PROSA-2: A PROBABILISTIC RESPONSE-SURFACE ANALYSIS AND SIMULATION CODE

by

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>1</td>
</tr>
<tr>
<td>I.  INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II. BASIC RESPONSE-SURFACE TECHNIQUES</td>
<td>4</td>
</tr>
<tr>
<td>III. ADVANCED RESPONSE-SURFACE TECHNIQUES</td>
<td>10</td>
</tr>
<tr>
<td>A.  Knot-point Selection</td>
<td>10</td>
</tr>
<tr>
<td>B.  Response Surfaces</td>
<td>10</td>
</tr>
<tr>
<td>C.  Functional Transformations</td>
<td>13</td>
</tr>
<tr>
<td>D.  Weighting Regionwise Response Surfaces</td>
<td>15</td>
</tr>
<tr>
<td>E.  Function Sampling</td>
<td>17</td>
</tr>
<tr>
<td>F.  Random Criteria for Conditional Distributions</td>
<td>18</td>
</tr>
<tr>
<td>IV. USER'S MANUAL</td>
<td>19</td>
</tr>
<tr>
<td>A.  Program Summary</td>
<td>19</td>
</tr>
<tr>
<td>B.  Program Abstract</td>
<td>19</td>
</tr>
<tr>
<td>C.  Program Use</td>
<td>22</td>
</tr>
<tr>
<td>1.  Task Descriptions</td>
<td>22</td>
</tr>
<tr>
<td>2.  Input Instructions</td>
<td>28</td>
</tr>
<tr>
<td>3.  Flow Diagrams</td>
<td>41</td>
</tr>
<tr>
<td>4.  Subroutine Functions</td>
<td>50</td>
</tr>
<tr>
<td>V.  SUMMARY</td>
<td>54</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>56</td>
</tr>
<tr>
<td>A.  Program Listing</td>
<td>56</td>
</tr>
<tr>
<td>B.  Sample Input/Output</td>
<td>157</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>189</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>190</td>
</tr>
</tbody>
</table>
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Use of PROSA-2 in Probabilistic Response-surface Analysis</td>
<td>3</td>
</tr>
<tr>
<td>2.</td>
<td>Schemes for Knot-point Selection.</td>
<td>7</td>
</tr>
<tr>
<td>3.</td>
<td>Probability Densities Obtained with Various Response Surfaces</td>
<td>13</td>
</tr>
<tr>
<td>4.</td>
<td>Cumulative Distributions of the Normalized Reactor Power.</td>
<td>17</td>
</tr>
<tr>
<td>5.</td>
<td>Sequence of Subprograms in PROSA-2; Part 1</td>
<td>42</td>
</tr>
<tr>
<td>6.</td>
<td>Sequence of Subprograms in PROSA-2; Part 2(A)</td>
<td>43</td>
</tr>
<tr>
<td>7.</td>
<td>Sequence of Subprograms in PROSA-2; Part 2(B)</td>
<td>44</td>
</tr>
<tr>
<td>8.</td>
<td>Sequence of Subprograms in PROSA-2; Part 2(C)</td>
<td>45</td>
</tr>
<tr>
<td>9.</td>
<td>Sequence of Subprograms in PROSA-2; Part 3(A)</td>
<td>46</td>
</tr>
<tr>
<td>10.</td>
<td>Sequence of Subprograms in PROSA-2; Part 3(B)</td>
<td>47</td>
</tr>
<tr>
<td>11.</td>
<td>Sequence of Subprograms in PROSA-2; Part 4-5(A)</td>
<td>48</td>
</tr>
<tr>
<td>12.</td>
<td>Sequence of Subprograms in PROSA-2; Part 5(B)</td>
<td>49</td>
</tr>
</tbody>
</table>

### LIST OF TABLES

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>Probability Distributions Available in the PROSA-2 Code</td>
<td>6</td>
</tr>
<tr>
<td>II.</td>
<td>Moments of the Distributions.</td>
<td>9</td>
</tr>
<tr>
<td>III.</td>
<td>Minimum Number of Knot Points for the Response Surfaces</td>
<td>11</td>
</tr>
<tr>
<td>IV.</td>
<td>Quadratic Approximation of a Transient Overpower Accident</td>
<td>14</td>
</tr>
</tbody>
</table>
PROSA-2: A PROBABILISTIC RESPONSE-SURFACE ANALYSIS AND SIMULATION CODE

by

J. K. Vaurio

ABSTRACT

Response-surface techniques have been developed for obtaining probability distributions of the consequences of postulated nuclear reactor accidents. In these techniques, probability distributions are assigned to the system and model parameters of the accident analysis. A limited number of parameter values (called knot points) are selected and input to a deterministic accident-analysis code. The results of the deterministic analyses are used to generate analytical functions (called response surfaces) that approximate the accident consequences in terms of selected system and model parameters. These analytical functions are then used in a Monte Carlo-type simulation to calculate probability distributions and related characteristics of the consequences. The use of response surfaces leads to considerable savings in computer time in comparison to direct simulation with long-running accident-analysis codes.

The response-surface methodology of this report includes both systematic and random knot-point selection schemes, second- and third-degree response surfaces, functional transformations of both input parameters and consequence variables, smooth synthesis of regionwise response surfaces and the treatment of random conditions for conditional distributions. The computer code PROSA-2 developed for implementing these techniques is independent of the deterministic accident-analysis codes. It can also be used for direct simulation of general analytical functions. The significance, accuracy and other merits of these features are discussed and typical results are presented for illustration purposes.

1. INTRODUCTION

The development of response-surface techniques for nuclear reactor safety analysis is a relatively new aspect in the probabilistic safety methodology. In general terms, the problem is to find the probability distribution of an accident consequence variable that is a function of many other random variables, such as system and model parameters. The functional relationship between a consequence variable and the input parameters is not known in analytical form but only through numerical mechanistic (deterministic)
accident-analysis codes. For the purpose of minimizing the need for longrunning computer programs in connection with a Monte Carlo-type simulation, probabilistic response-surface techniques and related computer codes have been developed at ANL. In these techniques, probability distributions are assigned to the input parameters, and combinations of parameter values are chosen from these distributions. These combinations of parameter values are then input to a deterministic accident-analysis code. The results of these deterministic consequence analyses are used to generate response surfaces for the consequences as functions of the selected system and model input parameters. These approximating functions are then used to generate the probability distributions and joint distributions of the consequences, with random sampling being used to obtain values for the accident parameters from their distributions. This use of response surfaces leads to considerable savings in computer time in comparison to direct simulation.

Figure 1 illustrates the use of the PROSA-2 code to implement the probabilistic response-surface techniques. The code is designed to be independent of any other accident-analysis code. However, it can be linked with practically any code that provides "data points" for the response-surface technique. Besides, a user can select his own knot points, thereby avoiding Pass 1 in Fig. 1, and can still use PROSA-2 in Pass 2.

Various versions of the code have been previously applied to problems on fast reactor core disruptive accidents, sodium fires, and loss-of-coolant accidents in light-water reactors, demonstrating that it can be linked with different types of accident-analysis codes.

The features of an earlier documented version (PROSA-1) are also included in the advanced version, PROSA-2, which is the subject of this report. The emphasis of the discussion is on the unique features of the new code. The features include both systematically and randomly selected knot points, and a least-squares fitting as well as a generalized Lagrange interpolation method to find second- and third-degree response surfaces. Functional transformations can be used for both input and output (consequence) variables, thereby expanding the family of response surfaces well beyond polynomial functions. Maximum and average errors are calculated for fitted response surfaces, thereby providing means of estimating the accuracy of the functions and of searching for optimal functional transformations. An analytical weighting scheme has been developed for regionwise response surfaces to improve the accuracy and continuity. Conditional distributions can be calculated, with criteria (conditions) being either random functions or fixed values. Another new feature of the code is that the sampling distributions in Pass 2 (Fig. 1) can be different from the distributions used for selecting the knot points in Pass 1. The code can also be used for Monte Carlo sampling of a known analytical function, without first finding a response surface to approximate the function.
The basic response-surface techniques are summarized in Chapter II. The advanced features are described in Chapter III, and the significance, accuracy, and other merits are discussed. Typical results are presented for illustration purposes. Chapter IV consists of the User's Manual for the PROSA-2 code. It contains a summary, an abstract, and detailed user-oriented information. Program listing and input/output examples are given in the appendices.

Fig. 1. Use of PROSA-2 in Probabilistic Response-surface Analysis
II. BASIC RESPONSE-SURFACE TECHNIQUES

The consequences of interest, \( \zeta \), which might include, for example, accident energetics and degrees of core and vessel damage, depend on many system and model parameters, \( z_1, z_2, \ldots, z_n \).

\[
\zeta = \zeta(z_1, z_2, \ldots, z_n) = \zeta(\bar{z}). \quad (1)
\]

The statistical variations of the parameters, \( z_i \), which include reactivity coefficients, heat-transfer parameters, etc., cause variations in \( \zeta \). It is possible, in principle, to sample values of the parameters, \( z_i \), from their probability distributions and to calculate \( \zeta \) for a sufficient number of cases using comprehensive accident-analysis codes. However, the long computing times of such codes often prevent this direct simulation. With response-surface techniques, the idea is to find a multivariate analytical approximation, \( \zeta(\bar{z}) \), to \( \zeta(\bar{z}) \), and perform the accident simulations for randomly selected values of \( \bar{z} \) with \( \zeta(\bar{z}) \).

Systematical techniques for minimizing the error \( |\zeta - \zeta(\bar{z})| \) in the important domain of \( \bar{z} \) space are presented in Chapter III.

Starting from a second-degree response surface, the approximation of a given consequence \( \zeta(\bar{z}) \), as a function of the accident parameters, \( z_1, \ldots, z_n \), has the following functional form:

\[
\hat{\zeta}(\bar{z}) = A + \sum_{j=1}^{n} \left[ B_j + C_j (z_j - z_{j0}) + \sum_{k=j+1}^{n} D_{jk} (z_k - z_{k0}) \right] (z_j - z_{j0}) \quad (2)
\]

To determine the unknown coefficients, a set of \( 1 + 2n + n(n - 1)/2 \) knot points \( \bar{z} \) are selected at which the approximation \( \hat{\zeta}(\bar{z}) \) is made equal to the actual values of \( \zeta(\bar{z}) \) calculated by a deterministic accident-analysis code.

The coefficients of Eq. 2 are

\[
A = \zeta_0 \quad B_j = R_{j1} (z_{j0} - z_{j2}) + R_{j2} (z_{j0} - z_{j1}) \quad C_j = R_{j1} + R_{j2}
\]

and
where

\[ R_{j1} = \frac{\zeta_1(j) - \zeta_0}{(z_{j1} - z_{j0})(z_{j1} - z_{j2})}, \]

\[ R_{j2} = \frac{\zeta_2(j) - \zeta_0}{(z_{j2} - z_{j0})(z_{j2} - z_{j1})}, \]

and

\[ D_{jk} = \frac{\zeta_0 + \zeta_{11}(j,k) - \zeta_1(j) - \zeta_1(k)}{(z_{j1} - z_{j0})(z_{k1} - z_{k0})}, \]

(3)

where \( \bar{z} = (z_{j1}^0, z_{j2}^0, \ldots, z_{n0}) \) is the reference point, \( z_{j1} \) and \( z_{j2} \) are two other selected values of \( z_j \) for all \( j = 1, \ldots, n \), and

\[ \zeta_0 = \zeta(\bar{z}_0), \quad \zeta_1(j) = \zeta(z_j = z_{j1}), \]

\[ \zeta_2(j) = \zeta(z_j = z_{j2}), \quad \zeta_{11}(j,k) = \zeta(z_j = z_{j1}, z_k = z_{k1}) . \]

The components of \( \bar{z} \) not explicitly given as arguments of \( \zeta(\_) \) have their reference values, \( z_k = z_{k0} \).

The knot-point coordinates \( z_{j0} \), \( z_{j1} \) and \( z_{j2} \) are selected so that \( z_{j0} \) is taken as the mean value of \( z_j \), and a user-specified probability truncation limit, \( P^* \), is used to calculate \( z_{j1} \) and \( z_{j2} \) from the conditions,

\[ \int_{z_{j1}}^{z_{j2}} f_j(z_j) dz_j = \int_{-\infty}^{z_{j2}} f_j(z_j) dz_j = P^*, \]

(4)

where \( f_j(z_j) \) is the probability density function of \( z_j \). The value of \( P^* \) depends on the problem at hand. If a certain safety characteristic has to be studied within the 99 percent confidence level, a natural choice is \( P^* = 0.01 \). Eight different distributions are available in PROSA, including uniform, normal, truncated normal, exponential, beta and log-normal distributions. The distributions are defined in Table 1. Some of the moments of these distributions are given in
<table>
<thead>
<tr>
<th>Name of Distribution</th>
<th>Functional Form</th>
<th>Parameters to be Specified</th>
</tr>
</thead>
<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^{- \left(\frac{z-\mu}{2\sigma}\right)^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 \geq 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 \leq 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^{- \left(\frac{z-\mu}{2\sigma}\right)^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^{- \left(\frac{z-\mu}{2\sigma}\right)^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(\gamma+n)}{\Gamma(\gamma) \Gamma(n)} \left(\frac{z-a}{b-a}\right)^{\gamma-1} \left[1-\frac{z-a}{b-a}\right]^{n-1} ; a \leq z \leq b )</td>
<td>( a, b, \gamma, \eta ; \gamma, \eta &gt; 0, b &gt; a )</td>
</tr>
<tr>
<td>Log-normal</td>
<td>( \frac{1}{\sigma z \sqrt{2\pi}} e^{- \left(\ln\frac{z-\mu}{\sigma}\right)^2} ; z &gt; 0 )</td>
<td>( \mu, \sigma ; \sigma &gt; 0 )</td>
</tr>
</tbody>
</table>

\* \( F(x) = .5 + .5 \operatorname{erf} \left(\frac{x-\mu}{\sigma \sqrt{2}}\right) \)
Table II. Especially the mean values and the standard deviations are needed as input to the code, as will be described in Chapter IV.

The knot points defined by Eq. 4 and used in Eqs. 3 are illustrated in Fig. 2A. In this case a single polynomial is used to represent a consequence in the entire parameter space. In the following, this is called a single-quadrant response surface (SQ).

The knot points defined by Eq. 4 and used in Eqs. 3 are illustrated in Fig. 2A. In this case a single polynomial is used to represent a consequence in the entire parameter space. In the following, this is called a single-quadrant response surface (SQ).

**Fig. 2. Schemes for Knot-point Selection**

The second scheme, illustrated in Fig. 2B, provides additional knot points so that separate response surfaces can be generated for each quadrant of Fig. 2, for all pairs \( z_j, z_k \). Equations 3 can be used in each quadrant separately. This combination of regionwise response surfaces is called a multi-quadrant surface (MQ). MQ is expected to more accurately predict the true consequence values than SQ. However, the number of deterministic calculations required to generate the response surfaces is larger, and is given by \( 1 + 4n + 2n(n - 1) \).

In the simulation phase, the coefficients to be used for a particular combination of input parameters (sampled from their distributions) are uniquely determined by the quadrants into which these parameters fall.

Sensitivity/importance measures are defined and used as described in Ref. 9 to organize the individual parameters and the cross terms, respectively,
in their orders of importance. These indicators can be used to eliminate less important input parameters to focus the more detailed scheme of Fig. 2B on the important parameters.

The calculation of the mean values, standard deviations, and higher moments of a quadratic response surface, as they depend on the moments of the input parameters (Table II) and the coefficients (Eqs. 3), is described in Ref. 9.

The case of correlated input parameters is analyzed as follows. First, the parameters are divided into two classes. Class 1 is called leading parameters and it consists of \( n_1 \) mutually independent parameters \( z_j \) with given total distributions \( f_j(z_j) \), \( j = 1,2, \ldots, n_1 \). The rest of the \( n \) parameters belong to Class 2, dependent parameters. Their distributions are assumed to depend on the parameters of Class 1 only. The expected value (conditional mean value) of a Class 2 parameter depends on the actual value of a Class 1 parameter. In this work, the forms of the conditional distributions of Class 2 parameters are assumed to be independent of other parameters, but the conditional mean values are assumed to be linear functions of Class 1 parameters. This means that any parameter \( z_k \) of Class 2 can be presented as a sum

\[
z_k = z_k' + \alpha_{jk}(z_j - z_{j0})
\]

where \( \alpha_{jk} \) is a constant, \( z_j \) belongs to Class 1 and is called the leading parameter of \( z_k \), and \( z_k' \) is an independent random parameter with known distribution \( f(z_k') \). The distributions of \( z_j \) and \( z_k' \) are input for PROSA-2. In addition to these distributions, one pair of values, \( z_j \) and \( \langle z_k \rangle \), are input* so that the program can calculate the value of the coefficient \( \alpha_{jk} \) in the above equation. In the sampling phase, PROSA-2 samples \( z_k' \) and \( z_j \) from their distributions (input), and calculates \( z_k \) from the above equation with \( \alpha_{jk} \) known.

The distributions of the response surfaces (accident consequences) are obtained by Monte Carlo sampling in the form of histograms with 12 and 26 categories. No time-consuming sorting is used in calculating the histograms: a reference value is subtracted from each sample and divided by the category width to obtain the category address. The reference value and the category width are calculated internally by the code so that the user does not have to know or guess these values in advance. The code is reasonably inexpensive to run. A typical running time is 1000 simulations per second CPU-time on IBM 370/195 for a problem with six input parameters and six consequence variables.

* The conditional mean value of \( z_k \), for a given value of \( z_j \), is

\[
\langle z_k \rangle = z_{k0} + \alpha_{jk}(z_j - z_{j0})
\]
<table>
<thead>
<tr>
<th>Name of Distribution</th>
<th>Mean value</th>
<th>Variance $\sigma^2$</th>
<th>$E[z-E(z)]^3$</th>
<th>$E[z-E(z)]^4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform</td>
<td>$a+b/2$</td>
<td>$(b-a)^2/12$</td>
<td>0</td>
<td>$(b-a)^4/80$</td>
</tr>
<tr>
<td>Normal</td>
<td>$\mu$</td>
<td>$\sigma^2$</td>
<td>0</td>
<td>$3\sigma^4$</td>
</tr>
<tr>
<td>Exponential I</td>
<td>$\alpha+\beta$</td>
<td>$\beta^2$</td>
<td>$2\beta^3$</td>
<td>$9\beta^4$</td>
</tr>
<tr>
<td>Exponential II</td>
<td>$\alpha-\beta$</td>
<td>$\beta^2$</td>
<td>$-2\beta^3$</td>
<td>$9\beta^4$</td>
</tr>
<tr>
<td>Truncated Normal I</td>
<td>$\mu+\Delta^a$</td>
<td>$\sigma^2+(a-\mu)\Delta-\Delta^2$</td>
<td>Note $^b$</td>
<td>Note $^c$</td>
</tr>
<tr>
<td>Truncated Normal II</td>
<td>$\mu+\Delta^d$</td>
<td>$\sigma^2+(b-\mu)\Delta-\Delta^2$</td>
<td>Note $^e$</td>
<td>Note $^f$</td>
</tr>
<tr>
<td>Beta</td>
<td>$a+(b-a)\gamma/y\gamma n$</td>
<td>$\frac{(b-a)^2\gamma n}{(\gamma n+1)^2(\gamma n+1)}$</td>
<td>$\frac{2(b-a)^3\gamma n(n-\gamma)}{(\gamma n+1)^3(\gamma n+1)(\gamma n+2)}$</td>
<td>$\frac{3(b-a)^4\gamma n[2\gamma^2+2\gamma n+\gamma n(y+n-2)]}{(\gamma n+1)^4(\gamma n+1)(\gamma n+2)(\gamma n+3)}$</td>
</tr>
<tr>
<td>Log-normal</td>
<td>$e^{\mu+\sigma^2/2}$</td>
<td>$e^{(\sigma^2-3e^2+2)}$</td>
<td>$e^{3\sigma^2-3e^2+2}$</td>
<td>$e^{6\sigma^2-4e^3+6e^2-3}$</td>
</tr>
</tbody>
</table>

Note:

$^a \Delta = \frac{a-\mu}{\sigma^2}$

$^b E[z-E(z)]^3 = [(a-\mu)^2-\sigma^2] \Delta - 3(a-\mu)\Delta^2 + 2\Delta^3$

$^c E[z-E(z)]^4 = 3\sigma^4 + [(a-\mu)^3 + 3\sigma^2(a-\mu)] \Delta - 12\sigma^2 + 4(a-\mu)^2 \Delta^2 + 6(a-\mu)\Delta^3 - 3\Delta^4$

$^d \Delta = -\frac{b-\mu}{\sigma^2}$

$^e E[z-E(z)]^3 = [(b-\mu)^2-\sigma^2] \Delta - 3(b-\mu)\Delta^2 + 2\Delta^3$

$^f E[z-E(z)]^4 = 3\sigma^4 + [(b-\mu)^3 + 3\sigma^2(b-\mu)] \Delta - 12\sigma^2 + 4(b-\mu)^2 \Delta^2 + 6(b-\mu)\Delta^3 - 3\Delta^4$
III. ADVANCED RESPONSE-SURFACE TECHNIQUES

This chapter describes new knot-point selection schemes, response-surface functions, functional transformations, weighting of regionwise response surfaces and sampling of general analytical functions. The significance of these features is illustrated by typical examples.

A. Knot-point Selection

Two basic knot-point selection schemes were described in Chapter II. They are illustrated in Figs. 2A and 2B and are called single- and multi-quadrant knot-point selection schemes, respectively. The following options are also available:

1. Knot points with randomly selected coordinates can be used. The scheme is illustrated in Fig. 2C in a two-parameter case. For each case (knot point) to be run, new values are sampled for all input parameters.

2. The knot-point selection distributions may be completely different (in all cases of Fig. 2) from the true probability distributions of the parameters. The latter are needed, of course, in the Monte Carlo simulation part of the analysis.

The first feature allows third-degree response surfaces to be fitted to the data, whereas schemes A and B only allow up to second-degree polynomials.

The second feature allows the knot points to be selected from the region where the response surface has to be most accurate. Thus, importance distributions (which can be found as conditional distributions of the input parameters) can be used for selecting the knot points. The second feature also means that no separate weighting is necessary in the least-squares fitting of a response surface, since selecting the knot points by a distribution actually performs the weighting. Furthermore, sensitivity studies with different sampling distributions can be made without additional deterministic analyses, i.e. without changing the knot points.

B. Response Surfaces

The single- and multi-quadrant response surfaces, referred to as SQ and MQ, respectively, are obtained by the interpolation Eqs. 3. Least-squares fitting with associated error-analysis techniques provides the following features:

1. A multivariate second-degree response surface can be fitted to the systematical knot points of Fig. 2B. This surface is denoted by MQF.
2. Multivariate second- and third-degree response surfaces can be fitted to the random knot points of Fig. 2C. These surfaces are denoted as RF2 and RF3, respectively.

3. Maximum positive and negative errors as well as the mean-square error of the fitted response surfaces are calculated in the knot points. This provides a convenient means of estimating the accuracy and adequacy of response surfaces.

Not only the accuracy but also the number of knot points needed (which equals the number of deterministic accident analyses) is an important factor directly related to the cost of the analysis. Table III lists the minimum number of knot points for the response surfaces SQ, MQ, MQF, RF2, and RF3 as functions of the number n of input parameters. The number \( FC = 2^n + 2n + 1 \) is given for comparison, since it would be the number of knot points in a factorial composite design. For a third-degree response surface (RF3), the minimum number of knot points is \( 1 + 3n + 3n(n - 1)/2 + n(n - 1)(n - 2)/6 \). Equations have been derived for the moments and correlation coefficients of the third-degree response surfaces. These tedious equations are not presented here, but can be found in the program listing in Appendix A.

<table>
<thead>
<tr>
<th>n</th>
<th>SQ and RF2</th>
<th>MQ and MQF</th>
<th>RF3</th>
<th>FC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>(3)</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>13</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>25</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>41</td>
<td>35</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>28</td>
<td>85</td>
<td>84</td>
<td>77</td>
</tr>
<tr>
<td>10</td>
<td>66</td>
<td>221</td>
<td>286</td>
<td>1045</td>
</tr>
<tr>
<td>15</td>
<td>136</td>
<td>481</td>
<td>816</td>
<td>32799</td>
</tr>
</tbody>
</table>

*The acronyms n, SQ, RF2, etc., are defined in the text.*
The simplest response surfaces, SQ or RF2, are normally used when \( n \) is large. The more refined surfaces are used with small \( n \), after the less important parameters have been eliminated. Concerning the accuracy, we expect RF2 to be more accurate than SQ in the central part of the distribution, but SQ may be more accurate in the tail area. This follows from the knot-point selection schemes. As a second-degree surface, MQF cannot be much better than RF2 or SQ, but it provides conservative upper limits for the errors of MQ. MQ and RF3 should be superior to the others, since they are most flexible in predicting the true functionality of the consequence variables.

To verify the above expectations, the steady-state maximum fuel temperature and the maximum clad temperature in a reactor with cylindrical fuel elements were selected for an example. The equations for these quantities are well known\(^{12}\) and complicated enough not to reveal any linear or quadratic dependence in advance. This example has been used before in another context,\(^{13}\) and the input parameters and their distributions were taken from Ref. 13.

The mean values and higher central moments were first calculated with different response surfaces. The mean values and the variances are relatively accurate for all response surfaces, but the third and fourth moments are most accurate with MQ and RF3. The higher the moment, the more erroneous are the values generated by RF2 and SQ. These results reflect the fact that the first two moments usually depend on the central part of the distribution, where all response surfaces are relatively accurate, whereas higher moments depend on the tails, where MQ and RF3 more accurately predict the true function.

When the accuracy of the fitted surfaces was analyzed in their own knot points, the errors of RF3 were smaller by an order of magnitude than the errors of RF2 and MQF. However, the errors of both RF2 and RF3 were large in the systematical knot points of Fig. 2B, even larger than the errors of MQF. The errors of MQ are zero, of course, in the knot points of Fig. 2B.

The lower tails of the fuel-temperature distribution are presented in Fig. 3; they were obtained with different response surfaces. The remarkable accuracy of the MQ surface may be ascribed to the following features:

1. MQ is in fact a combination of many regionwise response surfaces and therefore flexible to fit to the data.
2. The knot points for MQ emphasize the tail areas of the distributions.
3. One or two parameters often explain most of the variation; three-parameter interaction terms are seldom important.

The random knot points for RF2 and RF3 could also be selected from a wider distribution, thereby making these surfaces more accurate in the tail areas.
What can be said about the theoretical accuracy of MQ as compared with that of the fitted surface MQF? The latter can be estimated from the residual errors of the least-squares fit. It seems that the theory is readily available only for a one-dimensional (one parameter) case and requires an estimate for the third derivative of $c$ in the interpolation interval. It can be shown, for example, that if $c$ is a third-degree polynomial around the reference point and $\epsilon$ is the third-degree term, then the maximum error of MQF is 0.25 $||\epsilon||$ and that of MQ is 0.05 $||\epsilon||$, where $||\epsilon||$ is the maximum absolute value of $\epsilon$ in the interval. (Equally spaced knot points are assumed in this case.)

C. Functional Transformations

The accuracy of a response surface depends on the higher order derivatives of the consequence variable with respect to the input parameters. The accuracy can be improved by making functional transformations to the consequence and/or input variables such that the new consequence as a function of the new input variables is smooth and can be represented by low-degree polynomials. Thus, the purpose of making transformations is to be able to use a response surface of a simple polynomial form in the transformed variables, rather than a more complicated function in the original variables. Table IV illustrates the efficiency of logarithmic and product transformations in estimating the time of pin failure, $T$, and the peak power in case of a reactivity transient in the Fast Flux Test Facility. The ramp rates of 5, 20 and 100 cents/s were selected as knot points for this one-parameter case. The
accuracy of different approximations at ramp rates of 10, 50 and 300 cents/s can be compared in Table IV. It can be shown, for example, that \( \ln(T) \) is an almost linear function of \( \ln(R) \).

Table IV. Quadratic Approximation of the Transient Overpower Accident

<table>
<thead>
<tr>
<th>Reactivity Ramp Rate R (cents/s)</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>100</th>
<th>300</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \ln(R) )</td>
<td>1.6094</td>
<td>2.3026</td>
<td>2.9957</td>
<td>3.9120</td>
<td>4.6052</td>
<td>5.7038</td>
</tr>
<tr>
<td>Time to Failure, T(s)</td>
<td>18.9090</td>
<td>9.9090</td>
<td>5.7000</td>
<td>2.6955</td>
<td>1.5460</td>
<td>0.6180</td>
</tr>
<tr>
<td>- Quadratic Approximation of T in ( \ln(R) )</td>
<td>18.9090</td>
<td>11.1899</td>
<td>5.7000</td>
<td>1.8621</td>
<td>1.5460</td>
<td>5.6099</td>
</tr>
<tr>
<td>- Quadratic Approximation of RT divided by R</td>
<td>18.9090</td>
<td>10.2492</td>
<td>5.7000</td>
<td>2.6936</td>
<td>1.5460</td>
<td>0.6439</td>
</tr>
<tr>
<td>Peak Power (MW) at T</td>
<td>1069</td>
<td>1121</td>
<td>1373</td>
<td>2040</td>
<td>3396</td>
<td>5807</td>
</tr>
<tr>
<td>- Quadratic Approximation in ( \ln(R) )</td>
<td>1069</td>
<td>1055</td>
<td>1373</td>
<td>2305</td>
<td>3396</td>
<td>5807</td>
</tr>
<tr>
<td>- Quadratic Approximation in R</td>
<td>1069</td>
<td>1168</td>
<td>1373</td>
<td>2052</td>
<td>3396</td>
<td>1413</td>
</tr>
</tbody>
</table>

*Time T and Peak Power obtained from Hanford Engineering Development Laboratory Report HEDL-TME 75-50, Table VII.2 (1975).

This example illustrates that a flexible set of functional transformations is a necessity for efficient response-surface techniques. The following transformations are available and can be input-specified to the PROSA-2 code:

1. \( y = (x - a)^b \), \( b \neq 0 \);
2. \( y = \ln(x - a) \), \( x > a \);
3. \( y = \exp \frac{x - a}{b} \), \( b \neq 0 \);  

(5)
4. \( y = \arctan \frac{x - a}{b} \), \( b \neq 0 \);

5. \( y = \frac{x - a}{x - b} \), \( a \neq b \);

where \( x \) is the original parameter or consequence and \( y \) is the transformed parameter or consequence.

