0330 | 33  | 257  | 248.994 | 8.0060   |
| 11  | 208  | 218.158 | -10.1580 | 34  | 310  | 309.244 | 0.7560   |
| 12  | 413  | 391.283 | 21.7170  | 35  | 272  | 277.244 | -5.2440  |
| 13  | 342  | 343.47  | -1.4700  | 36  | 314  | 313.345 | 0.6550   |
| 14  | 314  | 307.22  | 6.7800   | 37  | 289  | 277.095 | 11.9050  |
| 15  | 315  | 311.47  | 3.5300   | 38  | 355  | 341.595 | 13.4050  |
| 16  | 294  | 275.22  | 18.7800  | 39  | 321  | 305.345 | 15.6550  |
| 17  | 283  | 281.137 | 1.8630   | 40  | 225  | 220.176 | 4.8240   |
| 18  | 278  | 281.137 | -3.1370  | 41  | 437  | 393.301 | 43.6990  |
| 19  | 286  | 309.387 | -23.3870 | 42  | 233  | 220.176 | 12.8240  |
| 20  | 296  | 309.387 | -13.3870 | 43  | 393  | 393.301 | -0.3010  |
| 21  | 304  | 279.119 | 24.8810  | 44  | 279  | 279.119 | -0.1190  |
| 22  | 257  | 279.119 | -22.1190 | 45  | 269  | 279.119 | -10.1190 |
| 23  | 266  | 279.119 | -13.1190 | 46  | 276  | 279.119 | -3.1190  |

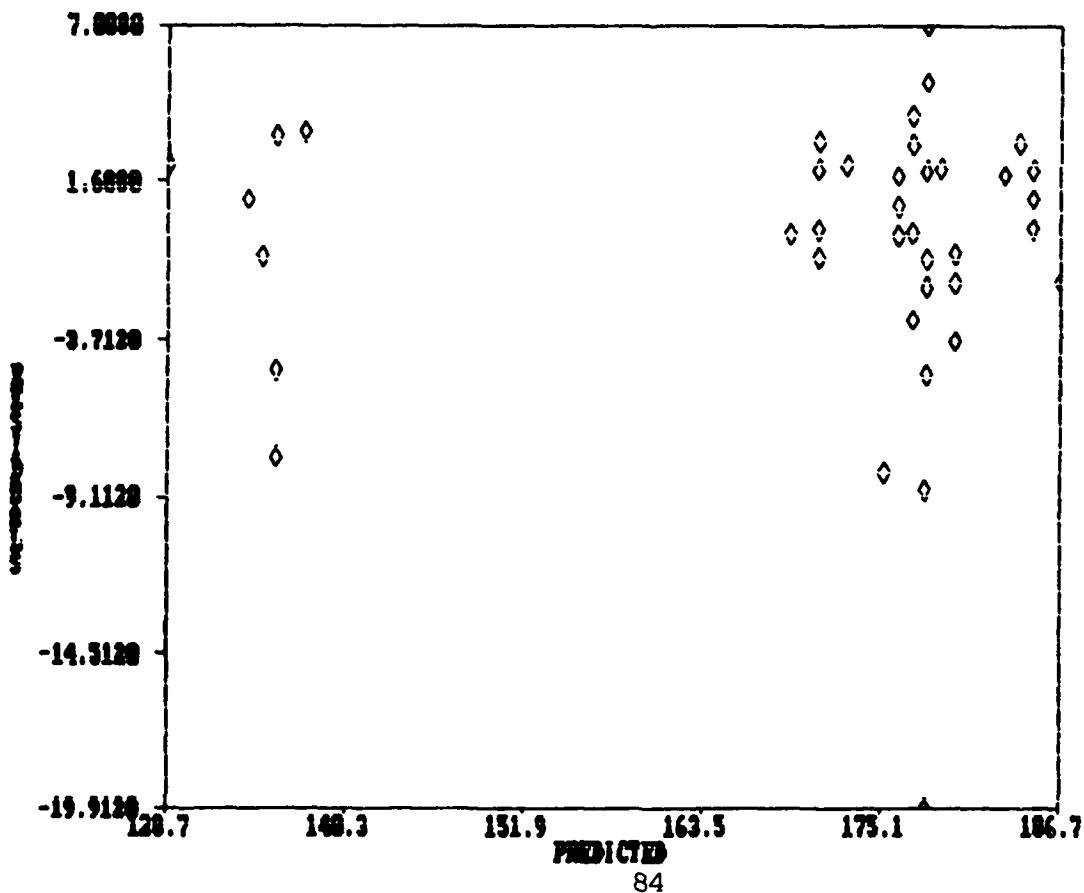
EUROPE REFUELING RESIDUAL PLOT



# Pacific Infil Residuals

| RUN | OBSR | PREDICT | RESIDUAL | RUN | OBSR | PREDICT | RESIDUAL |
|-----|------|---------|----------|-----|------|---------|----------|
| 1   | 131  | 135.737 | -4.7370  | 24  | 135  | 133.924 | 1.0760   |
| 2   | 128  | 135.737 | -7.7370  | 25  | 185  | 183.049 | 1.9510   |
| 3   | 185  | 184.862 | 0.1380   | 26  | 141  | 137.549 | 3.4510   |
| 4   | 187  | 184.862 | 2.1380   | 27  | 185  | 186.674 | -1.6740  |
| 5   | 178  | 176.099 | 1.9010   | 28  | 180  | 177.912 | 2.0880   |
| 6   | 176  | 179.724 | -3.7240  | 29  | 176  | 177.912 | -1.9120  |
| 7   | 177  | 176.099 | 0.9010   | 30  | 185  | 177.912 | 7.0880   |
| 8   | 178  | 179.724 | -1.7240  | 31  | 177  | 177.912 | -0.9120  |
| 9   | 131  | 128.728 | 2.2720   | 32  | 169  | 169.091 | -0.0910  |
| 10  | 169  | 177.853 | -8.8530  | 33  | 175  | 172.716 | 2.2840   |
| 11  | 134  | 134.853 | -0.8530  | 34  | 167  | 175.216 | -8.2160  |
| 12  | 187  | 183.978 | 3.0220   | 35  | 181  | 178.841 | 2.1590   |
| 13  | 176  | 176.099 | -0.0990  | 36  | 170  | 170.903 | -0.9030  |
| 14  | 178  | 176.099 | 1.9010   | 37  | 173  | 170.903 | 2.0970   |
| 15  | 179  | 179.724 | -0.7240  | 38  | 180  | 177.028 | 2.9720   |
| 16  | 179  | 179.724 | -0.7240  | 39  | 181  | 177.028 | 3.9720   |
| 17  | 174  | 170.903 | 3.0970   | 40  | 139  | 135.737 | 3.2630   |
| 18  | 171  | 170.903 | 0.0970   | 41  | 187  | 184.862 | 2.1380   |
| 19  | 177  | 177.028 | -0.0280  | 42  | 139  | 135.737 | 3.2630   |
| 20  | 174  | 177.028 | -3.0280  | 43  | 186  | 184.862 | 1.1380   |
| 21  | 173  | 177.912 | -4.9120  | 44  | 183  | 177.912 | 5.0880   |
| 22  | 158  | 177.912 | -19.9120 | 45  | 180  | 177.912 | 2.0880   |
| 23  | 180  | 177.912 | 2.0880   | 46  | 185  | 177.912 | 7.0880   |

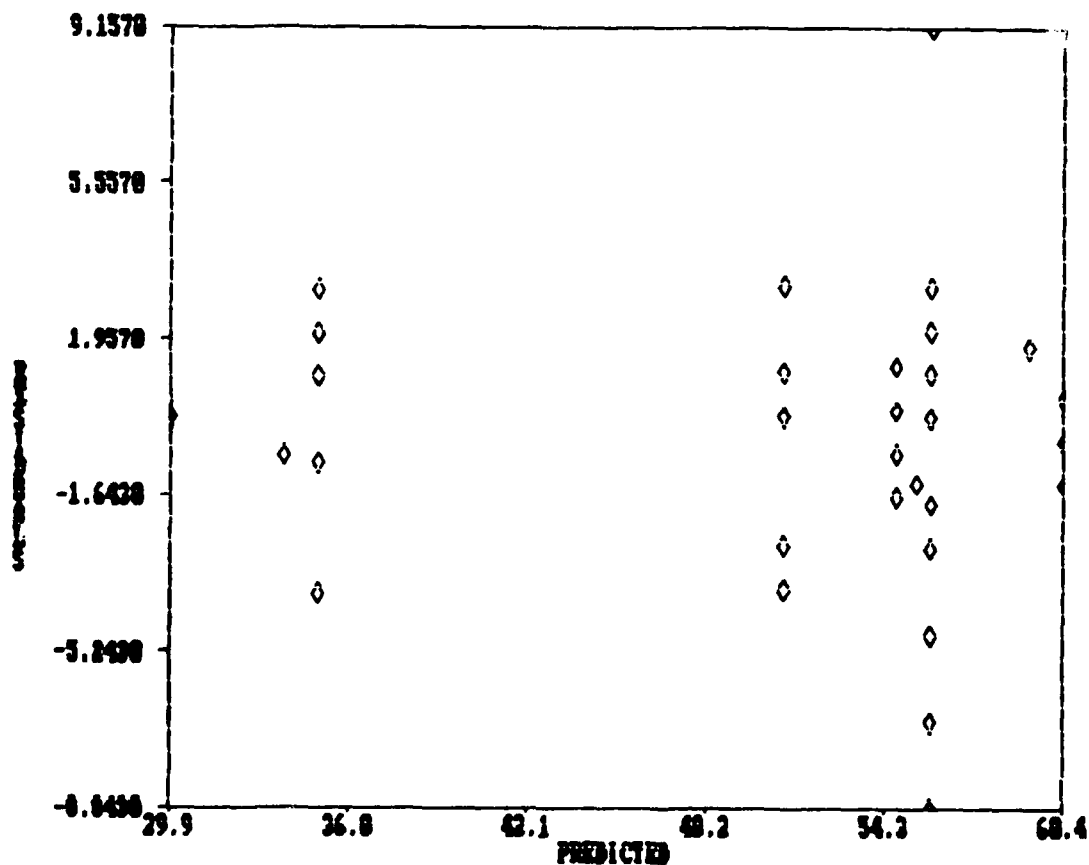
PACIFIC INFIL RESIDUAL PLOT



# Pacific Exfil Residuals

| RUN | OBSR | PREDICT | RESIDUAL | RUN | OBSR | PREDICT | RESIDUAL |
|-----|------|---------|----------|-----|------|---------|----------|
| 1   | 37   | 34.902  | 2.0980   | 24  | 36   | 34.902  | 1.0980   |
| 2   | 34   | 34.902  | -0.9020  | 25  | 61   | 60.402  | 0.5980   |
| 3   | 61   | 60.402  | 0.5980   | 26  | 31   | 34.902  | -3.9020  |
| 4   | 60   | 60.402  | -0.4020  | 27  | 60   | 60.402  | -0.4020  |
| 5   | 57   | 55.843  | 1.1570   | 28  | 49   | 55.843  | -6.8430  |
| 6   | 56   | 55.843  | 0.1570   | 29  | 51   | 55.843  | -4.8430  |
| 7   | 57   | 55.843  | 1.1570   | 30  | 53   | 55.843  | -2.8430  |
| 8   | 58   | 55.843  | 2.1570   | 31  | 57   | 55.843  | 1.1570   |
| 9   | 30   | 29.857  | 0.1430   | 32  | 51   | 50.798  | 0.2020   |
| 10  | 54   | 55.357  | -1.3570  | 33  | 48   | 50.798  | -2.7980  |
| 11  | 33   | 33.732  | -0.7320  | 34  | 53   | 54.673  | -1.6730  |
| 12  | 61   | 59.232  | 1.7680   | 35  | 54   | 54.673  | -0.6730  |
| 13  | 53   | 55.843  | -2.8430  | 36  | 54   | 50.798  | 3.2020   |
| 14  | 54   | 55.843  | -1.8430  | 37  | 54   | 50.798  | 3.2020   |
| 15  | 53   | 55.843  | -2.8430  | 38  | 55   | 54.673  | 0.3270   |
| 16  | 58   | 55.843  | 2.1570   | 39  | 56   | 54.673  | 1.3270   |
| 17  | 47   | 50.798  | -3.7980  | 40  | 38   | 34.902  | 3.0980   |
| 18  | 52   | 50.798  | 1.2020   | 41  | 61   | 60.402  | 0.5980   |
| 19  | 55   | 54.673  | 0.3270   | 42  | 34   | 34.902  | -0.9020  |
| 20  | 54   | 54.673  | -0.6730  | 43  | 59   | 60.402  | -1.4020  |
| 21  | 56   | 55.843  | 0.1570   | 44  | 57   | 55.843  | 1.1570   |
| 22  | 47   | 55.843  | -8.8430  | 45  | 59   | 55.843  | 3.1570   |
| 23  | 65   | 55.843  | 9.1570   | 46  | 65   | 55.843  | 9.1570   |

