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STATISTICAL IDENTIFICATION OF EFFECTIVE INPUT VARIABLES

by

J. K. Vaurio

Reactor Analysis and Safety Division

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ABSTRACT

A statistical sensitivity analysis procedure has been developed for ranking the input data of large computer codes in the order of sensitivity-importance. The method is economical for large codes with many input variables, since it uses a relatively small number of computer runs. No prior judgemental elimination of input variables is needed. The screening method is based on stagewise correlation and extensive regression analysis of output values calculated with selected input value combinations. The regression process deals with multivariate nonlinear functions, and statistical tests are also available for identifying input variables that contribute to threshold effects, i.e., discontinuities in the output variables.

A computer code SCREEN has been developed for implementing the screening techniques. The efficiency has been demonstrated by several examples and applied to a fast reactor safety analysis code (Venus-II). However, the methods and the coding are general and not limited to such applications.
I. INTRODUCTION

The purpose of sensitivity screening techniques is to identify a group of most important input parameters of a computer code when the total number of input variables is large or comparable to the number of computer runs that can be carried out within the limits of time and economy. Important input parameters are those that contribute most to the total uncertainty of an output variable. Thus, the output variable is sensitive to these input variables, and significant uncertainties are associated with these input variables so that the combination of the two characteristics contribute to the output uncertainty.

A statistical screening procedure has been developed at Argonne National Laboratory and applied for ranking input parameters of a large computer code. The method is especially aimed for complex codes with a large number of input variables. The conventional sensitivity method of varying the input parameters one-by-one to obtain the partial derivatives of the output variables can be an expensive process and it often relies on linearity. If nonlinear terms are included it is often necessary to make somewhat arbitrary assumptions about higher order derivatives to cut down the number of computer runs. Even many advanced statistical methods reported earlier need engineering judgement for initial screening of input parameters so that the final number submitted for the method is smaller than the number of data points (computer runs). The matrix method of Ref. 5 is relevant to the problem of many input parameters, but it also relies on linearity. Some earlier statistical works are described in Ref. 6.

This report presents a screening method that does not use subjective judgement to eliminate variables but deals with nonlinearities and many input parameters. Typical output variables of an accident-analysis code depend on many material properties and other input parameters. The uncertainty or variation of an output variable is determined by the uncertainties or variations of the input variables. The purpose of the sensitivity analysis method presented here is not to determine all sensitivity coefficients, i.e., first or higher order partial derivatives of an output variable with respect to all
input variables. The purpose is, rather, to determine a group of input variables that are most "effective" in the sense that their variation (uncertainty) causes most of the variation (uncertainty) of the output variable. Such information can be used to direct experimental work or physical modeling to important parameters or phenomena. Since the screening method uses a limited number of computer runs, the results obtained are true only to certain degree of probability, which increases as the number of runs increases.

One can also say that the purpose of the screening techniques is to identify a group of input parameters such that a relatively simple analytic function in terms of these parameters approximates the output variables well enough in the region of variation. Such approximating function is usually very economical to use in probabilistic Monte-Carlo studies.

The screening methodology is presented in Chapter II, including a comparison to the matrix method as well as a description of statistical tests that have to be done to assess the significance of the results at different stages of the analysis. Thus, standard statistical tables are needed in conjunction with this code. Verification of the method is illustrated in Chapters III and IV with several examples including a comprehensive sensitivity study on Venus-II accident analysis code. The user's manual for the computer code (SCREEN) developed to implement these techniques is presented in Chapter V. Program listing and input/output examples are given in the appendixes. A summary and possible future developments are described in Chapter VI.
II. SCREENING METHODS

A. The Procedure

The first task in the screening procedure is to determine the cases to be run with a deterministic accident-analysis code. This can be done by assigning probability distribution for all input variables to let the SCREEN code sample a certain number of cases, i.e., input value combinations. These combinations of parameter values are input to a deterministic accident-analysis code. The results of these deterministic consequence calculations are input to the second part of the SCREEN code that carries out the correlation and regression analysis to be described later in this report. Figure 1 illustrates the flow of information between the SCREEN code and a deterministic accident-analysis code.

B. Selection of Cases

Since the goal is to identify a group of most influential input variables using a relatively small number of computer runs, it is very important to select the input values for these cases so that the information content is maximized. This cannot be achieved, for example, by varying input parameters one at a time, since every run would only contain information about one sensitivity coefficient, and the total number of cases needed would exceed the total number of input variables. Most of the standard "designs", (as the input value selection schemes are called in the response surface literature) have the drawback that they require more cases than is the number of input variables. This makes most standard designs impracticable when one has tens or hundreds of input variables but wants to limit the number of runs to less than 100. It is evident that many or all of the input variables have to be varied from case to case to make sure that each case increases information about many input variables. One solution is to use random sampling. That is, for each case to be run, sample values for all input variables from certain probability (uncertainty) distributions.
Input Probability Distributions of the Input Parameters

SCREEN, Part I:
Samples Input Parameter Combinations

Deterministic Accident Analysis Code (e.g. VENUS-II)
Calculates Output (Consequences) for the Input Parameter Combinations

SCREEN, Part II:
Identifies Important Input Parameters by Stagewise Correlation, Successive Regression Analysis and Statistical Testing

Fig. 1. Use of SCREEN to Identify Effective Input Parameters.
Eight different distributions are available for this purpose in the SCREEN code. These are listed in Table I. Thus, continuous distributions are used rather than discrete levels. There is some justification to use uniform distributions in a sensitivity study, since that provides information evenly for the whole range of interest and also because the exact form of the distribution is usually not known. However, it is important to select the widths or standard deviations of the distributions as realistically as possible. For example, using 99% confidence intervals consistently for all variables ensures that the sensitivity/importance measures obtained by the screening procedure for different variables are meaningful for relative comparisons.

It may be worth mentioning here that systematic or stratified sampling is not considered necessary in this application, since it is very unlikely that too many variables would happen to have similar values in two different cases sampled. In any case, since the rest of the screening method and code (Part II) are independent of how the input values are selected (Part I), the user can select his own design without using the sampling options available in SCREEN. For example, Latin hypercube or fractional factorial designs may be used.

C. Stagewise Correlation Analysis

The screening is based on statistical methods available for selecting "best" regression equations. A brief description of the methods is given since they are slightly modified from standard techniques. The screening starts with a stagewise correlation analysis. The correlation coefficient between an input variable and an output variable is proportional to both the sensitivity coefficient and the uncertainty of the input variable, which product correctly reflects the importance. The impact of the input parameter most correlated with the output variable is subtracted from the data, and a new correlation analysis is performed for the residuals. The impact of the input parameter most correlated with the residual data is then subtracted, and a new correlation analysis is performed for the new residuals, and so on. This correlation procedure identifies parameters with strong linear or monotonic effect on the output.
TABLE I. Probability Distributions Available in the SCREEN Code

<table>
<thead>
<tr>
<th>Name of Distribution</th>
<th>Functional Form</th>
<th>Parameters to be Specified</th>
</tr>
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<tbody>
<tr>
<td>Uniform</td>
<td>$\frac{1}{b-a}$ ; $a \leq z \leq b$</td>
<td>$a, b$ ; $b &gt; a$</td>
</tr>
<tr>
<td>Normal</td>
<td>$\frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(z-\mu)^2}{2\sigma^2}}$</td>
<td>$\mu, \sigma$ ; $\sigma &gt; 0$</td>
</tr>
<tr>
<td>Exponential I</td>
<td>$\frac{1}{\beta} e^{-\frac{(z-a)}{\beta}}$ ; $z &gt; a$</td>
<td>$a, \beta$ ; $\beta &gt; 0$</td>
</tr>
<tr>
<td>Exponential II</td>
<td>$\frac{1}{\beta} e^{\frac{(z-a)}{\beta}}$ ; $z &lt; a$</td>
<td>$a, \beta$ ; $\beta &gt; 0$</td>
</tr>
<tr>
<td>Truncated Normal I</td>
<td>$\frac{K_a}{\sigma \sqrt{2\pi}} e^{-\frac{(z-\mu)^2}{2\sigma^2}}$ ; $z \geq a$, $K_a = \frac{1}{1-F(a)}$ *</td>
<td>$a, \mu, \sigma$ ; $\sigma &gt; 0$</td>
</tr>
<tr>
<td>Truncated Normal II</td>
<td>$\frac{K_b}{\sigma \sqrt{2\pi}} e^{-\frac{(z-\mu)^2}{2\sigma^2}}$ ; $z \leq b$, $K_b = \frac{1}{F(b)}$ *</td>
<td>$b, \mu, \sigma$ ; $\sigma &gt; 0$</td>
</tr>
<tr>
<td>Beta</td>
<td>$\frac{1}{b-a} \frac{\Gamma(\lambda+n)}{\Gamma(\lambda) \Gamma(n)} \left( \frac{z-a}{b-a} \right)^{\lambda-1} \left[ 1 - \frac{z-a}{b-a} \right]^{n-1}$ ; $a \leq z \leq b$</td>
<td>$a, b, \lambda, n$ ; $\lambda, n &gt; 0, b &gt; a$</td>
</tr>
<tr>
<td>Log-normal</td>
<td>$\frac{1}{cz \sqrt{2\pi}} e^{-\frac{(\ln z-\mu)^2}{2\sigma^2}}$ ; $z &gt; 0$</td>
<td>$\mu, \sigma$ ; $\sigma &gt; 0$</td>
</tr>
</tbody>
</table>

* $F(x) = 0.5 + 0.5 \text{erf} \left( \frac{x-\mu}{\sigma \sqrt{2}} \right)$
Assume that we want to identify input variables that explain more than a certain fraction \( \beta \) of the total variance of the output. For any sample size \( N \) (\( N = \text{no. of output values} = \text{no. of computer runs} \)) there is a probability \( \alpha \) that an input variable which really is not important, appears as if it explains a fraction \( \beta \) or more of the total variation. Table II has been constructed from an F-distribution to give \( N \) for a selected \( \beta \) when \( \alpha = 0.01 \). The table also gives \( F_{0.01}(1,N-2) = (N-2)\beta/(1-\beta) \). Similar tables can be constructed for other values of \( \alpha \) by using the relation

\[
\left( \frac{\alpha_1}{\alpha_2} \right)^2 = \frac{F_2}{F_1} \left[ \frac{1 + F_2/(N - 2)}{1 + F_1/(N - 2)} \right]^{N-3}, \tag{1}
\]

where \( F_1 \) and \( F_2 \) are the F-values corresponding to the tail probabilities \( \alpha_1 \) and \( \alpha_2 \), respectively.

<table>
<thead>
<tr>
<th>Sample N</th>
<th>Fraction ( \beta )</th>
<th>( F_{0.01}(1,N-2) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.919</td>
<td>34.12</td>
</tr>
<tr>
<td>10</td>
<td>0.585</td>
<td>11.26</td>
</tr>
<tr>
<td>15</td>
<td>0.411</td>
<td>9.07</td>
</tr>
<tr>
<td>20</td>
<td>0.315</td>
<td>8.28</td>
</tr>
<tr>
<td>30</td>
<td>0.214</td>
<td>7.64</td>
</tr>
<tr>
<td>40</td>
<td>0.162</td>
<td>7.35</td>
</tr>
<tr>
<td>60</td>
<td>0.109</td>
<td>7.10</td>
</tr>
<tr>
<td>80</td>
<td>0.082</td>
<td>6.97</td>
</tr>
<tr>
<td>100</td>
<td>0.066</td>
<td>6.91</td>
</tr>
</tbody>
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D. Successive Regression Analysis

The screening continues with a stepwise regression analysis, which is essentially a series of least-squares fittings of multivariate second-degree functions. This process is expected to identify parameters that may be mis-ranked in the correlation procedure. The regression is performed first with
quadratic functions of two parameters, going through all possible parameter pairs and identifying pairs that give a good fit to the data. The results obtained are used to select a seed group of parameters for the next phase. The regression analysis is then performed successively with overlapping groups of parameters, retaining parameters that have been found to be important (yielding small residual errors for the fitted function) and replacing the rest, going several times through all input variables. At each step the residual variance of the regression model of the parameter group is used as a criterion in selecting parameters for the next step. A measure of "spuriousness" has been developed that is the product of the residual variance and the total sensitivity of a model. It will be explained in the following section and it is also used as a selection criterion.

For a general nonlinear regression analysis the significance of adding an input variable to the model is tested by comparing the relative improvement in the residual sum of squares to an $F(N-K, N-M)$-variable, when $K$ is the number of coefficients in the seed model and $M$ the number of coefficients in the tested (larger) model. The SCREEN-code prints out information facilitating such statistical testing.

E. **Comparison with a Matrix Method**

A linear-sensitivity matrix method is included in SCREEN and its efficiency has been compared with other methods. The modification made to the original method of T. Krieger et al.\textsuperscript{5,12} are: (1) the values of the input parameters are sampled from a continuous interval rather than from two discrete levels, and (2) the reference point is dealt with in the same way as any other data point.

The matrix method assumes a linear relationship between the input and output variables:

$$X\Delta = \bar{y},$$ \hspace{1cm} (2)
where the components of \( \tilde{y} \) are the \( n \) output values (of a safety-analysis code), the components of \( \tilde{a} \) are the \( m \) \((m > n)\) unknown sensitivity coefficients, and \( X \) is a rectangular matrix of dimension \( n \times m \) with elements \( X_{ij} \) determined by the values of the input parameters in all \( n \) cases. An estimate for \( \tilde{a} \) is the special solution

\[
\tilde{a}_p = X^T(XX^T)^{-1} \tilde{y},
\]

(3)

where \( X^T \) is the transpose of \( X \). Equation 3 yields estimates for all \( m \) components of \( \tilde{a} \) even if the number of data in Eq. 2 is \( n < m \). The estimate \( \tilde{a}_p \) minimizes the sum

\[
\sum_{j=1}^{m} a_{pj}^2.
\]

(4)

In regression analysis, the starting equation is

\[
\tilde{y} = X\tilde{a} + \varepsilon,
\]

(5)

where \( m < n \) and the components \( \varepsilon_i \) of \( \varepsilon \) are the residual errors of the regression model. The least-squares solution

\[
\tilde{a}_{\text{ls}} = (X^TX)^{-1}X^T\tilde{y}
\]

(6)

now yields the minimum of

\[
\sum_{i=1}^{n} \varepsilon_i^2.
\]

(7)

The "spuriousness" referred to in Chapter II.D is defined in SCREEEN as

\[
\sqrt{\frac{1}{n-m} \sum_{i=1}^{n} \varepsilon_i^2 \cdot SENS^2 - \frac{\sigma^2}{\sigma_0}^2},
\]

(8)
where $a_0^2$ is the variance of the original raw data, $(\bar{y})$ and $\text{SENS}^2$ is a sensitivity measure of the regression model, closely related to

$$\sum_{i=1}^{m} a_i^2 s_i.$$  \hspace{1cm} (9)

The standard stepwise regression analysis using minimum residual error criterion only, Eq. (7), sometimes fails to identify an important input variable. The spuriousness criterion, Eq. (8), is provided in SCREEN as an alternative criterion for selecting seed groups of variables in each step of the regression procedure, to minimize the likelihood of missing important variables.

It may be worth mentioning that in our case the data $\bar{y}$ is free from random errors in the usual sense since it is obtained with a deterministic computer code that always produces the same $\bar{y}$ from the same input $X$. The error $\bar{e}$ in this case, Eq. (5), is due to the fact that our model $X\bar{a}$ is incomplete in general, due to both a limited number of parameters used, and the assumed form of dependency. The randomness of $\bar{e}$ is due to the fact that the input $X$ is randomly sampled. Nevertheless, the standard equations and arguments of correlation and regression analysis can be followed, and the input parameters that yield a good fit are natural candidates for significant parameters. Some extra test runs may be needed at the end to demonstrate the significance.

F. **Threshold Effect Analysis**

The SCREEN code also includes techniques to identify input variables that contribute to threshold effects (discontinuities) of an output variable. Examples to these discontinuities in fast reactor safety analysis are the super-prompt criticality and the molten fuel-coolant interaction in hypothetical accidents: these thresholds may not be exceeded in the "base case" analysis, but variations in input parameter values can lead to the undesirable side of a threshold. It is important to determine which input variables most likely bring the accident scenario across the boundary. Many consequences are discontinuous across such boundaries, since quite different physical
phenomena may dominate on different sides of the threshold. Therefore, the correlation and regression methods developed earlier can be misleading or ineffective.

The techniques developed here are based on statistical testing of the differences of the conditional distributions of the input variables on both sides of a threshold. The method is again aimed for codes that have a large number of input variables so that studying the sensitivities one by one would be prohibitively expensive. The procedure uses the same data as the correlation and regression analysis, i.e., a reasonably small number $n < 100$ output values, calculated with randomly sampled input value combinations. The input variables $X_i$ (i = 1, 2, ..., m) are sampled from probability density functions $p_i(X_i)$, defined in Table I. The criterion function $y(X)$ for a threshold, such as the maximum reactivity or the interface temperature, has a conditional probability distribution $P(y > a | X_i) = \text{probability that } y \text{ is greater than a given critical value, } a, \text{ given that input variable no. } i \text{ has a value } X_i$

Based on the theory of conditional probabilities, the conditional density of $X_i$ is

$$q_i(X_i | y > a) = \frac{P(y > a | X_i)p_i(X_i)}{P(y > a)}$$

where $P(y > a)$ is the unconditional distribution of y,

$$P(y > a) = \int P(y > a | X_i)p_i(X_i)dX_i.$$  

Now, if $y$ does not depend on $X_i$, $P(y > a | X_i) = P(y > a)$, and Eq. (10) yields $q_i = p_i$, i.e., the density of $X_i$ does not depend on whether $y > a$ or $y < a$. On the other hand, the more $y$ depends on $X_i$, the more we expect $q_i$ to deviate from $p_i$. The basis of the technique is to compare the characteristics of $q_i$ and $p_i$ (i = 1, 2, ..., m) and determine for which $i$ they are significantly different, thereby revealing parameters that contribute most to the threshold effect.
The condition $y > \alpha$ divides the sample of $n$ accident analysis cases into subsets $C_1$ with $n_1$ cases ($y < \alpha$) and $C_2$ with $n_2 = n - n_1$ cases ($y > \alpha$). For example, a sample may include $n_1$ super-prompt-critical versus $n_2$ non-prompt-critical cases. The $n$ values of a particular input parameter $X_i$ are originally sampled from $p_i$ for all $n$ cases, but the sample mean value of the values in the subset $C_1$ is different from the mean value in the subset $C_2$. Differences in the standard deviations and extreme values can also be tested with the SCREEN code. Significant differences imply the importance of $X_i$ to the particular threshold effect. For example, the following characteristic is calculated in SCREEN for all $i = 1, 2, ..., m$ and tested for significance 14:

$$t_i = \frac{(m_1 - m_2) \left[ n_1 n_2 (n - 2) \right]^{1/2}}{\left[ n(n_1 s_1^2 + n_2 s_2^2) \right]^{1/2}},$$

where $m_1$ and $m_2$ are the sample mean values of $X_i$ in the subsets $C_1$ and $C_2$, respectively, and $s_1$ and $s_2$ are the sample estimates for the standard deviations in the subsets. The parameters $t_1$ is tested against a Student's $t$ distribution with $n-2$ degrees of freedom. Other tests are also available for comparing $m_1$ with the total sample mean, and for comparing $s_1^2$ or $s_2^2$ with the original sampling variance. The parameters $t_2$ to be tested against a $t(n_1 - 1)$ distribution is

$$t_2 = \frac{m_1 - m}{\frac{\sqrt{(n_1 - 1)(n_1 + n_2)}}{n_2}},$$

where $m$ is the sample mean value = ($n_1 m_1 + n_2 m_2$)/$n$. The parameter $t_1$ is used when the criterion separating the two subsets is very clear and there is no uncertainty as to what subset each case belongs to. The parameter $t_2$ is used if only one subset ($C_1$) is "pure", while the complement subset $C_2$ may include cases that actually belong to the first subset.

An extreme value test is available for the smallest (or largest) value of $X_i$ in subset $C_1$, compared to that in the total sample. The test statistic is
\[ z_{\text{extr}} = \frac{\text{Max} \left\{ \frac{\text{Min}(z_j) - z_{j_2}}{C_1}, \frac{\text{Max}(z_j) - z_{j_1}}{C_1} \right\}}{\sigma_j}, \]

where \( z_{j_1} \) and \( z_{j_2} \) are the largest and smallest values of \( z_j \) in the total sample of \( n \) cases, and \( \sigma_j \) is the standard deviation of \( z_j \). Extreme-value distributions are used in SCREEN for testing \( z_{\text{extr}} \). The code calculates \( t_1 \), \( t_2 \), and \( z_{\text{extr}} \) for all input variables and lists 20 largest values of each.
III. CODE VALIDATION

To demonstrate the efficiencies of the screening methods, a problem with a known correct solution was analyzed. An example with 500 input variables was analyzed from 40 runs. The input variables $x_i$ ($i = 1, \ldots, 500$) were normalized and uniformly distributed between 0 and 1. The four output variables used in this study were

$$ y_j = f_{j1} + 2f_{j2} + 3f_{j3} + 4f_{j4} + 5f_{j5} + e(\bar{x}); \quad j = 1, 2, 3, 4, \quad (13) $$

where

$$ f_{1i} = x_i, \quad f_{2i} = x_i^2, \quad f_{3i} = (x_i - 1/2)^2, \quad \text{and} \quad f_{4i} = x_i x_{i-1}. \quad (14) $$

The term $e(\bar{x})$ is a "background" that depends on the input variables $x_6, \ldots, x_{500}$ and contributes about 25% of the total variation of $y_j$. Evidently, the correct order of importance of the input variables is No. 5, 4, 3, 2, 1, with the rest of the variables less important than $x_1$. The orders of importance obtained with different screening methods are listed in Table III for output variable $y_2$. Even in this case with a nonlinear (but monotonic) $y_2$, the correlation methods, as well as the matrix method of T. Krieger et al., work relatively well, about as well as for the linear output $y_1$.

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Matrix Method</th>
<th>Stagewise Correlation</th>
<th>Successful Regression Analyses/Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficients</td>
<td>Method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4-5/ME, MS</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>4</td>
<td>3-4-5/ME</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2-4-5/MS</td>
</tr>
<tr>
<td>4</td>
<td>297</td>
<td>280</td>
<td>3-4-5-254/ME</td>
</tr>
<tr>
<td>456</td>
<td>194</td>
<td>195</td>
<td>2-3-4-5/MS</td>
</tr>
<tr>
<td>297</td>
<td>425</td>
<td>2</td>
<td>2-3-4-5-300/ME</td>
</tr>
<tr>
<td>239</td>
<td>456</td>
<td>202</td>
<td>2-3-4-5-425/MS</td>
</tr>
<tr>
<td>340</td>
<td>3</td>
<td>306</td>
<td>2-3-4-5-MS</td>
</tr>
<tr>
<td>123</td>
<td>123</td>
<td>51</td>
<td>2-3-4-5-MS</td>
</tr>
<tr>
<td>51</td>
<td>84</td>
<td>349</td>
<td>2-3-4-5-MS</td>
</tr>
</tbody>
</table>


ME: This group yields minimum residual error.

MS: This group yields minimum spuriousness.
The regression analysis with an increasing number of parameters clearly confirms the first three parameters and indicates that \( x_2 \) is also an important candidate. The statistics of 40 cases is not enough to identify \( x_1 \) as an important contributor. The standard stepwise regression analysis using minimum residual error criteria only (ME in Table III) missed input variable \( x_2 \) as an important one. The spuriousness referred to by MS in Table III is defined in Eq. (8).

For the nonlinear, nonmonotonic output variables \( y_3 \) and \( y_4 \), neither the matrix method nor the correlation methods yield any significant results; the regression analyses are essential. The results obtained for \( y_3 \) are given in Table IV. For \( y_4 \), the regression analysis was equally effective. These analyses were also performed for an increased number of runs and demonstrated that the efficiency of all methods improves with increasing sample size.

**TABLE IV. Results for \( y_3 \) by Successive Regression**

<table>
<thead>
<tr>
<th></th>
<th>4-5/ME</th>
<th>2-3-4-5/ME, MS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5-280/MS</td>
<td>2-3-4-5-380/ME</td>
</tr>
<tr>
<td></td>
<td>3-4-5/ME</td>
<td>2-3-4-5-429/MS</td>
</tr>
<tr>
<td></td>
<td>2-4-5/MS</td>
<td></td>
</tr>
</tbody>
</table>

The relative rankings of the input variables 1-5 with these three methods are presented in Figs. 2, 3, 4 for the nonlinear but monotonic output variable \( y_2 \). Short horizontal lines in these figures indicate variables 6 to 500, which are known not to be really important ones. The correct ranking 5-4-3-2-1 is almost obtained by the stagewise correlation method with a sample size of 80, as indicated in Fig. 3.
Fig. 2. Ranking by Correlation Coefficients.
Fig. 3. Ranking by Stagewise-correlation Method.
Fig. 4. Ranking by Matrix Method.
In Figs. 2 and 4, variable 1 is not identified. The following conclusions can be drawn from these results:

1. There is a critical sample size (30-40 in this case) at which the correlation method can identify an effective input variable.

2. Even below the critical sample size, the matrix method ranks important variables toward the top of the list.

3. Above the critical sample size, the stagewise correlation method seems to be most effective. The matrix method and the correlation coefficients yield about identical results.

4. The successive regression analyses are essential for identifying input variables with nonlinear or nonmonotonic impact on the output (Table IV).

The threshold effect analysis, described in Chapter II.F, have also been demonstrated by using the same example of 500 input parameters and the functions $y_1$ and $y_2$ defined in Eq. (13). Notice that the criterion function $y$ can be continuous across the threshold, but does not have to be. The order of importance obtained for the input variables with test thresholds $y_1 > 3.0$, 2.0, 1.0 and 0.0 are given in Table V. The sample sizes are $n_2 = 11, 22, 34, 42$.

<table>
<thead>
<tr>
<th>$y_1 &gt; 3.0$</th>
<th>$y_1 &gt; 2.0$</th>
<th>$y_1 &gt; 1.0$</th>
<th>$y_1 &gt; 0.0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n_2 = 11$</td>
<td>$n_2 = 22$</td>
<td>$n_2 = 34$</td>
<td>$n_2 = 42$</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>301</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>490</td>
<td>3</td>
</tr>
<tr>
<td>383</td>
<td>490</td>
<td>5</td>
<td>135</td>
</tr>
<tr>
<td>123</td>
<td>331</td>
<td>2</td>
<td>490</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>171</td>
<td>2</td>
</tr>
</tbody>
</table>
and 42 in these cases (n = 80). The tests seem to be effective even with a relatively small subset, compared to the number of input variables (m = 500). Similar results were obtained with $y_2$. A few additional runs varying just the parameters at the top of the list would confirm which ones are really important (i.e., revealing parameters 5, 4, 3, 2). The number of computer runs needed in this technique is small compared to one-at-a-time studies. It should be mentioned also that the subset sample sizes ($n_2$) were too small for the correlation methods to identify important variables in these cases. Thus, testing subset statistics seems to be an effective way to identify input variables causing threshold effects. In an actual application, this technique has revealed that a high fuel swelling rate and initial porosity caused excessive steady-state temperatures in a fast reactor analysis with the SAS3D code.

With a nonmonotonic criterion function $y_3$ the mean value test is not effective, whereas tests based on comparison of standard deviations of the subsets are more effective.
IV. APPLICATIONS

The SCREEN code has been applied to Venus-II, a fast reactor disassembly-analysis code. The system analyzed was a demonstration-size LMFBR with a nominal power of 975 MWt. The postulated disassembly analysis was started from an elevated power and temperature level, assuming a voided core due to sodium boiling prior to the disassembly. Thirteen input parameters were varied in this study within the regions of variation given in Table VI. Experimental and theoretical evidence was used to determine the uncertainties for the material-property characteristics (A, B, F, H, I, J, K, L). The values in Table VI are assumed to represent approximately 99% confidence limits. For the initial-conditions variables (C, D, E, G, M), somewhat arbitrary uncertainty intervals were selected. For example, the reactivity ramp rates 50-90 $/s are higher than what is usually considered a best estimate value for a CRBR-type reactor. Higher values were selected in this study mainly to cut down computer time.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
<th>Nominal Value</th>
<th>Variation/Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Fuel vapor pressure factor</td>
<td>ANL-EOS(^a)</td>
<td>Factor 1/2 to 4</td>
</tr>
<tr>
<td>B</td>
<td>Heat capacity of fuel</td>
<td>0.437 kJ/kgK</td>
<td>± 12%</td>
</tr>
<tr>
<td>C</td>
<td>Radial restraint pressure</td>
<td>10* pascals</td>
<td>± 50%</td>
</tr>
<tr>
<td>D</td>
<td>Initial reactivity</td>
<td>1.0 dollar</td>
<td>± 20%</td>
</tr>
<tr>
<td>E</td>
<td>Reactivity insertion rate</td>
<td>70 dollar/s</td>
<td>± 20 dollars/s</td>
</tr>
<tr>
<td>F</td>
<td>Neutron generation time</td>
<td>0.5 us</td>
<td>± 20%</td>
</tr>
<tr>
<td>G</td>
<td>Initial power</td>
<td>50 P(_0)(^b)</td>
<td>± 50%</td>
</tr>
<tr>
<td>H</td>
<td>Heat of fusion of fuel</td>
<td>230 kJ/kg</td>
<td>± 5%</td>
</tr>
<tr>
<td>I</td>
<td>Doppler coefficient</td>
<td>-0.000435</td>
<td>± 20%</td>
</tr>
<tr>
<td>J</td>
<td>Density of fuel</td>
<td>9152 kg/m(^3)</td>
<td>± 2%</td>
</tr>
<tr>
<td>K</td>
<td>Density of sodium</td>
<td>843 kg/m(^3)</td>
<td>± 1%</td>
</tr>
<tr>
<td>L</td>
<td>Density of steel</td>
<td>7787 kg/m(^3)</td>
<td>± 1%</td>
</tr>
<tr>
<td>M</td>
<td>Initial fuel temperature (ave.)(^c)</td>
<td>2900 K</td>
<td>± 200%</td>
</tr>
</tbody>
</table>

\(^a\) Standard ANL equation-of-state in Venus-II.
\(^b\) P\(_0\) = 975 MW, nominal steady-state power of the reactor.
\(^c\) The melting point is 3040 K.
The screening was performed with respect to five different output variables considered to be meaningful indicators of potential core and vessel damage. These output variables were:

1. Total energy at the end of excursion above operating temperature ($E_t$).
2. Energy in molten fuel at or above melting point ($E_m$).
3. Work potential from isentropic fuel-vapor expansion to 1 atm ($W_1$).
4. Mass of fuel vaporized in expansion to 1 atm ($M_v$).
5. Work potential from isentropic fuel-vapor expansion to the cover gas volume 20 m$^3$ ($W_c$).

The first two can be calculated directly with VENUS-II. To perform the isentropic expansion work and vapor calculation, a subroutine developed earlier$^{16}$ was added to the VENUS-II code. The same equation of state (and input variables A and B) was used in the isentropic expansion calculation as was used in the VENUS-II disassembly phase.

Detailed damage-potential studies have shown the $W_c$, expansion work to cover-gas volume, is quantitatively the best measure of the damage potential. If the transient leads to the failure of the primary vessel, the fuel vapor is released to the containment building. In that case, $M_v$ is a measure of the total source of radioactivity. For this reason, $W_c$ and $M_v$ are considered as the most relevant consequence variables.

Since we have 13 input variables, 14 runs with VENUS-II would be needed to solve all linear sensitivities. A complete second-degree model would have 105 coefficients to be solved. In this work, we decided to study how much information the screening procedure is able to extract from $N = 40$ cases, with randomly selected input values within the uncertainty intervals indicated in Table VI. To cover the region of interest, the values were sampled from
uniform sampling distributions for all input variables B through M and for a logarithmic variable \( a = \ln(A)/69.979 \) within the interval 0.99-1.02, which corresponds to a factor 1/2 to 4 for A.

Table VII summarizes the output-variable statistics. The ratios \( E_t/E_m, E_m/M_v, \) and \( W_l/W_c \) have small variations around the mean values, as compared with the large variations of the individual consequences. This indicates strong correlation between the consequence variables. The correlation between \( M_v \) and \( W_c \) can be presented as

\[
M_v = 780 \text{ kg} + 5.5\frac{W_c}{\text{MJ}} + \epsilon.
\]

where the "scatter" \( \epsilon \) has a standard deviation of 150 kg.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
<th>Mean Value</th>
<th>Standard Deviation</th>
<th>Largest Value</th>
<th>Smallest Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E_t )</td>
<td>Total energy generated (MJ)</td>
<td>9579.</td>
<td>1472.</td>
<td>12710.</td>
<td>6635.</td>
</tr>
<tr>
<td>( E_m )</td>
<td>Energy in molten fuel (MJ)</td>
<td>8070.</td>
<td>1340.</td>
<td>11400.</td>
<td>5450.</td>
</tr>
<tr>
<td>( W_l )</td>
<td>Expansion work to 1 bar (MJ)</td>
<td>990.</td>
<td>343.</td>
<td>1859.</td>
<td>417.</td>
</tr>
<tr>
<td>( M_v )</td>
<td>Mass of vaporized fuel (kg)</td>
<td>2000.</td>
<td>463.</td>
<td>3046.</td>
<td>1117.</td>
</tr>
<tr>
<td>( W_c )</td>
<td>Expansion work to 20m³ (MJ)</td>
<td>220.</td>
<td>89.</td>
<td>485.</td>
<td>82.</td>
</tr>
<tr>
<td>( E_t/E_m )</td>
<td></td>
<td>1.19</td>
<td>0.06</td>
<td>1.40</td>
<td>1.09</td>
</tr>
<tr>
<td>( E_m/M_v )</td>
<td></td>
<td>4.11</td>
<td>0.38</td>
<td>5.30</td>
<td>3.48</td>
</tr>
<tr>
<td>( W_l/W_c )</td>
<td></td>
<td>4.61</td>
<td>0.60</td>
<td>5.90</td>
<td>3.80</td>
</tr>
</tbody>
</table>
The results of the screening process are presented in Table VIII for the work potential $W_c$. Listed are the input variables for which the F test indicated higher than 99% confidence. Variables identified at the 95% level are given in parentheses. The last column gives the residual errors of successive quadratic regression models and may be compared to the standard deviation of 89 MJ of the original raw data.

