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A STATISTICAL TOOL: ANALYSIS OF COVARIANCE

VOLUME III: PROGRAM LISTING, FLOW CHART AND USER'S MANUAL FOR ALGORITHM FOR HANDLING MULTIVARIATE COVARIANCE DATA WITH MISSING VALUES

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This report reviews the theoretical framework which permits analysis of multivariate covariance data in which missing values occur among both dependent and independent variables.

A flow chart and program listing is given for a computer program which will estimate the block and treatment parameters, as well as the regression coefficients for the covariates. The program will also calculate test statistics for testing hypotheses which are supplied by the user. -> next page

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cont.

It should be pointed out that this program allows for only two categories of design indicator variables, namely a block effect and a treatment effect which are assumed to be additive. The program is thus suitable for the usual randomized block model with additive block and treatment effects, or a general two-factor additive effects model (i.e., no interaction), or the usual one-way classification model (i.e., several treatments but only one block). It will not accommodate more complex designs such as a Latin Square Layout with a multivariate response and one or more covariates.

User instructions and a worked example are provided in this volume.

PREFACE

This report consists of three volumes which present the theory and application of a valuable data reduction tool, the analysis of covariance. Volume I introduces the analysis of covariance as a general linear model (GLM) and then expands the model to incorporate the multivariate case, unequal sample size, and missing observations on the response variable. Volume I also covers the analysis of covariance for nonparametric data.

Volumes II and III were prepared by the Department of Statistics, Oklahoma State University, Stillwater, Oklahoma 74074, under Air Force Contract F08635-76-C-0154, with the Air Force Armament Laboratory, Armament Development and Test Center, Eglin Air Force Base, Florida 32542. The contract dealt with the development and programming of the methodology for evaluating multiple variable data with missing observations on dependent and independent variables by the analysis of covariance method. The methodology also covers case for unequal sample size. This work was begun in January 1976 and completed in December 1976. This is Volume III.

This report has been reviewed by the information Officer (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

J. R. MURRAY
Chief, Analysis Division

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TABLE OF CONTENTS

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SECTION I

INTRODUCTION

Many techniques in multivariate analysis, such as multiple regression, principal component analysis, and canonical correlation, assume that one has an array of numbers $(Y_{i_1}, Y_{i_2}, \cdots, Y_{i_p}, X_{i_1}, X_{i_2}, \cdots, X_{i_q})$, $i = 1, \cdots, n$ on which various operations are performed. In ordinary multiple linear regression with a single dependent variable, p will be 1; in a designed experiment, some of the X's will be treatment and block indicators taking only the values 0 or 1.

In various experimental environments, it is not uncommon that some of the Y values and/or X values will be missing, resulting in one or more incomplete observations: an animal dies, a test tube breaks, a piece of equipment malfunctions, or a measuring instrument fails to record as intended.

Most computer programs currently available require that complete observations only be supplied for analysis. One therefore has the choice of discarding any observations on which at least one of the variables is missing, or using an estimation technique of some kind to fill in the missing values before submitting the data for computer analysis. If missing values occur frequently, the first alternative can result in a drastic reduction in the amount of data available for analysis. The second alternative presents difficult problems in estimation; no technique is available which works well under all circumstances. (See, for example, Haitovsky (1968).)

In Section II the results of a technique developed to handle the situation are discussed. Missing values occur among either dependent or independent variables, but not in the block or treatment design indicator variables. Full details of the theoretical development, an extension of the work of Kleinbaum (1973), are given in Volume I. The proposed approach requires neither the discarding of incomplete observations nor the prior estimation of missing values.

In Section III, user instructions are provided for a computer program written to perform an analysis of a set of data by the methods given in Section II. Section IV provides a worked example, while a flow chart and program listing are given in Appendices A and B, respectively.

SECTION II

REVIEW OF THE THEORETICAL FRAMEWORK

The theory, for a multivariate analysis of covariance model in which missing observations occur among the dependent and/or independent variables, was developed in Volume I, resulting in a general procedure which yields Best Asymptotic Normal (BAN) estimators of the design parameters and regression slopes and which allows hypothesis tests based on statistics which are asymptotically distributed as chi-square variables. Equation 10, described in Section III of Volume I, is used for the computation of a consistent and unbiased estimate of the variance-covariance matrix Σ. The value of $\hat{\Sigma}$ thus obtained is then used to obtain estimates of the design parameters, regression slopes, and chi-square statistics for the hypothesis tests. Although the formulae used to obtain these BAN estimates and test statistics are different in form from those described in Volume I, they are mathematically equivalent and are used in the actual calculations only to make the computations manageable on an electronic computer. These alternative formulae are obtained from the Matrix Modified representation of the MGMAC model which is described in the following paragraphs.

To obtain the general form of the Matrix Modified representation of the MGMAC model, assume that there are n experimental units and p response variates $V_1, \cdots, V_p$ in total and that the model can be written in the form

$$E(Y) = X\alpha + Z\beta$$

$$Var(Y) = I_n \otimes \Sigma$$

where Y is an nxp matrix composed of p-variate responses on n individuals with missing values recorded as blanks,

X is an $n \times m_x$ known design matrix of rank $R(x) = r_x (\leq m_x \leq n)$ corresponding to the classificatory variables of the model,

α is an $m_x xp$ matrix of unknown parameters

Z is an nxm_z matrix composed of concomitant variables with missing values recorded as blanks,

β is an $m_z xp$ matrix of unknown concomitant parameters.

$\Sigma = ((\sigma_{rs}))$ is a pxp positive definite matrix of usually unknown parameters which represents the variance-covariance matrix of any row of Y, and $A \otimes B$ is the Kronecker Product of the matrices A and B.

Then replace Z by Z* where Z* is derived from Z by augmenting Z (with 0's in place of missing values) by a matrix G of dimension (nxt) composed of t columns each with a one in the row position corresponding to the missing values in Z and zeroes elsewhere. (Note: Z has dimension (nxm_z^*) where $m_z^* = m_z + t$). Thus, the Matrix Modified representation of the MGMAC model may be written in the form

$$E(Y) = X\alpha + Z^*\binom{\beta}{\delta} \qquad (1)$$
$$Var(Y) = In \otimes \Sigma$$

where δ is a (txp) matrix of unknown parameters due to the t missing values in Z. Missing values in Y are then handled by an approach suggested by Srivastava (3) for incomplete multiresponse designs and later by Kleinbaum (1) for the MGLM model. For simplification of notation, the model [Equation (1)] is first written in the form

$$E(Y) = A^* \xi$$
$$Var(Y) = In \otimes \Sigma$$

where $A^*(nxm^*) = [X \mid Z^*]$, $m^* = m_x + m_z^*$ and $\xi(m^*xp) = \begin{bmatrix} \alpha \\ \beta \\ \delta \end{bmatrix}$. The n experimental units are then divided into u disjoint sets of experimental units $S_1, S_2, \ldots, S_u$ with n_j units in S_j. On each unit in the set S_j only $q_j (\leq p)$ responses are observed (i.e.,the remaining $p-q_j$ response variates are missing in S_j). Therefore, the MGMAC model is given by

$E(Y_j) = A_j^* \xi B_j$

$Var(Y_j) = In \otimes B_j' \Sigma B_j$, $j = 1,2,\ldots,u$

where $Y_j(n_j x q_j)$ is the matrix of observations for the j<u>th</u> set S_j

$A_j^*(n_j xm^*)$ is the design matrix for the set S_j,

$B_j(pxq_j)$ is the incidence matrix of rank $R(B_j) = q_j$ for the j<u>th</u> set of experimental units. It consists of 0's and 1's and is defined by $B_j = ((b_{(j)_{se}}))$ where

$$b_{(j)_{sr}} = \begin{cases} 1 \text{ if variate } V_s \text{ is the } r\underline{th} \text{ ordered variate} \\ \quad \text{measured in the } j\underline{th} \text{ experimental set } S_j \\ 0 \text{ otherwise.} \end{cases}$$

It is also assumed that Y_j and Y_j' are independent if $j \neq j'$ and the rows of Y_j are independent and distributed as a q_j-variate multinormal vector with variance-covariance matrix $B_j' \Sigma B_j$.

Based on the above Matrix Modified representation of the MGMAC model, the following results for estimation and hypothesis testing are obtained.

<u>Theorem 1.</u> A BAN estimator for an estimable linear set $\underline{\Theta} = H'\underline{\xi}$ is given by

$$\underline{\hat{\Theta}}_n = H'\underline{\hat{\xi}} = H'[\sum_{j=1}^{u} B_j(B_j' \hat{\Sigma} B_j)^{-1}B_j' \otimes A_j^{*}{}'A^*]^{-} \sum_{j=1}^{u} [B_j(B_j'\hat{\Sigma}B_j)^{-1} \otimes A_j^{*}{}'] \underline{y}_j$$

where $\hat{\Sigma}$ is defined in Theorem 4 of Volume I and $\underline{y}_j$ is formed by stacking the columns of Y_j underneath each other.

<u>Theorem 2.</u> The Wald Statistic for testing the hypothesis H_o: $H'\underline{\xi} = 0$ is given by

$$W_n = (H'\underline{\hat{\xi}})' \{H'[\sum_{j=1}^{u} B_j(B_j'\hat{\Sigma}B_j)^{-1}B_j' \otimes A_j^{*}{}'A_j]^{-} H\}^{-1} H'\underline{\hat{\xi}} .$$

Note: The above theorems follow easily from similar theorems by Kleinbaum (1).

SECTION III

INSTRUCTIONS FOR USE OF THE COMPUTER PROGRAM

In this section are outlined the steps for preparation of data cards and control cards necessary for execution of the computer program. A worked example illustrating these ideas and the resulting computer output is presented in the next section.

PREPARATION OF DATA CARDS

The methodology and computer program presented in this report were designed to assist in analyzing data from an experiment in which a complete observation consists of a block identifier, a treatment identifier, numerical values on one or more concomitant variables (covariables, independent variables), and numerical values on one or more dependent variables (response variables). For example, a complete observation may come from a single shot down a firing range, where block corresponds to metal type, treatment corresponds to projectile shape, the covariables are such things as initial projectile weight and initial projectile velocity, and the dependent variables are residual projectile weight, residual projectile velocity, and plug weight.

For this program the data card(s) corresponding to a complete observation should contain a block number, a treatment number, the covariables, and the dependent variables, as well as any identification the user desires. The order in which these occur on the card is not important. It is necessary, however, that both blocks and treatments be numbered sequentially beginning with "1."

The data card corresponding to the observation on block 3, treatment 2, may look like:

$$\underbrace{\text{TEST 06 SITE A}}_{\text{Identification}}\quad \underbrace{3\qquad 2}_{\text{Blk \& Trt}}\quad \underbrace{113.8\quad 680}_{\text{X's}}\quad \underbrace{110.7\quad 507\quad 8.9}_{\text{Y's}}$$

MISSING VALUES

The user is free to choose any number he desires to correspond to missing values among the Y's or X's. This number will then be punched in the data card for any X or Y value which, for reasons reviewed in Section I, was not recorded when the experiment was conducted. Of course, the selected number must not be the same as any of the X or Y values occurring in the data set being analyzed and must also be of a magnitude which allows it to be coded in the number of columns provided for the X's and Y's. Suppose that, in the example above, both 113.8 and 507 had not been recorded and were to be treated as missing values. If the missing value code selected by the user was 44.4, the card would have been punched as:

TEST 06 SITE A   3   2   044.4   680   110.7 44.4   8.9

CONTROL CARDS

We now present in sequence a description of the control cards which must accompany every job.

Control Card 1 - Current Data Set Information

The first 21 columns of this card consist of seven three-digit (i.e., I3) fields which contain in order the values of

NP - The number of dependent variables (Y's) $NP \geq 1$

NT - The number of treatments $NT \geq 1$

NB - The number of blocks $NB \geq 1$

NK - The number of covariates (X's) $NK \geq 1$

NN - The number of observations

IDGT - An input parameter to the LPSDOR subroutine (which computes a generalized inverse of a matrix). The elements of the matrix are assumed to be correct to IDGT places. Since this program computes the matrix elements in double precision, we suggest that the user supply IDGT=14.

NMISS - The number of missing values in the covariates only. Do not include, in this count, missing values in the dependent variables.

The next 8 columns are blank. Beginning in column 30 punch

Columns 30-39: EPS - A test value for zero which is used in the DMFGR subroutine which calculates the rank of a matrix. Suggest user let EPS = 1.0E - 07.

Columns 40-49: D - The double precision missing value code described in an earlier subsection of this section. In that subsection we used, as an example, a missing value code of 44.4. In this case we would code D = 44.4 DO.

Columns 50-63: These columns contain seven two-digit (I2) fields indicating the desired print options for the analysis. Each I2 field contains either "00," which requests that the printing be suppressed, or "01," which requests that the printing not be suppressed. In order, the 7 codes refer to

Columns 50-51: Print option for listing of MAC model.

Columns 52-53: Print option for listing of GMAC model.

Columns 54-55: Print option for listing of MGMAC model.

Columns 56-57: Print option for listing of sigma and its inverse.

Columns 58-59: Print option for listing of the matrix modified model.

Columns 60-61: Print option for subgroups of observations corresponding to the different patterns of missing values.

Columns 62-63: Print option for beta values.

With regard to the user's choice of the print options, we suggest that, for most purposes, it would be sufficient to code columns 50 through 63 with "01000001000001." This provides the user with a listing of the MAC model, sigma and its inverse, and the beta values as well as results of hypothesis tests.

Control Card 2 - Variable Format for the Input Data Set

On this card the user supplies a FORTRAN format statement which specifies the columns in which the block number, treatment number, dependent variables (Y_i, i = 1, ⋯, NP), and covariables (X_j, j = 1, ⋯, NK), in that order, are to be found. The block and treatment numbers must be read according to an Iw format, while the dependent and independent variables would ordinarily be read with F w.d or D w.d formats. This card must begin with a left parenthsis (in column 1) and end with a right parenthesis and contain no intervening blanks. For our example in the first subsection of this section, the variable format card would be

(T18, I1,6X,I1,T42,F5.1,1X,F4.0,3X,F4.1,T30,F5.1,1X,F4.0).

Control Card 3 - Number of Hypothesis Matrices Being Supplied

This is the simplest of all the control cards and merely states how many hypothesis matrices are to be supplied to provide basis for hypothesis tests for the particular job. This is an integer, NUMHYP, which is punched, right justified, in the first 5 columns of the card. Ordinarily this number will be less than 10, so that only column 5 need be punched.

Remaining Control Cards

Next, we must supply one group of cards for each of the hypotheses to be tested. The first card provides the following information relative to each hypothesis:

Columns 1-5: The number of rows, NR, in the hypothesis matrix. This is an integer, right justified in columns 1-5.

Columns 6-25: Any alphameric code which identifies the hypothesis being tested. This is simply an identification which will be listed with the output in the hypothesis testing section of the printout.

Columns 26-27: "00" if the user does not desire to have the test statistic evaluated for this hypothesis on all NP response variables simultaneously. "01" if the user does desire to have the test statistic evaluated for this hypothesis on all NP response variables simultaneously.

Columns 28-29: "00" if the user does not desire to have the test statistic evaluated for this hypothesis on the first response variable separately. "01" if the user desires to have the test statistic evaluated for this hypothesis on the first response variable separately.

.   .
.   .
.   .

Columns ((26+2NP)-(27+2NP)): "00" is the user does not desire to have the test statistic evaluated for this hypothesis on the NP^{th} response variable separately. "01" if the user does desire to have the test statistic evaluated for this hypothesis on the NP^{th} response variable separately.

The remaining NR cards in the group for a particular hypothesis give the coefficients for each fow of the hypothesis matrix, one row on each of NR cards. These coefficients are read from consecutive four-digit fields according to an F4.2 format. The number of coefficients read per card will be equal to (NB+NT+NK), with the exception that if the data set is composed of one block only (or one treatment only) the number will be (NB+NT+NK-1). This number will, of course, vary from one problem to the next. The number of rows in the hypothesis matrix, NR, will also vary from one hypothesis to the next and from problem to problem.

If we denote by NR_i, $i = 1, \cdots, NUMHYP$, the number of rows in the i^{th} hypothesis being tested, then the number of control cards after control card 3 will be $\sum_{i=1}^{NUMHYP} (NR_i + 1)$.

The method of constructing the hypothesis matrices will be demonstrated in the next subsection.

EXAMPLES ILLUSTRATING CONSTRUCTION OF HYPOTHESIS MATRICES

In Section II, we outlined the general formulation of the assumed model with

$$E(Y) = X\alpha + Z\beta$$

as the underlying mean structure for the data. Here α was an m_x by p matrix of unknown design parameters, and β was an m_z by p matrix of unknown regression coefficients for the concomitant variables. Let us stack the α matrix on the β matrix to form a matrix B. In keeping with the notation used in relation to our computer control cards, this will be a matrix with row dimension (NB+NT+NK) and column dimension NP.

Denoting the block parameters by b_{ij}'s, the treatment parameters by t_{ij}'s, and the regression coefficients by β_{ij}'s, we could think of the B matrix as

$$
B = \left[\begin{array}{cccc}
b_{11} & b_{12} & \cdots & b_{1_{NP}} \\
\vdots & \vdots & & \vdots \\
b_{NB_1} & b_{NB_2} & \cdots & b_{NB_{NP}} \\
\hline
t_{11} & t_{12} & \cdots & t_{1_{NP}} \\
\vdots & \vdots & & \vdots \\
t_{NT_1} & t_{NT_2} & \cdots & t_{NT_{NP}} \\
\hline
\beta_{11} & \beta_{12} & \cdots & \beta_{1_{NP}} \\
\vdots & \vdots & & \vdots \\
\beta_{NK_1} & \beta_{NK_2} & \cdots & \beta_{NK_{NP}}
\end{array}\right]
\begin{array}{l}
\left.\vphantom{\begin{array}{c}b\\ \vdots\\ b\end{array}}\right\}\text{NB rows for block parameters} \\
\left.\vphantom{\begin{array}{c}t\\ \vdots\\ t\end{array}}\right\}\text{NT rows for treatment paramters} \\
\left.\vphantom{\begin{array}{c}\beta\\ \vdots\\ \beta\end{array}}\right\}\text{NK rows for regression coefficients}
\end{array}
$$

This makes it easy to construct full rank hypothesis matrices to test hypotheses of the form H_0: $HB = 0_M$, where H is a full rank hypothesis matrix of dimension r(= rank of H) by (NB + NT + NK) and 0_M is the r by NP matrix containing all zeroes. For example, the hypothesis of no treatment differences (i.e., $t_{1_j} = t_{2_j} = \ldots = t_{NT_j}$ for all j = 1,2,...,NP) can be tested with an H matrix containing (NT-1) orthogonal rows. Similarly, the hypothesis of no influence of covariates ($\beta_{ij} = 0$, i = 1,...,NK; j = 1,...,NP) can be tested with a full rank hypothesis matrix of row dimension NK. Some specific examples will now be given to illustrate the construction of H matrices.