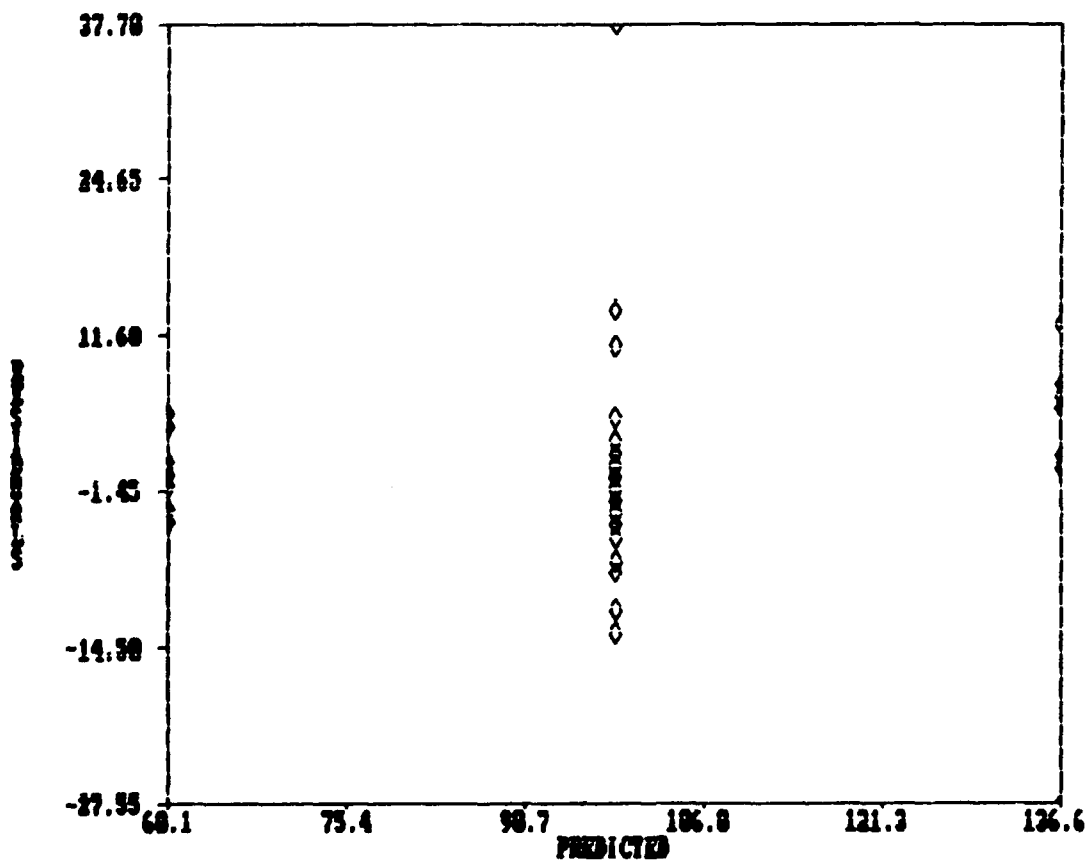
PACIFIC EXFIL RESIDUAL PLOT



# Pacific Resupply Residuals

| RUN | OBSR | PREDICT | RESIDUAL | RUN | OBSR | PREDICT | RESIDUAL |
|-----|------|---------|----------|-----|------|---------|----------|
| 1   | 56   | 60.054  | -4.0540  | 24  | 64   | 60.054  | 3.9460   |
| 2   | 65   | 60.054  | 4.9460   | 25  | 137  | 136.554 | 0.4460   |
| 3   | 142  | 136.554 | 5.4460   | 26  | 60   | 60.054  | -0.0540  |
| 4   | 149  | 136.554 | 12.4460  | 27  | 137  | 136.554 | 0.4460   |
| 5   | 97   | 98.304  | -1.3040  | 28  | 97   | 98.304  | -1.3040  |
| 6   | 94   | 98.304  | -4.3040  | 29  | 97   | 98.304  | -1.3040  |
| 7   | 97   | 98.304  | -1.3040  | 30  | 90   | 98.304  | -8.3040  |
| 8   | 95   | 98.304  | -3.3040  | 31  | 98   | 98.304  | -0.3040  |
| 9   | 65   | 60.054  | 4.9460   | 32  | 94   | 98.304  | -4.3040  |
| 10  | 109  | 136.554 | -27.5540 | 33  | 93   | 98.304  | -5.3040  |
| 11  | 57   | 60.054  | -3.0540  | 34  | 91   | 98.304  | -7.3040  |
| 12  | 144  | 136.554 | 7.4460   | 35  | 96   | 98.304  | -2.3040  |
| 13  | 87   | 98.304  | -11.3040 | 36  | 94   | 98.304  | -4.3040  |
| 14  | 101  | 98.304  | 2.6960   | 37  | 93   | 98.304  | -5.3040  |
| 15  | 99   | 98.304  | 0.6960   | 38  | 96   | 98.304  | -2.3040  |
| 16  | 95   | 98.304  | -3.3040  | 39  | 103  | 98.304  | 4.6960   |
| 17  | 109  | 98.304  | 10.6960  | 40  | 61   | 60.054  | 0.9460   |
| 18  | 100  | 98.304  | 1.6960   | 41  | 138  | 136.554 | 1.4460   |
| 19  | 96   | 98.304  | -2.3040  | 42  | 59   | 60.054  | -1.0540  |
| 20  | 94   | 98.304  | -4.3040  | 43  | 143  | 136.554 | 6.4460   |
| 21  | 103  | 98.304  | 4.6960   | 44  | 101  | 98.304  | 2.6960   |
| 22  | 85   | 98.304  | -13.3040 | 45  | 136  | 98.304  | 37.6960  |
| 23  | 112  | 98.304  | 13.6960  | 46  | 93   | 98.304  | -5.3040  |

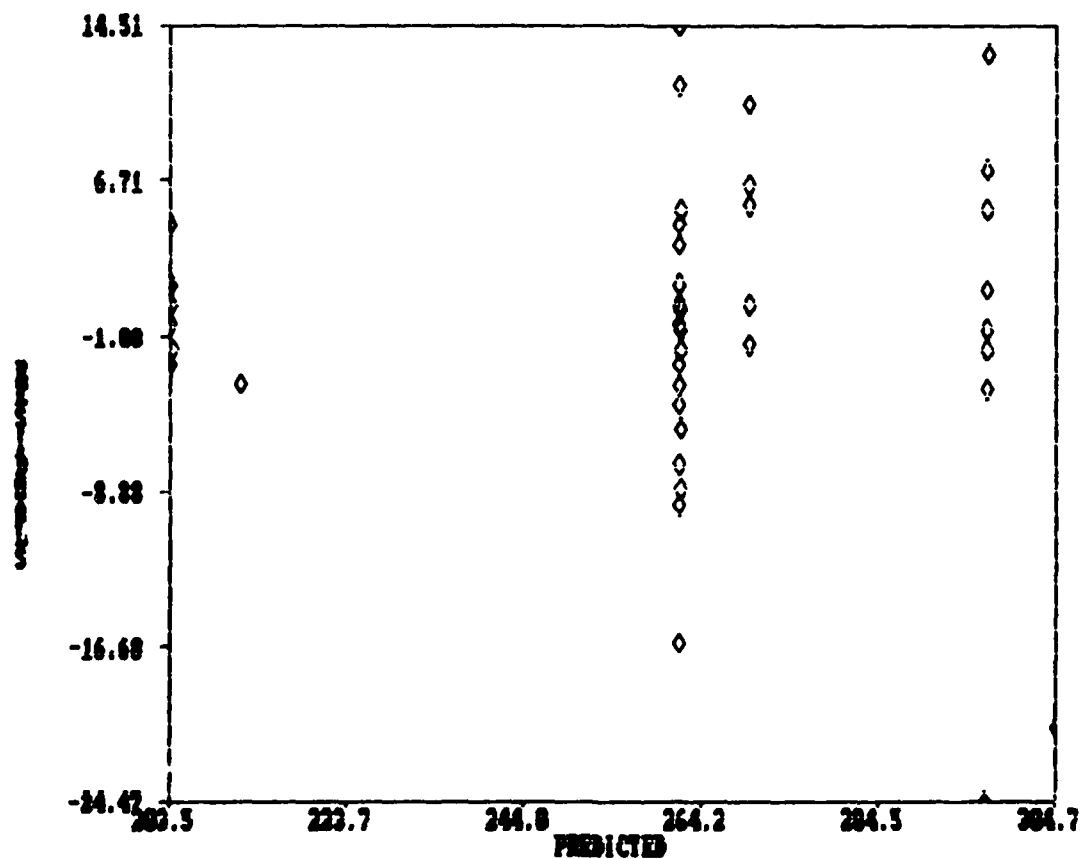
## PACIFIC RESUPPLY RESIDUAL PLOT



# Pacific Rescue Residuals

| RUN | OBSR | PREDICT | RESIDUAL | RUN | OBSR | PREDICT | RESIDUAL |
|-----|------|---------|----------|-----|------|---------|----------|
| 1   | 204  | 203.473 | 0.5270   | 24  | 208  | 203.473 | 4.5270   |
| 2   | 203  | 203.473 | -0.4730  | 25  | 295  | 296.723 | -1.7230  |
| 3   | 304  | 296.723 | 7.2770   | 26  | 205  | 203.473 | 1.5270   |
| 4   | 298  | 296.723 | 1.2770   | 27  | 293  | 296.723 | -3.7230  |
| 5   | 261  | 261.49  | -0.4900  | 28  | 259  | 261.49  | -2.4900  |
| 6   | 262  | 261.49  | 0.5100   | 29  | 259  | 261.49  | -2.4900  |
| 7   | 263  | 261.49  | 1.5100   | 30  | 266  | 261.49  | 4.5100   |
| 8   | 261  | 261.49  | -0.4900  | 31  | 261  | 261.49  | -0.4900  |
| 9   | 208  | 211.456 | -3.4560  | 32  | 268  | 269.473 | -1.4730  |
| 10  | 284  | 304.706 | -20.7060 | 33  | 280  | 269.473 | 10.5270  |
| 11  | 202  | 203.706 | -1.7060  | 34  | 267  | 261.723 | 5.2770   |
| 12  | 310  | 296.956 | 13.0440  | 35  | 260  | 261.723 | -1.7230  |
| 13  | 263  | 261.49  | 1.5100   | 36  | 270  | 269.473 | 0.5270   |
| 14  | 258  | 261.49  | -3.4900  | 37  | 272  | 296.473 | -24.4730 |
| 15  | 259  | 261.49  | -2.4900  | 38  | 253  | 261.723 | -8.7230  |
| 16  | 265  | 261.49  | 3.5100   | 39  | 256  | 261.723 | -5.7230  |
| 17  | 275  | 269.473 | 5.5270   | 40  | 201  | 203.473 | -2.4730  |
| 18  | 276  | 269.473 | 6.5270   | 41  | 302  | 296.723 | 5.2770   |
| 19  | 262  | 261.723 | 0.2770   | 42  | 205  | 203.473 | 1.5270   |
| 20  | 261  | 261.723 | -0.7230  | 43  | 296  | 296.723 | -0.7230  |
| 21  | 254  | 261.49  | -7.4900  | 44  | 245  | 261.49  | -16.4900 |
| 22  | 276  | 261.49  | 14.5100  | 45  | 273  | 261.49  | 11.5100  |
| 23  | 252  | 261.49  | -9.4900  | 46  | 257  | 261.49  | -4.4900  |