The results indicate that the uncertainties of the reactivity ramp rate (E) and Doppler coefficient (I) are most important to the uncertainty of the damage potential, but the heat capacity of the fuel (B) and the initial power level (G) are also effective. The group of six input variables, E, I, B, F, G and A, accounts for 99% of the total variance of $W_c$. The relative importance values of these variables in the order given are 1.00, 0.78, 0.53, 0.40, 0.35, and 0.28. These relative values include contributions from all terms in which the input variable appears, i.e., linear, quadratic, and product terms. The second-degree regression function (response surface) of these six variables is graphically presented in Fig. 5. The heat capacity B seems to become more important if the nominal value is increased. Increasing the initial power (G) or the Doppler coefficient (I), or decreasing the fuel-vapor pressure (A), would increase the sensitivities to these variables.

To verify the screening results, a conventional sensitivity analyses was carried out by varying input parameters one at a time. The most important sensitivities of $W_c$ are presented in Fig. 6. The variations of the input parameters in these calculations were 40-80 $\$/s for the ramp rate (E), 2740-3140 K for the average fuel temperature (M), factor 1-8 for the fuel-vapor pressure ($a = 1.00$ to 1.03), and the intervals of Table VIII for the rest of the input variables.

The results in Fig. 6 confirm the screening results of Fig. 5, but also reveal some features due to a different reference point. For example, increasing the initial fuel temperature (M) above the reference (melting) point increases the computation time considerably, due to short time steps requested by early vaporization and displacement-reactivity feedback. If larger variations above the melting point are realistic, then M belongs to the
group of important input variables. \( W_c \) is a nonmonotonic function of both \( A \) and \( M \).

The work potential \( W_c \) as a function of the heat capacity \( B \) is almost constant below the reference point, but increases rapidly above the reference value. Transformations can be used to linearize such behavior and further improve the accuracy of the response surface.

### TABLE VII. Orders of Importance Obtained with Different Methods for Output Variables \( W_c \)

<table>
<thead>
<tr>
<th>Correlation Coefficient</th>
<th>Stagewise Correlation</th>
<th>Successive Regression Analyses/Criteria</th>
<th>Residual Mean Square Error (MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>E</td>
<td>E-I/ME,MS(^a)</td>
<td>44.</td>
</tr>
<tr>
<td>(I)</td>
<td>I</td>
<td>E-I-B/ME</td>
<td>37.</td>
</tr>
<tr>
<td>(B)</td>
<td>A</td>
<td>E-I-A/MS</td>
<td>41.</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>E-I-B-F/MS</td>
<td>28.</td>
</tr>
<tr>
<td>(B)</td>
<td>E-I-B-A-F/ME,MS</td>
<td></td>
<td>16.</td>
</tr>
<tr>
<td>(K)</td>
<td>E-I-B-F-G-A/ME,MS</td>
<td></td>
<td>7.</td>
</tr>
</tbody>
</table>

\(^a\)ME = This group yields minimum residual error.

\( MS = This group yields minimum spuriousness. \)
Fig. 5 Best Regression Function of the Work Potential $W_c$. 
Fig. 6. Individual Sensitivities of the Work Potential $W_C$. 
The same data of 40 random cases used with SCREEN was also used with PROSA-2. It determined the response surface of \( W_c \) in terms of the six input variables identified by SCREEN and confirmed the regression coefficients. Then PROSA-2 was used to generate the probability distribution of \( W_c \) from 40,000 samples calculated from the response surface. The result is presented in Fig. 7. The horizontal error bar in Fig. 7 indicates that accuracy of the response surface. Since the sample of 40,000 is large, virtually no vertical error is present. The distribution of the 40 original random cases calculated with Venus-II (+ expansion subroutine) is also presented in Fig. 7. For this, the vertical error bars are large due to the small sample. Included in Fig. 7 is also a log-normal distribution fitted to the original 40 cases. However, no theoretical basis is known for the log-normal distribution in this case. The response surface simulation is preferable due to its superior overall accuracy.

The results of Fig. 7 were obtained using the original uniform distributions for the input variables. PROSA-2 can also use sampling distributions that are different from those used to select the original data points. In curves 1 and 2 of Fig. 8, the input variables have the same standard deviations but different distributions, uniform in curve 1 and normal in curve 2. Curve 3 was obtained with normal input distributions but standard deviations reduced so that the original 99% uncertainty intervals of the input variables correspond to \( \pm 2.58 \) standard deviations. Curve 3 in Fig. 8 represents a realistic distribution of the work potential in this example.

Similar sensitivity studies were performed for other output variables of Table VII. For \( M_v \), the screening gave the order of importance \( E, I, B, A, F, G \), with relative importance values \( 1.00, 0.78, 0.77, 0.47, 0.41, \) and \( 0.25 \), respectively. The main reason for the "scatter" \( \epsilon \) in Eq. 14 is that the fuel-vapor pressure uncertainty \( (A) \) and the specific heat \( (B) \) contribute more to \( M_v \) than to \( W_c \), i.e., \( \epsilon = \epsilon(A, B) \). A one-at-a-time sensitivity study confirmed these screening results. Figure 9 indicates that \( M_v \) in terms of \( A \) and \( B \) has a different behavior from that of \( W_c \) in Fig. 6.
Fig. 7. Probability Densities of the Work Potential $W_c$ with Uniform Sampling Densities for the Input Parameters.
Fig. 8. Probability Densities of $W_c$ with several Input Parameter Distributions.
Fig. 9. Sensitivities of the Mass of Fuel Vaporized, $M_v$. 
Fig. 10. Sensitivities of the Energy in Molten Fuel, $E_m$. 
Fig. 11. Sensitivities of the Total Energy, $E_t$. 
For the other consequences $W_1$, $E_m$, and $E_t$, the equation-of-state variables $A$ and $B$ turn out to be as important as $E$ and $I$, respectively. The most important sensitivities of $E_m$ are presented in Fig. 10 and those of $E_t$ in Fig. 11. The total energy $E_t$ is very sensitive to the initial temperature $M$, whereas $E_m$ is not. The total energy $F_t$ is proportional to the specific heat ($B$), a behavior very different from that of $W_C$ in Fig. 6.

In summary, this study shows that the screening process reliably identifies important input variables for a safety-analysis code such as VENUS-II. This work also revealed some nonlinearities and sensitivities that were not evident from earlier sensitivity studies made on VENUS-II. Concerning material properties in particular, there seems to be some justification for attempts to determine the fuel specific-heat parameter ($B$) and the vapor pressure ($A$) more accurately than they are currently known. However, the uncertainty of $A$ may be somewhat overestimated in Table VI. Use of a smaller uncertainty would reduce the sensitivity importance of $A$. The Doppler coefficient ($I$) and the reactivity ram, rate ($E$) currently cause most of the uncertainties in the disassembly damage potential. Thus, the greatest emphasis in the modeling should be directed toward determining correct conditions at the beginning of the disassembly calculation.
V. USER'S MANUAL FOR SCREEN

A. Program Summary

The program performs the following main functions:

1. The program selects values for the input parameters of a deterministic computer code from input-specified regions of interest. The regions are defined by probability distributions and confidence intervals. The program arranges the input values into combinations called "knot-points".

2. With output values ("consequences") from the deterministic code for each input-parameter combination provided above, the program identifies most important input parameters by using (1) stagewise correlation analysis, (2) successive regression analyses and (3) statistical testing of subset characteristics. The regression models used and evaluated are multi-variable second-degrees polynomials.

3. Produces input cards in correct format to a response surface analysis and simulation code PROSA-2, that calculates probability distributions of the output variables ("consequences").

The first step can be omitted if the user wants to use his own design of knot-points. The second and third steps would still be usable for screening and response surface calculations. Step three can be omitted if PROSA-2 will not be used.

The SCREEN code has been used mainly in conjunction with accident-analysis codes, but the methods and the programming are completely general and not limited to such applications.
B. Program Abstract

This program abstract is provided in the form recommended by the National Energy Software Center.

1. **Name of Program**: SCREEN

2. **Computer for Which Program is Designed**: IBM 370/195

3. **Description of Problem**: The problem is to determine a group of most important input parameters of a computer code when the total number of input variables is large, so large that standard sensitivity evaluations varying each input variable (one or two at a time) would be prohibitively expensive.

4. **Method of Solution**: As input data, the program needs the probability distributions and/or a specified interval for the input parameters of the deterministic computer code being evaluated. The first part of the program calculates input value combinations (knot-point coordinates) that serve as input for the deterministic code that calculates the values of interesting output variables (consequences) in the specified knot-points.

   The output/consequence values in the knot-points are used in the second part of SCREEN to determine (1) which input variables are most correlated with the output/consequence values, using stagewise correlation techniques, (2) which input variables most likely contribute to discontinuities or threshold effects in the output variables, using statistical tests for subset characteristics, and (3) which group of input parameters yields the best significant regression model, using quadratic models and successive regression analyses with increasing number of parameters. The regression part evaluates all regressions of two variables and uses the principle of stepwise regression analysis for larger number of variables. A special feature is that both residual errors and special sensitivity/spuriousness indexes can be used when selecting seed input variables for each step of the regression analysis. The significance of each added parameter of a model can be assessed by
F-statistics for regression models. The Students t-statistics and extreme value statistics are used for threshold effects testing.

5. Restrictions on the Complexity of the Problem: The maximum number of variable input parameters and consequence (output) variables that can be analyzed simultaneously are 1000 and 6, respectively. The restriction of six output variables is not serious since separate screening runs can be done for any additional consequence variables of interest.

When selecting the cases to be run (knot-points, in the first part of SCREEN) eight optional distributions are available for the input parameters, including uniform, exponential, normal, truncated normal, log-normal and beta distributions. Values for the input parameters are sampled from these distributions so that mutual independence of the parameters is preserved. This is important for the success of the correlation and regression procedures. (Correct correlations between input parameters, if any, can be applied when calculating probability distributions with the PROSA-2 code after the screening procedure).

6. Typical Running Time: The running time depends strongly on the size of the problem, i.e., number of input parameters (NTOT), knot-points (NRANKP) and the number of regression steps needed to complete the screening. For small problems (NTOT, NRANKP < 50) the total running time is typically a few seconds whereas large problems (NTOT ~ 500, NRANKP ~ 50) take several minutes per consequence (IBM 370/195).

7. Unusual Features of the Program: Compared to other screening techniques available the SCREEN program has several features that are somewhat unique.

   (1) The values of the input parameters (knot-point coordinates) are selected from a continuous distribution rather than from discrete levels. This provides information more evenly from the whole region of interest, and it also facilitates the use of nonlinear models. However, the user may also select his own design.
(2) Quadratic regression models are used, rather than linear models.

(3) The total number of input variables (NTOT) may be much larger than the number of cases (NRANKP), and no prior elimination of variables by judgement is needed.

(4) The regression analysis in SCREEN is more extensive than the standard stepwise regression analysis procedure. All regressions are calculated with one-and two-parametric models, whereas stepwise procedure is used for multiparametric models. At each step the residual error criterion as well as a special sensitivity/spuriousness criterion (developed in this work) can be used for selecting seed parameters for the next step. This provides redundancy and confidence that significant models, parameter combinations, are not missed (as it is known to happen sometimes when the standard stepwise process is applied routinely).

(5) Extreme value and t-tests are used to identify parameters important to threshold (discontinuity) effects.

8. Related and Auxiliary Programs: The SCREEN code can be used in conjunction with any separate deterministic code (typically an accident-analysis code) that provides data for screening.

The SCREEN code can also be used to generate input data for a response-surface analysis code PROSA-2 in correct format. However, SCREEN is a stand-alone code and does not need PROSA-2 for screening.

9. Status: SCREEN is operational at ANL and will be released to the National Energy Software Center.


12. **Programming Language Used**: FORTRAN IV.

13. **Operating System**: IBM System 370/Model 19', Fortran IV (G) or (H) compiler with optimizer.

14. **Other Programming or Operating Information or Restrictions**:

   a. The program contains some FORMAT statements in the T Format code as well as ERR= and END= operands in a READ statement. These are IBM extensions to ANSI FORTRAN.

   b. The program calls uniform random numbers U (between 0 and 1) by the statement.

   
   \[ U = FLTRNF (0). \]

   The FLTRNF function subprogram is a private library routine at ANL and should be provided separately in installations outside of ANL. Other random variates are calculated from U in the SCREEN code.

   c. Fixed dimensions cannot be used for the arrays (vectors and matrices) used in the regression analysis, because their size is determined by the number of parameters, knot-points and consequence variables in each job. Therefore, space for these arrays in the computer is organized using dynamic allocation. The main program SCREEN calls ANL library subroutines ALLOC2 and FREE2 that allocate and release correct space for the arrays that may vary from job to job.

15. **Name and Establishment of the Author**: J. K. Vaurio, FRSTMC, Argonne National Laboratory, Bldg. 207, 9700 South Cass Avenue, Argonne, Illinois 60439.

17. **Category**: P, General Mathematical and Computing System Routines.

18. **Keywords**: Accident analysis, correlation, disassembly, discontinuity, probabilistic, random, regression, response-surface, risk, safety, sampling, screening, sensitivity, spuriousness, statistical, stepwise, threshold, VENUS.

C. **Program Use**

SCREEN can be directed to perform different tasks. The task to be executed is specified by the input variable JOBS. The tasks are described in Section IV.C.1. The input for each task is specified in Section IV.C.2. The flow diagram of the program is presented in Section IV.C.3, and the function of each subroutine is briefly described in Section IV.C.4.

1. **Task Descriptions**

Each execution of the program performs one of the following tasks, specified by the input variable JOBS. After each task, the program control returns to the beginning and a new job starts (if not stopped by an END-OF-FILE).

**Task 1 (JOBS = 1): Knot-point Coordinates**

1. Reads in distributions of all NTOT input parameters.

2. Calculates variation intervals for all input parameters based on the probability range variable PROB and the distributions of the parameters.

3. Randomly samples NRANKP sets of values for the NTOT input parameters (from the distributions within the intervals determined above). These sets, i.e., input value combinations, are called knot-points.
(4) Prints and punches the knot-points, in a generic format as well as in the format determined in Subroutine SASIN.

(5) If TEST = 0, returns control to the beginning and starts a new job (if not stopped by an EOF).

(6) If TESTS = 1, calculates "consequences" in the knot-points using test subroutine TEXASS, and prints and punches these consequences. (This output can serve as input in later Tasks).

Task 2 (JOBS = 2): Stagewise correlation and subset properties

(1) Reads in consequences as well as coordinates (values of input parameters) for the NRANKP knot-points.

(2) Calculates mean values and standard deviations of the consequences and input variables (from the sample of NEWNKN or NRANKP cases), as well as the largest and smallest value of each consequence in the subset of NEWNKN cases. The histograms of the consequences are also calculated from the sample, and edited.

(3) Calculates and edits 20 largest correlation coefficients between a consequence variable and the input parameters.

(4) Subtracts the impact of the most correlating parameter from the original consequence data, and calculates the largest correlation coefficients between the residual consequence variable and the input parameters. Edits 20 largest coefficients for the residual consequence.

(5) Repeats the substraction and correlation analysis (stagewise correlation analysis) down to fourth residuals, for each consequence variable. Standard deviations of the residual consequences are also printed out, as well as F - statistics variables for significance testing.
(6) Calculates and edits 30 largest correlation coefficient between input parameters from the sample. (Since in the sampling in Task 1, input variables are mutually independent, the correlations between them as calculated from the sample of size NRANKP are due to statistical variations rather than real. A large coefficient between input variables that both appear high in the stagewise correlation lists is a warning that both may not really be important).

(7) Calculates characteristics of the input parameters in the subset of NEWNKN cases, compared to all NRANKP cases, to determine which input parameters may be important for causing a case to belong (or not belong) to the subset. These characteristics include 1) the deviation of the subset average from the true average, scaled by the standard deviation, 2) two Student's t-variables for testing the difference of two sample mean values, 3) deviations of the largest and smallest values in the subset from those in the total sample, 4) order statistics probabilities for these deviations. Based on these characteristics for all NTOT input parameters, 20 candidate parameters are listed that most likely cause or contribute to the subset categorization.

(8) Returns control to the beginning and starts a new job (if not stopped by an EOF).

Task 3 (JOBS = 3): Regression analyses with two variables

Task 3 performs a series of successive regression analyses.

(1) In subroutine GROUP1, performs least squares fitting of quadratic single-variable functions of the consequence variables. NTOT fittings are performed for each of the NCONS consequence variables, since the free (independent) variable goes one by one through all input
variables. The residual errors of each fit are calculated and 20 best
fitting input parameters are listed. The total sensitivities of all
fits are also calculated, and the spuriousness indeces are edited.

(2) If JOBS3G > 2, subroutine GROUP2 performs least squares fitting of
quadratic two-variable functions to the consequence variables. One of
the two variables is the one that gave the best fit in GROUP1, the other
one varies going through all other input parameters. The best fits by
residual errors, spuriousness indeces and error statistics are edited.
Then the permanent member of the variable pair is changed to the one
that gave the smallest residual error, and the process is repeated.

(3) If JOBS3G > 3, subroutine GROUP3 performs a procedure similar to GROUP2,
except that minimum spuriousness is the criterion in selecting new seed
variables (permanent members of the variable pairs).

(4) If JOBS3G > 4, subroutine GROUP4 fits quadratic functions of two
variables to the consequence variables, going through all parameters
pairs, and calculates residual errors, lists 20 best fits and edit also
spuriousness indeces. The total number of fits is NTOT x (NTOT - 1)/2.
GROUP4 is more complete and time consuming, than subroutines GROUP1, 2,
or 3.

(5) Calculates linear sensitivity estimates using essentially the matrix
methods approach of Refs. 5 and 12. (This option is provided for making
comparisons and testing the efficiency of various procedures). One
hundred input parameters with highest sensitivity estimates are listed
(all if NTOT < 100).

Task 4 (JOBS = 4): Successive regression analyses

Task 4 performs a series of least-squares fittings of multivariate
second-degree functions. Since it would be too expensive in many cases to
perform all possible regressions with more than two variables, the results of Task 3 are first used to select candidate seed input parameter pairs for Task 4. For each seed pair (input parameters no. 15 and 162, for example), Task 4 fits all quadratic functions of three parameters, keeping two of the parameters the same (no. 15 and 162 in the example) and varying the third through all the rest of the input parameters. Task 4 also calculates the residual errors and spuriousness indices of the fitted models, and lists 10 best-fitting triplets of the input parameters, together with information suitable for testing statistical significance of the added (third) input parameter. The sensitivity-importance of each input parameter in the model is also calculated.

The next step in screening is to select seed triplets, and let Task 4 to find best combinations of four input variables, and so on. Several seed groups can be input at the same time to be used in a single run.

**Task 5 (JOBS = 5): Specific regression models**

Task 5 fits multivariate second-degree functions (of user-specified input parameters) to the output (consequence) data and calculates residual errors and spuriousness indices for the fitted models. The sensitivity-importance of each input parameter in the model is also calculated. An arbitrary number of models can be fitted for each output variable in a single computer run.

No screening is performed automatically per se in task 5, i.e., only input-specified combinations of input parameters are used.

**Task 6 (JOBS = 6): Knot-points for PROSA-2**

Task 6 is normally used after the screening (Task 2, 3 or 4) has been completed, to generate input cards in correct format for the PROSA-2
code.\textsuperscript{8,19} Since PROSA-2 is used with a limited number of input variables (the number given by input variable NGPMax) compared to the total number (\textit{NTOT}), task 6 is used to pick up the values of the NGPMax input parameters in the knot-points, and to punch those values in suitable format on cards. As input, task 6 needs the numbers of the SCREEN input parameters that are defined as the input parameters for PROSA-2, as well as all NRANKP knot-point cards used for SCREEN in task 2, 3 and 4.
## 2. Input Instructions

### Card 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTOT</td>
<td>1-4</td>
<td>I4</td>
<td>Total number of input parameters (NTOT &lt; 1000).</td>
</tr>
<tr>
<td>JOBS</td>
<td>5-6</td>
<td>I2</td>
<td>Task indicator (see Sec. IV.C.1).</td>
</tr>
<tr>
<td>PROB</td>
<td>7-16</td>
<td>F10.8</td>
<td>Probability range to select the sampling intervals for knot-point coordinates. Select PROB &lt; 0.1.</td>
</tr>
<tr>
<td>NCONS</td>
<td>17-19</td>
<td>I3</td>
<td>Number of consequence (output) variables (&lt; 6).</td>
</tr>
<tr>
<td>LINIT</td>
<td>21-25</td>
<td>I5</td>
<td>Consequence no. to be started from, in Task 3. (Default = 1).</td>
</tr>
<tr>
<td>JOBS3G</td>
<td>26-30</td>
<td>I5</td>
<td>Indicates what subroutines GROUP1 to GROUP4 are used in Task 3. (Default = 4).</td>
</tr>
<tr>
<td>TEST</td>
<td>34-36</td>
<td>I3</td>
<td>Control variable for testing, using subroutine TEXASS (TEST = 0, 1, 2, 3, 4, 5).</td>
</tr>
<tr>
<td>WORK</td>
<td>37-42</td>
<td>I6</td>
<td>Work number.</td>
</tr>
<tr>
<td>NCORR</td>
<td>43-47</td>
<td>I5</td>
<td>Not in use; set blank or zero.</td>
</tr>
<tr>
<td>NRANKP</td>
<td>53-57</td>
<td>I5</td>
<td>Number of cases, i.e., number of knot-points available (JOBS &gt; 1) or to be selected (JOBS = 1).</td>
</tr>
<tr>
<td>NTRAPA</td>
<td>66-70</td>
<td>I5</td>
<td>Not in use; set blank or zero.</td>
</tr>
<tr>
<td>NTRACO</td>
<td>71-75</td>
<td>I5</td>
<td>Not in use; set blank or zero.</td>
</tr>
<tr>
<td>NGPMAX</td>
<td>76-78</td>
<td>I3</td>
<td>Maximum number of parameters to be included in the regression model (in Task 6 only).</td>
</tr>
</tbody>
</table>

**Note 1:** NCONS, LINIT, JOBS3G and NGPMAX are not used in Task 1 (JOBS = 1).
**Note 2:** Task 6 (JOBS = 6) only uses variables NTOT, JOBS, WORK, NRANKP and NGPMAX.
Additional Input

Additional input depends on the Task indicated by input variable JOBS.

Task 1 (JOBS = 1):

Next NTOT Cards

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>1- 3</td>
<td>I3</td>
<td>Parameter number (1 to NTOT)</td>
</tr>
<tr>
<td>NAME</td>
<td>4- 9</td>
<td>A6</td>
<td>Parameter name</td>
</tr>
<tr>
<td>JDIS</td>
<td>10-11</td>
<td>I2</td>
<td>Parameter-distribution indicator (1 &lt; JDIS &lt; 8).</td>
</tr>
<tr>
<td>UADIS</td>
<td>12-22</td>
<td>E11.5</td>
<td>First distribution parameter</td>
</tr>
<tr>
<td>UBDIS</td>
<td>23-33</td>
<td>E11.5</td>
<td>Second distribution parameter</td>
</tr>
<tr>
<td>UCDIS</td>
<td>34-44</td>
<td>E11.5</td>
<td>Third distribution parameter</td>
</tr>
<tr>
<td>UDDIS</td>
<td>45-55</td>
<td>E11.5</td>
<td>Fourth distribution parameter</td>
</tr>
<tr>
<td>JJK(12)</td>
<td>57-79</td>
<td>12I2</td>
<td>Not in use.</td>
</tr>
</tbody>
</table>

Note: The distributions and distribution parameters in use are as follows:
<table>
<thead>
<tr>
<th>JDIS</th>
<th>ADIS</th>
<th>BDIS</th>
<th>CDIS</th>
<th>DDIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 = Uniform</td>
<td>Upper limit</td>
<td>Lower limit</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2 = Normal</td>
<td>Mean value</td>
<td>Standard deviation</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3 = Exponential I</td>
<td>Lower limit</td>
<td>Scale constant</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4 = Exponential II</td>
<td>Upper limit</td>
<td>Scale constant</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5 = Truncated normal I</td>
<td>Mean value</td>
<td>Standard deviation</td>
<td>Lower limit</td>
<td>-</td>
</tr>
<tr>
<td>6 = Truncated normal II</td>
<td>Mean value</td>
<td>Standard deviation</td>
<td>Upper limit</td>
<td>-</td>
</tr>
<tr>
<td>7 = Beta</td>
<td>Mean limit</td>
<td>Upper limit</td>
<td>Mean value</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>8 = Log-normal</td>
<td>Mean value</td>
<td>Standard deviation</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Tasks 2, 3, 4, 5 (JOBS = 2, 3, 4 or 5):

Card 2

The integer variable NEWNKN, format 15, in columns 1 to 5 indicates how many of the total NRANKP cases (knot-points) are used in the screening process. Thus, this provides the possibility to use a subset of all available cases (NEWNKN < NRANKP). If all cases are used, NEWNKN can be set to zero (or = NRANKP).

Next cards (if NEWNKN > 0)

Next card(s) indicate(s) the NEWNKN knot-point numbers (i.e., case numbers) that are included, each occupying 5 columns in format 1615. One card is needed if 0 < NEWNKN < 17, two cards if 16 < NEWNKN < 33, etc.

Next NRANKP cards (Consequence cards)

These cards contain values for the NCONS consequence variables in all NRANKP knot-points.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>INDEX</td>
<td>1-2</td>
<td>I2</td>
<td>Not in use; set to 50.</td>
</tr>
<tr>
<td>KNOT</td>
<td>3-6</td>
<td>I4</td>
<td>Knot-point number (KNOT=1, 2,.., NRANKP).</td>
</tr>
<tr>
<td>CONS(1)</td>
<td>9-20</td>
<td>E12.6</td>
<td>The value of the first consequence variable at the knot-point KNOT.</td>
</tr>
<tr>
<td>CONS(2)</td>
<td>21-32</td>
<td>E12.6</td>
<td>The second consequence variable.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONS(NCONS)</td>
<td></td>
<td>E12.6</td>
<td>The last consequence variable (maximum NCONS = 6).</td>
</tr>
</tbody>
</table>
Knot-point coordinates

NRANKP sets of knot-point coordinates are input here.

The first card of each set contains:

1. INDEX in columns 1-2, format I2, that should be set to 50;

2. KNOT in columns 3-6, format I4, indicating the knot-point number (KNOT = 1, 2, ..., NRANKP);

3. The values of the first six input parameters in the knot-point KNOT, each occupying 12 columns in format G12.5.

The rest of the cards for each set (if NTOT > 6) contain values of the other input parameters in order, format 6G12.5, i.e., six parameters on each card, until all NTOT parameter values are given.

Thus, the total number of cards in this group is approximately NRANKP x NTOT/6.

Additional input for Task 4 only (JOBS = 4):

1. The first card in this group indicates how many seed groups will be used for each consequence in this run. These numbers ISINGL (L) are given in format 6I5, one number for each consequence (L = 1, 2, ..., NCONS < 6).

2. One additional card is needed for each seed group to identify its members (i.e., the input parameters by their numbers). Each of these cards contains the following information:
<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSINGL</td>
<td>1-5</td>
<td>I5</td>
<td>Seed group identification number, specified by the user (not used by the program).</td>
</tr>
<tr>
<td>NGP</td>
<td>6-10</td>
<td>I5</td>
<td>Number of parameters in each regression group; recommended value NP + 1.</td>
</tr>
<tr>
<td>NP</td>
<td>11-15</td>
<td>I5</td>
<td>Number of parameters in the seed group&lt;sup&gt;a&lt;/sup&gt;.</td>
</tr>
<tr>
<td>KORG(1)</td>
<td>16-20</td>
<td>I5</td>
<td>Number of the first parameter in the seed group.</td>
</tr>
<tr>
<td>KORG(2)</td>
<td>21-25</td>
<td>I5</td>
<td>Number of the second parameter in the seed group.</td>
</tr>
<tr>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>KORG(NP)</td>
<td>.</td>
<td>I5</td>
<td>Number of the last parameter in the seed group.</td>
</tr>
</tbody>
</table>

<sup>a</sup> Note: (NGP-NP) parameters are replaced at each step of the screening.

Additional input for Task 5 only (JOBS = 5)

Input for Task 5 is similar to that of Task 4, with the exception that NGP = NP. The parameter groups specified are not seed groups but specific groups of input parameters for which the regression analyses are performed.
Input for Task 6 only (JGRS = 6)

1. First input Card 1 that defines NTOT, JOBS (= 6), WORK, NRANKP and NGP MAX as described before.

2. Next NGP MAX cards define which NGP MAX input parameters (out of the total NTOT) will be used in a simulation with the PROSA-2 computer code. Each of these NGP MAX cards contains two numbers:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IND P(J)</td>
<td>1-5</td>
<td>15</td>
<td>The number of the input variable INDS(J) in the PROSA-2 calculations.</td>
</tr>
<tr>
<td>INDS(J)</td>
<td>6-10</td>
<td>15</td>
<td>The number of the input variable in the SCREEN calculations.</td>
</tr>
</tbody>
</table>

Note: Normally IND P(J) = J (J = 1, 2, . . . , NGP MAX), and the numbers INDS(J) indicates the input parameters that have been found to be most important in the SCREEN calculations (Tasks 2, 3 or 4).

3. Next NRANKP sets of cards contain the values of the input parameters in all NRANKP cases (knot-points).

The first card of each set contains:

(1) INDEX in columns 1-2, format 12. This number should be set to value 50;

(2) KNOT in columns 3-6, format 14, indicating the knot-point number (KNOT = 1, 2, . . . , NRANKP);

(3) The values of the first six input parameters in the knot-point KNOT, each occupying 12 columns in format G12.5.
The rest of the cards for each set (if \( NTOT > 6 \)) contain values of the other input parameters in order, format 6G12.5, i.e., six parameters on each card until all \( NTOT \) parameter values are given.

Thus, the total number of cards in this group is approximately \( NRANKP \times NTOT/6 \).

3. Flow Diagram

The flow diagram of the program is presented in Fig. 12. The main control routine (MAIN) consists of four major parts as indicated in Fig. 12. These parts can be associated with Tasks 1 through 4 \((JOBS = 1, 2, 3 \text{ and } 4)\) described in Section V. C. 1. These parts are not completely isolated from each other since certain portions of Part 1 are common to all tasks and special features cause interconnections between various parts of the MAIN program.

4. Subroutine Functions

Figure 12 shows the calling sequence and conditions for the subroutines. The function of each subroutine is described briefly below.

- **ABEND**: Terminates execution due to allocation error in ALLOC2.
- **ALLOC2**: Function subprogram in MAIN; dynamically allocates space for arrays used. Applied Mathematics Division library subprogram.
- **COMS**: Comdeck COMS is a group of COMMON statements called by subroutines.
- **FITIN**: Calculates correlations between input parameters and residual consequences variables, after seed-regression functions have been subtracted from the original consequence data (in Task 15).
- **FREE2**: Releases space allocated by ALLOC2.
Fig. 12. Sequence of Subprograms in SCREEN.
GROUP1  Fits second-degree functions of one input parameters to the consequence data and calculates residual errors. Finds a group of best fits, i.e., most influential input parameters.

GROUP2  Fits quadratic surfaces of two input parameters to the consequence data and calculates residual errors. Finds a group of best fits, i.e., most influential pair of input parameters.

GROUP3  Similar to GROUP2, but the selection criterion is the product of the residual error and the sensitivity of the model.

GROUP4  Fits quadratic surfaces of two input parameters to the consequence data going through all possible pairs of input parameters. Calculates residual errors and finds a group of best fits, i.e., most influential pairs of input parameters.

HISTO  Calculates histograms of the consequence variables.

INIT  Sets initial value zeros.

JOBS1  Calculates knot-point coordinates and variation intervals for input parameters.

KNOTSS  Calculates intervals for input parameters, using probability range input variable PROB.

LISENS  Calculates linear sensitivities with a matrix method.

MAIN  Overall control routine.

MATINV  Matrix inversion subroutine.

MXMULT  Matrix multiplication subroutine.
PACORR  Calculates correlations between input parameters (from the sample used as knot-points).

PLOTFP  Plots the histograms (distributions) of the consequence variables.

PRINTH  Edits probability distributions and joint distributions.

PROSIN  Prepares input cards for PROSA-2 from those input to SCREEN.

PUNCH   User specified: Punches input cards for an external code that calculates consequences.

READIN  Reads in consequences and co-ordinates (values of the input parameters) of the knot-points. Calculates statistics of the raw input data and performs stagewise correlation analysis.

SAMPLE  Samples values for the input parameters from their distributions.

SASIN   User specified; Prepares input cards for an external code that calculates consequences. (Current format in the program package is consistent with SAS3D accident analysis code).

SCRAM   Fits multivariate quadratic functions to the consequence data, calculates residual error statistics and sensitivities of the models finds most influential input parameters and prints the response surface coefficients.

SSHIFT  Calculates subset statistics to detect deviations from the total sample, to discover threshold effects.

TEXASS  User specified; Calculates consequence values from analytical equations.
In summary, statistical sensitivity analysis techniques and a related computer code SCREEN have been developed for identifying and ranking most important input parameters of large computer codes. These screening techniques are especially aimed for complex codes with a large number of input variables such that standard non-statistical sensitivity studies searching for all first- and second-order derivatives would be too expensive. The current techniques determine a group of most important input parameters rather than sensitivities with respect to all input variables. The result of the procedure is correct only within a certain degree of confidence (probability) and can be verified with a few extra test cases.

The methods used are (1) stagewise correlation analysis to determine input variables most correlated with the output variables, (2) extended stepwise regression analysis to determine most significant input variables with quadratic regression models, and (3) statistical testing of subset characteristics to determine input variables causing or contributing to discontinuities of the output variables.