Example 1:

Suppose we have two blocks, two treatments, one covariate, and three response variables. Here NB = NT = 2, NK = 1, and NP = 3. Thus, B can be written

$$
B = \begin{bmatrix}
b_{11} & b_{12} & b_{13} \\
b_{21} & b_{22} & b_{23} \\
t_{11} & t_{12} & t_{13} \\
t_{21} & t_{22} & t_{23} \\
\beta_{11} & \beta_{12} & \beta_{13}
\end{bmatrix}
$$

To test the hypothesis of no treatment differences, H will be the 1 by 5 matrix

$$
H = [0 \quad 0 \quad 1 \quad -1 \quad 0].
$$

Note that HB = 0 is equivalent to

$$[(t_{11} - t_{21})\ (t_{12} - t_{22})\ (t_{13} - t_{23})] = [0\ 0\ 0].$$

To test the hypothesis of no influence of the covariate, H will be the 1 by 5 matrix

$$H = [0\ 0\ 0\ 0\ 1].$$

Note that HB = 0 is equivalent to

$$[\beta_{11}\ \ \beta_{12}\ \ \beta_{13}] = [0\ \ 0\ \ 0].$$

Example 2:

Suppose we have two blocks, four treatments, two covariates, and three response variables. Here NB = 2, NT = 4, NK = 2, and NP = 3. Thus, B can be written

$$B = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ t_{11} & t_{12} & t_{13} \\ t_{21} & t_{22} & t_{23} \\ t_{31} & t_{32} & t_{33} \\ t_{41} & t_{42} & t_{43} \\ \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \end{bmatrix}$$

To test the hypothesis of no overall treatment differences, H will be the 3 by 8 matrix

$$H = \begin{bmatrix} 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & -2 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & -3 & 0 & 0 \end{bmatrix}.$$

To test the hypothesis of no overall block differences, H will be the 1 by 8 matrix

$$H = [1\ \ -1\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0].$$

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To test the hypothesis of no overall effect due to the covariates, H will be the 2 by 8 matrix

$$H = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}.$$

To test the hypothesis of no effect due to the first covariate only H will be the 1 by 8 matrix

$$H = [0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0].$$

To test the hypothesis of no difference between treatments one, three and four, H will be the 2 by 8 matrix

$$H = \begin{bmatrix} 0 & 0 & 1 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & -2 & 0 & 0 \end{bmatrix}.$$

Example 3.

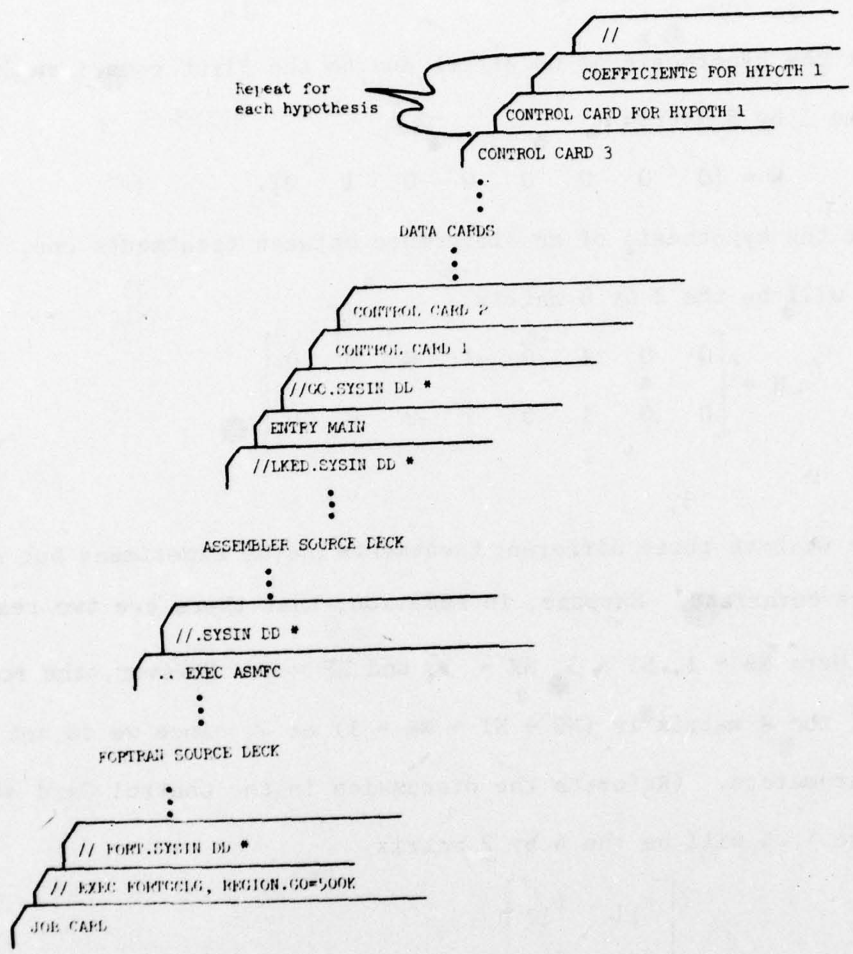
Suppose we have three different treatments in the experiment but only one block and one covariate. Suppose, in addition, that there are two response variables. Here NB = 1, NT = 3, NK = 1, and NP = 2. However, the row dimension of the B matrix is (NB + NT + NK - 1) or 4, since we do not require any block parameters. (Refer to the discussion in the Control Card subsection above.) B will be the 4 by 2 matrix

$$B = \begin{bmatrix} t_{11} & t_{12} \\ t_{21} & t_{22} \\ t_{31} & t_{32} \\ \beta_{11} & \beta_{12} \end{bmatrix}$$

The hypothesis matrix for testing "H_0: No Treatment Differences" will be the 2x4 matrix

$$H = \begin{bmatrix} 1 & -1 & 0 & 0 \\ 1 & 1 & -2 & 0 \end{bmatrix}.$$

The complete set of punched cards necessary to execute a job using the source program with a level G FORTRAN compiler are submitted to the card reader in the following order:



The form of the initial job card and the various job control cards may vary from one installation to another. The user should verify the validity of these with systems personnel at his particular computer center.

SECTION IV

A WORKED EXAMPLE

A sample problem will now be presented and the necessary programming steps illustrated. This data set was constructed to represent a set of results from a series of test shots involving two different metals from which projectiles were made (the blocks) and three different projectile shapes (the treatments). Each block/treatment combination was replicated five times, resulting in a total of 30 observations. Two concomitant variables were measured on each projectile. These were X_1=Initial Projectile Weight and X_2=Initial Projectile Velocity. The three dependent variables recorded were Y_1 = Residual Projectile Weight, Y_2 = Residual Projectile Velocity , and Y_3 = Plug Weight.

The data were generated using the model

$$Y_{ijk} = b_i + t_j + \beta_1 X_{1_{ijk}} + \beta_2 X_{2_{ijk}} + \varepsilon_{ijk}$$

where Y_{ijk} represents the k<u>th</u> replication of treatment j in block i for any one of the three response variates. For our problem i = 1,2; j = 1,2,3; k = 1,2,...,5. The disturbances were chosen from a table of random standard normal deviates (2). The values used for the model parameters were as shown in the following B matrix.

$$B = \begin{array}{c} \\ b_1 \\ b_2 \\ t_1 \\ t_2 \\ t_3 \\ \beta_1 \\ \beta_2 \end{array} \begin{array}{c} \begin{array}{ccc} Y_1 & Y_2 & Y_3 \end{array} \\ \left[\begin{array}{ccc} 0 & 0 & 0 \\ 2 & 20 & 0 \\ 10 & 8 & 0 \\ 10 & 8 & 0 \\ 20 & 20 & 4 \\ 8 & 0 & .005 \\ 0 & 7 & .01 \end{array} \right] \end{array}$$

20

The data resulting from this simulation were:

Observation	Block	Treatment	X_1	X_2	Y_1	Y_2	Y_3
1	1	1	110	710	98.0	504.4	7.3
2	1	1	110	710	97.5	503.2	5.2
3	1	1	112	695	98.2	494.5	8.3
4	1	1	111	705	100.0	501.1	8.2
5	1	1	112	690	100.1	490.9	8.1
6	1	2	110	710	98.4	504.6	8.3
7	1	2	109	705	95.5	501.2	8.8
8	1	2	107	700	94.6	497.0	10.5
9	1	2	111	700	99.3	498.8	9.5
10	1	2	112	710	98.9	504.3	7.5
11	1	3	116	810	110.7	586.4	8.1
12	1	3	115	770	112.4	558.9	8.5
13	1	3	116	790	113.3	572.6	8.9
14	1	3	116	800	110.6	581.1	8.7
15	1	3	117	790	115.3	572.9	7.4
16	2	1	109	705	98.3	522.8	6.6
17	2	1	112	705	101.0	521.3	8.3
18	2	1	111	690	99.1	510.0	6.3
19	2	1	110	700	99.8	517.2	8.3
20	2	1	111	710	103.1	524.3	8.4
21	2	2	112	700	100.9	517.6	5.8
22	2	2	112	690	100.5	510.5	7.2
23	2	2	114	695	103.1	514.6	6.2
24	2	2	112	700	99.5	517.3	7.4
25	2	2	113	705	102.0	522.9	8.8
26	2	3	115	795	114.2	597.1	12.3

27	2	3	116	800	114.8	598.6	12.5
28	2	3	117	795	115.9	598.0	12.7
29	2	3	116	790	116.0	593.0	12.3
30	2	3	117	805	115.2	602.4	12.4

For the purpose of a realistic example in which we have some missing observations among both the dependent and independent variables, we consider as missing the values of

Y_2 on observation 1

Y_3 and X_2 on observation 11

X_2 on observation 18

Y_2 and Y_3 on observation 24.

PREPARATION OF DATA CARDS

First we must select a value to use as the missing value code. Any negative number would suffice, as would zero. We have chosen D=50.0D0, a number intermediate in magnitude between Y_3 and the other X and Y variables. The data cards were punched as follows:

Columns 1-5 : The identification SAMPLE
Column 10: Block number
Column 12: Treatment number
Columns 13-16: X_1, in format F4.0
Columns 17-20: X_2, in format F4.0
Columns 22-25: Y_1, in format F4.1 (Decimal not punched)
Columns 27-30: Y_2, in format F4.1 (Decimal not punched)
Columns 31-34: Y_3, in format F4.1 (Decimal not punched)

For example, the first data card was, beginning in column 1:

SAMPLE 1 1 110 710 0980 0500 073

Note that the Y_2 value of 598.0 has been replaced by 50.0, since in this example we are treating it as a missing value.

PREPARATION OF CONTROL CARDS

Control Card 1:

To complete this card, we determine that for the present problem we have:

NP = 3

NT = 3

NB = 2

NK = 2

NN = 30

NMISS = 2

To provide a thorough look at the printout available from the program, we shall take every print option. Using the suggested values for EPS and IDGT, the first control card has the form, beginning in column 1:

```
003003002002030014002          1.00E-07  50.0D0  01010101010101
```

Control Card 2:

For this card, we may use any permissible FORTRAN format statement to read in the block number, treatment number, Y's and X's. One possibility for our data would be

(T10, I1, 1X, I1, T21, 2F5.1, F4.1, T14, F3.0, 1X, F3.0)

Control Card 3 and Subsequent Control Cards:

For this problem we shall test four hypotheses to illustrate the flexibility of this aspect of the program.

(1) H_o: No Block Differences

With only two blocks, the H matrix consists of one row which compares the two block effects. Recalling that for this problem the matrix of unknown parameters is

$$B = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ t_{11} & t_{12} & t_{13} \\ t_{21} & t_{22} & t_{23} \\ t_{31} & t_{32} & t_{33} \\ \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \end{bmatrix},$$

our H matrix is $H = \begin{bmatrix} 1 & -1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$. If we elect the overall test as well as the test on response variates two and three separately, the necessary control cards are:

```
00001NO BLK DIFF          01000101
0100-100
```

(2) H_o: No Treatment Differences

The H matrix for contrasting our three treatments requires two rows:

$$H = \begin{bmatrix} 0 & 0 & 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & -2 & 0 & 0 \end{bmatrix}$$

The necessary cards, electing the overall test as well as Y_1 and Y_2 separately, are:

```
00002NO TRT DIFF          01010100
000000000100-100
0000000001000100-200
```

(3) H_o: No Difference Between Treatments 1 and 2

If we elect the overall test as well as the test on each variate separately, the necessary cards are:

```
00001NO DIFF BETW TR 1&2 01010101
000000000100-100
```

(4) H_0: No Effect Due to Covariates

Electing the same test options as for the previous example, our control cards are

```
00002NO EFFECT COVARS    01010101
0000000000000000000000100
000000000000000000000000000100
```

These control cards for hypotheses must be preceded by control card 3, which for our problem will have a "4" punched in column 5, indicating that four hypotheses are to be tested.

THE PRINTED OUTPUT FROM THE PROGRAM

The program output, when all print options are exercised, has essentially 10 parts.

(1) Problem Dimensions:

This is the first page of the printout. It provides the user with the current program dimensions and dimensions for his particular job, as well as the print options chosen for the job.

(2) Listing of the Input Data:

Each observation is given with its block value, treatment value, dependent variables and independent variables in that order.

(3) The MAC Model Listing:

The response variables and complete design matrix are listed for the multivariate analysis of covariance model.

(4) The GMAC and MGMAC Model Listing:

These are given for each response variate separately, along with the rank of the corresponding design matrix.

(5) Sigma and Smoothed Sigma

The sigma matrix submitted to the subroutine SMOOTH is printed along with the smoothed sigma matrix which the subroutine returns.

(6) Sigma and Sigma Inverse

Sigma and its inverse, as computed by the LPSDOR subroutine, are given.

(7) The Matrix Modified Model

This is listed, showing the extra columns added to the design matrix to account for the missing values.

(8) The Groups of Observations with Different Patterns of Missing Values

These are the "S_j" sets referred to in Section II. The design matrices associated with these sets are used in the computation of the beta estimates and the Wald Statistics.

(9) Beta Values

The beta matrix of dimension (NB + NT + NK) by NP is given.

(10) Hypothesis Test Results

The hypothesis matrix and associated Wald Statistic are given for each of the hypotheses to be tested.

The listing of the computer printout for the sample problem follows in the remaining pages of this section.

It should be pointed out that it is normal for underflow errors to occur, particularly in large scale analyses. We might also add that the error code from LPSDOR is printed each time we call that subroutine; a successful call to LPSDOR results in an error code of zero.

```
PARAMETER VALUES READ FROM FIRST DATA CARD :


THE CURRENT VALUE BEING USED FOR THE MISSING CODE IS :      50.0000

THE VALUE OF IDGT SUPPLIED FOR USE IN LPSDOR SUBROUTINE IS :   14

THE VALUE OF EPS SUPPLIED FOR USE IN THE DMFGR SUBROUTINE IS :       .100000E-06

NUMBER OF MISSING VALUES IN COVARIATES :    2

MAX DIM RESP VECTOR:  7;CURRENT DIM RESP VECTOR:  3

MAX NUMB OBS:  100;CURRENT NUMB OBS:   30

MAX NUMB BLOCKS:     2;CURRENT NUMB BLOCKS:    2

MAX NUMB TRTS:     4;CURRENT NUMB TRTS:    3

MAX NUMB COVARS:     3;CURRENT NUMB COVARS:    2

MAX NUMB COLS IN MODIFIED DESIGN MATRIX:   10

CURRENT NUMBER COLS MAY BE SEEN IN LISTING OF MODIFIED DESIGN MATRIX TO FOLLOW LATER


PRINT OPTIONS CHOSEN FOR THIS PROGRAM: 0=NOPRINT,1=PRINT

PRINT OPTION FOR MAC MODEL :      1

PRINT OPTION FOR GMAC MODEL :      1

PRINT OPTION FOR MGMAC MODEL :      1

PRINT OPTION FOR SIGMA & ITS INVERSE :      1

PRINT OPTION FOR MATRIX MODIFIED MODEL :      1

PRINT OPTION FOR DEPENDENT VARIABLES AND DESIGN MATRIX FOR VARIOUS MISSING VALUE PATTERNS :      1

PRINT OPTION FOR BETA VALUES :      1
```

LISTING OF INPUT DATA

1	1	98.00	50.00	7.30	110.00	710.00
1	1	97.50	503.20	5.20	110.00	710.00
1	1	98.20	494.50	8.30	112.00	695.00
1	1	100.00	501.10	8.20	111.00	705.00
1	1	100.10	490.90	8.10	112.00	690.00
1	2	98.40	504.60	8.30	110.00	710.00
1	2	95.50	501.20	8.80	109.00	705.00
1	2	94.60	497.00	10.50	107.00	700.00
1	2	99.30	498.80	9.50	111.00	700.00
1	2	98.90	504.30	7.50	112.00	710.00
1	3	110.70	586.40	50.00	116.00	50.00
1	3	112.40	558.90	8.50	115.00	770.00
1	3	113.30	572.60	8.90	116.00	790.00
1	3	110.60	581.10	8.70	116.00	800.00
1	3	115.30	572.90	7.40	117.00	790.00
2	1	98.30	522.80	6.60	109.00	705.00
2	1	101.00	521.30	8.30	112.00	705.00
2	1	99.10	510.00	6.30	111.00	50.00
2	1	99.80	517.20	8.30	110.00	700.00
2	1	103.10	524.30	8.40	111.00	710.00
2	2	100.90	517.60	5.80	112.00	700.00
2	2	100.50	510.50	7.20	112.00	690.00
2	2	103.10	514.60	6.20	114.00	695.00
2	2	99.50	50.00	50.00	112.00	700.00
2	2	102.00	522.90	8.80	113.00	705.00
2	3	114.20	597.10	12.30	115.00	795.00
2	3	114.80	598.60	12.50	116.00	800.00
2	3	115.90	598.00	12.70	117.00	795.00
2	3	116.00	593.00	12.30	116.00	790.00