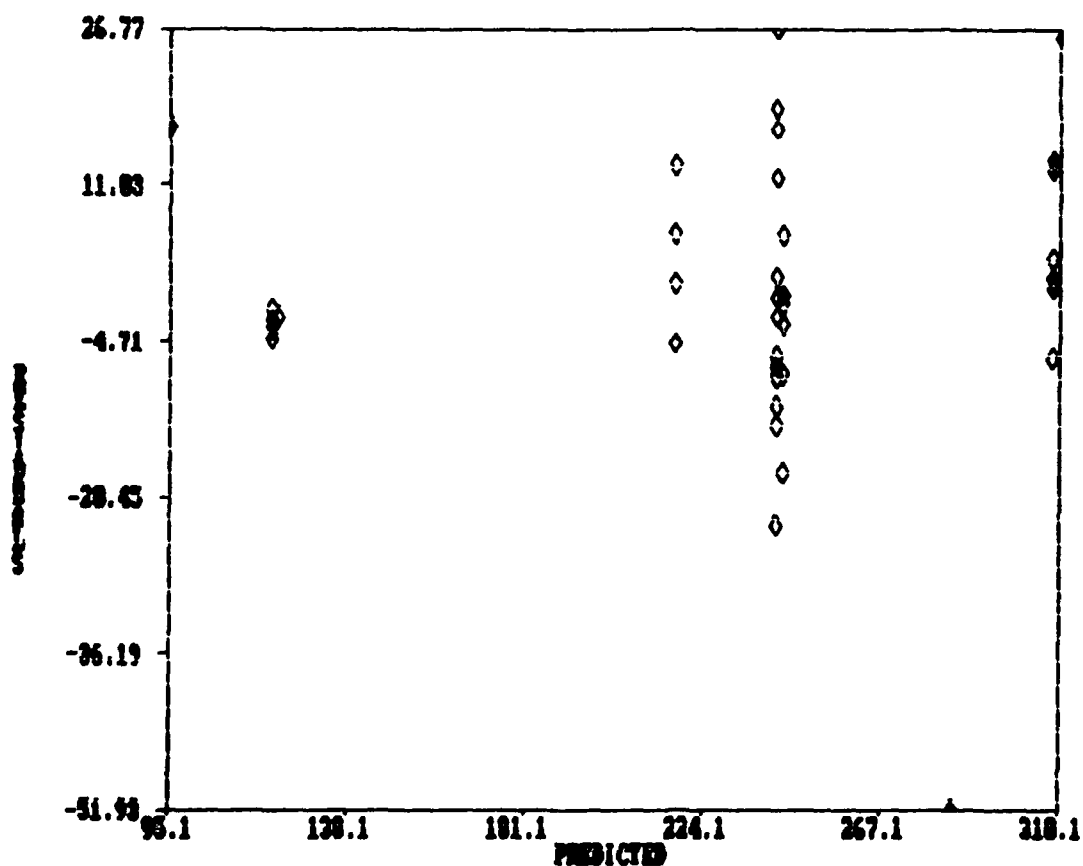
PACIFIC RESCUE RESIDUAL PLOT



# Pacific Refueling Residuals

| RUN | OBSR | PREDICT | RESIDUAL | RUN | OBSR | PREDICT | RESIDUAL |
|-----|------|---------|----------|-----|------|---------|----------|
| 1   | 117  | 119.46  | -2.4600  | 24  | 118  | 119.46  | -1.4600  |
| 2   | 115  | 119.46  | -4.4600  | 25  | 310  | 308.335 | 1.6650   |
| 3   | 321  | 308.335 | 12.6650  | 26  | 118  | 119.46  | -1.4600  |
| 4   | 322  | 308.335 | 13.6650  | 27  | 302  | 308.335 | -6.3350  |
| 5   | 243  | 241.235 | 1.7650   | 28  | 230  | 241.235 | -11.2350 |
| 6   | 239  | 241.235 | -2.2350  | 29  | 233  | 241.235 | -8.2350  |
| 7   | 239  | 241.235 | -2.2350  | 30  | 235  | 241.235 | -6.2350  |
| 8   | 239  | 241.235 | -2.2350  | 31  | 239  | 241.235 | -2.2350  |
| 9   | 112  | 95.059  | 16.9410  | 32  | 212  | 216.835 | -4.8350  |
| 10  | 232  | 283.934 | -51.9340 | 33  | 218  | 216.835 | 1.1650   |
| 11  | 119  | 121.184 | -2.1840  | 34  | 225  | 242.96  | -17.9600 |
| 12  | 336  | 310.059 | 25.9410  | 35  | 242  | 242.96  | -0.9600  |
| 13  | 228  | 241.235 | -13.2350 | 36  | 230  | 216.835 | 13.1650  |
| 14  | 241  | 241.235 | -0.2350  | 37  | 230  | 216.835 | 13.1650  |
| 15  | 234  | 241.235 | -7.2350  | 38  | 243  | 242.96  | 0.0400   |
| 16  | 239  | 241.235 | -2.2350  | 39  | 249  | 242.96  | 6.0400   |
| 17  | 223  | 216.835 | 6.1650   | 40  | 118  | 119.46  | -1.4600  |
| 18  | 223  | 216.835 | 6.1650   | 41  | 312  | 308.335 | 3.6650   |
| 19  | 240  | 242.96  | -2.9600  | 42  | 116  | 119.46  | -3.4600  |
| 20  | 235  | 242.96  | -7.9600  | 43  | 309  | 308.335 | 0.6650   |
| 21  | 235  | 241.235 | -6.2350  | 44  | 268  | 241.235 | 26.7650  |
| 22  | 218  | 241.235 | -23.2350 | 45  | 258  | 241.235 | 16.7650  |
| 23  | 260  | 241.235 | 18.7650  | 46  | 253  | 241.235 | 11.7650  |

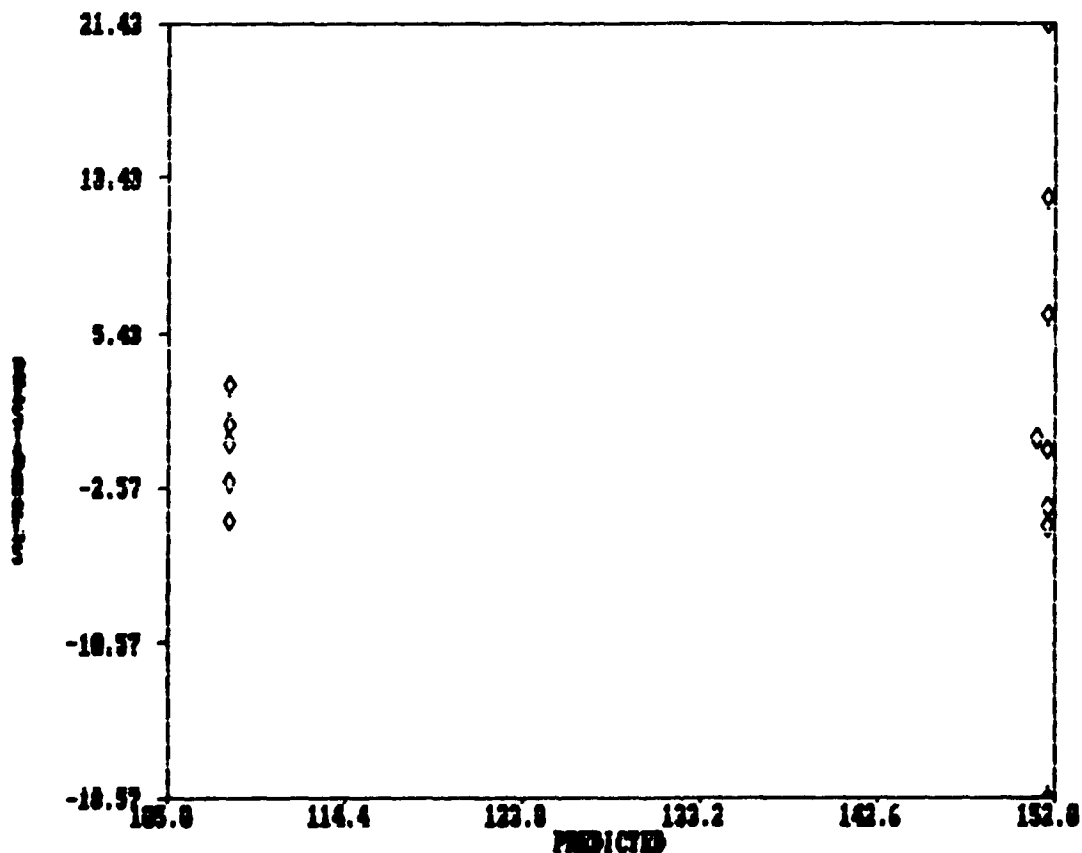
PACIFIC REFUELING RESIDUAL PLOT



Centcom Infil Residuals

| RUN | OBSR | PREDICT | RESIDUAL | RUN | OBSR | PREDICT | RESIDUAL |
|-----|------|---------|----------|-----|------|---------|----------|
| 1   | 111  | 108.25  | 2.7500   | 24  | 151  | 151.567 | -0.5670  |
| 2   | 151  | 151     | 0.0000   | 25  | 151  | 151.567 | -0.5670  |
| 3   | 111  | 108.25  | 2.7500   | 26  | 151  | 151.567 | -0.5670  |
| 4   | 151  | 151     | 0.0000   | 27  | 151  | 151.567 | -0.5670  |
| 5   | 151  | 151.567 | -0.5670  | 28  | 108  | 108.25  | -0.2500  |
| 6   | 151  | 151.567 | -0.5670  | 29  | 151  | 151     | 0.0000   |
| 7   | 148  | 151.567 | -3.5670  | 30  | 106  | 108.25  | -2.2500  |
| 8   | 151  | 151.567 | -0.5670  | 31  | 151  | 151     | 0.0000   |
| 9   | 151  | 151.567 | -0.5670  | 32  | 151  | 151.567 | -0.5670  |
| 10  | 151  | 151.567 | -0.5670  | 33  | 151  | 151.567 | -0.5670  |
| 11  | 151  | 151.567 | -0.5670  | 34  | 151  | 151.567 | -0.5670  |
| 12  | 151  | 151.567 | -0.5670  | 35  | 151  | 151.567 | -0.5670  |
| 13  | 109  | 108.25  | 0.7500   | 36  | 108  | 108.25  | -0.2500  |
| 14  | 151  | 151     | 0.0000   | 37  | 151  | 151     | 0.0000   |
| 15  | 109  | 108.25  | 0.7500   | 38  | 104  | 108.25  | -4.2500  |
| 16  | 151  | 151     | 0.0000   | 39  | 151  | 151     | 0.0000   |
| 17  | 151  | 151.567 | -0.5670  | 40  | 151  | 151.567 | -0.5670  |
| 18  | 151  | 151.567 | -0.5670  | 41  | 151  | 151.567 | -0.5670  |
| 19  | 151  | 151.567 | -0.5670  | 42  | 151  | 151.567 | -0.5670  |
| 20  | 151  | 151.567 | -0.5670  | 43  | 151  | 151.567 | -0.5670  |
| 21  | 151  | 151.567 | -0.5670  | 44  | 147  | 151.567 | -4.5670  |
| 22  | 158  | 151.567 | 6.4330   | 45  | 133  | 151.567 | -18.5670 |
| 23  | 164  | 151.567 | 12.4330  | 46  | 173  | 151.567 | 21.4330  |