The values of the input parameters for the cases that are used in the screening process are selected randomly from a continuous interval rather than from discrete levels, to ensure uniform coverage. Since the number of cases is normally large enough (20 or more), no special effort is needed to spread the cases satisfactory over the region. The regression analysis procedure is extended from the standard stepwise procedure by calculating all regressions with one-and two-parametric models, and using both residual errors and a special sensitivity/spuriousness criterion in the stepwise process with multi-parameter models. This provides redundancy and adds confidence to the results.
The methods and the code have been applied extensively to test problems and to a fast reactor accident analysis code VENUS-II. These studies demonstrate the consistency of the screening techniques and provide detailed sensitivity information about VENUS-II.

Future efforts may be directed towards increasing the efficiency and automation of the statistical tests, graphical displays of the results, further optimization of the selection of cases (designs) and models, including functional transformations similar to those used in PROSA-2.\textsuperscript{19}

Other avenues for sensitivity analysis development include development of perturbation methods using adjoint equations which is currently underway.\textsuperscript{22} This approach is complementary to the statistical screening techniques. It requires development of an adjoint code, the cost of which can in many cases exceed the cost of running the forward cases needed in statistical methods. On the other hand, statistical methods may not be the best solution to all problems.
APPENDIX A

Program Listing
*EMPE MAIN
C MAIN SCREEN
  COMMON ALLOC2
  COMMON /LARGE/ T(1)
  COMMON /NPRINT/JOB,JTH, JTWO, JTHREE
  COMMON /JOB/JOBS
*CALL CONS
  COMMON /ZETA/ZETA (103, 6)
  COMMON /ISPLO/NHS (6, 12), NJOINT (6, 6, 12, 12)
  COMMON /TRANSF/MTAPA,MTRACO,JTYPE (7), ITBA (7), LTYPE (7), APA (7), ACO (7), BCO (7)
  COMMON /SAVE/ZAVE (1000), ZSS (1000)
DIMENSION ISINGL (6)
C
C MAIN PROGRAM
C MAIN PROGRAM USES ALLOC2 (DOCUMENTATION... ABDLIB VOL. VIII)
C USES & ALLOC2 TO DYNAMICALLY ALLOCATE SPACE FOR ARRAYS USED IN
C CURVE FITTING Routines. SPACE NEEDED DEPENDS ON THE NUMBER OF
C PARAMETERS AND THE NUMBER OF CONSEQUENCES.
C NWORDS ... IS THE TOTAL NUMBER OF WORDS IN THESE ARRAYS.
C IPATFI ... DETERMINES THE PRECISION OF THE ARRAYS.
C (1=SINGLE, 2=DOUBLE, 4=QUADRUPLE)
C T ... ALLOCATED ARRAY WHERE THE OTHER ARRAYS (ZF, ETC.) ARE STORED
C IN THE CALL DRIVER STATEMENT, THE ADDRESS OF THE FIRST LOCATION OF
C EACH ARRAYS Is PASSED, AND DRIVER USES THE ARRAYS AS DIMENSIONED IN
C DRIVES (TWO DIMENSION, DOUBLE PRECISION). ALLOC2 RETURNS IERR AS
C AN NEGATIVE IF THE ALLOCATION IS UNSUCCESSFUL. ABOUND IS AN ABNORMAL
C TERMINATION DUMP.
C
DATA IREAD, IWRITE, IPUNCH / 5, 6, 7/
C 3 CONTINUE
C READ JOB INFO
C 1001 FORMAT (14, 12, P10.8, 13, 11, 15, 15, 3X, 13, 16, 15, 5X, 15, 8X, 215, 12)
C ECHO OUTPUT
C WRITE (IWRITE, 1002) WORK, JOBS, PROB, NCONS, TEST, NCORR, NRANKP, NTRAPA, NTRACO, NGPMA
C NGPMA IS USED IN JOBS=6 ONLY, MAXIMUM NUMBER OF MODEL PARAMETERS
C WITH NPAKE KNOT-POINTS
C
C 1002 FORMAT (1H1, 15X, 28HPARAMETER SCREENING WORK NO., 17, 7H, JOBS = 13, ///
C 11H, 5X, 7H TOTAL NUMBER OF PARAMETERS, 6H WORK NO. 15/1H, 5X, 3HPROBABI
C 2LITY RANGE PROB., 10.8/1H, 6X, 9HNUMBER OF CONSEQUENCES NCONS = 14, ///
C 13, 1H, 5X, 10HDEST OPTION TEST = 11/1H, 5X, 26DMO. OF CORRELATIONS NO
C 48P = 13, 1H, 5X, 33DMO. OF RANDOM KNOT-POINTS NPAKE = 14/1H, 5X, 40000
C 50. OF PARAME: TRANSFORMATIONS MTABA = 13/1H, 5X, 42DMO. OF COND):
C 4DE: SCREEN TRANSFORMATIONS MTABA = 13/1H, 5X, 45DMAXIMUM NO. OF PARAMETE
C 7RS IN A GROUP, NGPMA = 13, 1H)///
C
C LIMIT INDICATES THE CONSEQUENCE NUMBER TO BE STARTED FROM IN JOBS=3
C JOBS3G INDICATES WHAT SUBROUTINES GROUP1 TO GROUP4 ARE CALLED JOBS=3
C IF LIMIT = 1
C IF (JOBS3G).EQ. 0) JOBS3G = 4
C IF (JOBS3G).EQ. 3) WRITE (IWRITE, 1003) LIMIT, JOBS3G
C 1003 FORMAT (1H1, 5X, 4HTHE ANALYSIS STARTS FROM CONSEQUENCE NO. LIMIT =,
C 115/1H, 5X, 32HSUBROUTINES GROUP1 THROUGH GROUP, 11, 10H ARE USED ///}
C NUMBER NAME MAIN
    JOBSV = JOBS
    NKNOT = NRMANKP
    NCISV = NRMANKP
C NHOT=NRMANKP,BUT NRMANKP ONLY IN THE COMMON BLOCK, NKNOT IS PASSED
C DEFAULT FOR MGPMX
    PKNOT = 2. * FLOAT(NKNOT) + 0.2500
    PKNOT = SQRT(PKNOT)
    NORD = INT(PKNOT + 1.50)
    IF(NGPMX.LE.0. OR.NGPMX.GT.NSUP) WRITE(IWRITE,1501) MGPMX,NSUP
     1501 FORMAT('TH1,6X,10HINPUT MGPMX=',I3,1X,1HREPLACED BY,13//)
    IF(NGPMX.LE.0. OR.NGPMX.GT.NSUP) MGPMX = NSUP
    NPARA = NTOT
C MPWR IS IN COMMON BLOCK CONS, NTOT IS NOT
    IF(JOBS.EQ.0) CALL PROSM(MGPMX)
    IF(JOBS.EQ.6) GO TO 3
C
C DYNAMIC ALLOCATION FOR JOBS1 AND PERMANENT FOR JOBS.GT.1
C
C DIMENSION ST
    IRATPI = 2
    NWDSP = 11 * NTOT + IRATPI * NRMANKP * (NTOT + MCONS) + 20
    KLOC = ALLOC2(IERR, NWDSP)
    IF(IERR.GT.0) GO TO 129
    WRITE(IWRITE,1050) NWDSP, IOFFST, KLOC, JLOC
     1050 FORMAT('TH10,1O,1H1050 NWDSP=,I10,18HIOFFST=,I10,2X,6HKLOC=,I9,7BJLOC=,I110//)
    CALL ABEND
129 CONTINUE
    JLOC = T0CK(ST)
    IOFFST = (KLOC - JLOC)/4
    IPA = 1 + IOFFST
    IDI = IPA + NTOT
    IAD = IDI + NTOT
    IBD = IAD + NTOT
    ICD = IBD + NTOT
    IDD = ICD + NTOT
    ISE = IDD + NTOT
    IER = ISE + NTOT
    I20 = IER + NTOT
    IZ1 = I20 + NTOT
    IZ2 = IZ1 + NTOT
    IZP = IZ2 + NTOT
    ICP = IZP + NTOT + NRMANKP + IRATPI
    WRITE(IWRITE,1039) NWDSP, IOFFST, KLOC, JLOC
     1039 FORMAT('TH8O NWDSP=,I10,1O,1H1039 NWDSP=,I10,2X,6HKLOC=,I9,7BJLOC=,I110//)
    CALL JOBS ((ST(IPA),ST(IDI),ST(IAD),ST(IBD),ST(ICD),ST(IDER),ST(I20),ST(IZ1),ST(IZ2),ST(IZP),ST(I21),ST(I22),ST(NT)),NTOT, NRMANKP)
    IF(TST.EQ.0) GO TO 91
C
C PUNCH TEST CONSEQUENCES
    DO 97 T = 1, NRMANKP
        WRITE(IPUNCH,1622) INDEX, I, (ZETA(I,L), L=1, MCONS)
        IF(TST) WRITE(IWRITE,1627) INDEX, I, (ZETA(I,L), L=1, MCONS)
97 CONTINUE
     1621 FORMAT('TH10,6X,215,((EZ16.6))
IF(JOBS.EQ.1) GO TO 3
C END OF JOBS
CALL READING(ST(IZE),ST(ICF),NCT,NKNOT
C IF(KNOT AND NTRMKP MAY HAVE CHANGED IN READING,
C KNOSV SAVES THE ORIGINAL VALUE
C
C CALL %CORR(ST(IZE),ST(IZE),NCT,NKNOT,KNOTSV)
C CALL SSHIFT(ST(IPA),ST(IDT),ST(IAD),ST(IBD),ST(IDD),ST(IZE)
1),ST(IZE),ST(I2Z),ST(IZE),NCT,NKNOT,KNOTSV)
IF(JOBS.EQ.2) GO TO 3
C END OF JOBS?
C ALL DATA IS IN, SCRENING STARTS
4LOC = LOCT(T
NCONS = NCONS
DO 300 L=LIMIT,NCONS
WRITE(WRITE,1043) L
1043 FORMAT(4H0
NNDS = NRAPA * NCOEF2 * (2*NKNOT + NCONS + NCOEF2) + 10
KLOC = ALOC2(LBR,NWDS)
IF(IEPR.GT.O) GO TO 130
WRITE(WRITE,1050) NWDS
CALL PEPF(KLOC,NWDS)
130 CONTINUE
IOFFT = (KLOC - MLOC)/4
IF = 1+ IOFFT
C REMEMBER NCONS = 1 IFP
IFB = IZP + NKNOT + NCOEF2*IATPI
IFS = IZF + NCOEF2 + WCONS + IATPI
IATPI = IZP + NKNOT + NCOEF2 + IATPI
IEND = IATPI + NCOEF2 + KNOTSV + IOFFT
WRITE(WRITE,1040) NWDS,IPRO,IOFFT,KLOC,MLOC
1040 FORMAT(4H0
1NDS = 110,9H IEND = =110,2X,7HIOFFT =,110,2X,6H
L=,110,2X,6HLOC =,110,2X,6HLOC =,110,2X,6H
IF(IPAPA.EQ.1) CALL GROUP1(T(IZF),T(IBF),T(IZEP),T(IAMAT),ST(IZE)
1ST(IZE),NCT,NKNOT,NCOEF2,ST(I2Z),ST(I2Z),ST(IZE),NKOITS)
IF(IPAPA.EQ.2.AND.JOBS3G.GE.3)
1 CALL GROUP2(T(IZE),T(IBF),T(IZEP),T(IAMAT),ST(IZE)
1ST(IZE),NCT,NKNOT,NCOEF2,ST(I2Z),ST(I2Z),ST(IZE),NKOITS)
IF(IPAPA.EQ.0.AND.JOBS3G.GE.4)
1 CALL GROUP3(T(IZE),T(IBF),T(IZEP),T(IAMAT),ST(IZE)
1ST(IZE),NCT,NKNOT,NCOEF2,ST(I2Z),ST(I2Z),ST(IZE),NKOITS)
IF(IPAPA.EQ.2.AND.JOBS3G.GE.4)
1 CALL GROUP4(T(IZE),T(IBF),T(IZEP),T(IAMAT),ST(IZE)
1ST(IZE),NCT,NKNOT,NCOEF2,ST(I2Z),ST(I2Z),ST(IZE),NKOITS)
CALL PEPF(KLOC,NWDS)
20 CONTINUE
20 CONTINUE
N= IPAPA
BEGIN NAME MAIN
C PREPARE AND ALLOCATE FOR MAXIMUM GROUP SIZE.
C IT FITS A SECOND DEGREE SURFACE OF THE PARAMETERS OF THE GROUP TO
C THE CONSEQUENCE DATA AND EVALUATES THE CASUAL ERRORS, THEN GOES
C TO THE NEXT GROUP. IT EDITS THE BEST GROUPS (SMALLEST RESIDUAL MEAN
C SQUARE ERRORS) AND THE SENSITIVITIES OF THE PARAMETERS IN EACH GROUP
C THE BASE GROUP IS INPUT SPECIFIED BY THE PARAMETER NUMBERS
C CONSEQUENCE IS THE NUMBER OF BASE GROUPS FOR CONSEQ. 1.
C SEVERAL BASE GROUPS CAN BE USED IN THE SAME JOBS (WORK) FOR EACH
C BASE GROUP IS INPUT SPECIFIED BY THE PARAMETER NUMBERS
C CONSEQUENCE IS THE NUMBER OF BASE GROUPS FOR CONSEQ. 1.
C JOB 5 FITS INDIVIDUAL SECOND DEGREE SURFACES OF INPUT SPECIFIED
C PARAMETERS, IT DOES NOT AUTOMATICALLY GO THROUGH ALL PARAMETERS
C FOR JOBS 5 ISINGI(I) INDICATES THE NUMBER OF INDIVIDUAL GROUPS FOR CONSEQ.
C I, NGB=NP IN JOB 5 FOR EACH GROUP (EACH GROUP IS BASE GROUP)
30 CONTINUE
C LINEAR SENSITIVITIES WITH MATRIX METHOD, BLOCK 600 INSTRUCTIONS
DO 600 L=LINIT,WCONV
WRITE(IWRITE,1063) L
1363 FORMAT(1H1,153HLINEAR SENSITIVITIES BY MATRIX METHOD, CONSEQUENCE
101CE,131)
NC0F1 = N0T + 1
NWDS = IATPI*(N0COF1*(2*NKNOT + NCONS) + NWKNT*NKNOT)
KLOC = ALOC2(IERR,NWDS)
IF(IERR.GT.0) GO TO 030
WRITE(IWRITE,1050) NWDS
CALL AEND
630 CONTINUE
JOFFT = (KLOC - MLDC)/4
IZF = 1 + JOFFT
C STILW, NCONS=1, NCONS SAVES ORIGINAL NCONS
N0F1 = N0F1 + N0COF1*NCONS*IATPI
IATPI = IATPI + N0COF1*NCONS*IATPI
IATMAT = IATPI + NWKNT*N0COF1*IATPI
IERN = IERN + NWKNT*N0COF1*IATPI
WRITE(IWRITE,160) NWDS,IERN,JOFFT,KLOC,KLOC
CALL LIEMS(T(IZF),T(IBF),T(IATPI),T(IATMAT),ST(I2Z),ST(12Z),ST(I2P),ST(I2F))
ST(I2Z),ST(I2F),N0T,NWKNT,N0COF1,N0N0S)
CALL FRET2(KLOC,NWDS)
603 CONTINUE
C END OF LINEAR SENSITIVITY MATRIX METHOD BLOCK
IF(JOBS.FQ.3) GO TO 3
3 CONTINUE
C JOBS 4 KEEPS A SUBGROUP OF PARAMETERS WITHIN THE GROUP AND CHANGES THE REST
C JOBS 5 INDICATES HOW MANY SINGLE GROUPS FOR CONSEQUENCE L
C ISINGI(I) INDICATES HOW MANY SINGLE GROUPS FOR THE CONSEQUENCES ARE 6
50 CONTINUE
5J12 FORMAT(1H1,161HJOBS = 5, SINGLE GROUPS TO BE FITTED/180,6X,23NW
1ERRORS OF GROUPS FOR THE CONSEQUENCES ARE 5016/)
IF(JOBS.FQ.4) WRITE(IWRITE,5002) (ISINGI(I),I=1,NCONS)
50 CONTINUE
5J12 FORMAT(1H1,161HJOBS = 6, SINGLE GROUPS TO BE FITTED/180,6X,23NWU
1ERRORS OF GROUPS FOR THE CONSEQUENCES ARE 616/)
IF(JOBS.FQ.4) WRITE(IWRITE,5002) (ISINGI(I),I=1,NCONS)
C CSIMAX = ISIMGL(I)
IF(ISIMAX.LE.1) GO TO 430
WRITE(IWRITE,2000) L
DO 400 ISI=1,ISIMAX
430 WRITP(IPITE,2000) L
DO 400 ISI=1,ISIMAX
2001 FORMAT(315,1015)
417 CONTINUE
WRITE(IWRITE,2002) WSINGL,NGP,FP,(KORG(I),I=1,10)
C WSINGL IS NOT USED BY THE PROGRAM, IT IS FOR USERS IDENTIFICATION ONLY
C
C 20^2 FORMAT(1H ,9X,16HINPUT GROUP //1H,28HNSINGL NGP NP PARAME
ETERS//1H,315,1015//1H ,8X,54HNSINGL= IDENTIFICATION NUMBER FOR THE
INITIAL GROUP /1H ,8X,42HNGP = NUMBER OF PARAMETERS IN EACH G
GROUP/1H ,8X,57HNP = NUMBER OF PARAMETERS KEPT IN A GROUP AT EACH
4H STEP//)
C
C C NGP = NP = NUMBER OF PARAMETERS REPLACED AT EACH STEP
C IF(NGP.EQ.0.OR.NGP.GT.NSUP) WRITE(IWRITE,2303) NSUP
IF(NGP.EQ.0.OR.NGP.GT.NSUP) NGP = NSUP
2003 FORMAT(1H ,9X,15HNGP IS RESET TO,13//)
C
C IF(JOPS.EQ.5.AND.NP.NE.NGP) WRITE(IWRITE,2304) NP
IF(JOPS.EQ.5.AND.NP.NE.NGP) NGP = NP
IF(JOPS.EQ.15.AND.NP.NE.NGP) NGP = NP
2014 FORMAT(1H ,8X,14HNGP RESET TO,13,25H =NP BECAUSE JOPS = 5 //)
C
C IF(JOPS.EQ.15.AND.JOBS.GE.15.AND.NP.GE.NGP) WRITE(IWRITE,2035)
2005 FORMAT(1H ,8X,39HCONSISTENT WSINGL, NGP AND NP, I PASS//)
IF(JOPS.EQ.15.AND.JOBS.GE.15.AND.NP.GE.NGP) GO TO 400
C
C 4=NP
NCOPF2 = 1 + 2*NP + ((NP*(NP-1)) + 1) / 2
NWDS = IRAF * NCCEF2 * (2*NKNOT + NCENS + NCOPF2)
C
C KLOC = ALLOC2(IPFE,NWDS)
IF(IPFE.GT.0) GO TO 419
WRITE(IWRITE,1030) NWDS
CALL ARFND
439 CONTINUE
INOFT = (KLOC - 1LOC)/4
C
C 1ZF = 1 * INOFT
TPF = IZF + NKNOT * NCOPF2 * IRAF
17*P = IZF + NCOPF2 * NCENS * IRAF
CALL SCRAM(T(IZF),T(IBF),T(IZFF),T(IZAT),ST(I2E),ST(IPC),NIO,T,MCIP,ST(I2C),ST(I22),NMTSV)

CALL FREE2(KLOC,NVDS)

IF(JOBS.GT.4) GO TO 399
WRITE(1WITEP,3001) L,WSINGL

30^1 FORMAT(1H1,9X,65B) THE REFERENCE GROUP FITTING IS NOW PERFORMED FOR THIS CONSEQUENCE, 14, 3X, 16H, GROUP WSINGL =,16//)
%E(NGP+1) * (NGP+2)/2
MS = M/ANKP - M
KZ = MS - (NP+1) * (NP+2)/2
WRITE(INFINITE,3002) NP,NGP,ME,KE,WE

3002 FORMAT(1H1,5X,52H FOR TESTING THE SIGNIFICANCE OF THE ADDED PARAMETER 
1EREP, 15X, 51H USM(NP) - USM(IG) ) * (MANKP - M) / (K * USM(IG))
2/1H1,5X,53HMAY BE COMPARED TO AN F(K,NANKP-M) VARIABLE /
31HC,5X,7HUSM(NP) = RESIDUAL SUM OF SQUARES FOR THE BASE GROUP OF NP PARAMETERS, NP =,14//1H ,8X,85HUSM(IG) = SAME FOR A LARGER GROUP SUP IG WITH NGP PARAMETERS, INCL. THE BASE GROUP, NGP =,14/68)
6,8X,59HM = (NP+1) * (NP+2)/2 =,14//1H ,13X,25HK = M - (NP+1) * (NP+2) 
7/2 =,14//1H ,13X,12H MANKP - M =,15//1H)

MGP = NP
JOBS = NP
GO TO 410

399 JOBS = JOBS
GO CONTINUE

400 CONTINUE
GO TO 3
905 STOP 1
END
*COMDECK CONS
 INTEGER WORK, TEST
 REAL WMMA, NAME
 COMMON/IPTGRA/ JOMS, J
 COMMON/KNOT/ TEST, INDEX, J, K, MPARA
 COMMON/KNOTC/ PROB
 COMMON/KNOT1/ZAJ, XJ, XIXJ, ZIK, ZIKK, ZKX, ZETA, ZETI, ZETII
 COMMON/KNOTC/ZETC, ZETK, BJ, CJ, DJK, SJ
 COMMON/EXT/ CONS (6)
 COMMON/GFOPB/ MSINGL, MGP, MP, MORG (12)
 COMMON/HISTOC/ APEETA (6), AVEBT (6), SDZET (6), SCALE, MGHS
 COMMON/EIGCOM/
 2 SENAE (6), JMAX (6), SECMAX (6), KMAX (6), SIMSD (6),
 3 C PLOT (9), ZPLOT (9)
 COMMON/PFINT/ A DINT (12), ENJ (12), MC, MD
 COMMON/CMINTI/ MCF (6), LCF (4), FCF (4)
 COMMON/IFLAG/ IFLAG
 COMMON/COREL/ ITYPE (12), ILEAD (12), IORD (12), ILEAP (12), FLEAP (12),
 COMMON/ALPHA/ ALFA (12, 12)
 COMMON/CMCO/ C1 (12), C2 (12), C3 (12), C4 (12), CM11 (12, 12), CM12 (12, 12)
 COMMON/CMCO/ C F1 (6, 6), SINCOS (6, 6)
 COMMON/CPRTOUT/A (6), MSA, WORK
 COMMON/BSKAN/ MPASKP

*DECK
SUBROUTINE PITIN(ZR,CPNEW,WTOT,NKNOT)
C
USED IF AND ONLY IF INPUT JOBS=15, PITIN CALCULATES CORRELATIONS
C (AS IN JOBS 2) FOR RESIDUALS AFTER THE SEED REGRESSION RESULT (AS OF
C JOBS 5) IS SUBTRACTED FROM THE ORIGINAL DATA CONSEQUENCES
C
C CALLED BY SCRAM
C
REAL*8 ZR,ZP,CPNEW
*CALL COM
COMMON/ZETAR/ZZETA(100,6)
DIMENSION CPNEW(100,1)
DIMENSION ZR(100)
DIMENSION ZPCOP(20),ZPVAR(20),SPMEAN(20)
C
DATA IREAD,IVRITE,INIMA/5,F,5/
COMMON/TPANSF/N1BAPA,NTPACOJTTPA(7),LTRA(7),LTPA(7),APA(17),APA(7),ACO(7),BPA(7)
C
C INITIAL ZERCS
RKMEAN = 0.
RKCM2 = 0.
RKMAX = -1.0E+49
RKMIN = +1.0E+49
C
WRITE(IWRITE,2000)
?0) FORMAT(1H1,10I2,1HRESIDUAL CONSEQUENCES,13/I1H,7I5,INDEX,10I4,1H
10T,/) DO 11 K = 1, NANKP
RKCONS(C PNEW(K,1)
INDEX = 50
KNOT = K
WRITE(IWRITE,2002) INDEX,KNOT,RKCONS
C
RKMEAN = RKMEAN + RKCONS
RKCM2 = RKCM2 + RKCONS + RKCONS
IF(RKCONS.GT.RKMAX ) RKMAX = RKCONS
IF(RKCONS.LT.RKMIN ) RKMIN = RKCONS
11 CONTINUE
C
CPNEW IS A WORKING PLACE, ZETA PERMANENT STORAGE
C
2002 FORMAT(1H6X,15,8X,14,(6E16.6))
C
C
WRITE(IWRITE,1500)
WRITE = RKMEAN / NANKP
*BEGIN NAME FITIN
RKMAN = RKA

C C
RKVAF = RKCM2 / NEANKP - RKA * RKA
DKFAN = NEANKP - 1
DN = NEANKP
RKVM = RKVAF * DN / DKFAN
RKCM2 = RKVAF
RKSD = 0.
IF (RKVAF.GT.1.) RKSD = SORT(RKVAR)
WRITE(IWRITE,3001) L,RKAVE,RKSD,RKMAX ,RKMIN
C C
300) FORMAT('CONSEQUENCE CHARACTERISTICS OF RANDOM KNOT POINT SAMPLE CONSEQUENCES')
C C
1'"O CONSEQUENCE VALUE STD DEVIATION MAXIMUM VALUE MIN
VALUE VALUE
)
3001 FORMAT(10X,5X,14,1X,G14.5,1X,G14.5,1X,G14.5,1X,G14.5)
C READIN 2
C C
C THIS PART OF READIN CALCULATES AND EDITS NEAXP LARGEST CORRELATION COEFFICIENTS BETWEEN A CONSEQUENCE AND THE PARAMETERS
RKANP=READ((20,NTOT)
DO 110 J=1,NEAXP
SMEAN(J)=0.
SPCOP(J)=0.
SPVAR(J)=0.
JORG(J)=0
110 CONTINUE
WRITE(IWRITE,4000)
4000 FORMAT(10X,6X,14,1X,G14.5,1X,G14.5,1X,G14.5,1X,G14.5)
C PART I OF READIN, SUBROUTINE READIN CALLS SUBROUTINE SDLOT, WHERE SDLOT CALLS subroutine READIN ( CONTINUES )
C READIN 2
C C C
C PART I OF READIN, SUBROUTINE READIN CALLS SUBROUTINE SDLOT, WHERE SDLOT CALLS subroutine READIN ( CONTINUES )
C READIN 2
C C
MEMBER NAME P'TIN

INDMAX=MAXP - 1
DO 115 IND=1,INDMAX
IK=MAXP + 1 - IND
IKP=IK - 1
SPMEAN(IK)=SPMEAN(IKP)
SPCOR(IK)=SPCOR(IKP)
SPVAR(IK)=SPVAR(IKP)
JORG(IK)=JORG(IKP)
115 CONTINUE
SPMEAN(I)=SPMEAN(IKP)
SPCOR(I)=SPCOR(IKP)
SPVAR(I)=SPVAR(Ikp)
JORG(I)=JORG(IKP)

CONTINUE

SPMEAN(I)=SPMEAN(IKP)
SPCOR(I)=SPCOR(IKP)
SPVAR(I)=SPVAR(IKP)
JORG(I)=JORG(IKP)

CONTINUE

CONTINUE

MDF=MAXWP - 2
DO 120 I=1,MAXWP
JB=JORG(I)
SC=SPCOR(I)
R5O= SC * SC
FVAR= MDF * R5O
WRITE(IWFITP,400) JB, SC, R5O, FVAR
400 FORMAT(1H0,5X,1E10.5)
120 CONTINUE

WRITE(IWFITP,402) MDF
402 FORMAT(11H3,5I,30HTHC
fDST CORRELATING PABA.ETE,I3,/18 ,5I,29HHAS
SAMPLE STANDARD
DEVIATION,G12.5/1H ,5I,24HREGRESSION COEFFICIENT
2, 5X,G12.5//)

C RESIDUAL CONSEQUENCES
DO 200 K=1,MAXWP
CPNEW(K,1)=CPNEW(K,1)-SPMEAN-B1*(ZB(K,JB1)-Z(K))
200 CONTINUE

C CORRELATIONS WITH THE RESIDUAL CONSEQUENCE
DO 210 J=1,MAXWP
SPCOR(I)=0.
SPVAR(I)=0.
JORG(I)=0.
210 CONTINUE

DO 220 J=1,MAXWP
CPNEW(J,1)=0.
SPVAR(J)=0.
220 CONTINUE

DO 230 K=1,MAXWP
CPNEW(K,J)=2*Z(K,J)-2(J)
230 CONTINUE

SUM=0.
211 CONTINUE

DNP= MAXWP - 1
SVAP = SVAP/ MAXWP


**NAME** NAM A

**VITIN**

\[ \text{SZVAR} = \text{SZVAR} / \text{NBAKWP} \]

\[ \text{SCOP} = \text{SCOP} / \text{NBAKWP} \]

\[ \text{SCOP} = \text{SCOP} / \text{SQRT(SZVAR*SZVAR)} \]

\[ \text{ABSCOR} = \text{ABS(SCOP)} \]

\[ \text{DO 214 I=1,NAXP} \]

\[ \text{ABSP} = \text{ABS(SCCOR(I))} \]

\[ \text{IF(ABSCOR,LT,ABSP) GO TO 214} \]

\[ \text{INDMAX} = \text{NMAXP} - I \]

\[ \text{DO 215 IND=1,INDMAX} \]

\[ \text{IK=MAXP - IND} \]

\[ \text{JOBG(IK)=J} \]

\[ \text{SPCOR(I)=SCOP} \]

\[ \text{SPVAR(I)=SZVAR} \]

\[ \text{CONTINUE} \]

\[ \text{DO 214 CONTINUE} \]

\[ \text{SDEV=SQRT(SVAR)} \]

\[ \text{WRITE(IWRITE,4099) L,SDV} \]

\[ \text{FORMAT('1F,3X,'1CHCONSEQUENCE,13,2X,28HRESIDUAL STANDARD DEVIATION,1,G12.5/)} \]

\[ \text{WRITE(IWRITE,4100) L} \]

\[ \text{FORMAT('1H,6X,36HHCOEFFICIENTS OF RESIDUAL CONSEQUENCE,14,8H WITH 1H PARAMETER/37F PARAMETER COEF. SQUARE P/)} \]

\[ \text{DO 220 I=1,NAXP} \]

\[ \text{JB=JOBG(I)} \]

\[ \text{SC=SCOP(I)} \]

\[ \text{RSQ=SC*SC} \]

\[ \text{FVAR=NSDF*RSQ} \]

\[ \text{WRITE(IWRITE,4001) JB,SC,RSQ,FVAR} \]

\[ \text{CONTINUE} \]

\[ \text{WRITE(IWRITE,4092) NSDF} \]

\[ \text{JB2=JOBG(1)} \]

\[ \text{SSSD2=SQRT(SVAR(1))} \]

\[ \text{B2=SCCOR(1)*SQRT(SVAR)} / \text{SSD2} \]

\[ \text{WRITE(IWRITE,4193) JB2,SSSD2,B2} \]

\[ \text{FORMAT('1H,5X,32HSECOND CORRELATING PARAMETER/14,8H,28H SAMP LE STANDARD DEVIATION,612.5/18,5X,24HCORRELATION COEFFICIENT B,2,5X,G12.5/)} \]

\[ \text{C} \]

\[ \text{SECOND RESIDUALS OF THE CONSEQUENCES} \]

\[ \text{DO 300 K=1,NBAKWP} \]

\[ \text{CFNEW(K,1)=CFNEW(K,1)-B2*(ZB(K,JB2)-Z(JB2))} \]

\[ \text{CONTINUE} \]

\[ \text{C} \]

\[ \text{CORRELATIONS WITH SECOND RESIDUALS} \]

\[ \text{C} \]

\[ \text{DO 310 I=1,NMAXP} \]

\[ \text{SPCCOR(I)=0.} \]

\[ \text{SPVAR(I)=0.} \]
** MEMBER NAME PITTN**

**JOGG(I) = 0.**

**110 CONTINUE**
**DO 312 J=1,NPARA**
**SVAR = 0.**
**SVAR = 0.**
**DO 313 NH = 1, NPARA**
**ZR = ZR(KH,J) - Z(J)**
**SBUF = CFINEW(KH,1)**
**SCOR = SCOR + ZRR * SBUF**
**SVAR = SVAR + SBUF * SBUF**
**SIZVAR = SIZVAR + ZRR * ZRR**
**313 CONTINUE**
**DMP = NPARA - 1**
**SVAR = SVAR / NPARA**
**SIZVAR = SIZVAR / NPARA**
**SCOR = SCOR / SIZVAR**
**ABSLOC = ABS(SCOR)**
**DO 314 I=1,NMAIP**
**ABSLOC = ABS(SCOR(I))**
**IF (ABSLOC.LT.ABSLOC) GO TO 314**
**INMAX = NMAIP - 1**
**DO 315 IND=1,INMAX**
**IK = NMAIP - 1 - IND**
**IKP = IK + 1**
**JOBG(IK) = JOBG(IKP)**
**SPCOR(IK) = SPCOR(IKP)**
**SPVAF(IK) = SPVAF(IKP)**
**315 CONTINUE**
**JOBG(I) = J**
**SPC(S(I)) = SPCOR(I)**
**SPVAF(I) = SPVAF(I)**
**SCOR = J**
**ABSLOC = 0.**
**314 CONTINUE**

**112 CONTINUE**
**SDEV = SQRT(SVAR)**
**WRITE (*,WRITE,4099) L,SDEV**

**4099 FORMAT('HO,61,3#HCOEFFERLATION OF RESIDUAL CONSEQUENCE, I4, 16H WITH**
**' PARAMETER/37B PARAMETER CORR.COEI., SQUARE TO/'**)
**DO 320 I=1,NMAIP**
**JR = J(1)**
**SC = SPCOR(I)**
**SSQ = SC * SC**
**PVAR = DVAR - SSQ**
**WRITE (*,WRITE,4104) JB, SC, SSQ, PVAR**
**320 CONTINUE**
**WRITE (*,WRITE,4105) NDF**

**4104 FORMAT('HO,5X,31H THE THIRD CORRELATING PARAMETER, I3/IH, 5X, 29HHAS**
**SAMPLE STANDARD DEVIATION, 312.5/IH, 5X, 26H REGRESSION COEFFICIENT**
EMBER VATP FITIN