The constants \( a \) and \( b \) of the transformations should be selected such that the residual errors of the consequences are minimized or reduced to a satisfactory level. It should be noticed that only the surface-fitting part of the code is needed when searching for optimal transformations: no additional accident simulations or Monte Carlo calculations are needed. The residual errors of each trial appear on the output. Because of the low cost of running the code, this searching process is economically feasible.

Transformations have been applied to the fuel-temperature problem used in Fig. 3. The maximum positive and negative errors of the fitted response surface MQF of the maximum fuel temperature without any transformations are +29.2°C and -65.1°C. With the logarithmic transformation shown in item 2 of Eqs. 5 for the fuel temperature, the errors are +11.0°C and -39.8°C. With the exponential transformation shown in item 3 for the fuel thermal conductivity, the errors are +11.1°C and -36.2°C, respectively. When both transformations are combined, the errors are only +3.4°C and -18.2°C, respectively. These errors are small compared to the standard deviation of 160°C from the mean value of 190°C for the maximum fuel temperature.

When the probability distributions (histograms) are calculated for transformed variables, the code also performs inverse transformations for the category boundaries so that the histogram is also available in terms of the original variables.

D. Weighting Regionwise Response Surface

The regionwise response surfaces MQ, associated with Fig. 2B, are multivariate second-degree polynomials with coefficients different in different regions ("quadrants") of the parameter space. The response surface is continuous at the region boundaries, but the derivatives may be discontinuous. To make the derivatives also continuous and to improve accuracy, a weighting method has been developed that makes the resultant surface a smooth synthesis of the regionwise surfaces. The same purpose could be achieved by using so-called spline functions for functions of one variable, but the theory of splines is not yet well developed for functions of many variables.

With weighting, the coefficients of the quadratic response-surface Eq. 2 are not regionwise constants, but continuous functions of the input
parameters $z_j$. For example, the linear-term coefficients $B_j$ of the resultant surface are

$$B_j = \left[ W_{j4}(z_j)B_{j4} + W_{j0}(z_j)B_{j0} + W_{j3}(z_j)B_{j3} \right] / (W_{j4} + W_{j0} + W_{j3}), \tag{6}$$

where $B_{j4}$ is obtained from data in the knot points $z_{j2}, z_{j4}, z_{j0}$ of Fig. 2B, $B_{j0}$ in the knot points $z_{j4}, z_{j0}, z_{j3},$ and $B_{j3}$ in the knot-points $z_{j0}, z_{j3}, z_{j1},$ using equations similar to Eqs. 3, and

$$W_{jr} = \exp \left[ -(z_j - z_{jr})^2 / (2R_j^2) \right], \quad r = 0, 3, 4,$$

$$R_j = \rho(z_{j1} - z_{j2}) / 2. \tag{7}$$

A similar weighting principle is used for the $C_j$ and $D_{jk}$ coefficients. Details can be found in the program listing, Appendix A.

The user-specified parameter $\rho$ in Eq. 7 determines how far the effect of each regionwise coefficient extends. Studies with third-degree surfaces have indicated the optimal value for $\rho$ is about 0.33. With $\rho = 0.33$, the maximum error of the synthesis response surface is one third of the maximum error of the individual regionwise surfaces (which in turn are, by a factor of 5, more accurate than MQF, as indicated in Sec. IIIB). In general, the optimal value of $\rho$ depends on the form of the actual surface. Numerical studies indicate that values between 0.3 and 0.4 generally improve the accuracy. Smaller values do not perform efficient smoothing, and larger values destroy the flexibility by averaging too much. Use of the weighting routine increases the computer running time by about 30 percent.

Transformations reported in the previous section may be used with any response surface. With MQF, after a good transformation has been found, final refinement of the response surface can be made by weighting MQ. Figure 4 illustrates the effect of weighting on the distribution of the reactor power in the loss-of-flow accident studied in Ref. 6. The weighted response surface is denoted by MQW. An effective transformation would bring all the distributions of Fig. 4 close to each other.
E. Function Sampling

If the interesting output variables ("consequences" in our terminology) are known as analytical functions of the independent variables ("input parameters"), they can be programmed directly into a subroutine of PROSA-2 and used as such in Monte Carlo sampling. In this case, no external deterministic calculations (or response-surface fittings) are needed. The values are calculated in every simulation cycle directly from the equations without any response surfaces. The distributions so obtained are exact, in principle, the accuracy being determined by the sample size only. This feature is useful in safety areas such as reliability analysis, where interesting quantities are known in analytical form.

This technique was applied to obtain the exact distribution in Fig. 3. As another example, the unavailability of the sample fault tree of Ref. 16 was analyzed, essentially duplicating the results. Different failure classes (single component failures, double component failures, test and maintenance errors, common mode failures and system failures) can be analyzed simultaneously. The computer running time in this case was 10 s for 10,000 simulations (IBM 370/195). Compared to the SAMPLE program used in Ref. 16, PROSA-2 has a different selection of input distributions; it can handle partially correlated input parameters and forms the histograms without comparative sorting.
F. Random Criteria for Conditional Distributions

In certain cases, interesting consequences (e.g. failures) appear only when some criterion function exceeds a critical value. A procedure for calculating conditional distributions under such criteria is available and has been extended to more general problems in which the criteria values (conditions) are random variables. The importance of this feature can be illustrated by an example from structural mechanics. Even if a structure, e.g., a primary vessel, is designed for a specific load, the actual strength of the structure is a random variable. When evaluating failure probabilities and distributions of other consequences such as the amount of leakage when failure occurs, we must treat not only the loads but also the failure criteria as random variables. The PROSA-2 code does this automatically in every simulation cycle, sampling the value of a criterion from a user-specified distribution. Studies of this kind are important for evaluating the margin of safety or the degree of conservatism in structural-design guides. Current analytical stress-strength interference techniques are based on the evaluation of the overlapping of the unconditional stress and strength distributions. They only address the question of failure probability, and not the concurrent distributions of third variables, such as the amount of leakage.
IV. USER'S MANUAL

A. Program Summary

The program performs the following three main functions:

1. The program selects values for the input parameters of a deterministic computer code from an input-specified region 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 determines response surfaces approximating the functionality between the input and output of the deterministic code.

3. The program calculates the probability distribution of the output (consequence) variable as a histogram, using Monte Carlo sampling.

The options and special features available for each of these steps are described below in the Program Abstract. The first step can be omitted if the user wants to use his own design of knot points. Both first and second steps can be omitted if a known analytical function is to be sampled in Step 3.

The 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: PROSA-2

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

3. Description of Problem: The problem is to find the distribution of a random variable that is a function of many other random variables when this functionality is not known in analytical form and can be obtained only numerically through parametric studies with a deterministic computer code. The steps mentioned in the Program Summary are needed to solve this problem. A simpler problem of sampling a known analytical function can be solved by using the third step alone.
4. **Method of Solution:** As input data, the program needs the probability distributions of the input parameters of a deterministic code (for which a response surface is being searched). The first part of the program calculates knot-point coordinates. These 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 PROSA-2 to solve (1) global or regionwise response surfaces by using least-squares fitting or generalized Lagrange interpolation, (2) the errors of the fitted response surfaces, (3) the sensitivity/importance of each input parameter, (4) statistical moments of the input parameters and those of the consequences, and (5) the correlation coefficients between the consequences. By using random sampling of the input parameters and simulation with the response surface, the program calculates (6) the probability distributions as histograms, (7) sample moments of the consequence distributions, (8) joint distributions, and (9) the statistical-error estimates for the histograms. The distributions are obtained in the form of histogram tables with 12 categories and plots in 26 categories. The joint distributions have 12 x 12 = 144 categories. The width of each category is a user-specified fraction of the standard deviations of the consequences.

The program includes a technique for handling nonindependent (correlated) input parameters. Conditional distributions can also be calculated. Up to four simultaneous criteria or conditions can be specified for the consequences. By defining one or more input parameters to be consequences as well, the code can be used for calculating optimal importance distributions for the input parameters.

5. **Restrictions on the Complexity of the Problem:** The maximum number of variable input parameters and consequence variables that can be analyzed simultaneously are 12 and 6, respectively. Eight different distributions are available for the input parameters, including uniform, exponential, normal, truncated normal, log normal, and beta distributions. The correlations (if any) between the input parameters are limited to linear correlations.

For fitting second-degree response surfaces, the number of randomly selected knot points should be specified to be at least \((n + 1)(n + 2)/2\), where \(n\) is the number of input parameters. For third-degree surfaces the limit is \((n + 1)(n + 2)(n + 3)/6\).

6. **Typical Running Time:** Typical running time for six input parameters and six consequence variables is 60 s for 40,000 simulations (IBM 370/195).

7. **Unusual Features of the Program:** The program includes a weighting scheme that generates a smooth global response surface from regionwise response surfaces. A family of functional transformations is available for both input and output (consequence) variables so that essentially
nonpolynomial response surfaces can be generated and used. Optimal transformations can be searched due to the error estimation routines of the program. Both systematically and randomly selected knot points can be used. Least-squares fitting and generalized Lagrange interpolation can be used to find the coefficients of a response surface. Conditional distributions with random conditions can be calculated.

8. Related and Auxiliary Programs: The PROSA-2 code is an advanced version of an earlier documented code PROSA-1. Both codes are used in conjunction with a separate deterministic code (typically an accident-analysis code) that provides data for the response-surface techniques.

9. Status: PROSA-2 is operational at ANL and has been released to the National Energy Software Center (NESC). PROSA-1 is also available in the NESC.

10. References: References 8, 9, and 10.

11. Machine Requirements: IBM 370/195; Card Read/Punch; Line Printer.

12. Programming Language Used: FORTRAN IV.

13. Operating System: IBM System/370 Model 195; FORTRAN IV (G) or (H) compiler with optimizer.

14. Other Programming or Operating Information or Restrictions:

a. The program contains a few FORMAT statements in the T format code as well as ERR= and END= operatives in a READ statement. These are IBM extensions to AMS FORTRAN.

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

$$U = \text{FLTRNF}(0)$$

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 PROSA code.

c. Fixed dimensions can not be used for the arrays (vectors and matrices) used in the least-squares fitting equations, because their size is determined by the number of parameters and the number of output (consequence) variables in each job. Therefore, space in the computer for these arrays is organized using dynamic allocation. The main program of PROSA-2 calls an ANL library subroutine ALLOC2 that allocates correct space for all the arrays that may vary from job to job.

15. Name and Establishment of the Author: J. K. Vaurio, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439.
16. **Material Available:** Source decks, sample problem, job-control cards, and documentation.

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

18. **Keywords:** Accident analysis, Approximation, Distribution, Experimental design, Histogram, Joint distribution, Moments, Monte Carlo, Probabilistic, Random sampling, Response surface, Risk, Safety, Sampling, Sensitivity, Simulation, Transformation.

C. **Program Use**

PHOSA-2 can be directed to perform 18 different tasks. The task to be executed is specified by the input variable JOBI. The tasks are described in Sec. IV.C.1. The input for each task is specified in Sec. IV.C.2. The flow diagram of the program is presented in Sec. IV.C.3, and the function of each subroutine is briefly described in Sec. IV.C.4.

1. **Task Descriptions**

   Each execution of the program performs one of the following tasks, specified by the input variable JOBI. After each task, the program control returns to the beginning and a new job starts (if not stopped by End-Of-File).

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

   (1) Calculates and prints the systematical knot-point coordinates of the parameters.

   (2) Prints and punches the systematical knot points.

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

   (4) If TEST = 1, calculates "consequences" in the knot points using test subroutine TEXAS, and prints and punches these consequences. This consequence output can serve as input in later tasks for testing purposes.

   (5) If NRANKP > 0, calculates also NRANKP knot points by randomly sampling the values of the parameters from their distributions, and prints and punches these knot points. These knot points can be used as alternatives (or additions) to the systematical knot points selected in step 1.

   **Task 2 (JOBI = 2) Moments and Coefficients**

   Task 2 can be used only with the systematical knot points of Figs. 2A and 2B.
(1) Calculates and prints the systematical knot-point coordinates of the parameters (same as 1 of Task 2).

(2) Calculates, organizes, and prints sensitivity/importance measures of the parameters with respect to the consequences.

(3) Calculates and prints the coefficients of the single- or multi-quadrant response surfaces, moments and correlation coefficients of the parameters, and analytical moments and correlation coefficients of the response-surface consequences.

(4) If a regionwise (multiquadrant) response surface is used \( (\text{NQUAD} = 4) \) and there are less than nine parameters in the problem \( (\text{NPARA} < 9) \), then a second-degree surface is fitted to the systematical knot points. Otherwise, Step 5 is done and Task 2 ends there.

**NOTE:** When regionwise ("multiquadrant") response surfaces are used \( (\text{NQUAD} = 4) \), separate coefficients are obtained for each region ("quadrant"), but the analytical moments of the consequences are for the "overall" response surface.

(5) Sketches single- and multiquadrant response surfaces versus parameters.

(6) Prints coefficients of the fitted response surface, calculates and prints errors of the surface in the knot points, the maximum positive and negative errors, average error, the reference value, and the fractional error (average error/ref. value).

(7) Calculates and prints analytical moments and correlation coefficients of the fitted response-surface consequences, and sketches the surfaces versus parameters.

**Task 3 (JOB1 = 3): Distributions**

Task 3 can be used only with the systematical knot points of Figs. 2A and 2B.

(1) Performs steps 1-5 of Task 2.

(2) Defines 12 consequence categories for each consequence, six on each side of the analytical mean value obtained in Task 2. The width of each category is a user-specified fraction (input variable SCALE) of the analytical standard deviation of the consequence.

(3) Samples values for each parameter from its distribution, calculates values of the consequences in these sample points using the
response surfaces, and forms the histograms and joint-histograms of the consequences.

(4) Calculates the sample moments of the consequences (up to the fourth order) and the statistical-error estimates of the histogram-category probabilities.

(5) Prints the above moments, consequence-category limits, histograms, probability estimates, and error estimates, and sketches the distributions in half-category intervals.

(6) If fitted response surfaces are calculated (i.e. if \( \text{NPARA} < 9 \) and \( \text{NQUAD} = 4 \)), performs steps 6 and 7 of Task 2 and repeats steps 2–5 of Task 2 with the fitted response surfaces.

**Task 4 (\( \text{JOBI} = 4 \)) Conditional Distributions**

Task 4 can be used only with the systematical knot points of Figs. 2A and 2B.

(1) Performs steps 1–5 of Task 3.

(2) Calculates and prints the conditional distributions, conditional joint distributions, and conditional sample moments of the response-surface consequences (the condition being the criterion specified in the input for Task 4). The criteria limits may be fixed constants or random variables with input-specified distributions.

(3) Calculates and edits the fractions satisfying unrelieved (original) and relieved (see Note 2 below) criteria.

(4) If input variable \( \text{NSC} > 0 \), Task 4 punches (also prints if \( \text{TEST} = 4 \)) sampled parameter combinations that satisfy relieved criteria (see Note 2). Make \( \text{NSC} > 0 \) only if Task 5 will be used.

(5) If fitted response surfaces are calculated (i.e. if \( \text{NPARA} < 9 \) and \( \text{NQUAD} = 4 \)), performs step 6 of Task 3 and repeats steps 2–3 with the fitted surfaces.

**Note 1:** The category widths are the same as in Task 3, but the category limits may be shifted for conditional distributions.

**Note 2:** "Relieved criteria" here refer to the conditions for the conditional distributions [e.g., \( p(\xi | C > C_{cr} - \text{TOLE} \cdot q_{c}) \), where \( \xi \) is the consequence and \( C > C_{cr} \) is the unrelieved criterion] that are changed
(relieved) by an input-specified fraction TOLE of the analytical standard deviation of the consequence. TOLE can be used to study the sensitivity of conditional probabilities to the criteria.

Task 5 (JOBI = 5): Difference Distributions

Task 5 is provided to test the quality of the conditional distributions obtained in Task 4 using the response-surface consequences. It is presumed that the parameter combinations punched in Task 4 are input for the deterministic code and the consequence values so obtained are input for Task 5. These consequences are called "real consequences."

(1) Calculates and edits the conditional distributions of the real consequences.

(2) Calculates and edits the distributions of the differences between the real consequences and the response-surface consequences.

Note 1: If TEST = 5, the real consequences are calculated in the test-subroutine TEXAS, rather than input.

Note 2: The width of each difference category is TOLE/2 times the analytical standard deviation of the consequence.

Tasks 7 and 8 (JOBI = 7, 8): Sampling Distributions

Tasks 7 and 8 are provided to allow the user to use sampling distributions for the parameters different from those distributions used to select the knot points. Thus, Tasks 7 and 8 perform essentially the same steps as Tasks 3 and 4, respectively, but the sampling distributions for these tasks are input separately and are generally different from those used in Task 1.

Task 7 (JOBI = 7)

(1) Performs steps 1-6 of Task 2.

(2) Redefines the parameter distributions for sampling.

(3) Performs steps 2-6 of Task 3.

Task 8 (JOBI = 8)

(1) Performs all steps of Task 7.

(2) Performs steps 2-5 of Task 4.
Tasks 12-18: Quadratic Surfaces and Random Knot Points

These tasks use randomly selected knot points (Fig. 2C) generated by Task 1 with \( NRANKP > 0 \) or provided by the user. Tasks 12-18 perform essentially the same steps as Tasks 2-8, respectively, but use a second-degree polynomial response surface fitted to the random knot points.

If the input variable TEST is set equal to the Task number (JOBI), i.e. \( TES = 12-18 \), then the consequence values are calculated in subroutine TEXAS and no external deterministic code is needed.

Tasks 12 (JOBI = 12)

1. Calculates and prints systematical knot-point coordinates of the parameters (not used in this case).
2. Reads and prints consequences in random knot points.
3. Reads and prints random knot-point input.
4. Fits its second-degree response surfaces to random knot points. Prints coefficients of the fitted response surfaces, approximate and exact values and errors in knot points, maximum, minimum, and mean square of these errors and the fractional error (ratio of mean square error to reference value).
5. Calculates and prints sensitivity/importance measures of the parameters with respect to the consequences, moments and correlation coefficients of the parameters, and analytical moments and correlation coefficients of the fitted response consequences.

Task 13 (JOBI = 13): Distributions

1. Performs all steps of Task 12.
2. Performs steps 2-5 of Task 3.

Task 14: Conditional Distributions

1. Performs all steps of Task 13.
2. Performs steps 2-4 of Task 4.
Task 17

(1) Performs all steps of Task 12.

(2) Redefines the characteristics of the distributions of the parameters according to the second set of parameter input to be used in the sampling phase.

Task 18

(1) Performs all steps of Task 17.

(2) Performs steps 2-4 of Task 4. Redefinition of parameter distributions is also used in conditional sampling.

Tasks 22-28: Cubic Surfaces and Random Knot Points

These tasks fit a third-degree response surface to knot points chosen randomly from the parameter distributions. These "random knot points" (Fig. 2C) are calculated and punched by Task 1 with NRANKP > 0. A separate consequence-analysis code calculates the consequences in these knot points.

If the input variable TEST is set equal to the Task number (JOBI), i.e. TEST = 22-28, then the consequence values are calculated in subroutine TEXAS and no external deterministic code is needed. For Tasks 22 through 28 (third-degree fitted surface), the maximum number of variable input parameters is six.

Task 22 (JOBI = 22)

(1) Performs the same steps as Task 12, but using third-degree response surfaces.

Task 23 (JOBI = 23)

(1) Performs Task 22.

(2) Performs steps 2-5 of Task 3.

Task 24 (JOBI = 24)

(1) Performs Task 23.

(2) Performs steps 2-4 of Task 4.

Task 27 (JOBI = 27)

(1) Performs all steps of Task 22.
(2) Redefines the characteristics of the parameter distributions according to the second sec of parameter input; the redefined characteristics are to be used in the sampling phase.

(3) Performs steps 2-5 of Task 3.

Task 28 (JOBI = 28)

(1) Performs all steps of Task 27.

(2) Performs steps 2-4 of Task 4. Redefinition of parameter distributions is also used in conditional sampling.

Task 30

Task 30 is applied when the consequences are known in analytical form. In Task 30, the input variable TEST is set to 30, and JOBI can be 2, 3, 4, or 5. In this mode, the program performs the task indicated by JOBI, as above, but all the consequence values are calculated from equations in subroutine TEXAS.

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>NPARA</td>
<td>1-2</td>
<td>I2</td>
<td>Number of input parameters (&lt; 12).</td>
</tr>
<tr>
<td>LMPAIR</td>
<td>3-4</td>
<td>I2</td>
<td>Indicator to limit interaction terms in quadratic response surfaces (in Tasks 1 to 8, with NQUAD = 1); LMPAIR = 0, no limitation; LMPAIR = 1, pairs limited.</td>
</tr>
<tr>
<td>JOBI</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 knot-point coordinates (&lt; 0.4).</td>
</tr>
<tr>
<td>NCONS</td>
<td>17-19</td>
<td>I3</td>
<td>Number of consequence variables (&lt; 6).</td>
</tr>
<tr>
<td>NSA</td>
<td>21-27</td>
<td>I8</td>
<td>Number of sampling cycles.</td>
</tr>
<tr>
<td>SCALE</td>
<td>28-33</td>
<td>F6.2</td>
<td>Histogram category width (as a fraction of standard deviation). Recommended value 0.5 to 1.0.</td>
</tr>
<tr>
<td>Variable</td>
<td>Columns</td>
<td>Format</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>TEST</td>
<td>34-36</td>
<td>13</td>
<td>Control variable for testing, using subroutine TEXAS (TEST = 0, 1, ..., 30).</td>
</tr>
<tr>
<td>WORK</td>
<td>37-42</td>
<td>16</td>
<td>Work number.</td>
</tr>
<tr>
<td>NCORR</td>
<td>43-47</td>
<td>15</td>
<td>Number of correlations between the input parameters.</td>
</tr>
<tr>
<td>NQUAD</td>
<td>48-52</td>
<td>15</td>
<td>Response-surface option in Tasks 1 to 8: = 1, single quadratic surface = 4, regionwise &quot;multiquadrant&quot; surfaces. Use NQUAD = 1 for Tasks &gt; 8.</td>
</tr>
<tr>
<td>NRANKP</td>
<td>53-57</td>
<td>15</td>
<td>Number of random knot points in Tasks 1, 12 through 28.</td>
</tr>
<tr>
<td>NOFIT</td>
<td>58-60</td>
<td>13</td>
<td>Controls fitting a quadratic surface to all systematic knot points when NQUAD = 4; = 1, no least-squares fittings; = 0, fitted surface also used.</td>
</tr>
<tr>
<td>RANGE</td>
<td>61-65</td>
<td>F5.2</td>
<td>Range parameter for weighting regionwise surfaces when NQUAD = 4 (p in Eq. 7). Recommended value RANGE = 0.3 to 0.35. If RANGE = 0, no weighting is used.</td>
</tr>
<tr>
<td>NTRAPA</td>
<td>66-70</td>
<td>15</td>
<td>Number of input parameters subject to functional transformations (NTRAPA &lt; NPARA).</td>
</tr>
<tr>
<td>NTRACO</td>
<td>71-75</td>
<td>15</td>
<td>Number of consequence variables subject to functional transformations (NTRACO &lt; NCONS).</td>
</tr>
</tbody>
</table>

Note: NCONS, NSA, SCALE, NOFIT, RANGE, NTRAPA and NTRACO are not used in Task 1 (JOBI = 1). NSA, SCALE and RANGE are not used in Tasks 2, 12 and 22.
### Variable Formats

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>1-2</td>
<td>I2</td>
<td>Parameter number (1, 2, ..., 12).</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 ( \leq ) JDIS ( \leq ) 8).</td>
</tr>
<tr>
<td>ADIS</td>
<td>12-22</td>
<td>F11.5</td>
<td>First distribution parameter.</td>
</tr>
<tr>
<td>BDIS</td>
<td>23-33</td>
<td>F11.5</td>
<td>Second distribution parameter.</td>
</tr>
<tr>
<td>CDIS</td>
<td>34-44</td>
<td>F11.5</td>
<td>Third distribution parameter.</td>
</tr>
<tr>
<td>DDIS</td>
<td>45-55</td>
<td>F11.5</td>
<td>Fourth distribution parameter.</td>
</tr>
<tr>
<td>JJK (12)</td>
<td>57-68</td>
<td>12I2</td>
<td>Used when LMPAIR = 1 to indicate the pairs of parameter K to be taken into account in the cross terms of the response surface.</td>
</tr>
</tbody>
</table>

### Note:

The distributions and parameters available 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>
</tbody>
</table>
For distributions 5 and 6 the mean value and standard deviation are those for the untruncated normal distribution. For distribution 8, the mean value and standard deviation are those of the logarithm of the parameter. The mathematical expressions for these distributions are given in Table I.

<table>
<thead>
<tr>
<th>JDIS</th>
<th>ADIS</th>
<th>BDIS</th>
<th>CDIS</th>
<th>DDIS</th>
</tr>
</thead>
<tbody>
<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>Lower 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>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITYPE</td>
<td>1-5 E15</td>
<td>Correlation type; not in use.</td>
</tr>
<tr>
<td>ILLAD</td>
<td>6-10 I15</td>
<td>Number (K) of a leading parameter.</td>
</tr>
<tr>
<td>FLEAD</td>
<td>11-25 E15.6</td>
<td>A value of the leading parameter (other than mean value).</td>
</tr>
<tr>
<td>IDEP</td>
<td>26-30 I15</td>
<td>Number (K) of a dependent parameter.</td>
</tr>
<tr>
<td>FDEP</td>
<td>31-45 E15.6</td>
<td>Expected value of the dependent parameter when the leading parameter has the value FLEAD.</td>
</tr>
</tbody>
</table>

Note 1: The order of the parameters must satisfy ILEAD < IDEP.
Note 2: Several dependent parameters may have a common leading parameter; not more than one leading parameter may be assigned for any dependent parameter.

Next NTRAPA Cards
(if NTRAPA > 0)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>JTRA</td>
<td>1-5</td>
<td>I5</td>
<td>Number of the parameter to be transformed (JTRA = 1, 2, ..., NPARA).</td>
</tr>
<tr>
<td>JTYPE</td>
<td>6-10</td>
<td>I5</td>
<td>Transformation type (JTYPE = 1, 2, 3, 4, 5).</td>
</tr>
<tr>
<td>APA</td>
<td>11-25</td>
<td>E15.6</td>
<td>First transformation parameter.</td>
</tr>
<tr>
<td>BPA</td>
<td>26-40</td>
<td>E15.6</td>
<td>Second transformation parameter.</td>
</tr>
</tbody>
</table>

Note: The transformations available for the parameters are as follows:

<table>
<thead>
<tr>
<th>JTYPE</th>
<th>Transformation$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X = (Z - APA) ** BPA</td>
</tr>
<tr>
<td>2</td>
<td>X = LOG(Z - APA)</td>
</tr>
<tr>
<td>3</td>
<td>X = EXP[(Z - APA)/BPA]</td>
</tr>
<tr>
<td>4</td>
<td>X = ATAN[(Z - APA)/BPA]</td>
</tr>
<tr>
<td>5</td>
<td>X = (Z - APA)/(Z - BPA)</td>
</tr>
</tbody>
</table>

$^a$Z is the original (input) parameter, X is the transformed parameter used internally by the program.
### Next NTRACO Cards
(if NTRACO > 0)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTRA</td>
<td>1-5</td>
<td>15</td>
<td>Number of the parameter to be transformed (LTRA = 1, 2, ..., NCONS).</td>
</tr>
<tr>
<td>LTYPE</td>
<td>6-10</td>
<td>15</td>
<td>Transformation type (LTYPE = 1, 2, 3, 4, 5).</td>
</tr>
<tr>
<td>ACO</td>
<td>11-25</td>
<td>E15.6</td>
<td>First transformation parameter.</td>
</tr>
<tr>
<td>BCO</td>
<td>26-40</td>
<td>E15.6</td>
<td>Second transformation parameter.</td>
</tr>
</tbody>
</table>

**Note:** The transformations available for the parameters are as follows:

<table>
<thead>
<tr>
<th>JTYPE</th>
<th>Transformation&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( Y = (C - ACO)^2 \times BPA )</td>
</tr>
<tr>
<td>2</td>
<td>( Y = \log(C - ACO) )</td>
</tr>
<tr>
<td>3</td>
<td>( Y = \exp[(C - ACO)/BCO] )</td>
</tr>
<tr>
<td>4</td>
<td>( Y = \tan[(C - ACO)/BCO] )</td>
</tr>
</tbody>
</table>

<sup>a</sup>C is the original (input) consequence variable, \( Y \) is the transformed consequence used internally by the program.

### Consequence Cards

The consequences in the knot points have to be input for all Tasks > 1 (JOBI > 1), unless they are calculated in subroutine TEXAS for testing purposes (TEST > 0). The consequences are normally calculated by a separate accident-analysis code outside PROSA-2.
The format of the knot-point consequence cards depends on the knot-point scheme and task as follows:

**Consequence Cards for Task 2 through 8 (1 < JOBI < 9)**

The first six columns (INDEX, variables J and K) are copied directly from the knot-point coordinate cards produced by Task 1 (JOBI = 1) without any manipulation.

The last consequence card should be followed by a card with -1 in columns 1-2. (This indicates the end of the consequence cards.)

<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>Indicates the location of the knot point with respect to the mean value(s) of parameter(s) J (and K).</td>
</tr>
<tr>
<td>J</td>
<td>3-4</td>
<td>I2</td>
<td>Parameter number (1 &lt; J &lt; NPARA).</td>
</tr>
<tr>
<td>K</td>
<td>5-6</td>
<td>I2</td>
<td>Parameter number (J &lt; K &lt; NPARA), ≠ 0 only for cross terms, i.e., when INDEX &gt; 10.</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 specified by INDEX, J, K.</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>.</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>

**Note:** Relevant values of INDEX are
NQUAD = 1: 0, 1, 2, 11
NQUAD = 4: 0, 1, 2, 3, 4, 11, 22, 33, 44.

**Consequence Cards for Task's 12 through 28 (11 < JOBI < 29)**

The first two columns of these NRANKP cards contain number 50 (INDEX = 50), indicating that randomly selected knot-point coordinates are used. The first six columns are normally copied directly from the random knot-point cards produced by Task 1 (JOBI = 1) without changes.
<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>Indicates the type of the knot points (INDEX = 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>E12.6</td>
<td></td>
<td>The last consequence variable</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(maximum NCONS = 6).</td>
</tr>
</tbody>
</table>

**Consequence Cards for Task 30**

No consequence cards are needed in Task 30, since the consequences are calculated by subroutine TEXAS (defined by the user). The control variable TEST has to be set TEST = 30 on the first input card, and JOBI = 2, 3, 4 or 5, depending on the tasks and output requested. Task 30 is provided for sampling known analytical functions that are not necessarily polynomials.