30 OBSERVATIONS HAVE BEEN READ FOR THE CURRENT DATA SET. DOES THIS AGREE WITH THE CURRENT # OBS GIVEN EARLIER?

THE VALUES OF Y AND A FOLLOW   MAC MODEL

98.00	50.00	7.30	1.00	0.0	1.00	0.0	0.0	110.00	710.00
97.50	503.20	5.20	1.00	0.0	1.00	0.0	0.0	110.00	710.00
98.20	494.50	8.30	1.00	0.0	1.00	0.0	0.0	112.00	695.00
100.00	501.10	8.20	1.00	0.0	1.00	0.0	0.0	111.00	705.00
100.10	490.90	8.10	1.00	0.0	1.00	0.0	0.0	112.00	690.00
98.40	504.60	8.30	1.00	0.0	0.0	1.00	0.0	110.00	710.00
95.50	501.20	8.80	1.00	0.0	0.0	1.00	0.0	109.00	705.00
94.60	497.00	10.50	1.00	0.0	0.0	1.00	0.0	107.00	700.00
99.30	498.80	9.50	1.00	0.0	0.0	1.00	0.0	111.00	700.00
98.90	504.30	7.50	1.00	0.0	0.0	1.00	0.0	112.00	710.00
110.70	586.40	50.00	1.00	0.0	0.0	0.0	1.00	116.00	50.00
112.40	558.90	8.50	1.00	0.0	0.0	0.0	1.00	115.00	770.00
113.30	572.60	8.90	1.00	0.0	0.0	0.0	1.00	116.00	790.00
110.60	581.10	8.70	1.00	0.0	0.0	0.0	1.00	116.00	800.00
115.30	572.90	7.40	1.00	0.0	0.0	0.0	1.00	117.00	790.00
98.30	522.80	6.60	0.0	1.00	1.00	0.0	0.0	109.00	705.00
101.00	521.30	8.30	0.0	1.00	1.00	0.0	0.0	112.00	705.00
99.10	510.00	6.30	0.0	1.00	1.00	0.0	0.0	111.00	50.00
99.80	517.20	8.30	0.0	1.00	1.00	0.0	0.0	110.00	700.00
103.10	524.30	8.40	0.0	1.00	1.00	0.0	0.0	111.00	710.00
100.90	517.60	5.80	0.0	1.00	0.0	1.00	0.0	112.00	700.00
100.50	510.50	7.20	0.0	1.00	0.0	1.00	0.0	112.00	690.00
103.10	514.60	6.20	0.0	1.00	0.0	1.00	0.0	114.00	695.00
99.50	50.00	50.00	0.0	1.00	0.0	1.00	0.0	112.00	700.00
102.00	522.90	8.80	0.0	1.00	0.0	1.00	0.0	113.00	705.00
114.20	597.10	12.30	0.0	1.00	0.0	0.0	1.00	115.00	795.00
114.80	598.60	12.50	0.0	1.00	0.0	0.0	1.00	116.00	800.00
115.90	598.00	12.70	0.0	1.00	0.0	0.0	1.00	117.00	795.00
116.00	593.00	12.30	0.0	1.00	0.0	0.0	1.00	116.00	790.00

THE VALUES OF Y AND A FOR VARIATE 1 FOLLOW GMAC MODEL

98.00	1.00	0.0	1.00	0.0	0.0	110.00	710.00
97.50	1.00	0.0	1.00	0.0	0.0	110.00	710.00
98.20	1.00	0.0	1.00	0.0	0.0	112.00	695.00
100.00	1.00	0.0	1.00	0.0	0.0	111.00	705.00
100.10	1.00	0.0	1.00	0.0	0.0	112.00	690.00
98.40	1.00	0.0	0.0	1.00	0.0	110.00	710.00
95.50	1.00	0.0	0.0	1.00	0.0	109.00	705.00
94.60	1.00	0.0	0.0	1.00	0.0	107.00	700.00
99.30	1.00	0.0	0.0	1.00	0.0	111.00	700.00
98.90	1.00	0.0	0.0	1.00	0.0	112.00	710.00
110.70	1.00	0.0	0.0	0.0	1.00	116.00	50.00
112.40	1.00	0.0	0.0	0.0	1.00	115.00	770.00
113.30	1.00	0.0	0.0	0.0	1.00	116.00	790.00
110.60	1.00	0.0	0.0	0.0	1.00	116.00	800.00
115.30	1.00	0.0	0.0	0.0	1.00	117.00	790.00
98.30	0.0	1.00	1.00	0.0	0.0	109.00	705.00
101.00	0.0	1.00	1.00	0.0	0.0	112.00	705.00
99.10	0.0	1.00	1.00	0.0	0.0	111.00	50.00
99.80	0.0	1.00	1.00	0.0	0.0	110.00	700.00
103.10	0.0	1.00	1.00	0.0	0.0	111.00	710.00
100.90	0.0	1.00	0.0	1.00	0.0	112.00	700.00
100.50	0.0	1.00	0.0	1.00	0.0	112.00	690.00
103.10	0.0	1.00	0.0	1.00	0.0	114.00	695.00
99.50	0.0	1.00	0.0	1.00	0.0	112.00	700.00
102.00	0.0	1.00	0.0	1.00	0.0	113.00	705.00
114.20	0.0	1.00	0.0	0.0	1.00	115.00	795.00
114.80	0.0	1.00	0.0	0.0	1.00	116.00	800.00
115.90	0.0	1.00	0.0	0.0	1.00	117.00	795.00
116.00	0.0	1.00	0.0	0.0	1.00	116.00	790.00

31

THE VALUES OF Y AND A FOR VARIATE 1 FOLLOW   MGMAC MODEL

98.00	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0	0.0
97.50	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0	0.0
98.20	1.00	0.0	1.00	0.0	0.0	112.00	695.00	0.0	0.0
100.00	1.00	0.0	1.00	0.0	0.0	111.00	705.00	0.0	0.0
100.10	1.00	0.0	1.00	0.0	0.0	112.00	690.00	0.0	0.0
98.40	1.00	0.0	0.0	1.00	0.0	110.00	710.00	0.0	0.0
95.50	1.00	0.0	0.0	1.00	0.0	109.00	705.00	0.0	0.0
94.60	1.00	0.0	0.0	1.00	0.0	107.00	700.00	0.0	0.0
99.30	1.00	0.0	0.0	1.00	0.0	111.00	700.00	0.0	0.0
98.90	1.00	0.0	0.0	1.00	0.0	112.00	710.00	0.0	0.0
110.70	1.00	0.0	0.0	0.0	1.00	116.00	0.0	1.00	0.0
112.40	1.00	0.0	0.0	0.0	1.00	115.00	770.00	0.0	0.0
113.30	1.00	0.0	0.0	0.0	1.00	116.00	790.00	0.0	0.0
110.60	1.00	0.0	0.0	0.0	1.00	116.00	800.00	0.0	0.0
115.30	1.00	0.0	0.0	0.0	1.00	117.00	790.00	0.0	0.0
98.30	0.0	1.00	1.00	0.0	0.0	109.00	705.00	0.0	0.0
101.00	0.0	1.00	1.00	0.0	0.0	112.00	705.00	0.0	0.0
99.10	0.0	1.00	1.00	0.0	0.0	111.00	0.0	0.0	1.00
99.80	0.0	1.00	1.00	0.0	0.0	110.00	700.00	0.0	0.0
103.10	0.0	1.00	1.00	0.0	0.0	111.00	710.00	0.0	0.0
100.90	0.0	1.00	0.0	1.00	0.0	112.00	700.00	0.0	0.0
100.50	0.0	1.00	0.0	1.00	0.0	112.00	690.00	0.0	0.0
103.10	0.0	1.00	0.0	1.00	0.0	114.00	695.00	0.0	0.0
99.50	0.0	1.00	0.0	1.00	0.0	112.00	700.00	0.0	0.0
102.00	0.0	1.00	0.0	1.00	0.0	113.00	705.00	0.0	0.0
114.20	0.0	1.00	0.0	0.0	1.00	115.00	795.00	0.0	0.0
114.80	0.0	1.00	0.0	0.0	1.00	116.00	800.00	0.0	0.0
115.90	0.0	1.00	0.0	0.0	1.00	117.00	795.00	0.0	0.0
116.00	0.0	1.00	0.0	0.0	1.00	116.00	790.00	0.0	0.0

THE RANK OF THE DESIGN MATRIX FOR VARIATE 1 FOR THE MGMAC MODEL IS 5

ERROR CODE FROM LPSDOR = 0

ERROR CODE FROM LPSDOR = 0

ERROR CODE FROM LPSDOR = 0

THE VALUES OF Y AND A FOR VARIATE 2 FOLLOW GMAC MODEL

503.20	1.00	0.0	1.00	0.0	0.0	110.00	710.00
494.50	1.00	0.0	1.00	0.0	0.0	112.00	695.00
501.10	1.00	0.0	1.00	0.0	0.0	111.00	705.00
490.90	1.00	0.0	1.00	0.0	0.0	112.00	690.00
504.60	1.00	0.0	0.0	1.00	0.0	110.00	710.00
501.20	1.00	0.0	0.0	1.00	0.0	109.00	705.00
497.00	1.00	0.0	0.0	1.00	0.0	107.00	700.00
498.80	1.00	0.0	0.0	1.00	0.0	111.00	700.00
504.30	1.00	0.0	0.0	1.00	0.0	112.00	710.00
586.40	1.00	0.0	0.0	0.0	1.00	116.00	50.00
558.90	1.00	0.0	0.0	0.0	1.00	115.00	770.00
572.60	1.00	0.0	0.0	0.0	1.00	116.00	790.00
581.10	1.00	0.0	0.0	0.0	1.00	116.00	800.00
572.90	1.00	0.0	0.0	0.0	1.00	117.00	790.00
522.80	0.0	1.00	1.00	0.0	0.0	109.00	705.00
521.30	0.0	1.00	1.00	0.0	0.0	112.00	705.00
510.00	0.0	1.00	1.00	0.0	0.0	111.00	50.00
517.20	0.0	1.00	1.00	0.0	0.0	110.00	700.00
524.30	0.0	1.00	1.00	0.0	0.0	111.00	710.00
517.60	0.0	1.00	0.0	1.00	0.0	112.00	700.00
510.50	0.0	1.00	0.0	1.00	0.0	112.00	690.00
514.60	0.0	1.00	0.0	1.00	0.0	114.00	695.00
522.90	0.0	1.00	0.0	1.00	0.0	113.00	705.00
597.10	0.0	1.00	0.0	0.0	1.00	115.00	795.00
598.60	0.0	1.00	0.0	0.0	1.00	116.00	800.00
598.00	0.0	1.00	0.0	0.0	1.00	117.00	795.00
593.00	0.0	1.00	0.0	0.0	1.00	116.00	790.00
602.40	0.0	1.00	0.0	0.0	1.00	117.00	805.00

THE VALUES OF Y AND A FOR VARIATE 2 FOLLCW   MGMAC MODEL

503.20	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0	0.0
494.50	1.00	0.0	1.00	0.0	0.0	112.00	695.00	0.0	0.0
501.10	1.00	0.0	1.00	0.0	0.0	111.00	705.00	0.0	0.0
490.90	1.00	0.0	1.00	0.0	0.0	112.00	690.00	0.0	0.0
504.60	1.00	0.0	0.0	1.00	0.0	110.00	710.00	0.0	0.0
501.20	1.00	0.0	0.0	1.00	0.0	109.00	705.00	0.0	0.0
497.00	1.00	0.0	0.0	1.00	0.0	107.00	700.00	0.0	0.0
498.80	1.00	0.0	0.0	1.00	0.0	111.00	700.00	0.0	0.0
504.30	1.00	0.0	0.0	1.00	0.0	112.00	710.00	0.0	0.0
586.40	1.00	0.0	0.0	0.0	1.00	116.00	0.0	1.00	0.0
558.90	1.00	0.0	0.0	0.0	1.00	115.00	770.00	0.0	0.0
572.60	1.00	0.0	0.0	0.0	1.00	116.00	790.00	0.0	0.0
581.10	1.00	0.0	0.0	0.0	1.00	116.00	800.00	0.0	0.0
572.90	1.00	0.0	0.0	0.0	1.00	117.00	790.00	0.0	0.0
522.80	0.0	1.00	1.00	0.0	0.0	109.00	705.00	0.0	0.0
521.30	0.0	1.00	1.00	0.0	0.0	112.00	705.00	0.0	0.0
510.00	0.0	1.00	1.00	0.0	0.0	111.00	0.0	0.0	1.00
517.20	0.0	1.00	1.00	0.0	0.0	110.00	700.00	0.0	0.0
524.30	0.0	1.00	1.00	0.0	0.0	111.00	710.00	0.0	0.0
517.60	0.0	1.00	0.0	1.00	0.0	112.00	700.00	0.0	0.0
510.50	0.0	1.00	0.0	1.00	0.0	112.00	690.00	0.0	0.0
514.60	0.0	1.00	0.0	1.00	0.0	114.00	695.00	0.0	0.0
522.90	0.0	1.00	0.0	1.00	0.0	113.00	705.00	0.0	0.0
597.10	0.0	1.00	0.0	0.0	1.00	115.00	795.00	0.0	0.0
598.60	0.0	1.00	0.0	0.0	1.00	116.00	800.00	0.0	0.0
598.00	0.0	1.00	0.0	0.0	1.00	117.00	795.00	0.0	0.0
593.00	0.0	1.00	0.0	0.0	1.00	116.00	790.00	0.0	0.0
602.40	0.0	1.00	0.0	0.0	1.00	117.00	805.00	0.0	0.0

THE RANK OF THE DESIGN MATRIX FOR VARIATE 2 FOR THE MGMAC MODEL IS 5

ERROR CODE FROM LPSDOR = 0

ERROR CODE FROM LPSDOR = 0

THE VALUES OF Y AND A FOR VARIATE 3 FOLLOW GMAC MODEL

7.30	1.00	0.0	1.00	0.0	0.0	110.00	710.00
5.20	1.00	0.0	1.00	0.0	0.0	110.00	710.00
8.30	1.00	0.0	1.00	0.0	0.0	112.00	695.00
8.20	1.00	0.0	1.00	0.0	0.0	111.00	705.00
8.10	1.00	0.0	1.00	0.0	0.0	112.00	690.00
8.30	1.00	0.0	0.0	1.00	0.0	110.00	710.00
8.80	1.00	0.0	0.0	1.00	0.0	109.00	705.00
10.50	1.00	0.0	0.0	1.00	0.0	107.00	700.00
9.50	1.00	0.0	0.0	1.00	0.0	111.00	700.00
7.50	1.00	0.0	0.0	1.00	0.0	112.00	710.00
8.50	1.00	0.0	0.0	0.0	1.00	115.00	770.00
8.90	1.00	0.0	0.0	0.0	1.00	116.00	790.00
8.70	1.00	0.0	0.0	0.0	1.00	116.00	800.00
7.40	1.00	0.0	0.0	0.0	1.00	117.00	790.00
6.60	0.0	1.00	1.00	0.0	0.0	109.00	705.00
8.30	0.0	1.00	1.00	0.0	0.0	112.00	705.00
6.30	0.0	1.00	1.00	0.0	0.0	111.00	50.00
8.30	0.0	1.00	1.00	0.0	0.0	110.00	700.00
8.40	0.0	1.00	1.00	0.0	0.0	111.00	710.00
5.80	0.0	1.00	0.0	1.00	0.0	112.00	700.00
7.20	0.0	1.00	0.0	1.00	0.0	112.00	690.00
6.20	0.0	1.00	0.0	1.00	0.0	114.00	695.00
8.80	0.0	1.00	0.0	1.00	0.0	113.00	705.00
12.30	0.0	1.00	0.0	0.0	1.00	115.00	795.00
12.50	0.0	1.00	0.0	0.0	1.00	116.00	800.00
12.70	0.0	1.00	0.0	0.0	1.00	117.00	795.00
12.30	0.0	1.00	0.0	0.0	1.00	116.00	790.00
12.40	0.0	1.00	0.0	0.0	1.00	117.00	805.00

THE VALUES OF Y AND A FOR VARIATE 3 FOLLCW MGMAC MODEL

7.30	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0
5.20	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0
8.30	1.00	0.0	1.00	0.0	0.0	112.00	695.00	0.0
8.20	1.00	0.0	1.00	0.0	0.0	111.00	705.00	0.0
8.10	1.00	0.0	1.00	0.0	0.0	112.00	690.00	0.0
8.30	1.00	0.0	0.0	1.00	0.0	110.00	710.00	0.0
8.80	1.00	0.0	0.0	1.00	0.0	109.00	705.00	0.0
10.50	1.00	0.0	0.0	1.00	0.0	107.00	700.00	0.0
9.50	1.00	0.0	0.0	1.00	0.0	111.00	700.00	0.0
7.50	1.00	0.0	0.0	1.00	0.0	112.00	710.00	0.0
8.50	1.00	0.0	0.0	0.0	1.00	115.00	770.00	0.0
8.90	1.00	0.0	0.0	0.0	1.00	116.00	790.00	0.0
8.70	1.00	0.0	0.0	0.0	1.00	116.00	800.00	0.0
7.40	1.00	0.0	0.0	0.0	1.00	117.00	790.00	0.0
6.60	0.0	1.00	1.00	0.0	0.0	109.00	705.00	0.0
8.30	0.0	1.00	1.00	0.0	0.0	112.00	705.00	0.0
6.30	0.0	1.00	1.00	0.0	0.0	111.00	0.0	1.00
8.30	0.0	1.00	1.00	0.0	0.0	110.00	700.00	0.0
8.40	0.0	1.00	1.00	0.0	0.0	111.00	710.00	0.0
5.80	0.0	1.00	0.0	1.00	0.0	112.00	700.00	0.0
7.20	0.0	1.00	0.0	1.00	0.0	112.00	690.00	0.0
6.20	0.0	1.00	0.0	1.00	0.0	114.00	695.00	0.0
8.80	0.0	1.00	0.0	1.00	0.0	113.00	705.00	0.0
12.30	0.0	1.00	0.0	0.0	1.00	115.00	795.00	0.0
12.50	0.0	1.00	0.0	0.0	1.00	116.00	800.00	0.0
12.70	0.0	1.00	0.0	0.0	1.00	117.00	795.00	0.0
12.30	0.0	1.00	0.0	0.0	1.00	116.00	790.00	0.0
12.40	0.0	1.00	0.0	0.0	1.00	117.00	805.00	0.0

THE RANK OF THE DESIGN MATRIX FOR VARIATE 3 FOR THE MGMAC MODEL IS 5

```
ERROR CODE FROM LPSDOR =        0


INPUT MATRIX TO SMOOTH
      1.0281164          -.11701501          .19631602
     -.11701501          .69946443           .11176522
      .19631602          .11176522           2.2882109


MATRIX OUTPUT BY SMOOTH
      1.0281164          -.11701501          .19631602
     -.11701501          .69946443           .11176522
      .19631602          .11176522           2.2882109



THE VALUE OF SIGMA FOLLOWS


   1.02812      -.117015      .196316

  -.117015       .699464      .111765

   .196316       .111765      2.28821

ERROR CODE FROM LPSDOR =        0



THE VALUE OF SIGMA INVERSE FOLLOWS


   1.01196       .184607      -.958379D-01

   .184607       1.47459      -.878630D-01

  -.958379D-01  -.878630D-01   .449537
```