2 R,51,942.51
C THIRD RESIDUAL STANDARD DEVIATION
DO 400 K=1,NRANFP
   CFW(K,1) = CFW(K,1) - &2*(ZP(K,J82) - Z(J82))
400 CONTINUE
C STANDARD DEVIATION OF THE THIRD RESIDUALS
   SVAR = 1.
   DO 413 KK=1,NBANFP
      SEUO = CFW(KK,1)
      SVAR = SVAR + SEUO*SEUO
413 CONTINUE
   SVAR = SVAR/ NBANFP
   SDEV = SORT(SVAR)
   WRITE(IWRITE,4099) L,SDEV
111 CONTINUE
RETURN
END
SUBROUTINE GROUP1(ZP,BF,ZFP,AMAT,EB,CF,NKNOT,NCORP2,20,21,22,
  KNOTS)
C
C FITS QUADRATIC SURFACES TO THE CONSEQUENCE DATA, NPARA=1, NCONS=1
C
C OUTPUT OPTIONS
C
IOUT = 0 , MINIMUM OUTPUT
IOUT = 1 , ERROR STATISTICS OUTPUT FOR ALL PARAMETERS
IOUT = 2 , ERRORS OUTPUT IN ALL KNOTS FOR ALL PARAMETERS
C
CALL CONS
REAL *R ZP,BF,ZFP,AMAT,EB,CF,APA,,DAP,DZK
COMMON/TRANSP/WTRA,WTRA,JTRA(JTRO),LTRA(JTRO),JTYPE(JTRO),APA(JTRO)
COMMON/EBIT/JONE,JTO,JSRRE
C
DIMENSION ZP(NKNOT,NCORP2),BP(NCORP2,1),ZFP(NCORP2,NKNOT)
DIMENSION AMAT(NCORP2,NCORP2),Z2(NKNOT,NTOT),CF(NKNOT,1),Z2(NTOT)
DIMENSION JTO(NTOT),Z2(NTOT)
COMMON/TRANSP/WTRA,ZETA(100,6)
DIMENSION SENS(20),ERRS(20),JORG(20)
DIMENSION ERS(20)
DATA IWRITE/6/
DATA IOUT/0/
DATA IWRITE/6/
DATA IBMIG,IMA,AMS/0.0,0.0,1.0/
C
THE VALUE OF 1 (CONSEQUENCE INDEX) IS DETERMINED IN MAIN THRU CONS
PARAMETER CYCLING INSIDE GROUP1 WITH VARIABLE JP
C
NPAPA = 1 IN THIS SUBROUTINE, NTOT = TOTAL NO. OF PARAMETERS
NCONS = 1 IN THIS SUBROUTINE, NCONS = NO. OF CONSEQUENCES, KNOWN TO MAIN ONLY
C
JTO = 0
PDMIN = 1.0E+48
WRITE (IWRITE,167C)
167C FORMAT ('P1,3I,20H**SUBROUTINE GROUP1 1/')
C
DO 5 J = 1,NCORP2
  DO 1 M = 1,NCORP2
    AMAT(M,J) = 0.000
  5 AMAT(M,J) = 0.000
DO 10 J = 1,NCORP2
  DO 8 M = 1,NCORP2
Z2(M,J) = 0.000
  8 Z2(M,J) = 0.000
DO 9 J = 1,NCORP2
  DO 7 M = 1,NCORP2
BP(M,J) = 0.000
  7 BP(M,J) = 0.000
DO 9 J = 1,NCORP2
  DO 7 M = 1,NCORP2
CF(J,1) = ZETA(J,1)
  7 CF(J,1) = ZETA(J,1)
C
NMAXP=3INS(95,NTOT)
DO 11 I = 1,NMAXP
  JORG(10) = 0
  11 JORG(10) = 0

**NAME**

**GROUP**

**DEFINE MATRIX**

**ZF** AND **ZFP**

```plaintext
DO ROC JF=1,MTOT
IF(JOUT.GT.0)
WRITE(1680,1680) JP
END DO
```

**FORMAT**

```
(1H3,3X,208EXPLhNINg PARAMETER,I4/)
```

```plaintext
DO 2 KNOT=1,NPANKP

**ZF**

```plaintext
ZF(KNOT,1) = 1.0DD
ZF(J,1) = 1.0DD
DO 3 J=1,NPABA
J1 = J+1
J2 = J1+NPABA
J3 = NPABA+1 + J*NPABA - J*J1/2
DZJ = ZB(KNOT,JP) - Z(FJ)
ZF(KNOT,J1) = DZJ
ZF(KNOT,J2) = DZJ*DZJ
ZFP(J1,KNOT) = DZJ
ZFP(J2,KNOT) = DZJ*DZJ
IF(J.GE.NPARA) GO TO 3
END DO
```

```plaintext
DO LOOP 4 IS BYPASSED IN GROUP ;
```

```plaintext
DO 4 K=J1,NPABA
K1 = J3+ K
DZK = ZB(KNOT,K) - ZC(K)
ZF(KNOT,K1) = DZJ*DZK
4 CONTINUE
```

**THE NEXT THREE STATEMENTS SOLVE LEAST SQUARES FITTING EQUATION**

```plaintext
(ZF'ZF)**BP = ZF'CF PCB BP
```

```plaintext
CALL YMULT(ZFP,CFB,CFB,NCOF2,NPANKP,NCONS,NCORS)
CALL YMULT(ZFP,ZFP,AMAT,NCORF2,NPANKP,NCORB2,NPANKP)
CALL YMULT(AMAT,NCORF2,AMAT,NCORF2,NPANKP)
```

```plaintext
ICTOP = ICTOP * 30
```

```plaintext
WRITE(2300,2300) DET2,ICOR
```

**FORMAT**

```
(1C,10I,23H*FITTED SURFACE ERROR*/IRO,5F,15HAPPR
1OXIMATION,5X,10DIFFEERENCE,5X,15HPCORE CONSEQUENCE,I4//)
```

**CALCULATE AND OUTPUT FITTED SURFACE ERROR**: MAXIMUM AND MINIMUM,

**MEAN** SQUARE ERROR, REFERENCE VALUE AND FRACTIONAL ERROR.

```plaintext
IF(INOUT.GE.2) WRITE(2300,2300) DET2,ICOR
```

**FORMAT**

```
(1C,15I,23H*FITTED SURFACE ERROR*/IRO,5F,15HAPPR
1OXIMATION,5X,10DIFFEERENCE,5X,15HPCORE CONSEQUENCE,I4//)
```

**DM** = NPANKP - NCORS