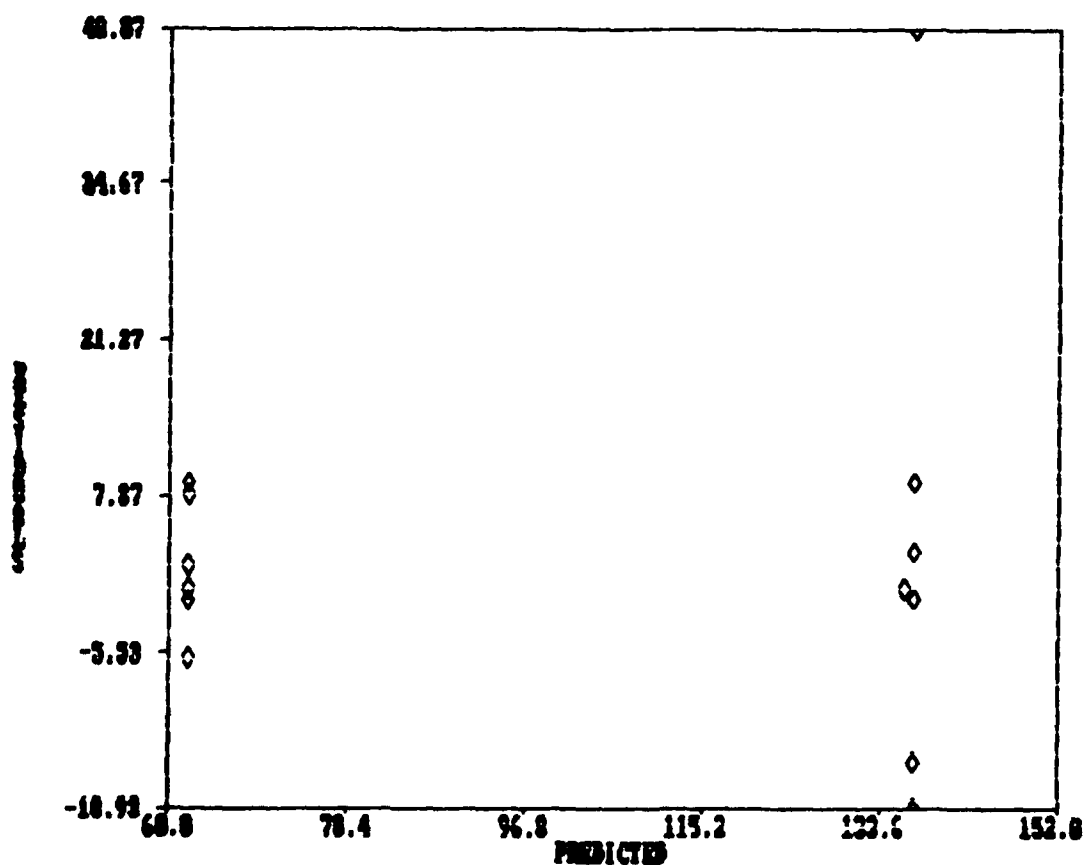
**CENTCOM INFIL RESIDUAL PLOT**



# Centcom Exfil Residuals

| RUN | OBSR | PREDICT | RESIDUAL | RUN | OBSR | PREDICT | RESIDUAL |
|-----|------|---------|----------|-----|------|---------|----------|
| 1   | 61   | 62      | -1.0000  | 24  | 136  | 136.933 | -0.9330  |
| 2   | 136  | 136     | 0.0000   | 25  | 136  | 136.933 | -0.9330  |
| 3   | 56   | 62      | -6.0000  | 26  | 136  | 136.933 | -0.9330  |
| 4   | 136  | 136     | 0.0000   | 27  | 136  | 136.933 | -0.9330  |
| 5   | 136  | 136.933 | -0.9330  | 28  | 62   | 62      | 0.0000   |
| 6   | 136  | 136.933 | -0.9330  | 29  | 136  | 136     | 0.0000   |
| 7   | 136  | 136.933 | -0.9330  | 30  | 70   | 62      | 8.0000   |
| 8   | 136  | 136.933 | -0.9330  | 31  | 136  | 136     | 0.0000   |
| 9   | 136  | 136.933 | -0.9330  | 32  | 136  | 136.933 | -0.9330  |
| 10  | 136  | 136.933 | -0.9330  | 33  | 136  | 136.933 | -0.9330  |
| 11  | 136  | 136.933 | -0.9330  | 34  | 136  | 136.933 | -0.9330  |
| 12  | 136  | 136.933 | -0.9330  | 35  | 136  | 136.933 | -0.9330  |
| 13  | 64   | 62      | 2.0000   | 36  | 56   | 62      | -6.0000  |
| 14  | 136  | 136     | 0.0000   | 37  | 136  | 136     | 0.0000   |
| 15  | 56   | 62      | -6.0000  | 38  | 71   | 62      | 9.0000   |
| 16  | 136  | 136     | 0.0000   | 39  | 136  | 136     | 0.0000   |
| 17  | 136  | 136.933 | -0.9330  | 40  | 136  | 136.933 | -0.9330  |
| 18  | 136  | 136.933 | -0.9330  | 41  | 136  | 136.933 | -0.9330  |
| 19  | 136  | 136.933 | -0.9330  | 42  | 136  | 136.933 | -0.9330  |
| 20  | 136  | 136.933 | -0.9330  | 43  | 136  | 136.933 | -0.9330  |
| 21  | 136  | 136.933 | -0.9330  | 44  | 122  | 136.933 | -14.9330 |
| 22  | 140  | 136.933 | 3.0670   | 45  | 118  | 136.933 | -18.9330 |
| 23  | 146  | 136.933 | 9.0670   | 46  | 185  | 136.933 | 48.0670  |

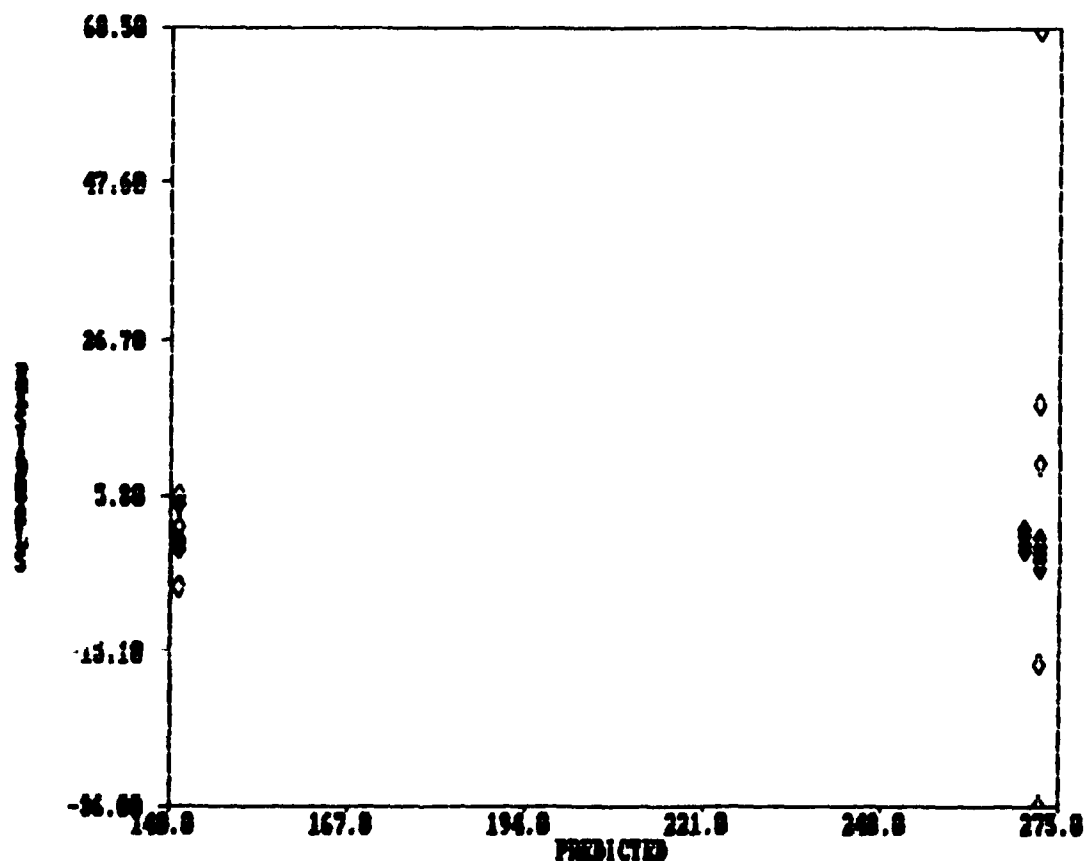
CENTCOM EXFIL RESIDUAL PLOT



# Centcom Refueling Residuals

| RUN | OBSR | PREDICT | RESIDUAL | RUN | OBSR | PREDICT | RESIDUAL |
|-----|------|---------|----------|-----|------|---------|----------|
| 1   | 143  | 141.25  | 1.7500   | 24  | 271  | 271.833 | -0.8330  |
| 2   | 268  | 269.5   | -1.5000  | 25  | 271  | 271.833 | -0.8330  |
| 3   | 140  | 141.25  | -1.2500  | 26  | 270  | 271.833 | -1.8330  |
| 4   | 268  | 269.5   | -1.5000  | 27  | 270  | 271.833 | -1.8330  |
| 5   | 272  | 271.833 | 0.1670   | 28  | 141  | 141.25  | -0.2500  |
| 6   | 269  | 271.833 | -2.8330  | 29  | 269  | 269.5   | -0.5000  |
| 7   | 268  | 271.833 | -3.8330  | 30  | 147  | 141.25  | 5.7500   |
| 8   | 270  | 271.833 | -1.8330  | 31  | 269  | 269.5   | -0.5000  |
| 9   | 270  | 271.833 | -1.8330  | 32  | 270  | 271.833 | -1.8330  |
| 10  | 270  | 271.833 | -1.8330  | 33  | 270  | 271.833 | -1.8330  |
| 11  | 269  | 271.833 | -2.8330  | 34  | 272  | 271.833 | 0.1670   |
| 12  | 269  | 271.833 | -2.8330  | 35  | 270  | 271.833 | -1.8330  |
| 13  | 141  | 141.25  | -0.2500  | 36  | 270  | 141.25  | 128.7500 |
| 14  | 271  | 269.5   | 1.5000   | 37  | 271  | 269.5   | 1.5000   |
| 15  | 135  | 141.25  | -6.2500  | 38  | 146  | 141.25  | 4.7500   |
| 16  | 270  | 269.5   | 0.5000   | 39  | 270  | 269.5   | 0.5000   |
| 17  | 270  | 271.833 | -1.8330  | 40  | 270  | 271.833 | -1.8330  |
| 18  | 270  | 271.833 | -1.8330  | 41  | 271  | 271.833 | -0.8330  |
| 19  | 270  | 271.833 | -1.8330  | 42  | 270  | 271.833 | -1.8330  |
| 20  | 268  | 271.833 | -3.8330  | 43  | 270  | 271.833 | -1.8330  |
| 21  | 272  | 271.833 | 0.1670   | 44  | 255  | 271.833 | -16.8330 |
| 22  | 282  | 271.833 | 10.1670  | 45  | 236  | 271.833 | -35.8330 |
| 23  | 290  | 271.833 | 18.1670  | 46  | 340  | 271.833 | 68.1670  |