THE VALUES OF Y AND A FOLLOW

MATRIX MODIFIED MODEL

98.00	50.00	7.30	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0	0.0
97.50	503.20	5.20	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0	0.0
98.20	494.50	8.30	1.00	0.0	1.00	0.0	0.0	112.00	695.00	0.0	0.0
100.00	501.10	8.20	1.00	0.0	1.00	0.0	0.0	111.00	705.00	0.0	0.0
100.10	490.90	8.10	1.00	0.0	1.00	0.0	0.0	112.00	690.00	0.0	0.0
98.40	504.60	8.30	1.00	0.0	0.0	1.00	0.0	110.00	710.00	0.0	0.0
95.50	501.20	8.80	1.00	0.0	0.0	1.00	0.0	109.00	705.00	0.0	0.0
94.60	497.00	10.50	1.00	0.0	0.0	1.00	0.0	107.00	700.00	0.0	0.0
99.30	498.80	9.50	1.00	0.0	0.0	1.00	0.0	111.00	700.00	0.0	0.0
98.90	504.30	7.50	1.00	0.0	0.0	1.00	0.0	112.00	710.00	0.0	0.0
110.70	586.40	50.00	1.00	0.0	0.0	0.0	1.00	116.00	0.0	1.00	0.0
112.40	558.90	8.50	1.00	0.0	0.0	0.0	1.00	115.00	770.00	0.0	0.0
113.30	572.60	8.90	1.00	0.0	0.0	0.0	1.00	116.00	790.00	0.0	0.0
110.60	581.10	8.70	1.00	0.0	0.0	0.0	1.00	116.00	800.00	0.0	0.0
115.30	572.90	7.40	1.00	0.0	0.0	0.0	1.00	117.00	790.00	0.0	0.0
98.30	522.80	6.60	0.0	1.00	1.00	0.0	0.0	109.00	705.00	0.0	0.0
101.00	521.30	8.30	0.0	1.00	1.00	0.0	0.0	112.00	705.00	0.0	0.0
99.10	510.00	6.30	0.0	1.00	1.00	0.0	0.0	111.00	0.0	0.0	1.00
99.80	517.20	8.30	0.0	1.00	1.00	0.0	0.0	110.00	700.00	0.0	0.0
103.10	524.30	8.40	0.0	1.00	1.00	0.0	0.0	111.00	710.00	0.0	0.0

100.90	517.60	5.80	0.0	1.00	0.0	1.00	0.0	112.00	700.00	0.0	0.0
100.50	510.50	7.20	0.0	1.00	0.0	1.00	0.0	112.00	690.00	0.0	0.0
103.10	514.60	6.20	0.0	1.00	0.0	1.00	0.0	114.00	695.00	0.0	0.0
99.50	50.00	50.00	0.0	1.00	0.0	1.00	0.0	112.00	700.00	0.0	0.0
102.00	522.90	8.80	0.0	1.00	0.0	1.00	0.0	113.00	705.00	0.0	0.0
114.20	597.10	12.30	0.0	1.00	0.0	0.0	1.00	115.00	795.00	0.0	0.0
114.80	598.60	12.50	0.0	1.00	0.0	0.0	1.00	116.00	800.00	0.0	0.0
115.90	598.00	12.70	0.0	1.00	0.0	0.0	1.00	117.00	795.00	0.0	0.0
116.00	593.00	12.30	0.0	1.00	0.0	0.0	1.00	116.00	790.00	0.0	0.0

41

```
****** DEPENDENT VARIABLES AND DESIGN MATRIX FOR THE VARIOUS GROUPS CORRESPONDING TO DIFFERENT PATTERNS OF MISSING VALUES

**** THERE ARE     7 DIFFERENT POSSIBLE GROUPS NUMBERED FROM 1 TO    7 THOUGH IN GENERAL NOT ALL GROUPS WILL APPEAR

*** WHICH ONES OCCUR DEPENDS ON THE PATTERN OF MISSING VALUES.HOWEVER THE TOTAL # OBSERVATIONS IN ALL GROUPS MUST EQUAL NN
THE DEPENDENT VARIABLES AND CORRESPONDING DESIGN MATRIX FOLLOW FOR GROUP     4 WHICH HAS    1 OBSERVATIONS ON    1 VARIATES


   99.50    50.00    50.00    0.0    1.00    0.0    1.00    0.0   112.00   700.00    0.0    0.0
THE DEPENDENT VARIABLES AND CORRESPONDING DESIGN MATRIX FOLLOW FOR GROUP     5 WHICH HAS    1 OBSERVATIONS ON    2 VARIATES


   98.00    50.00     7.30    1.00    0.0    1.00    0.0    0.0   110.00   710.00    0.0    0.0

ERROR CODE FROM LPSDOR =      0

THE DEPENDENT VARIABLES AND CORRESPONDING DESIGN MATRIX FOLLOW FOR GROUP     6 WHICH HAS    1 OBSERVATIONS ON    2 VARIATES


  110.70   586.40    50.00    1.00    0.0    0.0    0.0    1.00   116.00    0.0    1.00    0.0

ERROR CODE FROM LPSDOR =      0

THE DEPENDENT VARIABLES AND CORRESPONDING DESIGN MATRIX FOLLOW FOR GROUP     7 WHICH HAS   27 OBSERVATIONS ON    3 VARIATES
```

97.50	503.20	5.20	1.00	0.0	1.00	0.0	0.0	110.00	710.00	0.0	0.0
98.20	494.50	8.30	1.00	0.0	1.00	0.0	0.0	112.00	695.00	0.0	0.0
100.00	501.10	8.20	1.00	0.0	1.00	0.0	0.0	111.00	705.00	0.0	0.0
100.10	490.90	8.10	1.00	0.0	1.00	0.0	0.0	112.00	690.00	0.0	0.0
98.40	504.60	8.30	1.00	0.0	0.0	1.00	0.0	110.00	710.00	0.0	0.0
95.50	501.20	8.80	1.00	0.0	0.0	1.00	0.0	109.00	705.00	0.0	0.0
94.60	497.00	10.50	1.00	0.0	0.0	1.00	0.0	107.00	700.00	0.0	0.0
99.30	498.80	9.50	1.00	0.0	0.0	1.00	0.0	111.00	700.00	0.0	0.0
98.90	504.30	7.50	1.00	0.0	0.0	1.00	0.0	112.00	710.00	0.0	0.0
112.40	558.90	8.50	1.00	0.0	0.0	0.0	1.00	115.00	770.00	0.0	0.0
113.30	572.60	8.90	1.00	0.0	0.0	0.0	1.00	116.00	790.00	0.0	0.0

115.30	572.90	7.40	1.00	0.0	0.0	0.0	1.00	117.00	790.00	0.0	0.0
98.30	522.80	6.60	0.0	1.00	1.00	0.0	0.0	109.00	705.00	0.0	0.0
101.00	521.30	8.30	0.0	1.00	1.00	0.0	0.0	112.00	705.00	0.0	0.0
99.10	510.00	6.30	0.0	1.00	1.00	0.0	0.0	111.00	0.0	0.0	1.00
99.80	517.20	8.30	0.0	1.00	1.00	0.0	0.0	110.00	700.00	0.0	0.0
103.10	524.30	8.40	0.0	1.00	1.00	0.0	0.0	111.00	710.00	0.0	0.0
100.90	517.60	5.80	0.0	1.00	0.0	1.00	0.0	112.00	700.00	0.0	0.0
100.50	510.50	7.20	0.0	1.00	0.0	1.00	0.0	112.00	690.00	0.0	0.0
103.10	514.60	6.20	0.0	1.00	0.0	1.00	0.0	114.00	695.00	0.0	0.0
102.00	522.90	8.80	0.0	1.00	0.0	1.00	0.0	113.00	705.00	0.0	0.0
114.20	597.10	12.30	0.0	1.00	0.0	0.0	1.00	115.00	795.00	0.0	0.0
114.80	598.60	12.50	0.0	1.00	0.0	0.0	1.00	116.00	800.00	0.0	0.0
115.90	598.00	12.70	0.0	1.00	0.0	0.0	1.00	117.00	795.00	0.0	0.0
116.00	593.00	12.30	0.0	1.00	0.0	0.0	1.00	116.00	790.00	0.0	0.0
115.20	602.40	12.40	0.0	1.00	0.0	0.0	1.00	117.00	805.00	0.0	0.0

```
ERROR CODE FROM LPSDOR =      0

IHO208I IBCOM - PROGRAM INTERRUPT (P) -  UNDERFLOW   OLD PSW IS  071D000D625F7642 . REGISTER CONTAINED   7A10000000000000

TRACEBACK  ROUTINE  CALLED FROM ISN   REG. 14   REG. 15   REG.  0   REG.  1

           LSVALR            0018     625F1F24  005F2328  00000000  005F1B58

           LPSDOR            0554     625EAF56  005F1A20  00000008  005912C4

           MAIN                       00C08AA2  01590A78  00D5F378  0060EFF8

ENTRY POINT=  01590A78

STANDARD FIXUP TAKEN , EXECUTION CONTINUING

IHO208I IBCOM - PROGRAM INTERRUPT (P) -  UNDERFLOW   OLD PSW IS  071D000D625F759E . REGISTER CONTAINED   7A10000000000000

TRACEBACK  ROUTINE  CALLED FROM ISN   REG. 14   REG. 15   REG.  0   REG.  1

           LSVALR            0018     625F1F24  005F2328  00000000  005F1B58

           LPSDOR            0554     625EAF56  005F1A20  00000008  005912C4

           MAIN                       00C08AA2  01590A78  00D5F378  0060EFF8

ENTRY POINT=  01590A78

STANDARD FIXUP TAKEN , EXECUTION CONTINUING

IHO208I IBCOM - PROGRAM INTERRUPT (P) -  UNDERFLOW   OLD PSW IS  071D000D625F7642 . REGISTER CONTAINED   7FFFFFFE00000010
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        LSVALR            0018    625F1F24  005F2328  00000000  005F1858
        LPSDOR            0554    625EAF56  005F1A20  00000008  005912C4
        MAIN                      00C08AA2  01590A78  00D5F378  0060EFF8
ENTRY POINT=  01590A78
STANDARD FIXUP TAKEN . EXECUTION CONTINUING
IHO208I IBCOM - PROGRAM INTERRUPT (P) -  UNDERFLOW   OLD PSW IS  071D000D925F7430 . REGISTER CONTAINED   F9FFFFFE0000000
TRACEBACK  ROUTINE  CALLED FROM ISN    REG. 14   REG. 15   REG.  0   REG.  1
        LSVALR            0018    625F1F24  005F2328  00000000  005F1858
        LPSDOR            0554    625EAF56  005F1A20  00000008  005912C4
        MAIN                      00008AA2  01590A78  00D5F378  0060EFF8
ENTRY POINT=  01590A78
STANDARD FIXUP TAKEN . EXECUTION CONTINUING
IHO208I IBCOM - PROGRAM INTERRUPT (P) -  UNDERFLOW   OLD PSW IS  071D000D925F7420 . REGISTER CONTAINED   72FFFFFF40000024
TRACEBACK  ROUTINE  CALLED FROM ISN    REG. 14   REG. 15   REG.  0   REG.  1
        LSVALR            0018    625F1F24  005F2328  00000000  005F1858
        LPSDOR            0554    625EAF56  005F1A20  00000008  005912C4
        MAIN                      00008AA2  01590A78  00D5F378  0060EFF8
ENTRY POINT=  01590A78
STANDARD FIXUP TAKEN . EXECUTION CONTINUING

ERROR CODE FROM LPSDOR =      0
```

****** LISTING OF PARAMETER ESTIMATES IN THE ORDER : BLOCKS, TRTS, REGRESSION COEFFICIENTS DOWN THE PAGE ******

VAR#1	VAR#2	VAR#3	VAR#4	VAR#5	VAR#6	VAR#7
3.43125	3.49547	11.0229				
5.32569	23.7083	12.1166				
-.200726	4.59276	7.10731				
-.980883	4.81954	7.69098				
9.93823	17.7915	8.34121				
.897697	.876527D-01	-.347398				
-.563294D-02	.685404	.391009D-01				

```
****** HYPOTHESIS TESTING SECTION ******

4 HYPOTHESIS MATRICES SHALL BE USED, IN TURN,FOR COMPUTING CHI SQUARE STATISTICS

EACH MATRIX SHOULD HAVE      7 COLUMNS AS FCLLOWS :

 THE FIRST      2 COLUMNS CORRESPOND TO BLOCK PARAMETERS
 THE NEXT       3 COLUMNS CORRESPOND TO TREATMENT PARAMETERS
 THE LAST       2 COLUMNS CORRESPOND TO CCVARIATE COEFFICIENTS
```

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**** LISTING OF HYPOTHESIS MATRIX     1 FCLLOWED BY ITS EXTENSION FOR MODIFIED MODEL.HYPOTH ID IS: NO BLK DIFF


  1.00 -1.00  0.0   0.0   0.0   0.0   0.C

ROW( 1):   1.00 -1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 2):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.00 -1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 3):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.00 -1.00
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ERROR CODE FRCM LPSDOR =       0

THE WALD STATISTIC FCR HYPOTHESIS    1 FOR ALL     3 RESPONSE VARIABLES SIMULTANEOUSLY IS :        3489.4482

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH     3 DEGREES OF FREEDOM
```

```
****** RESULTS OF HYPOTHESIS TESTS ON INDIVIDUAL VARIATES FOR HYPOTH MATRIX  1 WITH ID: NO BLK DIFF            ******

   *** THE OPTIONS FOR THE   3 INDIVIDUAL VARIATES ARE:   0  1  1

  ERROR CODE FROM LPSDOR =       0

  THE WALD STATISTIC FOR HYPOTHESIS     1 RESTRICTED TO RESPONSE VARIATE     2 ONLY IS :        3310.2092

  ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    1 DEGREES OF FREEDOM


  ERROR CODE FROM LPSDOR =       0

  THE WALD STATISTIC FOR HYPOTHESIS     1 RESTRICTED TO RESPONSE VARIATE     3 ONLY IS :           3.0643

  ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    1 DEGREES OF FREEDOM
```

```
**** LISTING OF HYPOTHESIS MATRIX    2 FCLLCWED BY ITS EXTENSION FOR MODIFIED MODEL.HYPOTH ID IS: NO TRT DIFF

  0.0   0.0   1.00 -1.00  0.0   0.0   0.0

  0.0   0.0   1.00  1.00 -2.00  0.0   0.C

ROW( 1):  0.0   0.0   1.00 -1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 2):  0.0   0.0   1.00  1.00 -2.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 3):  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.00 -1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 4):  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.00  1.00 -2.00  0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 5):  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1.00 -1.00  0.0   0.0   0.0   0.0   0.0

ROW( 6):  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1.00  1.00 -2.00  0.0   0.0   0.0   0.0

ERROR CODE FROM LPSDOR =      0

THE WALD STATISTIC FOR HYPOTHESIS   2 FOR ALL    3 RESPONSE VARIABLES SIMULTANEOUSLY IS :        63.8415

ITS ASYMPTOTIC DISTRILUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    6 DEGREES OF FREEDOM
```

```
****** RESULTS OF HYPOTHESIS TESTS ON INDIVIDUAL VARIATES FOR HYPOTH MATRIX  2 WITH ID: NO TRT DIFF            ******


 *** THE OPTIONS FOR THE   3 INDIVIDUAL VARIATES ARE:   1  1  0

ERROR CODE FRCM LPSDOR =      0

THE WALD STATISTIC FOR HYPOTHESIS    2 RESTRICTED TO RESPONSE VARIATE    1 ONLY IS :          18.4689

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPCTHESIS  IS CHI-SQUARE WITH    2 DEGREES OF FREEDOM


ERROR CODE FROM LPSDOR =      0

THE WALD STATISTIC FOR HYPOTHESIS    2 RESTRICTED TO RESPONSE VARIATE    2 ONLY IS :          35.9924

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    2 DEGREES OF FREEDOM
```

```
**** LISTING OF HYPOTHESIS MATRIX    3 FOLLOWED BY ITS EXTENSION FOR MODIFIED MODEL.HYPOTH ID IS: NO DIFF BETW TR 1&2

  0.0   0.0   1.00 -1.00  0.0   0.0   0.0

ROW( 1):   0.0   0.0   1.00 -1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 2):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.00 -1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 3):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1.00 -1.00  0.0   0.0   0.0   0.0   0.0

ERROR CODE FRCM LPSDOR =      0
```



```
THE WALD STATISTIC FOR HYPOTHESIS    3 FOR ALL    3 RESPONSE VARIABLES SIMULTANEOUSLY IS :          3.8482

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    3 DEGREES OF FREEDOM
```

```
****** RESULTS OF HYPOTHESIS TESTS ON INDIVIDUAL VARIATES FOR HYPOTH MATRIX  3 WITH ID: NO DIFF BETW TR 1&2  ******


 *** THE OPTIONS FOR THE   3 INDIVIDUAL VARIATES ARE:   1  1  1

ERROR CODE FROM LPSDOR =      0

THE WALD STATISTIC FOR HYPOTHESIS    3 RESTRICTED TO RESPONSE VARIATE    1 ONLY IS :          2.7376

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPCTHESIS  IS CHI-SQUARE WITH    1 DEGREES OF FREEDOM


ERROR CODE FROM LPSDOR =      0

THE WALD STATISTIC FOR HYPOTHESIS    3 RESTRICTED TO RESPONSE VARIATE    2 ONLY IS :          0.3090

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    1 DEGREES OF FREEDOM


ERROR CODE FROM LPSDOR =      0

THE WALD STATISTIC FOR HYPOTHESIS    3 RESTRICTED TO RESPONSE VARIATE    3 ONLY IS :          0.6594

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    1 DEGREES OF FREEDOM
```

```
**** LISTING OF HYPOTHESIS MATRIX    4 FCLLOWED BY ITS EXTENSION FOR MODIFIED MODEL.HYPOTH ID IS: NO EFFECT COVARS


  0.0   0.0   0.0   0.0   0.0   1.00  0.C

  0.0   0.0   0.0   0.0   0.0   0.0   1.00


ROW( 1):   0.0   0.0   0.0   0.0   0.0   1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 2):   0.0   0.0   0.0   0.0   0.0   0.0   1.00  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 3):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.00  0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 4):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   1.00  0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   0.0   0.0   0.0

ROW( 5):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   1.00  0.0   0.0   0.0

ROW( 6):   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 0.0   0.0   0.0   0.0   1.00  0.0   0.0

ERROR CODE FROM LPSDOR =       0


THE WALD STATISTIC FOR HYPOTHESIS   4 FOR ALL    3 RESPONSE VARIABLES SIMULTANEOUSLY IS :       1043.5830


ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    6 DEGREES OF FREEDOM
```