```plaintext
IF(DM.LE.0.) DM = 1.0E-10
```

```plaintext
SUMSQ = 0.0
BIG = 1.0E+49
SMALL = 1.0E-49
```

```plaintext
IF(INOUT.EQ.2) WRITE(1490,1490) L
```

```plaintext
DO 21 I=1,NSANKP
```

```plaintext
CFA = 0.1
```

```plaintext
DO 22 IC=1,NCOF2
```
CFA = CFA + 7F(IP, IC) * OP(IC, 1)

22 CONTINUE
X = CFA - CF(IB, 1)
IF(X.GT.BIG) IBIG = I
IF(X.GT.BIG) BIG = X
IF(X.LT.SMALL) SMALL = I
IF(X.LT.SMALL) IISMAI L = IP
IF(IOUT.EQ.7) WRITE(IWRITE, 1700) IB, CFA, CF(IR, 1), X

C
SUMSQ = SUMSQ + X*X
21 CONTINUE
IF(TOUT.GT.C) WRITE(INFINITE, 1701) L, IBIG, BIG, SMALL, SMALL
IF(MTRACO.LE.0) GO TO 99
C MAX ERROR CONSEQUENCES TO BE INVERSE TRANSFORMED
LTYP = 0
DO 70 I = 1, MTRACO
LL = LTRA(I)
C
IF(LL.NE.1) GO TO 701
LTYP = LTYPE(I)
AC = ACO(I)
BC = BCO(I)
CFBIG = CF(IBIG, L)
CFABIG = CFABIG + BIG
C
CPHSA = CF(ISMALL, L)
CPASHA = CPASHA + SMALL
GO TO (101, 200, 300, 400, 500, 600, 700), LTYP
101 BCC = 1 / BC
C
CFBIG = CFBIG**BCC + AC
CPABIG = CPABIG**BCC + AC
CPHMA = CPHMA**BCC + AC
CPASHA = CPASHA**BCC + AC
C
GO TO 701
200 CFBIG = EXP(CFBIG) + AC
CPABIG = EXP(CPABIG) + AC
CPHMA = EXP(CPHMA) + AC
CPASHA = EXP(CPASHA) + AC
GO TO 701
300 CFBIG = BC*ALOG(CFBIG) + AC
CPABIG = BC*ALOG(CPABIG) + AC
CPHMA = BC*ALOG(CPHMA) + AC
CPASHA = BC*ALOG(CPASHA) + AC
C
GO TO 701
400 CFBIG = PC*TAN(CFBIG) + AC
CPABIG = PC*TAN(CPABIG) + AC
CPHMA = PC*TAN(CPHMA) + AC
CPASHA = PC*TAN(CPASHA) + AC
500 CONTINUE
600 CONTINUE
700 CONTINUE
701 CONTINUE
IF (LTYPE.EQ.7) GO TO 95
BIG = CPABIG - CPB
SMALL = CPSMA - CPSMA
PBABIG = BIG/CPB
PBPSMA = SMALL/CPB
WRITE (IWFITE,7001) CPABIG,CPB,BIG,PRABIG
WRITE (IWFITE,7002) CPSMA,CPB,SMALL,PRASMA
7001 FORMAT ('H+',4X,2CHSuRE Tz R Ml,APPR=,E12.5,2X,6HEXACT=,E12.5,2X,6
1HEXACT=,E12.5,2X,6HEXACT=,F10.6/)
7002 FORMAT ('H+',4X,2CHSuRE Tz R Ml,APPR=,E12.5,2X,6HEXACT=,E12.5,2X,6
1HEXACT=,E12.5,2X,6HEXACT=,F10.6/)
99 CONTINUE
C ERRORS INVERSE TRANSFORMED
FMSE= SQRT (SUMSQ/DN)
IF (BP(1,1).EQ.0.) FRAERR = 0.0
IF (PF(1,1).NE.0.0) FRAERR = FMSE / ABS(BP(1,1))
IF (IOUT.GE.1)
1700 FORMAT (1H ,4X,14,3X,216.6,2X,215.6,4X,215.6)
1701 FORMAT (1H ,12H consequence,14,3X,15HMax Error Knot=,14,7H Value=,E
116.6,3X,15HMax Error Knot=,14,7H Value=,E15.6/)
1702 FORMAT (1H ,91,8HNP =,I4,QX,RP12,25HSUM OF RESIDUAL
1 SQUARES =,G13.5/)
1A = BF(1,1)
1BB = BF(2,1)
CC = BF(3,1)
DZ1 = Z1(JP) - ZC(JP)
DZ2=Z2(JP) - ZC(JP)
SENSIT = ABS ((BB + CC*DZ1) * DZ1) + ABS ((BB + CC*DZ2) * DZ2)
PMTF = WEIG*BIG * WSM*FMAE - WSM*SMALL
SIN = SQRT(L)
SO2 = SIN * SIN
PFMP = PMTE2/(SO2-FMTE2)
IF (PFMP.GT.2.37) GO TO 30
FACTOR = PMTE2/(SO2-PMTE2)
PRCD = SENSIT * FACTOR
IF (PRCD.EQ.0.0) JVNO = JP
IF (PRCD.EQ.0.0) JVNO = JP
DC 114 I=1,NMAXP
VFST=PFM(1)
MEYBER NAME GROUP1
IF (FMFP.CT. VERT) GO TO 114
INDMAX = MAXP - I
C
C
DO 115 IND = 1, INDMAX
IK = MAXP + 1 - IND
IF (IK = 1)
SENS(IK) = EPS(IKP)
JORG(IK) = JORG(IKP)
C
EPS(IK) = EPS(IKP)
C
115
SENS(IK) = SENS(IKP)
JORG(I) = JP
EPS(I) = FMTE
SENS(I) = SENSIT
EPS(I) = FACTOR * SENSIT
FMTE = 1.1E+49
SENSIT = 0.
114
CONTINUE
C
C
C
C
30 CONTINUE
900 CONTINUE
C
C AVERAGE EPSW/40 IS NOT EQUAL TO THE MEAN SQUARE EPSW EXACTLY
WRITE (WRITE, 4000)
400 FORMAT (A10, 6X, 51IPEHAPTEIZ IN THE ORDER OF INCREASING AVERAGE EPSW
10R/190.538 FAHIAM AV. SENSITIVITY SPURIOUSNESS ///
WRITE (WRITE, 4001) (JORG(I), EPS(I), SENS(I), EPS(I), I = 1, MAXP)
401 FORMAT (4H, 3X, (16, 3G12.5))
WRITE (WRITE, 402) PROMIN, JTW0
402 FORMAT (4H, 5X, 19SMALLEST SPURIOUS IS, 1G12.5) FOR PARAMETER, I4(1)
JTW0 = JORG(I)
RETURN
END
SUBROUTINE GROUP2(ZF,BF,ZFP,AMAT,ZB,CP,NKNOT,NCOEF2,Z1,Z2,Z1TSV)

FITS QUADRATIC SURFACES TO THE CONSEQUENTIAL DATA, NPARA=2, NCAMS=1
TWO PARAMETER SURFACES, ALL PAIRS WITH LEADING PARAMETER JONE PERMANENT
JONE SET BY CALL. GROUP1 FIRST
IN GROUP2 JONE CHANGED TO THE PARTNER THAT DECREASES M.S. ERROR MOST
IN GROUP3 JONE SELECTED TO MINIMIZE THE PRODUCT OF M.S. ERROR AND THE
SENSITIVITY OF THE MODEL

*CALL CONS
REAL NAMPA, NAMNB
REAL*8 ZF,BF,ZFP,AMAT,ZB,CP,CFI,X,DF1,DF2
COMMON/4KWT/JONE,JTWO,JTTHREE
COMMON/TRANSF/MTAPPA,MTRACO,JTFA(7),LTFA(7),LTYPE(7),JTYPE(7),APA(17),BPA(7),ACO(7),BCO(7)

DIMENSION ZP(NKNOT,NCOEF2),BP(NCOEF2,1),ZFP(NCOEF2,NKNOT)
DIMENSION AMAT(NCOEF2,NCOEF2),ZB(NKNOTV,NKNOT),CP(NKNOTV,1),ZF1(NKNOT)
DIMENSION Z11(NKNOT),Z22(NKNOT)
COMMON/ZETA/ZETA(100,6)
DATA IWRITE/6/
DATA OUTOUT/0/
DIMENSION SENS(20),BRMS(20),JORG(20)
DIMENSION EPS(20)

THE VALUE OF I (CONSEQUENTIAL INDEX) IS DETERMINED IN MAIN PROGRAM CONS
PARAMETER CYCLING INSIDE GROUP2 WITH VARIABLE JP
NCAMS=1 IN THIS SUBROUTINE, NCAMS=GO. OF CONSEQUENTIALS, KNOWN TO MAIN ONLY
WRITE(1670)

1670 FORMAT(1H1,1X,18SUBROUTINE GROUP 2/)

JONESV = JONE
EPMAJ = 1.0E+49
3 CONTINUE
DO 5 J = 1,NCOEF2
DO 1 M = 1,NCOEF2
4 AMAT(M,J) = 0.000
DO 5 K = 1,NKNOT
ZF(K,J) = 0.000
5 ZFP(J,K) = 0.000
DO 7 M = 1,NCOEF2
BF(M,1) = 0.000
DO 9 J = 1,NKNOT
CP(J,1) = ZETA(J,1)
7 NMAXP=MINO(J0,NKNOT)
DO 110 J=1,NMAXP

...
PARAMETER JONE IS PERMANENTLY THE FIRST (I=1), DETERMINED FIRST IN GROUP 1

ZP(KNOT,1) = 1.0D0
ZPF(KNOT,1) = 1.0D0
J = 1
J1 = J + 1
J2 = J1 + NPARA
J3 = NPARA + 1 + J * NPARA - J * J1/2
DZJ = ZF(KNOT, JONE) - ZF(JONE)
ZP(KNOT, J1) = DZJ
ZP(KNOT, J2) = DZJ * DZJ
ZPF(J1, KNOT) = DZJ
ZPF(J2, KNOT) = DZJ * DZJ

K = J1
K1 = J3 + K
DZK = ZF(KNOT, JP) - ZF(JP)
ZP(KNOT, 3) = DZK
ZP(KNOT, 5) = DZK * DZK
ZPF(3, KNOT) = DZK
ZPF(5, KNOT) = DZK * DZK
ZP(KNOT, K1) = DZJ * DZK
ZPF(K1, KNOT) = DZJ * DZK
CONTINUE

THE NEXT THREE STATEMENTS SOLVE LEAST SQUARES FITTING EQUATION
C

CALL MULT(2PF, CP, BF, NCOEF2, NPARA, NCONS, KNOT)
CALL MULT(2PF, ZP, AMAT, NCOEF2, NPARA, NCONS, NPARA)
CALL MATRIX(AMAT, NPARA, BF, NCONS, DET2, ICOR)
IP(DET2, EQ.C.) WRITE(IWRITE, 16AC) JONE, JP
ICOF = 1 COF * 30
IF (IP(GE, GE, 1)) WRITE(IWRITE, 2400) DET2, ICOR
2300 FORMAT('DETERMINANT OF ZPF*ZP = ', G15.6, ' TIMES 1.0D0', I4)

CALCULATE AND OUTPUT FITTED SURFACE ERROR: MAXIMUM AND MINIMUM,
C

MAXIMUM ERROR: REFERENCE VALUE AND HAPTICAL ERROR.
16AC FORMAT(1X, 10X, 23X, FITTED SURFACE ERRORS, 10X, 5X, 4XKNOT, 6X, 13HAPPE
ATION, 8X, 5X, SHEAR, 7X, 13CHDIFFERENCE, 5X, 15HAPF CONSEQUENCE, 14//1
DN = NFANKF - NCObama2
IF(DN.LE.0.) DN = 1.0E-10
SUMSQ = 0.0
BIG = -1.0E+49
IBIG = 1
SMALL = -1.0E+49
ISmall = 1
IF(IOUT.EQ.2) WRITE(IWRITE,1650) L
DO 21 IB=1,NFANKF
CFA = 0.0
DO 22 IC=1,NCOBP2
CFA + ZF(IC,IC) * BF(IC,1)
22 CONTINUE
X = CFA - CF(IB,1)
IF(X.GT.BIG) IBIG = IB
IF(X.GT.BIG) BIG = X
IF(X.LT.SMALL) ISmall = IB
IF(X.LT.SMALL) SMALL = X
IF(IOUT.EQ.2) WRITE(IWRITE,1700) IB,CFA,CF(IB,1),X
SUMSQ = SUMSQ + X*X
21 CONTINUE
IF(IOUT.GE.1) WRITE(IWRITE,1700) L,IBIG,BIG,ISmall,SMALL
IF(NTRACO.LE.0) GO TO 99

ERROR CONSEQUENCES TO BE INVERSE TRANSFORMED
LTPF = 0
DO 701 I=1,NTRACO
L = LTPA(I)
701 IF(ILL.WE.L) GO TO 701
LTPF = LTPF(I)
AC = ACO(I)
BC = BCO(I)
CFBIG = CF(IBIG,1)
CFBIG = CFBIG * BIG

CFSMA = CF(ISmall,L)
CFSMA = CFSMA * SMALL
GO TO (1C1,200,200,400,500,600,7G3),LTPF =
101 BCC = 1./BC
C
CFBIG = CFBIG**BCC + AC
CFABIG = CFABIG**BCC + AC
CFSMA = CFSMA**BCC + AC
CFSMA = CFSMA**BCC + AC
C
GO TO 711
500 CONTINUE
600 CONTINUE
700 CONTINUE
701 CONTINUE
IF(ITEMP.EQ.0) GO TO 99
BIG = CFABIG - CFBIG
SMALL = CFASMA - CFSMA
FRABIG = BIG/CFBIG
FRAASMA = SMALL/CFSMA
WRITE(UNIT=700) CFABIG,CFBIG,BIG,FRAEIG
WRITE(UNIT=700) CFASMA,CFSMA,SMALL,FRAASMA
7001 FORMAT('1H+,4X,2OCHINVERSE TR NAT,APPB=,E12.5,2X,6HEXACT=,E12.5,2X,6
1HERROE=,E12.5,2X,6HFRACTION=',F10.6/)
*EMBRACE MADE GROUP2

C

C DK1 = Z1(JP) - Z0(JP)
DK2 = Z1(JP) - Z0(JP)
SENS1 = CD * DZ1 * DK1 * CROSSW
SENS12 = ABS(SENS12)
SENS1 = ABS((B1 + C1*DZ1) * DZ1) + ABS((B1 + C1*DZ2)*DZ2)
SENS2 = ABS((B2 + C2*DK1)*DK1) + ABS((B2 + C2*DK2) * DK2)
SENSIT = SENS1 + SENS2 + SENS12

C

C

C SINT = SDFET(L)
SO2 = SINT * SINT
FMSE2 = FMSE * FMSE
IF(FMSE2.GE.SO2) GO TO 10
FACTOR = FMSE2/(SO2 - FMSE2)
FES = FACTOR * SENSIT

C

C DO 114 I = 1, NMA XP
FMSP = RMS(I)
IF(FMSP.GT.VERT) GO TO 114
INDMAX = NMAXP - I

C

C DO 115 IND = 1, INDMAX
I = NMA XP + 1 - IND
IKP = IK - 1
EBMS(IK) = EBMS(IKP)
RRS(IK) = FFS(IPF)
JORG(IK) = JORG(IPF)

C

C 115 SENS(I) = SENS(TIK)
JORG(I) = JP
EBMS(I) = FMSE
SENS(I) = SENSII
ERS(I) = FES
FMSE = 1.1E+49
SENSIT = 0.

114 CONTINUE

C

C 30 CONTINUE

800 CONTINUE

WRITE(IWRITE,4000) L
4000 FORMAT(12H CONSEQUENCE,14,J74
1/15,5IPARAMETER CALLS, M.S. ERRORS AND TOTAL SENSITIVITIES, SPOI
20USNESS)

WRITE(*WHITE,4001)JONE, (JOBS(I),EBMS(I),SENS(I),ERS(I),I = 1,NMA XP)

4001 FORMAT(1H,15H CALL PARAMETERS, I4, (ID, JG12.5))

VFP = RMS(1)
IF(VFPT.IF.FMA J) JONE = JOR G(1)
IF(VFPT.IF.FMA J) FMA J = VERT
JRF = JOR G(1)
TF(JONE.EQ.JRF) 30 TO 1
RETURN
SUBROUTINE GROUP 3(ZP,BF,FP,AMAT,ZR,CF,MTOT,KNOT,NCOEF2,DL,Z1,Z2,
1KNOTSV)
C
C FIT S QUADRATIC SURFACES TO THE CONSEQUENCE DATA, NPAPA=2, NCONS=1
C TVC PARAMETER SURFACES, ALL PAIRS WITH LEADING PARAMETER JONE PERMANENT
C JONE SET BY SORP, GROUP: FIRST
C IN GROUP2 JONE CHANGED TO THE PARTNER THAT DECREASES A.S. ERROR 57ST
C IN GROUP3 JONE SELECTED TO MINIMIZE THE PRODUCT OF MS ERROR AND THE
C SENSITIVITY OF THE MODEL
C
*CALL CONS
C
REAL WAMFA,WAMEB
REAL *8 ZP,BF,FP,AMAT,ZR,CF,CTA,I,DLZ,DLZ
COMMON/HORIT/JONE,JTWO,JTHREE
COMMON/*RAMP/MTAPA,MTACP,JWTRO(7),LTRA(7),LTYPE(7),ITA(17),BPA(7),ACO(7),RCO(7)
C
DIMENSION ZP(NKNOT,UCOPF2),BF(NCOEF2,1),FP(NCOEF2,KNOT)
DIMENSION AMAT(NCOEF2,NCOEF2),FP(KNOTSV,MTOT),CF(KNOTSV,1),ZO(NTOT)
11
DIMENSION Z1(NTOT),Z2(NTOT)
COMMON/ZETA/ZEBA('CO,E)
DATA IITE/6/
DATA IOOT/0/
DATA CNSSW/1.0/
DIMENSION SENS(20),RMS(20),JORG(20)
DIMENSION ERS(30)
C
C THE VALUE OF 1 (CONSEQUENCE INDEX) IS DETERMINED IN MAIN THRO CONS
C PARAMETER CYCLING INSIDE GROUP2 WITH VARIABLE JP
C
C NCONS=1 IN THIS SUBROUTINE, NCONS=NO. OF CONSEQUENCES KNOWN TO MAIN ONLY
WRITE(UNIT,1670)
1670 FORMAT('MP1,J1,1M1SUBROUTINE GROUP 3//')
C
ERSBAJ = 1.0E+49
JONESV = JONE
CONTINUE
DO J J = 1,NCOEF2
DO I M = 1,NCOEF2
1 AMAT(N,J) = 0.000
DO K K = 1,NKNOTP
2 FP(K,J) = 0.000
5 ZFP(J,K) = 0.000
DO H = 1,NCOEF2
7 BF(H,11) = 0.000
DO J = 1,NKNOTP
9 CF(J,1) = ZETA(J,1)
MMAXP=YNQ(20,MTOT)
DO 110 I = 1,MMAXP
JORG(I) =
PARAMETER NAME GROUP3

ERS(I) = 1.0E+24
SERS(I) = 1.0E+24

110 CONTINUE
C
C DEFINE MATRIX ZF AND ZFP
C
DO 800 JP=1,NTOT
IF (JP.EQ.JONE) GO TO 800
IF (IOUT.GT.0)
WRITE (WRITE,168C) JONE,JP

1680 FORMAT (10D,3L,10PARAMETERS,I4,1H,14//)
DO 2 KNOT=1,NNBANK
C
C PARAMETER JONE IS PERMANENTLY THE FIRST (J=1), DETERMINED FIRST IN GROUP 1
C
ZF(KNOT,1) = 1.0DD
ZFP(1,KNOT) = 1.0DD
J= 1
J1 = J+1
J2 = J1+NPARA
J3 = NPARA+1 + J*NPARA - J1/2
DF = ZF(KNOT,JONE) - ZF(JONE)
ZF(KNOT,1) = DF
ZF(KNOT,J2) = DF
ZFP(J1,1) = DF
ZFP(J2,KNOT) = DF
ZFP(1,KNOT) = DF
ZFP(KNOT,3) = DF
ZF(KNOT,K1) = DF
ZFP(K1,KNOT) = DF

2 CONTINUE

C
C THE NEXT THREE STATEMENTS SOLVE LEAST SQUARES FITTING EQUATION
C (ZF'ZF)BF = ZF'CF
C
CALL MNULT(ZF,CF,BF,NCORF2,NNBANK,NCORS,KNOTSY)
CALL MNULT(ZF,PF,AMAT,NCORF2,NNBANKP,NCORF2,NNBANKP)
CALL MNULT(AMAT,NCORF2,BF,NCORS,BF2,ICOMP)
ICOMP = TCBR * 30

IP(TOTT,GR.1)
WRITE (WRITE,2300) DET2,ICOMP
IF (DET2.EQ.0.) WRITE (WRITE,166C) JONE,JP

2300 FORMAT (1D,10H,23H,MAXIMUM AND MINIMUM,23H,ERROR.
1H690 FORMAT (1D,10H,23H,FITTED SURFACE ERROR
10MATION,Rx,SHI(FACT),10H,10HDIFPCRF,5X,15HPCF CONSEQUENC,
13H4//)
\begin{verbatim}
PROBLEM NAME GROUP3
  C
  C
  DM = WRANKP - #COLP?
IF(DM.LT.0.) DM = 1.0E+10
SUMSQ = (1.0
BIG = -1.0E+49
IBIG = 1
SMALL = 1.0E+49
ISNALL = 1
IF(JOUT.EQ.2) WRITE(IWRITE,1690) L
DO 21 IR=1,NRANKF
CFA = 0.0
DO 22 IC=1,NCOLP2
CFA=CFA + ZP(IR,IC) * BP(IC,1)
22 CONTINUE
X = CFA - CF(1,1)
IF(X.GT.BIG) IBIG = IR
IF(X.LT.SMALL) ISNALL = IR
IF(X.LT.SMALL) SMALL = I
IF(JOUT.EQ.2) WRITE(IWRITE,1700) IR,CFA,CF(1,1)
C
SUMSQ = SUMSQ + X*X
21 CONTINUE
IF(JOUT.GE.1)
WRITE(IWRITE,1700) L,IBIG,BIG,ISNALL,SMALL
IF(MTP(ACC.LE.0) GO TO 99
C
*AN ERROR CONSEQUENCES TO BE INVERSE TRANSFORMED
C
LTYP = L
DO 701 I=1,NTRACO
LL = LTFA(I)
C
IF(LL.NF.L) GO TO 701
LTYP = LTYP(I)
AC = AC(I)
BC = BC(I)
CFBIG = CF(TPI,L)
CPFAT = CFBIG + BIG
C
CPFSMA = CF(SNALL,I)
CPASMA = CPFSMA + SMALL
GO TO (101,200,300,400,506,600,700),LTYP
101 BCC = 1./BC
C
CFBIG = CFBIG*BCC + AC
CPFAT = CPFAT*BCC + AC
CPFSMA = CPFSMA*BCC + AC
CFAFMA = CPASMA*BCC + AC
C
JC TO 777
\end{verbatim}
EMBER NAME GROUP

200 CFBIG = EXP(CFBIG) + AC
CFABIG= EXP(CFABIG) + AC
CFBSMA = EXP(CFSMA) + AC
CFASMA= EXP(CPASMA) + AC
GO TO 71

300 CFBIG =PC*ALOG(CFBIG) + AC
CFABIG=BC*ALOG(CFABIG) + AC
CFBSMA = BC*ALOG(CFSMA) + AC
CFASMA= BC*ALOG(CPASMA) + AC

GO TO 71

400 CFBIG = BC*TAN(CFBIG) + AC
CFABIG= BC*TAN(CFABIG) + AC
CFBSMA = BC*TAN(CFSMA) + AC
CFASMA= BC*TAN(CPASMA) + AC

900 CONTINUE
600 CONTINUE
700 CONTINUE
710 CONTINUE

IF(LTTP.EQ.) GO TO 99
BIG = CFABIG - CFBIG
SMALL = CFASMA - CFBSMA
PHABIG = BIG/CFBIG
PHASMA = SMALL/CFBSMA
WRITE (WRITE, 7002) CFABIG,CFBIG,BIG,PHABIG
WRITE (WRITE, 7002) CFBSMA,CFBSMA,SMALL,PHASMA

7001 FORMAT(1H4,,2X,CHFVERSE TN MAX,APPR=,E12.5,2X,MAXHACT=,E12.5,2X,6
1HBESOR=,F12.5,2X,CHFFACTION=,F10.6/)

7002 FORMAT('M+,'X,2CHFVERSE TN MIN,APPR=,E12.5,2X,MINHACT=,E12.5,2X,5
1HBESOR=,F12.5,2X,CHFFACTION=,F10.6/)

99 CONTINUE

EFORMS INVERSE TRANSFORMD

FMSE= 502T(SUBSQ/DM)
IF(RF(1,1).EQ.G.) PFAESP = 3.0
IF(RF(1,1).EQ.0.C) PFAESP = FMSE / DABS(BF(1,1))
IF(TOMT.GT.0) WRITE (WRITE, 1702) FMSE, BF(1,1),PFAESP,SUBSQ

1700 FORMAT(TH,,X,14,3X,E11.6,2X,E11.6,4X,E15.6)
1701 FORMAT(TH,,X,12HCONSEQUENCE,14,3X,15HMAX ERROR KNOT=,I4,7H VALUE=,E11.6,3X,15HMIN ERROR KNOT=,I4,7H VALUE=,E11.6,6X)
1702 FORMAT('H,,20H MAX SQUARE BRKOF=,E15.6,11H REF VALUE'=,E15.6,3X,1
1CHFFACTION =,F9.5,3X,15HSON OF SQUARES=,G13.5/)

AA= RF(1,1)
B1= RF(2,1)
C1= RF(3,1)
B2= RF(5,1)
C2= RF(6,1)
DD= RF(6,1)
D31= X*(JONM) - 20(JONM)
D22= X*(JONP) - 20(JONP)

C

C
DO 114 I=1,\#MAXP
   VERI = EPS(I)
   IF(VERI.GT.VERT) GO TO 114
   INDX = \#MAXP - I

DO 115 IND=1,INDMAX
   IK = \#MAXP + 1 - IND
   IKP = IK - 1
   ERS(IK) = ERS(IP)
   JORG(IK) = JORG(IP)
   ERS(IK) = EPS(I)
   ERS(I) = FES
   SENST(I) = SENST(IP)
   JOR(I) = JP
   ERS(IK) = EPS(IK)
   SENST(I) = SENST(IK)
   JORG(IK) = JORG(IK)
   GO TO 114

CONTINUE

30 CONTINUE

WRITE(1,4000) I
4000 FORMAT(12H CONSEQUENCE,14,37H
   1/1H,65H PARAMET\$ PAIRS, 9.5 ERRORS AND TOTAL SENSITIVITI\$S, SPURI
   2OUSNESS/)
SUBROUTINE GROUP4(ZP,BP,ZPP,AMAT,ZR,CP,MTOT,KNOT,MOEF2,21,22,1KNOTSV)

C
C THIS GROUP4 FITS QUADRATIC SURFACES TO THE CONSEQUENCE DATA. NPARA=2, NCONS=1
C TWO PARAMETER SURFACES, ALL PAIRS WITH LEADING PARAMETER JONE REMAIN
C JONE SET BY SUBR. GROUP1 FIRST
C IN GROUP2 JONE CHANGED TO THE PARTNER THAT DECREASES R.S. ERROR MOST
C IN GROUP3 JONE SELECTED TO MINIMIZE THE PRODUCT OF MS ERROR AND THE
C SENSITIVITY OF THE MODEL
C GROUP4 FITS ALL POSSIBLE REGRESSIONS OF TWO PARAM. QUADRATIC
C
*CALL CONS
C REAL NPARA,NAMES
C REAL *H ZP,BP,ZPP,AMAT,ZR,CP,X,D2J,D2K
C COMMON/BRIT/JONE,JTWO,JTHREE
C COMMON/TRANS/NTPAPA,NTPACO,JTPA(7),LTPA(7),LTYPE(7),APA(7),SPA(7),ACO(7)
C COMMON/SWIN/SVALUE,SWON/100,6
C DATA (WRITE/6/
C DATA IOMT/0/
C DATA ICROSS/1.0/
C DIMENSION SFNST(20),SNMS(20),JOPG(20)
C DIMENSION EPS(20)
C DIMENSION JURF(20)
C DATA JFIPST,JLAST/1,153/
C IF(JFIPST.LE.0) JFIPST = 1
C IF(JLAST.LE.0) JLAST = JFIRST
C IF(JLAST.GT.NTOT) JLAST = NTOT
C IF(JFIRST.GT.JLAST) JFIRST = JLAST
C THE VALUE OF 1 (CONSEQUENCE INDEX) IS DETERMINED IN MAIN THEP CONS
C PARAMETER CYCLING INSIDE GROUP2 WITH VARIABLE JP
C
C NCONS=1 IN THIS SUBROUTINE, NCONS=NO. OF CONSEQUENCES, KNOWN TO MAIN ONLY
C WRITE (WRITE,1670)
C 1670 FORMAT(1X,14,1EH0SUBROUTINE GROUP 4//)
C
C ERSMAJ = 1.0E+49
C JONESV = JONE
C JONE = JFIRST - 1
C DELTA = MTOT
C MAXP=MAXP(20,NOFLTA)
C DC 17C J=1,MAXP
C JOPG(J) = 0
C SNMS(I) = 1.0E+24
C SENSE(') = 1.0E+24
C ERS(I) = 1.0E+24
C JOPF(I) = 0
PARAMETER JONE IS PERMANENTLY THE FIRST (J=1), DETERMINED FIRST IN GROUP 1

JF (KNOT, J) = ZETA (J, 1)  
JF (J, KNOT) = ZETA (J, 1)  

C THE NEXT THREE STATEMENTS SOLVE LEAST SQUARES FITTING EQUATION

CALL MONT (ZF, CP, FF, MOEFP, MRAFP, MOEWS, XG1STV)
C
CALCULATE AND OUTPUT FITTED SURFACE ERRORS: MAXIMUM AND MINIMUM, 
MEAN SQUARE ERROR, REFERENCE VALUE AND RELATIVE ERROR.
1690 FORMAT(1PO,10X,13H*FITTED SURFACE ERRORS*/ lHO,5X,4HREF.,6X,13HAPP*
10XIMATION,8X,5HFACT,10X,10HDIFFERENCE,5X,15HFOR CONSEQUENCE,18/)
C
C
DN = WAVANKP - NCOEF2
IF(DN.LT.0.) WRITE(IWRITE,5500) DN

5500 FORMAT(1SH - NCOEF2 IS GT 3% EQ WANKP, DN =,F6.1/)
IF(DN.LE.0.) DN = 1.0E-10 
SUMSQ = 0.0
IBIG = 1.0E+49
SMALL = 1.0E-49
ISTALL = 1
IF(IOUT.EQ.2) WRITE(IWRITE,1700) L
DO 21 I=1, NRANKP
CFA= 0.0
DO 22 IC=1,NCCOEF2
CFA=CFA + ZF(IR,IC) * BF(IC,1)
22 CONTINUE
X=CFA - CF(IR,1)
IF(X.GT.0.)IBIG = IP
IF(X.GT.IBIG) BIG = X
IF(X.LT.SMALL) SMALL = IP
IF(X.LT.SALL) SMALL = X
IF(IOUT.EQ.2) WRITE(IWRITE,1700) IR,CFA,CF(IR,1),X

SUMSQ = SUMSQ + X*X
21 CONTINUE
IF(IOUT.GE.1)
'WRITE(IWRITE,1701) L,IBIG,BIG,SMALL
IP(MTRACO.IE.0) GO TO 99

MAX ERROR CONSEQUENCES TO BE INVERSE TRANSFORMED
LTP = 1
DO 7C1 I=1,MTRACO
L = LTRACO(I)
7C1 CONTINUE
IF(L.LT.0.) GO TO 701
LTP = 1
AC = ACO(I)
BC = NCO(I)

}
CPBIG = CF(IBIG, L)
CPABIG = CPBIG + BIG

C

CFSHA = CF(ISMALL, L)
CFASMA = CFSHA + SMALL
GO TO (1C, 200, 100, *C0, 500, 600, 700), ITP

191 BCC = 1 / BC

C

CPBIG = CPBIG**BCC + AC
CPABIG = CPABIG **BCC + AC
CFSHA = CFSHA **BCC + AC
CFASMA = CFASMA **BCC + AC

C

GO TO 701

200 CPBIG = EXP(CFABIG) + AC
CPABIG = EXP(CFABIG) + AC
CFSHA = EXP(CFSHA) + AC
CFASMA = EXP(CFASMA) + AC
GO TO 701

300 CBIG = BC*ALOG(CPBIG) + AC
CPBIG = BC*ALOG(CPBIG) + AC
CFSHA = BC*ALOG(CPSMA) + AC
CFASMA = BC*ALOG(CPSMA) + AC

C

GO TO 701

400 CPBIG = BC*TAN(CPBIG) + AC
CPABIG = BC*TAN(CPBIG) + AC
CFSHA = BC*TAN(CFSHA) + AC
CFASMA = BC*TAN(CFASMA) + AC

C

GO TO 701

500 CONTINUE

600 CONTINUE

700 CONTINUE

701 CONTINUE

IF (ITP.PQ.0) GO TO 99
BIC = CBABIG - CBIG
SMALL = CFSHA - CFSHA
FRAEIG = BIG/CBIG
FPASSA = SMALL/CFSMA
WRITE (WRITE, 7001) CPABIG, CPBIG, BIG, PHASMA
WRITE (WRITE, 7002) CFSHA, CFSHA, SMALL, PHASMA

7001 FORMAT('INP, A1, 2CINVERSE IN :I, APPR=, E12.5, 2x, 6HRIAC=, E12.5, 2x, 6
1REPHR=, F12.5, 2x, 6HRFACTION=, E10.6/)

C

7002 FORMAT('INP, A1, 2CINVERSE IN :I, APPR=, E12.5, 2x, 6HRIAC=, E12.5, 2x, 6
1REPHR=, F12.5, 2x, 6HRFACTION=, E10.6/)

99 CONTINUE

C

FPRORS INVERSE TRANSFORM

C

FAIL = SOME (SUMS/DIM)
IF (BF(1, 1).PQ.0) PRAPPF = .0
IF (PF(1, 1).PQ.2.0) PRAPPF = FAIL / DABS(BF(1, 1))
IF(icut G.0)
WRITE(*,17C2) IMSE,BF(1,1),FAEBP,SOBSQ
1700 FORMAT(1F,4X,14.3F,E16.6,2X,E15.6,4X,E16.6)
1701 FORMAT(1H0,12H*CONSEQUENCE,14,3X,15HHAX ERROR KNOT=,14,7H VALUE=,1
16.6,3X,15HHAX ERROR KNOT=,14,7H VALUE=,E16.6)
1702 FORMAT(1H,20H MEAN SQUARE ERROR=,E15.6,11H REF VALUE=,E15.6,3X,1
10**FRACTION=,F5.5,3X,15HH SQ OF SQUARES=,G13.5//)
AA = BF(1,1)
B1 = BF(2,1)
C1 = BF(4,1)
B2 = BF(3,1)
C2 = BF(5,1)
DD = BF(6,1)
E21 = Z1(J0WE) - Z0(J0WE)
E22 = Z2(J0WE) - Z0(J0WE)
C
C
DK1 = Z1(JP) - Z3(JP)
SUBROUTINE HISTO(NPLO,NIS,POINT)
C
C SUBROUTINE HISTO CALCULATES DISTRIBUTIONS (HISTOGRAMS) OF THE CONSEQUENCES
C
*CALL CONS
D DIMENSION NPLO(6,26)
D DIMENSION NIS(6,12),POINT(6,6,12,12)
D DO 421 L=1,NCONS
D DEV= (AZETA(L) - ATZET(L))/(SCALE*SDZET(L))
D HISL=DEVL +7.
C PISL= DEV*2. +14.
C IF(NP.LT.0)NP=1
C IF(NP.GT.26)NP=26
C NPLO(L,NP) = NPCLC(L,NP)+1
C NIS(L,NP) = NISL+1
C IF(N. LT.1)NL=1
C IF(N.GT.12)NL=12
C POINT(L,N,NL,NN) = POINT(L,N,NL,NN) +1
C IF(L.NE.NCONS) GO TO 421
C LPI=L+1
D DO 422 =LPI,NCONS
D DEV= (AZETA(M) - ATZET(M))/(SCALE*SDZET(M))
D HIS=M +7.
C IF(M.LT.1)MM=1
C IF(M.GT.12)MM=12
C POINT(L,N,M,MM) = POINT(L,N,M,MM) +1
422 CONTINUE
421 CONTINUE
RETURN
C END HISTOGRAM SUBROUTINE
END
SUBROUTINE INIT(IPARA, IDIS, ADIS, BDIS, CDIS, ZB, NTOT, NKNOT)

C
C SUBROUTINE INIT SETS INITIAL VALUE ZEROS

REAL*8 IF

*CALI. CONS
COMMON/TRANSF/NTA,APA,MTA,ACO,TRA(7),JTRA(7),JTRA(7),JTRA(7),AFA(7),APA(7),ACO(7),BCO(7)

COMMON/ZETAR/ ZETA(100,6)

DIMENSION IPARA(NTOT), IDIS(NTOT), ADIS(NTOT), BDIS(NTOT), CDIS(NTOT),

1 DDIS(NTOT), ZB(NKNOT, NTOT)

3 DO 4 I = 1, NTOT
ADIS(I) = 0.
BDIS(I) = 0.
CDIS(I) = 0.
DDIS(I) = 0.
IDIS(I) = 0.
IPARA(I) = 0.
DO 4 IL = 1, NKNOT
ZB(IL, I) = 0.
4 CONTINUE

DO 5 IL = 1, NCONS
5 ZEIA(IL, I) = 0.
DO 70 I = 1, 7
JTRA(I) = 0
LTRA(I) = 0
JTRA(I) = 0
LTRA(I) = 0
70 CONTINUE
RETURN
END
*CALL CONS
COMMON ZETA(19,6), TPARA(TOT), IDIS(NTOT), ADIS(NTOT), BDIS(NTOT),
CDIS(TOT), DDIS(NTOT), ZO(NTOT), Z1(NTOT), Z2(NTOT), ZR(NTOT,NTOT)
DIMENSION IPLO(6,26), TPL(26), XP(26)
DIMENSION ICPLO(6,26), TPL(26), XC(26)
DIMENSION SUMA(6), SUMB(6), SUMC (6), SUMD(5)
DIMENSION SAVZET(6)
DIMENSION CSU(6), CSUMB(6), CSUC(6), CSUDD(6)
DIMENSION CS1EAN(6), CS3D (6)
DIMENSION Z(100)
DATA ISAS/1/
1002 FORMAT (1H1,T4,'INPUT DATA - WORK',I6,3X,6H JOBS ,12/)
1003 FORMAT (I3,4X,A2,12,4E1.5,1X,12I2)
1004 FORMAT (1H0,26H NUMBER OF PARAMETERS = ,I3/)
1005 FORMAT (7H ,I6,4X,A4,A2,16,6X,4G11.5,4X,12I3)
1006 FORMAT (1H0,7A,'NUMBER',J17,'NAME',24,'DISTRIBUTION',T93,'PARAMETER
IPS',T94,'PAIRS IF LIMITED NUMBER'/)
1010 FORMAT (16 ,10I1,15,8H CORRELATIONS BETWEEN INPUT PARAMETERS/) 
1011 FORMAT (27H INDEPENDENT INPUT PARAMETERS/) 
1012 FORMAT (7H NUMBER OF CONSEQUENCES = ,I3/)
1013 FORMAT (7H NUMBER OF SIMULATION CYCLES =,I10/)
1014 FORMAT (1H0,31H NUMBER OF SIMULATIONS = ,I5/)
1015 FORMAT (1H0,27H NUMBER OF SIMULATION CYCLES = ,I10/18H CATEGORY WIDTH
1H0,24H STANDARD DEVIATIONS/) 
1016 FORMAT (5I6H CONSEQUENCES CALCULATED BY THE SUBROUTINE (TEKAS) )/
1017 FORMAT (1H0,15,5,6,15,5,6)
1018 FORMAT (1H0,6,16CORRELATION TYPE,14,11H LEAD PARA,14,8H, VALUE=,
1E14.6,1X,14,6,1X,1INDEPENDENT PARA,14,5H SHIFTED MEAN',E14.6/) 
1019 FORMAT (1H0)
1020 FORMAT (9H0 DISTRIBUTION FIRST PARAMETER SECOND PARAMETER
1THIRD PARAMETER FOURTH PARAMETER/) 
1021 FORMAT (6H6H 1=UNIFORM UPPER LIMIT LOWE LIMIT
1 /N/A )
1022 FORMAT (6H6H 2=LOGNORMAL MEAN VALUE STANDARD DEVIATION
1 /N/A )
1023 FORMAT (6H6H 3=EXPOENTIAL LOWER LIMIT SCALE CONSTANT
1 /N/A )
1024 FORMAT (6H6H 4=EXPOENTIAL UPPER LIMIT SCALE CONSTANT
1 /N/A )
1025 FORMAT (6H6H 5=LOGNORMAL MEAN VALUE STANDARD DEVIATION
1 LOWER LIMIT /N/A )
1026 FORMAT (6H6H 6=LOGNORMAL MEAN VALUE STANDARD DEVIATION
1 UPPER LIMIT /N/A )
1027 FORMAT (9H7=BETA LOWER LIMIT UPPER LIMIT
1 MEAN STANDARD DEVIATION
1 6=LOGNORMAL MEAN VALUE STANDARD DEVIATION
1 /N/A )
1029 FORMAT (6X,'FOR DISTRIBUTIONS 5 AND 6, THE VALUES FOR THE MEAN
1 AND STANDARD DEVIATION ARE THOSE FOR THE UNTRUNCATED NORMAL
2 DISTRIBUTIONS.',1X,6X,'FOR DISTRIBUTION 9, THE VALUES FOR MEAN AND STAN
3 DARD DEVIATION ARE THOSE OF THE LOGARITHM OF THE PARAMETER.' )
DATA IP,READ,WRITE,IPUNCH/5,6,7/
READ PARAMETER INFO AND ORGANIZE
DO 11 IM=1,NPAPA
READ(5,1601) K,NAMEA,NAMER,JDJS,UDIS,UCDIS,DDDJS,JDJS,UDIS,UCDIS,DDDJS,JDJS
IPAPA(K)=K
JDJS(K)=JDJS
UDIS(K)=UDIS
UCDIS(K)=UCDIS
DDDJS(K)=DDDJS
11 CONTINUE
IF(NCORR.LE.0) GO TO 15
DO 13 I=1,NCORR
READ(5,1601) IYPE(I),ILEAD(I),FLEAD(I),IDEP(I),FDIP(I)
13 WRITE(6,1019) IYPE(I),ILEAD(I),FLEAD(I),IDEP(I),FDIP(I)
15 CONTINUE
CALL KPCSS(IPAPA,JDJS,UDIS,UCDIS,DDDJS,EBIS,Z0,Z1,Z2,NTOT)
DO 15 T=1,NPAPA
WRITE(6,1020) IYPE(T),I,22(T),Z1(T)
15 CONTINUE
WRITE(6,1600)
160 FORMAT(1X,6I6,2HANGES OF THE PARAMETERS/IN,9H PARA NO.,9H Z'S/)
CALI KPCSS(IPAPA,JDJS,UDIS,UCDIS,DDDJS,EBIS,20,21,22,NTOT)
DC 15 T=1,NPAPA
WRITE(6,1631) I,22(I),Z1(I)
1631 FORMAT(1X,5X,14,9X,18,H6)
C INPUT PARAMETER TRANSFORMATIONS
IF(WPAPA.LE.0) GO TO 81
WRITE(INF1,1047) WPAPA
FORMAT(1HO,T5,T3H TRANSFORMED PARAMETERS/1H ,59WPAPA NO., TR. TYPE
1. APA = 1ST TR. PARA., BPA = 2ND TR. PARA./)
DO 80 I=1,WPAPA
READ(INPAD,1042) JPA(I),JTYPE(I),APA(I),BPA(I)
WRITE(INF1,1048) JPA(I),JTYPE(I),APA(I),BPA(I)
80 CONTINUE
1042 FORMAT(15,I5,E15.6,E15.6)
1048 FORMAT(1H3,' PARAMETER TRANSFORMATION DEFINITIONS
11HO,' TR. TYPE EQUATION
21H ',' 1 X = (Z - APA)**BPA
31H ',' 2 X = LOG(Z - APA)
41H ',' 3 X = EXP((Z - APA)/BPA)
51H ',' 4 X = ATAN((Z - APA)/BPA)
C END OF PARAMETER TRANSFORMATION INPUT AND DEFINITIONS
81 CONTINUE
IF(JOBS.GT.1) RETURNC
C PUNCH AND PRINT KNOT-POINTS
C SAMPLE STANDARD RANDOM KNOT-POINTS AND EDIT
C INDEX = 5
90 IF(WRANKP.LE.0) RETURN
WRITE(INF1,1620) WRANKP
INDEX = 50
DO 91 I=1,WRANKP
CALL SAMPLE(IDIS,ADIS,BDIS,CDIS,DDIS,ZR,NT3T,NKNOT,T)
91 CONTINUE
DO 92 J=1,NPAPA
IMIN = 1
IMAX = 1
ZMIN = ZR(IMIN,J)
ZMAX = ZR(IMAX,J)
IF(ZR.GT.ZMAX) IMAX = J
IF(ZR.LT.ZMIN) IMIN = J
92 CONTINUE
Z(R,IMIN,J) = ZMIN(J)
Z(IMP,IMAX,J) = ZMAX(J)
93 CONTINUE
DO 94 I=1,WRANKP
WRITE(INF1,1621) INDEX,1.(CA(I,J),J=1,NPAPA)
CALL TECLASS(NKNOT,MKNOT,ZR)
WRITE(INFOR,1F25) INDEX,1.(ZB(I,J),J=1,NPAPA)
DO 94 J=1,NTP
Z(J) = ZR(J,J)
95 CONTINUE
IF(IZ.TE.1) CALL TECLASS(Z,1)
WRITE(INFOR,1F24) INDEX,1.(ZB(I,J),J=1,NPAPA)
IF(IZ.TE.1) CALL CASIN(MKNOT,MKTP,ZR)
1621 FORMAT(1H1,10X,32H RANDOM KNOT-POINT COORDINATES -15,45STIS//)
1F25 FORMAT(1H1,6X,21X,(4E12.5))