**Random Knot-point Coordinates for Tasks 12-28**

NRANKP sets of random knot-point coordinates that were used to obtain the consequences have to be input here for Tasks 12-28 (when 11 < JOBI < 29). These coordinates would normally be produced by Task 1. (However, the user could have selected his own design since the code does not care in Tasks 12-28 how those coordinates were chosen.)

<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>Indicates the type of the knot points (INDEX = 50).</td>
</tr>
<tr>
<td>KNOT</td>
<td>3-6</td>
<td>I4</td>
<td>Knot-point number (KNOT = 1, 2, ..., NRANKP).</td>
</tr>
</tbody>
</table>
Variable Columns Format Description
Z(1) 9-20 E12.6 Value of parameter 1 in knot-point KNOT.
Z(2) 21-32 E12.6 Value of parameter 2.
Z(NPARA) E12.6 Value of parameter NPARA.

This information specifies one knot point. It consists of one card if NPARA ≤ 6 or two cards if NPARA > 6. Thus, the total input here is NRANKP cards or 2 NRANKP cards depending on NPARA.

Sampling Distributions for Tasks 7, 8, 17, 18, 27 and 28

These NPARA cards define distributions of the parameters, to be used in sampling when calculating the histograms. These distributions may be different from those used in selecting the systematical knot-point coordinates in Task 1.

Variable Columns Format Description
K 1-2 I2 Parameter number (1, 2, ..., 12).
NAME 4-9 A6 Parameter name.
JDIS 10-11 I2 Parameter-distribution indicator (1 ≤ JDIS ≤ 8).
ADIS 12-22 F11.5 First distribution parameter.
BDIS 23-33 F11.5 Second distribution parameter.
CDIS 34-44 F11.5 Third distribution parameter.
DDIS 45-55 F11.5 Fourth distribution parameter.
JJK(12) 57-68 I212 Used when LMPAIR = 1 to indicate the pairs of parameter K to be taken into account in the cross terms of the response surface.

Note: The distributions and parameters available are as follows:
### JDIS ADIS BDIS CDIS DDIS

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Uniform</td>
<td>Upper limit</td>
<td>Lower limit</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Normal</td>
<td>Mean value</td>
<td>Standard deviation</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Exponential I</td>
<td>Lower limit</td>
<td>Scale constant</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Exponential II</td>
<td>Upper limit</td>
<td>Scale constant</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Truncated normal I</td>
<td>Mean value</td>
<td>Standard deviation</td>
<td>Lower limit</td>
</tr>
<tr>
<td>6</td>
<td>Truncated normal II</td>
<td>Mean value</td>
<td>Standard deviation</td>
<td>Upper limit</td>
</tr>
<tr>
<td>7</td>
<td>Beta</td>
<td>Lower limit</td>
<td>Upper limit</td>
<td>Mean value</td>
</tr>
<tr>
<td>8</td>
<td>Log-normal</td>
<td>Mean value</td>
<td>Standard deviation</td>
<td>-</td>
</tr>
</tbody>
</table>

For distributions 5 and 6, the mean value and standard deviation are those for the untruncated normal distribution. For distribution 8, the mean value and standard deviation are those of the logarithm of the parameter. The mathematical expressions for these distributions are given in Table I.

---

**Next NCORR Cards for Tasks 7, 8, 17, 18, 27, and 28**

(if NCORR > 0)

If the parameters are correlated in the sampling phase, these cards specify the correlations.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITYPE</td>
<td>1-5</td>
<td>I5</td>
<td>Correlation type; not in use.</td>
</tr>
<tr>
<td>ILEAD</td>
<td>6-10</td>
<td>I5</td>
<td>Number (K) of a leading parameter.</td>
</tr>
<tr>
<td>FLEAD</td>
<td>11-25</td>
<td>E15.6</td>
<td>A value of the leading parameter (other than mean value).</td>
</tr>
</tbody>
</table>
Variable | Columns | Format | Description
---|---|---|---
IDEP | 26-30 | I5 | Number (K) of a dependent parameter.
FDEP | 31-45 | E15.6 | Expected value of the dependent parameter when the leading parameter has the value FLEAD.

Note 1: The order of the parameters must satisfy $\text{ILEAD} \leq \text{IDEP}$.

Note 2: Several dependent parameters may have a common leading parameter; not more than one leading parameter may be assigned for any dependent parameter.

Condition Cards

These cards specify conditions or criteria (limits) for conditional distributions calculated in Tasks 4, 5, 14 and 24 ($\text{JOB1} = 4, 5, 14$ or 24). These criteria can be fixed constants, upper or lower limits, for specified consequence variables. They can also be random variables, sampled separately in each simulation cycle from distributions specified here.

First Card:

| Variable | Columns | Format | Description
---|---|---|---
NSB | 1-6 | I6 | Number of simulation cycles satisfying conditions (limit). Either NSA or NSB (whichever occurs first) ends the simulation.
NSC | 7-12 | I6 | Number of cards output in Task 4, 14 or 24 (limit). Use $\text{NSC} > 0$ if Task 5 will be used later.
TOLE | 13-18 | F6.2 | Tolerance for relieved conditions (as a fraction of standard deviation).
NCOND | 19-24 | I6 | Number of criteria (conditions) specified ($\text{NCOND} < 5$).
Next NCOND Cards:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCRIT</td>
<td>1-2</td>
<td>I2</td>
<td>Number of the consequence variable (1, ..., NCONS) that is also a criterion/condition variable.</td>
</tr>
<tr>
<td>LCRIT</td>
<td>3-4</td>
<td>I2</td>
<td>Condition type, = 1 when consequence NCRIT has an upper limit; = 0 when lower limit.</td>
</tr>
<tr>
<td>JDIS</td>
<td>5-6</td>
<td>I2</td>
<td>Distribution indicator for the criterion limit (0 &lt; JDIS &lt; 8). = 0, when fixed constant (UADIS), = 1, ..., 8, when one of the distributions available.</td>
</tr>
<tr>
<td>UADIS</td>
<td>7-17</td>
<td>F11.5</td>
<td>First distribution parameter.</td>
</tr>
<tr>
<td>UBDIS</td>
<td>18-28</td>
<td>F11.5</td>
<td>Second distribution parameter.</td>
</tr>
<tr>
<td>UCDIS</td>
<td>29-39</td>
<td>F11.5</td>
<td>Third distribution parameter.</td>
</tr>
<tr>
<td>UDDIS</td>
<td>40-50</td>
<td>F11.5</td>
<td>Fourth distribution parameter.</td>
</tr>
</tbody>
</table>

Note: The distributions indicated by JDIS are the same as described earlier for parameters. The variables UADIS, UBDIS, UCDIS and UDDIS have the same meaning as ADIS, BDIS, CDIS and DDIS defined earlier in this section. With JDIS = 0, the program uses UADIS as a fixed constant limit for consequence NCRIT.

Conditional Parameter Cards

These NSC cards or 2 NSC cards are needed for Task 5 only (JOBI = 5) and are output from Task 4.
This information specifies one parameter combination that satisfies relieved conditions. It consists of one card if NPARA ≤ 6 or two cards if 7 < NPARA < 12. Thus, the total input is NSC or 2 NSC cards depending on the number of parameters, NPARA.

### Real Consequence or Parameter Input

This input is needed for Task 5 only and depends on whether the consequences are calculated by an external deterministic code (TEST = 0) or in the subroutine TEXAS (TEST = 5).

- **TEST = 5:** Input "Conditional Parameter Cards" as described above.
- **TEST = 0:** Input NSC cards with the following information calculated in the parameter points generated in Task 4.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONS(1)</td>
<td>9-20</td>
<td>E12.6</td>
<td>Value of the first consequence variable.</td>
</tr>
<tr>
<td>CONS(2)</td>
<td>21-32</td>
<td>E12.6</td>
<td>Value of 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>Value of the consequence variable NCONS (&lt;6).</td>
</tr>
</tbody>
</table>
3. **Flow Diagrams**

The flow diagram of the program is presented in Figs. 5 through 12. The main control subroutine DRIVER consists of five parts, as indicated. These parts can be roughly associated with Tasks 1 through 5 (JOB1 = 1, 2, 3, 4 and 5) described in Sec. IV.C.1. These parts are not completely isolated from each other, since Tasks 7 through 28 and special features of the code cause interconnections between various parts of the DRIVER subroutine.
Fig. 5. Sequence of Subprograms in PROSA-2; Part 1
Fig. 6. Sequence of Subprograms in PROSA-2; Part 2(A)
Fig. 7. Sequence of Subprograms in PROSA-2; Part 2(B)
Fig. 8. Sequence of Subprograms in PROSA-2; Part 2(C)
Fig. 9. Sequence of Subprograms in PROSA-2; Part 3(A)
Fig. 10. Sequence of Subprograms in PROSA-2; Part 3(B)
Fig. 11. Sequence of Subprograms in PROSA-2; Part 4-5(A)
Fig. 12. Sequence of Subprograms in PROSA-2; Part 5(B)
4. **Subroutine Functions**

Figures 5 through 12 show the calling sequence and conditions for the subroutines. The function of each subroutine is described briefly below.

**ALLOC2** Function subprogram in MAIN, dynamically allocates space of arrays used in DRIVER. Applied Mathematics Division library subprogram.

**BIASD** Calculates additional terms in analytical mean values of the consequences.

**CEMOPA** Calculates additional terms for the central moments of the parameters.

**CENTRS** Calculates linear and quadratic-term coefficients of a central response surface (when NQUAD = 4).

**CISTO** Calculates conditional histograms and joint histograms.

**CMPARA** Calculates the mean values and central moments of the parameters.

**COEFSN** Calculates polynomial coefficients for multiquadrant response surfaces.

**COKNOT** Calculates knot-point coordinates for correlated input parameters.

**COMMP** Comdeck COMMP is a group of COMMON statements called by the subroutines.

**CORRE3** Calculates correlation coefficients of the third-degree response-surface consequences.

**COVARI** Calculates terms in analytical correlations between the consequences.

**CRISAM** Samples random criteria for conditional distributions.

**CRITIN** Reads criteria cards for NCOND consequences, assigns category boundaries.

**DRIVER** Has control of the program throughout the execution. Called by MAIN.
FITCO Fits a second-degree response surface in systematical knot-point coordinates.

FITEDT Prints coefficients of the response surfaces calculated in FITCO; calculates and prints errors in the knot points, and knot-point numbering system used by FITCO.

FLTRNF(0) Samples a uniformly distributed random number (0,1) (a library-function subprogram).

GAMRN Function subprogram in the SAMPLE routine; calculates gamma-distributed random variates.

HISTO Calculates histograms and joint histograms.

INIT Sets initial value zeros.

INITC Sets initial value zeros.

KNOTST Calculates systematical knot-point coordinates.

KNOUT Punches and prints systematical knot-point coordinates in Task 1.

MAIN For each task, dynamically allocates space for and correctly dimensions arrays used, and then calls DRIVER.

MATINV Matrix inversion routine.

MOMEN3 Calculates the standard deviation of a third-degree response surface consequence. Also calculates the standard deviation of a linear model.

MSHIFT Calculates the standard shift term for correlated input parameters in sampling.

MXMULT Multiplies two matrices.

NEWZO Calculates new reference-point coordinates for sampling parameter distributions in Tasks 7, 8, 17, 18, 27, and 28, when correlated input parameters are present.

NSHIFT In Tasks 7, 8, 17, 18, and 28, calculates the shift term for correlated input parameters in sampling.

PLOTFP Plots the sketches of the consequences versus parameters and the distributions of the consequences.
POLYQ Calculates consequences of multiquadrant response surfaces in the simulation phase.

POINT Edits knot-point coordinates (and calculates consequences if TEST = 1).

PRINTH Edits probability distributions, joint distributions, and error estimates.

QUADST Calculates coefficients for multiquadrant response surfaces.

REPLAC Replaces the overall quadratic response surfaces with fitted response surfaces.

RESPON Calculates third-degree response-surface consequence values in sampling phase.

RFIT2 Fits second-degree response surface to random knot-point coordinates, calculates and prints errors in knot points, and calculates sensitivities of the parameters.

RFIT3 Fits third-degree response surface to random knot-point coordinates, calculates and prints coefficients, errors in knot points, and calculates sensitivities of parameters.

SAMDIS In tasks 7, 8, 17, 18, 27, and 28, reads new parameter distributions for sampling phase.

SAMPLE Takes a random sample of the input parameters based on their distributions.

TEXAS Calculates consequence values, used as a testing subroutine.

TEXOUT Punches and prints test consequences calculated in TEXAS.

TRACO Performs functional transformations for the consequences in the knot points.

TRAMO Calculates approximate moments for parameters that are subject to functional transformations.

TRAPA Performs functional transformations for the parameters.

VARI Calculates additional terms in analytical variances of the consequences.
<table>
<thead>
<tr>
<th>Program</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEIERR</td>
<td>Calculates and edits errors of the smoothened response surface obtained by weighting regionwise (multiquadrant) response surfaces.</td>
</tr>
<tr>
<td>WEIPOL</td>
<td>Calculates the smoothened response surface by weighting regionwise surfaces.</td>
</tr>
<tr>
<td>ZTRAP</td>
<td>Performs functional transformations for the systematical knot-point coordinates of parameters.</td>
</tr>
</tbody>
</table>
V. SUMMARY

In summary, response-surface techniques and a related computer code have been developed with several optional knot-point selection schemes, interpolation schemes, and fitting routines for second- and third-degree surfaces. Techniques have also been developed for estimating and improving the accuracy of the surfaces by transformations and by smoothing regionwise surfaces.

The relative merits of these features have been discussed, including the options for function sampling and for conditional distributions with random criteria. Typical results have been presented for illustration purposes. Quantitative error estimation capability makes these techniques a sound basis for probabilistic analysis of the consequences of postulated accidents in cases where direct simulation is too expensive.

Further development is needed in the area of threshold effects when the consequence variable or its derivative is discontinuous and different response surfaces are needed on different sides of the threshold.

As alternatives to the least-squares fitting method, it would be possible to estimate the response-surface coefficients by minimizing the maximum absolute error or the average absolute error. However, if the selected response surface does not fit well with the ordinary least-squares method, the other fitting methods cannot improve the situation significantly. On the other hand, if the fit is good, it does not matter in practice which one of the methods is used.

More significant improvements may be obtained in some applications by expanding the selection of functional transformations. The use of inverse polynomials, which is being pursued, is one obvious alternative. It can be easily implemented by defining a new consequence (output) variable that is the product of the input variables divided by the original consequence variable, and then using PROSA-2 to fit polynomial response surfaces to the new consequence data.

Some improvements may be possible by optimal selection of the knot points i.e. by optimizing the experimental design. This topic is still under development in the mathematical literature. In any case, PROSA-2 is flexible for use with individually selected knot points: a user can select his own design for Pass 1 (Fig. 1) and still use PROSA-2 in Pass 2 to obtain the response surface and the distribution characteristics. When the random knot-point selection scheme is used, a user can define special distributions in Pass 1 to make the response surface accurate in the region of his choice, and still use correct sampling distributions in Pass 2.
Another area for future development is the identification of most important parameters of large accident-analysis codes. Table III indicates that response-surface techniques are feasible if the number of variable input parameters is relatively small. Development work on identifying the most influential input variables is under way. Both statistical methods $^{22-24}$ and perturbation methods using adjoint equations $^{25}$ are being implemented.
APPENDIX A

Program Listing

MEMBER NAME MAIN

INTEGER ALLOC2
COMMON /LARGE/ T(1)
COMMON /WEIGHT/ HOFIT, RANGE, RADSO(12), RANGEP
COMMON /TRANSF/ NTRA2, NTRA2, JTRA(7), JTYPE(7), LTRA(7), LTYPE(7), APA(17), BPA(7), ACO(7), BCO(7)

C C MAIN PROGRAM C
C MAIN PROGRAM USES ALLOC2 (DOCUMENTATION... AMDLIB VOL. VIII C
C ZEROS A ALLOC2) TO DYNAMICALLY ALLOCATE SPACE FOR ARRAYS USED IN C
C CURVE FITTING ROUTINES. SPACE NEEDED DEPENDS ON THE NUMBER OF C
C PARAMETERS AND THE NUMBER OF CONSEQUENCES.
C NWDS ... IS THE TOTAL NUMBER OF WORDS IN THESE ARRAYS.
C IFATPI ... DETERMINES THE PRECISION OF THE ARRAYS.
C T ... ALLOCATED ARRAY WHERE THE OTHER ARRAYS(TP, ETC.) ARE STORED C
C IN THE CALL DRIVER STATEMENT, THE ADDRESS OF THE FIRST LOCATION OF C
C EACH ARRAY IS PASSED, AND DRIVER USES THE ARRAYS AS DIMENSIONED IN C
C DRIVER. (TWO DIMENSION, DOUBLE PRECISION). ALLOC2 RETURNS IEBR AS C
C ASSUMED IF THE ALLOCATION IS UNSUCCESSFUL. ABEND IS AN ABNORMAL C
C TERMINATION DUMP.
C DATA IREAD, IWRITE, IPUNCH/5, 6, 7/
C *CALL COMP
C
C 3 CONTINUE C
C READ JOB INFO C
C IF PAIRS LIMITED
C READ(5, 1001, END=989) NPARA, LPAIR, JOBI, PROB, NCONS, NSA, SCALE, TEST, WO
C NCOEF2 = 1 + 2 * N + (N * (N - 1)) / 2
C NKNOT = 1 + 2 * N * (N - 1)
C NCOEP3 = 1 + 3 * N + 3 * (N - 1) * (N - 1) / 2 + N * (N - 1) * (N - 2) / 6
C WRITE(IWRITE, 1002) NKNOT, NCOEP2, NKNOE2, NREPORT
C WRITE(IWRITE, 1003) NKNOT, NCOEF2, NKREP2
C IF PAIRS LIMITED C
C Fomat(17HOIN MAIN NKNOT = ,I6,10H NCOEP3 = ,I6,10H NKREP2 = ,I6)
C Fomat(17HOIN MAIN NKNOT = ,I6,10H NCOEF2 = ,I6,10H NKREP2 = ,I6)
C DIMENTION T.
C IFATPI = 2
C NWDS = IFATPI * (NKNOT * NCONS + NCOEP2 * (NKNOT + NCONS + NKNOT + 1) * NCOEP2) + 100
C KLOC = ALLOC2(1EBR, NWDS)
C IF (IEBR.GT.0) GO TO 130
C WRITE(IWRITE, 1050) NWDS
C CALL ABEND
C 130 CONTINUE C
C JLOC = LCCF(T)
C IOFFST = (KLOC - JLOC) / 4
C 1050 FORMAT(1HW, 10X, 3HERROR--UNABLE TO ALLOCATE SPACE FOR ,I6,23H SING
C 1LE PRECISION WORDS/11X, 24HEXECUTION WILL TERMINATE)
IZF = 1 + IOFFST
ICF = IZF + NKNOT * NCOEF2 * IRATPI
IBF = ICF + NCONS * NKNOT * IRATPI
IZFP = IEF + NCOEF2 * NCONS * IRATPI
IAMAT = IZFP + NKNOT * NCOEF2 * IRATPI
IEND = IAMAT + NCOEF2 * NCOEF2 * IRATPI - IOFFST
WRITE(IWRITE, 1040) NWDS, IEND, IOFFST, KLOC, JLOC
1040 FORMAT(910 NWDS =, I10, 9H IEND =, I10,
1 2X, 6HIOFFST =, I10, 2X, 10HKLOC, JLOC, 2X10)
CALL DRIVE6(T(IZF), T(ICF), T(IBF), T(IZFP), T(IAMAT), NKNOT, NCOEF2)
GO TO 3
989 STGF 1
END
### MEMBER NAME DRIVER

**SUBROUTINE DRIVER**

```fortran
REAL*8 ZF,CF,BF,ZFP,AMAT,NKNOT,NCOEF2

DIMENSION ZF(NKNOT,NCOEF2), CF(NKNOT,NCONS), BF(NKNOT,NCONS),
ZFP(NCOEF2,NKNOT), AMAT(NCOEF2,NCOEF2)

DIMENSION IPLO(6,2L), TP(2L), XP(26)
DIMENSION ICPLO(6,2L), TP(2L), XP(26)
DIMENSION SUMA(6), SUH(6), SUMC(6), SUH(6)
DIMENSION SAMEAN(6), SSD(6)
DIMENSION CSUMA(), CSUMC(6), CSUMD(6)
```

#### Data Section

```
1 FORMAT(1H1,'IPREAD, IWRITE, IPUNCH/5,6,7/
```

---

### Table: Correlations Between Input Parameters

<table>
<thead>
<tr>
<th>Number of Parameters</th>
<th>Correlation Type</th>
<th>Lead Parameter</th>
<th>Value</th>
<th>Shifted Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

### Format Statements

```
1003 FORMAT(1H1,T40,'INPUT DATA - WORK',I6,3X,6H JOB ,I2/)
1002 FORMAT(12,1X,A4,A2,12,4F11.5,1,1212)
1003 FORMAT(1H1,26H NUMBER OF PARAMETERS = ,I3/)
1004 FORMAT(7H ,I4,4X,A4,A2,14,6X,4F11.5,4X,1213)
1005 FORMAT(1F9.4,'NUMBER',117,'NAME',124,'DISTRIBUTION',1W3,'PARAMETER
1E8',1W4,'PAIRS IF LIMITED NUMBER')
1006 FORMAT(1H1,10X,I5,8HH CORRELATIONS BETWEEN INPUT PARAMETERS')
1007 FORMAT(34H SINGLE RESPONSE SURFACE (NQUAD=1)'
1008 FORMAT(42H MULTI QUADRANT RESPONSE SURFACE (NQUAD=4)'
1009 FORMAT(32H BETWEEN 1 AND 4, SEE 1/)
1010 FORMAT(26H INDEPENDENT INPUT PARAMETERS)
1011 FORMAT(24H NUMBER OF PAIRS LIMITED)
1012 FORMAT(18H PAIRS UNLIMITED)
1013 FORMAT(27H NUMBER OF CONSEQUENCES = ,I3/)
1014 FORMAT(20H UCLALLEABILITY RANGE ,1E12.5/)
1015 FORMAT(31H NUMBER OF SIMULATION CYCLES =,I10/18H CATEGOR S WIDTH
1E8',2.2E12.5/)
1016 FORMAT(52H COSEQUENCES CALCULATED BY TEST SUBROUTINE (T0IAS')'
1017 FORMAT(14H,4X,16H CORRELATION TYPE,A4,11H LEAD PARA,A4,8H, VA LUE,1E14.6,3X,1A9 INDEPENDENT PARA1,A4,15H SHI PLED MEAN=,E14.6')
1018 FORMAT(1H)
1019 FORMAT(91H DISTRIBUTION FIRST PARAMETER SECOND PARAMETER
1THIRD PARAMETER FOURTH PARAMETER/
1020 FORMAT(91H DISTRIBUTION FIRST PARAMETER SECOND PARAMETER
1THIRD PARAMETER FOURTH PARAMETER/
1021 FORMAT(91H DISTRIBUTION FIRST PARAMETER SECOND PARAMETER
1THIRD PARAMETER FOURTH PARAMETER/
1022 FORMAT(91H DISTRIBUTION FIRST PARAMETER SECOND PARAMETER
1THIRD PARAMETER FOURTH PARAMETER/
1023 FORMAT(91H DISTRIBUTION FIRST PARAMETER SECOND PARAMETER
1THIRD PARAMETER FOURTH PARAMETER/
1024 FORMAT(91H DISTRIBUTION FIRST PARAMETER SECOND PARAMETER
1THIRD PARAMETER FOURTH PARAMETER/
1025 FORMAT(91H DISTRIBUTION FIRST PARAMETER SECOND PARAMETER
1THIRD PARAMETER FOURTH PARAMETER/
1026 FORMAT(91H DISTRIBUTION FIRST PARAMETER SECOND PARAMETER
1THIRD PARAMETER FOURTH PARAMETER/
1027 FORMAT(91H DISTRIBUTION FIRST PARAMETER SECOND PARAMETER
1THIRD PARAMETER FOURTH PARAMETER/
1028 FORMAT(91H DISTRIBUTION FIRST PARAMETER SECOND PARAMETER
1THIRD PARAMETER FOURTH PARAMETER/
1029 FORMAT(91H DISTRIBUTION FIRST PARAMETER SECOND PARAMETER
1THIRD PARAMETER FOURTH PARAMETER/
```

---

### Data Section

```
C DATA IREAD, IWRITE, IPUNCH/5,6,7/
```
*CALL CCMP

COMMON/CRAY/CRAVE(4)
COMMON/CONDJS/NSSC,NSC,NSOD,TOL
COMMON/CALDIS/ICIS(4),ACIS(4),BCIS(4),CCIS(4)

COMMON/CZNEW/CCNV(12)
COMMON/CCNV/LGIEV
COMMON/WEIGHT/HFIT,PAGE,PADSO(12),RANGE
COMMON/TRANS/*RPA,JACO,JTRA(7),JITGE(7),LTBA(7),LTYPE(7),APA(17),EPA(7),ACO(7)
COMMON/SVC0/SCSV(12)

CALL INIT
NCOEF3 = NCOEF2
IFIT = 0

C IFIT IS AN INTERNAL FLAG SET TO 1 IN DRIVER IF NQUAD=4 AND NPARA LE 8
C (A FITTED RESIDUE SURFACE IS TO BE SOLVED), SET 2 IN SUBROUTINE
C REPLAC. IFIT IS NOT USED IN JOBI 1.
C

JOBISV=JC3I
WRITE(6,1060) WORK,JOBI
WRITE(6,1000) NPARA
IF(NCORR.GT.0) WRITE(6,1006) NCORR
IF(INMJAIE.LE.C) WRITE(6,1012) IFIT
WRITE(6,1014) ?PCB
IF(NCONS.GT.0) WRITE(6,1013) NCONS
IF(JOBISV.EQ.3) WRITE(6,1015) NSA,SCALE
IF(TEST.EQ.1) WRITE(6,1016)

C DEFAULT NQUAD = 1 OR 4

IF(NQUAD.EQ.3) WRITE(6,1007)
IF(NQUAD.GT.1.AND.NQUAD.LT.4) WRITE(6,1009)
IF(NQUAD.GT.1.AND.NQUAD.LT.4) NQUAD=1
IF(NQUAD.EQ.1) NQUAD=1
IF(NQUAD.EQ.4) WRITE(6,1008)
IF(NQUAD.EQ.4).JQAD=4
IF(NQUAD.GE.4.AND.NPARA.LE.5.AND.JOBI.GT.11) IFIT=1
IF(TEST.EQ.3.AND.IFIT.EQ.1) IFIT = 9

C NOFIT FLAG DATA ELIMINATES FITTING TO SYSTEMATICAL KNOT-POINTS
C IF NOFIT=1

IF(NQUAD.EQ.4.AND.NOFIT.EQ.1.AND.JOBI.GT.11) WRITE(IWRITE,1030)
1030 FORMAT(1E0,6H RANGE =,F7.3,2X,3CH'JSED IN WEIGHTING M-Q SUBFACES/1H + ,15X,25H/FRACTION OF (Z1

- Z2)/2.//)

IF(NQUAD.GE.4.AND.JOBI.GT.11) WRITE(IWRITE,1031)
1031 FORMAT(1E0,9X,4H WARNING - NQUAD=4 WITH JOBI.GT.11 NOT DEFINED//)

IF(NQUAD.GE.4.AND.JOBSV.LT.10) WRITE(IWRITE,1032) RANGE
1032 FORMAT(1E0,8H RANGE =,F7.3,2X,3CHUSED IN WEIGHTING M-Q SUBFACES/1H + ,15X,25H/FRACTION OF (Z1

- Z2)/2.//)

C WEIGHTING FUNCTION IS EXP(-((DISTANCE/RANGE)**2)/2.1)

IF(NTRAPA.LE.0.AND.NTRACO.LE.0) WRITE(IWRITE,1034)
1034 FORMAT(1E0,9X,4H NO TRANFORMATIONS FOR PARAMETERS/1H + ,15X,25H/FRACTIONS FOR CONSEQUENCES//)

IF(NQUAD.GE.4.AND.JOBSV.GT.11) NQUAD=1
IF(NQUAD.LE.1) IFIT=0
IF(NQUAD.GE.4) NPAIR=0
IF(NPAIR.EQ.0) WRITE(6,1011)
NQ=NQUAD
IF(NCORR.LE.0) WRITE(6,1013)
C READ PARAMETER INFO AND ORGANIZE
DO 11 I=1,NPARA
READ(5,1002) K, NAMEA, NAMEB, JDIS, UDIS, UBDIS, UDDIS, JJK
WRITE(6,104) K, NAMEA, NAMEB, JDIS, JADIS, UBDIS, UDDIS
IPARA(K) = K
PNAMEA(K) = NAMEA
PNAMEB(K) = NAMEB
JDIS(K) = JDIS
ADIS(K) = UADIS
BDIS(K) = UBDIS
CDIS(K) = UCDIS
DDIS(K) = UDDIS
C IF CROSS-TIES NOT LIMITED GO TO 11
IF (LMFAJK .LE. ?) GO TO 11
DO 12 L=1,12
JA = JJK(L)
IF (JA .LE. K) GO TO 13
JK(K,JA) = 1
GO TO 12
13 IF (JA .LE. 0) GO TO 12
JK(JA,K) = 1
12 CONTINUE
11 CONTINUE
IF (NCORF .LE. 0) GO TO 16
DO 18 I=1,NCORF
READ(5,1017) ITYPE(I), ILEAD(I), FLEAD(I), IDEP(I), FDEP(I)
WRITE(6,1019) ITYPE(I), ILEAD(I), FLEAD(I), IDEP(I), FDEP(I)
18 CONTINUE
C CALL KNOTST TO SET KNOT POINTS
CALL KNOTST
C ZEROS FOR JGII 2, EARLY BECAUSE OF TESTING (TEXAS)
CALL INITC
C INPUT PARAMETER TRANSFORMATIONS
IF (NTRAPA .LE. 0) GO TO 90
WRITE(3,1041) NTRAPA
1041 FORMAT (14H0,15,23H TRANSFORMED PARAMETERS/1H,59H PARA NO., 1H, 15H, PARA =1ST TB. PARA, BPA =2ND TB. PARA/)
DO 802 I=1,NTRAPA
READ(3,1042) JTRA(I), JTYPE(I), APA(I), BPA(I)
WRITE(3,1048) JTRA(I), JTYPE(I), APA(I), BPA(I)
802 CONTINUE
1042 FORMAT (15,I5,E15.6,E15.6)
1048 FORMAT (1H,15,7X,I4,7X,E15.6,6X,E15.6/)
WRITE(3,1045)
1045 FORMAT (1H,0,' PARAMETER TRANSFORMATION DEFINITIONS','/110H,' 1H,15,7X,I4,7X,E15.6,6X,E15.6/)