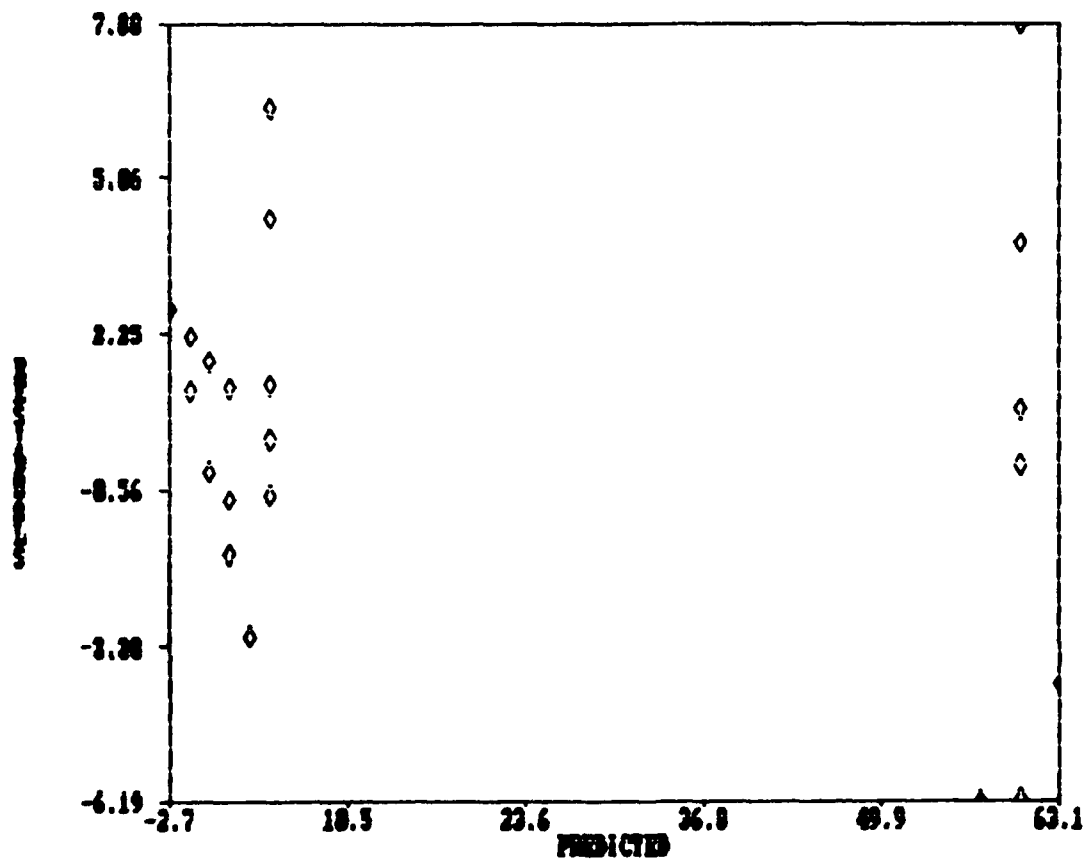
CENTCOM REFUELING RESIDUAL PLOT



# Centcom Resupply Residuals

| RUN | OBSR | PREDICT | RESIDUAL | RUN | OBSR | PREDICT | RESIDUAL |
|-----|------|---------|----------|-----|------|---------|----------|
| 1   | 64   | 60.125  | 3.8750   | 24  | 4    | 4.671   | -0.6710  |
| 2   | 0    | 0.25    | -0.2500  | 25  | 5    | 4.671   | 0.3290   |
| 3   | 64   | 60.125  | 3.8750   | 26  | 0    | -1.204  | 1.2040   |
| 4   | 0    | 0.25    | -0.2500  | 27  | 0    | -1.204  | 1.2040   |
| 5   | 5    | 4.671   | 0.3290   | 28  | 61   | 60.125  | 0.8750   |
| 6   | 0    | -1.204  | 1.2040   | 29  | 0    | 0.25    | -0.2500  |
| 7   | 11   | 4.671   | 6.3290   | 30  | 54   | 60.125  | -6.1250  |
| 8   | 0    | -1.204  | 1.2040   | 31  | 0    | 0.25    | -0.2500  |
| 9   | 0    | 1.733   | -1.7330  | 32  | 9    | 4.671   | 4.3290   |
| 10  | 1    | 1.733   | -0.7330  | 33  | 1    | -1.204  | 2.2040   |
| 11  | 0    | 1.733   | -1.7330  | 34  | 6    | 4.671   | 1.3290   |
| 12  | 0    | 1.733   | -1.7330  | 35  | 0    | -1.204  | 1.2040   |
| 13  | 59   | 63.063  | -4.0630  | 36  | 68   | 60.125  | 7.8750   |
| 14  | 0    | 3.188   | -3.1880  | 37  | 2    | 0.25    | 1.7500   |
| 15  | 51   | 57.188  | -6.1880  | 38  | 60   | 60.125  | -0.1250  |
| 16  | 0    | -2.687  | 2.6870   | 39  | 0    | 0.25    | -0.2500  |
| 17  | 0    | 1.733   | -1.7330  | 40  | 1    | 1.733   | -0.7330  |
| 18  | 0    | 1.733   | -1.7330  | 41  | 1    | 1.733   | -0.7330  |
| 19  | 0    | 1.733   | -1.7330  | 42  | 0    | 1.733   | -1.7330  |
| 20  | 0    | 1.733   | -1.7330  | 43  | 1    | 1.733   | -0.7330  |
| 21  | 1    | 1.733   | -0.7330  | 44  | 0    | 1.733   | -1.7330  |
| 22  | 3    | 1.733   | 1.2670   | 45  | 0    | 1.733   | -1.7330  |
| 23  | 3    | 1.733   | 1.2670   | 46  | 0    | 1.733   | -1.7330  |

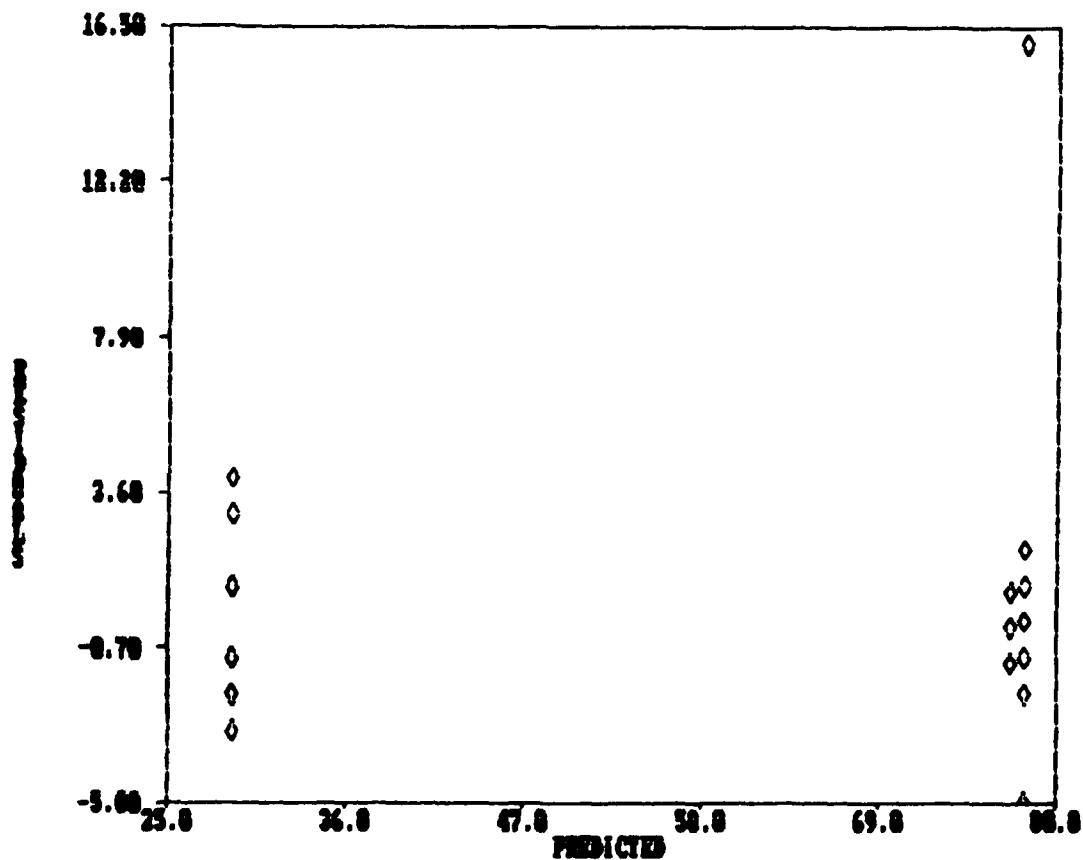
CENTCOM RESUPPLY RESIDUAL PLOT



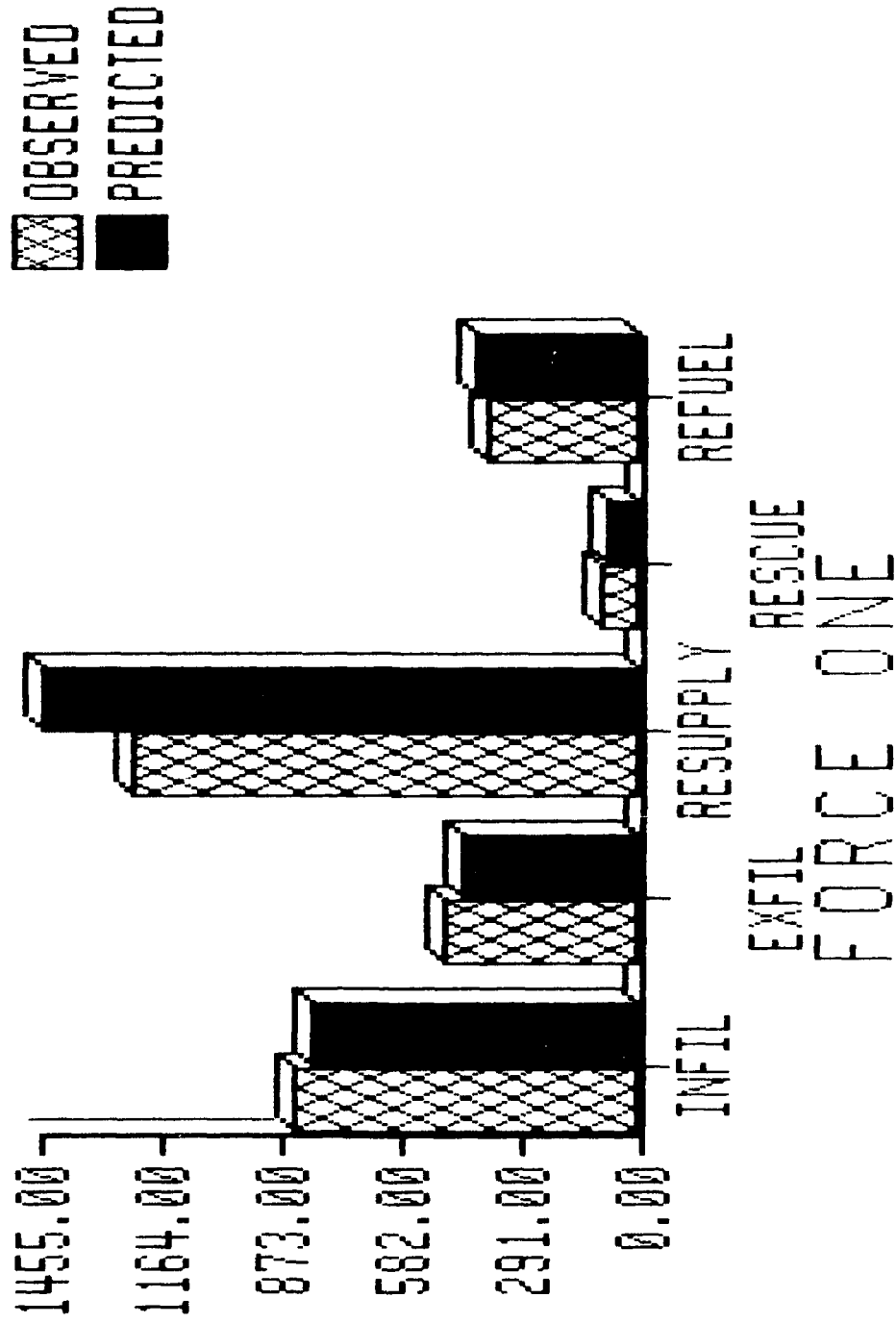
### Centcom Rescue Residuals

| RUN | OBSR | PREDICT | RESIDUAL | RUN | OBSR | PREDICT | RESIDUAL |
|-----|------|---------|----------|-----|------|---------|----------|
| 1   | 26   | 29      | -3.0000  | 24  | 78   | 77.967  | 0.0330   |
| 2   | 77   | 77.125  | -0.1250  | 25  | 80   | 77.967  | 2.0330   |
| 3   | 32   | 29      | 3.0000   | 26  | 77   | 77.967  | -0.9670  |
| 4   | 77   | 77.125  | -0.1250  | 27  | 77   | 77.967  | -0.9670  |
| 5   | 77   | 77.967  | -0.9670  | 28  | 27   | 29      | -2.0000  |
| 6   | 79   | 77.967  | 1.0330   | 29  | 78   | 77.125  | 0.8750   |
| 7   | 77   | 77.967  | -0.9670  | 30  | 30   | 29      | 1.0000   |
| 8   | 77   | 77.967  | -0.9670  | 31  | 78   | 77.125  | 0.8750   |
| 9   | 77   | 77.967  | -0.9670  | 32  | 73   | 77.967  | -4.9670  |
| 10  | 77   | 77.967  | -0.9670  | 33  | 77   | 77.967  | -0.9670  |
| 11  | 78   | 77.967  | 0.0330   | 34  | 78   | 77.967  | 0.0330   |
| 12  | 78   | 77.967  | 0.0330   | 35  | 77   | 77.967  | -0.9670  |
| 13  | 28   | 29      | -1.0000  | 36  | 26   | 29      | -3.0000  |
| 14  | 77   | 77.125  | -0.1250  | 37  | 76   | 77.125  | -1.1250  |
| 15  | 33   | 29      | 4.0000   | 38  | 30   | 29      | 1.0000   |
| 16  | 77   | 77.125  | -0.1250  | 39  | 77   | 77.125  | -0.1250  |
| 17  | 78   | 77.967  | 0.0330   | 40  | 77   | 77.967  | -0.9670  |
| 18  | 77   | 77.967  | -0.9670  | 41  | 79   | 77.967  | 1.0330   |
| 19  | 80   | 77.967  | 2.0330   | 42  | 77   | 77.967  | -0.9670  |
| 20  | 77   | 77.967  | -0.9670  | 43  | 76   | 77.967  | -1.9670  |
| 21  | 79   | 77.967  | 1.0330   | 44  | 76   | 77.967  | -1.9670  |
| 22  | 77   | 77.967  | -0.9670  | 45  | 79   | 77.967  | 1.0330   |
| 23  | 76   | 77.967  | -1.9670  | 46  | 94   | 77.967  | 16.0330  |