NAME JOBS1
1601 FORMAT (4H14,3X,4X,14,3E14.6)
1401 FORMAT (4H14,3X,4X,5E14.6)
RETURN
END
MEMBER NAME KNUTSS
SUBROUTINE KNUTSS (IPARA, IDIS, ADIS, BDIS, CDIS, DDIS, Z0, Z1, Z2, NTO)
CC
C CALCULATES INTERVALS Z2, Z0, Z1
C OUTPUT IN SUBROUTINE JOBS
CC
*CALL COMS

DIMENSION IPARA(NTOT), IDIS(NTOT), ADIS(NTOT), BDIS(NTOT), CDIS(NTOT), DDIS(NTOT), Z0(NTOT), Z1(NTOT), Z2(NTOT)
1501 FORMAT (30H unknow distribution IDIS = '4,20H parameter number
1 = '4,20H name = '24H)
1502 FORMAT (20H, ALUS used Z0 = E14.6, 5H Z1 = E14.6, 5H Z2 = E14.6)
1503 FORMAT (20H, TOO large for exponential parameter, '4,20H)

C DATA INPUT/6/
DO 16 I=1, NPARA
M=IDIS(I)
IF (M.LT.1. OR. M.GT.8) GO TO 17
GO TO (2C, 3', 40, 9050, 9060, 9070, 9080, 9090), !
C UNIFORM DISTRIBUTION IDIS = 1
20 Z1(I) = ADIS(I)
Z2(I) = BDIS(I)
Z0(I) = 0.5*(Z1(I) + Z2(I))
GO TO 15
C EXPONENTIAL DISTRIBUTION IDIS = 3
40 I = LOG (.1, PROB)
TT = ALOG (1./(1.-PROB))
Z1(I) = ADIS(I) + BDIS(I)
Z2(I) = ADIS(I) + BDIS(I)*TT
GO TO 15
C NORMAL DISTRIBUTION IDIS = 2
30 T = LOG (1./(PROB*PROB))
T = SQRT(T)
XUP = 2.15517 +(.82853 +.010328* T) + T
XLOW = 1.+(1.432*PROB +(.189269 + .001338* T)*T)*T
X = T - XUP/XLOW
Z1(I) = ADIS(I)
Z2(I) = ADIS(I) + BDIS(I)*X
Z0(I) = ADIS(I) - BDIS(I)*X
GO TO 15
C
C
C *** EXPONENTIAL DISTRIBUTION IDIS=4
9015 I = LOG (1./(1.-PROB))
TT = LOG (1./(1.-PROB))
Z1(I) = ADIS(I) - BDIS(I)
Z2(I) = ADIS(I) - BDIS(I)*TT
Z0(I) = ADIS(I) - BDIS(I)*TT
GO TO 15
9016 WRITE (6, 1503) IPARA(I)
GO TO 9111
C *** NORMAL DISTRIBUTION WIT Z0 = 5 IDIS=5
9025 T = ASQ(1./(PROB*PROB))
T = SQRT(T)
SENREP NAME KNOTSS
XUP=2.51557 + (.32053 + .01328 #*T)*T
XLOW=1. + (.43278 + .189269 + .501308 #*T)*T
X=T-XUP/ILOW
AK=1./(.5*EEF((CDIS(I)-ADIS(I))/(SQRT(2.97)*BDIS(I))))
FACT=BDIS(I)*AK/SQRT(6.2832)*EXP(-((CDIS(I)-ADIS(I))^2)/(2.*BDIS(I))
**2))
ZC(I)=ADIS(I)*FACT
Z1(I)=ADIS(I)+BDIS(I)*I
Z2(I)=ADIS(I)-BDIS(I)*I
IF(72(I)<=CDIS(I)) Z2(I)=CDIS(I)
GO TO '5
C *** NORMAL DISTRIBUTION WITH ZUL IDIS=6
9070 T=ALOG(1./(PROB*PROB))
T=SQRT(T)
XUP=2.51557 + (.32053 + .01328 #*T)*T
XLOW=1. + (.43278 + .189269 + .501308 #*T)*T
X=T-XUP/ILOW
BK=1./(.5*EEF((CDIS(I)-ADIS(I))/(SQRT(2.97)*BDIS(I))))
FACT=BDIS(I)*BK/SQRT(6.2832)*EXP(-((CDIS(I)-ADIS(I))^2)/(2.*BDIS(I)
**2))
ZC(I)=ADIS(I)*FACT
Z1(I)=ADIS(I)+BDIS(I)*I
Z2(I)=ADIS(I)-BDIS(I)*I
IF(72(I)TLE.CDIS(I)) Z2(I)=CDIS(I)
GO TO '5
C *** BETA DISTRIBUTION IDIS=7
CC
C APPROPRIATE FORMULAS USED FOR CALCULATING Z1 AND Z2, VALID FOR SMALL PROB
CC
9080 Z0(I)=CDIS(I)
BETA=BDIS(I)-ADIS(I)
C=CDIS(I)-ADIS(I)
GAMM=CEA/BDIS(I)*((CEA*(BDIS(I)-ADIS(I)/BDIS(I))**2)-1.)
ETA1=GAMM*BDIS(I)/CEA
GAM1=GAMM*BDIS(I)/CEA
IF(GAM1.LE.0.) WRITE(6,9501) IPARA(I)
IF(GAM1.GT.57.) WRITE(6,9502) IPARA(I)
9501 FORMAT(3H ***BETA DISTRIBUTION PARAMETERS, 14,37H HAS TOO LARGE STA
NDARD DEVIATION****//)
9502 FORMAT(3H ***BETA DISTRIBUTION PARAMETERS, 14,37H HAS TOO SMALL STA
NDARD DEVIATION****//)
RATIO=(PI*GAMM*(GAMM*GAM1)/GAMMA(ETA1))/GAMMA(GAM1)
Z1(I)=BDIS(I)-((GAM1*ETA1+BETA**ETA1)**2/(1./ETA1))
Z2(I)=ADIS(I)*RATIO+GAMMEG*BDIS(I)**2/(1./GAMM)
GO TO '5
C *** LOG NORMAL DISTRIBUTION IDIS=8
9090 T=ALOG(1./(PROB**2))
XUP=2.51557 + (.32053 + .01328 #*T)*T
XLOW=1. + (.43278 + .189269 + .501308 #*T)*T
X=T-XUP/ILOW
Z0(I)=EXP(ADIS(I)+.5*BDIS(I)**2)
Z1(I)=EXP(ADIS(I)+BDIS(I)*I)
Z2(I)=EXP(ADIS(I)-BDIS(I)**2)
GO TO '5
C DISTRIBUTION UNKNOWN, ASSUMED UNIFORM ADIS=YEAR, WIDTH=2*BDIS
17 Z0(I)= ADIS(I)
21(I)= ADIS(I)+BDIS(I)
22(I)= ADIS(I)-BDIS(I)
WRITE (6, 1501) IDIS(I), PARA(I)
WRITE (6, 1502) 20(I), 21(I), 22(I)
GO TO 15
15 CONTINUE
C IF CORRELATED INPUT PARAMETERS, CALL CKNOT
C IF (SCOPR.GT.0) CALL CKNOT(IDIS)
16 CONTINUE
RETURN
END
SUBROUTINE LKENS(ZP,BF,ZFP,AMAT,ZR,CP,Z1,Z2,NTOT,NKNOT,NCOEF1, NKNOTSV)
C CALCULATES LINEAR SENSITIVITIES WITH A MATRIX METHOD
C CALCULATES LINEAR SENSITIVITIES WITH A MATRIX METHOD
C
*CALL CONS
BEGIN ZF,BF,ZFP,AMAT,ZR,CP,Z1,Z2,NTOT,NKNOT,NCOEF1, NKNOTSV
DIMENSION AMAT(NKNOT,NKNOT), ZP(NKNOT,NKNOT), ZF(NKNOT,NKNOT), Z1(NKNOT), Z2(NKNOT)
COMMON/ZETA/ZETA(100,6)
DATA IWRITE/6/
WRITE(IWRITE,1001) AVZET(L)
1001 FORMAT(IHO SAMPLE RNW = 014.6/21H LINEAR SENSITIVITIES/)
DO 1 M=1,NKNOT
DO 2 J=1,NKNOT
2 AFAT(M,J) = 0.000
CONTINUE
DO 3 N=1,NCOEF1
3 BF(M,1) = 0.000
DO 9 J=1,NPAKP
9 CP(J,1) = ZETA(J,L) - AVZET(L)
DO 11 KNOT=1,NPANKP
DO 12 J=1,NTOT
DZR = ZP(KNOT,J) - Z0J
DZ = Z1(J) - Z2(J)
ZF(KNOT,J) = DZR/DZ
12 ZFP(J,KNCT) = DZR/DZ
ZF(KNOT,NCOEF1) = 1.00
ZFP(NCOEF1,KNOT) = 1.00
11 CONTINUE
FACT = FLOAT(NTOT)/FLOAT(NRANKP)
CALL XMULT(ZF,ZFP,AMAT,NRANKP,NCOEF1,NKNOTSV)
CALL MATINV(AMAT,NRANKP,CF,NCONSDETIICO)
CALCMIULT(ZFP,CF,BF,NCOEF1,NRANKP,UCOUS,PAU KP)
C THE COMPONENTS OF BF ARE SENSITIVITY ESTIMATES = NKNOT/NTOT
BJ = BF(NCOEF1,1) * FACT
WRITE(IWRITE,1002) BJ
1002 FORMAT(1H3L,3L3HREFERENCE VALUE - MEAN VALUE =,G12.5/)
WMA = RNW(100,NTOT)
DO 22 JA=1,WMAIP
JMA = JA
PMA = 0.0
DO 21 JA=1,WMAIP
BMA = BF(JA,1)
21 CONTINUE
BMA = BMA * FACT
WRITE(IWRITE,1003) JMA , BMA
1003 FORMAT(IHO , 81,IU,41,G12.5)
BF(JMA,1) = 0.000
22 CONTINUE
RETURN
END
SUBROUTINE IWINV(A,MM,NN,M,DELTA,ICOR)
IMPLICIT REAL*(A-H,O-Z), INTEGER*(I-N)
DIMENSION A(MM,MM), M(0:M,0:M)
DIMENSION B(M), C(M), D(M), L(M,0:M), IZ(M)
C
DATA WRITE(/6/)
C
MATRIX INVERSION SUBROUTINE FOR EQUATION OF THE FORM AX = Y.
RETURNs THE INVERSE OF A IN PLACE OF A AND X IN PLACE OF Y.
C
A GIVEN MATRIX, DIMENSIONED FOR MM X NN
MM ORDER OF A
NN X NN
AUG Y, DIMENSIONED FOR MM X NN
NN NUMBER OF COLUMNS IN AUG
DFA A DETERMINANT OF A
C
...IF ONLY THE INVERSE MATRIX IS SOUGHT, SET M = 0.
...IF X IS ALSO WANTED (AND Y GIVEN), SET M = 1.
...AUG MUST BE DIMENSIONED AND ENTERED IN THE
CALL STATEMENT WHETHER GIVEN OR NOT.
C
N = MM
M = MM
EPS = 1.0D-49
DELA = 1.0000
ICOR = 0
C
DO 1 I = 1,N
IZ(I) = I
1 CONTINUE
C
DO 11 I = 1,N
F = I
Y = A(I,I)
IF( IF .GT. M ) GOTO 3
C
DO 2 J = IP,N
W = A(I,J)
IF( DABS(W) .LT. DABS(Y) ) GOTO 2
K = J
Y = W
2 CONTINUE
C
ADELT = DABS(DELTA)
IF( ADELT .GT. 1.0D+13) ICOR = ICOR + 1
IF( ADELT .GT. 1.0D+30) DELTA = DELTA * 1.0D-30
IF( ADELT .GT. 1.0D+30) ICOR = ICOR + 1
IF( ADELT .LT. 1.0D-30) DELTA = DELTA * 1.0D+30
AAB = DABS(Y)
IF( AAB .GT. 1.0D+30) AND ADELT.GT.1.0D+15) ICOR = ICOR + 1
IF( AAB .GT. 1.0D+30) AND ADELT.GT.1.0D+15) DELTA = DELTA * 1.0D-10
IF( AAB .GT. 1.0D+30) AND ADELT.GT.1.0D+15) ICOR = ICOR - 1
ADELT = DABS(DELTA)
EXP = 0.0D0
IF( ADELT.GT.1.0D15) 72ZP = DLOG(ADELT)
IF (IFX.GT.0,00) TEXP = TEXP + OLGC(ABY)
IF (TEXP.GT.160,00) WRITE (WRITE,1000) DELTA,Y
IF (TEXP.LT.-160,00) WRITE (WRITE,1000) DELTA,Y
1000 FORMAT (2H#3X,6PEG2D11,1H T =,E21.4,3H DELTA =,D11.4 FORMAT (/))
IF (TEXP.GT.160,00) DELTA = 1.0D0
IF (TEXP.LT.-160,00) DELTA = 1.0D0
DELTA = DELTA * Y
IF (DABS(Y).GE.EPS) GO TO 4
 delta,y
1001 FORMAT (I1H#3X,6PEG2D11,1H T =,E21.4,15H BUT I CONTINUE/) 
IF (OABS(Y).EQ.O.) WRITE(IWRITE, 1002)
1002 FORMAT (I1H#3X,6PEG2D11,1H IS ZERO IN SUBR. NATINV, I RETURN/)
IF (DABS(Y).EQ.O.) RETURN
Y = 1.000 / Y
C
DO 5 J = 1,M
   C(J) = A(J,K)
   A(J,K) = A(J,I)
   A(J,I) = -C(J) * Y
   B(J) = A(I,J) * Y
   B(J) = B(J)
5 CONTINUE
C
IF (M.LT.1) GO TO 7
DO 6 J = 1,M
   D(J) = AUG(I,J) * Y
   AUG(I,J) = D(J)
6 CONTINUE
C
A(I,I) = Y
J = IZ(I)
IZ(J) = IZ(K)
IZ(K) = J
C
DO 10 K = 1,M
   IF (K.EQ.I) GO TO 11
C
DO 8 J = 1,M
   IF (J.EQ.I) GO TO 8
   A(K,J) = A(K,J) - B(J) * C(K)
8 CONTINUE
C
IF (M.LT.1) GO TO 16
DO 9 J = 1,M
   AUG(K,J) = AUG(K,J) - D(J) * C(K)
9 CONTINUE
10 CONTINUE
C
DO 16 I = 1,M
   F = IZ(I)
   IF (K.EQ.I) GO TO 16
C
DC 3 J = 1,M
   W = A(I,J)
   A(I,J) = A(K,J)
C
A(F,J) = W
CONTINUE

IF( M .LT. 1 ) GO TO 15
GO TO 14
J = 1,
W = AUG(I,J)
AUG(I,J) = AUG(K,J)
AUG(K,J) = W
CONTINUE

IP = IZ(I)
IZ(I) = IZ(K)
IZ(K) = IP
DELTA = -DELTA
GOTO 12
CONTINUE

RETURN
END
SUBROUTINE MIMULT(A, B, C, M1, M2, M3)
IMPLICIT REAL*8 (A-H, O-Z)
DIMENSION A(M1, 1), B(M3, 1), C(M1, 1)

DATA WRITE/6/]
C SUBROUTINE MIMULT RETURNS THE PRODUCT OF MATRICES A AND B
C IN THE ARRAY C. (AB = C)
C M1 IS THE NUMBER OF ROWS IN MATRIX A
C M3 IS THE NUMBER OF ROWS IN MATRIX B
C M1 IS THE NUMBER OF COLUMNS IN MATRIX A
C M2 IS THE NUMBER OF COLUMNS IN MATRIX B
C C IS AN M1 X M2 MATRIX AND MUST BE DIMENSIONED AS SUCH IN
C THE CALLING PROGRAM. M1, M1, M2 MUST BE INTEGERS GREATER THAN ZERO.
C M3.GE.M1
DO 15 I = 1, M1
  DO 15 J = 1, M2
    SUM = 0.0
    DO 10 K = 1, M1
      PROD = A(I, K) * B(K, J)
      SUM = PROD + SUM
    10 C(I, J) = SUM
  15 C(I, J) = SUM
C WRITE(UNIT, 220)
C 220 FORMAT (45H0 MIMULT EXECUTED. RETURN TO CALLING PROGRAM./) RETURN
END
CALL CONS
DIMENSION ZR(KNOTSV,WTOT),ZO(WTOT)
DIMENSION JA(J0),JB(J0),RHO(J0)
DATA IRZ/6/
NRA=NHO(J0,WTOT)
DO 10 I=1,20
JA(I) = 0
JB(I) = 0
RHO(I) = 0.
10 CONTINUE
WRITE(WRITE,1001)
1001 FORMAT(10I5,10E6,1000 SAMPLE CORRELATIONS BETWEEN INPUT PARAMETERS//)
DO 11 J=1,WTOT
11 K1=J+1
IF(K1.GT.WTOT) GO TO 11
SA=0.
SSA=0.
DO 23 KN=1,NRAKP
ZRA=ZR(KN,J)-ZO(J)
SA=SA+ZRA
23 SSA=SSA+ZRA*ZRA
SSA=SSA-SSA*SA
DO 12 K=1,WTOT
12 SB=0.
SSB=C.
SC=0.
DO 13 KN=1,NRAKP
ZBB=ZR(KN,K)-ZO(K)
SB=SB+ZBB
SSB=SSB+ZBB*ZBB
SC=SC+ZBB*ZBB
13 CONTINUE
SC=SC-SSA*SSB
SSB=SSB-SSA*SSB
DIV=SQR(SSA*SSB)
CORJK=SC/DIV
ABSJK=ABS(CORJK)
DO 14 I=1,NRAKP
ABSP=ABS(RHO(I))
IF(ABSJK.LT.ABSP) GO TO 14
INDMAX=NRAKP-1
DO 15 IND=1,INDMAX
IK=NRAKP+1-IND
JA(IK)=JA(I)
JB(IK)=JB(I)
RHO(IK)=RHO(I)
15 CONTINUE
14 CONTINUE
12 CONTINUE
DO 120 I=1,NMAXP
  KA =JA (I)
  KB =JB (I)
  EC =PH0 (I)
  PCC=EC*KC
120 WRITE (WRITE,1002) KA,KB,EC,PCC
1002 FORMAT (1H4,5X,I4,I5,F10.5,F10.5) RETURN
END
SUBROUTINE PLOTFP(NPRINT,T,X)
C
C SUBROUTINE PLOTFP PLOTS CONSEQUENCES
C OF THE COISFQUEICES
DIMENSION T(26),X(26),LINE(120)
DATA IREAD, IWRITE/5,6/
DATA MLAN,MSTAB,MINUS,LTDI/
BIG=-1.0E+49
SMALL=1.0E+49
DO 40 I=1,NPRINT
  I7(I)=X(I)
  IF(X(I).LT.SMALL) SMALL=X(I)
40 CONTINUE
DELT=BIG-SMALL
TES=ABS(SMALL)/10000E-49
IF(DELT.LT.TES) DELT=TES
F=50.0/DELT
DO 60 I=1,PRINT
  DO 50 K=2,51
    LINE(K)=BLANK
    IF(I.EQ.1) LINE(K)=MIUS
50 CONTINUE
LINE(1)=LTRI
J=INT((X(I)-SMALL)*F+1.501)
LINI(J)=STAR
VBIT(IWPITE,603) T(I),I7(I),(LINI(L),L=1,51)
60 CONTINUE
503 FORMAT (17X,G11.4,2X,G11.4,2I,51A1)
RETUN
END
SUBROUTINE PRINT (NIS,NOINT,NSIN)
C SUBROUTINE PRINT
*CALL CONS
COMMON/GEAVY/CRAVE(4)
COMMON/CFIDS/ICIS(4),DCIS(4),CICIS(4),DCIS(4)
COMMON/TRANSF/HTAPA,NTRA0,IPPA(7),LTYPE(7),LTPA(7)
COMMON/ACO(7),BCO(7)
DIMENSION NIS(6,12),NOINT(6,6,12,12)
C CATEGORY BOUNDARIES FOR CRITERIA CONSEQUENCES BASED ON AVERAGE CRITERIA
C CRAVE(N) - TO BE BETWEEN CATEGORIES 6 AND 7 FOR REALLY RANDOM CRITERIA
C - TO BE UL OF CATEGORY 1 IF ICIS(N)=0 AND LCR(N)=0
C CATEGORY 12 IF ICIS(N)=0 AND LCR(N)=1
IF(MTRA0.GT.0) WRITE(6,7001)
7001 FORMAT(1P0,2X,75H FOR TRANSFORMED CONSEQUENCES THE CATEGORY LIMITS
ARE ALSO GIVEN IN TERMS OF 42H THE ORIGINAL UNTRANSFORMED CONSEQUENCES/4I
BREMENTS IN THE TITLES ARE AWAI. MOMENTS OF THE TRANSFORMED CONSEQUENCES//I)
DO 371 L=1,NCONS
WRITE(6,3003) L,AVZET(L),SDZET(L),SCALE
3003 FORMAT(14H CONSEQUENCE,14,4X,5HMEAN,.E14.6,3H,19HSTANDARD DEVIAT
ION,.E14.6,8H SCALE=.F6.2/)
WRITE(5,3004)
3004 FORMAT(90H CATEGORY LOWER B UPPER B COUNTS PROBA
TILITY ACCURACY PERCENT//)
3005 FORMAT(3H,17,E15.6,E14.6,10,E4X,E10.6,10,E3X,E17.3,4H P/C,2X
18HMD CAT=.E13.6)
DO 372 WI=1,NL
FNL=FLOAT (NI)
FSA=FLOAT (NSI1)
BLOW = AVZET(L)+ (FNL-7.)* SCALE* SDZET(L)

C NEW CATEGORY LIMITS FOR CRITERIA FUNCTION
IF(IFLAG) 470,470,471
471 DO 460 K=1,4
IF(L.WT.NCR(K)) GO TO 460
FPXP = CRAVE(K)
BLOW = FPXP + (FNL-7.)* SCALE* SDZET(L)
460 CONTINUE
472 BUUF = PNOW + SCALE* SDZET(L)
COUNTS = FLOAT (NIS(L,NI))
ICOUNT=INT (COUNTS)
PROOF = COUNTS / FSA
IF(PROOF) 175,375,174
375 PROOF=100.
EPFO = C.
GO TO 173
174 ERROR = ((1.-PROOF) * PROOF/KSA)**.5
PROOF = 100.* ERROR/PROOF
373 CONTINUE
BAVF = (BLOW + BUUF) * 0.50
WRITE(6,3005) NL,BLOW,BUUF,ICOUNT,PROOF,ERROR,PROOF,BAVE
IF(NTRACC.LE.0) GO TO 372
C CATEGORY BOUNDARIES INVERSE TRANSFORMED IF CONSEQUENCE TRANSFORMED
LTPA = 0
C 89LOW,BAVF,BBUFF DEFINED HERE. BECAUSE THE OPTIMIZER TAKES THE ALGS.
C OUT OF THE DO LOOP IN ANY CASE , AND ARGUMENTS COULD BE NEGATIVE.
NAME PRINTHE
BBLOW=J.
BBAVE=^.
BBUPP=0.
IF(510'.GT.0.) BBLOW = ALOG(BLOW)
IF(BAVE.GT.O.) BBAVE = ALOG(PAVE)
IF(BUPP.GT.0.) BBUPP = ALOG(BUPP)
DO 701 I=1,NPACO
LA = LTYP(I)
IF(LA.NE.L) GO TO 702
WRITE(6,2000) LA,L,LTYP
2000 FORMAT(1HO,3I5/)
AC = ACO(I)
BC = BCO(I)
GO TO (100,200,300,400,500,600,700),LTYP
100 BCC = 1./BC
BLOWS = BLOW**BCC +AC
BAVES = PAVE**BCC +AC
BUPPS = BUPP**BCC +AC
GO TO 701
200 BLOWS = EXP(PLOW) +AC
BAVES = EXP(PAVE) +AC
BUPPS = EXP(PUPP) +AC
GO TO 701
300 BLOWS = BC*BLOW + AC
BAVES = BC* BAVE + AC
BUPPS = BC* BUPP + AC
GO TO 701
400 BLOWS = BC * TAN(BLOW) + AC
BAVES = BC * TAN(BAVE) + AC
BUPPS = BC * TAN(BUPP) + AC
GO TO 701
501 CONTINUE
600 CONTINUE
700 CONTINUE
BLOWS = BLOW
BUPPS = BUPP
BAVES = BAVE
702 CONTINUE
IF(LTYP.IQ.0) GO TO 372
C BLOW, BAVE AND BUPP HAVE BEEN INVERSE TRANSFORMED
WRITE(6,7005) LA,BLOWS,BUPPS,BAVES
7005 FORMAT(1HO,13I5,6E14.6,4X,E1.6/E)
372 CONTINUE
371 CONTINUE
1911 FORMAT(2H1, JOINT DISTRIBUTIONS OF POLYNOMIAL CONSEQUENCES/) 1912 FORMAT(2HO CONSEQUENCE NUMBER,15,10H VERTICAL/) 1913 FORMAT(2HO CONSEQUENCE NUMBER,15,12H HORIZONTAL/) 1914 FORMAT(19HO PROBABILITY AND ACCURACY (STANDAD DEVIATION/) 1915 FORMAT(11I6 CATEGORY 1 2 3 4 5 6 7 8 9 10 11 12/) 1916 FORMAT(1H ,15,12F9.6/) 1917 FORMAT(1H ,15,12F9.6/) NCOL=MCONS-1 IF(NCOL.IE.0) RETURN
HEMMED FAXE PRRITH
WRITE(6,3011)
DO 381 L=1,MCOI
LPI=I+1
DO 382 M=LPI,NCONS
WRITE(6,3012) L
WRITE(6,3013) M
WRITE(6,3014)
WRITE(6,3015)
DO 383 NI=1,12
DO 384 NM=1,12
AJQINT(IM) = FLOAT(WONT(I,M,NL,WM))/PSA
PROBAL = AJQINT(NM)
PRB(NM) = (((1.-PROBAL) * PROBAL/PSA)**.5
CONTINUE
WRITE(6,3016) NL, AJQINT
WRITE(6,3017) NI, PRB
CONTINUE
CONTINUE
CONTINUE
CONTINUE
C END OF PRRITH
RETURN
END
SUBROUTINE PROSIN(NGPMAX)

C PREPARES RANDOM KNOT-POINT CARDS FOR PROSA FROM THOSE INPUT FOR SCREEN
C
C READS NGPMAX CARDS FIRST. EACH SPECIFY A PAIR OF IDENTIFICATION NUMBERS
C FIRST NUMBER (15) IS THE IDENT. NO. FOR PROSA
C SECOND NUMBER (15) IS THE IDENT. NO. OF THE SAME PARAMETER FOR SCREEN
C NGPMAX SHOULD NOT EXCEED MAXIMUM VALUE
C
C THEN READS THE RANDOM KNOT-POINT COORDINATE CARDS OF SCREEN
C AND PICKS THE VALUES OF THOSE PARAMETERS SELECTED FOR PROSA
C AND OUTPUTS THE KNOT-POINT CARDS PCP PROSA-2 IN .OBJECT FORMAT
C
C PROSIN (JOBS 6) USES ONLY VARIABLES NTOT,JOBS,WORK,NRANKP AND NGPMAX
C FROM THE FIRST INPUT CARD
*

CALL CONS

DIMENSION INDP(12),INDS(12),ZP(12)
DIMENSION Z(1000)
DATA IFP,AD,IWRITE/IPUPCH/5,6,7/
WRITE(IWRITE,1001)
DO 2 J=1,NGPMAX
READ(IFPAD,1002) INDP(J),INDS(J)
2 WRITE(IWRITE,1012)
FORMAT(5I5)
1002 FORMAT(I5,I5)
1012 FORMAT(IH,10X,I5,5X,I5)
1003 FORMAT(3HSCREENED PARAMETERS FOR PROSA//28HT PROSA PARA NO. SCR
1004 FORMAT(IH,4X,28HSCREEN AND PROSA KNOT-POINTS//)
1005 FORMAT(I5,6X,15,4X,15,(6G16.6))
DO 3 J=1,NRANKP
READ(IFPAD,1033) INDEX,KNOT,(ZP(L),L=1,NPARA)
WRITE(IWRITE,1004) INDEX,KNOT,(ZP(L),L=1,NPARA)
DO 4 JR=1,NGPMAX
LOC= INDP(JR)
LOCs= INDS(JR)
ZP(LOC) = Z(LOCs)
4 CONTINUE
WRITE(IWRITE,1004) INDEX,KNOT,(ZP(J),J=1,NGPMAX)
WRITE(IWRITE,1005) INDEX,KNOT,(ZP(J),J=1,NGPMAX)
3 CONTINUE
WRITE(IWRITE,1005)
1005 FORMAT(45H0 END OF KNOT-POINTS IN JOBS 6, SUBROUTINE PROSIN//)
RETURN
END
SUBROUTINE PUNCH(LOC,ZIN)

C PUNCHES INPUT CARDS FOR A DETERMINISTIC/Mechanistic code that calculates
C output variables
C
C IN THIS CASE SAS3D
C
DATA IPOUNCH,IPWRITE/7,6/
NSAS = 1
WRITE ('PUNCH,2003') LOC,NSAS,ZIN
2003 FORMAT (216,5E12.5)
WRITE ('IPWRITE,2004') LOC,NSAS,ZIN
2004 FORMAT (18,216,5E12.5)
RETURN
END
SUBROUTINE READIN (ZR, CF, NTOF, NKNOP)
C
C READS CONSEQUENCES AND COORDINATES OF THE RANDOM KNOT-POINTS
C CF CONTAINS THE CONSEQUENCES, ZR THE COORDINATES (PARAMETER VALUES)
C
C BEGINS 2,2,CF
*CALC! CONS
COMMON/PTAB/ZE(TA(100,6))
COMMON/SAVE/ZAVE(100),ZSS(100)
DIMENSION Z(1000)
DIMENSION ZR(NKNOP,7001),CF(NKNOP,CONS)
DIMENSION SPCOB(20),JOBS(20),SPVAR(20),SPMEAN(20)
DIMENSION FFMEAN(6),RKC(20),RMAX(5),RMIN(6)
C
DATA READ,WRITE,IMINIT,5,6,5/
COMMON/TRANSF/TPAPA,TPACO,TPACO,JTRA(7),JTYPE(7),LTRA (7),LTYPE(7),APA (17),BPA(7),ACO(7),BOC(7)
C
COMMON/HISPLO/His(6,12),NOJOIN(6,6,12,12)
DIMENSION IPLO(6,26),TP(26),IP(26)
DIMENSION NNNKN(100)
NKNOP = NKNOP
SCALE = 0.50

C INITIAL ZEROS
C
DO 9 L=1,CONS
RKNIO(L) = 0.
RMAX(L) = -1.0E+49
RMIN(L) = +1.0E+49
DO 5 INK=1,12
DO 7 L2 =1,CONS
DO 8 IRQ=1,12
SNJOIN(L,L2,INK,IRQ) = 0
5 CONTINUE
6 IPLO(L,IP) = 0.1
CONTINUE
8 CONTINUE
DO 10 BLJ=1,NPARA
ZAVE(JJ) = 0.
ZSS(JJ) = 0.
10 CONTINUE
FPA = 1./NPARA

C KNOT-POINT (DATA-POINT) NO. 5 TO BE INCLUDED IN THIS WORK
READ(IREAD,7001) NNEWKN
7001 FORMAT(15)
IF (NEWKN.EQ.0) GO TO 770
READ(IREAD,7002) (NEWKN(I),I=1,NEWKN)
7002 FORMAT(1E15)
WRITE(WRITE,7003) NEWKN
7003 FORMAT(1H1,8X,14,H3) H5 NEWKN I, NEWKN(I) , NEWKN(I) , NEWKN(I)
WRITE(WRITE,7004) (I,NEWKN(I),I=1,NEWKN)
7004 FORMAT(15,15)
770 CONTINUE
C
READ CONSEQUENCES IN RANDOM KNOT-POINTS, NBRANKP SETS
WRITE(WRITE,2000) JOBS,CONS
MEMBER NAME: READING

2000 FORMAT(1H0,10X,74H=CONSEQUENCES IN RANDOM KNOT-POINTS. INPUT IN
SUBROUTINE READING FOR JOBS,14/1H ,7X,5HINDEX,10X,4H,WHKNOT,6X,13,13H
2CONSEQUENCES/)

KIN = 11
DO 11 K = 1,NBANKP
BEAT(IPEAD,2001) INDEX,KNOT,(CONS(I),I=1,NCONS)
IF(NEWKWP.EQ.0) GO TO 712
DO 11 I IN = 1,NEWKWP
KCOMP = F
KIN = 1
IF(NOT,K.NE.KCOMP) GO TO 711
KNOT = IN
KIN = KIN + 1
GO TO 712
711 CONTINUE
GO TO 11
712 CONTINUE

WRITE(IWRITE,2002) INDEX,KNOT,(CONS(I),I=1,NCONS)
C TRANSFORM KNOT-POINT CONSEQUENCES
C IF(NTRAC(C.T.O) CALL TRACO(CONS)
C IF(NTRACC.GT.0) WRITE(IWRITE,2005) INDEX,J,K,(CONS(I),I=1,NCONS)
2005 FORMAT(1H0,7X,TRANSFORMED VALUES/SH+ ,?IS,(6E16.6))
C CONSEQUENCES TRANSFORMED
C DEFINE MATRIX CF
C DO 11 L=1,NCONS
RKCONS = CONS(L)
RM2(L) = RM(L) + RKCONS
RM1(L) = RM2(L) + RKCONS*PKCONS
IF(RKCONS.GT.RKMAX(L)) RKMAX(L) = RKCONS
IF(RKCONS.LT.RKMIN(L)) RKMIN(L) = RKCONS
ZETA(KNOT,L) = CONS(L)
Z(KIN,N.E.NKNOT) = CONS(L)
11 CONTINUE
C 
C IF(KIN.NF.NEWNKN) WRITE(IWRITE,7011) KIN,NEWNKN
7011 FORMAT (1H0,5X,INPUT ERROR, KIN = ,I4,21H KNOTS FOUND, NEWNKN = ,I4,1//)
C IF(KIN.NF.NEWNKN) STOP
C CF IS A WORKING PLACE,ZETA PERMANENT STORAGE
C 2001 FORMAT(12,14,2X,(6E12.6))
2002 FORMAT(1H0,6X,15,H,14,(6E16.6))
C READING
C C READ RANDOM KNOT-POINT COORDINATES
C ^ WRITE(IWRITE,1621) JOBS
1621 FORMAT(1H0,10X,39H RANDOM KNOT-POINT COORDINATES FOR JOBS,13/)
1622 FORMAT(12,14,2X,(6E12.6))
1623 FORMAT(1H0,6X,15,H,14,(6E16.6))
KIN = 11
DO 2 I =1,NBANKP
DO 721 JK=1,NPARA
ZR(KNOT,JK) = Z(J) + ZBR*ZRF
ZAVE(JK) = ZAVE(JK) + ZRF
702 CONTINUE
IF (NEWKNE.EQ.0) GO TO 722
DO 721 JK=1,NEWKN
KCOMP = NEWKNE(IN)
IF (KNOT.NE.KCOMP) GO TO 721
KIN = JK
KIN = KIN+1
GO TO 722
721 CONTINUE
GO TO 2
722 CONTINUE
WRITE (WHITE,1673) INDEX,KNOT, (Z(J), J=1,1,PARA)
C TRANSFORM KNOT-POINT COORDINATES
C IF (MTTRAP.GT.0) CALL TRAP(A(Z))
C IF (MTTRAP.GT.0) WRITE (WRITE, 2623) INDEX, KNOT, (Z(J), J=1,1,PARA)
C PARAMETERS TRANSFORMED
2523 FORMAT (1H TRANSFORMED VALUES/1H (I5,I5,I5,I5,(E16.6))
C READIN 1
C
WRITE (WRITE, 2000)
DO 100 JK=1,MCORS
ZAVE = PKMEAN(L) / NBRANK
PKMEAN(L) = ZAVE
C
ERVAR = PKS2(L) / NBRANK - RKAVE * RKAVE
OMN = NBRANK - 1
DM = NBRANK
ERVX = ERVAR * DM / OMN
PKS2(L) = ERVAR
PKSD = 0.
IF (PKVAR.GT.0.) PKSD = SQRT(PKVX)
5041 FORMAT (1H L, RKAVE, PKSD, PKMAI(L), BRMAIN(L)
$\alpha_{\text{INT}} = \text{PKAVE}$

C
100 CONTINUE
C
THIS PART OF READING CALCULATES THE HISTOGRAMS OF RAW DATA
C
3000 FORMAT('G CHARACTERISTICS OF RANDOM NODE POINT SAMPLE CONSEQUENCES
1/6 CONSEQUENCE MEAN VALUE STD DEVIATION MAXIMUM VALUE MINIMUM VALUE')
C
3001 FORMAT(3H0,6X,4I,6G,14.5,1I,G14.5,1I,G14.5,1I,G14.5,1I,G14.5)
C
DO 82 KI=1,NAINTP
DO 81 L=1,NCONS
$\alpha_{\text{INT}} = \text{ZETA}(K1,L)$
81 CONTINUE
CALL HISTO(IPLO,NHIS,MJOINT)
82 CONTINUE
CALL PRINTH(NHIS,NJOINT,NAINTP)
C
DO 380 L=1,NCONS
WRITE(IWITF,4600) L
DIV = 1./(SCALE*SDZETA(L))
DO 381 K=1,26
NC = NAINTP
FNC=FLOAT(NC)
KPI(K) = FLOAT(IPLO(L,K))/FNC*2.5
TP(K) = FLOAT(INT(FLOAT(K)/2.))
PROUNT = XP(K) * DIV
WRITE(IWITF,4601) TP(K),PROUNT
381 CONTINUE
WRITE(IWITF,3201) L
CALL PLOTPP(26,TP,XP)
380 CONTINUE
3201 !OPMAT(1H0,10X,11HCONSEQUENCE,I3//)
4600 FORMAT(1H0,35HPROBABILITY PER UNIT OF CONSEQUENCE,I3//)
4601 FORMAT(17X,G11.4,2X,G11.4)
C
C READING 2
C
C THIS PART OF READING CALCULATES AND EDITS NAINTP LARGEST CORRELATION
C COEFFICIENTS BETWEEN A CONSEQUENCE AND THE PARAMETERS
$\alpha_{\text{INT}} = \text{NAINTP}(20,\text{NAINTP})$
DO 11 J=1,NCONS
DO 110 I=1,NAINTP
SPVAF(I)=0.
SCOF(I)=0.
JORG(I)=C
110 CONTINUE
WRITE(IWITF,4000)!
4000 FORMAT(1H0,9X,4C1NCONNECTION COEFFICIENTS FOR CONSEQUENCE,14,12N.
1PARAMETERS/3N ,9PARAMETER,25NCONNECT.COFFEF. SQUARE F/)
DO 112 J=1,NAINTP
SEVFAC=0.
SIVAF=2.
SCOF=0.
DO 113 K=1,NAINTP
TEMPRA NAME READIN
ZVAR=ZVAR(RM, J)
SZMEAN=SZMEAN + ZVAR
SZVAR=SZVAR + ZVAR*ZVAR
SCOP= SCOP + ZVAR*CP(RM, L) - BEAN(L)
113 CONTINUE
SZMEAN=SZMEAN/NBNKP
C FROM NOW ON 2(J) IS USED
C SAVE SZMEAN'S IN THIS SUBROUTINE
Z(J)=SZMEAN
SZVAR=SZVAR/NBNKP - SZMEAN * SZMEAN
SCOP= SCOR/NBNKP
SCOR= SCOR/SQRT(SVIBAR*SRKCN4(L)*BNRMEAN/DR)
ABSCOR=ABS(SCOR)
DO 114 J=1,NMAXP
ABS=ABS(SCOR(J))
IF(ABS*C.OR.ABSF) GO TO 114
INDMAX=MAX1 - I
DO 115 IND=1,INDMAX
IK=IKAP - I
SPNEAP(I)=SZNEAP
SPCOAP(I)=SCOB
SPYAP(I)=SZYAP
JOFG(I)= JOFG(IK)
115 CONTINUE
SPNEAP(I)=SZNEAP
SPCOAP(I)=SCOB
SPYAP(I)=SZYAP
JOFG(I)= JOFG(I)
114 CONTINUE
112 CONTINUE
NDF=NBANKP - 2
DO 120 I=1,NMAXP
JP=JOFG(I)
SC=SCOR(J)
BSQ= SC * SC
PVAR= NDF * BSQ
WRITE(INSKTE,4001) JB, SC, BSQ, PVAR
4001 FORMAT(1X,5X,10.5,F10.5,F10.5/)
120 CONTINUE
WRITE(INSKTE,4002) NDF
4002 FORMAT(1H,5X,30B0000,LINE LAST COLUMN TO AN F(I,, I3, 9H) VARIABLE//)
JB1 = JOFG(I)
SZSD1= SQRT(SVAR(J))
B1 = SCOR(J) * SQRT(RKCN4(L))/SZSD1
WRITE(INSKTE,4003) JB1, SZSD1, B1
4003 FORMAT(1H,5X,3CH THE MOST CORRELATING PARAMETER, J3,1H,5X,29H AS
SAMPLE STANDARD DEVIATION, G12.5/1H, 5X,29H REGRESSION COEFFICIENT B
2, 5X, G17.5/)
C RESIDUAL CONSEQUENCES
DO 210 K=1,NBANK
CP(K, L) = CP(K, L) - ZMEAN(L) - P1* (ZK(JB1) - Z(JB1))
210 CONTINUE
C CORRELATIONS WITH THE RESIDUAL CONSEQUENCES
DO 210 I=1,NMAXP
SCOR(I)=0.
CONTINUE
DO 212 J=1,NPARA
SCOR=0,
SZVAR=0,
DO 213 KN=1,NPARA
ZER=ZER(KN,J) - Z(J)
SEUR=CP(KN,L)
SCOR=SCOF + ZER*SEUR
SZVAR=SZVAR + SEUR*SEUR
CONTINUE

DO= NHANKP -1
SZVAR = SZVAR / NHANKP
SZVAR = SZVAR / NHANKP
SCOR = SCOR / NHANKP
SCOR = SCOR / SQRT(SVAR*SZVAR)
ABS=ABS(SCOR)
DO 214 I=1,NHANKP
ABS=ABS(SPCOF(I))
IF(ABS<ABS) GO TO 214
INDMAX = NHANKP - I
DO 215 IND=1,INDMAX
IKF=IKF + 1 - IND
JORG(IK)= JORG(IK)
SPCOF(IK) = SPCOF(IK)
SPVAR(IK)= SPVAR(IK)
CONTINUE

JORG(I) = J
SPCOF(I) = SCOR
SPVAR(I)= SZVAR
SCOR = 0,
CONTINUE

SDEV = SQRT(SVAR)
WRITE(WRITE,4099) L,SDEV
4099 FORMAT(1X,11FCONSEQUENCE,13,2X,10HRESIDUAL STANDARD DEVIATION =
1,12.5I/)
WRITE(WRITE,4100) L
4100 FORMAT(1X,16HCORRELATIONS OF RESIDUAL CONSEQUENCE,14,16H WITH
1H PARAMETERS/37H PARAMETER CORR.CO!.) SQUARE /I/
DO 210 J=1,NHANKP
JB=JORG(I)
SC= SPCOF(I)
RSQ = SC * SC
FVAR = MDF * RSD
WRITE(WRITE,4101) JB,SC,RSQ,FVAR
CONTINUE

WRITE(WRITE,4200) MDF
4200 FORMAT(1X,J1,15H = JORG(I))
SRSQ = SQRT(SVAR(I))
R2 = SPCOF(I) * SQRT(SVAR) / SRSQ2
MEMBER NAME READIN

\begin{verbatim}
WHITE(IWF1T,4103) J82, S5S02, E2

C
C SECOND RESIDUALS OF THE CONSEQUENCES
C
DO 300 K=1,NRANKP
   CF(K,L) = CF(K,1) - B7*(ZR(J,K2) - Z(J))
300 CONTINUE
C
C CORRELATIONS WITH SECOND RESIDUALS
C
C
DO 310 I=1,NMAXP
   SCOR(I) = 0.
   S3VAR(I) = 0.
   J0PG(I) = 0.
310 CONTINUE
DO 312 J=1,NPAPA
   SVAR = 0.
   SCOE = 0.
   SZVAR = 0.
   DO 313 KN = 1, NPANKP
      ZRF = ZR(KN,1) - Z(J)
      SEUP = CF(KN,1)
      SCOE = SCOE + ZRF * SEUP
      SZVAR = SZVAR + SEUP
   313 CONTINUE
   SWP = NPANKP - 1
   SVAR = SWP / NPANKP
   S3VAR = S3VAR / NPANKP
   SCOE = SCOE / SPVAR
   SCOE = APS(SCOE)
   ABSCOE = APS(SCOE)
   DO 314 I=1,NMAXP
      APS = APS(SCOE(I))
      IF(APS .LT. 0.0001) GO TO 314
   314 INDAX = NMAXP - 1
   DO 315 IND = 1, INDAX
      IK = NMAXP + 1 - IND
      IMP = IK - 1
      J0PG(IK) = J0PG(IMP)
      SCOE(IK) = SCOE(IMP)
      S3VAR(IK) = S3VAR(IMP)
   315 CONTINUE
   J0PG(I) = J
   SCOE(I) = SCOE
   S3VAR(I) = S3VAR
   SCOE = 0.
   ABSCOE = 0.
314 CONTINUE
312 CONTINUE
SDV = SCRT(SVAF)
WRITE(*,'(13F9.9)') SDV
WRITE(*,'(13F9.9)')
\end{verbatim}
125

DO 320 I=1,NMAXP
   JB = JOPG(I)
   SC = SCOR(I)
   RSQ = SC * SC
   SVP = SVP + RSQ
   WRITE(IWRITE,4004) JB, SC, RSQ, SVP
320 CONTINUE
   WRITE(IWRITE,4004) SVP
C
   JB2 = JOPG(I)
   SZSD2 = SQRT(SVP(I))
   B2 = SCOR(I) * SQRT(SVAR) / SZSD2
   WRITE(IWRITE,4104) JB2, SZSD2, B2
4104 FORMAT('HJD, 5I1', 'THE THIRD CORRELATING PARAMETER, 13/1H, 5X, 29HHAS
SAMPLE STANDARD DEVIATION, 1G12.5/1H, 5X, 26HREGRESSION COEFFICIENT
2 B, 5X, G12.5/')
C
   DO 406 F=1,NBANKP