MEMBER NAME DRIVER
21H , ' 1 I = (Z - APA)*BPA
31H , ' 2 I = LOG(Z - APA)
41H , ' 3 I = EXP((Z - APA)/BPA)
51H , ' 4 I = ATAN((Z - APA)/BPA)

801 CONTINUE
C END OF PARAMETER TRANSFORMATION INPUT AND DEFINITIONS
C PRINT KNCT POINT Z-VALUES
C
1600 FORMAT (27H1 PARAMETER VALUES SELECTED/ T5,'NUMBER',T14,'NAME',T26,
1'Z2',T40,'ZC',T54,'Z1'/)
1601 FORMAT (4H ,i4,3X,A4,A4,31 4.6)
1602 FORMAT (27H1 PAr.AMETEL VALUES SLLLCILD/ T5,'NAME',T14,'NAME',T26,
1'Z2',T40,'ZC',T54,'Z1'/)
1603 FORMAT (4H ,i4,3X,A4,A4,5E14.6)
IF(NQ.GT.1) GO TO 46
WRITE (6, 1600)
46 IF(NQ.GT.1) GO TO 47
WRITE (6,1602)
DO L=1,NPARA
IF(NQ.GT.1) GO TO 47
WRITE(6,1603) IPARA(L),PNAMEA(L),PNAMEB(L),Z2(L),Z0(L),Z1(L)
47 IF(JOB1.GT.1) GO TO 103
ZOSV(L) = Z0(L)
IF(JCD1.GT.1) GO TO 103
C CONSEQUENCE OUTPUT FOR TESTING ONLY (TEST.GT.0)
IF(ZEST.EQ.1)CALL TEXOUT
C SAMPLE NRANKP RANDOM KNOT-POINTS AND EDIT
INDEX = 50
90 IF(NRANKP.LE.0) RETURN
WRITE(6,1620) NRANKP
INDEX = 50
DO I=1,NRANKP
91 CALL SAMPLE
WRITE(6,1621) INDEX,1,(Z(L),L=1,NPARA)
91 WRITE(IPUNCH, 1622) INDEX,1,(Z(L),L=1,NPARA)
1620 FORMAT (1I1,10X,32H*?ANDCM KNOT-POINT COORDINATES -,I5,4HSETS//)
1621 FORMAT (312,2X,(6E12.6))
1622 FORMAT (5E:,315,(6E16.6))
RETURN
C END OF TEST OUTPUT - JOBI 1
C JOBI 2
2000 FORMAT(36H1 INPUT CONSEQUENCES IN KNOT POINTS//T7,'INDEX', T15,'J
1 K ',I3,14H -CONSEQUENCES/)
C stdout index card ends JOB12 input for separate problems if more than 1
C for random knot-points calculate surface and sensitivities in EFIT
103 continue
C input consequence transformations if any
IF(NTRACC.GT.1) GO TO 811
WRITE(IWRITE,1043) NTRACO
1043 FORMAT(1H0,15,25H TRANSFORMED CONSEQUENCES/1H,56HCONS NO., TR. TY
1TH, ACO =1ST TR. PARA., BCO =2ND TR. PARA./)
DO 812 I=1,NTRACO
READ(IREAD,1042) LTHA(I),LTYPE(I),ACO(I),BCO(I)
WRITE(IWRITE,1045) LTHA(I),LTYPE(I),ACO(I),BCO(I)
812 continue
WRITE(IWRITE,1046)
WRITE(IWRITE,1047)
1046 FORMAT(1H0,1H CONSEQUENCE TRANSFORMATION DEFINITIONS '/
11TH," TR. TYPE EQUATION '/
21H, 1 NEW CONS = (CONS - ACO)**BCO '/
31H, 2 NEW CONS = LOG(CONS - ACO) '/
41H, 3 NEW CONS = EXP((CONS - ACO)/BCO) '/
51H, 4 NEW CONS = ATAN((CONS - ACO)/BCO) '/
61H, 5 TO BE DEFINED '/
71H, 6 TO BE DEFINED '/
81H, 7 TO BE DEFINED '/
1047 FORMAT(3H0 107HTRANSFORMED CONSEQUENCES USED IN RESPONSE SURFACE
15 AND IN SIMULATION, ERBOPS AND CATEGORIES FOR USE IN EFIT Too)'
811 continue
C end of consequence transformation input and definitions
IF(JOB1.GT.2.AND.TEST.EQ.30) CALL KNOT
C only jobi = 2,3,4 meaningful with test = 30, possible for jobi 7,8
IF(JOB1.GT.1.AND.TEST.EQ.30) GO TO 119
IF(JOB1.GT.11.AND.JOB1.LT.21) CALL EFIT (ZF, CF, BF, ZF2, AMAT, NCOEF2, 1 IFIT)
IF(JOB1.GT.11.AND.JOB1.LT.21) GO TO 118
IF(JOB1.GT.21.AND.JOB1.LT.31) CALL EFIT (ZF, CF, BF, ZF2, AMAT, NCOEF3, 1 IFIT)
IF(JOB1.GT.21.AND.JOB1.LT.31) GO TO 138
WRITE(IWRITE,20G0)
READ(5,2C01,ERROR=98C,END=990)
INDEX,J,K),(CONS(I),I=1,NCONS)
WRITE(6,2.3C2)
INDEX,J,K),(CONS(I),I=1,NCONS)
II=INDEX
IF(II.LT.0) GO TO 990
C transform knot-point consequences
IF(NTRAC.GT.0) CALL TRACO(CONS)
IF(NTRAC.GT.0) WRITE(IWRITE,2005) INDEX,J,K,(CONS(I),I=1,NCONS)
2005 FORMAT(21H TRANSFORMED VALUES/5H,3I5,6E16.6))
C
C consequences transformed
C
IF(I1G.CT.44) GO TO 981
DO 111 L=1,NCONS
IF(INDEX.EQ.0) ZETA0(L)=CONS(L)
IF(INDEX.EQ.1) ZETA1(L,J)=CONS(L)
IF(INDEX.EQ.2) ZETA2(L,J)=CONS(L)
IF(INDEX.EQ.3) ZETA3(L,J)=CONS(L)
IF(INDEX.EQ.4) ZETA4(L,J)=CONS(L)
IF(INDEX.EQ.11) ZETA11(L,J,K)=CONS(L)
C single response surface case ZETA3 = ZETA1
IF(NQ.EQ.1.AND.INDEX.EQ.11) ZETA3(L,J)=ZETA1(L,J)
MEMBER NAME DRIVER

IF (NQ.EQ.1) GO TO 111
IF (INDEX.EQ.22) ZETA22(L,J,K) = CONS(L)
IF (INDEX.EQ.33) ZETA33(L,J,K) = CONS(L)
IF (INDEX.EQ.44) ZETA44(L,J,K) = CONS(L)

111 CONTINUE
GO TO 107

980 WRITE(6,25CD0)
2500 FORMAT(360
"ERROR IN CONSEQUENCE INPUT -JOB1 2//")
STOP

981 WRITE(6,2501)
2501 FORMAT(4?HO
"ERROR IN CONSEQUENCE INPUT -JOB1 2//")
STOP

990 CONTINUE
WRITE(6,2003)
2003 FORMAT(3ZHO
"NEGATIVE INDEX IS FOR EOF ONLY/")

C OVERALL
C SENSITIVITIES AND COEFFICIENTS CALCULATION
C SINGLE SURFACE CASE (NQ=1) REMEMBER Z3=Z1 AND ZETA3= ZETA1
119 DO 120 L=1,NCONS
   A(L) = ZETA0(L)
   DO 121 J=1,NPARA
      IF (J.EQ.1) GO TO 128
      JPI = J + 1
      DO 122 K=JPI,NPARA
         IF (LMPAIR.GT.0) GO TO 130
         IF (ZETA11(L,J,K).LT.0.) GO TO 132
         IF (NQ.EQ.1) ZETA3(L,J) = ZETA1(L,J)
         IF (NQ.EQ.1) ZETA3(L,K) = ZETA1(L,K)
         DIFF = ZETA11(L,J,K) + ZETA0(L) - ZETA3(L,J) - ZETA3(L,K)
         SENS3(L,J,K) = DIFF / ((Z3(J) - Z0(J)) * (Z3(K) - Z0(K)))
      END
122 CONTINUE
120 CONTINUE

C MULTI QUADRANT COEFFICIENTS
IF (NQUAD.GT.1) CALL QUADST
C CENTRAL PART COEFFICIENTS IN MULTIQUADRANT CASE (NQUAD=4) IN CENTES
IF (NQUAD.GT.1) CALL CENTES

C EDIT POLYNOMIAL COEFFICIENTS
C FOR MULTIQUADRANT CASES IQ = QUADRANT INDICATOR
C THE ORDER OF THE PARAMETERS IS IMPORTANT IN DEFINING THE QUADRANT
C IF NQ=4 WE HAVE 2 E- AND C-COEFFICIENTS FOR EACH PARAMETER, 4 D-COEFFICIENTS
C QUADRANTS 1 AND 4 HAVE SAME B AND C COEFFICIENTS
C QUADRANTS 2 AND 3 HAVE SAME B AND C COEFFICIENTS
C THIS CONVENTION IMPORTANT IN THE SAMPLING AND SIMULATION PHASE
C
205C FORMAT(4WH1 THE COEFFICIENTS OF THE POLYNOMIALS/10H
162H A
262H + B(J) * (Z(J)-Z0(J)) , SUM J
362H + C(J) * (Z(J)-Z0(J))**2 , SUM J
462H + D(J,K) * (Z(J)-Z0(J)) * (Z(K)-Z0(K)) , SUM J,K (K.GT.J)
64

AEMBE&
NAKEDRIVER
58080 IN MULTIQURADRANT CASE (NQUAD=4) IQ INDICATES THE QUADRANT IN
6 Z(J)/Z(K) PLANE/
2051 FORMAT (1H0/1H0,12I,11HCONSEQUENCE,14,1//)
2052 FORMAT (1H0/1H0,1H0=6G15.6/)
2053 FORMAT (1H0/1H0,1H0=6G15.6/)
2054 FORMAT (1H0/1H0,1H0=6G15.6/)
2055 FORMAT (1H0/1H0,1H0=6G15.6/)
2056 FORMAT (4H0/1H0,1H0=6G15.6/)
2057 FORMAT (4H0/1H0,1H0=6G15.6/)
2058 FORMAT (4H0/1H0,1H0=6G15.6/)
118 CONTINUE
IF (JOB1.EQ.12) JOB1=2
IF (JOB1.EQ.13) JOB1=3
IF (JOB1.EQ.14) JOB1=4
IF (JOB1.EQ.17) JC1=7
IF (JOB1.EQ.18) JOB1=8
IF (JOB1.EQ.19) WRITE (1WRITE,1000) JOB1,J
1000 FORMAT (1H0JOB 1,J WITH 2ND DEGREE
1SURFACE FITTED TO RANDOM KNOT-POINTS//)
WRITE(6,2050)
DO 141 L=1,NCOUS
WRITE(6,2051) L
WRITE(1WRITE,2052) A(L)
DO 143 IC=1,NQ
WRITE(6,2053) (B(L,J),J=1,NPARA)
WRITE (6,2054) (C(L,J),J=1,NPARA)
DO 142 J=1,NPARA
WRITE(6,2055) J,(D(L,J,K),K=NKI,NPARA)
142 CONTINUE
143 CONTINUE
141 CONTINUE
WRITE (6,2160)
2160 FORMAT (1E1)
CALL CURVE FITTING AND EDITING SUBROUTINES.
IF (NPARA.GT.6) WRITE (6,2200)
IF (IFIT.EQ.1) CALL FITCO (ZP,CP,EP,ZP,FAMAT,NKNOT,NCOEP)
IF (IFIT.EQ.1) CALL FIT3DT (ZP,CP,EP,ZP,FAMAT,NKNOT,NCOEP)
2200 FORMAT (55H0NUMBER OF PARAMETERS GREATER THAN 6. FITCO NOT CALLED.)
C
GO TO 140
132 WRITE (6,2510) L,J,K
WRITE (6,2511)
2510 FORMAT (2H00 JK(J,K)=1 BUT ZETA11 L=13,3H J=I4,3H K=I4,5H ZERO/) 2511 FORMAT (6H0 YOU BETTER MAKE SURE ALL CROSS TERM INPUT CARDS IN, I
1 CONTINUE)
GO TO 125
130 IF (JK(J,K).EQ.1) GO TO 126
125 IF (JK(J,K).EQ.1) ZETA11(L,J,K)=ZETA1 (L,J)+ZETA1 (L,K)-ZETA0(L)
126 IF (JK(J,K).NE.0) AND (JK(J,K).NE.1) WRITE (6,2513)
2513 FORMAT (5SH0 SOMETHING WRONG WITH JK(J,K) NOT EQUAL 0 OR 1/) 2514 CONTINUE
GO TO 125
138 CONTINUE
MEMBER NAME DRIVER

IF(JOBI.EQ.22) JOBI = 2
IF(JOBI.EQ.23) JOBI = 3
IF(JOBI.EQ.24) JOBI = 4
IF(JOBI.EQ.27) JOBI = 7
IF(JOBI.EQ.28) JOBI = 8

C SENSITIVITY / IMPORTANCE ORGANIZATION -SINGLE PARAMETERS

140 M = 0
WRITE(6,2011)
150 M=M+1
DO 151 L=1,NCONS
SEMAX(L) = 0.
DO 152 J=1,NPARA
IF(SEMAX(L).GT.SENS(L,J)) GO TO 152
SEMAX(L) = SENS(L,J)
JMAX(L) = J
152 CONTINUE
K=JMAX(L)
SENS(L,K) = -SENS(L,K) - 1.0E-49
151 CONTINUE

2011 FORMAT(1H0,6(I4,E14.6))
WRITE(6,2012) (JMAX(L),SEMAX(L),L=1,NCONS)
IF(M.LT.NPARA) GO TO 150
M = 0
IF(NPARA.LT.2) GO TO 170
C CROSS-TERM SENSITIVITY ORGANIZATION

2013 FORMAT(1H0,32Hthree factor interaction sensitivities***/)
WRITE(6,2015) (JMAX(L),KMAX(L),SECMAX(L),L=1,NCONS)
IF(M.LT.MALL) GO TO 160
2015 FORMAT(4H0,6(I4,E14.6))
C WRITE THREE FACTOR INTERACTION SENSITIVITIES

2065 FORMAT(1H0,32Hthree factor sensitivities***/)
MEMBER NAME DRIVER

2066 FORMAT(1H0,6X,11HCONSEQUENCE,1J,10X,17HJ K M SENSHP)
2067 FORMAT(1H ,27X,314,1X,E13.6)

IF(JOBISV.LT.21.AND.JOBISV.GT.30) GO TO 170
WRITE(IWRITE,2065)
IF(NPAH.LT.3) GO TO 170
DO 166 L=1,NCONS
NPA= NPAH -1
WRITE(IWRITE,2066) L
NPA= NPAH -2
DO 166 J=1,NPA
J=J+1
DO 167 K=J1,NPA
K=K+1
DO 168 L=K1,NPABA
WEITE(IWFITE,2067) J,K,M,SENSH(L,J,K,M)
168 CONTINUE
167 CONTINUE
166 CONTINUE
170 CONTINUE

C CONSEQUENCE FLCTTING INFO

2060 FORMAT(1H1,30X,17HCONSEQUENCE VS PARAMETERS//558 NINE EQUALLY
1SPACED VALUES FROM Z2(J) THROUGH Z1(J)/*
2061 FORMAT(1H0,30X,17HCONSEQUENCES,14,/
2062 FORMAT(1H ,11HCONSEQUENCE,14,1X,9G11.4,/
2063 FORMAT(1H0,12X,35H CONSEQUENCE VERSUS PARAMETER SKETCH/)
IF (NCORB.GT.0) CALL CC1CPA
IF (MRAPA.GT.0) CALL TRAMO
C PRINT MOMENTS OF THE PARAMETERS
2016 FORMAT (1X,23,2X,A4,A4,G14.6,G14.6,G14.6,G14.6,G14.6)
WRITE (6,2016)
IF (JOBISV.EQ.7.or.JOBISV.EQ.8) WRITE (IWRIT3,2700)
IF (MRAPA.GT.0) WRITE (6,2707)
2707 FORMAT ('0 ANALYTICAL MOMENTS NOT EXACT FOR TRANSFORMED PARAMETERS
1/5 Approximate RELAATIONS USED/', 'C31 = TRANSFORMED REFERENCE POINT ZO(J)',
3 'C34 = 3.* CM2 * C22 */', 'DO 172 J=1,NPARA
WRITE (6,2017) J,PNAMEA(J),PNABEB(J),PNA1(J),CH2(J),CM3(J),CH4(J)
172 CONTINUE
WRITE (6,2056)
2056 FORMAT (1X,10X,55H ANALYTICAL CENTRAL MOMENTS OF THE PARAMETERS
1 FAIRS/16H PARA 1 PARA 2 PARA 3 PARA 4 PARA 5 PARA 6 PARA 7 PARA 8 PARA 9)
DO 250 J=1,NPARA
WRITE (6,2057) J,K,C11(J,K),C12(J,K)
250 CONTINUE
C ANALYTICAL MOMENTS OF THE RESPONSE SURFACE CONSEQUENCES
C (OVERALL RESPONSE SURFACE IF NQAD.GT.1)
C (FITTED RESPONSE SURFACE IF NQAD.GT.1)
610 CONTINUE
C
IF (JOBISV.GT.21.AND.JOBISV.LT.31) GO TO 173
DO 181 L=1,NCONS
AVZET(L) = A(L)
DO 182 J=1,NPARA
BIAS = C(L,J)*CM2(J)
AVZET(L) = AVZET(L) + BIAS
182 CONTINUE
DO 184 L=1,NCONS
VARSUM =0.
DO 185 J=1,NPARA
SINV = B(L,J) *B(L,J) *CM2 (J)
VARA = SINV + C(L,J) *CM2 (J)
VARA = VARA + C(L,J) *CM2 (J) -CM2 (J) *CM2 (J)
VARB =0.
IF (J.EQ.NPAEA) GO TO 186
JPI=J+1
DO 187 K =JPI,NPARA
VARB = VARB + D(L,J,K) *D(L,J,K) *CM2 (J) *CM2 (K)
187 CONTINUE
186 VARSUM = VARSUM + VARA + VARB
SINV = SINV + SINV
185 CONTINUE
SDZET(L) = VARSUM**.5
MEMBER NAME DRIVER

SIMSD(L) = SIMSUM**.5
184 CONTINUE
GO TO 189
173 DO 175 L = 1,NCONS
AVZET(L) = A(L)
175 AVZET(L) = AVZET(L) + C(L,J) * CM2(J) + E(L,J) * CM3(J)
C
C MOMEN3 calculates SDZET(L) and SIMSD(L) using third degree coefficients.
C
CALL MOMEN3
189 IF(NCORE.GT.0) CALL BIASD(D,NPARA)
IF(NCORE.GT.0) CALL VARI(B,NPARA)
C
C ANALYTICAL CORRELATIONS BETWEEN THE RESPONSE SURFACE CONSEQUENCES
C
C (OVERALL RESPONSE SURFACES IF NQUAD.GT.1)
C
IF(JOBISV.GT.21.AND.JOBISV.LT.31) GO TO 197
DO 191 L=1,NCONS
IF(L.EQ.NCONS)GO TO 191
LPI=L+1
DO 192 M=LPI,NCONS
COVSUM=0.
SIMCUM=0.
DO 193 J=1,NPARA
SIMCO = B(L,J)*B(M,J) * CM2(J)
COVA=SIMCO+CM3(J)*(B(L,J)*C(M,J)+B(M,J)*C(L,J))
COVA=COVA+C(L,J)*C(M,J)*(CM4(J)-CM2(J)*CM2(J))
CCVB=0.
IF(J.EQ.NPARA) GO TO 195
JPI=J+1
DO 194 K=JPI,NPARA
COVB=COVA*D(L,J,K)*D(M,J,K) * CM2(J) * CM2(K)
194 CONTINUE
195 COVSUM=COVSUM + COVA + COVB
SIMCUM=SIMCUM + SIMCO
193 CONTINUE
SDZL  = SDZET(L)
SDZM  = SDZET(M)
IF(SDZL.EQ.0.) SDZET(L) = 1.E-24
IF(SDZM.EQ.0.) SDZET(M) = 1.E-24
SDZL  = SIMSD(L)
SDZM  = SIMSD(M)
IF(SDZL.EQ.0.) SIMSD(L) = 1.E-24
IF(SDZM.EQ.0.) SIMSD(M) = 1.E-24
COBPEL(L,J) = COVSUM/(SDZET(L)*SDZET(M))
SIMCOR(L,J) = SIMCUM/(SIMSD(L)*SIMSD(M))
192 CONTINUE
191 CONTINUE
GO TO 198
C
C SUBROUTINE COFRE3 calculates correlation coefficients using third degree polynomial coefficients.
C
197 CALL COFRE3
198 IF(NCORE.GT.0) CALL COVARI(B,NPARA)
C
C OUTPUT ANALYTICAL MOMENTS AND CORRELATIONS
200 WRITE(6,2020)
2020 FORMAT(63H1, Momen of the analytical response surface consequences/)
IF (JOBISV.EQ.7.OR.JOBISV.EQ.8) WRITE(IWRITE,2700)
2021 FORMAT(1H,9X,15HQUADSTIC MONDEL,2X,16HLINEARIZED MONDEL//)
2023 FORMAT(1E,15.E,6E14.6,4X,E14.6,E14.6)
WRITE(6,2021)
WRITE(6,2022)
DO 201 L=1,NCONS
    WRITE(IWRITE,2023) L, AVZET(L), SDZET(L), A(L), SIMSD(L)
201 CONTINUE
C MOMENT INFO INVERSE TRANSFORMATIONS
IF (NTRACC.LE.0) GO TO 749
WRITE(IWRITE,7049)
7049 FORMAT(1H,46d INVERSE TRANSFORMED VALUES FOR TRANSF CONSEQ//)
    DO 741 I=1,NTRACO
        LL = LTRAI(I)
        LTIP = LTYPE(I)
        AC = ACO(I)
        BC = BC0(I)
        ALL = A(LL)
        AVLI = AVZET(LL)
        BLL = ALL + SDZET(LL)
        GO TO (710,720,730,740,750,760,770),LTIP
    710 BCC = 1./EC
        AREF = ALL**BCC + AC
        AVEEF = AVLI**BCC + AC
        BEEF = ELL**BCC + AC
        GO TO 748
    720 AREF = EXP(ALL) + AC
        BREF = EXP(BLL) + AC
        AVREF = EXP(AVLL) + AC
        GO TO 748
    730 AREF = BC*ALOG(ALL) + AC
        BREF = BC*ALOG(BLL) + AC
        AVREF = BC*ALOG(AVLL) + AC
        GO TO 746
    740 AREF = BC* TAN(ALL) + AC
        BREF = BC* TAN(BLL) + AC
        AVREF = BC* TAN(AVLL) + AC
        GO TO 746
    750 CONTINUE
    760 CONTINUE
    770 CONTINUE
        AREF = ALL
        BREF = BLL
        AVREF = AVLL
    748 BREF = AES(BEEP - AVEEP)
    WRITE(IWRITE,7050) LL, AREF, AVREF, BREF
7050 FORMAT(1H,2X,11HCONSEQUENCE,12,18HMEAN VALUE=,E12.5,17H ERROR VALUE=,E12.5//)
    WRITE(IWRITE,7051)
7051 FORMAT(1H,41H END OF INVERSE TRANSFORMED MOMENT VALUES//)
    749 CONTINUE
C END OF MOMENT INFO INVERSE TRANSFORMATIONS
2022 FORMAT(6H CONSEQ MEAN VALUE STANDARD DEV MEAN VALUE S
STANDARD DEV//)
    IF (NCONS.LT.2) GO TO 208
2030 FORMAT(54H CON1 CON2 CORREL COEFF LIN CORREL COEFF//)
2031 FORMAT(1H,15JX,114,6X,F10.8,12X,F10.8)
MEMBER NAME DRIVER

2032 FORMAT(34H0 2ND OF MOMENT OUTPUT IN JOBI 2/) WRITE(6,2030) WCOI=NCONS-1 DO 206 L=1,NCOI LPJ=L+1 DO 207 M=LPJ,NCONS WRITE(6,2031) L,M,CGt2EL(L,M),SIMCOR(L,M)

207 CONTINUE
206 CONTINUE
208 WRITE(6,2032)

IF(JCBI.GT.2) GO TO 300
C IF IFIT =1, JOBI 2 MOMENTS CALCULATED FOR THE FITTED RESPONSE
C SURFACES, DISC.
IF(IFIT.NE.1) RETURN
C THE FIRST CALL OF SUBROUTINE REPLAC SETS IFIT = 2, REPLAC NOT CALLED
C AGAIN.
CALL REPLAC(BF,NCOEF2,IFIT)
WRITE(6,4001)
GO TO 610

4001 FORMAT(1H1,6X,70H*** ANALYTICAL MOMENTS OF THE FITTED RESPONSE SURFACE CONSEQUENCES ***//16X,48HSECOND DEGREE FITTED TO SYSTEMATIC 2 KNOT-POINTS//)
C JOBI 3, DISTRIBUTIONS OF APPROXIMATE CONSEQUENCES
300 CONTINUE
IF(NQUAD.LT.4.OR.JOBI.NE.7) GO TO 702
C USE RANGE LT 0.1 OR RANGE NFEDED IN POLYQ SUBROUTINE, RADSQ IN WEIPOL
C DEFAULT RANGE = RANGE
IF(RANGE.LT.0.) RANGE = 0.33
DO 701 J=1,NPARA DELR = RANGE *(Z1(J)-Z2(J))* 0.5 RADSQ(J) = 0.5/(DPLR*DELR)
701 CONTINUE
702 CONTINUE
C WEIERR calculates the errors of the weighted x-q surface in its k-pts
CALL WEIERR
IF(JOBI.FQ.7.OR.JOBI.EQ.8) CALL SANDIS
IF(JOBI.FQ.7.OR.JOBI.EQ.8) CALL NEWZO
IF(JOBI.EQ.7) JOBI=3
IF(JOBI.EQ.8) JOBI=4
NDQ = 0
NE=0
C #SA=NUMBER OF SIMULATION CYCLES IN JOBI 3
C NEXT TEST IS TO PROTECT DRIVER FROM READING IN THIS INFORMATION TWICE
C
C SUBROUTINE CRITIN READS CRITERIA FOR CONDITIONAL DISTRIBUTIONS
IF(JOBI.FQ.4.AND.IFIT.NE.2) CALL CRITIN
C CONDITIONS DETERMINE CATEGORY LIMITS (BOUNDARIES), TOO,
C FOR CRITERIA VARIABLES.
C FOR IS UPPER LIMIT OF CONSEQ NCE IF LCE GT 0, OTHERWISE LOWER LIMIT
4001 FORMAT(2J16,F6.2,2X,4(I2,12,G11.4))
C 12 HISTOGRAM CATEGORIES , WIDTH = SCALE*ANALYTICAL STANDARD DEVIATION
DO 360 L=1,6 SUMA(L)=0.
MEMBER NAME DRIVER
SOME(L) = 0.
SUC(L) = 0.
SUBD(L) = 0.
CSUMA(L) = 0.
CSUBE(L) = 0.
CSUMC(L) = 0.
CSUDD(L) = 0.
DO 364 J = 1, 12
NHIS(L, J) = 0
NCIS(L, J) = 0
DO 362 M = 1, 6
DO 363 K = 1, 12
NJINT(L, M, J, K) = 0
NCINT(L, M, J, K) = 0
363 CONTINUE
362 CONTINUE
364 CONTINUE
DO 365 K = 1, 26
IFC(L, K) = 0
ICPIC(L, K) = 0
365 CONTINUE
360 CONTINUE
NC = 0
C INDEX SET TO 30 FOR FUNCTION SIMULATION BY TEXAS
IF (TEST.EQ.30) INDEX = 30
IF (JOBI.EQ.5) GO TO 501
310 NC = NC + 1
C RANDOM SAMPLING
CALL SAMPLE
IF (TEST.EQ.30) CALL TEXAS
IF (TEST.EQ.30.AND.MTREC.GT.0) CALL TRACO(CONS)
IF (TEST.EQ.30) GO TO 350
IF (MTREC.GT.0) CALL TRACO(Z)
IF (JOBSV.GT.21.AND.JOBISV.LT.31) CALL RESPON
IF (JOBSV.GT.21.AND.JOBISV.LT.31) GO TO 351
C CALCULATE POLYNOMIAL CONSEQUENCES
IF (NQUAD.LT.2.OR.IFIT.EQ.2) GO TO 350
CALL PCLYQ
GO TO 351
350 CONTINUE
DO 341 L = 1, NCONS
IF (TEST.EQ.30) APZETA(L) = CONS(L)
IF (TEST.EQ.30) GO TO 341
APZETA(L) = A(L)
DO 342 J = 1, NPARA
DTERM = 0.
IF (J.EQ.NPARA) GO TO 344
JPI = J + 1
DO 343 K = JPI, NPARA
DTERM = DTERM + D(L, J, K) * (Z(K) - Z0(K))
343 CONTINUE
344 CONTINUE
DTERM = B(L, J) * C(L, J) * (Z(J) - Z0(J)) + DTERM
APZETA(L) = APZETA(L) + DTERM * (Z(J) - Z0(J))
342 CONTINUE
341 CONTINUE
351 CONTINUE
C UNCONDITIONAL SAMPLE MEAN VALUE AND CENTRAL MOMENT SUMS
72