```
****** RESULTS OF HYPOTHESIS TESTS ON INDIVIDUAL VARIATES FOR HYPOTH MATRIX  4 WITH ID: NO EFFECT COVARS      ******

 *** THE OPTIONS FOR THE    3 INDIVIDUAL VARIATES ARE:   1  1  1

ERROR CODE FROM LPSDOR =       0

THE WALD STATISTIC FOR HYPOTHESIS     4 RESTRICTED TO RESPONSE VARIATE     1 ONLY IS :          36.6924

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    2 DEGREES OF FREEDOM


ERROR CODE FROM LPSDOR =       0

THE WALD STATISTIC FOR HYPOTHESIS     4 RESTRICTED TO RESPONSE VARIATE     2 ONLY IS :         985.3437

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    2 DEGREES OF FREEDOM


ERROR CODE FROM LPSDOR =       0

THE WALD STATISTIC FOR HYPOTHESIS     4 RESTRICTED TO RESPONSE VARIATE     3 ONLY IS :           3.9067

ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS  IS CHI-SQUARE WITH    2 DEGREES OF FREEDOM
```

SUMMARY OF ERRORS FOR THIS JOB	ERROR NUMBER	NUMBER OF ERRORS
	208	8

REFERENCES

1. Natrella, M.G. (1963). Experimental Statistics. NBS Handbook 91, U.S. Department of Commerce.

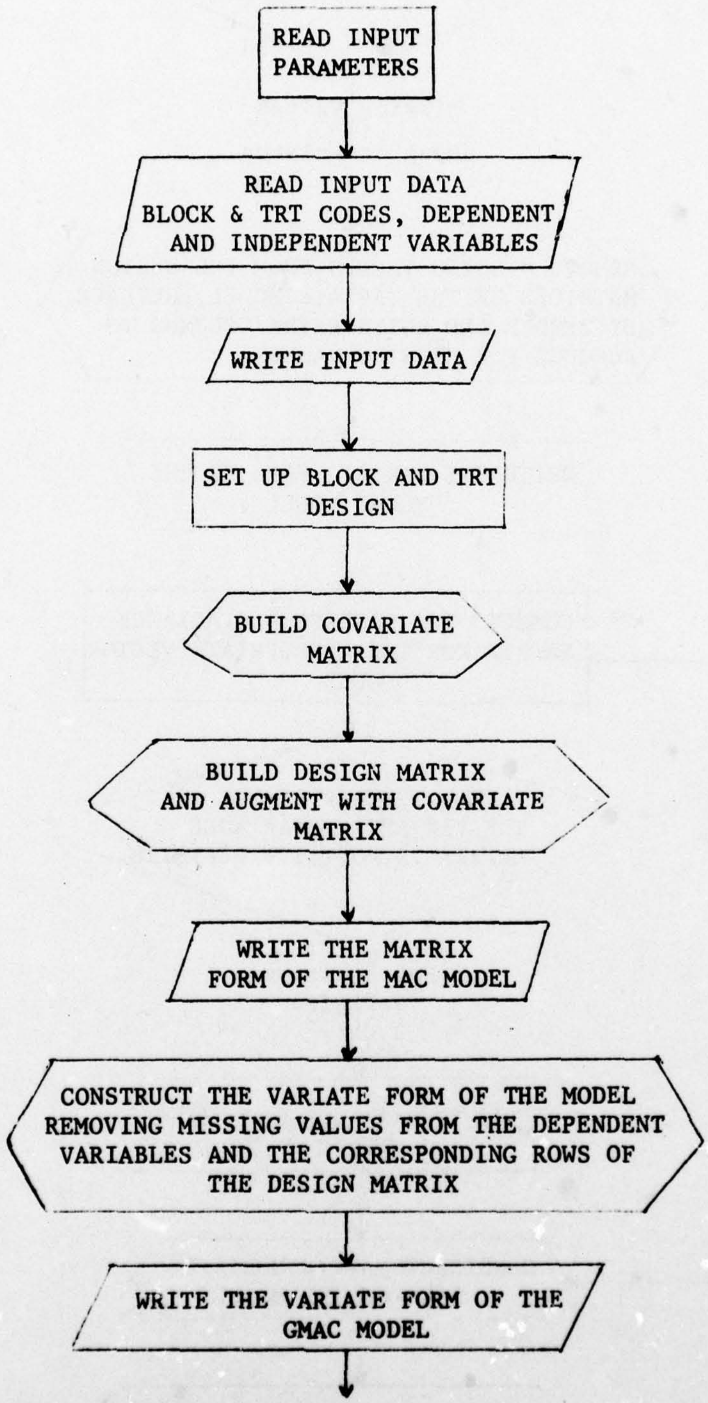
2. Srivastava, J.N. (1968). On a General Class of Designs for Multi-response Experiments, Ann. Math. Stat., 39: 1825-1843.

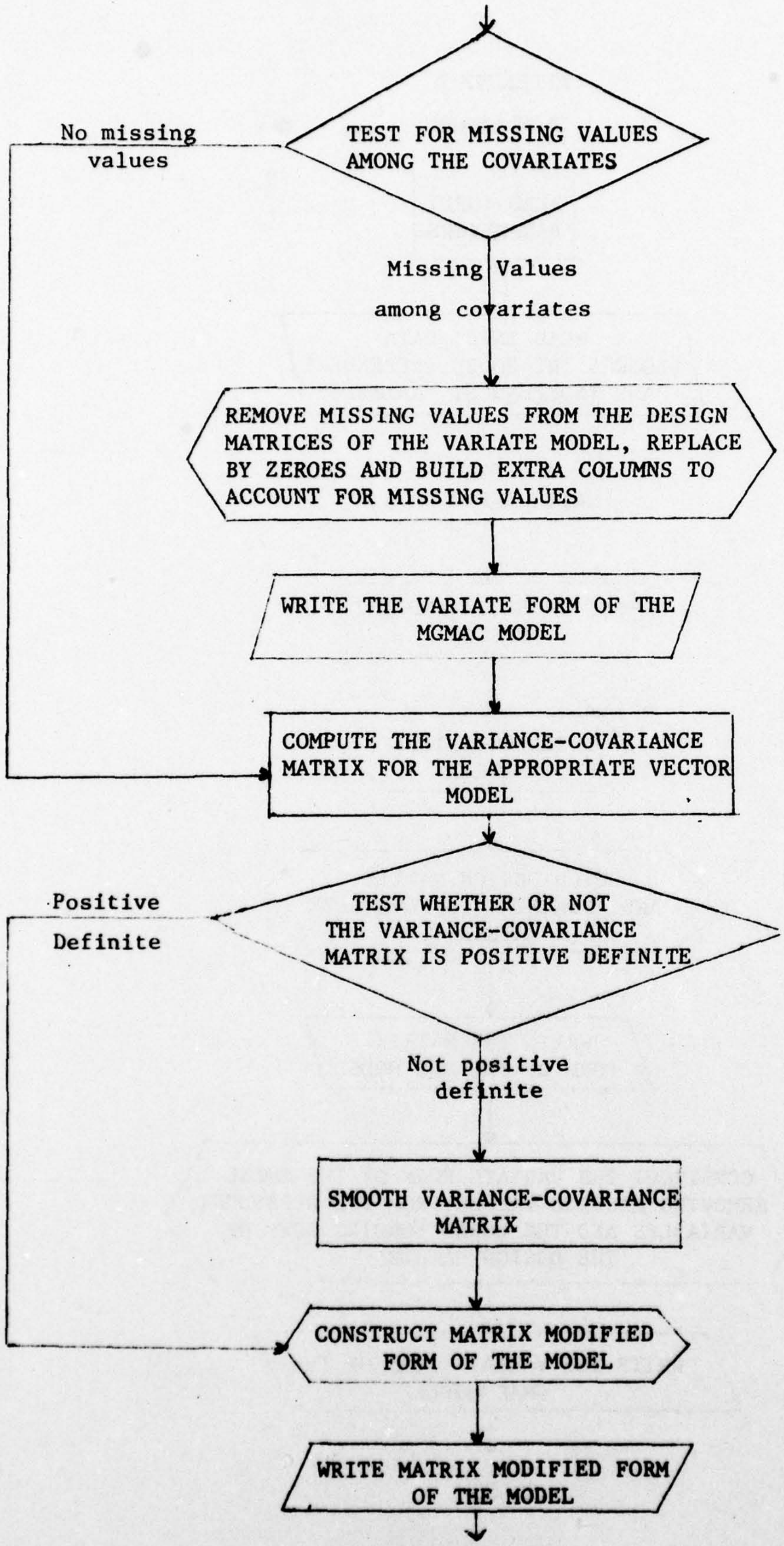
3. Haitovsky, Y. (1968). Missing Data in Regression Analysis, J. Roy. Stat Society, Series B., 30: 67-82.

4. Kleinbaum, D.G. (1973). Testing Linear Hypotheses in Generalized Multivariate Linear Models, Comm. in Stat., 1(5), 433-457.

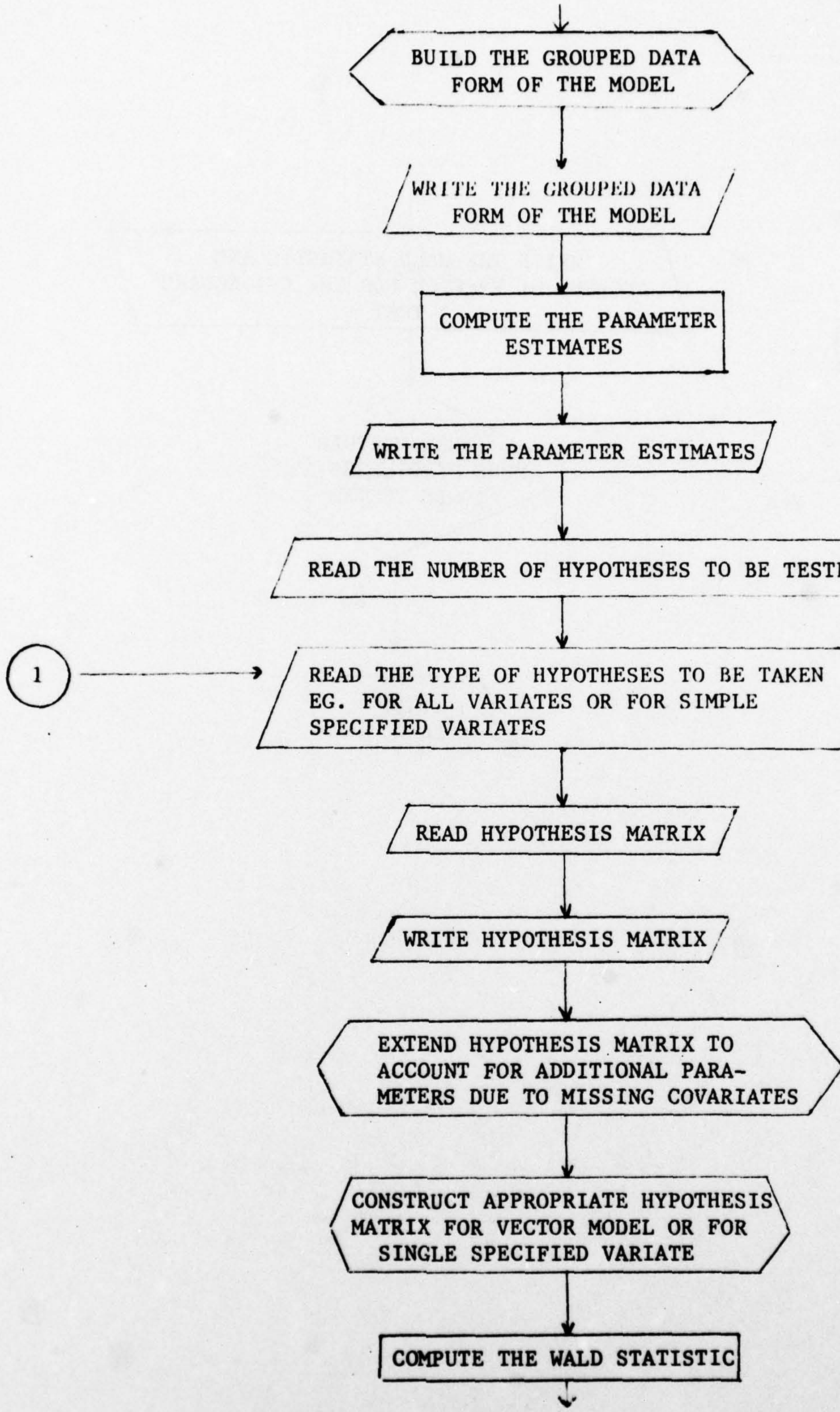
APPENDIX A

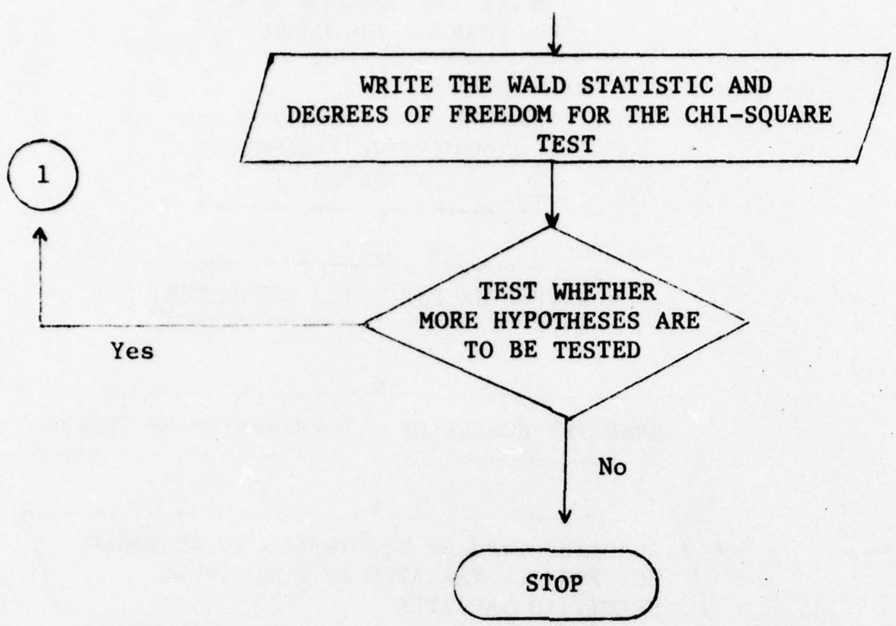
FLOW CHART





TEST FOR MISSING VALUES AMONG THE COVARIATES
No missing values
Missing Values among covariates
REMOVE MISSING VALUES FROM THE DESIGN MATRICES OF THE VARIATE MODEL, REPLACE BY ZEROES AND BUILD EXTRA COLUMNS TO ACCOUNT FOR MISSING VALUES
WRITE THE VARIATE FORM OF THE MGMAC MODEL
COMPUTE THE VARIANCE-COVARIANCE MATRIX FOR THE APPROPRIATE VECTOR MODEL
TEST WHETHER OR NOT THE VARIANCE-COVARIANCE MATRIX IS POSITIVE DEFINITE
Positive Definite
Not positive definite
SMOOTH VARIANCE-COVARIANCE MATRIX
CONSTRUCT MATRIX MODIFIED FORM OF THE MODEL
WRITE MATRIX MODIFIED FORM OF THE MODEL


BUILD THE GROUPED DATA FORM OF THE MODEL
WRITE THE GROUPED DATA FORM OF THE MODEL
COMPUTE THE PARAMETER ESTIMATES
WRITE THE PARAMETER ESTIMATES
READ THE NUMBER OF HYPOTHESES TO BE TESTED
1
READ THE TYPE OF HYPOTHESES TO BE TAKEN EG. FOR ALL VARIATES OR FOR SIMPLE SPECIFIED VARIATES
READ HYPOTHESIS MATRIX
WRITE HYPOTHESIS MATRIX
EXTEND HYPOTHESIS MATRIX TO ACCOUNT FOR ADDITIONAL PARA-METERS DUE TO MISSING COVARIATES
CONSTRUCT APPROPRIATE HYPOTHESIS MATRIX FOR VECTOR MODEL OR FOR SINGLE SPECIFIED VARIATE
COMPUTE THE WALD STATISTIC


WRITE THE WALD STATISTIC AND DEGREES OF FREEDOM FOR THE CHI-SQUARE TEST
1
TEST WHETHER MORE HYPOTHESES ARE TO BE TESTED
Yes
No
STOP

APPENDIX B

PROGRAM LISTING

In the subsequent pages, a listing of the FORTRAN source program is given. This is the program which was used to provide the printout for the sample problem in Section IV, Volume II.

We do not list the subroutines used from the Scientific Subroutine Package nor the International Mathematical and Statistical Library. These are available in the appropriate manuals.

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```
                C
0001                  REAL*8 A(100,10),AJA(10,10),AS(100,10),B(7,7),BB(100, 7),BETA( 70)
                     *,BLK(100,2),BS(7,7),BT(100,6),BSIG(7,7),BSIGB(7,7),BSIGIB(7,7),
                     #BBSIGI(7,7),BETAMX(26,7)
                C
0002                  INTEGER*4 IBLK(100),ITRT(100),IR(7),IRR(7,7),IN(100,7),IND(100),
                     %NCJ(127),NCL(127),NCMK(9),NCM(7,9),NCMC(7,7,9),NCTC(7,7),NCT(7),
                     @NMA(7),NMAC(7,7),NUMRCW(9)
0003                  INTEGER*4 IROW(26),ICOL(26),IPRKOD(7),KDRESP(7)
                C
0004                  REAL*4 FMT(20),EPS,HYPID(5)
                C
0005                  REAL*8 F(100,10),W,D,SIGI,H(56, 70),HPRNV(56, 70),HPRH(56,56),
                     %HBETA(56),HBETAP(56),HP(8, 70),PROD2(70,70)
                C
0006                  REAL*8 RV( 70),RSS(10,10),RSSS(100),S(100,10),T( 5180),SIG(7,7),
                     #SIGINV(7,7),TRT(100,4),U(100,100),V(100)
                C
                C
0007                  REAL*8 X(100,3),Y(100,7),YYS(100,7),YS(100,7),Z(100),ZT(100),
                     <ZY(100),ZZ(7)
                C
                C *** ARRAYS WHICH MAY HAVE TO BE REDIMENSIONED TO HANDLE A LARGER #
                C *** OF MISSING VALUES ARE : A,AJA,AS,BETA,BETAMX,F,H,HPRNV,PROD2,RV,
                C *** RSS,RSSS,S,T,NCMK,NCM,NCMC,IROW,ICOL
                C
                C ***   CURRENT DIMENSIONS OF ARRAYS; INCREASE THESE AND THE CORRESPONDING
                C ***   DIMENSIONS TO INCREASE THE CAPACITY OF THE PROGRAM
                C
0008                  NPDIM = 7
0009                  NNDIM = 100
0010                  NBDIM = 2
0011                  NTDIM = 4
0012                  NKDIM=3
0013                  NADIM = 10
0014                  NFDIM = 10
0015                  NPROD=70
0016                  NHPRHD=56
                C
                C
                C     EQUIVALENCE (T(1),AS(1)),(X(1),S(1)),(H(1),U(1))
                C
0017                  DATA B/49*0.0D0/,BLK/200*0.0D0/,H/3920*0.0D0/,IN/700*1/,
                     @PROD2/4900*0.0D0/,RV/70*0.0D0/,TRT/400*0.0D0/
0018                  DATA RSS/100*0.0D0/
                C
                C   NP EQUALS THE NUMBER OF DEPENDENT VARIABLES
                C   NT EQUALS THE NUMBER OF TREATMENTS
                C   NB EQUALS THE NUMBER OF BLOCKS
                C   NK EQUALS THE NUMBER INDEPENDENT VARIABLES
                C
                C READ INPUT DATA
                C
0019                  READ(5,1) NP,NT,NB,NK,NN,IDGT,NMISS,EPS,D,IPRKOD
0020                1 FORMAT(7I3,T30,E10.0,D10.0,7I2)
0021                  WRITE(6,9901)
0022             9901 FORMAT('1','PARAMETER VALUES READ FROM FIRST DATA CARD : ',////)
0023                  WRITE(6,9909) D
```