      CF(F,L) = CF(K,L) - B2*(ZB(K,JE2) - Z(JB2))
406 CONTINUE
   DO 410 I=1,NMAXP
      SPCOR(I) = 0
      SVPAB(I) = 0
      JOPG(I) = 0
410 CONTINUE
   DO 412 J=1,NPAPK
      SVAR = 0
      SCOPE = 0
      SZVAR = 0
      DO 413 KN = 1, NPAPK
         ZRF = CF(KN,J) - Z(J)
         SZUR = CF(KN,L)
         SCOR = SCOR + ZRF * SZUR
         SVAR = SVAR + SZUR * SZUR
         SZVAR = SZVAR + ZRF * ZRF
413 CONTINUE
   NZP = NPAPK - 1
   SVAF = SVAF / NZP
   SZVAR = SZVAR / NZP
   SCOPE = SCOPE / NZP
   SPCOR = SPCOR / NZP
   ABSCORABS = ABS(SCOR)
   DO 414 I=1,NMAXP
      ABST = ABS(SCOR(I))
      IF(ABST.LT.ABSCORABS) GO TO 414
      JINDMAX = I
   414 CONTINUE
   JIND=1, JINDMAX
   IKP = IKP + 1 - JIND
   IF (IKP.EQ.1) THEN
      JOPG(IKP) = JOPG(IKP)
      SPCOR(IKP) = SPCOR(IKP)
      SVPAB(IKP) = SVPAB(IKP)
      CONTINUE
   ELSE
      JOPG(IKP) = JOPG(IKP)
      SPCOR(IKP) = SPCOR(IKP)
      SVPAB(IKP) = SVPAB(IKP)
515 CONTINUE
   JOPG(I) = JOPG(I)
   SPCOR(I) = SPCOR(I)
   SVPAB(I) = SVPAB(I)
   SCOPE = SCOPE
M'I8EP NAlt READIN

\[
\text{ABSCOB} = 0.
\]

CONTINUE

\[
\text{SDEV} = \text{SQRT(SVAR)}
\]

\[
\text{WRITE(IWRITE,4099)} \ L, \text{SDEV}
\]

\[
\text{WRITE(IWRITE,4100)} \ L
\]

DO 420 I = 1, NMAIP

\[
\text{JB} = \text{JORG(I)}
\]

\[
\text{SC} = \text{SPCON(1)}
\]

\[
\text{RSQ} = \text{SC} * \text{SC}
\]

\[
\text{FVAR} = \text{NDF} * \text{RSQ}
\]

\[
\text{WRITE(IWRITE,4001)} \ JB, \text{SC}, \text{RSQ}, \text{FVAR}
\]

CONTINUE

\[
\text{WRITE(IWRITE,4002)} \ \text{NDF}
\]

\[
\text{JB2} = \text{JORG(1)}
\]

\[
\text{SZSD2} = \text{SQRT(SVAR(1))}
\]

\[
\text{B2} = \text{SPCON(1)} * \text{SQRT(SVAR)} / \text{SZSD2}
\]

\[
\text{WRITE(IWRITE,5104)} \ JB2, \text{SZSD2}, \text{B2}
\]

FORMAT(180,5X,318) FOURTH CORRELATING PARAMETER, I3/I1H, 5X, 29H HAS

1 SAMPLE STANDARD DEVIATION, G12.5/I1H, 5X, 26H REGRESSION COEFFICIENT

2 B, 5X, G12.5/

C

\[
\text{FOURTH RESIDUAL STANDARD DEVIATION}
\]

DO 500 K = 1, NFANKP

\[
\text{CP(K,L)} = \text{CP(K,L)} - \text{B2*(ZB(K,JB2) - Z(JB2))}
\]

500 CONTINUE

C

\[
\text{STANDARD DEVIATION OF AE FOURTH RESIDUALS}
\]

\[
\text{SVAR} = 1.
\]

DO 513 KN=1, NBANKP

\[
\text{SEUR} = \text{CP(KN,L)}
\]

\[
\text{SVAR} = \text{SVAR} + \text{SEUR} * \text{SEUR}
\]

513 CONTINUE

\[
\text{SVAR} = \text{SVAR} / \text{NFANKP}
\]

\[
\text{SDEV} = \text{SQRT(SVAR)}
\]

\[
\text{WRITE(IWRITE,4099)} \ L, \text{SDEV}
\]

111 CONTINUE

\[
\text{NKNP} = \text{NKNOI}
\]

\[
\text{RETURN}
\]

END
SUBROUTINE SAMPLE (IDIS, ADIS, CDIS, DDIS, ZB, WIOT, WKNOT, I)
C SAMPLE'S INPUT PARAMETERS
C
*CALL CONS
REAL*8 7P
DIMENSION IDIS(WTOT), ADIS(WTOT), CDIS(WTOT), DDIS(WTOT), ZB
IP(WKNOT, WTOT)
C
COMMON/NEWREF/ZONEW (12)
COMMON/CONTPL/JOPISV
DO 312 J = 1, WPARA
M = IDIS(J)
U = FLTPNF(0)
GO TO (320, 325, 330, 330, 9335, 931P, 9345, 9350) ,'I
325 U = FLTPNF(0)
ZY = BOIS(J) * U * (ADIS(J) - BDIS(J))
C IF(NCORR.GT.0) CALL MSHIFT(ZO)
GO TO 311
325 U = FLTPNF(0)
V = FLTPNF(0)
W = 1./U
GA = (32.*AIOG(W)**.5) * COS(6.2831853 ** V)
ZY = ADIS(J) + GA * BDIS(J)
C IF(NCORR.GT.0) CALL MSHIFT(ZO)
GO TO 311
330 U = FLTPNF(0)
ZY = ADIS(J) - BDIS(J) * ALOG(U)
IF(M.EQ.4) ZY = ADIS(J) + BDIS(J) * ALOG(U)
C IF(NCORR.GT.0) CALL MSHIFT(ZO)
GO TO 311
9335 U = FLTPNF(0)
V = FLTPNF(0)
W = 1./U
GA = (32.*AIOG(W)**.5) * COS(6.2831853 ** V)
ZY = ADIS(J) + GA * BDIS(J)
IF(ZY .GT. CDIS(J)) GO TO 9335
C IF(NCORR.GT.0) CALL MSHIFT(ZO)
GO TO 311
9340 U = FLTPNF(0)
V = FLTPNF(0)
W = 1./U
GA = (32.*AIOG(W)**.5) * COS(6.2831853 ** V)
ZY = ADIS(J) + GA * BDIS(J)
IF(ZY .GT. CDIS(J)) GO TO 9340
C IF(NCORR.GT.0) CALL MSHIFT(ZO)
GO TO 311
C THE SAMPLING GENERATOR FOR THE DPTA DISTRIBUTION IS DONE USING A
C PAIR OF GAMMA RANDOM VARIATES WHICH IN TURN USE EXPONENTIAL, AND
C THEREFORE, THE UNIFORM RANDOM VARIATE.
9345 BEAY = BDIS(J) - ADIS(J)
CEAY = CDIS(J) - ADIS(J)
G2MW = (CEAY/BTAY) * ((CEAY * (BDIS(J) - CDIS(J)) / LOIS(J) ** 2) - 1.)
ETANFW = G2MW * (BEAY/CEAY - 1.)
Y = GAMNF ('1., GAMAZV)
T = -NRMW ('1., ETANFW)
Z1 = (Y/T/1.) * (BDIS(J) - ADIS(J)) + ADIS(J)
C IF(LINEX .GT. J) CALL MSHIFT(ZD)
GO TO 315
9150 U=FLTRNF(0)
V=FLTRNF(0)
W=1./U
GA = ((2.*ALOG(W)**.5) * COS(6.2831853 * V))
BN = ADIS(J) + GA * BDIS(J)
ZY = EXP(1000)
C IF(LINEX .GT. 0) CALL MSHIFT(ZD)
311 CONTINUE
ZR(I,J) = ZY
312 CONTINUE
RETURN
END

FUNCTION GAMMA (ALAN, ETA)
V=ETA
F=PTA-N
IF(F.EQ.0) GO TO 8100
9010 P=FLTRNF(0)
IF(P.LT.F/P*2.71828)) GO TO 8120
Q=FLTRNF(0)
Y=Q**(1./P)
IF(P.GT.Y**(-Y)) GO TO 8100
GO TO 8050
8100 Y=Q.
GO TO 8070
8120 S=FLTRNF(0)
Y=1.-ALOG(S)
IF(P.GT.Y**(-Y-1.)) GO TO 8010
8050 IF(N.EQ.0) GO TO 8150
8070 Z=1.0
GO 8150 I=1,N
8080 Z=Z*FLTRNF(0)
Y=Y-1./LCT(I)
8150 GAMMA=Y/ALAN
RETURN
END
C PUNCH CARDS TO INPUT FOR VENUS, SENSITIVITY STUDY 1979.
C TAKE OUT THIS BLOCK IF VENUS IS NOT USED (200 SERIES STATEMENTS)
*CALC CONS

C

DATA WRITE,IPUNCH/6,7/
DO 205 I=1,NRANP
VAPRES = ZR(I,1)
CPPUEL = ZR(I,2)
WRITE(IPUNCH,2001) VAPRES,CPPUEL

2001 FORMAT (2E12.4)
IPRESS = ZP(I,3)
TONFR = 0.
WRITE(IPUNCH,2002) IPRESS,TDTOP

2002 FORMAT (2F12.5)
DELKO = ZR(I,4)
RAHF = ZR(I,5)
SECBTH = 0.0
AAMBD = ZP(I,6)
ALSW = 0.98
WRITE(IPUNCH,2003) DELKO,RAHF,SECBTH,AAMBD,ALSW

2003 FORMAT (5F12.5)
PPFIRST = 1.0E+20
PZERO = ZR(I,7)
PEDO = 2.5E+10
PCRIT = 3.0
WRITE(IPUNCH,2004) PFIRST,PZERO,PEDO,PCRIT

2004 FORMAT (6E12.5)
DO 20 J=1,4
A=0.
B=0.
C=3.
THELT = 3040.
HFUSE = ZF(I,8)
20 WRITE(IPUNCH,2005) A,B,C,THELT,HFUSE

2005 FORMAT (5F12.5)
AD = 0.
DOPLB = ZP(I,9)
CD = 0.
DD = 0.
WT = 1.750
WRITE(IPUNCH,2006) AD,DOPLB,CD,DD,WT
WT = 0.2560
WRITE(IPUNCH,2006) AD,DOPLB,CD,DD,WT
FT = 0.0924
"JIE(IPUNCH,2006) AD,DOPLB,CD,DD,WT
WT = 0.1633
WRITE(IPUNCH,2006) AD,DOPLB,CD,DD,WT

2006 FORMAT (5F12.5)
DF = 0.3633
RHGWI = ZR(I,10)
RHGW = ZR(I,11)
RHSS = ZR(I,12)
FP = 1.3489
FMA = 2.4
FSS = 0.3345
NAME: SASIM

1) WRITE (IPUNCH,2007) RHOO, RNOMA, RHOS5, PF, FMA, FSS

2007 FORMAT (E212.5)
TB = 1200.
ATMPF = 2B(1,13)
WRITE (IPUNCH,2008) ATMPF, TB

2009 FORMAT (2F12.5)
CONTINUE
RETURN
END
SUBROUTINE SCRAM(ZF,BF,ZPP,AMAT,ICAT,BF,AMAT,ZR,CP,NTOT,NKNOT,NCOEF2,ZF,Z1,Z2,KNOTSV)
REAL *8 ZF,BF,ZPP,AMAT,CF,X,DZJ,DZK
REAL *8 CFNEW
DIMENSION CFNEW(100,1)
COMMON/JOB/JOBFV
*CALL CONS
COMMON/WBIT/JUNE,JTWO,JTHREE
COMMON/TTRANS/WTRAPA,WTRACO,JTRA(7),LTRA(7),LTYPE(7),JTRA(17),BFA(7),ACO(7),UCO(7)
COMMON/ZETAB/ZETA(100,6)
DATA IWRITE/6/
DATA IOUT/0/
DIMENSION JGPG(10,12),GSENS(10),GSENS(10,12)
DIMENSION ZP(NKNOT,NCOEF2),BF(NCOEF2,1),ZPP(NCOEF2,NKNOT)
DIMENSION AMAT(NCOEF2,NCOEF2),ZR(KNOTSV,NTOT),CF(KNOTSV,1),ZO
DIMENSION JGP(12),SENS(12),SENSCR(12,12),SZNST(12),ZGF(12)
DIMENSION B(12),C(12),D(12,12)
C THE VALUE OF L (CONSEQUENCE INDEX) IS DETERMINED IN MAIN THRU CONS
C PARAMETER CYCLING INSIDE GROUP2 WITH VARIABLE JP
C NCONCS=1 IN THIS SUBROUTINE, NCONSV=NO. OF CONSEQUENCES, KNOWN TO MAIN ONLY
C
IF(NTOT.LT.NGP) WRITE(IWRITE,1500)
IF(NTOT.LT.NGP) RETURN
1500 FORMAT('H0,10X,45HNTOT LESS THAN NGP IN SUBROUTINE SCRAM, I PASS//')
C
DO 5 J = 1,NCOEF2
DO 1 N = 1,NCOEF2
1 AMAT(M,J) = 0.000
DO 5 K = 1,NCOEF2
2P(K,J) = 0.000
5 ZPP(J,K) = 0.000
DO 7 M = 1,NCOEF2
BP(M,1) = 0.000
7 BF(M,1) = 0.000
DO 8 J = 1,NCOEF2
CF(J,1) = ETA(JL)
8 IF(NP.LT.FGII) GO TO 40
FGII = (NTOT - NP) / (NP + NP) + 0.959
C
IF(NP.MP.NP) GO TO 40
FGIII = (NTOT - NP) / (NP + NP) + 0.959
C
131 = 131(FGLIII)
WRITE(IWRITE,2100) NLIN
2100 FORMAT('I0,10X,52HTHE NUMBER OF GROUPS =,I4//')
C CONTINUE
IF (JOBS.EQ.4) WGLIN=WLIN
IF (JOBS.EQ.5) WGLIN=1
IF (JOBS.EQ.15) WGLIN=1
NMAIG = MINO(10, RGLIN)
NMAXP = MINO(12, NTOT)
DO 110 IG = 1, NMAIG
GEEMS(IG) = 1.0D+99
110 CONTINUE

DEFINE MATRIX ZP AND ZPP
JFLAG = 0
JP = 0
JPSV = 0

FILL JGP ARRAY
NV = NGP - NP
JGP(I) CONTAINS THE NUMBERS OF THE PARAMETERS IN THE REGRESSION MODEL
... E. GROUP THE FIRST NP ARE THOSE ACCEPTED FROM THE PREVIOUS GROUP
DO 50 I = 1, NP
KG = KORG(I)
50 CONTINUE
JGP(I) = KG
JP(JG) = KG

IF (JOBS.EQ.5) GO TO 59
51 CONTINUE
51 IS AN IMPORTANT STATEMENT NUMBER TO BE RETURNED TO WITH NEW G
JGOFG(IG,IP) IS THE NUMBER OF THE IP'TH IMPORTANT PARAMETER IN THE IG'TH
GROUP. INITIAL VALUES FOR JGOFG(1,1) ARE GIVEN INPUT BY KORG(I), I.E. NP
DO 53 JV = 1, NV
I = NP + JV
55 JP = JP + 1
IF (JP.GT. NTOT) JFLAG = 1
IF (JP.EQ. NTOT) JP = JP - NDOT

JP HAS TO BE COMPARED TO THE NOS OF PARA ALREADY IN THE GROUP
DO 54 K = 1, NP
I = JTEST = JGP(K)
IF (JP.EQ. JTEST) GO TO 55
54 CONTINUE
JGP(I) = JP
53 CONTINUE
CONTINUE
IF (IOUT.GT.0 .OR. JOBS.EQ.5)
WRITE (*,1110) (JGP(IS),IS = 1,NGP)
1110 FORMAT (1H0,6I3,32H THE PARAMETERS OF THIS GROUP ARE,12I5//)

DO 2 KNOT=1,NBANKP
ZF(KNOT, 1) = 1.000
ZFP(1, KNOT) = 1.000
2

DO 3 J=1,NGP
J1 = J + 1
J2 = J1 + NGP
J3 = NGP + 1 + J*NGP - J*J1/2
3

JIND = JGP(J)
DZJ = ZP(KNOT, JIND)
DZJ = DZJ - ZO(JIND)

DO 4 K = J1,NGP
K1 = J1 + K
KIND = JGP(K)
DZK = ZP(KNOT, KIND)
DZK = DZK - ZO(KIND)
4

CONTINUE
2

? F AND ZFP AND CF ARE NOW DEFINED FOR THIS GROUP
THE NEXT THREE STATEMENTS SOLVE LEAST SQUARES FITTING EQUATION
(ZF'ZF)BF = ZP'CP

CALL NMULT (ZFP, CP, BP, MCOEF, NBANKP, MCONS, KNOTSV)
CALL NMULT (ZFP, ZP, AMAT, MCOEF, NBANKP, MCOEF2, NBANKP)
CALL RAVAV (AMAT, MCOEF2, BP, MCONS, DET2, ICOB)
ICOB = ICOB * 30
IF (IOUT.GT.0)
WRITE (*,1300) DET2, ICOB
1300 FORMAT (' DETERMINANT OF ZFP*ZF = ',G15.6,' TIMES 1.0D',I4)
C CALCULATE AND OUTPUT FITTED SURFACE ERRORS: MAXIMUM AND MINIMUM,
C MEAN SQUARE ERROR, REFERENCE VALUE AND FRACTIONAL ERROR.
1690 FORMAT(150,10X,23H*FITTED SURFACE ERRORS*/140,5X,13HAPPB
10XITWTON,1X,5X,HACT,10X,10DIFFE,5X,15BFPOR CONSEQUENCE,14//)
C
C
DO N = NANKP - NCOE2
IF(DN.LE.0.)DN = 1.0E-10
SU = C.O.
BIG = -1.0E+49
IBIG = 1
SMALL = 1.0E+49
ISMALL = 1
IF(IOUT.EQ.1)WRITE(IWRITE,1690) L
DO I = 1,NBANKP
CFA = 0.0
DO 27 IC = 1,NCOE2
CFA = CFA + ZP(IP,IC) * BP(IC,1)
C
22 CONTINUE
X = CFA - CP(IR,1)
IF(X.GT.BIG)IBIG = IR
IF(X.GT.BIG)BIG = X
IF(X.LT.SMALL)SMALL = IR
IF(X.LT.SMALL)SMALL = X
IF(IOUT.GT.1)WRITE(IWRITE,1700) IR,CPA,CFA,CP(IR,1),X

C
SU = SU + X*I
CFNEW(IP,1) = 0.
IF(JOBSV.EQ.15)CPNEW(IB,1) = -X
C
21 CONTINUE
IF(IOUT.GT.0.OR.JOBS.EQ.5.OR.JOBS.EQ.15)
WRITE(IWRITE,1701) L,IBIG,BIG,ISMALL,SMALL
IF(NTRACO.LE.0) GO TO 99
C
C MAX ERROR CONSEQUENCES TO BE INVERSE TRANSFORMED
C
LTYPE = 0
DO 701 I = 1,NTRACO
LL = LTPA(I)
C
IF(LL.NP.L) GO TO 701
LTYPE = LTYPE(I)
AC = AC(I)
BC = BC(I)
CFEIG = CF(IBIG,L)
CFAEIG = CFBIG + BIG
C
CFSHA = CF(ISMALL,L)
CFSHA = CFSHA + SMALL
GO TO (101,201,300,400,500,600,700),LTYPE
101 BCC = 1./BC
C
CFBIG = CFBIG**BCC + AC
IF(ITYP.FQ.C) GO TO 99
BIG = CPABIG - CPBIG
SMALL = CPSMA - CPSMA
PFAPIG = BIG/CPBIG
FRASMA = SMALL/CPSMA
WRITE(IWFITE,7001) CPABIG,CPBIG,BIG, FRABIG
WRITE(IWFITE,7002) CPSMA,CPSMA,SMALL,FRASMA
7001 FORMAT(1H*,4X,2HINVERSE TN IAX,APPR=,E12.5,2X,6HEXACT=,E12.5,2X,6HERROR=,E12.5,1X,9HFRACTION=,F10.6/)
MEMBER NAME  SCRAM
CROSS= 1.
JA=BF(1,1)
C COEFFICIENTS FOR THE GROUP PESDONSE SURFACE
DO 33 J=1,MGP
JA = J + 1
JB = JA + MGP
JC = JA*MGP + 1 - J*JA/2
C
B(J) = BF(JA,1)
C(J) = BF(JB,1)
IF(J.GP.MGP) GO TO 33
DO 37 K=JA,MGP
KPI = JC + K
32 D(J,K) = BF(KPI,1)
33 CONTINUE
C
C SENSITIVITIES FOR THE GROUP PARAMETERS
C
DO 35 J=1,MGP
BB = B(J)
JIND = JGP(J)
DZ1 = D1(JIND) - Z0(JIND)
C
DZJ2 = D2(JIND) - Z1(JIND)
CC = C(J)
SENS(J) = ABS((BB + CC*DZ1)*DZ1) + ABS((BP CC DZJ2) * DZJ2)
C
J1 = J + 1
IF(J.GP.MGP) GO TO 35
DO 36 K=J1,MGP
KIND = JGP(K)
SENSCR(J,K) = CROSS * ABS(D(J,K) * DZ1 * (21(KIND) - Z0(KIND)))
36 SENSCR(K,J) = SENSCR(J,K)
35 CONTINUE
C
C TOTAL SENSITIVITY MEASURE SENS(T)
C
DO 37 J=1,MGP
SENS (J) = SENS(J)
C
DO 38 X=1,MGP
IF(K.EQ.J) GO TO 38
SENS(J) = SENS(J) + SENSCK(J,K)
34 CONTINUE
37 CONTINUE
C
C RANKING THE GROUP ACCORDING TO RESIDUAL ERROR
DO 114 IG=1,MMAXG
VERT = GFRMS(IG)
IF(FRMS.GT.VERT) GO TO 114
IF(JOB.EQ.5.OR.JOB.EQ.15) GO TO 117
C
INDMAX = MMAXG -1G
DO 115 IND=1,INDMAX
115 K= MMAXG + 1 - IND
C
DO 116 IP=1,NMAXP
JGORG(IP,IP) = JGORG(IKP,IP)
GSEMS(IP,IP) = GSEMS(IKP,IP)
116 CONTINUE
115 CONTINUE
117 CONTINUE

C C
GSEMS(IG) = FMS
M=0
C PANKING THE PARAMETERS WITHIN THE GROUP THAT CHANGES GROUP RANKING
150 M=M+1
SEMAX1 = 0.
DO 152 J =1,NGP
IF(SEMAX1.GT.SEST(J)) GO TO 152
C C
SEMAX1 = SEST(J)
JMAX1 = JG(J)
JSV = J
GSEMS(IG,M) = SMAX1
JGORG(IG,JSV) = JMLX1
152 CONTINUE
C C
SEST(JSV) = SESTJ - SMAX1 - 1.0E-49
IF(M.LT.NGP) GO TO 150
M=0
SEMAX1 = 0.
FMS = 1.0E+49
114 CONTINUE
C C
IF(JOB.EQ.4. AND.JFLAG.NE.1) GO TO 51
C C
30 CONTINUE
DO 161 IG=1,NMAXG
WRITE(UNIT,4001) IG,(JGORG(IG,I),I=1,NMAXP)
WRITE(UNIT,4002) GSEMS(IG)
GPSEMS = 0.
C C
4001 FORMAT(1P0,FX,5HGROUP,JS,3X,1CHPARAMETERS,1216/)
4002 FORMAT(1H,6X,28HRESIDUAL MEAN SQUARE ERROR =,10X,G12.5/)
FRC2 = C.
IF(GD2**(L),GZ.0.)
FRC2 = GSEMS(IG) / SDZET(L)
C C
FMS = GSEMS(IG)
USS = DN * FMS * FMS
WRITE(UNIT,4003) USS
4003 FORMAT(1P0,10X,7HGROUP=,I4,5X,7HMCOEF2,15X,16NSUM OF SQUARES =
1,G13.5/)
C C
WRITE(UNIT,4004) SDZET(L),FRC2
C   GROUP SENSITIVITY = SAMPLE VARIANCE/(RESIDUAL S. E. ERROR*GROUP SENSITIVITY)
C   THE TOTAL SENSITIVITY IS = THE INDIVIDUAL SENSITIVITY + ALL INTERACTION
C   TERMS OF THE PARAMETER
C
C   HIGH GROUP SENSITIVITY WITH SMALL FITTING ERRORS (RESIDUALS)
C   INDICATES THAT WE MAY BE FITTING AN 'ELEPHANT'
C
C   ALSO A SUDDEN INCREASE IN THE SENSITIVITY OF AN INDIVIDUAL PARAMETER
C   ALONG THE SCREENING PROCESS MAY BE SPURIOUS
DO 162 JIP = 1,NGP
   JG(JIP) = JGF(JIP)
   GPSENS = GPSENS + GSENS(JG(JIP),JIP)
   WRITE(IWRITE,4005) JG(JIP),GPSENS(JG(JIP),JIP)
162 CONTINUE
GPWT = SDZET(L)/(FRAC2*GPSENS)
WRITE(IWRITE,4007) GPSENS,GPWT
4007 FORMAT(1H0,6X,19HGROUP SENSITIVITY = ,G12.5,251,19HGROUP MERIT IND)
   2X = ,G12.5)
4005 FORMAT(1H ,4X,16,7X,G12.5,5X,G12.5/)
161 CONTINUE
IF(JOBS.EQ.4) RETURN
C PRINT RESPONSE SURFACE COEFFICIENTS
C FOR THIS GROUP IN JOBS = 5
WRITE(IWRITE,2050)
WRITE(IWRITE,2051) (JGP(IP),IP= 1,NGP)
WRITE(IWRITE,2052) AA
WRITE(IWRITE,2053) (B(IP),IP=1,NGP)
C
C WHITE(IWRITE,2054) (C(IP),IP=1,NGP)
DO 172 JIP = 1,NGP
   IF(JIP.EQ.NGP) GO TO 172
   NKI = JIP + 1
   JPP = JGF(JIP)
   WRITE(IWRITE,2055) JPP, (D(JIP,K),K=NKI,NGP)
2050 FORMAT(1H0,5X,48HTHE COEFFICIENTS OF THE FITTED POLYNOMIALS /)
   162H  
   267H  + B(J) * ( Z(J) -Z0(J) ) ,SUN J  
   362H  + C(J) * ( Z(J) -Z0(J) )**2 ,SUN J  
   462H  + D(J,K) * ( Z(J) -Z0(J) ) * ( Z(K) -Z0(K) ) ,SUN J,K (K, J)  
2051 FORMAT(1H ,5X,75HTHE PARAMETERS ARE J,K = ,12ISE//)
2052 FORMAT(1H ,7X,3HA = ,G15.6//)
2053 FORMAT(1H ,4X,6FB(J) =,(U8G15.6)/)
2054 FORMAT(1H ,5X,6HC(J) =,(E6G15.6)/)
C CONTINUE
C
172 CONTINUE
C
2055 FORMAT(1H ,1X,2HD(I2,5H,K) =,(E6G15.6/) WRITE(IWRITE,2060)
SEMREP NAME SCRAM

IF (NGP.EQ.1) GO TO 193
WEP = NGP - 1
DO 182 IP=1,WEP
   KP = IP + 1
   WRITE (IWRITE, 2061) JGP(IP), SENS(IP), (SENSCR(IP, K), K=KP, NGP)
CONTINUE
182 WRITE (IWRITE, 2061) JGP(NGP), SENS (NGP)

IF (JOBSV.EQ.15) CALL FTTIN(ZBCFEBW, NTOT, MKNOT)

2060 FORMAT (1H0, 6X, 48HSENSITIVITIES AND INTERACTION SENSITIVITIES
          160H J, SENS(j), SENSQ(J,K), K=J+1,, WGP
2061 FORMAT (1H0, J4, G14.6, (6G14.6)/)
END
SUBROUTINE SSHIFT (IPARA, IDIS, ADIS, BDIS, CDIS, ZO, Z1, Z2, ZH, NTOT, NKNOT, KNOTSV)

C C CALCULATES THE DEVIATIONS OF THE INPUT PARAMETERS DISTRIBUTION CHARACTERISTIC
C ZAVE(J) IS THE SAMPLE MEAN VALUE OF THE PARAMETER Z(J), CALCULATED C FROM THE TOTAL INPUT SET OF KNOTSV CASES IN SUBROUTINE READIN
C USED IN TESTING SUBSET AVERAGE DEVIATIONS, FOR DETECTING IMPORTANT C PARAMETERS FOR THRESHOLD EFFECTS
C C SAMPLE SMALLEST VALUE FROM Z2 C SAMPLE LARGEST VALUE FROM Z1 C IN COMPARABLE TERMS TO HAVE A PROBABILITY MEASURE C FORMULAS DIRECTLY MEANINGFUL IF THE DISTRIBUTIONS OF THE INPUT PARA C ARE UNIFORM C USEFUL IN SEARCHING SENSITIVE INPUTS FOR SUBSETS
C REAL*8 Z, ZB, CF
*CALL CONS
COMMON/ZETA/100, 6)
COMMON/SAVE/ZAVE(1000), ZAVE(1000)
DIMENSION Z(1000)
DIMENSION IPARA(NTOT), IDIS(NTOT), ADIS(NTOT), BDIS(NTOT), CDIS(NTOT), DDIS(NTOT), ZO(NTOT), Z1(NTOT), Z2(NTOT)
DIMENSION JORG(20), SPMEAN(20), SPVAR(20), SPIAI(23)
DIMENSION STUDT(20)
DATA IPEAD, IWRITE, IWINA/5, 6, 5/
COMPCN/TRANSF/NTRAPA, NTFAKO, JTRA(7), JTYPE(7), LIRA(7), LTYPE(7), APA(17), ACO(7), BCO(7)
DIMENSION NEVKN(100)
DIMENSION MORG(2G)
C INITIAL ZEROS
NM''XP='INO(20, WCT)
DO 110 J = 1, NM''XP
SPMEAN(J) = 0.
STUDT(J) = 0.
CONTINUE
FM = HRAJO
FSV = 'MOTS
C WRITE(IWRITE, 4000)
4000 FORMAT('SAMPLE STATISTICS FOR INPUT PARAMETERS/1H, B1, 4, 3H 'FIRST DEVIATIONS OF THE SAMPLE MFPAM FROM Z2, 8H OF ZAVE/
WRITE(IWRITE, 3999)
3999 FORMAT('MEAN SHIFT, 12H 1-VARIABLE, 3E, 7HELDSD. 1, 3, 10MATA 0/5/1)
DO 112 J = 1, MPAPA
SIMPAN(J) = 1.
SZVAP = 7.
DO 113 FM = 1, NEVKN
MEMBER NAME SSHIFT

113 CONTINUE

C SAVE SMEAN'S IN THIS SUBROUTINE

C UNIFORM DISTRIBUTION
901 SDZ = (ADIS(J) - BDIS(J)) / SQRT(12.*FN)
GO TO 15

C NORMAL DISTRIBUTION
902 SDZ = BDIS(J)
GO TO 15

C EXPONENTIAL DISTRIBUTION
903 CONTINUE
904 CONTINUE
905 CONTINUE
906 CONTINUE
907 CONTINUE
908 CONTINUE

15 CONTINUE

C INDNAX = NPAXP - I

DO 114 I = 1, NPAXP
ABS = ABS(ZSHIFT)
SDZSA = SQRT(VAPA)
ZSHIFT = (SZMEAN + Z0(J))/SDZSA
IF(ABS <= SDZSA) GO TO 114
MEMBER NAME SSHIFT
JORG(I) = J
ZSHIFT = 0.
ABS5 = 0.
CONTINUE

ABVAR = ABS(SZVAR)
IF(ABVAR.LT.1.0) SZYAB = -SZVAR
IF(ABVAR.LT.1.0) AVAR = 1./ABVAR
DO 414 I=1,NMAXP
ABWA = ABS(SPVAR(I))
IF(AVAR.GT.1.0) ABWA = 1.0/ABWA
IF(AVAR.LT.1.0) GO TO 414

C
INDIAN = NMAXP - I
DO 415 IND = 1,INDIAN
IK = IF(I.EQ.0) - IND
IF(I .EQ. 0) SPVAR(I) = SPVAR(I)
MORG(I) = MORG(I)
CONTINUE

414 CONTINUE

412 CONTINUE
PDIF = 1.
IF(NANKP.EQ.KNOTSV) PDIF = FNSV/(FNSV-FN)
DO 410 J=1,NMAXP
JB = JORG(I)
MB = MORG(J)
SC = SPVAR(I)
SC = SC * SQRT(PDIF)
SD = SPVAR(I)
SCC = STUDT(I) * PDIF
SCC = SCC * SD
SSD = S3VAR(I)
C SCC = Student's T-Variable FOR TESTING TWO SAMPLE MEAN VALUES
WRITE(IWPRINT,4001) JB,SC,5B,SSD
4001 FORMAT(1H6,5X,14,2F13.4, 10X,4H ,I4,6X,P10.5/)
CONTINUE

4002 FORMAT(1H8,5X,14, Z10.4, 1H8,2F13.4, 10X,4H ,I4,6X,P10.5/)
CONTINUE

212 CONTINUE
DO 212 J=1,NHANK
Z2IN = 1./J
DO 213 K=1,NHANK
ZPR = ZPR
IF(ZPR.LT.SPWIN) Z2IN = ZIK
213 CONTINUE
M = DIS(J)
GO TO (911,912,913,914,915,916,917,919), M
911 SMZ = 4DIS(J) - 8DIS(J)
GO TO 25
912 SMP = 21(J) - 27(J)
GO TO 25
913 CONTINUE
915 CONTINUE
917 CONTINUE
EMBER NAME  SSHIFT
916 CONTINUE
917 CONTINUE
918 CONTINUE
27 SMZ = Z1(J) - Z2(J)
25 CONTINUE
23 SSHIFT = (SZMIN - Z2(J)) / SMZ
DO 214 I=1,NMAXP
ABS = SPHIN(I)
IF (SZSHIFT.I.T.ABS) GO TO 214
INDMAX = NMAXP - I
DO 215 IND = 1,INDMAX
IF=IND + 1 - IND
IKP = IV - 1
SPMIN(IP) = SPHIN(IP)
JOBG(IK) = JORG(IKP)
215 CONTINUE
SPHIN(I) = SSHIFT
JOBG(I) = J
214 CONTINUE
212 CONTINUE
DO 220 I=1,NMAXP
JB = JORG(I)
SC = SPMIN(I)
SCC = 1. - SC**PRNKP
WRITE(I9PITE,411) JB,SC,SCC
220 CONTINUE
4011 FORMAT(1H ,5X,14,F10.4,F10.5/)
WRITE(IWIPIT,4012)
4012 FORMAT(1H0,5X,35HDEVIATIONS OF LARGEST VALUE FROM Z1/) C
C SCC IS THE PROBABILITY OF GETTING MINIMUM VALUE DEVIATING THIS MUCH
C OR MORE FROM Z2, OR MAXIMUM VALUE FROM Z1
C C
C MAXIMUM VALUE BLOCK
C
DO 310 J=1,NMAXP
JOBG(I) = 0
310 CONTINUE
DO 312 J=1,NP4A4
S2MAX = -1.0E+48
DO 317 IK=1,NRANKP
ZPR = ZP(KM,J)
IF (ZPR.IMT.S2MAX) S2MAX = ZPR
313 CONTINUE
M = IDIS(J)
GO TO (921,922,923,924,925,926,927,928),M
921 SMZ = ADIS(J) - BDIS(J)
GO TO 25
922 SMZ = Z1(J) - Z2(J)
GO TO 35
923 CONTINUE
925 CONTINUE
924 CONTINUE
926 CONTINUE
927 CONTINUE
928 CONTINUE
SHIFT
37  $M_{Z} = Z(J) - Z'(J)
35  CONTINUE
   ZSHIFT = ($M_{Z} A - Z'(J) ) / SMZ
   DO 314 I=1,MAXP
   ABS = $M_{Z} A(I)
   IF (ZSHIFT .GT. ABS) GO TO 314
   IP = I - 1
   DO 315 IP = 1,INDMAX
   IK = IP + 1
   IP = IP - 1
   $M_{Z} A(IP) = $M_{Z} A(IP)
   JORG(IK) = JORG(IK)
315  CONTINUE
   $M_{Z} A(I) = ZSHIFT
   JORG(I) = J
   ZSHIFT = +1.
314  CONTINUE
312  CONTINUE
   DO 320 I=1,MAXP
   JB = JORG(I)
   SC = $M_{Z} A(I)
   SCC = (1. + SC)**(N+1)
   WRITE(IWRITE, 4011) JB, SC, SCC
320  CONTINUE
RETURN
END
SUBROUTINE TEXASS(Z, I)
C SUBROUTINE TEXSS FOR TESTING ONLY (TEST.GT.0)
  *CALL CONS
  DIMENSION Z(1000)
  COMMON/ZETA/ ZETA(100,6)
C
  DATA BACK/0.25/
C
C NEW MODIFICATIONS FOR NEW TEXASS
C
X1 = Z(1)
X2 = Z(2)
X3 = Z(3)
X4 = Z(4)
X5 = Z(5)
CONS(1) = X1 + 2.*X2 + 3.*X3 + 4.*X4 + 5.*X5 -7.500
CONS(2) = X1*X1 + 2.*X2*X2 + 3.*X3*X3 + 4.*X4*X4 + 5.*X5*X5
C
SUNCO = 0.
DO 5 JD=6,100
SUNCO = SUNCO + Z(JD) - 0.500
  5 CONTINUE
SUNCO = BACK - SUNCO
CONS(1) = CONS(1) + SUNCO
CONS(2) = CONS(2) + SUNCO
X1 = X1 - 0.5
X2 = X2 - 0.5
X3 = X3 - 0.5
X4 = X4 - 0.5
X5 = X5 - 0.5
CONS(3) = X1*X1 + 2.*X2*X2 + 3.*X3*X3 + 4.*X4*X4 + 5.*X5*X5 + SUNCO
  *25
CONS(4) = X1*X2 + 2.*X2*X3 + 3.*X3*X4 + 4.*X4*X5 + 5.*X5*X1 +SUNCO
  *25
C
DO 10 L = 1,4CONS
ZETA(I,L) = CONS(L)
10 CONTINUE
RETURN
END
APPENDIX B

Sample Input/Output

This sample problem performs Task 4 (JOBS=4) for a problem of 13 input parameters and three consequence variables. This example is part of an application to the Venus-II code described in Chapter IV. The number of Venus-II runs (= the number of knot-points) in this case is 40.

The first three pages contain the listing of the input cards for Task 4. Five consequence variables are input on the consequence cards (cards 15-54) but only the first three are used since the variable NCONS is given value three on the first card. The last three input cards specify seed-groups of two input parameters (parameters no. 5 and 9) for each of the three consequence variables used, and the successive regression procedure seeks for the best third input variables.

In the output listing that follows, the first page indicates some input variables as well as sizes and locations of certain arrays important for the dynamic allocation of space (used internally by the code). The second page of the output also contains input information, and the third page gives the ranges of the input variables (lower limits, mean values and the upper limits).

The fourth output page contains the listing of the values of the three consequence variables in all 40 cases (knot-points). Pages five and six contain the co-ordinates (values of the 13 input variables) of those 40 knot-points. The following pages contain statistics calculated from the sample of 40 cases (moments, histograms, joint distributions and plots of the histograms.

The screening output starts with correlation coefficients between consequences no. 1 and all the input variables, ranked by the magnitude of the correlations. Results of four stages of the stagewise correlation analysis are output for all three consequences variables, revealing that input parameters five and nine correlate most with all three consequences.
After the correlation analysis a number of largest correlation coefficients between the input parameters are listed. This is provided as an information for the user to check if high correlation between particular input variables could be a reason for having them both correlating highly with an output variable. In this case the input variables five and nine do not appear to be highly correlated.

The next two pages of the output give results for the threshold effects testing. This part is not relevant in this example since the input card no. 15 is blank (i.e. all knot-points that are input are included in the analysis).

The rest of the output contains results of the successive regression analysis with input parameters five and nine as a seed-group. For each consequence variable the program lists ten combinations of three input variables that yield best fits of quadratic functions to the consequence data. The residual errors of the best fits are also given as well as the values of a "group merit index", the inverse of which is defined by Eq. (8). The program also prints out instructions on how to use statistical testing with F-variates to verify the significance of the parameters included.

The computer running time (CPU) for this example was 3s on IBM 370/195.
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NUMBER OF CONSEQUENCES KCONS = 3
TEST OPTION TEST = 0
NO. OF CORRELATIONS NEQNS = 0
NO. OF RANDOM KNOT-POINTS NPARS = 40
NO. OF PARAMETER TRANSFORMATIONS NTRANS = 0
NO. OF CONSEQUENCE TRANSFORMATIONS NIACONS = 0
MAXIMUM NO. OF PARAMETERS IN A GROUP, NEQNSMAX = 6

MUDP = 1803180528 KLOC = 194596A JLOC = 732776
NUMBER OF PARAMETERS = 13
PROBABILITY RANGE = 0.00500000
NUMBER OF CONSEQUENCES = 3

NO TRANSFORMATIONS OF PARAMS OR CONSEQUENCES

INDEPENDENT INPUT PARAMETERS

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DISTRIBUTION FIRST PARAMETER SECOND PARAMETER THIRD PARAMETER FOURTH PARAMETER

1#UNIFORM UPPER LIMIT LOWER LIMIT
2#NORMAL MEAN VALUE STANDARD DEVIATION
3#EXPONENTIAL LOWER LIMIT SCALE CONSTANT
4#EXPONENTIAL UPPER LIMIT SCALE CONSTANT
5#NORMAL MEAN VALUE STANDARD DEVIATION