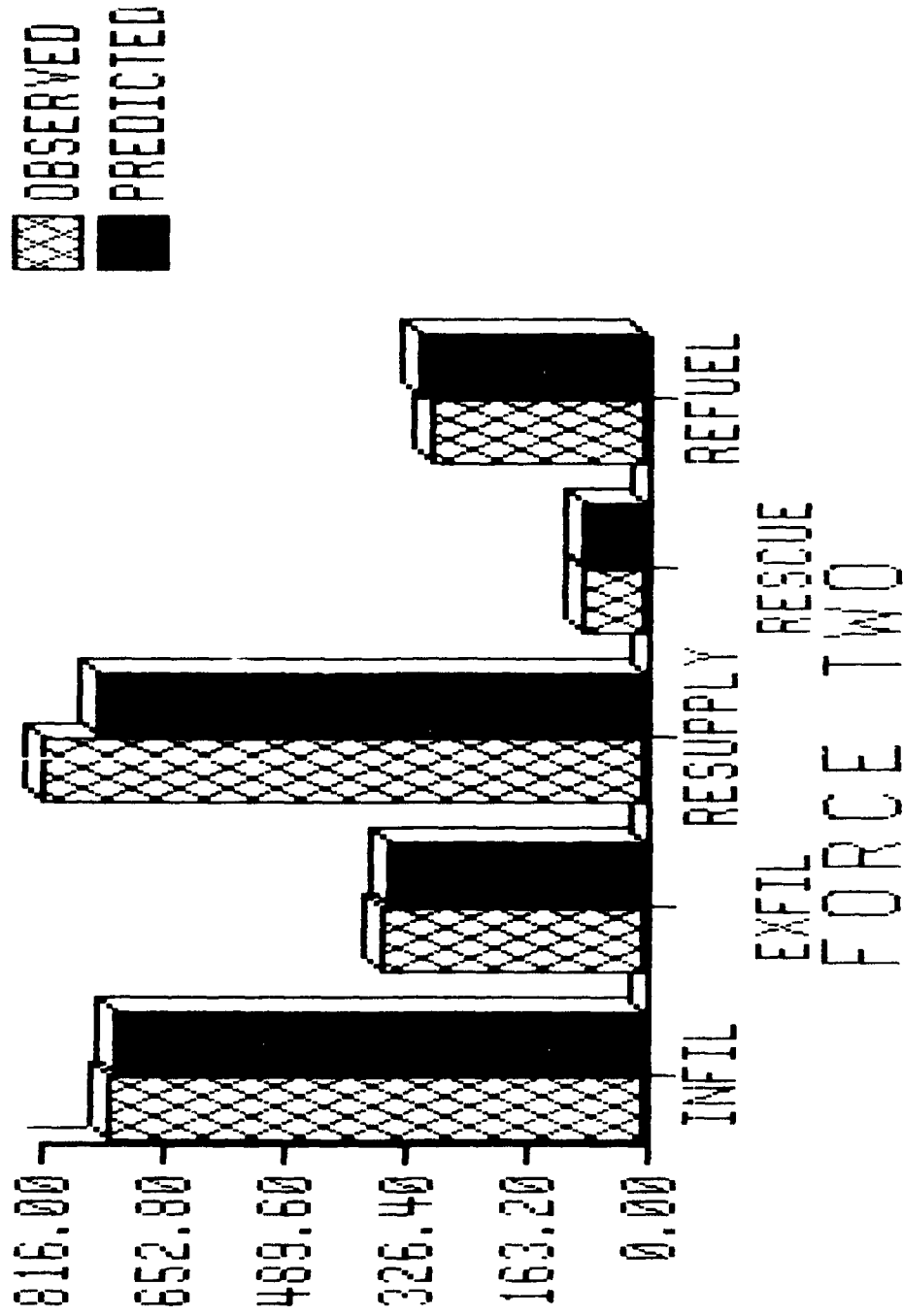
**CENTCOM RESCUE RESIDUAL FLOT**



# OBSERVED vs PREDICTED EUROPE

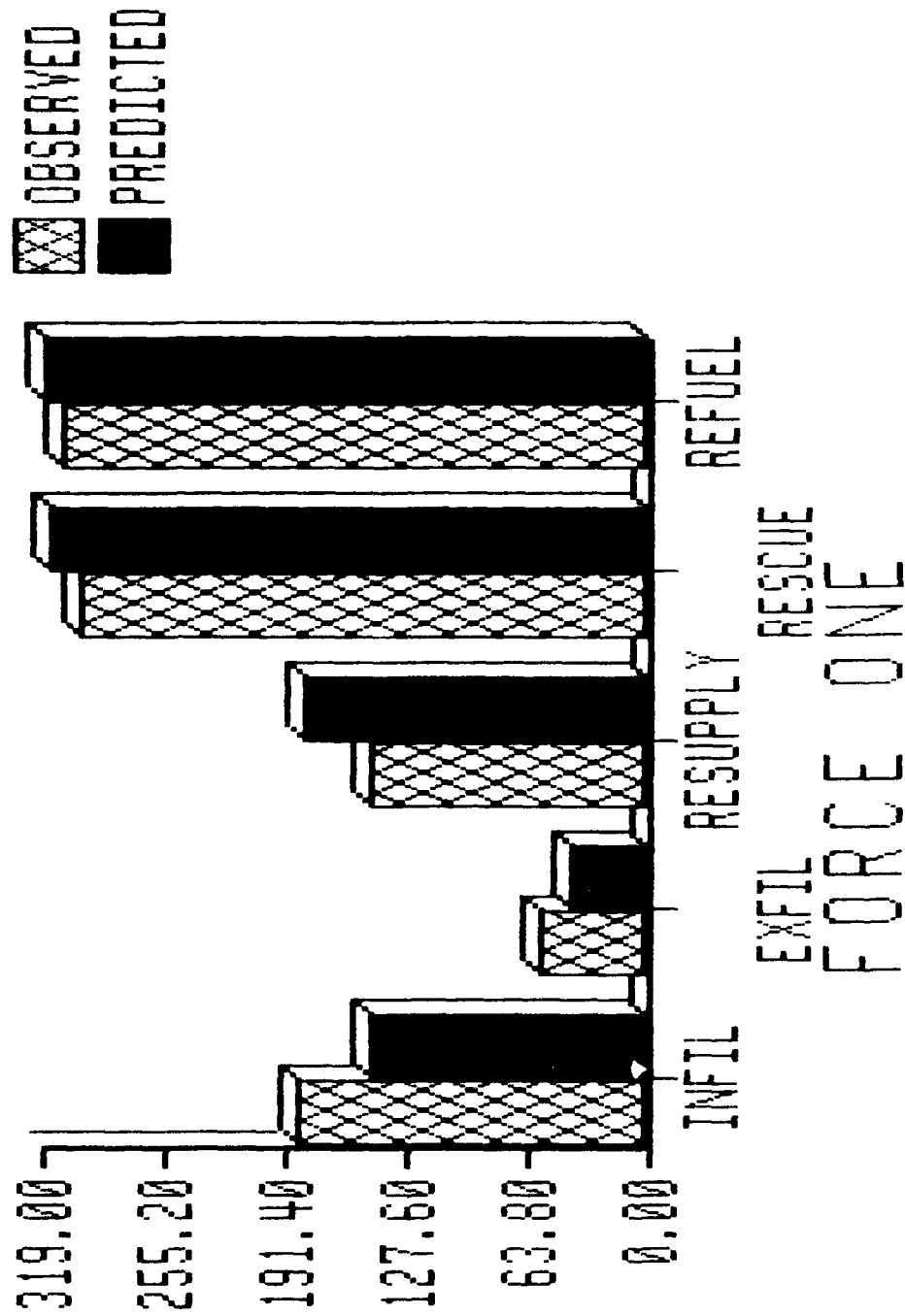


# OBSERVED vs. PREDICTED EUROPE



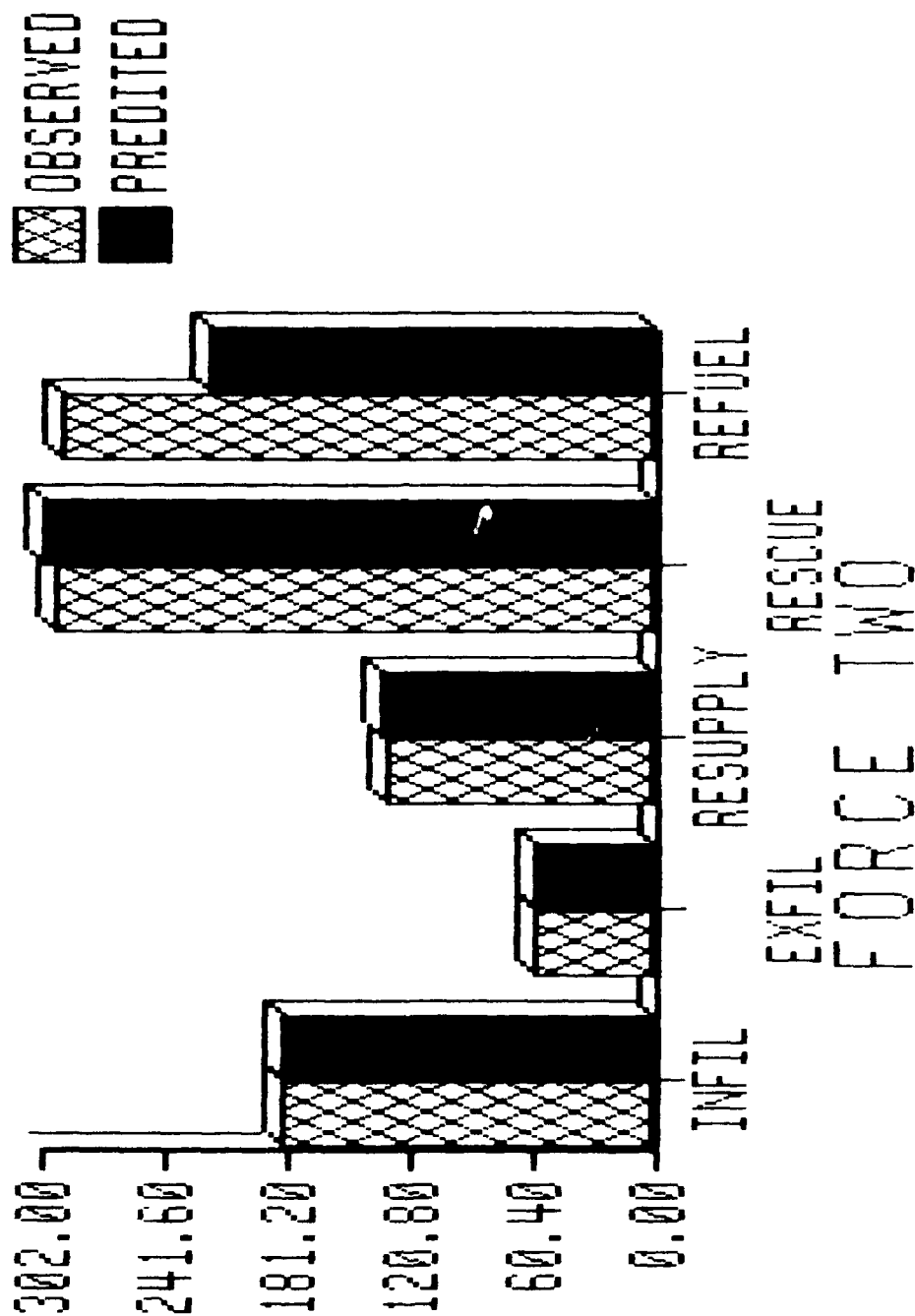
SNOISSIW

# OBSERVED vs. PREDICTED PACIFIC



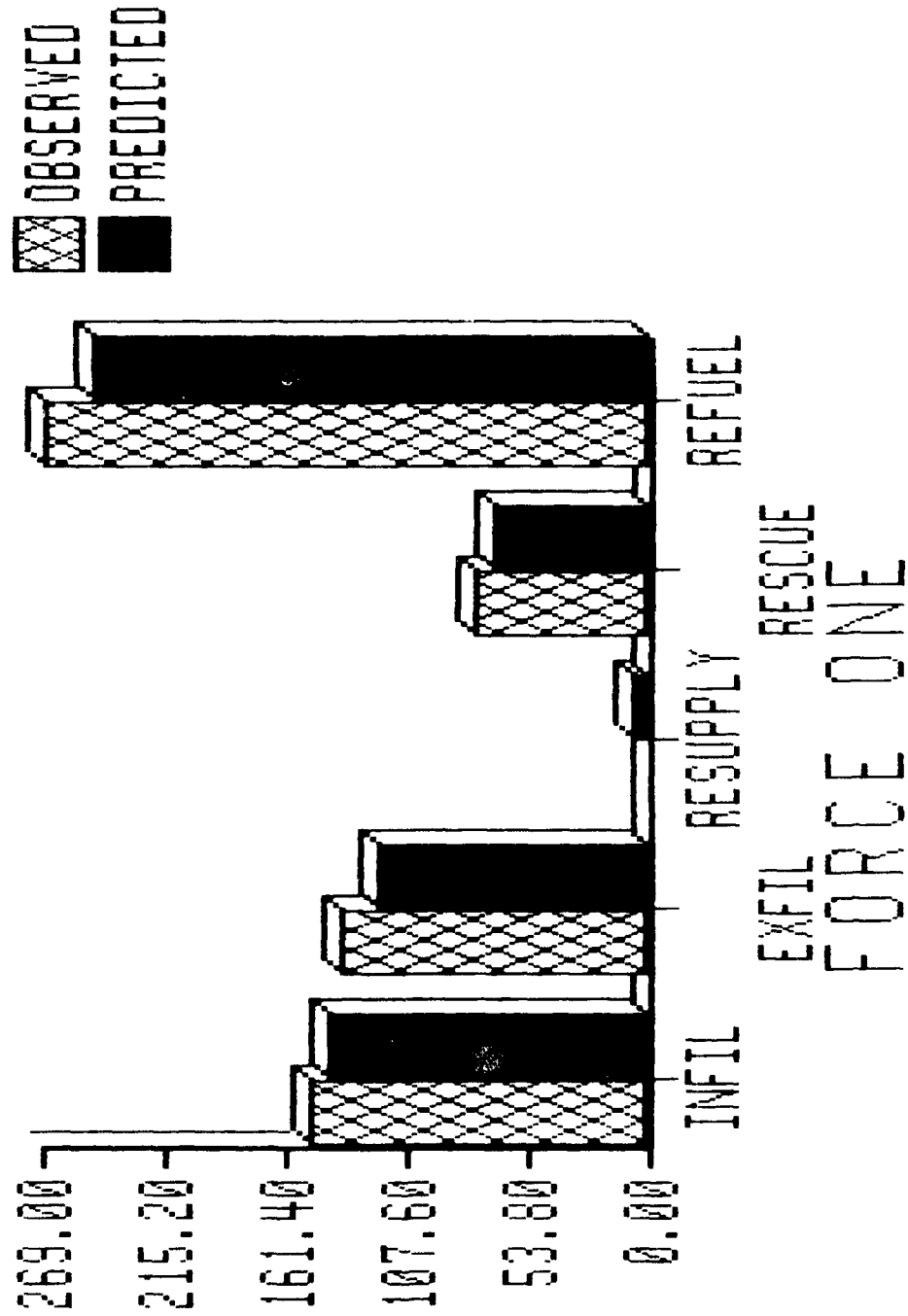
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# OBSERVED vs. PREDICTED PACIFIC