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```
      9909 FORMAT('0','THE CURRENT VALUE BEING USED FOR THE MISSING CODE IS :
          <',G16.6)
           WRITE(6,9910) ICGT
      9910 FORMAT('0','THE VALUE OF IDGT SUPPLIED FOR USE IN LPSDOR SUBROUTIN
          *E IS :',I5)
           WRITE(6,9911) EFS
      9911 FORMAT('0','THE VALUE OF EPS SUPPLIED FOR USE IN THE DMFGR SUBROUT
          *INE IS : ',G16.6)
           WRITE(6,9902) NMISS
      9902 FORMAT('0','NUMEER OF MISSING VALUES IN COVARIATES :',I5)
           WRITE(6,9903) NFDIM,NP
      9903 FORMAT('0','MAX CIM RESP VECTOR:',I3,';CURRENT DIM RESP VECTOR:',
          #I3)
           WRITE(6,9904) NNDIM,NN
      9904 FORMAT('0','MAX NUMB OBS:',I5,';CURRENT NUMB OBS:',I5)
           WRITE(6,9905) NBDIM,NB
      9905 FORMAT('0','MAX NUMB BLOCKS:',I5,';CURRENT NUMB BLOCKS:',I5)
           WRITE(6,9906) NTDIM,NT
      9906 FORMAT('0','MAX NUMB TRTS:',I5,';CURRENT NUMB TRTS:',I5)
           WRITE(6,9907) NKDIM,NK
      9907 FORMAT('0','MAX NUMB COVARS:',I5,';CURRENT NUMB COVARS:',I5)
           WRITE(6,9908) NADIM
      9908 FORMAT('0','MAX NUMB COLS IN MODIFIED DESIGN MATRIX:',I5,/,/,1X,
          #'CURRENT NUMBER CCLS MAY BE SEEN IN LISTING OF MODIFIED DESIGN MAT
          URIX TO FOLLOW LATER',//)
           WRITE(6,9770)
      9770 FORMAT('0','PRINT OPTICNS CHOSEN FOR THIS PROGRAM: 0=NOPRINT,1=PRI
          #NT')
      9769 FORMAT('0','PRINT CPTICN FOR MAC MODEL : ',I5)
      9768 FORMAT('0','PRINT OPTION FOR GMAC MODEL : ',I5)
      9767 FORMAT('0','PRINT OPTION FOR MGMAC MODEL : ',I5)
      9766 FORMAT('0','PRINT CPTICN FOR SIGMA & ITS INVERSE : ',I5)
      9765 FORMAT('0','PRINT OPTION FOR MATRIX MODIFIED MODEL : ',I5)
      9764 FORMAT('0','PRINT CPTICN FOR DEPENDENT VARIABLES AND DESIGN MATRIX
          * FOR VARIOUS MISSING VALUE PATTERNS : ',I5)
      9763 FORMAT('0','PRINT OPTION FOR BETA VALUES : ',I5)
           WRITE(6,9769) IFRKOD(1)
           WRITE(6,9768) IFRKOD(2)
           WRITE(6,9767) IFRKOD(3)
           WRITE(6,9766) IFRKCD(4)
           WRITE(6,9765) IFRKOD(5)
           WRITE(6,9764) IFRKOD(6)
           WRITE(6,9763) IFRKOD(7)
           READ(5,2) FMT
         2 FORMAT(20A4)
C
C    WRITE INPUT DATA
C
           WRITE(6,3)
         3 FORMAT(1H1,'LISTING OF INPUT DATA',///)
           IF(NB.LE.1.AND.NT.LE.1) GO TO 11
           IF(NB.LE.1) GO TC 29
           IF(NT.LE.1) GO TC 28
           IKKK=0
           DO 4 I=1,NN
           READ(5,FMT) IBLK(I),ITRT(I),(Y(I,J),J=1,NP),(X(I,J),J=1,NK)
           IKKK=IKKK+1
           WRITE(6,5) IBLK(I),ITRT(I),(Y(I,J),J=1,NP),(X(I,J),J=1,NK)
```

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```
      5 FORMAT(1H0,2I4,15F8.2)
C
C     SET UP BLOCK DESIGN
C
        DO 7 II=1,NB
        IF(IBLK(I).EQ.II) BLK(I,II)=1.0D0
      7 CONTINUE
C
C     SET UP TREATMENT DESIGN
C
        DO 6 II=1,NT
        IF(ITRT(I).EQ.II) TRT(I,II)=1.0D0
      6 CONTINUE
      4 CONTINUE
        WRITE(6,9798) IKKK
   9798 FORMAT('0',//,'C',I5,' OBSERVATIONS HAVE BEEN READ FOR THE CURRENT
       # DATA SET. DOES THIS AGREE WITH THE CURRENT # OBS GIVEN EARLIER?')
C
C     BUILD DESIGN MATRIX BY AUGMENTING BLOCKS, TREATMENTS AND COVARIATES
C
        CALL ARRAY(2,NN,NB,NNDIM,NBDIM,BLK,BLK)
        CALL ARRAY(2,NN,NT,NNDIM,NTDIM,TRT,TRT)
        CALL CTIE(BLK,TRT,BT,NN,NB,0,0,NT)
        NBT=NB+NT
        GO TO 25
     11 IKKK=0
        DO 41 I=1,NN
        READ(5,FMT) (Y(I,J),J=1,NP),(X(I,J),J=1,NK)
        IKKK=IKKK+1
        WRITE(6,95) (Y(I,J),J=1,NP),(X(I,J),J=1,NK)
     95 FORMAT(1H0,15F8.2)
     41 CONTINUE
        WRITE(6,9798) IKKK
        DO 22 I=1,NN
        DO 22 K=1,NK
        A(I,K)=X(I,K)
     22 CONTINUE
        NM = NK
        GO TO 26
     29 IKKK=0
        DO 40 I=1,NN
        READ(5,FMT) ITRT(I),(Y(I,J),J=1,NP),(X(I,J),J=1,NK)
        IKKK=IKKK+1
        WRITE(6,45) ITRT(I),(Y(I,J),J=1,NP),(X(I,J),J=1,NK)
     45 FORMAT(1H0,I4,15F8.2)
        DO 60 II=1,NT
        IF(ITRT(I).EQ.II) TRT(I,II)=1.0D0
     60 CONTINUE
     40 CONTINUE
        WRITE(6,9798) IKKK
        DO 24 II=1,NN
        DO 24 K=1,NT
        BT(II,K) = TRT(II,K)
     24 CONTINUE
        CALL ARRAY(2,NN,NT,NNDIM,NTDIM,BT,BT)
        NBT = NT
        GO TO 25
     28 IKKK=0
```

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```
            DO 42 I=1,NN
            READ(5,FMT) IBLK(I),(Y(I,J),J=1,NP),(X(I,J),J=1,NK)
            IKKK=IKKK+1
            WRITE(6,46) IBLK(I),(Y(I,J),J=1,NP),(X(I,J),J=1,NK)
         46 FORMAT(1H0,I4,15F8.2)
            DO 61 II=1,NB
            IF(IBLK(I).EQ.II) BLK(I,II) = 1.0D0
         61 CONTINUE
         42 CONTINUE
            WRITE(6,9798) IKKK
            DO 27 I=1,NN
            DO 27 K=1,NB
            BT(I,K)=BLK(I,K)
         27 CONTINUE
            CALL ARRAY(2,NN,NB,NNDIM,NBDIM,BT,BT)
            NBT = NB
         25 CALL ARRAY(2,NN,NK,NNDIM,NKDIM,X,X)
            CALL CTIE(BT,X,A,NN,NBT,0,0,NK)
            NM=NBT+NK
            CALL ARRAY(1,NN,NM,NNDIM,NADIM,A,A)
            NBMOD=NB
            NTMOD=NT
            IF (NB.EQ.1) NBMOD=NB-1
            IF (NT.EQ.1) NTMOD=NT-1
C
C   NM EQUALS THE NUMEER OF COLUMNS IN THE DESIGN MATRIX
C
C   WRITE THE MATRIX FORM OF Y AND A FOR THE MAC MODEL
C
         26 WRITE(6,12)
         12 FORMAT(1H1,'THE VALUES OF Y AND A FOLLOW      MAC MODEL',///)
            IF (IPRKOD(1).EQ.0) GO TO 9797
            DO 13 I=1,NN
            WRITE(6,19) (Y(I,J),J=1,NP),(A(I,J),J=1,NM)
         19 FORMAT('0',14F9.2)
         13 CONTINUE
            GO TO 9795
       9797 WRITE(6,9796)
       9796 FORMAT('0','    THE ABOVE LISTING WAS SUPPRESSED : IPRTKOD(1)=0')
C
C   COMPUTE THE VARIATE FORM OF Y AND A FOR THE GMAC MODEL
C
       9795 DO 8 J=1,NP
C
C   WRITE THE VARIATE-WISE FORM OF Y AND A FOR GMAC MODEL
C
            WRITE(6,16) J
         16 FORMAT(1H1,'THE VALUES OF Y AND A FOR VARIATE',I2,'  FOLLOW
           *GMAC MODEL',///)
            IF (IPRKOD(2).EQ.0) GO TO 9794
            GO TO 9792
       9794 WRITE(6,9793)
       9793 FORMAT('0','    THE ABOVE LISTING WAS SUPPRESSED : IPRTKOD(2)=0')
       9792 ICT=0
            DO 9 I=1,NN
            IF(Y(I,J).EQ.0) GO TO 9
            ICT=ICT+1
            Z(ICT) = Y(I,J)
```

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```
            DO 10 K=1,NM
            F(ICT,K) = A(I,K)
         10 CONTINUE
            IF (IPRKOD(2).EQ.0) GO TO 9
            WRITE(6,18) Z(ICT), (F(ICT,K),K=1,NM)
         18 FORMAT('0',14F9.2)
          9 CONTINUE
C
C    NCT(J) EQUAL THE NUMBER OF OBSERVATIONS FOR VARIATE J,J=1,....,NP
C
            NCT(J)=ICT
            NBB=0
            IF(NMISS.EQ.0) GO TO 6000
            DO 3000 I = 1,NN
            DO 3000 K = 1,NMISS
            BB(I,K) = 0.0D0
       3000 CONTINUE
C
C    REMOVE MISSING VALUES FROM A MATRICES AND REPLACE BY ZEROES
C    BUILD EXTRA COLUMSS FOR A MATRICES TO ACCOUNT FOR MISSING VALUES
C
            KK=NBT+1
            DO 90 K=KK,NM
            L=NCT(J)
            NCM(J,K)=0
            DO 100 I = 1,L
            IF(F(I,K).NE.0) GO TO 100
            F(I,K) = 0.0D0
            NCM(J,K) = NCM(J,K) + 1
        110 KKK= NCM(J,K)
            BB(I,KKK) = 1.0D0
            NBB = NBB + 1
        100 CONTINUE
         90 CONTINUE
C
C    BUILD NEW A MATRICES FOR MGMAC MODEL BY AUGMENTATION
C
            L = NCT(J)
C
C    NMA(J) EQUALS THE NUMBER OF COLUMNS IN THE DESIGN MATRIX FOR VARIATE J
C
            NMA(J) = NM + NBB
            DO 130 K1=1,L
            NMP1 = NM + 1
            NMAJ = NMA(J)
            DO 130 K2 = NMP1,NMAJ
            NDUM = K2 - NMP1 + 1
            F(K1,K2) = BB(K1,NDUM)
        130 CONTINUE
C
C    WRITE THE VARIATE-WISE FORM OF Y AND A FOR THE MGMAC MODEL
C
            WRITE(6,51) J
         51 FORMAT(1H1,'THE VALUES OF Y AND A FOR VARIATE',I2,' FOLLOW
           *MGMAC MODEL',///)
            IF (IPRKOD(3).EQ.0) GO TO 9791
            GO TO 9790
       9791 WRITE(6,9789)
```

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```
      9789 FORMAT('0','     THE ABOVE LISTING WAS SUPPRESSED : IPRTKOD(3)=0')
           GO TO 6000
      9790 LL=NMA(J)
           DO 52 I=1,L
           WRITE(6,53) Z(I), (F(I,K),K=1,LL)
        53 FORMAT('0',14F9.2)
        52 CONTINUE
      6000 NMA(J) = NM + NEE
           L1=NCT(J)
           M1=NMA(J)
C
C    COMPUTE VARIANCE
C
C    FIND F'F
C
C    TEST FOR RANK OF F AND COMPUTE (F'F) INVERSE=RINV
C
           DO 3002 I = 1,M1
           DO 3002 L = 1,M1
           RSS(I,L) = 0.0D0
           DO 3003 K = 1,L1
           IF(F(K,I).EQ.0.0D0 00.OR.F(K,L).EQ.0.0D0 00) GO TO 3003
           RSS(I,L) = RSS(I,L) + F(K,I)*F(K,L)
      3003 CONTINUE
      3002 CONTINUE
           DO 900 I=1,M1
           DO 900 K=1,M1
           IK1=(I-1)*M1 + K
       900 RSSS(IK1)=RSS(I,K)
           CALL DMFGR(RSSS,M1,M1,EPS,IRANK,IROW,ICOL)
           IR(J) = IRANK
           WRITE(6,55) J,IR(J)
        55 FORMAT(1H0,'THE RANK OF THE DESIGN MATRIX FOR VARIATE',I5,' FOR TH
          *E MGMAC MODEL IS',I5,'     ',///)
           CALL LPSDOR(RSS,M1,M1,NFDIM,RSS,IDGT,T,IER)
           WRITE(6,9864) IER
      9864 FORMAT('0',/,' ','ERROR CODE FROM LPSDOR = ',I6,/)
C
C    FORM THE PRODUCT F(RINV)
C
      9753 DO 3004 I = 1,L1
           DO 3004 L = 1,M1
           S(I,L) = 0.0D0
           DO 3005 K = 1,M1
           IF(F(I,K).EQ.0.0D0 00.OR.RSS(K,L).EQ.0.0D0 00) GO TO 3005
           S(I,L) = S(I,L) + F(I,K)*RSS(K,L)
      3005 CONTINUE
      3004 CONTINUE
C
C
C    COMPUTE F(RINV)F'
C
           DO 3006 I = 1,L1
           DO 3006 L = 1,L1
           U(I,L) = 0.0D0
           DO 3007 K = 1,M1
           IF(S(I,K).EQ.0.0D0 00.OR.F(L,K).EQ.0.0D0 00) GO TO 3007
           U(I,L) = U(I,L) + S(I,K)*F(L,K)
```

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```
 3007 CONTINUE
 3006 CONTINUE
C
C     COMPUTE  Z'IZ = Z'Z
C
      ZZ(J) = 0.0D0
      DO 320 II=1,L1
      ZZ(J) = ZZ(J) + Z(II)**2
  320 CONTINUE
C
C     COMPUTE Z'F(RINV)F'
C
      DO 3008 I = 1,L1
      V(I) = 0.0D0
      DO 3009 L = 1,L1
      IF(U(L,I).EQ.0.CD0 00) GO TO 3009
      V(I) = V(I) + Z(L)*U(L,I)
 3009 CONTINUE
 3008 CONTINUE
C
C     COMPUTE Z'F(RINV)F'Z
C
      W = 0.0D0
      DO 3010 I = 1,L1
      W = W + Z(I)*V(I)
 3010 CONTINUE
      SIG(J,J) = (ZZ(J) - W)/(L1 - IR(J))
C
C     COMPUTE COVARIANCE
C
      JJ = J + 1
      IF(JJ.GT.NP) GO TO 8
      DO 411 JJJ = JJ,NP
      ICTC = 0
      DO 409 I = 1,NN
      IF(Y(I,JJJ).EQ.C.CR.Y(I,J).EQ.D) GO TO 409
      ICTC = ICTC + 1
      Z(ICTC) = Y(I,J)
      ZY(ICTC) = Y(I,JJJ)
      DO 410 K = 1,NM
      F(ICTC,K) = A(I,K)
  410 CONTINUE
  409 CONTINUE
      NCTC(J,JJJ) = ICTC
      NBBC = 0
      IF(NMISS.EQ.0) GO TO 6001
      DO 3001 I = 1,NN
      DO 3001 K = 1,NMISS
      BB(I,K) = 0.0D0
 3001 CONTINUE
      KK = NBT + 1
      DO 490 K = KK,NM
      L = NCTC(J,JJJ)
      NCMC(J,JJJ,K) = 0
      DO 4100 I = 1,L
      IF(F(I,K).NE.D) GC TO 4100
      F(I,K) = 0.0D0
      NCMC(J,JJJ,K) = NCMC(J,JJJ,K) + 1
```