MEMBER NAME DRIVER

DO 346 L=1,NCONS
APZ1=APZETA(L)-AVZET(L)
SUMA(L)=SUMA(L)+APZ1
APZ2=APZ1*APZ1
SUMB(L)=SUMB(L)+APZ2
SUMC(L)=SUMC(L)+APZ1*APZ2
SUMD(L)=SUMD(L)+APZ2*APZ2
346 CONTINUE

C HISTOGRAM
CALL HISTO(IFLO,WHIS,NJOINT)
IF (JOBI.EQ.4) GO TO 401
353 IF (NC.LT.NSA) GO TO 310

C PRINT DISTRIBUTIONS JOBI 3
3001 FORMAT(6Z1 *DISTRIBUTIONS OF THE RESPONSE SURFACE CONSEQUENCES,
1* WORK,17//6H **CATEGORIES DEFINED BY ANALYTICAL MOMENTS**/)
3002 FORMAT(38H NUMBER OF SIMULATION CYCLES =,18/)
369 WRITE(6,3001) WORK
3 C PRINT UNCONDITIONAL SAMPLE CHARACTERISTICS
3100 FORMAT(6X,*WORK',17,'1X,'NUMBER OF SAMPLES','=,'18,'1/)
WRITE(6,3102)
3102 FORMAT(T2,'CONSEQUENCE',T15,'SAMPLE MEAN VALUE',T36,'SAMPLE STANDA
1RD DEVIATION',T65,'SCM3',T83,'SCM4'/)
FSAMPL=FLOAT(NC)
DO 37C L=1,NCONS
SAMEAN(L)=SUMA(L)/FSAMPL+AVZET(L)
DEL=AVZET(L)-SAMEAN(L)
SUB=SUMB(L)/FSAMPL-DEL**2
SASD(L)=SQRT(FSAMPL*SUB/(FSAMPL-1.))
SCM3=SUMC(L)/FSAML+3.*SUB/(FSAML*DEL-2.*DEL**3)
SCM4=SUMD(L)/FSAML+4.*DEL*SUB/(FSAML*DEL**2*SUBB(L)/FSAML-3.*DEL**4
WRITE(6,31G1) L,SAMEAN(L),SASD(L),SCM3,SCM4
3101 FORMAT(5X,12,8X,G14.6,11X,G14.6,6X,G14.6,6X,G14.6)
370 CONTINUE
IFLAG = 0
WRITE(6,3002) NC
CALL PRINTW(NHIS,NJOINT,NC)
WRITE(5,3018)
3018 FORMAT(4CH0 END OF JOINT DISTRIBUTIONS IN JOBI 3)

C DISTRIBUTION PLOTTING INFO
WRITE(6,32G0)
3200 FORMAT(1H60H PROBABILITY PER CATEGORY SKETCH IN HALF CATEGORY I
1NTervalS/16O,16X,5H CATEGORY,3X,11HPROBABILITY,20X,7H SKETCH/)
DO 380 L=1,NCONS
WRITE(IWRITE,4G0) L
DIVE = 1. / (SCALE*SCZET(L))
DO 381 K=1,26
FNC=FLOAT(NC)
IP(K)= FLOAT(IPLO(L,K))/FNC * 2.
TP(K)= FLOAT(INT(FLOAT(K)/2.))
PROUNT = IP(K) * DIVE
WRITE(IWRITE,46G1) TP(K),PROUNT
381 CONTINUE
WRITE(6,3201) L
CALL FLCTFP(26,TP,XP)
380 CONTINUE
3201 FORMAT(1H1L,10X,11HCONSEQUENCE,13/)
MEMBER NAME DRIVER
C JOB 3 ENDS HERE IF NOT REPEATED WITH FITTED RESPONSE SURFACE
C IF (JOB1.NE.3) GO TO 400
C IF IFIT=1 JOB 3 AND ANALYTICAL MOMENTS OR JOB 2 ARE CALCULATED
C WITH THE FITTED RESPONSE SURFACE ALSO
C IF (IFIT.NE.1) RETURN
C (IF IFIT =0 OR 2) RETURN
C THE FIRST CALL OF SUBROUTINE EEPLAC SETS IFIT = 2, EEPLAC NOT CALLED
C AGAIN.
C CALL EEPLAC(BP,NCOEP2,IFIT)
C WRITE(IWFITE,6002)
C GO TO 610
6002 FORMAT(1HI1,6X,58H*** JOB 3 WITH THE FITTED QUADRATIC RESPONSE SURFACE
C ***/2CH1,52H FITTED TO THE SYSTEMATICAL MULTIQUADRIANT KNOT-PO
C INTS/**)C JOB 4
C CONTINUE
C JOB 4
C CONTINUE
C ELLIPTED CRITERIA CHECKING
C 401 DO 403 K=1,4
C NCBIT= NCBIT(K)
C LCRIT= LCR(K)
C PCBIT= PCBIT(K)
C SAMPLE CRITERIA (IF ANY)
C IF(K.LE.1) OR (COND) CALL CHISAM(FCRIT,K)
C IF(NTRACC.LE.0) GO TO 440
C SAMPLE CRITERIA MUST BE TRANSFORMED IF IT IS A TRANSFORMED CONSEQUENCE
C DO 706 I=1,NTRACO
C LL = LTFI(I)
C IF(LL.NE.NCBIT) GO TO 706
C LTYP = LTYPE(I)
C AC = ACC(I)
C BC = BCC(I)
C DFCRIT = FCRIT-AC
C GO TO (711,721,731,742,751,761,771),LTYP
C 711 FCRIT = DFCRIT*BC
C GO TO 706
C 721 FCRIT = ALOG(DFCRIT)
C GO TO 706
C 731 FCRIT = EXP(DFCRIT/BC)
C GO TO 706
C 742 FCRIT = ATAN(DFCRIT/BC)
C GO TO 706
C 751 CONTINUE
C 761 CONTINUE
C 771 CONTINUE
C 706 CONTINUE
C SAMPLE CRITERIA TRANSFORMED
C 400 CONTINUE
C PCBIT(K) = FCRIT
C IF(NCRIT.LE.0) GO TO 403
C COZETA = APZETA(NCRIT)
C TOLL = TCLS*SDZETA(NCRIT)
C IF(LCRIT) 405,406,406
C 405 IF(COZETA - FCRIT + TOLL).LT.353,403,403
C 406 IF(COZETA - FCRIT + TOLL).GT.303,403,353
C 403 CONTINUE
C OUTPUT FOR CAC SIMULATION
IF (NE .GE. NSC) GO TO 407

4002 FORMAT (8X, (6112, 6))
IF (IFIT .NE. 2 .AND. JOBISV .EQ. 14 .OR. JCBISV .EQ. 24)
1 WRITE (6, PUNCH, 4002) (Z(L), L = 1, NPABA)
C SET TEST = 4 IF CONDITIONAL POINTS TO BE PRINTED TOC
IF (TEST .EQ. 4 .AND. IFIT .NE. 2) WRITE (6, PUNCH) (Z(L), L = 1, NPARA)
407 NE = NE + 1
C UNRELIEVED CRITERIA CHECKING
DO 413 K = 1, 4
NCIT = NCR(K)
LCBIT = LCE(K)
PCBIT = FCR(K)
IF (NCIT .LE. 0) GO TO 413
COZETA = APZETA(NCRIT)
IF (LCBIT) 415, 415, 416
415
IF (COZETA - FCRIT) 417, 413, 413
416 IF (COZETA - PCBIT) 41x, 413, 417
413 CONTINUE
ND = ND + 1
C CONDITIONAL SUMS
DO 430 L = 1, NCONS
APZ1 = APZETA(L) - AVZET(L)
CSUMA(L) = CSUMA(L) + APZ1
APZ2 = APZ1 * APZ1
CSUME(L) = CSUME(L) + APZ1 * APZ2
CSUMC(L) = CSUMC(L) + APZ1 * APZ2
CSUMD(L) = CSUMD(L) + APZ2 * APZ2
430 CONTINUE
C CONDITIONAL HISTOGRAM
CALL CISTO(ICLLO, NCLS, NCOINT)
417 IF (NSB .GE. NSB) GO TO 369
GO TO 353
4010 FORMAT (7CH1 CONDITIONAL DISTRIBUTIONS OF CONSEQUENCES - JOBI 4 -
1 WORK NUMBER =, 18//)
490 WRITE (6, 4010) WORK
WRITE (6, 4010)
4020 FORMAT (54H SELECTIVE SIMULATION OF POLYNOMIAL CONSEQUENCES//)
WRITE (6, 4011) NSA, NSB, NSC, TCTLE, NCON, (NCR(K), LCE(K), K = 1, 4)
C MODIFY HISTOGRAM CATEGORY SHIFT IN CISTO FOR COND. DISTRIBUTION
WRITE (6, 4017)
WRITE (6, 4012) NC, ND, NE
C LIMITS FOR SIMULATION CYCLES
4011 FORMAT (18, 6X, 46H LIMIT FOR UNCONDITIONAL SIMULATION CYCLES NSA =, 18
1/1H , 6X, 46H LIMIT FOR UNRELIEVED CONDITION. CYCLES NSB =, 17/1H , 6
2X, 46H LIMIT FOR RELIEVED CONDITION. CYCLES NSC =, 17/1H , 6
2X, 46H LIMIT FOR CONDITIONAL CYCLES NSD =, 17/1H , 6
ACTUAL CONDITIONS =, 10H, 9X, 11H, 16H)
4017 FORMAT (18, 26X, 6X, 12H LIMIT TYPE =, 14)
4012 FORMAT (10H, 6X, 25H NUMBERS OF SIMULATION CYCLES//)
WRITE (6, 4014) (FRACN, 8X, 18H CONDITIONAL NO. =, 18, 1H , 2X, 21H UNRELIEVED CON
2DIT , NE =, 18//)
4015 FORMAT (54H FOR POLYNOMIAL CONSEQUENCES WITH UNRELIEVED CRITERIA)
WRITE (6, 4014) (FRACN, 8X, 18H)
WRITE (6, 4018) REPRAC
4014 FORMAT (42H FRACTION SATISFYING CONDITIONS = ND/NC =, F8.6//)
NEBE& NANE DRIVEP 4018 FORMAT(1H,47H FRACTION SATISFYING RELIEVED CONDITIONS NE/NC=,F8.6
1,/) WRITE(6,4015)
WRITE(6,4013) ND C PRINT CONDITIONAL SAMPLE MEAN VALUE AND CENTRAL MOMENT CHARACTERISTICS C OF THE APPROXIMATE (RESPONSE SURFACE) CONSEQUENCES BASED ON ND VALUES WRITE(6,4400) JOEI, WORK
4400 FORMAT(1H0,10X,57H SAMPLE CONDITIONAL MEAN AND OTHER CHARACTERISTIC
1S IN JOEI,13,3,H (RESPONSE SURFACE CONSEQUENCES)/1H0,10X,YMC WORK 2K ,16/1E,10X,11H CONSEQUENCE,34,11H MEAN VALUE,4X,18H STANDARD DEVI
3ATION,6X,GNSCCM3 ,12X,T0BSCCM4 /
FND=FLCAM(ND)
DO 431 L=1, NCONS
IF(ND.LE.1)
CSMEAN(L)=CSUMA(L)/FND+AVZET(L)
DEL= AVZET(L)-CSMEAN(L)
CUB=CSUME(L)/FND - DEL**2
CSSD(L) = SQRT(FND * CUB/(FND - 1.))
SCCC(L)=CSUMC(L)/FND+3.*CSUMB(L)/FND*DEL - 2.*DEL**3
SCCM3 =CSUMD(L)/FND+4.*DEL*CSUMC(L)/FND+6.*DEL**2*CSUMB(L)/FND
1-3.*DEL**4
WRITE(6,4401) L, CSMEAN(L), CSSD(L), SCCC(L), SCCM3
4401 FORMAT(1L1,20X,25EiCONDITICNAL DISVRIBUTIDN//55H (ANALYT
ICAL UNCONDITIONAL MOMENTS IN TITLES)/)
C CONDITIONAL DISTRIBUTION PLOTTING INFO
WRITE(6,3200)
WRITE(6,4200)
4200 FORMAT(1H0,10X,47H CONDITIONAL DISTRIBUTIONS OF THE RESPONSE SURFS)
4600 FORMAT(1H0,10X,47H PROBABILITY PDF UNIT OF CONSEQUENCE',13/) 4601 FORMAT(1H1,15X,13X,K,G12.6,G12.6,G12.6,G12.0,G12.6)
DO 485 L=1, NCONS
WRITE(6,4600) L
DIVE = 1. / (SCALE*SDZET(L))
DO 486 K=1,26
FND = FLCAT(ND)
XC(K) = FLOAT(IPCLO(L,K))/FND*2.
TC(K) = FLOAT(INT(FLOAT(K)/2.))
PROUNT = XC(K) * DIVE
WRITE(6,4601) TC(K), PROUNT
486 CONTINUE
WRITE(6,3201) L
CALL PLCTFP(26,TC,LC)
485 CONTINUE
C JOBI 4 ENDS HERE IF NOT REPEATED WITH FITTED SURFACE
IF(IFIT.NE.1) RETURN
C THE FIRST CALL OF SUBROUTINE REPLAC SETS IFIT =2, REPLACE NOT CALLED
C AGAIN
CALL REPLAC(BF, NCOEF2, IFIT)
WRITE(6,6003)
GO TO 610
6003 FORMAT(1H1,6X,57H*** JOBI 4 WITH THE FITTED QUADRATIC RESPONSE SUB
MEMBER NAME DRIVER
1PACE ***//20X,57HPITTED TO THE SYSTEMATICAL MULTIGRANANT KNOT-PO
ZINIS ***//)
501 NA=0
NB=0
C
C READ CONDITIONS BY CRITIN
C JOBI 5 MEANINGFUL WITH FIXED CONDITIONS ONLY,ICIS(K) =0 , OR WITH
C NON-EFFICIENT CONDITIONS
IF(JOBI.EQ.5) CALL CRITIN
DO 502 I=1,NSC
READ(5,4002) (Z(L),L=1,NPARA)
C CALCULATE POLYNOMIAL CONSEQUENCES
IF(NQUAL.LT.2) GO TO 550
CALL FLYQ
GO TO 551
550 CONTINUE
DO 541 L=1,NCONS
APZETA(I) = A(L)
DO 542 J=1,NPARA
DTERM=0.
IF(J.EQ.NPARA) GO TO 544
JPI=J-1
DO 543 K=JPI,NPARA
DTERM = DTERM + D(L,J,K) * (Z(K)-ZO(K))
543 CONTINUE
544 ATERM = P(L,J) + C(L,J) * (Z(J)-ZO(J)) + DTERM
APZETA(L) = APZETA(L) + ATERM * (Z(J)-ZO(J))
APZ(I,L) = A(L)
541 CONTINUE
551 CONTINUE
C UNRELIEVED CRITERIA CHECKING
DO 513 K=1,4
MCRIT = NCR(K)
LCRIT = LCR(K)
FCRIT = FCR(K)
CALL CRISAM(FCRIT,K)
C SAMPLE RANDOM CRITERIA (IF ANY)
IF(K.LE.NCOND) CALL CRISAM(FCHIT,K)
FCR(K) = FCHIT
IF(NCRIT.LE.0) GO TO 513
CZETA = APZETA(NCRIT)
IF(LCRIT) 515,515,516
515 IF(CCZETA .LT. FCRIT) 502,513,513
516 IF(CCZETA .GT. FCHIT) 502,513,516
513 CONTINUE
NA=NA+1
502 CONTINUE
F5A = FLOAT(NA) / FLOAT(NSC)
DO 504 I=1,NSC
IF(TEST.NE.5) READ(5,5004) (CONS(M),M=1,NCONS)
5004 FORMAT( 8x,5E12.6)
IF(TEST.EQ.5) READ(5,4002) (Z(J),J=1,NPARA)
IF(TEST.EQ.5) CALL TEXAS
DO 531 L=1,NCONS
APZETA(L) = CONS(L)
531 CONTINUE
C UNRELIEVED CRITERIA CHECKING
DO 573 K=1,4
MEMBER NAME DRIVER
NCIT = NCR(K)
LCIT = LCR(K)
FEBIT = FCR(K)
IF(NCIT.LE.0) GO TO 573
COZETA = APZETA(NCIT)
IF(LCIT) 575, 575, 576
573 CONTINUE
NB = NB + 1
CALL CISTO(ICPLO, NCIS, NCOINT)
SSAVE = SCALE
SCALE = TOLE/2.
DO 561 L = 1, NCONS
APZETA(L) = CONS(L) - APZ(I, L)
SAVZET(L) = AVZET(L)
AVZET(L) = 0.
561 CONTINUE
CALL HISTO(IPLO, NHIS, NJOINT)
SCALE = SSAVE
DO 562 L = 1, NCONS
562 AVZET(L) = SAVZET(L)
504 CONTINUE
FEB = FLOAT(NB) / FLOAT(NSC)
WRITE(6,5005) WOK, NSC, FRA, TOLE, FRB
WBITE(4011) NSA, NSE, NSC, TOLE, NCOint, (ICR(K), LCR(K), c = 1, 4)
5005 FORMAT (1H1, 25X, 17H5 RESULTS FOR WEEK, 17/100, 15X, 25H STATISTICS
1 BASED ON NSC = , 14, 18 CONSEQUENCE CARDS/140, 15X, 62% FRACTION OF AP
2 APPROXIMATE CONSEQUENCES SATISFYING UNBELIEVED CONDITIONS/140, 15X, 3
3 HB/NASC = , F9.5/1H , 15X, 11% WITH TOLE =, F6.2/1H0, 15X, 62% FRACTION OF
4 EXACT CONSEQUENCES SATISFYING UNBELIEVED CONDITIONS/140, 15X, 63HB/N
5SC = , F9.5/1H0, 15X, 92% HISTOGRAMS FOR EXACT CONSEQUENCES (TITLE NO
6ENTS FOR UNCONDITIONAL APPROXIMATE CONSEQUENCES) 
IF(TEST.EQ.5) WRITE(6,5007)
5007 FORMAT (1H1, 15X, 3B8H EXACT CONSEQUENCES FROM TEXAS (TEST=5) )
IFLAG=1
CALL PRINTH(NHIS, NJOINT, NB)
WRITE(6,3260)
C FLOWING INFO
DO 565 L = 1, NCONS
DO 566 K = 1, 26
FND = FLCAT(NB)
XC(K) = FLOAT(ICPLG(L, K)) / FND*2.
TC(K) = FLOAT(INT(FLOAT(K)/2.))
586 CONTINUE
WRITE(6,3201)L
CALL PICTPP(26, TC, XC)
AVZET(L) = 0.
585 CONTINUE
SCALE = TOLE/2.
IFLAG=0
WRITE(6,5006) NB, SCALE
5006 FORMAT (1H1, 15X, 19H HISTOGRAMS FOR THE , 14, 51H DIFFERENCES-EXACT MI
1NS APPROXIMATE- WITH SCALE =, F6.2, 18H CENTERED AROUND 0/1H , 15X,
218H (MEAN VALUE NOT 0 ) )
CALL PRINTH(NHIS, NJOINT, NB )
WRITE(6,3200)
DO 580 L = 1, NCONS
MEMBER NAME DRIVER

DO 581 K=1,26
FNC=FLOAT(NB)
XP(K) = FLOAT(IPLO(L,K))/FNC * 2.
TP(K) = FLOAT(INT(FLOAT(K)/2.))
581 CONTINUE
WRITE(6,3201) L
CALL PLOTFP(26,TP,XP)
580 CONTINUE
RETURN
END
SUBROUTINE BIASD(DEE, NY)

C SUBROUTINE BIASD CALCULATES TERMS IN ANALYTICAL MEAN VALUES OF THE CONSEQUENCES IF CORRELATED INPUT PARAMETERS PRESENT CALLED BY MAIN, ONLY IF NCORR.GT.0

*CALL COMM

DIMENSION DEE(d,12,12)
DO 163 L = 1, NCONS
   SU = 0.
   DO 168 J = 1, NY
      IF (J.EQ.NY) GO TO 168
      JPI = J + 1
      DO 169 K = JPI, NY
         SU = SU + DEE(L, J, K) * CM11(J, K)
      169 CONTINUE
   168 CONTINUE
   AVZET(L) = AVZET(L) + SU
163 CONTINUE
RETURN
END
SUBROUTINE CEMOPA

C SUBROUTINE CEMOPA CALCULATES FINAL CENTRAL MOMENTS OF THE PARAMETERS
C WHEN CORRELATED INPUT PARAMETERS PRESENT
C CALLED BY MAIN, ONLY IF NCORR GT 0
C
CALL COdMP

DO 173 I=1,NCOFB
  JJ=ILEAD(I)
  KK=IDEP(I)
  AYES= ALFA(JJ,KK)**2
  CM2(KK)= CM2(KK) + CM2(JJ) * AYES
  CM3(KK)= CM3(KK) + AYES*CM3(JJ) * ALFA(JJ,KK)
  CM11(JJ,KK)= AYES * CM2(JJ) * CM2(KK)
  CM11(KK,JJ)= AYES * (CM2(JJ) * CM2(KK) + CM2(JJ) * CM2(KK))
  CM11(JJ,KK)= ALFA(JJ,KK) * CM2(JJ)
  CM11(KK,JJ)= CM2(JJ) * CM2(KK)
  CM11(KK,JJ)= CM11(JJ,KK) + CM11(JJ,KK)
  CM11(JJ,KK)= CM11(JJ,KK) * ALFA(JJ,KK) * CM2(JJ)
  CM11(KK,L)= CM2(JJ) * ALFA(JJ,KK) * ALFA(JJ,L)
  CM11(KK,L)= CM11(KK,L) + CM11(KK,L)

173 CONTINUE

DO 177 I=1,NCOFB
  IF(I.EQ.NCOFB) GO TO 177
  L=L+1
  LSAV = L
  DO 179 L=L,L,NCOFB
    IF(ILEAD(L).NE.JJ) GO TO 179
    LL=IDEP(L)
    CM11(KK,LL)= CM2(JJ) * ALFA(JJ,KK) * ALFA(JJ,LL)
    CM11(KK,LL)= CM11(KK,LL) + CM11(KK,LL)

177 CONTINUE

L = LSAV
RETURN
END
SUBROUTINE CENTS
C CALCULATES E- AND C- COEFFICIENTS IN THE CENTRAL PART KNOT-POINTS
C 4,0,3 RATHER THAN 2,0,1. CALLED BY DRIVER WHEN NQUAD =4.
*CALL CCMP
DO 10 L=1,NCONS
DO 20 J=1,14
B1 = (ZETA3(L,J)-ZETAO(L)) / ((Z3 (J)-Z0(J)) * (Z3(J)-Z4(J))
B2 = (ZETA4(L,J)-ZETAO(L)) / ((Z4 (J)-Z0(J)) * (Z4(J)-Z3(J))
C(L,J) = B1 + B2
20 B(L,J) = F1*(Z0(J) - Z4(J)) + B2 *(Z0 (J) - Z3(J))
10 CONTINUE
RETURN
END
SUBROUTINE CISTO(MCPLO,MIS,NCONS)

C C CISTO CALCULATES CONDITIONAL DISTRIBUTIONS IN JOBIS

C *CALL CCMHF

C * CCMDN/GFAYV/CAVF(4)

C * CCMDN/CONDIS/NSE,NSE,NSE,NCONS,TOLE

C DIMENSION MCPLO(L,24)

C DIMENSION MIS(L,4),ICIS(L,4),BCIS(L,4),CCIS(L,4),DCIS(L,4)

C C CATEGORY EQUATIONS FOR CRITERIA CONSEQUENCES BASED ON AVERAGE CRITERIA VALUE

C C CHAVE(P) TO BE BETWEEN CATEGORIES 6 AND 7 FOR REALLY RANDOM CRITERIA

C C TO BE LL OF CATEGORY 1 IF ICIS(M)=0 AND LCR(K)=1

C C TO BE UL OF CATEGORY 12 IF ICIS(M)=0 AND LCR(K)=1

C AVERAGE CRITERIA BETWEEN CATEGORIES 6 AND 7

C EXCEPT FIXED CRITERION IS AT THE END

DO 441 L=1,NCONS

DIVE = 1./(SCALE*SDZET(L))

DEVL = (APZETA(L)-AVZET(L))*DIVE

HISL = DEVL +7.

PISL = HISL + HISL

DO 450 K=1,4

IF (L.NE.LCR(K)) GO TO 450

IF (ICIS(K)) 443,44X,444

443 FREE = CFAVE(K)

DEVL = (APZETA(L) - FREE) * DIVE

HISL = DEVL +7.

IF (ICIS(K).EQ.0) HISL = DEVL +1

GO TO 450

444 FREE = CFAVE(K)

DEVL = (FREE - APZETA(L)) * DIVE

HISL = 7. - DEVL

IF (ICIS(K).EQ.0) HISL = 13. - DEVL

PISL = HISL + HISL

GO TO 450

450 CONTINUE

NL = INT(HISL)

NP = INT(PISL)

IP(NP.LE.0) NP = 1

IF (NP.GT.26) NP = 26

MCPLO(L,NP) = MCPLO(L,NP) +1

IF (NL.LE.11) NL = 11

IF (NL.GT.12) NL = 12

MIS(L,NL) = MIS(L,NL) +1

IF (L.EQ.NCONS) GO TO 441

LPI = L+1

DO 442 M=LPI,NCONS

DIM = 1./(SCALE*SDZET(NP))

DEVM = (APZETA(NP) - AVZET(NP)) * DIM

HISM = DEVM +7.

DO 460 K=1,4

IF (NR.NE.LCR(K)) GO TO 460

IF (ICIS(K).EQ.0) HISM = DEVM + 1.

GO TO 460

463 FREE = CHAVE(K)

DEVM = (APZETA(NP) - FREE) * DIM

HISM = DEVM + 7.

IF (ICIS(K).EQ.0) HISM = DEVM + 1.

GO TO 460

464 FREE = CFAVE(K)
MEMBER NAME CISTIC

DEVE = (FFEF - APLETA(S)) * DIM
HISE = 7. - DEVM
IF(ICIS(F).EQ.0) HISM = 13. - DEVM

C CAN STILL BE OPTIMIZED
460 CONTINUE
  MM = INT(HISE)
  IF(MM.LT.3) MM = 1
  IF(MM.GT.12) MM = 12
  NCO_L(N,M,NL,N3) = NCOINT(L,3,NL,MM) + 1
442 CONTINUE
441 CONTINUE
RETURN
END
C
C SUBROUTINE CMPABA CALCULATES MEAN VALUE AND HIGHER CENTRAL MOMENTS
C OF THE PARAMETERS
C
CALL CMPABA
LSAV = L
GO TO 171
J = 1, NPAAL
L = DIS(J)
CM(J) = 0(J)
IF(L .EQ. 6) GO TO 174
GO TO (174, 174, 174, 178, 182, 184, 186, 186)
174 HELpis = (DIS(J) + DIS(J) ** 2)
CM(J) = 0.
CM(J) = HELpis/12.
CM(J) = HELpis*HELpis/80.
GO TO 171
176 CM2(J) = DIS(J) * DIS(J)
CM3(J) = 0.
CM4(J) = 3.0 * CM2(J) * CM2(J)
GO TO 171
178 CM2(J) = DIS(J) * DIS(J)
CM3(J) = DIS(J) ** 2 - 1. * DIS(J) ** 2 - 3. * HELpis ** 2 + 2. * HELpis ** 3
CM4(J) = 3.0 * CM2(J) * CM2(J)
CM(J) = 0.5 * DIS(J) * CM3(J)
IF(L .EQ. 4) CM3(J) = -CM3(J)
GO TO 171
180 AK = 1./(.5 - .5*ERF((TJUS(J) - ADIS(J))/SQRT(2.) * DIS(J) ** 2))
AM = ADIS(J) - DIS(J)
AM = AM
FACT = DIS(J) * AK/SQRT(6.2832) * EXP(-DIS(J) ** 2/2. * DIS(J) ** 2)
CM2(J) = FACT ** 2 + AM * FACT - FACT ** 2
CM3(J) = AM ** 2 + FACT + AM * FACT ** 2 + 2. * FACT ** 3
CM4(J) = 3.0 * DIS(J) ** 2 * FACT + FACT ** 2 + 2. * FACT ** 3
CM5(J) = CM2(J) + CM3(J) + CM4(J)
GO TO 171
182 BK = 1./(.5 - .5*ERF((TJUS(J) - ADIS(J))/SQRT(2.) * DIS(J) ** 2))
BM = BM
FACT = DIS(J) * BK/SQRT(6.2832) * EXP(-DIS(J) ** 2/2. * DIS(J) ** 2)
CM2(J) = FACT ** 2 + BM * FACT - FACT ** 2
CM3(J) = BM ** 2 - 1. * DIS(J) ** 2 - 3. * HELpis ** 2 + 2. * HELpis ** 3
CM4(J) = 3.0 * DIS(J) ** 4 + FACT ** 2 + FACT ** 3 + FACT ** 4
CM5(J) = CM2(J) + CM3(J) + CM4(J)
GO TO 171
184 CM2(J) = DIS(J) ** 2
BEAY = DIS(J) - ADIS(J)
CM3(J) = BEAY ** 3/2.
CM4(J) = (CM2(J) ** 2 + CM3(J) ** 2 + CM4(J) ** 2) / (CM2(J) ** 2) - 1.
CM5(J) = CM2(J) ** 2 + CM3(J) ** 2 + CM4(J) ** 2 + CM5(J) ** 2 - 1.
CM6(J) = CM2(J) ** 2 + CM3(J) ** 2 + CM4(J) ** 2 + CM5(J) ** 2 + CM6(J) ** 2
GO TO 171
GO TO 171
MEMBER NAME CHEAPA

9166 CM7(J) = (EXP(2.*ADIS(J) + BDIS(J)**2)) * (EXP(5.*DIS(J)**2) - 1.)
CM3(J) = EXP(3.*ADIS(J)) * EXP(1.5*BDIS(J)**2) * (EXP(3.*BDIS(J)**2) - 3. * EXP(BDIS(J)**2) + 2.)
CM4(J) = EXP(4.*ADIS(J) + 2.*BDIS(J)**2) * (EXP(6.*BDIS(J)**2) - 4.*EXP(3.*BDIS(J)**2) + 6.*EXP(BDIS(J)**2) - 3.)