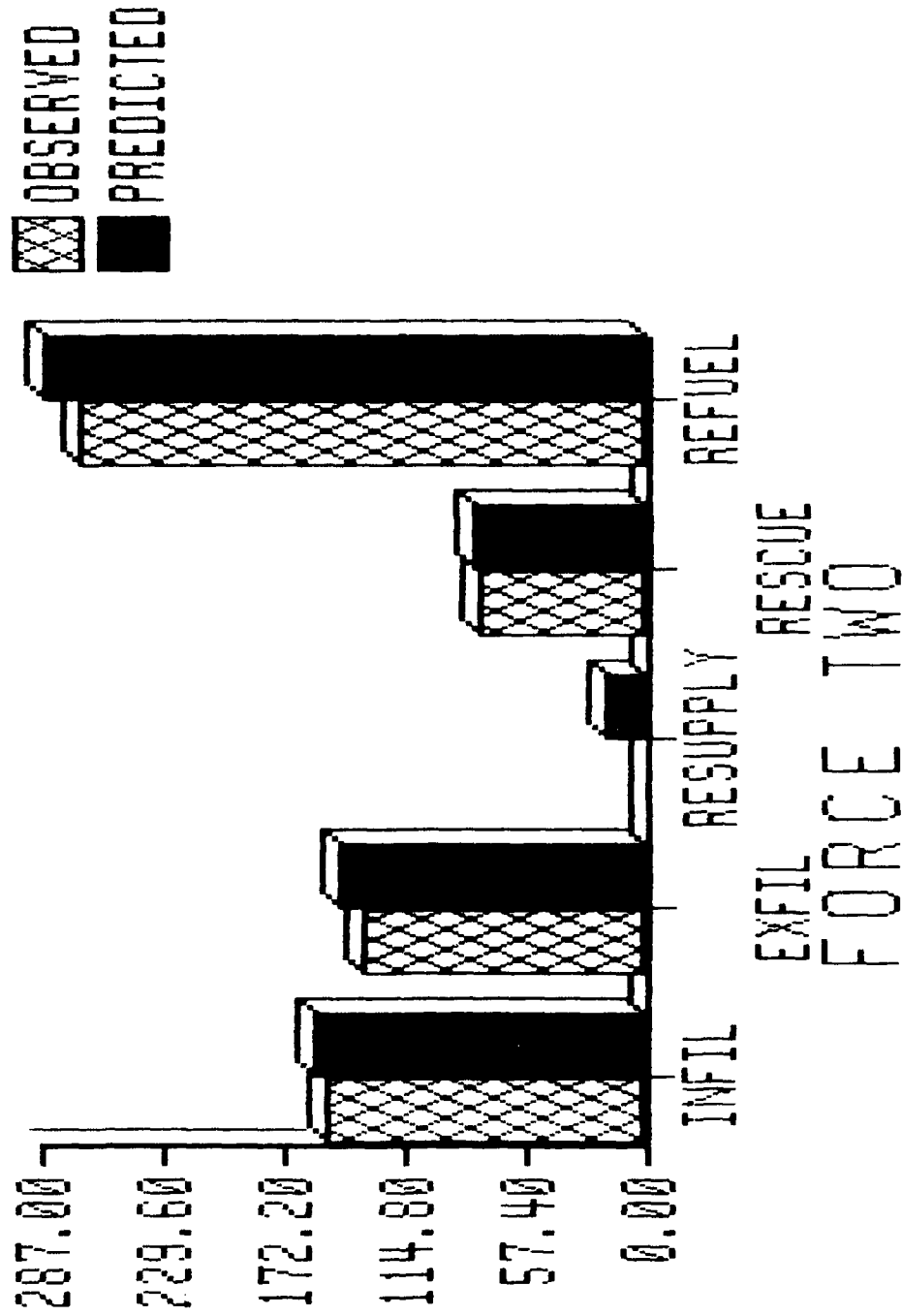
SNOISSIW

# OBSERVED vs. PREDICTED CENTCOM



SNOISSIW

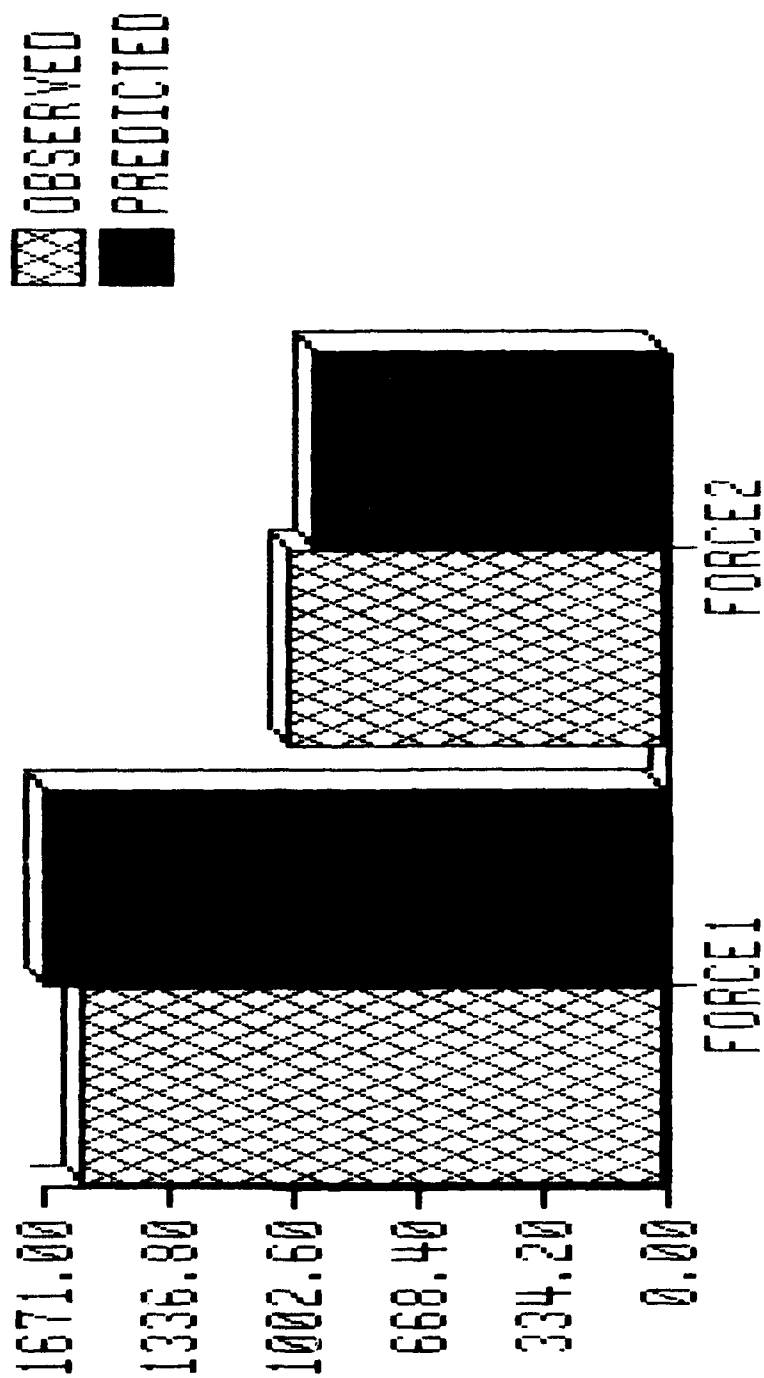
# OBSERVED vs. PREDICTED CENTCOM



MISSIONS

COMPOSITE VALUE

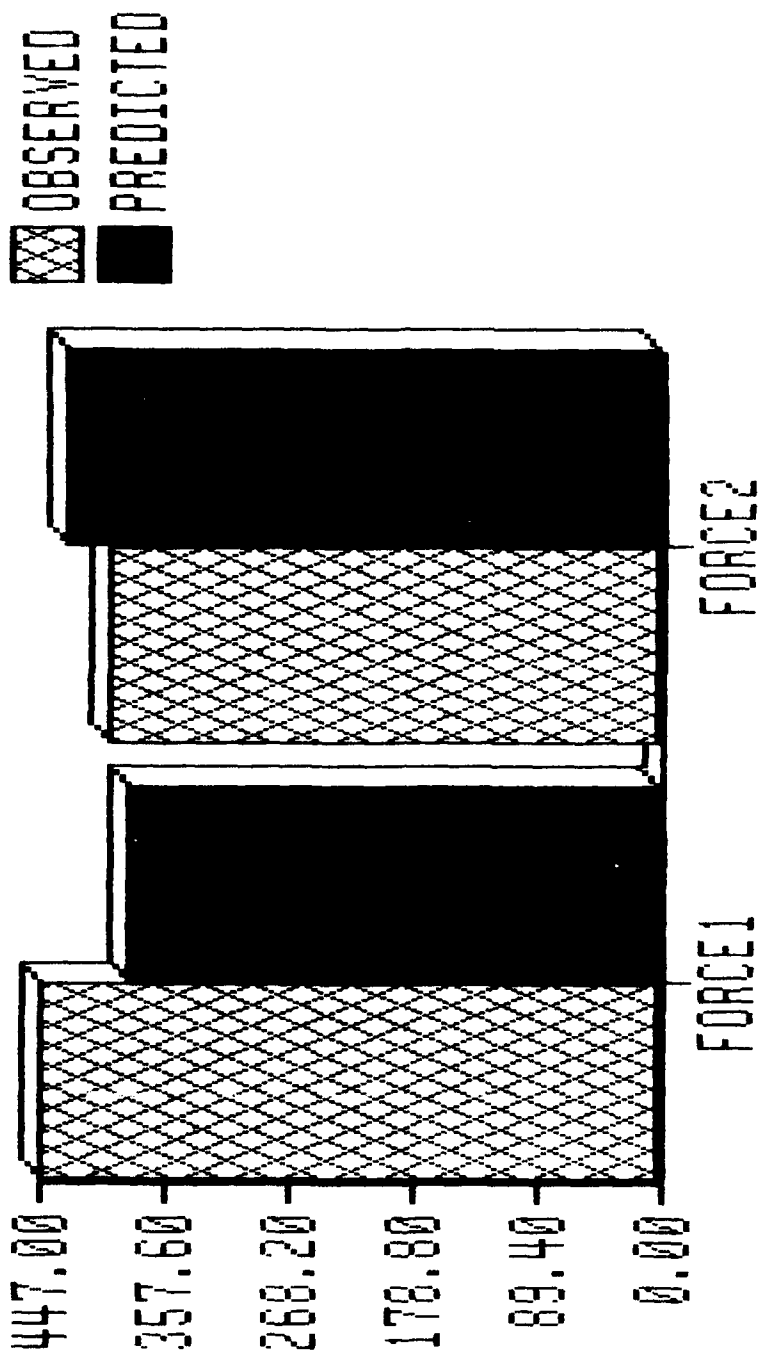
# CAPABILITY INDEX EUROPE



PRIMARY MISSION ACTIVITY

COMPOSITE VALUE

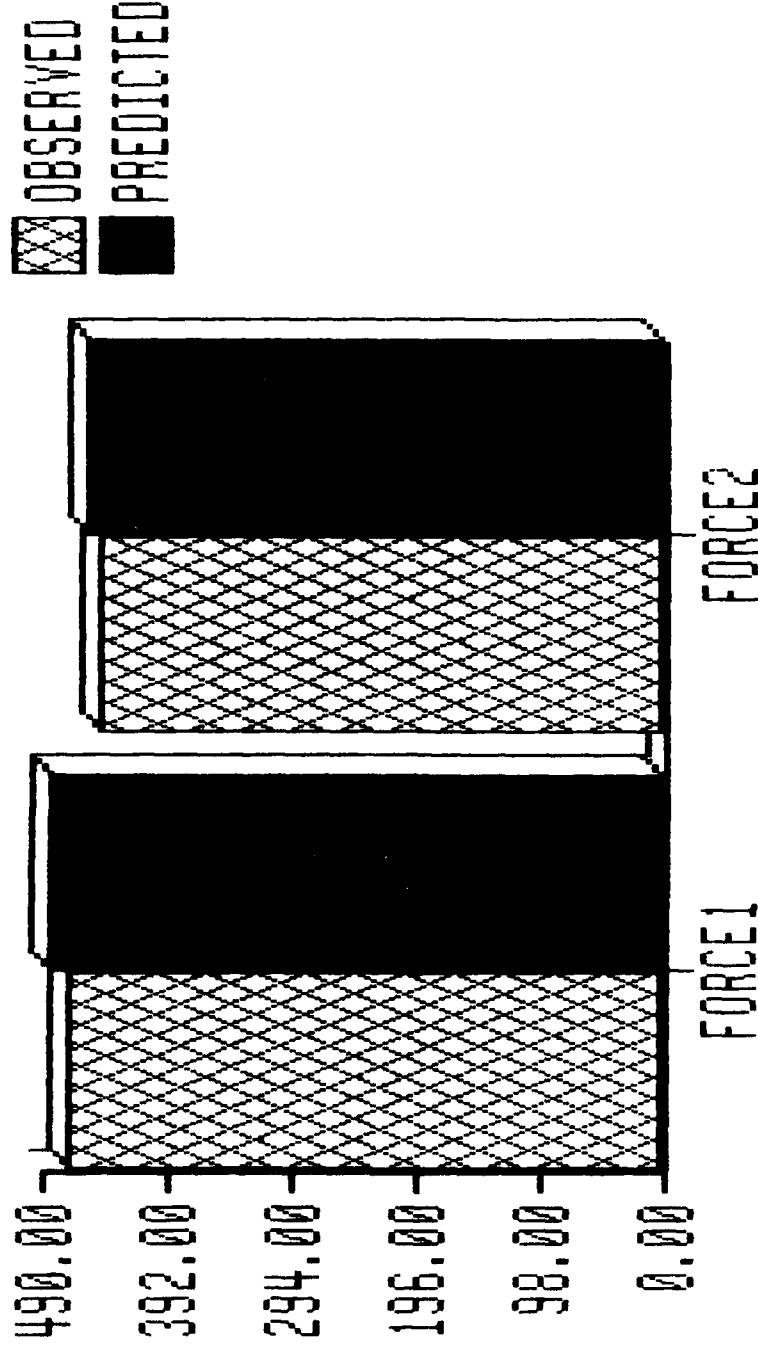
# CAPABILITY INDEX EUROPE



SUPPORT MISSION ACTIVITY

# CAPABILITY INDEX PACIFIC

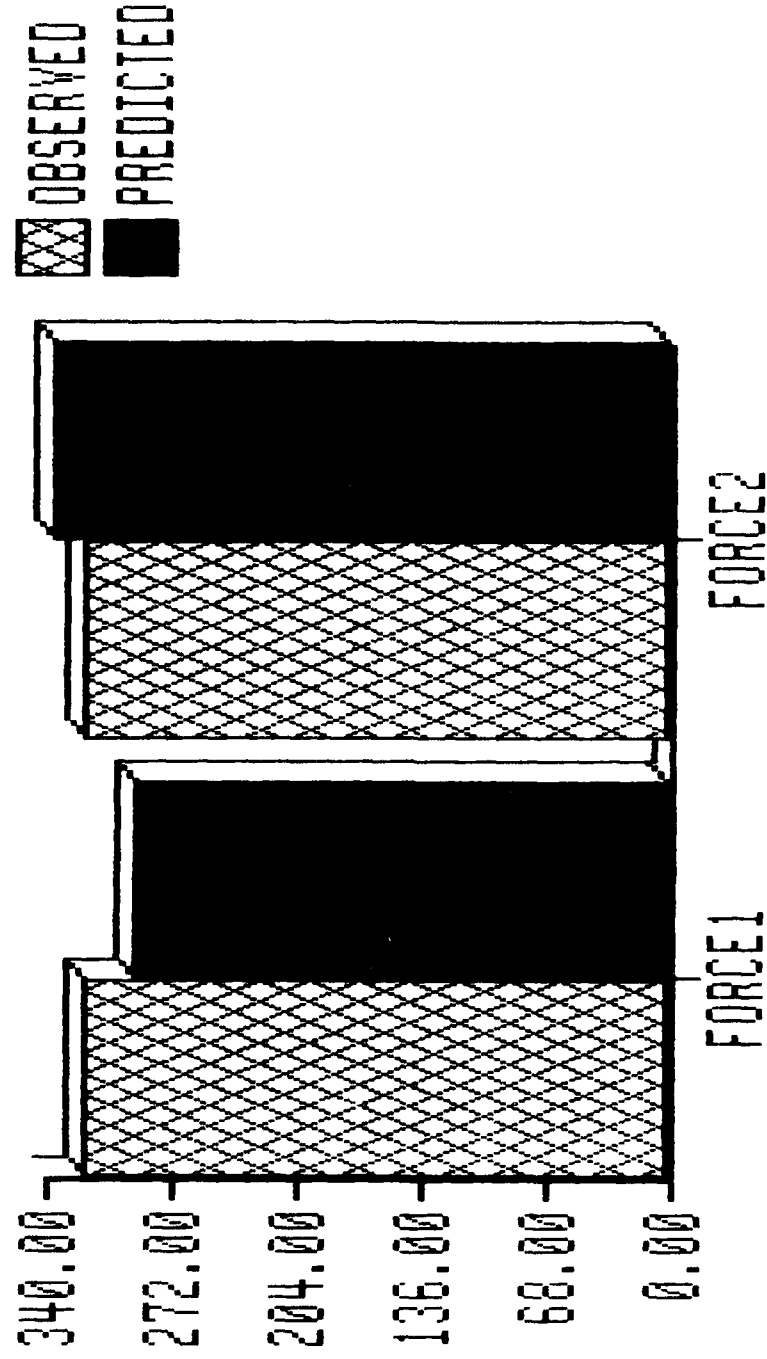
COMPOSITE VALUE



SPECIAL MISSION ACTIVITY

COMPOSITE VALUE

# CAPABILITY INDEX CENTCOM



SPECIAL MISSION ACTIVITY

Vita

Captain Steven Harris [REDACTED]

[REDACTED] in 1978 [REDACTED]

entered the USAF as an accounting technician. After a two year commitment he was selected for the Airman Scholarship Commissioning Program at Alabama State University, from which he received the degree of Bachelor of Art in Mathematics in August 1983. He has been assigned to Headquarters Air Force Communication Command and Headquarters Twenty Third Air Force. He then served at Headquarters Military Airlift Command as a combat mobility analyst until entering the School of Engineering, Air Force Institute of Technology, in June 1987.

[REDACTED] [REDACTED]  
[REDACTED]

# REPORT DOCUMENTATION PAGE

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| Title: A RESPONSE SURFACE APPROACH TO THE COMBAT RESCUE AND SPECIAL OPERATIONS<br>SIMULATION MODEL                                                                                                                                                                                                                                                                                                                                                                                             |       |                                                      |                                                                                   |                                                     |                                |
| Thesis Chairman: Kenneth W. Bauer, JR., Major, USAF<br>Asst Professor of Operations Research                                                                                                                                                                                                                                                                                                                                                                                                   |       |                                                      |                                                                                   |                                                     |                                |
| This thesis proposes a methodology for producing response surface metamodels to enhance the force sizing capability at Military Airlift Command. Output generated by the Combat Rescue and Special Operations Forces simulation model was used to develop the sets of predictive response equations. The methodology produced statistically accurate predictive metamodels using a Box and Behnken fractional factorial. Multivariate techniques were used to reduce the dimensionality of the |       |                                                      |                                                                                   |                                                     |                                |
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19. (con't) responses modeled by the simulation model to further enhance the decision making process on force sizing issues.