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```
              KKK = NCMC(J,JJJ,K)
              BB(I,KKK) = 1.0D0
              NBBC = NBBC + 1
         4100 CONTINUE
          490 CONTINUE
              L = NCTC(J,JJJ)
              NMAC(J,JJJ) = NM + NBBC
              DO 4130 K1 = 1,L
              NMP1 = NM + 1
              NMAJ = NMAC(J,JJJ)
              DO 4130 K2 = NMP1,NMAJ
              NDUM = K2 - NMP1 + 1
              F(K1,K2) = BB(K1,NDUM)
         4130 CONTINUE
         6001 NMAC(J,JJJ) = NM + NBBC
              L2 = NCTC(J,JJJ)
              M2 = NMAC(J,JJJ)
        C
        C   FIND F'F
        C
              DO 3012 I = 1,M2
              DO 3012 L = 1,M2
              RSS(I,L) = 0.0D0
              DO 3013 K = 1,L2
              IF(F(K,I).EQ.0.0D0 00.OR.F(K,L).EQ.0.0D0 00) GO TO 3013
              RSS(I,L) = RSS(I,L) + F(K,I)*F(K,L)
         3013 CONTINUE
         3012 CONTINUE
        C
        C   TEST FOR RANK OF F AND COMPUTE INVERSE
        C
              DO 901 I = 1,M2
              DO 901 K = 1,M2
              IK1=(I-1)*M2 + K
              RSSS(IK1)=RSS(I,K)
          901 CONTINUE
              CALL DMFGR(RSSS,M2,M2,EPS,IRANK,IROW,ICOL)
              IRR(J,JJJ) = IRANK
              CALL LPSDOR(RSS,M2,M2,NFDIM,RSS,IDGT,T,IER)
              WRITE(6,9864) IER
        C
        C   FORM THE PRODUCT F(RINV)
        C
              DO 3014 I = 1,L2
              DO 3014 L = 1,M2
              S(I,L) = 0.0D0
              DO 3015 K = 1,M2
              IF(F(I,K).EQ.0.0D0 00.OR.RSS(K,L).EQ.0.0D0 00) GO TO 3015
              S(I,L) = S(I,L) + F(I,K)*RSS(K,L)
         3015 CONTINUE
         3014 CONTINUE
        C
        C   COMPUTE F(RINV)F'
        C
              DO 3016 I = 1,L2
              DO 3016 L = 1,L2
              U(I,L) = 0.0D0
              DO 3017 K = 1,M2
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```
                  IF(S(I,K).EQ.0.0D0 00.OR.F(L,K).EQ.0.0D0 00) GO TO 3017
                  U(I,L) = U(I,L) + S(I,K)*F(L,K)
            3017 CONTINUE
            3016 CONTINUE
C
C   COMPUTE Z'IZZ
C
                  ZZ(J) = 0.0D0
                  DO 620 II= 1,L2
                  ZZ(J) = ZZ(J) + Z(II)*ZY(II)
             620 CONTINUE
C
C   COMPUTE  Z'F(RINV)F'
C
                  DO 3018 I = 1,L2
                  V(I) = 0.0D0
                  DO 3019 L = 1,L2
                  IF(U(L,I).EQ.0.0D0 00) GO TO 3019
                  V(I) = V(I) + Z(L)*U(L,I)
            3019 CONTINUE
            3018 CONTINUE
C
C.  COMPUTE Z'F(RINV)F'ZY
                  W = 0.0D0
                  DO 3020 I = 1,L2
                  W = W + ZY(I)*V(I)
            3020 CONTINUE
                  SIG(J,JJJ) = (ZZ(J) - W)/(L2 - IRR(J,JJJ))
                  SIG(JJJ,J) = SIG(J,JJJ)
             411 CONTINUE
               8 CONTINUE
C
C *** CALL TO SMOOTH FOLLOWS THIS CARD
C
                  CALL SMOOTH(SIG,NP,1)
C
C   WRITE OUT SIGMA AND SIGMA INVERSE
C
                  WRITE(6,695)
             695 FORMAT(1H1,'THE VALUE OF SIGMA FOLLOWS',///)
                  IF (IPRKOD(4).EQ.0) GO TO 9786
                  DO 9788 JJJ=1,NF
                  WRITE(6,9787) (SIG(JJJ,JJJJ),JJJJ=1,NP)
            9787 FORMAT('0',10(1X,G12.6))
            9788 CONTINUE
                  GO TO 9784
            9786 WRITE(6,9785)
            9785 FORMAT('0','     THE ABOVE LISTING WAS SUPPRESSED : IPRTKOD(4)=0')
            9784 CALL LPSDOR(SIG,NP,NP,NPDIM,SIGINV,IDGT,T,IER)
                  WRITE(6,9864) IER
                  WRITE(6,699)
             699 FORMAT(1H1,'THE VALUE OF SIGMA INVERSE FOLLOWS',///)
                  IF (IPRKOD(4).EQ.0) GO TO 9783
                  DO 9782 JJJ=1,NF
                  WRITE(6,9781) (SIGINV(JJJ,JJJJ),JJJJ=1,NP)
            9781 FORMAT('0',10(1X,G12.6))
            9782 CONTINUE
                  GO TO 9780
```

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```
      9783 WRITE(6,9785)
     C
     C    REMOVE MISSING VALUES FRCM A ANC REPLACE BY ZEROES
     C    BUILD EXTRA COLUMNS FOR A MATRIX TO ACCOUNT FOR MISSING VALUES
     C
      9780 NBB = 0
           IF(NMISS.EQ.0) GC TO 6002
           DO 5005 I = 1,NN
           DO 5005 K = 1,NMISS
           BB(I,K) = 0.0D0
      5005 CONTINUE
           KK = NBT + 1
           DO 1011 K = KK,NM
           NCMK(K) = 0
           DO 1012 I = 1,NN
           IF(A(I,K).NE.D) GO TO 1012
           A(I,K) = 0.0D0
           NCMK(K) = NCMK(K) + 1
           KKK = NCMK(K)
           BB(I,KKK) = 1.0D0
           NBB = NBB + 1
      1012 CONTINUE
      1011 CONTINUE
     C
     C    BUILD NEW A MATRIX FOR MATRIX MODIFIED MODEL
     C
     C    NA EQUALS THE NUMBER OF COLUMNS IN THE MODIFIED DESIGN MATRIX
     C
           NA = NM + NBB
           DO 1114 K1 = 1,NN
           NMP1 = NM + 1
           DO 1114 K2 = NMP1,NA
           NDUM = K2 - NMP1 + 1
           A(K1,K2) = BB(K1,NDUM)
      1114 CONTINUE
     C
     C    WRITE THE MATRIX MODIFIED FORM OF Y AND A
     C
           WRITE(6,1020)
      1020 FORMAT(1H1,'THE VALUES OF Y AND A FOLLOW
          *MATRIX MODIFIED MODEL',///)
           IF (IPRKOD(5).EC.0) GO TO 9779
           DO 1021 I = 1,NN
           WRITE(6,1022) (Y(I,J),J=1,NP),(A(I,K),K=1,NA)
      1022 FORMAT('0',14F9.2)
      1021 CONTINUE
           WRITE(6,9729)
      9729 FORMAT('1','         ****** DEPENDENT VARIABLES AND DESIGN MATRIX FOR
          % THE VARIOUS GROUPS CORRESPONDING TO DIFFERENT PATTERNS OF MISSING
          $ VALUES')
           NDIGRP=2**NP - 1
           WRITE(6,9703) NDIGRP,NDIGRP
      9703 FORMAT('0','**** THERE ARE ',I4,' DIFFERENT POSSIBLE GROUPS NUMBER
          XED FROM 1 TO',I4,' THOUGH IN GENERAL NOT ALL GROUPS WILL APPEAR',/
          #/,'0','*** WHICH ONES OCCUR DEPENDS ON THE PATTERN OF MISSING VALU
          <ES.HOWEVER THE TOTAL # OBSERVATIONS IN ALL GROUPS MUST EQUAL NN')
           GO TO 6002
      9779 WRITE(6,9778)
```

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```
 9778 FORMAT('0',' THE ABOVE LISTING WAS SUPPRESSED : IPRTKOD(5)=0')
      WRITE(6,9729)
 6002 NA = NM + NBB
      DO 1019 J = 1,NP
      B(J,J) = 1.000
 1019 CONTINUE
      DO 1000 I = 1,NA
      IND(I) = 0
      DO 1001 J = 1,NP
      IF(Y(I,J).NE.0) GO TO 1030
      IN(I,J) = 0
 1030 L = NP - J
      IND(I) = IND(I) + IN(I,J)*2**L
 1001 CONTINUE
 1000 CONTINUE
      KP = 2**NP - 1
      DO 1002 LL = 1,KP
      NCL(LL) = 0
      DO 1003 I = 1,NA
      IF(IND(I).NE.LL) GO TO 1003
      NCL(LL) = NCL(LL) + 1
      ICT = NCL(LL)
      DO 1004 J = 1,NP
      YS(ICT,J) = Y(I,J)
 1004 CONTINUE
      DO 1005 K = 1,NA
      AS(ICT,K) = A(I,K)
 1005 CONTINUE
 1003 CONTINUE
      IF(NCL(LL).EQ.0) GO TO 1002
      JCT = 0
      DO 1007 J = 1,NP
      IF(YS(1,J) .EQ.0) GO TO 1007
      JCT = JCT + 1
      DO 1008 JJ = 1,NP
      BS(JJ,JCT) = B(JJ,J)
 1008 CONTINUE
 1007 CONTINUE
      NCJ(LL) = JCT
C
C     WRITE THE GROUPED DATA FORM OF Y AND A FOR THE MODIFIED MATRIX MODEL
C
      K = NCL(LL)
      JJ = NCJ(LL)
      WRITE(6,1032) LL,K,JJ
 1032 FORMAT(1H0,'THE DEPENDENT VARIABLES AND CORRESPONDING DESIGN MATRI
     *X FOLLOW FOR GROUP',I5,' WHICH HAS',I5,' OBSERVATIONS ON',I5,' VAR
     *IATES',///)
      IF (IPRKOD(6).EQ.0) GO TO 9777
      DO 1024 I = 1,K
      WRITE(6,1025) (YS(I,J),J=1,NP),(AS(I,KK),KK=1,NA)
 1025 FORMAT('0',14F9.2)
 1024 CONTINUE
      GO TO 9776
 9777 WRITE(6,9775)
 9775 FORMAT('0',' THE ABOVE LISTING WAS SUPPRESSED : IPRTKOD(6)=0')
C
C     COMPUTE THE SUM OVER ALL GROUPS OF (B(INV(B'*SIGMA*B))XA')Y
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```
C
C   COMPUTE     B'*SIGMA
C
 9776 NAP = NA*NP
      NJ = NCJ(LL)
      DO 1036 I = 1,NJ
      DO 1036 L = 1,NF
      BSIG(I,L) = 0.0D0
      DO 2066 K = 1,NF
      IF(BS(K,I).EQ.0.0D0 00) GO TO 2066
      BSIG(I,L) = BSIG(I,L) + BS(K,I)*SIG(K,L)
 2066 CONTINUE
 1036 CONTINUE
C
C   COMPUTE     B'*SIGMA*B
C
      DO 1037 I = 1,NJ
      DO 1037 L = 1,NJ
      BSIGB(I,L) = 0.0D0
      DO 2067 K = 1,NF
      IF(BS(K,L).EQ.0.0D0 00) GO TO 2067
      BSIGB(I,L) = BSIGB(I,L) + BSIG(I,K)*BS(K,L)
 2067 CONTINUE
 1037 CONTINUE
C
C   COMPUTE         INV(B'*SIGMA*B)
C
      IF(NJ.EQ.1) GO TO 1038
      CALL LPSDOR(BSIGB,NJ,NJ,NPDIM,BSIGB,IDGT,T,IER)
      WRITE(6,9864) IER
      GO TO 1039
 1038 BSIGB(NJ,NJ) = 1.0D0/BSIGB(NJ,NJ)
C
C   COMPUTE      B(INV(B'*SIGMA*B))
C
 1039 DO 1040 I = 1,NF
      DO 1040 L = 1,NJ
      BBSIGI(I,L) = 0.0D0
      DO 2070 K = 1,NJ
      IF(BS(I,K).EQ.0.0D0 00) GO TO 2070
      BBSIGI(I,L) = BBSIGI(I,L) + BS(I,K)*BSIGB(K,L)
 2070 CONTINUE
 1040 CONTINUE
C
C   COMPUTE         (B(INV(B'*SIGMA*B))XA')
C
      NL = NCL(LL)
C
C   GET COLUMNS OF Y
C
      DO 1042 I = 1,NL
      DO 1042 J = 1,NJ
      YYS(I,J) = 0.0DC
      DO 2072 K = 1,NF
      IF(BS(K,J).EQ.0.0D0 00) GO TO 2072
      YYS(I,J) = YYS(I,J) + YS(I,K)*BS(K,J)
 2072 CONTINUE
 1042 CONTINUE
```

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```
C
C    COMPUTE      B(INV(B'*SIGMA*B))XA')Y
C
        II = 0
        DO 1043 I = 1,NP
        DO 1043 K = 1,NA
        II = II + 1
        DO 1043 J = 1,NJ
        DO 2073 L = 1,NL
        IF(BBSIGI(I,J).EQ.0.0D0 00.OR.AS(L,K).EQ.0.0D0 00) GO TO 2073
        RV(II) = RV(II) + BBSIGI(I,J)*AS(L,K)*YYS(L,J)
  2073 CONTINUE
  1043 CONTINUE
C
C     COMPUTE THE SUM CVER ALL GROUPS OF  ((B(INV(B'*SIGMA*B)B')XA'A)
C    AND COMPUTE THE INVERSE
C
C    COMPUTE      B(INV(B'*SIGMA*B)B'
C
        DO 1051 I = 1,NP
        DO 1051 L = 1,NP
        BSIGIB(I,L) = 0.0D0
        DO 2081 K = 1,NJ
        IF(BS(L,K).EQ.0.0D0 00.OR.BBSIGI(I,K).EQ.0.0D0 00) GO TO 2081
        BSIGIB(I,L) = BSIGIB(I,L) + BBSIGI(I,K)*BS(L,K)
  2081 CONTINUE
  1051 CONTINUE
C
C    COMPUTE      A'A
C
        NL = NCL(LL)
        DO 1052 I = 1,NA
        DO 1052 L = 1,NA
        AJA(I,L) = 0.0D0
        DO 2082 K = 1,NL
        IF(AS(K,I).EQ.0.0D0 00) GO TO 2082
        AJA(I,L) = AJA(I,L) + AS(K,I)*AS(K,L)
  2082 CONTINUE
  1052 CONTINUE
C
C    COMPUTE      (B(INV(B'*SIGMA*B)B')XA'A
C
C    PUT THE ABOVE INTC A MATRIX
C
        II = 0
        DO 1054 I = 1,NP
        DO 1054 K = 1,NA
        KK = 0
        II = II + 1
        DO 1054 J = 1,NP
        DO 1054 L = 1,NA
        KK = KK + 1
        PROD2(II,KK) = FRCD2(II,KK) + BSIGIB(I,J)*AJA(L,K)
  1054 CONTINUE
  1002 CONTINUE
C
C    COMPUTE THE INVERSE OF THE ABOVE SUM
C
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0554              CALL LPSDOR(PROD2,NAP,NAP,NPRCD,PROD2,IDGT,T,IER)
0555              WRITE(6,9864) IER
0556              DO 1056 I = 1,NAP
0557              BETA(I) = 0.0D0
            C
            C   COMPUTE BETA ESTIMATES
            C
0558              DO 1056 L = 1,NAP
0559              BETA(I) = BETA(I) + PROD2(I,L)*RV(L)
0560         1056 CONTINUE
0561              DO 9728 I8=1,NP
0562              DO 9728 I9=1,NA
0563              I7=(I8-1)*NA+I9
0564         9728 BETAMX(I9,I8)=BETA(I7)
0565              WRITE(6,1067)
0566         1067 FORMAT('1','          ****** LISTING OF PARAMETER ESTIMATES IN THE ORD
                 #ER : BLOCKS, TRTS, REGRESSION COEFFICIENTS DOWN THE PAGE ******')
0567              IF (IPRKOD(7).EQ.0) GO TO 9774
0568              WRITE(6,1062)
0569         1062 FORMAT('0','          VAR#1                VAR#2                VAR#3
                 <          VAR#4                VAR#5                VAR#6
                 %  VAR#7')
0570              DO 1060 I8=1,NM
0571              WRITE(6,9727) (BETAMX(I8,I9),I9=1,NP)
0572         9727 FORMAT('0',7(1X,G18.6))
0573         1060 CONTINUE
            C     WRITE(6,1926)
            C1926 FORMAT(//,' ','                ****** ESTIMATES OF DUMMY PARAMETERS INT
            C    %RODUCED BECAUSE OF MISSING VALUES ******')
            C     IF (NM.EQ.NA) GO TO 1919
            C     NMP1=NM+1
            C     DO 1925 I8=NMP1,NA
            C     WRITE(6,9727) (BETAMX(I8,I9),I9=1,NP)
            C1925 CONTINUE
            C     GO TO 1917
            C1919 WRITE(6,1918)
            C1918 FORMAT('0','                THERE ARE NO DUMMY PARAMETERS ( THERE WER
            C    #E NO MISSING VALUES )')
0574              GO TO 1917
0575         9774 WRITE(6,9773)
0576         9773 FORMAT('0','    THE ABOVE LISTING WAS SUPPRESSED : IPRTKOD(7)=0')
0577         1917 CONTINUE
            C
            C   READ IN THE SPECIFIED HYPOTHESES MATRICES
            C
0578              WRITE(6,9756)
0579         9756 FORMAT('1','                         ****** HYPOTHESIS TESTING SEC
                 $TION ****** ',///)
0580              READ(5,2020) NUMHYP
0581         2020 FORMAT(I5)
0582              WRITE(6,9772) NUMHYP
0583         9772 FORMAT('0',I5,' HYPOTHESIS MATRICES SHALL BE USED,IN TURN,FOR COMP
                 #UTING CHI SQUARE STATISTICS',///)
0584              WRITE(6,9771) NM
0585         9771 FORMAT('0','EACH MATRIX SHOULD HAVE ',I5,' COLUMNS AS FOLLOWS : ')
0586              WRITE(6,9759) NEWCD
0587         9759 FORMAT('0',' THE FIRST ',I5,' COLUMNS CORRESPOND TO BLOCK PARAMETE
                 %RS')
```