171 CONTINUE

L = LSAV
RETURN
END
SUBROUTINE COEFSN

C SUBROUTINE COEFSN CALCULATES B AND C COEFFICIENTS OF THE MULTIGRADEANT C POLYNOMIALS. CALLED BY QUADST ONLY.

C

*CALL COMBP

B1 = (ZETX - ZETy) / ((ZXJ - ZHJ) * (ZXJ - ZXJJ))
B2 = (ZETX - ZETy) / ((ZXLJ - ZJ) * (ZXXJ - ZJJ))
CJ = B1 + B2
SJ = ABS(ZETX - ZETy) + ABS(ZETX - ZETy)
BQ(L, I, J) = B1
CQ(L, I, J) = CJ
SENSQ(L, I, J) = SJ
RETURN
END
SUBROUTINE CKNOT(NDIST)

C SUBROUTINE CKNOT CALCULATES FINAL KNOT POINT COORDINATES Z0, Z1, Z2
C WHEN CORRELATED INPUT PARAMETERS
C CKNOT CALLED BY MAIN, ONLY IF (NCORR .GT. 0)

!CALL CCHMF
DIMENSION NDIST(12)
DO 6 I = 1, NCORR
J J = I LEAD ( I )
K K = I DEP ( I )
AHELP = ( I DEP ( I ) - ZO ( K K ) ) / ( PLEAD ( I ) - ZO ( J J ) )
ALPHA(JJ, KK) = AHELP
IF ( AHELP ) 8, 7, 7
7 DZJ1 = Z1 ( J J ) - ZO ( J J )
DZJ2 = Z2 ( J J ) - ZO ( J J )
GO TO 9
8 DZJ1 = Z2 ( J J ) - ZO ( J J )
DZJ2 = Z1 ( J J ) - ZO ( J J )
9 IF ( NLIST ( K K ) .GT. 1 .AND. NDIST ( J J ) .EQ. 1 ) GO TO 5
Z1 ( K K ) = ZO ( K K ) + SQRT ( ( Z1 ( K K ) - ZO ( K K ) ) ** 2 + ( AHELP * DZJ1 ) ** 2 )
Z2 ( K K ) = ZO ( K K ) + SQRT ( ( Z2 ( K K ) - ZO ( K K ) ) ** 2 + ( AHELP * DZJ2 ) ** 2 )
GO TO 6
5 Z1 ( K K ) = Z1 ( K K ) + AHELP * DZJ1
Z2 ( K K ) = Z2 ( K K ) + AHELP * DZJ2
6 CONTINUE
END
 MEMBER NAME COMMP  
*CCDECK COMM
  INTEGR WORK, TEST  
REAL NAME, NAME
 COMMON/INPFEI/LFAIR, JDBL, L  
COMMON/ZDUC/ 2(12), TEST, INDY, J, K, NPFAI
 COMMON/INOC/ 20 (12), 21 (12), 22 (12), PBOB
 COMMON/KNOT/ ZJL, ZXJ, ZAK, ZAK, ZAK, ZAK, ZCJ, ZCK, ZETA, ZETX, ZETXX
 1, ZETC, ZETO, ZETC, ZETC, ZETC, ZETC, ZETC, ZETC
 COMMON/SEE/ CCNS (6), ZETA0 (6), ZETA1 (6, 12), ZETA2 (6, 12), ZETA3 (6, 12, 12)
 COMMON/MULTI/Q/ NQAD, IQ, NQ, 
 123 (12), 24 (12), ZTA1 (6, 12), ZETA4 (6, 12),
 2ZETA2 (6, 12, 12), ZTAA3 (6, 12, 12), ZETA4 (6, 12, 12)
 COMMON/CCSPP/ B (6, 12), D (6, 12, 12), SEJS (6, 12, 12), SEJSCE (6, 12, 12)
 COMMON/CNFG/ EQ (6, 4, 12), CO (6, 4, 12), DQ (6, 4, 12, 12), SENEQ (6, 4, 12),
 1SENCRQ (6, 4, 12, 12)
 COMMON/HISTOC/ APZETA (6), ZVZET (6), SDZET (6), SCALE, NCONS
 COMMON/EIGCOM/ JK (12, 12),
 1 ADIS (12), BDIS (12), CDIS (12), DDIS (12), IDIS (12), IPARA (12),
 2 JJK (12), JMA (6), JMA (6), JMAX (6), JMAX (6), SIMSC (6),
 3 PNAME (12), PNAME (12),
 4 NCIS (6, 12), NCONIJ (6, 6, 12, 12), NHI (6, 12), NJOMT (5, 6, 12, 12)
 52, CELE (9), ZPLO (9)
 COMMON/EIMA/ AJOINT (12), EZER (12), NC, ND
 COMMON/CONDIT/ N4 (4), NCE (4), TCE (4)
 COMMON/FLAG/ IFLAG
 COMMON/CFREL/ ITYPE (12), ILEE (12), IEDE (12), IDFE (12), IDLE (12), PDEF (12),
 1IDOCR
 COMMON/ALPHA/ ALEF (12, 12)
 COMMON/CMP/ C1 (12), CM2 (12), CM3 (12), CM4 (12), CM11 (12, 12), COR (12, 12)
 COMMON/CNSC/ CSREL (6, 6), SINCOR (6, 6)
 COMMON/CFSOUT/ A (6), NSA, WORK
 COMMON/FRAN/ NSAKP
 COMMON/THIRD/ E (6, 6), 6 (6, 6, 6), 6 (6, 6, 6, 6), SESS (6, 6, 6, 6)
*DECK
MEMBER NAME: CORRE3

SUBROUTINE CORRE3

C
C CORRE3 CALCULATES CORRELATIONS BETWEEN CONSEQUENCES, USING THE THIRD
C DEGREE COEFFICIENTS.
C
*CALL CCMEP
C
C

DO 60 L = 1, NCONS
IF(L.EQ. NCONS) GO TO 60
LPI = L + 1
DO 50 M = LPI, NCONS
COVSUM = 0.
SINCM = 0.
DO 40 J = 1, NPARA

SIMCO = B(L,J) * B(M,J) * CM2(J)
COVA = SIMCC + (B(L,J) * C(M,J) + B(J,J) * C(L,J) + CM3(J)
1 + C(L,J) * C(M,J) * (CM3(J) - CM2(J) * CM2(J))

C
C E AND E*E TERMS GO HERE WHEN HIGHER MOMENTS AVAILABLE.
C

COVB = 0.
COVC = 0.
IF(J.EQ. NPARA) GO TO 35
JPI = J + 1
DO 30 K = JPI, NPARA

COVB = COVB + (B(L,J) * F(M,J,K) + B(M,J) * F(L,J,K)
1 + D(L,J,K) * D(M,J,K) * CM2(J) + CM2(K)
4 + CM3(J) * CM2(K) + CM3(K)
6 + CM2(J) * CM4(K) + CM3(K)
8 + CM4(J) * CM2(K) + CM4(K)
10 + CM3(J) * CM3(K)

COVB = COVB + COVC
COVC = 0.
IF(K.EQ. NPARA) GO TO 30
KPI = K + 1
DO 20 N = KPI, NPARA

COVC = COVC + CM2(J) * CM2(K) * CM2(N)
1 + (F(L,J,N) * F(K,J,K) * E(J,J,K) * F(L,K,N) +

CONTINUE
30 CONTINUE
35 COVSUM = COVSUM + COVA + COVB
40 SINCM = SINCM + SIMCO
IF(SDZET(L).EQ.0.) SDZET(L) = 1. E-24
IF(SDZET(M).EQ.0.) SDZET(M) = 1.E-24
IF(SIMSD(L).EQ.0.) SIMSD(L) = 1.E-24
IF(SIMSD(S).EQ.0.) SIMSD(S) = 1.E-24
CORBEI(L,M) = COVSUM / (SDZET(L) * SDZET(M))
SINCOS(L,M) = SINCOSM / (SIMSD(L) * SIMSD(M))
CONTINUE
RETURN
END
SUBROUTINE COVARI(BEE,NY)

C SUBROUTINE COVARI CALCULATES TERMS IN ANALYTICAL CORRELATIONS BETWEEN C CONSEQUENCES, CALLED BY MAIN, ONLY IF NCORR.GT.0

*CALL COMM*

DIMEN$ICH BEE(6,12)
DO 296 L=1,NCONS
IF(L.EQ.NCONS) GO TO 296
LPI=L+1
DO 297 M=LPI,NCONS
COSU=0.
DO 296 J= 1,NY
IF(J.EQ.NY) GO TO 298
JPI= J+1
DO 299 K=JPI,NY
COSU= COSU + ( BEE(L,J)*BEE(M,K) + BEE(L,K)*BEE(M,J) ) *CM11(J,K)
299 CONTINUE
298 CONTINUE
CORBEL(L,M) = CORBEL(L,M) + COSU/(SDZET(L)*3DZET(M))
297 CONTINUE
296 CONTINUE
RETURN
END
SAMPLES RANDOM CRITERIA FOR CONDITIONAL DISTRIBUTIONS (JOB 4)

NO CORRELATIONS ASSUMED BETWEEN THE CRITERIA VARIABLES

COMMON/CRISAM/ICIS(4), ACIS(4), BCIS(4), CCIS(4), DCIS(4)
DATA IRBITE/6/
LDIS = ICIS(KK) + 1

LDIS = DISTRIBUTION INDICATOR + 1
GO TO TC(10, 20, 25, 30, 35, 40, 45, 50), LDIS
WRITE(IWRIT,1001) KK, ICIS(KK)

10 DUMFCR = ACIS(KK)
RETURN

20 U = FLTBNF(0)
DUMFCR = BCIS(KK) + U * (ACIS(KK) - BCIS(KK))
RETURN

25 U = FLTBNF(0)
V = FLTBNF(0)
W = 1. / U
GA = ((2. * ALOG(W)) ** .5) * COS(6.2831853*V)
DUMFCE = ACIS(KK) + GA * BCIS(KK)
RETURN

30 U = FLTBNF(0)
DUMFCR = ACIS(KK) - BCIS(KK) * ALOG(U)
IF(LDIS.EQ.5) DUMFCR = ACIS(KK) + GA * BCIS(KK)
RETURN

35 U = FLTBNF(0)
V = FLTBNF(0)
W = 1. / U
GA = ((2. * ALOG(W)) ** .5) * COS(6.2831853*V)
DUMFCE = ACIS(KK) + GA * BCIS(KK)
IF(DUMFCR.LT.CCIS(KK)) GO TO 35
RETURN

40 U = FLTBNF(0)
V = FLTBNF(0)
W = 1. / U
GA = ((2. * ALOG(W)) ** .5) * COS(6.2831853*V)
DUMFCE = ACIS(KK) + GA * BCIS(KK)
IF(DUMFCR.GT.CCIS(KK)) GO TO 40
RETURN

45 BEEAY = BCIS(KK) - ACIS(KK)
CEEAY = CCIS(KK) - ACIS(KK)
GAMEW = (BEEAY/CEEAY) * ((BEEAY*(BCIS(KK) - CCIS(KK))/DCIS(KK)**2 - 1.)
ETANEW = GAMEW * ((BEEAY/CEEAY - 1.)
Y = GAMBN(1., GAMEW)
T = GAMBN(1., ETANEW)
DUMFCE = ((Y/(Y+T)) * (BCIS(KK) - ACIS(KK))) + ACIS(KK)
RETURN

C FUNCTION GAMBN(ALAM,ETA) IS A FUNCTION SUBPROGRAM

50 U = FLTBNF(0)
V = FLTBNF(0)
W = 1. / U
GA = ((2. * ALOG(W)) ** .5) * COS(6.2831853*V)
RN = ACIS(KK) + GA* BCIS(KK)
DUMFCE = EXP(RN)
RETURN

1001 FORMAT(180, 9X, 9HCONDITION, 13, 22H, NO DISTRIBUTION, ICIS=, I6, 3X, 20HIN
1 SUBROUTINE CRISAM//)
END
MEMBER  NAME  CRITIN

SUBROUTINE  CRITIN

C  READS  CRITERIA  FOR  CONDITIONAL  DISTRIBUTIONS  (JOB1  4)

*CALL  COMMP

COMMON/CMRY/CRAVE(4)
COMMON/CBCDIS/WSC,NSC,NCND,TOL
COMMON/CCDIS/ICIS(4),ACIS(4),BCIS(4),CCIS(4),DCIS(4)
COMMON/TRANS/FTRAPA,FTABCO,JTRFA(7),JTYPE(7),LTRA(7),LTYPE(7),APA(17),BPA(7),ACO(7),BCO(7)
DATA  ISREAD,WRITE/5,6/
READ(IPEAD,4001) NSB,NSC,TOL,NCND
WRITE(IWRITE,4002) NSB,NSC,TOL,NCND
4001  FORMAT(2I6,F6.2,I6)
4002  FORMAT(1H1//1B,91,44CRITERIA  INPUT  FOR  CONDITIONAL  DISTRIBUTIONS
1/IH,6X,4HNSB=,I6,3X,4HNSC=,I6,3X,5HTOLE=,F6.2,31,6HNCOND=,I6/)
4003  FORMAT(2122,I2,4F11.5)

C  READ  CRITERIA  FOR  EACH  CONSEQUENCE
C  NCRIT = CRITERIA  CONSEQUENCE  NUMBER
C  LCRIT = LIMIT  TYPE, 0 FOR LOWER  LIMIT, 1 FOR UPPER LIMIT
C  JDIS  INDICATES  DISTRIBUTION  TYPE  FOR  THE  CRITERIA  VARIABLE
C  GADIS, [BDIS,UCDIS, UDDIS  ARE DISTRIBUTION  PARAMETERS  FOR  CRITERIA  VARIABLES
DO  2  M=1,NCND
READ(IPEAD,4003) NCRIT,LCRIT,JDIS,UADIS,UBDIS,UCDIS,UDDIS
WRITE(IWRITE,4004) NCRIT,LCRIT,JDIS,UADIS,UBDIS,UCDIS,UDDIS
LCR(M) = NCRIT
LCR(M) = LCRIT
C  FOR  FIXED  NON-RANDOM  CRITERIA  JDIS = 0 AND CRITERIA  VALUE = UADIS
IF(JDIS.EQ.0) Goto 3
C  FOR  RANDOM  CRITERIA  JCR(M) MUST BE SAMPLED FOR EVERY SIMULATION CYCLE
4004  FORMAT(1H1//1B,8H  CRITERIA  INPUT  FOR  CONDITIONAL  DISTRIBUTIONS
1/IH,6X,4HNSB=,I6,3X,4HNSC=,I6,3X,5HTOLE=,F6.2,31,6HNCOND=,I6/)
15,7H  BDIS=,F11.5,7H  CDIS=,F11.5,7H  DDIS=,F11.5/)
ICIS(M) = JDIS
ACIS(M) = UADIS
BCIS(M) = UBDIS
CCIS(M) = UCDIS
DCIS(M) = UDDIS
C  CONDITIONAL  DISTRIBUTION  CATEGORIES  TO BE DEFINED  BASED ON THESE DISTRIBUTION
C  PARAMETERS  SO THAT MOST  OF THE DISTRIBUTION  SHOWS UP
C  CATEGORY  BOUNDARIES  FOR  CRITERIA  CONSEQUENCES  BASED ON AVERAGE CRITERIA VALUE
C  CRAVE(M) - TO BE BETWEEN  CATEGORIES  6 AND 7 FOR REALLY RANDOM CRITERIA
C  - TO BE LESS OF CATEGORY 1 IF ICIS(M)=0  AND LCR(M)=0
C  - TO BE UL OF CATEGORY 12 IF ICIS(M)=0  AND LCR(M)=1
C  CALCULATE  MEAN  VALUE  OF THE CRITERIA, CRAVE(M), USED IN CATEGORY LIMITS ONLY
JDIS = JDIS+1
GO TO (10,20,30,40,50,60,70,80,90),JDIS
10 CRAVE(M) = UADIS
GO TO 2
20 CRAVE(M) = UADIS
GO TO 2
30 CRAVE(M) = UADIS
GO TO 2
40 CRAVE(M) = UADIS
GO TO 2
50 CRAVE(M) = UADIS
GO TO 2
60 CRAVE(M) = UADIS
C IS NOT EXACTLY MEAN VALUE  FOR TRUNCATED NORMAL DISTRIBUTION  BUT IS USED FOR CRAVE
GO TO 2
编程代码如下：

```fortran
CEND OF CRITIN
RETURN
END
```
SUBROUTINE FITCO(ZF, CF, BF, ZFP, AMAT, NKNOT, NCOEF2)

C CALL COEMP
C
REAL*8 ZF, CF, BF, ZFP, AMAT
DIAGNOSIS ZF(NKNOT, NCOEF2), CF(NKNOT, NCONS), BF(NCOEF2, NCONS),
1 ZFP(NCOEF2, NKNOT), AMAT(NCOEF2, NCOEF2)
DATA IREAD, IWRITE, IPUNCH/5, 6, 7/
C
SUBROUTINE FITCO USES LEAST SQUARES METHOD TO FIT A SECOND DEGREE
MULTIPLY RESPONSE SURFACE TO SYSTEMATIC KNOT-POINTS.

FOR EACH CONSEQUENCE VARIABLE, FITCO DEFINES THE CONSEQUENCE VECTOR
WITH COEFFICIENTS EQUAL TO THE CONSEQUENCE VALUES IN THE KNOT-POINTS.
THESE VECTORS ARE PUT IN THE MATRIX CF(NKNOT, NCONS).
NKNOT IS THE NUMBER OF KNOT-POINTS. NCONS IS THE NUMBER OF CONSEQUENCE VARIABLES. NCOEF2 IS THE NUMBER OF COEFFICIENTS IN A SECOND DEGREE MULTIPLY SURFACE.

THE MATRIX ZF(NKNOT, NCOEF2) IS CALCULATED, TO BE USED IN THE LEAST SQUARES FITTING EQUATIONS TO OBTAIN THE UNKNOWN COEFFICIENT VECTORS BF(NCOEF2, NCONS). THE MATRIX EQUATION FOR LEAST SQUARES FITTING IS (ZF'ZF)BF = ZF'CF. SUBROUTINE DXULT, A MATRIX MULTIPLICATION ROUTINE, AND SUBROUTINE SADINT, A MATRIX INVERSION ROUTINE, ARE USED TO SOLVE THIS EQUATION FOR BF.

W = WFAPA
WRITE(1,WHITE,201) NKNOT, NCOEF2
C
C FOR PARAMETERS WITH PROBABILITY DENSITY FUNCTIONS THAT ARE SYMMETRIC
C WITH RESPECT TO THE REFERENCE VALUE ZO(J), DZ2 = -DZ, DZ4 = -DZ3 AND
C DZK3 = -DZK4. AEPS AND EPSZ ARE A CHECK TO ELIMINATE OFF ERROR
C WHICH MAY RESULT FROM THE PREVIOUS CALCULATIONS OF Z1(J), Z2(J),
C Z3(J), AND Z4(J).
C
AEPS = 2.03E-05
MA = N*(M-1)
DO 40 J = 1, N
C
C CALCULATE SUBSCRIPTS FOR ZF.
C SUBSCRIPTS ARE SUCH THAT EACH ROW VECTOR IN BF TIMES THE CO-

DO 25 IR = 1, NKNOT
DO 10 ID = 1, NCONS
10 CF(IR, ID) = 0.000
DO 20 IC = 1, NCOEF2
20 ZF(IR, IC) = 0.000
25 ZF(IR, 1) = 1.000
C
DO 32 IR = 1, NCOEF2
DO 28 ID = 1, NCONS
28 BF(IR, ID) = 0.000
DO 30 IC = 1, NCOEF2
30 AMAT(IR, IC) = 0.000
32 CONTINUE
C
NAME FITC0

EFFICIENT VECTOR IN BF GIVES CORRESPONDING CONSEQUENCE VALUE IN CF.

JA = J + 1
JA1 = JA * N
JA2 = JA1 + N
JA3 = JA2 + N

IN ZETA1(J), DZ CORRESPONDS TO B TERM. DZ**2 CORRESPONDS TO C TERM.

DZ = Z1(J) - Z0(J)
ZF(JA,JA) = DZ
ZF(JA,JA1) = DZ * DZ

IN ZETA2(J), DZ2 CORRESPONDS TO B TERM. DZ2**2 CORRESPONDS TO C TERM.

DZ2 = Z2(J) - Z0(J)
EPSDZ = (DZ + DZ2) / (DZ - DZ2)
IF(ABS(EPSDZ) .LT.AEPS) DZ2 = -DZ
ZF(JA1,JA) = DZ2
ZF(JA1,JA1) = DZ2 * DZ2

IN ZETA3(J), DZ3 CORRESPONDS TO B TERM. DZ3**2 CORRESPONDS TO C TERM.

DZ3 = Z3(J) - Z0(J)
ZF(JA2,JA) = DZ3
ZF(JA2,JA1) = DZ3 * DZ3

IN ZETA4(J), DZ4 CORRESPONDS TO B TERM. DZ4**2 CORRESPONDS TO C TERM.

DZ4 = Z4(J) - Z0(J)
EPSDZ = (DZ3 + DZ4) / (DZ3 - DZ4)
IF(ABS(EPSDZ) .LT.AEPS) DZ4 = -DZ3
ZF(JA3,JA) = DZ4
ZF(JA3,JA1) = DZ4 * DZ4

IF(J.EQ.N) GO TO 50
DO 40 K = JA,N
CALCULATE SUBSCRIPTS FOR ZF.

JB = 1 + K + N * (3 + J) - ((J * JA) + 1) / 2
JC = JB * (KA + 1) / 2
JD = JB + NA
JE = JB + (3 * NA + 1) / 2
JG = JB - 2 * N

CALCULATE VALUES FOR CBGSS-TERMS, KJ, Z(N) = Z0(N) FOR N NOT EQUAL TO K OR J.

JB CORRESPONDS TO ZETA11
JC CORRESPONDS TO ZETA22
JD CORRESPONDS TO ZETA33
JE CORRESPONDS TO ZETA44

KA = K + 1
KA1 = KA * N
DZK3 = Z3(K) - Z0(K)
DZK4 = Z4(K) - Z0(K)
EPSDZ = (DZK3 + DZK4) / (DZK3 - DZK4)
FIP: ABS(EPSDZ) .LT. AEPS) DZK4 = -DZK3

C
C THESE ELEMENTS CORRESPOND TO THE D TERMS.
C
ZF(JB, JG) = DZ3 * DZK3
ZF(JC, JG) = DZ4 * DZK3
ZF(JD, JG) = DZ4 * DZK4
ZF(JE, JG) = DZ3 * DZK4

C
C DZ ELEMENTS CORRESPOND TO THE B TERMS, DZ SQUARED ELEMENTS
C CORRESPOND TO THE C TERMS.
C
ZF(JB, JA) = DZ3
ZF(JB, JA1) = DZ3 * DZ3
ZF(JB, KA) = DZK3
ZF(JB, KA1) = DZK3 * DZK3

C
ZF(JC, JA) = DZ4
ZF(JC, JA1) = DZ4 * DZ4
ZF(JC, KA) = DZK4
ZF(JC, KA1) = DZK4 * DZK4

C
ZF(JD, JA) = DZ4
ZF(JD, JA1) = DZ4 * DZ4
ZF(JD, KA) = DZK4
ZF(JD, KA1) = DZK4 * DZK4

C
ZF(JE, JA) = DZ3
ZF(JE, JA1) = DZ3 * DZ3
ZF(JE, KA) = DZK4
ZF(JE, KA1) = DZK4 * DZK4

C
50 DO 70 L = 1, NCONS

C ENTER VALUES OF ZETA'S IN CORRESPONDING ELEMENTS OF CF.
C REFERENCE VALUE IN FIRST ROW OF CF CF.
C
CF(1, L) = ZETA0(L)
DO 70 J = 1, N

C CALCULATE SUBSCRIPTS FOR CF
C
JA = J + 1
JA1 = JA + M
JA2 = JA1 + M
JA3 = JA2 + M

C ENTER VALUES OF ZETA 'S IN CORRESPONDING ELEMENTS OF CF
C
CF(JA1, L) = ZETA1(L, J)
CF(JA2, L) = ZETA2(L, J)
CF(JA3, L) = ZETA3(L, J)
CF(JA4, L) = ZETA4(L, J)

C IF(J.EQ.M) GO TO 70
DO 60 K = JA, M

C CALCULATE SUBSCRIPTS FOR CF.
MENDER

\[
JB = 1 + K + M * (3 + J) - ((J * JA) + 1) / 2
\]
\[
JC = JB + (NA + 1) / 2
\]
\[
JD = JB + NA
\]
\[
JE = JB + (3 * NA + 1) / 2
\]

ENTER VALUES OF ZETA'S IN CORRESPONDING ELEMENTS OF CF.

\[
CF(JB,L) = ZETA11(L,J,K)
\]
\[
CF(JC,L) = ZETA22(L,J,K)
\]
\[
CF(JD,L) = ZETA33(L,J,K)
\]
\[
CF(JE,L) = ZETA44(L,J,K)
\]

CONTINUE

PUT TRANSPOSE OF MATRIX ZF INTO ARRAY ZFP.

\[
ZF' * ZF = A IN MATRIX EQUATION AX = Y
\]

CALL MXMULT(ZFP,ZF,ANAT,NCOEF2,NKNOT,NCOEF2)

\[
ZF' * CF = Y IN MATRIX EQUATION AX = Y
\]

CALL MXMULT(ZFP,CF,BF,NCOEF2,NKNOT,NCONS)

WRITE(IWRITE,20)
DO 94 I = 1,NCONS
94 WRITE(IWRITE,206) I, CF(I,J)

CALL MATINV(AMAT,NCOEF2,bF,NCONS,DETICOP)

ICOR = ICOb * 30
WRITE(IWRITE,204) DET,ICOR
IF(DET.EQ.0) WRITE(IWRITE,200)

PRINT ARRAY BF IN MATRIX FOB. SUBSCRIPTS ARE PRINTED PRECEDING EACH ELEMENT.