6#NORMAL MEAN VALUE STANDARD DEVIATION
7#BETA LOWER LIMIT UPPER LIMIT
8#LOG NORMAL MEAN VALUE STANDARD DEVIATION

FOR DISTRIBUTIONS 5 AND 6, THE VALUES FOR THE MEAN AND STANDARD DEVIATION ARE THOSE FOR THE UNTRUNCATED NORMAL DISTRIBUTION.

FOR DISTRIBUTION 9, THE VALUES FOR MEAN AND STANDARD DEVIATION ARE THOSE OF THE LOGARITHM OF THE PARAMETER.
### Ranges of the Parameters

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### Notes
- The table above represents the probability per unit of consequence for various consequence levels. Each cell indicates the probability value for a specific consequence level.
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### Correlation Coefficients for Consequence 1. Parameters

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<th>Square F</th>
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<td>Corr. Coef</td>
<td>Square</td>
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<td>0.04301</td>
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<td>0.00529</td>
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</table>

Compare last column to an F(1, 38) variable
THE SECOND CORRELATING PARAMETER
HAS SAMPLE STANDARD DEVIATION: 0.95114E-02
REGRESSION COEFFICIENT = 7.25372.

CONSEQUENCE 1 RESIDUAL STANDARD DEVIATION = 3.250

<table>
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<td>PARAMETER  CORR.COEFF.  SQUARE  F</td>
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<td>7  0.30798  0.15045  5.77925</td>
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<tr>
<td>2  0.30600  0.02949  1.60585</td>
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<tr>
<td>11 0.22972  0.05235  1.94762</td>
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<td>6  0.07995  0.00639  0.20923</td>
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<tr>
<td>3  0.05833  0.00257  0.97850</td>
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<tr>
<td>5  0.04172  0.00200  0.07600</td>
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<tr>
<td>10 0.04400  0.00129  0.03797</td>
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<tr>
<td>13 0.03234  0.00145  0.33926</td>
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<tr>
<td>12 0.01510  0.00023  0.00666</td>
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<tr>
<td>8  0.00206  0.00001  0.00277</td>
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<td>9  0.00000  0.00000  0.00000</td>
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COMPARE LAST COLUMN TO AN F(1, 38) VARIABLE

THE THIRD CORRELATING PARAMETER 1
HAS SAMPLE STANDARD DEVIATION: 0.83906E-02
REGRESSION COEFFICIENT = 2215.1

CONSEQUENCE 1 RESIDUAL STANDARD DEVIATION = 39.054

<table>
<thead>
<tr>
<th>CORRELATIONS OF RESIDUAL CONSEQUENCE 1 WITH PARAMETERS</th>
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</thead>
<tbody>
<tr>
<td>PARAMETER  CORR.COEFF.  SQUARE  F</td>
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<tr>
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<tr>
<td>11 0.33829  0.11888  4.38861</td>
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<td>9  0.18466  0.03610  1.29576</td>
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<td>Parameter</td>
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Compare last column to an F(1, 38) variable.

Fourth Correlating Parameter 6

Has Sample Standard Deviation -5.993E-07

Regression Coefficient \( \beta \) 0.01776E+09

Consequence 1 Residual Standard Deviation 34.926

Correlation Coefficients for Consequence 2 Parameters

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Compare last column to an F(1, 38) variable.

The Post Correlating Parameter 7

Has Sample Standard Deviation 4.0321E-01

Regression Coefficient \( \beta \) 7731.0
### Correlations of Residual Consequence 2 with Parameters

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**Consequence 2 Residual Standard Deviation: 334.03**

---

### Correlations of Residual Consequence 2 with Parameters

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**Consequence 2 Residual Standard Deviation: 211.14**

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### Correlated Parameters

- **Parameter**: A, B, C, D, E, F
- **Correlation Coefficient**: R
- **Square**: S
- **F**: Value for Chi-Square Test

---

**Note**: These correlations are significant at the 0.01 level (2-tailed).
The table below shows the correlations of residual consequence with parameters:

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Compare last column to an F(1, 38) variable.
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<th>( r )</th>
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</table>

**THE SECOND CORRELATING PARAMETER 9**

- Sample standard deviation: 1.5119e-03
- Regression coefficient: 0.3120e+06

**CONSEQUENCE 3: RESIDUAL STANDARD DEVIATION:** 151.67

**CORRELATIONS OF RESIDUAL CONSEQUENCE 3 WITH PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CORR. COEF.</th>
<th>SQUARE F</th>
<th>( r )</th>
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Compare last column to an $F(1, 35)$ variable.

**FOURTH CORRELATING PARAMETER 4**

* MASS SAMPLE STANDARD DEVIATION: $5.49928 \times 10^{-7}$
* REGRESSION COEFFICIENT: 0 $1.42788 \times 10^{-10}$

CONSEQUENCE: 4. RESIDUAL STANDARD DEVIATION: 0.071
### Sample Correlations Between Input Parameters

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Note: The table entries represent the sample correlations between input parameters.
### Sample Statistics for Input Parameters

First Deviations of the Sample Mean from Z0 or Zave

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<th>Mean Shift</th>
<th>T-Variable</th>
<th>Rel. RD.</th>
<th>Ratio Freq</th>
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### Deviations of Smallest Value from Z2

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### Deviations of Largest Value from Z1

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</table>
JOBS = 4, NUMBERS OF INITIAL GROUPS FOR THE CONSEQUENCES ARE

1 1 1

SCREENING FOR CONSEQUENCE 1

INPUT GROUP

NSINGL NGP HP PARAMETERS
1 3 2 5 9 0 0 0 0 0 0 0 0 0 0

NSINGLE IDENTIFICATION NUMER FOR THE INITIAL GROUP
NGP = NUMBER OF PARAMETERS IN EACH GROUP
HP = NUMBER OF PARAMETERS KEPT IN A GROUP AT EACH STEP

NWDS = 1820 IENO = 1821 IUFFT = 301356 KLOC = 1930320 MLOC = 732764

THE NUMBER OF GROUPS = 11

GROUP 1 PARAMETERS 5 0 2 0 0 0 0 0 0 0 0 0

RESIDUAL MEAN SQUARE ERROR = 56.457

NRANKPS 40 MCOEFZ = 10 SUM OF SQUARES = 40312.

SAMPLE ST. DEVI. = 0.233 NORMALIZED ERROR 0.1680

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT.NO. TOTAL SENSITIVITY

5 316.10
2 148.20

GROUP SENSITIVITY = 463.77

GROUP MERIT INDEX = 32725

GROUP 2 PARAMETERS 5 9 6 0 0 0 0 0 0 0 0 0

RESIDUAL MEAN SQUARE ERROR = 37.140

NRANKPS 40 MCOEFZ = 10 SUM OF SQUARES = 41390.

SAMPLE ST. DEVI. = 0.233 NORMALIZED ERROR 0.01826

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT.NO. TOTAL SENSITIVITY

5 319.00
GROUP SENSITIVITY = 472.30

GROUP 1 PARAMETERS 5 4 7 0 0 0 0 0 0
RESIDUAL MEAN SQUARE ERROR = 37.686

N RANK = 40 N COEF = 10 SUM OF SQUARES = 42425.

SAMPLE ST. DEV. = 89.233 NORMALIZED ERROR 0.02143

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT. NO. TOTAL SENSITIVITY

<p>| | | | | | | | | | |</p>
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<td>143.21</td>
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</table>

GROUP SENSITIVITY = 722.65

GROUP 2 PARAMETERS 5 9 11 0 0 0 0 0 0
RESIDUAL MEAN SQUARE ERROR = 38.425

N RANK = 40 N COEF = 10 SUM OF SQUARES = 44294.

SAMPLE ST. DEV. = 89.233 NORMALIZED ERROR 0.43061

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT. NO. TOTAL SENSITIVITY

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GROUP SENSITIVITY = 634.96

GROUP 3 PARAMETERS 5 9 1 0 0 0 0 0 0
RESIDUAL MEAN SQUARE ERROR = 41.256

N RANK = 40 N COEF = 10 SUM OF SQUARES = 51061.

SAMPLE ST. DEV. = 89.233 NORMALIZED ERROR 0.46234

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT. NO. TOTAL SENSITIVITY

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GROUP SENSITIVITY = 531.89

GROUP MERIT INDEX = 0.31899

GROUP SENSITIVITY = 472.30

GROUP MERIT INDEX = 0.31899

GROUP SENSITIVITY = 722.65

GROUP MERIT INDEX = 0.29309

GROUP SENSITIVITY = 634.96

GROUP MERIT INDEX = 0.32843

GROUP SENSITIVITY = 531.89

GROUP MERIT INDEX = 0.31899
GROUP 0 PARAMETERS 5 0 4 0 0 0 0 0 0 0 0 0 0 0 0
RESIDUAL MEAN SQUARE ERROR = 84.096

Sample St. Dev. = 89.233 NORMALIZED ERROR 0.49406

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT.NO. TOTAL SENSITIVITY
5 282.08
0 146.48
0 100.97

GROUP SENSITIVITY = 579.55
GROUP MERIT INDEX = 0.31157

GROUP 7 PARAMETERS 5 9 3 0 0 0 0 0 0 0 0 0
RESIDUAL MEAN SQUARE ERROR = 44.528

Sample St. Dev. = 89.233 NORMALIZED ERROR 0.49406

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT.NO. TOTAL SENSITIVITY
5 286.17
9 178.54
3 97.647

GROUP SENSITIVITY = 543.36
GROUP MERIT INDEX = 0.31785

GROUP 8 PARAMETERS 5 9 13 0 0 0 0 0 0 0 0 0
RESIDUAL MEAN SQUARE ERROR = 44.887

Sample St. Dev. = 89.233 NORMALIZED ERROR 0.50303

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT.NO. TOTAL SENSITIVITY
5 282.52
9 187.23
13 111.62

GROUP SENSITIVITY = 581.57
GROUP MERIT INDEX = 0.30502

GROUP 9 PARAMETERS 5 0 8 0 0 0 0 0 0 0 0 0
<table>
<thead>
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<th>IDENT.NO.</th>
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<th>GROUP SENSITIVITY</th>
<th>GROUP MERIT INDEX</th>
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GROUP PARAMETERS

SAMPLE ST. DEV. = 89.233  NORMALIZED ERROR 0.56321

PARAMETERS IN THE ORDER OF SENSITIVITY

IDENT.NO.  TOTAL SENSITIVITY
5          273.48
0          124.38
10         64.528

GROUP SENSITIVITY = 529.39  GROUP MERIT INDEX = 0.33020

SAMPLE ST. DEV. = 89.233  NORMALIZED ERROR 0.51087

PARAMETERS IN THE ORDER OF SENSITIVITY

IDENT.NO.  TOTAL SENSITIVITY
5          273.48
0          124.38
10         64.528

GROUP SENSITIVITY = 529.39  GROUP MERIT INDEX = 0.33020
THE REFERENCE GROUP FITTING IS NOW PERFORMED FOR THIS CONFEERENCE. GROUP USING L = 1

FOR TESTING THE SIGNIFICANCE OF THE ADDED PARAMETERS,

\((\text{US}(\text{NP}) - \text{US}(\text{IG})) * (\text{NP} + \text{K}) / (\text{K} * \text{US}(\text{IG}))\)

MAY BE COMPARED TO AN \(F(K,N-P-M)\) VARIATE

\(\text{US}(\text{NP}) = \text{RESIDUAL SUM OF SQUARES FOR THE BASE GROUP OF NP PARAMETERS, NP = 2}\)

\(\text{US}(\text{IG}) = \text{SAME FOR A LARGER GROUP IG WITH NPG PARAMETERS, INCL. THE BASE GROUP, NPG = 3}\)

\(= (\text{NPG} + 1)(\text{NPG} + 2)/2 = 10\)

\(= \text{K} = \text{N} - (\text{NP} + 1)(\text{NP} + 2)/2 = 0\)

\(\text{K} = \text{M} = 10\)
INPUT GROUP

NSING GROUP PARAMETER
1 2 2 5 9 0 0 0 0 0 0

NSING* IDENTIFICATION NUMBER FOR THE INITIAL GROUP
NGP = NUMBER OF PARAMETERS IN EACH GROUP
NP = NUMBER OF PARAMETERS KEPT IN A GROUP AT EACH STEP

NWBS = 1044 IEND = 1045 TOFF = 302160 KLNC = 1941420 MLOC = 732760

THE PARAMETERS OF THIS GROUP ARE 5 9

*CONSEQUENCE 1 -- MAX ERROR KNOT = 10 VALUE = 0.657611E+02 MIN ERROR KNOT = 25 VALUE = -0.138066E+03

MEAN SQUARE ERROR = 0.440811E+02 REF VALUE = 0.208762D+03 FRACTION = 0.21115

GROUP 1: PARAMETERS 5 9 0 0 0 0 0 0 0 0 0

RESIDUAL MEAN SQUARE ERROR = 48.491

--- --- NRMKPM = 40 NCOEFZA & SUM OF SQUARES = 66067.

--- --- SAMPLE-87: DEVR = 09.233 NORMALIZED ERROR 0.0400

--- --- PARAMETERS IN THE ORDER OF SENSITIVITY

IDENT, NO. TOTAL SENSITIVITY

S 289.96 9 169.75

GROUP SENSITIVITY = 039.75 GROUP MERIT INDEX = .01077

--- --- THE COEFFICIENTS OF THE FITTED POLYNOMIALS

\[ \begin{align*}
A & = \{ (J) \rightarrow (J) \} \\
C(J) & = \{ (J) \rightarrow (J) \}_1 \\
D(J,K) & = \{ (J) \rightarrow (J) \} \cdot \{ (K) \rightarrow (K) \}_1 \\
& \quad \text{SUM J,K (K,GT,J)} \\
& \quad \text{THE PARAMETERS ARE J,K = 5 9}
\end{align*} \]

--- \[ \begin{align*}
B(J) & = 209.24 \\
C(J) & = 3571.37 \\
D(5,K) & = 562268.
\end{align*} \]

--- --- SENSITIVITIES AND INTERACTION SENSITIVITIES

J, SENS(J), SENS(J,K), SENS(J,K), K=J+1..., NGP

S 235.819 30.1483
SCREENING FOR CONSEQUENCE 2

INPUT GROUP

NSINGL  NSCP  NSP  PARAMETERS
2  3  2  5  9  0  0  0  0  0  0

NSINGL: IDENTIFICATION NUMBER FOR THE INITIAL GROUP
NSCP = NUMBER OF PARAMETERS IN EACH GROUP
NSP = NUMBER OF PARAMETERS KEPT IN A GROUP AT EACH STEP

NDOS =  1620  IEED =  1621  IOFFT =  300300  KLOC =  1930320  MLOC =  732748

THE NUMBER OF GROUPS = 11

GROUP 1 PARAMETERS 5 9 2 0 0 0 0 0 0 0
RESIDUAL MEAN SQUARE ERROR = 110.50

NPATKP = 40  NCOEF2 = 10  SUM OF SQUARES = 366300E+06
SAMPLE ST. DEV. = 463.42  NORMALIZED ERROR 0.2388#

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT. NO.  TOTAL SENSITIVITY
5  1452.0
6  1133.3
2  1082.1

GROUP SENSITIVITY = 3458.4  GROUP MERIT INDEX = .53110

GROUP 2 PARAMETERS 5 9 11 0 0 0 0 0 0 0
RESIDUAL MEAN SQUARE ERROR = 188.76

NPATKP = 40  NCOEF2 = 10  SUM OF SQUARES = 106890E+07
SAMPLE ST. DEV. = 463.42  NORMALIZED ERROR 0.40732

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT. NO.  TOTAL SENSITIVITY
5  1430.0
6  1117.0
11  1013.91

GROUP SENSITIVITY = 3731.8  GROUP MERIT INDEX = .38349

GROUP 3 PARAMETERS 5 9 6 0 0 0 0 0 0 0

GROUP SENSITIVITY = 2913.7
PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT.NO. TOTAL SENSITIVITY

GROUP 1 PARAMETERS

RESIDUAL MEAN SQUARE ERROR = 204.04

GROUP 2 PARAMETERS

RESIDUAL MEAN SQUARE ERROR = 204.04

GROUP 3 PARAMETERS

RESIDUAL MEAN SQUARE ERROR = 204.04

GROUP 4 PARAMETERS

RESIDUAL MEAN SQUARE ERROR = 204.04

GROUP 5 PARAMETERS

RESIDUAL MEAN SQUARE ERROR = 204.04

GROUP 6 PARAMETERS

RESIDUAL MEAN SQUARE ERROR = 204.04
### Parameters in the Order of Sensitivity

#### Group 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sensitivity</th>
<th>Total Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1212.0</td>
<td>1431.1</td>
</tr>
<tr>
<td>13</td>
<td>407.00</td>
<td>464.84</td>
</tr>
</tbody>
</table>

**Group Sensitivity:** 2881.1  
**Group Merit Index:** 0.34315

**Residual Mean Square Error:** 221.55

**Normalized Error:** 0.17609

#### Group 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sensitivity</th>
<th>Total Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1295.1</td>
<td>1493.8</td>
</tr>
<tr>
<td>10</td>
<td>216.97</td>
<td>262.94</td>
</tr>
</tbody>
</table>

**Group Sensitivity:** 2851.8  
**Group Merit Index:** 0.39535

**Residual Mean Square Error:** 223.59

**Normalized Error:** 0.14996

#### Group 3

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sensitivity</th>
<th>Total Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1295.1</td>
<td>1493.8</td>
</tr>
<tr>
<td>10</td>
<td>216.97</td>
<td>262.94</td>
</tr>
</tbody>
</table>

**Group Sensitivity:** 2851.8  
**Group Merit Index:** 0.39535

**Residual Mean Square Error:** 223.59

**Normalized Error:** 0.14996
SAMPLE ST. DEV. = 48.342  NORMALIZED ERROR 0.48208

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT.NO. TOTAL SENSITIVITY

5  1360.9
4  997.10
3  329.45

GROUP SENSITIVITY = 2677.0

GROUP IN PARAMETERS 4  4  4  0  0  0  0  0  0  0  0

RESIDUAL MEAN SQUARE ERROR = 223.98

SAMPLE ST. DEV. = 48.342  NORMALIZED ERROR 0.48208

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT.NO. TOTAL SENSITIVITY

5  1284.5
4  1025.4
3  178.70

GROUP SENSITIVITY = 2491.6

GROUP MERIT INDEX = 0.35673

GROUP SENSITIVITY = 2677.0

GROUP MERIT INDEX = 0.35673

GROUP SENSITIVITY = 2491.6

GROUP MERIT INDEX = 0.35673
THE REFERENCE GROUP FITTING IS NOW PERFORMED FOR THIS CONSEQUENCE & GROUP USING = 2

FOR TESTING THE SIGNIFICANCE OF THE ADDED PARAMETERS
( \text{USS}(NP) - \text{USS}(IG) ) \cdot \frac{(N_{\text{RANK}} - M - 1)}{K \cdot \text{USS}(IG)}

MAY BE COMPARED TO AN $F(n, n_{\text{RANK}} - M)$ VARIABLE

\text{USS}(NP) = RESIDUAL SUM OF SQUARES FOR THE BASE GROUP OF NP PARAMETERS, NP = 2

\text{USS}(IG) = SAME FOR A LARGER GROUP IG WITH NGP PARAMETERS, INCL. THE BASE GROUP, NGP = 3

= (NGP+1)\cdot(NGP+2)/2 = 10

K = M - (NP+1)\cdot(NP+2)/2 = 4

N_{\text{RANK}} = M = 10
The parameters of this group are 5 9

GROUP 1 PARAMETERS 5 9 0 0 0 0 0 0 0 0

GROUP SENSITIVITY = 2131.3

GROUP MERIT INDEX = 0.7153
## Parameters Input Group

<table>
<thead>
<tr>
<th>N</th>
<th>SINGL</th>
<th>NSGP</th>
<th>NPT</th>
<th>PARAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- **NSINGL**: Identification number for the initial group.
- **NSGP**: Number of parameters in each group.
- **NPT**: Number of parameters kept in a group at each step.

### Initial Group

- **NG0S**: 1820
- **INO**: 1821
- **IOFFT**: 301389
- **KLOC**: 1938320
- **MLOC**: 732768

- **The number of groups**: 11

### Group Parameters

#### Group 1

- **Parameters**: 5
- **Residual mean square error**: 86.605

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>NCOEF</th>
<th>SUM OF SQUARES</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>22501E+06</td>
</tr>
</tbody>
</table>

- **Sample st. dev.**: 342.60
- **Normalized error**: 0.25278

#### Parameters in the order of sensitivity

<table>
<thead>
<tr>
<th>IDENT. NO.</th>
<th>TOTAL SENSITIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1104.6</td>
</tr>
<tr>
<td>2</td>
<td>775.91</td>
</tr>
</tbody>
</table>

- **Group sensitivity**: 271.4

- **Group merit index**: 0.6936

#### Group 2

- **Parameters**: 5
- **Residual mean square error**: 132.6

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>NCOEF</th>
<th>SUM OF SQUARES</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>523333E+06</td>
</tr>
</tbody>
</table>

- **Sample st. dev.**: 342.60
- **Normalized error**: 0.36551

#### Parameters in the order of sensitivity

<table>
<thead>
<tr>
<th>IDENT. NO.</th>
<th>TOTAL SENSITIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1132.1</td>
</tr>
<tr>
<td>2</td>
<td>765.40</td>
</tr>
<tr>
<td>11</td>
<td>511.11</td>
</tr>
</tbody>
</table>

- **Group sensitivity**: 2529.8

- **Group merit index**: 0.35140

#### Group 3

- **Parameters**: 5
- **Residual mean square error**: 132.6

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>NCOEF</th>
<th>SUM OF SQUARES</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>523333E+06</td>
</tr>
</tbody>
</table>

- **Sample st. dev.**: 342.60
- **Normalized error**: 0.36551

#### Parameters in the order of sensitivity

<table>
<thead>
<tr>
<th>IDENT. NO.</th>
<th>TOTAL SENSITIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1132.1</td>
</tr>
<tr>
<td>2</td>
<td>765.40</td>
</tr>
<tr>
<td>11</td>
<td>511.11</td>
</tr>
</tbody>
</table>

- **Group sensitivity**: 2529.8

- **Group merit index**: 0.35140
SAMPLE ST. DEV. = 342.60  NORMALIZED ERROR 0.39185

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT.NO.  TOTAL SENSITIVITY

| GROUP SENSITIVITY | 2341.8 |
| GROUP PARAMETER | 5 9 7 0 0 0 0 0 0 0 |
| RESIDUAL MEAN SQUARE ERROR = 142.15 |

SAMPLE ST. DEV. = 342.60  NORMALIZED ERROR 0.41492

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT.NO.  TOTAL SENSITIVITY

| GROUP SENSITIVITY | 2329.1 |
| GROUP PARAMETER | 5 9 7 0 0 0 0 0 0 0 |
| RESIDUAL MEAN SQUARE ERROR = 146.68 |

SAMPLE ST. DEV. = 342.60  NORMALIZED ERROR 0.42813

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT.NO.  TOTAL SENSITIVITY

<p>| GROUP SENSITIVITY | 2193.7 |
| GROUP PARAMETER | 5 9 7 0 0 0 0 0 0 0 |
| RESIDUAL MEAN SQUARE ERROR = 150.88 |</p>
<table>
<thead>
<tr>
<th>Group Sensitivity</th>
<th>Group Merit Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>2249.9</td>
<td>0.38577</td>
</tr>
<tr>
<td>1859.2</td>
<td>0.37354</td>
</tr>
<tr>
<td>1851.6</td>
<td>0.39183</td>
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</table>

**Parameters in the Order of Sensitivity**

<table>
<thead>
<tr>
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<th>Total Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
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</tr>
<tr>
<td>9</td>
<td>714.67</td>
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<tr>
<td>13</td>
<td>583.73</td>
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Residual Mean Square Error: 159.57

<table>
<thead>
<tr>
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<th>NCOEF</th>
<th>SUM of Squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>76387E+06</td>
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</tbody>
</table>

**Parameters in the Order of Sensitivity**

<table>
<thead>
<tr>
<th>Ident. No.</th>
<th>Total Sensitivity</th>
</tr>
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<tbody>
<tr>
<td>5</td>
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</tr>
<tr>
<td>9</td>
<td>726.20</td>
</tr>
<tr>
<td>1</td>
<td>271.21</td>
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Residual Mean Square Error: 161.13

<table>
<thead>
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<tbody>
<tr>
<td>1</td>
<td>4</td>
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</table>

**Parameters in the Order of Sensitivity**

<table>
<thead>
<tr>
<th>Ident. No.</th>
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</thead>
<tbody>
<tr>
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<tr>
<td>0</td>
<td>241.11</td>
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<tr>
<td>6</td>
<td>263.64</td>
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</table>

Residual Mean Square Error: 162.61

<table>
<thead>
<tr>
<th>Rank</th>
<th>NCOEF</th>
<th>SUM of Squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>79328E+06</td>
</tr>
</tbody>
</table>
PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT.NO. TOTAL SENSITIVITY
5 895.23
4 715.71
0 121.20

GROUP SENSITIVITY = 1732.1
GROUP MERIT INDEX = 1.01473

GROUP 10 PARAMETERS
5 9 10 0 0 0 0 0 0 0 0

RESIDUAL MEAN SQUARE ERROR = 162.65

RANK = 40
NCOEF = 10
SUM OF SQUARES = 79360E+06

SAMPLE ST. DEV. = 542.86
NORMALIZED ERROR 0.47473

PARAMETERS IN THE ORDER OF SENSITIVITY
IDENT.NO. TOTAL SENSITIVITY
5 939.34
4 679.34
10 112.80

GROUP SENSITIVITY = 1726.4
GROUP MERIT INDEX = 0.41798
THE REFERENCE GROUP FITTING IS NOW PERFORMED FOR THIS CONSEQUENCE 3 , GROUP USING = 3

FOR TESTING THE SIGNIFICANCE OF THE ADDED PARAMETERS

\[(\text{USB}(\text{NP}) - \text{USB}(\text{IG})) * (\text{MRANK} - 1)/ (N - \text{USB}(\text{IG}))\]

MAY BE COMPARED TO AN \( F(4, \text{MRANK}-N) \) VARIABLE

\( \text{USB}(\text{NP}) \) = RESIDUAL SUM OF SQUARES FOR THE BASE GROUP OF NP PARAMETERS , \( N = 2 \)

\( \text{USB}(\text{IG}) \) = SAME FOR A LARGER GROUP IG WITH NGR PARAMETERS, INCL. THE BASE GROUP, NGR = 3

\[ n = (\text{NGR}+1) * (\text{NGR}+2)/2 = 10 \]

\[ \epsilon = n - (\text{NP}+1) * (\text{NP}+2)/2 = 2 \]

\[ \text{MRANK} - n = 10 \]
INPUT GROUP

NUMBER OF PARAMETERS
3 2 2 5 4 0 0 0 0 0 0 0 0

NUMBER IDENTIFICATION NUMBER FOR THE INITIAL GROUP
NGP = NUMBER OF PARAMETERS IN EACH GROUP
NP = NUMBER OF PARAMETERS KEPT IN A GROUP AT EACH STEP

NMS = 1044 IEND = 1045 IOFFT = 302160 LLOC = 198126 MLOC = 732766

THE PARAMETERS OF THIS GROUP ARE 5 9
- CONSEQUENCE 3 MAX ERROR KNOT 20 VALUE 0.353367E+03 MIN ERROR KNOT 25 VALUE -0.932289E+03
- SUM OF ERROR SQUARES = 0.0194E+06
- MEAN SQUARE ERROR = 0.154533E+03 REF VALUE = 0.910128D+03 FRACTION = 0.16979
- GROUP 1 PARAMETERS 5 9 0 0 0 0 0 0 0 0 0
- RESIDUAL MEAN SQUARE ERROR = 150.3
- NPARAM = 0 COEFE2 = 0 SUM OF SQUARES = 0.0194E+06

- - - PARAMETERS IN THE ORDER OF SENSITIVITY
- IDENT. NO. TOTAL SENSITIVITY

<p>| | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<td></td>
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</tr>
</tbody>
</table>

GROUP SENSITIVITY = 1554.5

- GROUP MERIT INDEX = 0.48863

THE COEFFICIENTS OF THE FITTED POLYNOMIALS

A(J) = 12(J) - 20(J)
B(J) = 24(J) - 20(J) + 12(J) - 20(J)
C(J) = 48(J) - 20(J) + 12(J) - 20(J)

Sums J, Sums J, Sums J, Sums J, Sums J

SENSITIVITIES AND INTERACTION SENSITIVITIES

J, SENS(J), SENSER(J), KJ=1...NGP

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
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</table>
ACKNOWLEDGEMENTS

The author wishes to thank R. B. Williams for his contributions in programming and testing parts of the SCREEN code, J. E. Cahalan and J. M. Kyser of their valuable support in solving computational problems, and E. E. Morris and D. L. Graff for their assistance in using the VENUS-II code.

REFERENCES