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```
      WRITE(6,9758) NTMOD
 9758 FORMAT(' ',' THE NEXT  ',I5,' COLUMNS CORRESPOND TO TREATMENT PARA
     %METERS')
      WRITE(6,9757) NK
 9757 FORMAT(' ',' THE LAST  ',I5,' COLUMNS CORRESPOND TO COVARIATE COEF
     %FICIENTS')
      DO 2000 I = 1,NUMHYP
      READ(5,2021) NUMROW(I),HYPID,KODOVL,(KDRESP(I9),I9=1,NP)
 2021 FORMAT(I5,5A4,2012)
      NR = NUMROW(I)
      WRITE(6,1999) I,HYPID
 1999 FORMAT(1H1,'**** LISTING OF HYPOTHESIS MATRIX',I5,' FOLLOWED BY IT
     @S EXTENSION FOR MODIFIED MODEL.HYPOTH ID IS: ',5A4,///)
      DO 2001 J = 1,NR
      READ(5,2022) (H(J,K),K=1,NM)
 2022 FORMAT(20F4.2)
      WRITE(6,1998) (H(J,K),K=1,NM)
 1998 FORMAT('0',20(1X,F5.2))
 2001 CONTINUE
      NRP = NR*NP
C
C                NRP=NR*NP AND NAP=NA*NP
C.
C    EXTEND HYPOTHESIS MATRIX TO ACCOUNT FOR ADDITIONAL PARAMETERS
C    RESULTING FROM MISSING INDEPENDENT VARIABLES
C
      IF(NM.EQ.NA) GO TO 2002
      DO 2003 J = 1,NR
      DO 2003 K = 1,NEB
      KK = NM + K
      H(J,KK) = 0.0D0
 2003 CONTINUE
C
C    BUILD HYPOTHESIS MATRIX FOR PARAMETER VECTOR
C
 2002 DO 2004 L = 1,NP
      DO 2004 J = 1,NR
      JJ = J + NR*(L - 1)
      DO 2004 K = 1,NA
      KK = K + NA*(L - 1)
      H(JJ,KK) = H(J,K)
 2004 CONTINUE
      DO 4000 J=1,NRP
      WRITE(6,9755) J,(H(J,K),K=1,NAP)
 9755 FORMAT(' ',//,' ','ROW(',I2,'): ',20(1X,F5.2))
 4000 CONTINUE
      IF (KODOVL.EQ.0) GO TO 9749
C
C    COMPUTE THE TEST STATISTIC
C
C    COMPUTE H'*PRINV
C
      DO 2005 J = 1,NRP
      DO 2005 L = 1,NAP
      HPRNV(J,L) = 0.0D0
      DO 2006 K = 1,NAP
      IF(H(J,K).EQ.0.0D0 00.OR.PROD2(K,L).EQ.0.0D0 00) GO TO 2006
      HPRNV(J,L) = HPRNV(J,L) + H(J,K)*PROD2(K,L)
```

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```
      2006 CONTINUE
      2005 CONTINUE
C
C     COMPUTE H'*PRINV*H
C
           DO 2007 J = 1,NFP
           DO 2007 L = 1,NFP
           HPRH(J,L) = 0.0D0
           DO 2008 K = 1,NAP
           IF(HPRNV(J,K).EQ.0.0D0 00.OR.H(L,K).EQ.0.0D0 00) GO TO 2008
           HPRH(J,L) = HPRH(J,L) + HPRNV(J,K)*H(L,K)
      2008 CONTINUE
      2007 CONTINUE
C
C     COMPUTE THE INVERSE OF H'*PRINV*H
C
           CALL LPSDOR(HPRH,NRP,NRP,NHPRHD,HPRH,IDGT,T,IER)
           WRITE(6,9864) IER
C
C     COMPUTE H'*BETA
C
           DO 2009 J = 1,NFP
           HBETA(J) = 0.0D0
           DO 2010 L = 1,NAP
           IF(H(J,L).EQ.0.0D0 00) GO TO 2010
           HBETA(J) = HBETA(J) + H(J,L)*BETA(L)
      2010 CONTINUE
      2009 CONTINUE
C
C     COMPUTE (H'*BETA)'(INV(H'*PRINV*H))
C
           DO 2011 J = 1,NFP
           HBETAP(J) = 0.0D0
           DO 2011 L = 1,NFP
           HBETAP(J) = HBETAP(J) + HBETA(L)*HPRH(J,L)
      2011 CONTINUE
C
C     COMPUTE (H*BETA)'(INV'H'*PRINV*H))(H*BETA)
C
           WALD = 0.0D0
           DO 2012 J = 1,NFP
           WALD = WALD + HBETAP(J)*HBETA(J)
      2012 CONTINUE
           WRITE(6,2013) I,NF,WALD
      2013 FORMAT(1H0,//,1H0,'THE WALD STATISTIC FOR HYPOTHESIS',I4,' FOR ALL
          # ',I4,' RESPONSE VARIABLES SIMULTANEOUSLY IS : ',F15.4,//)
           WRITE(6,2015) NFF
      2015 FORMAT('0','ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS
          # IS CHI-SQUARE WITH ',I4,' DEGREES OF FREEDOM',///)
C
C    COMPUTE THE TEST STATISTIC FOR THE TESTS ON INDIVIDUAL RESPONSE VARIABLES
C
      9749 WRITE(6,9750) I,HYPID
      9750 FORMAT('1',' ****** RESULTS OF HYPOTHESIS TESTS ON INDIVIDUAL VARI
          BATES FOR HYPOTH MATRIX',I3,' WITH ID: ',5A4,' ******',///)
           WRITE(6,9708) NP,(KORESP(I9),I9=1,NP)
      9708 FORMAT(//,' ',' *** THE OPTIONS FOR THE ',I3,' INDIVIDUAL VARIATE
          %S ARE: ',10I3,/)
```

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```
 0665               DO 9748 IV=1,NP
 0666               IF (KDRESP(IV).EQ.0) GO TO 9748
              C
              C   EXTRACT APPROPRIATE PART OF  THE H MATRIX CONSTRUCTED EARLIER
              C
 0667               DO 9747 IV1=1,NR
 0668               DO 9747 IV2=1,NAP
 0669               IV3=(IV-1)*NR+IV1
 0670          9747 HP(IV1,IV2)=H(IV3,IV2)
              C
              C   COMPUTE H'*PRINV
              C
 0671               DO 9746 J=1,NR
 0672               DO 9746 L=1,NAP
 0673               HPRNV(J,L)=0.D0
 0674               DO 9745 K=1,NAP
 0675               IF (HP(J,K).EQ.0.D0.OR.PROD2(K,L).EQ.0.D0) GO TO 9745
 0676               HPRNV(J,L)=HPRNV(J,L) + HP(J,K)*PROD2(K,L)
 0677          9745 CONTINUE
 0678          9746 CONTINUE
              C
              C   COMPUTE H'*PRINV*H
              C
 0679               DO 9744 J=1,NR
 0680               DO 9744 L=1,NR
 0681               HPRH(J,L)=0.D0
 0682               DO 9743 K=1,NAP
 0683               IF (HPRNV(J,K).EQ.0.D0.OR.HP(L,K).EQ.0.D0) GO TO 9743
 0684               HPRH(J,L)=HPRH(J,L) + HPRNV(J,K)*HP(L,K)
 0685          9743 CONTINUE
 0686          9744 CONTINUE
              C
              C   COMPUTE THE INVERSE OF H'*PRINV*H
              C
 0687               CALL LPSDOR(HPRH,NR,NR,NHPRHD,HPRH,IDGT,T,IER)
 0688               WRITE(6,9864) IER
              C
              C   COMPUTE H'*BETA
              C
 0689               DO 9742 J=1,NR
 0690               HBETA(J)=0.D0
 0691               DO 9741 L=1,NAP
 0692               IF (HP(J,L).EQ.0.D0) GO TO 9741
 0693               HBETA(J)=HBETA(J) + HP(J,L)*BETA(L)
 0694          9741 CONTINUE
 0695          9742 CONTINUE
              C
              C   COMPUTE (H'*BETA)'(INV(H'*PRINV*H))
              C
 0696               DO 9740 J=1,NR
 0697               HBETAP(J)=0.D0
 0698               DO 9740 L=1,NR
 0699               HBETAP(J)=HBETAP(J) + HBETA(L)*HPRH(J,L)
 0700          9740 CONTINUE
              C
              C   COMPUTE (H*BETA)'(INV'H'*PRINV*H))(H*BETA)
              C
 0701               WALD=0.D0
```

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```
      DO 9739 J=1,NR
 9739 WALD=WALD + HBETAF(J)*HBETA(J)
      WRITE(6,9738) I,IV,WALD
 9738 FORMAT('0','THE WALD STATISTIC FOR HYPOTHESIS ',I4,' RESTRICTED TO
     % RESPONSE VARIATE ',I4,' ONLY IS : ',F15.4,/)
      WRITE(6,9737) NR
 9737 FORMAT('0','ITS ASYMPTOTIC DISTRIBUTION UNDER THE NULL HYPOTHESIS
     # IS CHI-SQUARE WITH ',I4,' DEGREES OF FREEDOM',////)
 9748 CONTINUE
      DO 9736 I9=1,NHFRHD
      DO 9736 I8=1,NPFOD
 9736 H(I9,I8)=0.D0
 2000 CONTINUE
 9999 STOP
      DEBUG SUBCHK
      END
```


81

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```
FORTRAN IV G1  RELEASE 2.0                MAIN                DATE = 76320          21/26/16

   *OPTIONS IN EFFECT*  NOTERM,ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP,NOTEST
   *OPTIONS IN EFFECT*  NAME = MAIN    , LINECNT =        60
   *STATISTICS*     SOURCE STATEMENTS =        715,PROGRAM SIZE =    376500
   *STATISTICS*  NO DIAGNOSTICS GENERATED
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```
FORTRAN IV G1   RELEASE 2.0 SMOOTH             DATE = 76320           21/26/16

          SUBROUTINE SMOOTH(AI,N,KOD)
C
C ***     THIS SUBROUTINE ACCEPTS A DOUBLE PRECISION INPUT MATRIX AI OF DIMENSION
C ***     N BY N AND CHECKS TO SEE IF IT IS POSITIVE SEMIDEFINITE. IF SO IT IS LEFT
C ***     INTACT AND RETURNED. IF NOT IT IS SMOOTHED BY THE LEAST SQUARES ALGORITHM
C ***     ( NOT GENERALIZED LEAST SQUARES ) OF SCHWERTMAN AND ALLEN (UNIV KENTUCKY
C ***     DEPT. STATISTICS TECH REPORT #56,SEPTEMBER 1973) TO THE NEAREST POSITIVE
C ***     SEMIDEFINITE MATRIX AND RETURNED.
C ***
C ***     AN OPTION IS AVAILABLE TO PRINT BOTH THE MATRIX SUBMITTED TO THE ROUTINE
C ***     AND THE ONE RETURNED BY IT :
C ***                         KCC = 0 BYPASSES THE PRINT OPTION
C ***                         KCD = 1 INVOKES THE PRINT OPTION.
C ***
C ***
C ***     THE PROGRAM CAN BE MADE TO HANDLE LARGER MATRICES BY INCREASING NDIM, THE
C ***     DIMENSIONS OF VA, EG, AND AI IN THE SUBROUTINE SMOOTH. THESE SHOULD MATCH
C ***     THE DIMENSION OF THE AREA HOLDING THE INPUT MATRIX IN THE CALLING PROGRAM.
C
          REAL*8 VA(7,7),TRC,EG(7,7),AI(7,7)
          NDIM=7
          DO 14 I=1,N
          DO 14 J=1,N
       14 VA(I,J)=AI(I,J)
          IF (KOD.EQ.0) GC TO 13
          CALL MATOUT (VA,N,N,'INPUT MATRIX TO SMOOTH  ',NDIM,NDIM)
       13 TRC=0.0D0
          CALL HDIAG(VA,N,C,EG,NR,NDIM)
          DO 15 I=1,N
          IF (VA(I,I).LT.C.0D0) TRC=TRC+VA(I,I)
       15 CONTINUE
          DO 16 I=1,N
          IF (VA(I,I).LT.C.0D0) GO TO 17
       16 CONTINUE
          GO TO 40
       17 DO 21 I=1,N
          DO 21 J=1,N
       21 AI(I,J)=0.0D0
          DO 20 I=1,N
          IF (VA(I,I).LT.0.0D0) GO TO 20
          DO 19 J=1,N
          DO 19 L=1,N
          AI(J,L)=AI(J,L) + EG(J,I) * VA(I,I) * EG(L,I)
       19 CONTINUE
       20 CONTINUE
       40 IF (KOD.EQ.0) GC TO 41
          CALL MATOUT(AI,N,N,'MATRIX OUTPUT BY SMOOTH ',NDIM,NDIM)
       41 RETURN
          DEBUG SUBCHK
          END
```

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```
FORTRAN IV G1  RELEASE 2.0              SMOOTH             DATE = 76320          21/26/16

   *OPTIONS IN EFFECT*  NOTERM,ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP,NOTEST
   *OPTIONS IN EFFECT*  NAME = SMOOTH   , LINECNT =        60
   *STATISTICS*     SOURCE STATEMENTS =        32,PROGRAM SIZE =       2352
   *STATISTICS*  NO DIAGNOSTICS GENERATEC
```

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```
      SUBROUTINE HDIAG (H,N,IEGEN,U,NR,NN)
      IMPLICIT REAL*8 (A-H,O-Z)
        DIMENSION H(NN,NN),U(NN,NN),X(100),IQ(100)
      IF(IEGEN)50,10,50
   10 DO40I=1,N
      DO40J=1,N
      IF(I-J)30,20,30
   20 U(I,J)=1.0D0
      GOTO40
   30 U(I,J)=0.0D0
   40 CONTINUE
   50 NR=0
      IF(N-1)470,470,60
   60 NMI1=N-1
      DO80I=1,NMI1
      X(I)=0.0D0
      IPL1=I+1
      DO80J=IPL1,N
      IF(X(I)-DABS(H(I,J)))70,70,80
   70 X(I)=DABS(H(I,J))
      IQ(I)=J
   80 CONTINUE
      RAP=7.450580596D-9
      HDTEST=1.0D38
   90 DO120I=1,NMI1
      IF(I-1)110,110,100
  100 IF(XMAX-X(I))110,120,120
  110 XMAX=X(I)
      IPIV=I
      JPIV=IQ(I)
  120 CONTINUE
      IF(XMAX)470,470,130
  130 IF(HDTEST)150,150,140
  140 IF(XMAX-HDTEST)150,150,180
  150 HDIMIN=DABS(H(1,1))
      DO170I=2,N
      IF(HDIMIN-DABS (H(I,I)))170,170,160
  160 HDIMIN=DABS (H(I,I))
  170 CONTINUE
      HDTEST=HDIMIN*RAP
      IF(HDTEST-XMAX)180,470,470
  180 NR=NR+1
      IF(H(IPIV,IPIV)-H(JPIV,JPIV))200,190,200
  190 S=1.0D0
      TANG=DSIGN (2.0D0,S)*H(IPIV,JPIV)/(DABS(H(IPIV,IPIV)-H(JPIV,JPIV))
     1+DSQRT ((H(IPIV,IPIV)-H(JPIV,JPIV))**2+4.0D0*H(IPIV,JPIV)**2))
      GO TO 210
  200 TANG=DSIGN (2.0D0,(H(IPIV,IPIV)-H(JPIV,JPIV)))*H(IPIV,JPIV)/(DABS(
     1H(IPIV,IPIV)-H(JPIV,JPIV))+DSQRT ((H(IPIV,IPIV)-H(JPIV,JPIV))**2+4
     2.0D0*H(IPIV,JPIV)**2))
  210 COSINE=1.0/DSQRT (1.0D0+TANG**2)
      SINE=TANG*COSINE
      HII=H(IPIV,IPIV)
      H(IPIV,IPIV)=COSINE**2*(HII+TANG*(2.0D0*H(IPIV,JPIV)+TANG*H(JPIV,J
     1PIV)))
      H(JPIV,JPIV)=COSINE**2*(H(JPIV,JPIV)-TANG*(2.0D0*H(IPIV,JPIV)-TANG
     1*HII))
      H(IPIV,JPIV)=0.0D0
```

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```
      IF(H(IPIV,IPIV)-H(JPIV,JPIV))220,230,230
  220 HTEMP=H(IPIV,IPIV)
      H(IPIV,IPIV)=H(JPIV,JPIV)
      H(JPIV,JPIV)=HTEMP
      HTEMP=DSIGN (1.0D0,-SINE)*COSINE
      COSINE=DABS (SINE)
      SINE=HTEMP
  230 CONTINUE
      DO310I=1,NMI1
      IF(I-IPIV)250,310,240
  240 IF(I-JPIV)250,310,250
  250 IF(IQ(I)-IPIV)260,270,260
  260 IF(IQ(I)-JPIV)310,270,310
  270 K=IQ(I)
  280 HTEMP=H(I,K)
      H(I,K)=0.0D0
      IPL1=I+1
      X(I)=0.0D0
      DO300J=IPL1,N
      IF(X(I)-DABS (H(I,J)))290,290,300
  290 X(I)=DABS (H(I,J))
      IQ(I)=J
  300 CONTINUE
      H(I,K)=HTEMP
  310 CONTINUE
      X(IPIV)=0.0D0
      X(JPIV)=0.0D0
      DO440I=1,N
      IF(I-IPIV)320,440,360
  320 HTEMP=H(I,IPIV)
      H(I,IPIV)=COSINE*HTEMP+SINE*H(I,JPIV)
      IF(X(I)-DABS (H(I,IPIV)))330,340,340
  330 X(I)=DABS (H(I,IPIV))
      IQ(I)=IPIV
  340 H(I,JPIV)=-SINE*HTEMP+COSINE*H(I,JPIV)
      IF(X(I)-DABS (H(I,JPIV)))350,440,440
  350 X(I)=DABS (H(I,JPIV))
      IQ(I)=JPIV
      GOTO440
  360 IF(I-JPIV)370,440,400
  370 HTEMP=H(IPIV,I)
      H(IPIV,I)=COSINE*HTEMP+SINE*H(I,JPIV)
      IF(X(IPIV)-DABS (H(IPIV,I)))380,390,390
  380 X(IPIV)=DABS(H(IPIV,I))
      IQ(IPIV)=I
  390 H(I,JPIV)=-SINE*HTEMP+COSINE*H(I,JPIV)
      IF(X(I)-DABS(H(I,JPIV)))350,440,440
  400 HTEMP=H(IPIV,I)
      H(IPIV,I)=COSINE*HTEMP+SINE*H(JPIV,I)
      IF(X(IPIV)-DABS (H(IPIV,I)))410,420,420
  410 X(IPIV)=DABS (H(IPIV,I))
      IQ(IPIV)=I
  420 H(JPIV,I)=-SINE*HTEMP+COSINE*H(JPIV,I)
      IF(X(JPIV)-DABS (H(JPIV,I)))430,440,440
  430 X(JPIV)=DABS (H(JPIV,I))
      IQ(JPIV)=I
  440 CONTINUE
      IF(IEGEN)90,450,90
```

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```
      450 DO460I=1,N
          HTEMP=U(I,IPIV)
          U(I,IPIV)=COSINE*HTEMP+SINE*U(I,JPIV)
      460 U(I,JPIV)=-SINE*HTEMP+COSINE*U(I,JPIV)
          GOTO90
      470 RETURN
          DEBUG SUBCHK
          END
```

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```
FORTRAN IV G1  RELEASE 2.0                HDIAG               DATE = 76320           21/26/16

   *OPTIONS IN EFFECT*  NOTERM,ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP,NOTEST
   *OPTIONS IN EFFECT*  NAME = HDIAG    , LINECNT =        60
   *STATISTICS*    SOURCE STATEMENTS =       119,PROGRAM SIZE =      9266
   *STATISTICS*  NO DIAGNOSTICS GENERATED
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FORTRAN IV G1 RELEASE 2.0 MATOUT DATE = 76320 21/26/16

```
      SUBROUTINE MATOLT(A,M,N,TITLE,NR,MC)
      REAL*8 A
      DIMENSION A(NR,MC),TITLE(6)
    1 FORMAT('0'/'0',6A4)
    2 FORMAT(' ',7G18.8)
      WRITE(6,1) TITLE
      DO 3 I=1,M
    3 WRITE(6,2) (A(I,J),J=1,N)
      RETURN
      DEBUG SUBCHK
      END
```

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```
FORTRAN IV G1  RELEASE 2.0              MATOUT            DATE = 76320          21/26/16

   *OPTIONS IN EFFECT*  NOTERM,ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP,NOTEST
   *OPTIONS IN EFFECT*  NAME = MATOUT   , LINECNT =       60
   *STATISTICS*     SOURCE STATEMENTS =        11,PROGRAM SIZE =        700
   *STATISTICS*  NO DIAGNOSTICS GENERATED

   *STATISTICS*  NO DIAGNOSTICS THIS STEP
```

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ASD/XRP	1
COMIPAC/I-232	1

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