WRITE(IWRITE,210)
DO 97 I = 1,NCOEF2
97 WRITE(IWRITE,202) (I,J,BF(I,J), J = 1,NCONS)

200 FORMAT(25HODETERMINANT OF AMAT IS ZERO.)
201 FORMAT(19H0 IN FITCO NKNOT = .I4,10H NCOEF2 = .I4//)
202 FORMAT(1H0,6(I4,12,G14.5))
204 FORMAT(31HODETERMINANT OF MATRIX ZF*ZF = .G15.6,11H TIMES 1.0D,14)
206 FORMAT(1P ,14.6(2E,G16.6))
210 FORMAT(20HSOLUTION MATRIX BF.)
220 FORMAT(1 ChopRAXCF)
RETURN
END
SUBROUTINE FITEDT(ZFCF,BFZFP,AMAT,NKNOT,NCOEF2)
C
CALL COMB
COMMON/TRANSP/NTRAPA,NTRACO,JTRA(7),JTYPE(7),LTRA(7),LTYPE(7),APA(17),BFA(7),ACO(7),ECO(7)
C
REAL*8 ZFCF,BFZFP,AMAT,CFA,X
DIMENSION ZF(NKNOT,NCOEF2),CI(NKNOT,NCONS),BF(NCOEF2,NCONS),1
ZFP(NCOEF2,NKNOT),AMAT(NCOEF2,NKNOT),BFZFP(NCOEF2,NCONS)
DATA IREAD,1WRITE,IPUNCH/5,6,7/
C
SUBROUTINE FITEDT EDITS THE RESULTS OBTAINED BY SUBROUTINE FITCO.
C
THE FIRST PART EDITS THE CONSEQUENCE VECTORS BF(J,L) OBTAINED BY
SUBROUTINE FITCO SO THAT COMPARISON WITH THE RESULTS OF JOBI 2 IS
SIMPLIFIED.
C
N = NPAIRA
M1 = N - 1
MB2 = 2 * M + 1
MB = M + 2
NA = M + 1
WRITE(IWRITE,201) NKNOT,NCOEF2
WRITE(IWRITE,200)
C
DO 10 L=1,NCONS
WRITE(IWRITE,202) L
WRITE(IWRITE,203) BF(1,L)
C
WRITE(IWRITE,204) (BF(J,L), J=2,NA)
WRITE(IWRITE,205) (BF(J,L), J=MB,MB2)
C
DO 8 J=1,MB2
JG = J + 2 + M * (J + 1) - ((J * (J + 1)) + 1) / 2
JH = 1 + M * (J + 2) - ((J * (J + 1)) + 1) / 2
8 WRITE(IWRITE,206) J,(BF(K,L), K=JG,JH)
10 CONTINUE
C
200 FORMAT(4(1HI)) THE COEFFICIENTS OF THE POLYNOMIALS//4H OBTAINED FROM SURFACE FITTING ROUTINE.
201 FORMAT(2H0 IN FITEDT NKNOT = ,14,10H NCOEF2 = ,14//)
202 FORMAT(11C/1H0,12X,11HCONSEQUENCE,14,//)
203 FORMAT(6H AMIT =,G15.6//)
204 FORMAT(11d BFIT(J) =,(6G15.6))
205 FORMAT(11H0 CFIT(J) =,(6G15.6))
206 FORMAT(6b0 DFIT(,11,5H,K) =,(6G15.6))
C
PART 2 OF SUBROUTINE FITEDT EDITS THE KNOT-POINT NUMBERING USED BY
SUBROUTINE FITCO.
C
IR = 1
INDEX = 0
J = 0
K = 0
WRITE(IWRITE,900)
WRITE(IWRITE,901) IR,INDEX
C
DO 51 INDEX=1,4
JA = 1 * (INDEX - 1) * M
DO 50 J = 1,N
   IR = J + JA
50   WRITE(IWRITE, 901) IR,INDEX,J
51 CONTINUE

C DO 54 IHELP=1,4
   JA = (IHELP - 1) * ((N * N1) / 2)
   INDEX = IHELP * 11
C DO 53 J= 1,N1
   JL = J + 1
C DO 52 K=JL,N
   IR = 1 + K + 1 * (J + 3) - (J * JL + 1) / 2 + JA
52   WRITE(IWRITE,301) IR,INDEX,J,K
53 CONTINUE
54 CONTINUE

C 900 FORMAT(33HOFITCO KNOT-POINT NUMBERING TABLE//36H IR,INDEX,J)
   901 FORMAT(1H0,10I,I5,5I5)
C C PART 3 OF SUBROUTINE FITEDT CALCULATES AND EDITS ERRORS.
C C CF(IR,L) IS THE IS-TH EXACT VALUE OF CONSEQUENCE L. THE IR-TH
C ELEMENT OF THE PROJECT VECTOR ZF*BF IS THE IR-TH APPROXIMATE
C RESPONSE SURFACE VALUE OF CONSEQUENCE L. PART 3 CALCULATES AND
C EDITS THE MAXIMUM AND MINIMUM ERRORS IN THESE VALUES, THE MAX
C SQUARE ERRORS, REFERENCE VALUE (ZETAO(L)) AND THE FRACTIONAL ERROR
C WRITE(IWRITE,1000)
   DN = NKNOT - NCOEP2
   DO 95 L=1,NCONS
      SUMSQ = 0.
      WRITE(IWRITE,1010) L
      BIG = -1.0E+49
      SMALL = +1.0E+49
      IBIG = 1
      ISMALL = 1
      DO 93 I= 1,NKNOT
         CPA = 0.
      90         CPA = CPA + ZF( IB,IC ) * BF( IC,L )
      91         IR = CPA - CF(IR,L)
      WRITE(IWRITE,1020) IR, IR
      IF(X.GT.BIG) IBIG = IR
      IF(X.GT.BIG) BIG = X
      IF(X.LT.SMALL) ISMALL = IR
      IF(X.LT.SMALL) SMALL = X
      93         SUMSQ = SUMSQ + X * X
      C
      PBER = SQRT(SUMSQ / DN)
      PBERED = PBER / ABS(ZETAO(L))
      C WRITE(IWRITE,1030) L,IBIG,BIG,ISMALL,SMALL
      IF(MTBACG.LE.0) GO TO 99
      C MAX ERROR CONSEQUENCES TO BE INVERSE TRANSFORMED
      LTIP = 0
101

NAME VITEDT

DO 701 I=1,NTEACO
LL = ITRA(I)
IF(LL.NE.L) GO TO 701
LTYPE = ITYPE(I)
AC = ACC(I)
BC = BCO(I)
CFBIG = CF(IBIG,L)
CFABIG = CFBIG + BIG
CFSNMA = CF(ISMAL,L)
CFASMA = CFASMA + SMALL
GO TO (100,220,300,400,500,600,700),LTYPE

100 BCC = 1./BC
CFBIG = CFBIG**BCC + AC
CFABIG = CFABIG**BCC + AC
CFSNMA = CFSMA**small + AC
CFASMA = CFASMA**BCC + AC
GO TO 701

220 CFBIG = EXP(CFBIG) + AC
CFABIG = EXP(CFABIG) + AC
CFSNMA = EXP(CFSMA) + AC
CFASMA = EXP(CFASMA) + AC
GO TO 701

300 CFBIG = BC*ALOG(CFBIG) + AC
CFABIG = BC*ALOG(CFABIG) + AC
CFSNMA = BC*ALOG(CFSMA) + AC
CFASMA = BC*ALOG(CFASMA) + AC
GO TO 701

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

500 CONTINUE
600 CONTINUE
700 CONTINUE
701 CONTINUE

IF(LTYPE.EQ.0) GO TO 99
BIG = CFBIG - CFBIG
SMALL = CFASMA - CFSMA
FBABIG = BIG/CFBIG
FBASMA = SMALL/CFSMA
WRITE(IWRITE,7001) CFBIG,CFBIG,BIG,FRABIG
WRITE(IWRITE,7002) CFSMA,CFASMA,small,FBASMA

7001 FORMAT(1H+,4I,2OH-inverse th max.appr=,E12.5,2X,6HEXACT=,E12.5,2X,6
1HEBERR=E12.5,2X,5HFRACTION=,F10.6/)
7002 FORMAT(1F+,4I,2OH-inverse th min.appr=,E12.5,2X,6HEXACT=,E12.5,2X,6
1HEPFO=E12.5,2X,5HFRACTION=,F10.6/)
99 CONTINUE

C ERRORS INVERSE TRANSFORMED
95 WRITE(IWRITE,1040) PSE, ZETA0(L), PBSZEE

C 1000 FORMAT(18O,16I,4OH-FITTED SURFACE ERRORS IN THE KNOT-POINTS//)
1010 FORMAT(18 ,12I,11HCONSEQUENCE,I4/IH ,7X,11HKNOT NUMBER,9X,5HERROR/1)
1020 FORMAT(18 ,12I,14,8X,15.6)
1030 FORMAT(18 ,5X,11HCONSEQUENCE,I5,18H MAX ERROR IN KNOT,I4,7H VALUE=1,E12.5,1EH MIN ERROR IN KNOT,I4,9H VALUE= ,E12.5//)
1040 FORMAT(180,101,2OH MEAN SQUARE ERROR = ,E12.5,19H REFERENCE VALUE =1 ,E12.5,20H FRACTIONAL ERROR = ,E12.5//)
SUBROUTINE HISTO(NPLO, NIS, NOINT)

C SUBROUTINE HISTO CALCULATES DISTRIBUTIONS (HISTOGRAMS) OF THE CONSEQUENCES
C IN JCBI 3 AND 4

*CALL COMMP

DIMENSION NPLO(6,26)
DIMENSION NIS(6,12), NOINT(6,6,12,12)
DO 421 L = 1, NCONS

DBVL = (AVZETA(L) - AVZET(L)) / (SCALE * SDZET(L))
HISL = DBVL + 7.
PISL = DBVL * 2. + 14.
NP = INT(PISL)
IF (NP .LE. 0) NP = 1
IF (NP .GT. 24) NP = 24
NELC(L,NP) = NPLO(L,NP) + 1

NL = INT(HISL)
IF (NL .LT. 1) NL = 1
IF (NL .GT. 12) NL = 12
NIS(L,NL) = NIS(L,NL) + 1
IF (L .EQ. NCONS) GO TO 421

LPI = L + 1
DO 422 D = LPI, NCONS

DEVB = (AVZETA(D) - AVZET(D)) / (SCALE * SDZET(D))
HISM = DEVB + 7.
NB = INT(HISM)
IF (NB .LT. 1) NB = 1
IF (NB .GT. 12) NB = 12
NOINT(L,B,NL,NB) = NOINT(L,B,NL,NB) + 1

422 CONTINUE
421 CONTINUE
RETURN

C END HISTOGRAM SUBROUTINE
END
SUBROUTINE INIT

C
C SUBROUTINE INIT SETS INITIAL VALUE ZEROS

CALL COMMON

COMMON/TRANSF,MTAPAM,MTACO,MTA(7),JTYPE(7),LTRA(7),LTYPE(7),APA(17),BPA(7),ACO(7),BCO(7)

3 DO 4 I= 1,12
  ADIS(I)=0.
  BDIS(I)=0.
  CDIS(I)=0.
  DDIS(I)=0.
  IPA(I)=0.
  IPAMES(I)=0.
  IPAMESB(I)=0.
  Z(I)=0.
  Z1(I)=0.
  Z2(I)=0.
  Z3(I)=0.
  Z4(I)=0.
  Z5(I)=0.
  ITYPE(I)=0.
  ITYPE(I)=0.
  LTRA(I)=0.
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  LTYPE(I)=0.
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SUBROUTINE INITC

C SUBROUTINE INITC SETS INITIAL VALUE ZEROS FOR JOBI 2

CALL CONP

COMMON/G&AVY/CRAVE(4)

101 DO 104 I=1,6
2 ETA0(L) = 0.
CONS(L) = 0.
DO 105 J=1,12
2 ETA1(L,J) = 0.
ZETA2(L,J) = 0.
ZETA3(L,J) = 0.
ZETA4(L,J) = 0.
SENS(L,J) = 0.
B(L,J) = 0.
C(L,J) = C.
DO 106 K=1,12
ZETA11(L,J,K) = 0.
IF(NQ.LE.1) GO TO 103
ZETA22(L,J,K) = 0.
ZETA33(L,J,K) = 0.
ZETA44(L,J,K) = 0.
103 CONTINUE
SENSCR(L,J,K) = 0.
D(L,J,K) = 0.
106 CONTINUE
105 CONTINUE
104 CONTINUE
DO 5 I=1,4
CRAVE(I) = 0.
NBV(I) = 0.
LCR(I) = 0.
FCR(I) = 0.
5 CONTINUE
RETURN
END
SUBROUTINE KNOTST

C SUBROUTINE KNOTST CALCULATES THE BASIC KNOT POINT CO-ORDINATES
C Z1, Z0, Z2, ALSO Z3 AND Z4 FOR MULTIQUADREANT CASES

C *CALL GGMP

1501 FORMAT(30HO UNKNOWN DISTRIBUTION IDIS = ,I4,2OH PARAMETER NUMBER
1 = ,14,8H NAME = ,2A4)
1502 FORMAT(2(10 HO VALUES USED) ZO = ,E14.6, 5H Z1 = ,E14.6,5H Z2 = ,E14.6)
1503 FORMAT(46H0FPP0B 100 LARGE FOR EXPONENTIAL PARAMETER,14,2A4)

C DO 15 I=1, NPARA
  M=IDIS(I)
  IF(M.LT.1.OR.M.GT.8) GO TO 17
  GO TO (2C,30,40,9050,9060,9070,9080,9090),d
C UNIFORM DISTRIBUTION IDIS = 1
  20 Z1(I)= ADIS(I)
  Z2(I)= EDIS(I)
  Z0(I)= 0.5*(Z1(I)+Z2(I))
  GO TO 15
C EXPONENTIAL DISTRIBUTION IDIS = 3
  40 IF(PEDB.GT.0.) GO TO 41
  T= ALOG(1./PEDB)
  ZO(I)= ADIS(I) + BDIS(I)
  Z1(I)= ADIS(I) + E1IS(I) + T
  Z2(I)= ADIS(I) + BDIS(I)*T
  GO TO 15
41 WRITE(6,15C3)IPARA(I),PNAMEA(I),PNAMEB(I)
  GO TO 42
C NORMAL DISTRIBUTION IDIS = 2
  30 T= ALOG((1.-PR0B)/P0B)
  T= SQRT(T)
  XUP = 2.515517 + (.802853 + .010328*T)*T
  XLOW = 1. + (1.432788 + (.189269 + .001308*T)*T)*T
  T= X - XUP/XLOW
  ZO(I)= ADIS(I)
  Z1(I)= ADIS(I) + BDIS(I)*T
  Z2(I)= ADIS(I) - BDIS(I)*T
  GO TO 15
C

C *** EXPONENTIAL DISTRIBUTION IDIS=4
9050 IF(PE0B.GT.0.36) GO TO 9010
9011 T= ALGC((1.-PE0B)/PE0B)
  TT= ALOG(1./PE0B)
  ZO(I)= ADIS(I) - BDIS(I)
  Z1(I)= ADIS(I) - BDIS(I)*T
  Z2(I)= ADIS(I) - BDIS(I)*TT
  GO TO 15
9010 WRITE(6,15C3)IPARA(I),PNAMEA(I),PNAMEB(I)
  GO TO 9011
C *** NORMAL DISTRIBUTION WITH ZLL IDIS=5
9060 T= ALOG((1./P0B*PE0B))
  T= SQRT(T)
  XUP = 2.51557 + (.802853 + .010328*T)*T
  XLOW = 1. + (1.432788 + (.189269 + .001308*T)*T)*T
  T= T - XUP/XLOW
BEKNOTST

AK = 1./(.5 -.5 * ERF((CDIS(I) - ADIS(I)) / (SQRT(2.) * BDIS(I))))

FACT = BDIS(I) * AK / SQRT(6.2832) * EXP(- (CDIS(I) - ADIS(I)) **2 / (2. * BDIS(I) **2))

Z0(I) = ADIS(I) * FACT
Z1(I) = ADIS(I) + BDIS(I) * X
Z2(I) = ADIS(I) - BDIS(I) * X
IF(Z2(I) .LE. CDIS(I)) Z2(I) = CDIS(I)
GO TO 15

C *** NORMAL DISTRIBUTION WITH ZUL IDIS=6

9070 I = ALOG(1. / (FACT * PROB))
T = SQRT(T)
XUP = 2.51557 + (.625053 + .010328 * T) * T
XLOW = 1. + (1.47577 + .182589 + .041328 * T) * T
I = T - XUP / XLCW

BK = 1./(.5 -.5 * ERF((CDIS(I) - ADIS(I)) / (SQRT(2.) * BDIS(I))))
FACT = BDIS(I) * AK / SQRT(6.2832) * EXP(- (CDIS(I) - ADIS(I)) **2 / (2. * BDIS(I) **2))

Z0(I) = ADIS(I) * FACT
Z1(I) = ADIS(I) + BDIS(I) * X
Z2(I) = ADIS(I) - BDIS(I) * X
IF(Z1(I) .GE. CDIS()) Z1(I) = CDIS(I)
GO TO 15

C *** BETA DISTRIBUTION IDIS=7

CC

C APPROXIMATIVE FORMULAS USED FOR CALCULATING Z1 AND Z2, VALID FOR SMALL PROB

CC

9080 Z0(I) = CDIS(I)
BEEAY = BDIS(I) - ADIS(I)
CEEAY = CDIS(I) - ADIS(I)
GAMEW = CEEAY * (BEEAY - ADIS(I) / DDIS(I) **2) - 1.
BTANEW = GAMENW * (BEEAY / CEEAY - 1.)
GAMETA = GAMENW * TABNW
IF(GAMENW .LE. 0.) WRITE(6,9501) IPARA(I)
IF(GAMENW .GT. 57.) WRITE(6,9502) IPARA(I)

9501 FORMAT(31H *** BETA DISTRIBUTED PARAMETER, I4,37H HAS TOO LARGE STA
1NDARD DEVIATION****//)
9502 FORMAT(31H *** ETA DISTRIBUTED PARAMETER, I4,37H HAS TOO SMALL STA
1NDARD DEVIATION****//)

Z1(I) = EDIS(I) - (BETAR*BTANEW*BEEAY**BTANEW) **(1./BTANEW)
Z2(I) = ADIS(I) + (RATIO*GAME**BEEAY**GAMEW)**(1./GAMEW)
GO TO 15

C *** LOG NORMAL DISTRIBUTION IDIS=8

9090 T = SQRT(ALOG(1./FACT**2))
XUP = 2.51557 + (.625053 + .010328 * T) * T
XLOW = 1. + (1.47577 + .182589 + .041328 * T) * T
I = T - XUP / XLCW

Z0(I) = EXP(ADIS(I) + .5 * BDIS(I) **2)
Z1(I) = EXP(ADIS(I) + BDIS(I) * X)
Z2(I) = EXP(ADIS(I) - BDIS(I) * X)
GO TO 15

C DISTRIBUTION UNKNOWN, ASSUMED UNIFORM, ADIS=MEAN, WIDTH=2*BDIS

17 Z0(I) = ADIS(I)
Z1(I) = ADIS(I) + BDIS(I)
Z2(I) = ADIS(I) - BDIS(I)
WRITE(6,1501) IDIS(I), IPARA(I), PHASE(I), PPHASE(I)
WRITE(6,1502) Z0(I), Z1(I), Z2(I)
GO TO 15
IF (MCORB .GT. 0) CALL COKNOT(IDIS)
DO 16 I = 1, WPABA
23(I) = Z0(I) + SQRT(2.) * (Z1(I) - ZO(I)) * .5
24(I) = Z0(I) + SQRT(2.) * (Z2(I) - ZO(I)) * .5
IF (NQ .EQ. 1) ZJ(I) = Z1(I)
IF (NQ .EQ. 1) Z4(I) = Z2(I)
16 CONTINUE
RETURN
END
SUBROUTINE KNOT

C PRINTS AND PUNCHES KNOT-POINTS

*CALL COMMP

COMMON/IPANSF/NTPAPA,NTRACO,JTRA(7),JTYPE(7),LTRA(7),LTYPE(7),APA(
17),APA(7),ACO(7),BCO(7)

C REFERENCE POINT

WRITE(6,1610)
DO 49 L=1,12
   Z(L)=Z0(L)
49 CONTINUE
INDEX=0
J=0
K=0
CALL PCINT

C OFF REFERENCE POINTS

50 DO 51 L=1,NPAI
   Z(L)=Z1(L)
   INDEX=1
   J=L
   CALL PCINT
   Z(L)=Z2(L)
   INDEX=2
   CALL PCINT
   IF(NQ.EQ.1) GO TO 70
   Z(L)=Z3(L)
   INDEX=3
   CALL PCINT
   Z(L)=Z4(L)
   INDEX=4
   CALL PCINT
   Z(L)=Z0(L)
51 CONTINUE
NPAI=NPAI-1

C CROSS POINTS

INDEX=0
59 CONTINUE
   INDEX=INDEX+11
   DO 52 J=1,NPAI
      JPI=J+1
      DO 53 K=JPI,NPARA
         IF(LMPAIR.GT.0) GO TO 60
      71 CONTINUE
         IF(INDEX.EQ.22) GO TO 56
         IF(INDEX.EQ.33) GO TO 57
         IF(INDEX.EQ.44) GO TO 58
      54 CONTINUE
         Z(J)=Z3(J)
         Z(K)=Z3(K)
         CALL PCINT
         Z(K)=Z0(K)
         GO TO 53
      56 CONTINUE
         Z(J)=Z4(J)
         Z(K)=Z3(K)
         CALL PCINT
         Z(K)=Z0(K)
         GO TO 53
110

NAME: KNOT

57 CONTINUE
Z(J) = Z4(J)
Z(K) = Z4(K)
CALL PCINT
Z(K) = Z0(K)
GO TO 53

58 CONTINUE
Z(J) = Z3(J)
Z(K) = Z4(K)
CALL PCINT
Z(K) = Z0(K)

53 CONTINUE
Z(J) = Z0(J)

52 CONTINUE
IF(NQ.LE.1) GO TO 55
IF(INDEX.LT.44) GO TO 59
GO TO 55

60 IF(JK(J,K) .EQ. 1) GO TO 71
GO TO 53

55 WRITE(6,1613)

1610 FORMAT (1000, KNOT - POINTS/16,'INDEX',15,'J K Z-VALUES'/)
1611 FORMAT (5H ,315,(6E16.6))
1613 FORMAT (420 END OF FIXED KNOT - POINT OUTPUT; RETURN
END)
SUBROUTINE MATINV(A,NN,AUG,MM,DELTA,ICOR)
IMPLICIT REAL*8(A-H,O-Z),INTEGER*4(I-N)
DIMENSION A(AM,NN), AUG(AM,MM)
DIMENSION B(64), C(64), D(64), IZ(64)

KINV...6
DIMENSION A(NN,NN), AUG(4N,MM)
NINV...4
DIMENSION B(b4), C(b4), D(84), IZ(64)
KINV... 5

C KINV...6 C
KINV...7 C
KINV...8 C
KINV...9 C
KINV...10 C
KINV...11 C
KINV...12 C
KINV...13 C
KINV...14 C
KINV...15 C
KINV...16 C
KINV...17 C
KINV...18 C
KINV...19 C
KINV...20 C
KINV...21 C
KINV...22 C
KINV...23 C
KINV...24 C
KINV...25 C
KINV...26 C
KINV...27 C
KINV...28 C
KINV...29 C
KINV...30 C
KINV...31 C
KINV...32 C
KINV...33 C
KINV...34 C
KINV...35 C
KINV...36 C
KINV...37 C
KINV...38 C
KINV...39 C
KINV...40 C
KINV...41 C
KINV...42 C
KINV...43 C
KINV...44 C

N = NN
M = NN
EPS = 1.0D-46
DELTA = 1.0D0
ICOR = 0

C DO 1 I = 1,N
1 CONTINUE
C DO 11 I = 1,N
K = I
I = A(I,I)
IF = I + 1
IF( IF .GT. M ) GOTO 3
C DO 2 J = IF,N
W = A(I,J)
IF( DABS(W) .LE. DABS(Y)) GOTO 2
3 ADELT = DABS(DELTA)
IF( ADELT .GT. 1.0D+30) ICOR = ICOR + 1
IF( ADELT .GT. 1.0D+30) DELTA = DELTA * 1.0D-30
IF( ADELT .LT. 1.0D-30) ICOR = ICOR - 1
IF( ADELT .LT. 1.0D-30) DELTA = DELTA * 1.0D+30
ABY = DABS(Y)
IF( ABY.GT.1.0D+30.AND.ADELT.GT.1.0D-15) ICOR = ICOR + 1
IF( ABY.GT.1.0D+30.AND.ADELT.GT.1.0D-15) DELTA = DELTA * 1.0D-30
IF( ABY.LT.1.0D-30.AND.ADELT.LT.1.0D+15) ICOR = ICOR - 1
IF( ABY.LT.1.0D-30.AND.ADELT.LT.1.0D+15) DELTA = DELTA * 1.0D+30
ADELT = CABS(DELTA)
TEXP = C.DO
IF(ADELT.GT.0.00) TEXP = DLOG(ADELT)
IF(ABY.GT.0.00) TEXP = TEXP + DLOG(ABY)
IF (TEP.GT.10.00) WRITE(IWRITE,1000) DELTA,Y
1000 FORMAT(2H,*3X,63HDETERMINANT CALCULATION IN NINV LEADS TO EXTRE)
1 VALUES, DELTA=G12.4,3H Y=G12.4/13H DELTA RESET/)
IF(TEP.LT.-160.DO) WRITE(IWRITE,1000) DELTA,Y

DELTA = DELTA * Y
IF(DABS(Y) .GE. EPS) GOTO 14
INV..44
VWRITE(IWRITE,1001) Y
INV..45
1001 FORMAT(1H,*4X,3LHSSALL ABS(Y) IN SUBR. NINV,Y=G12.4,1SH BUT I C
1002 CONTINUE/)
IF(DABS(Y) .EQ.0.) WRITE(IWRITE,1G02)
INV..46
1002 FORMAT(1H,*4X,3LHY IS ZLO
INV..47
C INV..48
DO 5 J = 1,N
C(J) = A(J,K)
A(J,K) = A(J,I)
A(J,I) = -C(J) * Y
B(J) = A(I,J) * Y
A(I,J) = B(J)
5 CONTINUE
C
IF(N .LT. 1 ) GO TO 7
DO 6 J = 1,N
D(J) = AUG(I,J) * Y
AUG(I,J) = D(J)
6 CONTINUE
C
7 A(I,I) = Y
J = !2(I)
I2(I) = !2(K)
I2(K) = J

DC 10 K = 1,N
IF( K .EQ. I ) GOTO 10
C
DO 8 J = 1,N
IF( J .EQ. I ) GOTO 8
A(K,J) = A(K,J) - B(J)*C(K)
8 CONTINUE
C
IF(N .LT. 1 ) GO TO 10
DO 9 J = 1,N
AUG(K,J) = AUG(K,J) - D(J)*C(K)
9 CONTINUE
10 CONTINUE
11 CONTINUE
C
DO 16 I = 1,N
K = I2(I)
IF( K .EQ. I ) GOTO 16
C
DO 13 J = 1,N
W = A(X,J)
A(X,J) = A(K,J)
A(K,J) = W
13 CONTINUE
14 CONTINUE
C
DO 18 I = 1,N
K = !2(I)
IF( K .EQ. I ) GOTO 18
C
DO 16 J = 1,N
W = A(X,J)
A(X,J) = A(K,J)
A(K,J) = W
16 CONTINUE
18 CONTINUE
C
DO 22 I = 1,N
K = !2(I)
IF( K .EQ. I ) GOTO 22
C
DO 13 J = 1,N
W = A(X,J)
A(X,J) = A(K,J)
A(K,J) = W
13 CONTINUE
22 CONTINUE
C
DO 26 J = 1,N
WM = A(K,J)
A(K,J) = A(X,J)
A(X,J) = WM
26 CONTINUE
IF( M .LT. 1 ) GO TO 15
DO 14 J = 1, M
   W = AUG(I, J)
   AUG(I, J) = AUG(K, J)
   AUG(K, J) = W
14 CONTINUE

IF( IZ(I) ) GO TO 15
IZ(I) = IZ(K)
IZ(K) = IF
DELTA = -DELTA
GOTO 16
16 CONTINUE
RETURN
SUBROUTINE N3M3

C SUBROUTINE N3M3 CALCULATES THE STANDARD DEVIATION OF THE
C ANALYTICAL RESPONSE SURFACE CONSEQUENCES, FOR THE CUBIC AND
C LINEARIZED MODELS, FROM THE FITTED THIRD DEGREE SURFACE.
C
*CALL COMEP
C
DO 50 L = 1,NCONS
VARSUM = 0.
SISUM = 0.
DO 40 J = 1,NPARA
   SIMVA = B(L,J) * B(L,J) * CM2(J)
   VAPFA = SIMVA + 2. * B(L,J) * (C(L,J) * CH3(J) + CI(J) * CM4
   (J)) + C(L,J) * C(L,J) * (CM4(J) - CM2(J) CM2(J))
   VARH = 0.
   VABB = 0.
   IF(J.EQ.NPAPA) GO TO 35
   JA = J + 1
   DO 30 K = JA,NPARA
      VARP = VARB + D(L,J,K) * D(L,J,K) * CM2(J) * CM2(K) + 2.
      + (F(L,J,K) * B(L,K) * CM2(J) * CM2(K) + CI(J,K) *
      CM2(J) * CM2(K) + B(L,J) * CM2(J) * CM2(K)
      + 2*(L,J)
      + CM4(J) * CM2(K) + D(L,J,K) * CM2(J) * CM3(K) + 2
      + F(L,J,K) * CM3(K) * CM3(K) + F(L,J,K) * F(L,J,K) *
      + CM2(J) * CM4(K) + G(L,J,K) * G(L,J,K) * CM2(K) + 2.
      + VARH = C.
      IF(K.EQ.NPAPA) GO TO 30
      KA = K + 1
      DO 20 M = KA,NPARA
         VARM = VARH + CM2(J) * CM2(K) * CM4(K) * CM4(K)
      1   + (F(L,J,M) * F(L,J,M) + G(L,J,M) * G(L,J,M) +
   CONTINUE
   30  VARSUM = VARSUM + VARA + VABB
   40  SISUM = SISUM + SIMVA
   SDZET(L) = VAPFS**.5
   SIMSD(L) = SIMSD**.5
RETURN
END
SUBROUTINE MSHIFT(ZMEAN)
C LINEAR EXPECTED VALUE (CONDITIONAL MEAN) SHIFT
C
C SUBROUTINE MSHIFT CALCULATES MEAN VALUE SHIFT FOR CORRELATED INPUT PARAMETERS
C CALLED BY SAMPLE, JOBI 17, 27 AND 18, 28 HAVE ALREADY BEEN CHANGED TO 3 AND 4
C
*CALL COMMON
COMMON/NEWREF/ZONEW(12)
COMMON/CCA/JOBI
DIMENSION ZMEAN(12)
IF(JOBI .EQ. 7.0 OR JOBI .EQ. 8) CALL MSHIFT(ZONEW)
IF(JOBI .EQ. 7.0 OR JOBI .EQ. 8) RETURN
IF(JOBI .EQ. 17.0 OR JOBI .EQ. 18) CALL MSHIFT(ZONEW)
IF(JOBI .EQ. 17.0 OR JOBI .EQ. 18) RETURN
IF(JOBI .EQ. 27.0 OR JOBI .EQ. 28) CALL MSHIFT(ZONEW)
IF(JOBI .EQ. 27.0 OR JOBI .EQ. 28) RETURN
DO 312 I = 1, NCORE
IF(IDEF(I) .NE. J) GO TO 312
IL = ILEAD(I)
SHIFT = (IDEF(I) - ZMEAN(J)) * (Z(IL) - ZMEAN(IL)) / (FLEAD(I) - ZMEAN(IL))
Z(J) = Z(J) + SHIFT
312 CONTINUE
RETURN
END
MEMBER NAME IMULT

SUBROUTINE IMULT(A, B, C, N1, M1, M2)
IMPLICIT REAL*8 (A-H, O-Z)
DIMENSION A(N1, 1), B(M1, 1), C(N1, 1)
DATA IREAD, IWRITE, IPUNCH / 5, 6, 7/
C SUBROUTINE IMULT RETURNS THE PRODUCT OF MATRICES A AND B
C IN THE ARRAY C. (AB = C)
C N1 IS THE NUMBER OF ROWS IN MATRIX A
C M1 IS THE NUMBER OF COLUMNS IN MATRIX A
C AND THE NUMBER OF ROWS IN MATRIX B
C M2 IS THE NUMBER OF COLUMNS IN MATRIX B
C C IS AN N1 X M2 MATRIX AND MUST BE DIMENSIONED AS SUCH IN
C THE CALLING PROGRAM. N1, M1, M2 MUST BE INTEGERS GREATER THAN ZERO.
DO 20 I = 1, N1
  DO 15 J = 1, M2
    SUM = 0.0D0
    DO 10 K = 1, M1
      PROD = A(I, K) * B(K, J)
      SUM = SUM + PROD
  10 C(I, J) = SUM
20 CONTINUE
WRITE (IWRITE, 220)
220 FORMAT (45 HO MXMULT EXECUTED. RETURN TO CALLING PROGRAM./)
RETURN
END
SUBROUTINE NEWZC
C CALCULATES NEW REFERENCE POINT COORDINATES FOR SAMPLING DISTRIBUTIONS
C IN JOBI 7,8 CALLED BY DRIVER, NEEDED IF NCORR.GT.0
C
CALL COMMON/NEWEP/RZNEW(12)
DO 15 I = 1,NPAEA
  M=IDIS(I)
  IF(M.IT.1.GR.N.GT.8) GO TO 17
  GO TO (2C,30,4G,95C,9060,9090),M
C UNIFORM DIST
  20 ZNEW(I) = 0.5*(ADIS(I) + BDIS(I))
  GO TO 15
C EXPONENTIAL
  40 ZNEW(I) = ADIS(I) + BDIS(I)
  GO TO 15
C NORMAL
  30 ZNEW(I) = ADIS(I)
  GO TO 15
  9050 ZNEW(I) = ADIS(I) - BDIS(I)
  C EXPONENTIAL IDIS=4'
  9060 AK=1./(5-.5*EXP((CDIS(I)-ADIS(I))/(SQRT(6.2832)*BDIS(I))))
    FACT=BDIS(I)*AK/SQRT(6.2832)*EXP(-((CDIS(I)-ADIS(I))**2)/(2.*BDIS(I)**2))
    ZNEW(I) = ADIS(I) + FACT
    GO TO 15
  9070 BK=1./(5+.5*EXP((CDIS(I)-ADIS(I))/(SQRT(6.2832)*BDIS(I))))
    FACT=-BDIS(I)*BK/SQRT(6.2832)*EXP(-((CDIS(I)-ADIS(I))**2)/(2.*BDIS(I)**2))
    ZNEW(I) = ADIS(I) + FACT
    GO TO 15
C BETA
  9080 ZNEW(I) = CDIS(I)
  GO TO 15
C LOG-NORMAL
  9090 ZNEW(I) = EXP(ADIS(I) + .5*BDIS(I)**2)
  GO TO 15
  17 ZNEW(I) = ADIS(I)
  15 CONTINUE
  RETURN
END
SUBROUTINE NSHIFT(ZMEAN)
C SHIFTS MEAN VALUES (CONDITIONAL) IF NCORR.GT.0 IN JOBI 7,8
C
*CALL COMPP
   DIMENSION ZMEAN(12)
   DO 312 I=1,NCCOR
   IF(IDEP(I).NE.J) GO TO 312
   IL = ILEAD(I)
   SHIFT = (FDEP(I) - ZMEAN(J)) * (Z(IL) - ZMEAN(IL)) / (FLEAD(I) - ZMEAN(IL))
   Z(J) = Z(J) + SHIFT
312 CONTINUE
RETURN
END
SUBROUTINE PLOTFP(MPRINT,T,X)
C
C SUBROUTINE PLOTFP PLOTS CONSEQUENCES VS PARAMETERS AND DISTRIBUTIONS
C
DIMENSION T(26),X(26),LINE(120)
DATA IREAD, IWRITE/5,6/
DATA MBLANK,MSTAE,MINUS,LTRI/ \H-4H* 4H- 4H /
BIG= -1.0E+49
SMALL=1.0E+49
DO 40 I=1, MPRINT
IF(X(I).GT.BIG) BIG= X(I)
IF(X(I).LT.SMALL) SMALL=X(I)
40 CONTINUE
DELT= BIG-SMALL
TES=ABS(SMALL)/10000.+1.0E-49
IF(DELT.LT.TES) DELT= TES
F= 50.0/DELT
DO 60 I=1, MPRINT
DO 50 K= 2,51
LINE(K) = MBLANK
IF(I.EQ.1) LINE(K) = MINUS
50 CONTINUE
LINE(1) = LTRI
J= (( X(I) - SMALL)*F + 1.501
LINE(J) = MSTAE
WRITE(IWRITE, 603) T(I),X(I),(LINE(L),L=1,51)
60 CONTINUE
603 FORMAT(17X,G11.4,2X,G11.4,2X,51A1)
RETURN
END
SUBROUTINE POLYQ

SUBROUTINE POLYQ CALCULATES RESPONSE SURFACE CONSEQUENCES IN THE SIMULATION

CALL COMNP

COMMON/WEIGHT,NCFIT,RANGE,RADSQ(12),RANGEP

C NO WEIGHTING IF RANGE.EQ.0.
IF(RANGE.GT.0.) CALL WEIPOL
IF(RANGE.GT.0.) RETURN

LSAV=L
DO 341 I=1,NCGNS
APZETA(L)=ZETAQ(L)
DO 342 J=1,NPARA
ZZJ=Z(J)-ZO(J)
DTERM=0.
IF(J.EQ.NPARA)GO TO 344
IQ=*
JPI=J+1
DO 343 K=JPI,NPARA
ZZK=Z(K)-ZO(K)
IF(ZZK)602,801,601
802 CONTINUE
IF(ZZJ.LT.0.)IQ=3
IF(ZZJ.GT.0.)IQ=4
803 CONTINUE
DTERM=DTERM+DQ(L,IQ,J,K)*ZZK
343 CONTINUE
344 CONTINUE
BQDUM=BQ(L,1,J)
CQDUM=CQ(L,1,J)
IF(ZZJ.LT.0.)BQDUM=BQ(L,3,J)
IF(ZZJ.LT.0.)CQDUM=CQ(L,3,J)
ATEM=BQDUM+CQDUM*ZZJ+DTERM
APZETA(L)=APZETA(L)+ATEM*ZZJ
342 CONTINUE
341 CONTINUE
L=LSAV
RETURN
END
SUBROUTINE POINT

C SUBROUTINE POINT OUTPUTS KNOT-POINT COORDINATES IN JOBI 1
C CALLED BY MAIN, CALLS TEXAS IF TEST = 0
*CALL COSMP
COMMON/TRANSF,NTRAPA,NTRACO,JTRA(7),JTYPE(7),LTRA(7),LTYPE(7),APA(17),BPA(7),ACO(7),ECO(7)
1611 FORMAT (5D,315,(6E16.6))
1612 FORMAT (312,2X,(6F12.6))
LSAV=L
WRITE(6,1611) INDEX, J, K, (Z(L),L=1,NPARA)
IF(TEST.EQ.30) WRITE(7,1612) INDEX,J,K,(Z(L),L=1,NPARA)
IF(TL.EQ.1) CALL TEXAS
IF(TEST.EQ.30) CALL TEXAS
IF(INDEX.EQ.30) CP.NTRACO.LZ.0) GO TO 7
CALL TRACO(CONS)
DO 71 I=1,6
IF(INDEX.EQ.0) ZETA0(L)=CONS(L)
IF(INDEX.EQ.1) ZETA1(L,J)=CONS(L)
IF(INDEX.EQ.2) ZETA2(L,J)=CONS(L)
IF(INDEX.EQ.4) ZETA4(L,J)=CONS(L)
IF(INDEX.EQ.11) ZETA11(L,J,K)=CONS(L)
IF(INDEX.EQ.22) ZETA22(L,J,K)=CONS(L)
IF(INDEX.EQ.33) ZETA33(L,J,K)=CONS(L)
IF(INDEX.EQ.44) ZETA44(L,J,K)=CONS(L)
71 CONTINUE
7 CONTINUE
L=LSAV
RETURN
C END POINT
END
SUBROUTINE PRINTH (NIS, NOINT, NSIM)

C SUBROUTINE PRINTH
*CALL COME

COMMON/CFIDIS/ICIS(4), ACIS(4), BCIS(4), CCIS(4), DCIS(4)
COMMON/TRANSF/ITRAPA,NTRACO,JTRI(7), JTRA(7), LTRA(7), LTYPE(7), APA(17), EPA(7), ACO(7), BCO(7)

DIMENSION NIS(6,12), NGIN(6,6,12,12)

C CATEGORY BOUNDARIES FOR CRITERIA CONSEQUENCES BASED ON AVERAGE CRITERIA VALUE
C CRAVE(M) - TO BE BETWEEN CATEGORIES 6 AND 7 FOR REALLY RANDOM CRITERIA
C - TO BE LL OF CATEGORY 1 IF ICIS(M) = 0 AND LCR(M) = 0
C - TO BE UL OF CATEGORY '2' IF ICIS(M) = 0 AND LCR(M) = 1

IF(NTRACO .GT. 0) WRITE(6, 7001)
7001 FORMAT(120, 2X, 75H FOR TRANSFORMED CONSEQUENCES THE CATEGORY LIMITS ARE ALSO GIVEN IN TERMS OF 42H THE ORIGINAL UNTRANSFORMED CONSEQ 2ONENCES 74H MOMENTS IN THE TITLES ARE ANAL. MOMENTS OF THE TRANSF 3ORED SEQUENCE/)
DC 371 L=1,NCOPS
WRITE(6,30C3) L,AVZET(L), SDZET(L),SCALE

C NEW CATEGORY LIMITS FOR CRITERIA FUNCTION

DO 371 NL=1,12
FNL=FLCAT(NL)
ESA=FLOAT(NSIM)
BLOW=AVZET(L)+(FNL-7.)*SCALE*SDZET(L)
IF(ICIS(h).EQ.O.ANL.LCR(K).EQ.1)BLOW=FREF+(FNL-13.)*SCALE*SDZET(L)
CONTINUE

CONTINUE

BUPP = BLOW + SCALE * SDZET(L)
COUNTS = FLOAT(NIS(L,NL))
ICOUNT=INT(COUNTS)
PROBAL = COUNTS / PSA
ERROR = ((1.-PROBAL)* PROBAL/PSA)**.5
IF(FECBAL).LT.375,375,374
375 PROS=100.
GO TO 373
374 PROS = 100.* ERROR/PROBAL
GO TO 373

CONTINUE

BAVE = (BLOW + BUPP) .5
WRITE(6,3005) NL,BLOW,BUPP,ICOUNT,PROBAL,ERROR,PROS,BAVE
372 CONTINUE

C CATEGORY BOUNDARIES INVERSE TRANSFORMED IF CONSEQUENCE TRANSFORMED
LTP = 0
C BBLOW,BBAVE,BBUPP DEFINED HERE BECAUSE THE OPTIMIZER TAKES THE LOGS
C OUT OF THE DO LOOP IN ANY CASE 
C AND ARGUMENTS COULD BE NEGATIVE
SEABEE

NAME

PRINTB

BBLOW = 0.
BBAVE = 0.
BBUPP = 0.

IF (BLCW .GT. 0.) BLOW = ALOG (BLOW)

IF (PAVE .GT. 0.) BBAVE = ALOG (BBAVE)

IF (BUPP .GT. 0.) BBUPP = ALOG (BBUPP)

CLOW = 0.
CBAVE = 0.
CUPP = 0.

DLOW = 0.
DAVE = 0.
DUPP = 0.

IF (BLCW .LT. -150.) GO TO 8

IF (BLOW .LT. 150.) CLOW = EXP (BLOW)

IF (BAVE .LT. 150.) CBAVE = EXP (BAVE)

IF (BUPP .LT. 150.) CUPP = EXP (BUPP)

8 CONTINUE

1 = 0

7 I = I + 1

LA = LTEA (I)

IF (LA .NE. L) GO TO 702

LTYP = LTYPE (I)

AC = ACC (I)

BC = BCC (I)

IF (LTYP .NE. 1) GO TO 6

BCC = 0.

IF (EC .NE. 0.) CC = 1./ EC

IF (ECC .EQ. 0.) GO TO 6

IF (ELOW .GT. 0.) LLGW = BLCW ** BCC

IF (EAVE .GT. 0.) DAVE = BBAVE ** BCC

IF (EUPP .GT. 0.) DUPP = BBUPP ** BCC

6 CONTINUE

GO TO (100, 200, 300, 500, 600, 700), LTYE

100 BLOWS = LCh + AC

BAVES = DAVE + AC

BUPPS = DUPP + AC

GO TO 701

200 BLOWS = CLOW + AC

BAVES = CAVE + AC

BUPPS = CUPP + AC

GO TO 701

300 BLOWS = EC * BLOW

BAVES = PC * BBAVE

BUPPS = BC * BBUPP

GO TO 701

400 PLOWS = bC * TAN (BLOW)

EAVES = BC * TAN (BAVE)

BUPPS = EC * TAN (BUPP)

GO TO 701

500 CONTINUE

600 CONTINUE

700 CONTINUE

BLOWS = BLOW

BAVES = BAVE

BUPPS = BUPP

702 CONTINUE

701 CONTINUE

IF (I .LT. NTRACO) GO TO 7
IF(LTYP.EQ.0) GO TO 372
C BLOW, BAVE AND BUPP HAVE BEEN INVERSE TRANSFORMED
WRITE(6,7005) NL,BLOWS,BUPPS,DAVES
7005 FORMAT(3H,C13,L15.6,214.6,4X,44HARE INVERSE TRANSF CATEGORY LIMITS, NICE CAT=,E16.6/)
372 CONTINUE
371 CONTINUE
3011 FORMAT(52H JOINT DISTRIBUTIONS OF POLYNOMIAL CONSEQUENCES/)
3012 FORMAT(2LHO CONSEQUENCE NUMBER,I5,10H VERTICAL)
3013 FORMAT(2CH CONSEQUENCE NUMBER,I5,12H HORIZONTAL/)
3014 FORMAT(45HO PROBABILITY AND ACCURACY (STANDARD DEVIATION)/)
3015 FORMAT(111H CATEGORY 1 2 3 4 5 6 7 8 9 10 11 12//)
3016 FORMAT(1H ,I5,12F9.6)
3017 FORMAT(1H ,I5,12F9.6/)
  WRITE(6,3011)
  NCOL=NCOLS-1
  DO 381 L=1,NCOL
    LPI=L+1
    DO 382 M=LPI,NCOLS
      WRITE(6,3012) L
      WRITE(6,3013) M
      WRITE(6,3014)
      WRITE(6,3015)
      DO 383 NL=1,12
      DO 384 NC=1,12
         AJOINT(NM)=FLOAT(NJOINT(L,M,NL,NC))/FSA
         PROBAL=AJOINT(NM)
         ERR(NM)=((1.-FPROB*L)*PROBAL/FSA)**.5
      384 CONTINUE
      WRITE(6,3016) NL, AJOINT
      WRITE(6,3017) NL, ERR
      383 CONTINUE
      382 CONTINUE
      381 CONTINUE
C END CP PRINTH
RETURN
END
SUBROUTINE QUADST

C SUBROUTINE QUADST CALCULATES COEFFICIENTS FOR MULTI-QUADRANT RESPONSE
C SURFACES, CALLS COEFSN TO HELP IN B AND C COEFFICIENTS
C QUADST CALLED BY MAIN, ONLY IF NQ.GT.1
C
*CALL COMMP

NQ=NQUAD
DO 120 L=1, NCONS
ZETM=ZETA0(L)
DO 101 IQ=1, NQ
IF(NQ.EQ.2) GO TO (601, 603), IQ
GO TO (601, b02, 6b3, 6604), IQ

601 CONTINUE
DO 121 J=1, NPAEA
ZMJ=Z0(J)
ZMJ=Z3(J)
ZXXJ=Z1(J)
ZCJ=Z3(J)
ZETX=ZETA3(L, J)
ZETXX=ZETA11(L, J)
ZETCJ=ZETA3(L, J)
CALL CCEFSN
IF(J.EQ.PARA) GO TO 128
JP1=J+1
DO 122 K=JP1, NPAFA
ZMK=Z0(K)
ZCK=Z3(K)
ZETCK=ZETA3(L, K)
ZETC=ZETA11(L, J, K)
DIFF=ZETC+ZETM-ZETCJ-ZETCK
SENCbEQ(L, IQ, J, K)=ABS(DIFF)
DQ(L, IQ, J, K)=DIFF/(ZCJ-ZMK)*ZCK-ZMK
122 CONTINUE
121 CONTINUE
128 CONTINUE
GO TO 102

602 CONTINUE
DO 221 J=1, NPAFA
ZMJ=Z0(J)
ZMJ=Z4(J)
ZXXJ=Z2(J)
ZCJ=Z4(J)
ZETX=ZETA4(L, J)
ZETXX=ZETA2(L, J)
ZETCJ=ZETA4(L, J)
CALL CCEFSN
IF(J.EQ.PARA) GO TO 228
JP1=J+1
DO 222 K=JP1, NPAFA
ZMK=Z0(K)
ZCK=Z3(K)
ZETCK=ZETA3(L, K)
ZETC=ZETA22(L, J, K)
DIFF=ZETC+ZETM-ZETCJ-ZETCK
SENCPC(L, IQ, J, K)=ABS(DIFF)
DQ(L, IQ, J, K)=DIFF/(ZCJ-ZMK)*ZCK-ZMK
222 CONTINUE
EIBER MNAE QUADST

221 CONTINUE

228 CONTINUE
GO TO 102

603 CONTINUE
DO 321 J=1,NPABA
ZBJ=ZO(J)
ZJ=Z4(J)
ZIJ=Z2(J)
ZCJ=Z4(J)
ZETX=ZETA4(L,J)
ZETX=ZETA2(L,J)
ZETCJ=ZETA4(L,J)
CALL CCEFSW
IF(J.EQ.NPABA) GO TO 328
JP1=J+1
DO 322 K=JP1,NPABA
ZK=ZO(K)
ZCK=Z4(K)
ZETCK=ZETA4(L,K)
ZETC=ZETA33(L,J,K)
DIFF=ZETC+ZETK-ZETCJ-ZETCK
SENCBQ(LIQJK)=ABS(DLP)
DQ(L,IQ,J,K)=DIFF/((ZCJ-Z1J)*(ZCK-ZBEK))
322 CONTINUE
321 CONTINUE
328 CONTINUE
GO TO 102

604 CONTINUE
DO 421 J=1,NPABA
ZBJ=ZO(J)
ZJ=Z3(J)
ZIJ=Z1(J)
ZCJ=Z3(J)
ZETX=ZETA3(L,J)
ZETCJ=ZETA3(L,J)
CALL CCEFSW
IF(J.EQ.NPABA) GO TO 428
JP1=J+1
DO 422 K=JP1,NPABA
ZK=ZO(K)
ZCK=Z4(K)
ZETCA=ZETA4(L,K)
ZETC=ZETA44(L,J,K)
DIFF=ZETC+ZETK-ZETCJ-ZETCK
SENCBQ(LIQJK)=ABS(DIFF)
DQ(L,IQ,J,K)=DIFF/((ZCJ-Z1J)*(ZCK-ZBEK))
422 CONTINUE
421 CONTINUE
428 CONTINUE
120 CONTINUE
RETURN
END
SUBROUTINE REPLACE(EF,NCOEP2,IFIT)
C SUBROUTINE REPLACE REPLACES THE OVERALL QUADRATIC RESPONSE SURFACE
C WITH A FITTED RESPONSE SURFACE. CALLED BY DRIVER ONLY IN MULTIQUADRANT
C CASE WHEN NPARA.LT.8 (IFIT = 1)
*CALL CONVF
C
REAL*8 BF
DIMENSION BF(NCOEP2,1)
IFIT = 2
DO 4 L=1,NCONS
   A(L) = BF(1,L)
C
DO 3 J=1,NPARA
   JA = J + 1
   JB = JA + NPARA
   JC = JA + NPARA + 1 - J * JA / 2
C
   B(L,J) = BF(JA,L)
   C(L,J) = BF(JB,L)
   IF(J.GE.NPARA) GO TO 3
   DO 2 K=JA,NPARA
      KPI = JC + K
      D(L,J,K) = BF(KPI,L)
   CONTINUE
   3 CONTINUE
   4 CONTINUE
C
RETURN
END
SUBROUTINE RESPON

*CALL CORNP

DO 342 L = 1, NCONS
     APZETA(L) = A(I)

DO 342 J = 1, NPARA
     DZJ = Z(J) - 20(J)
     DFG = 0.
     IF(J.EQ.NPAPA) GO TO 360

JA = J + 1

DO 343 K = JA, NPARA
     DZK = Z(K) - 20(K)
     HTERM = 0.
     IF(K.EQ.NPAPA) GOTO 350

KA = K + 1

DO 344 M = KA, NPARA
     DZM = Z(M) - 20(M)

     HTERM = HTERM + H(L,J,K,M) * DZM

344 CONTINUE

350 DFG = DFG + DZK * (D(L,J,K) + P(L,J,K) * DZJ + G(L,J,K) * 1
     + DZK * HTERM)

343 CONTINUE

360 ATERM = B(L,J) + DZJ * (C(L,J) + E(L,J) * DZJ) + DFG

342 APZETA(L) = APZETA(L) + DZJ * ATERM

RETURN
END
SUBROUTINE RFIT2(ZF, CF, BP, ZFP, AMAT, NCOEF2, IFIT)

C SUBROUTINE RFIT2 READS CONSEQUENCES AND COORDINATES OF THE RANDOM KNOT-POINTS, AND SOLVES THE FITTED 2ND DEGREE SURFACE COEFFICIENTS AND SENSITIVITIES.

C ZF CONTAINS RANDOMLY CHOSEN KNOT-POINT CO-ORDINATES. CF CONTAINS CONSEQUENCE VALUES IN THESE KNOT-POINTS.

DATA IREAD, IWRITE / 5, 6 /*
REAL*8 ZF, CF, BP, ZFP, AMAT, CFA, X
DIMENSION ZP(NRANKP, NCOEF2), CF(NRANKP, NCONS), BP(NCOEF2, NCONS),
1 ZFP(NCOEF2, NRANKP), AMAT(NCOEF2, NCOEF2),
DIMENSION RKMEAN(6), RKCM2(6), RKMAX(6), RKMIN(6), RKMEAN(6)

CALL CCMF
COMMON TRANSF/NTPAPA, NTRACO, JTRACO, JTA(7), JTRA(7), LTRACO(7), APA(17), EPA(7), ACO(7), ECC(7)

IF(NRANKP.LT.NCOEF2) WRITE(IWRITE, 1500)
1500 FORMAT (3H NPANKP = , I5, 30H LESS THAN NCOEF2 = , I4, 7H I STOP/)

C INITIAL ZERCS

DO 5 J = 1, NCOEF2
5 AMAT(K, J) = 0.000
DO 1 M = 1, NCOEF2
1 AMAT(M, J) = 0.000
DO 9 K = 1, NRANKP
ZFP(J, K) = 0.000
DO 5 L = 1, NCONS
RKMEAN(L) = 0.
RKCM2(L) = 0.
RKMAX(L) = -1.0E+49
RKMIN(L) = +1.0E+45
DO 7 M = 1, NCOEF2
7 BP(K, L) = 0.000
DO 9 J = 1, NRANKP
9 CF(J, L) = 0.000

C READ CONSEQUENCES IN RANDOM KNOT-POINTS, NRANKP SETS

IF TEST GT 11 AND LT 21; SUBROUTINE TEXAS CALCULATES CONSEQUENCES

IF (TEST.GT.11.AND.TEST.LT.21) GO TO 10
10 WRITE(IWRITE, 2000)
2000 FORMAT (1H TEST = , I4/3H CONSEQUENCES IN RANDOM KNOT-POINTS, INPUT IN SUBROUTINE RFIT2 FOR JOB1, I4/I1, 7I15.5, 20H KNOT, 6X, I3, 13H CONSEQUENCES/)

DO 11 K = 1, NRANKP
11 READ(IREAD, 2001) INDEX, KNOT, (CONS(I), I = 1, NCONS)
WRITE(IWRITE, 2002) INDEX, KNOT, (CONS(I), I = 1, NCONS)

C TRANSFORM KNOT-POINT CONSEQUENCES

IF (NTRACO.GT.0) CALL TRACO(CONS)
IF (NTRACO.GT.0) WRITE(IWRITE, 2005) INDEX, J, K, (CONS(I), I = 1, NCONS)
2005 FORMAT (2H TRANSFORMED VALUES/5H CONSEQUENCES/)

C CONSEQUENCES TRANSFORMED
DEFINE MATRIX CF

DO 11 L=1,NCONS
  RKCONS = CONS(L)
  RKMEAN(L) = RKMEAN(L) + RKCONS
  RKCM2(L) = RKCM2(L) + RKCONS * RKCONS
  IF(RKCONS.GT.RKMAX(L)) RKMAX(L) = RKCONS
  IF(RKCONS.LT.RKMIN(L)) RKMIN(L) = RKCONS
  11 CF(KNOT,L) = CONS(L)

2001 FORMAT(I2,I4,2X,(6E12.6))
2002 FORMAT(I5,6X,I5,4X,I5,6E16.6)

READ RANDOM KNOT-POINT COORDINATES

10 WRITE(IWRITE,1621) JOB
1621 FORMAT(I1H,10X,35H*RANDOM KNOT-POINT COORDINATES FOR JOB,J4//)
1622 FORMAT(I2,I4,2I,(6F12.6))
1623 FORMAT(IH ,6X,I5,4X,I5,(6F16.6))
DO 2 I=1,NRANKP
  READ(IREAD,1622) INDEX,KNOT,(Z(L), L=1,NPARA)
  WRITE(IWRITE,1623) INDEX,KNOT, (Z(L), L=1,NPARA)
2623 FORMAT(21H TRANSFORMED VALUES/1H+,6X,I5,4X,I5,(6F16.6))

TRANSFORM KNOT-POINT COORDINATES

IF(NPARA.GT.0) CALL TRAPA(Z)
IF(NPARA.GT.0) WRITE(IWRITE,2623) INDEX,KNOT, (Z(L), L=1,NPARA)

C TEST CONSEQUENCES CALCULATED IN TEXAS AND OUTPUT FOR EACH KNOT

50 CALL TEXAS
DO 51 L=1,NCONS
  RKCONS = CONS(L)
  RKMEAN(L) = RKMEAN(L) + RKCONS
  RKCM2(L) = RKCM2(L) + RKCONS * RKCONS
  IF(RKCONS.GT.RKMAX(L)) RKMAX(L) = RKCONS
  IF(RKCONS.LT.RKMIN(L)) RKMIN(L) = RKCONS
MEMBER NAME  EPITZ

IF(RKCONS.LT.RKMIN(L)) RKMIN(L) = RKCONS
51 CF(KNOT,L) = CCNS(L)
2 CONTINUE
C
C EDIT ARRAY CF IF IT IS CALCULATED BY TEXAS.
C
IF((TEST.LE.11.OR.TEST.GE.21)) GO TO 60
WRITE(IWRITE,2100) TEST
DO 54 IM = 1,NHANKP
54 WRITE(IWRITE,2160) IM, (CF(IM,IL), IL = 1,NCONS)
2100 FORMAT(16,I6,6(2X,D15.6))
2200 FORMAT( 8HTEST = ,I3,2H ARRAY CF AS CALCULATED BY TEXAS)
C
C THE NEXT THREE STATEMENTS SOLVE LEAST SQUARES FITTING EQUATION
C
(ZF'Zk)bF = ZF'CF FOR BF
C
60 CONTINUE
WRITE(IWRITE,3000)
DO 100 L = 1,NCONS
   RKAVE = RKMLAN(L) / NHANKP
   EKVAR = EKCM2(IL) / NHANKP - RKAVE * RKAVE
   EKSD = 0.
   IF(EKVAR.GT.0.) EKSD = SQRT(EKVAR)
WRITE(IWRITE,3001) L,RKAVE,EKSD,RAKMAX(L),RKMIN(L)
100 CONTINUE
3000 FORMAT(5H 0 CHARACTERISTICS OF RANDOM KNOT POINT SAMPLE CONSEQUENCES
   1/10 CONSEQUENCE MEAN VALUE STD DEVIATION MAXIMUM VALUE MINUS VALUE/)
3001 FORMAT(16G,6X,14H,G14.5,1X,G14.5,1X,G14.5,1X,G14.5)
CALL MMULT(ZFP,CF,BF,NCOEF2,NHANKP,NCONS)
CALL MATINV(AMAT,NCOEF2,BF,NCONS,DET2,ICOF)
   ICOF = ICOF * 30
WRITE(IWRITE,3260) DET2,ICOF
2300 FORMAT(5H 0 DETERMINANT OF ZFP*ZF = ',G15.6,' TIMES 1.0D',I4)
C
C CALCULATE AND OUTPUT FITTED SURFACE ERRORS: MAXIMUM AND MINIMUM,
C MEAN SQUARE ERROR, REFERENCE VALUE AND FRACTIONAL ERROR.
C
1690 FORMAT(1H1,10X,23H*FITTED SURFACE ERRORS*/1H0,5X,4HKNAPS,6X,13HAPPR
   10IMATION,6X,5HEXACT,10X,10HDIFFERENCE,5X,15HPOW
   CONSEQUENCE,I4/)
DN = BNANKP - NCOEF2
IF(DN.LE.0.) DN = 1.0E-10
DO 20 IR=1,NHANKP
   SUMS = 0.0
   BIG = 1.0E+49
   IBIG = 1
   SMALL = 1.0E+49
   ISMALL = 1
WRITE(IWRITE,1690) L
20 CONTINUE
   CF = 0.0
   DO 22 IC=1,NCOEF2
      CF = CF + ZF(IR,IC) * BF(IC,L)
22 CONTINUE
   X = CF - CF(IR,L)
IF(X.GT.BIG) IBIG = IR
IF(X.GT.BIG) IBIG = I
C MAX ERROR CONSEQUENCES TO BE INVERSE TRANSFORMED
LTYPE = 0
DO 701 I=1,NTRACO
LL = LFA(I)
IF(LL.NE.L) GO TO 701
AC = ACO(I)
BC = BCO(I)
CFBIGGER = CF(IBIG,L)
CFABIG = CFBIG + BIG
CFSMA = CF(ISMALL,L)
CFASMA = CFSMA + SMALL
GO TO (101,200,300,400,500,600,700),LTYPE
101 BCC = 1./BC
CFBIGGER = CFBIG**BCC + AC
CFABIG = CFABIG **BCC + AC
CFSMA = CFSMA **BCC + AC
GO TO 701
200 CFBIG = EXP(CFBIG) + AC
CFABIG = EXP(CFABIG) + AC
CFSMA = EXP(CFSMA) + AC
GO TO 701
300 CFBIG = BC*ALOG(CFBIG) + AC
CFABIG = BC*ALOG(CFABIG) + AC
CFSMA = BC*ALOG(CFSMA) + AC
GO TO 701
400 CFBIG = BC*TAN(CFBIG) + AC
CFABIG = EC*TAN(CFABIG) + AC
CFSMA = EC*TAN(CFSMA) + AC
CPASMA = EC*TAN(CPSMA) + AC
GO TO 701
500 CONTINUE
600 CONTINUE
700 CONTINUE
701 CONTINUE
IF(LTYPE.EQ.0) GO TO 99
BIG = CBABIG - CFBIG
SMALL = CPASMA - CFSMA
FRABIG = BIG/CFBIG
FRASMA = SMALL/CFSMA
WRITE(IWRITE,7001) CFBIG,CPBIG,BIG,FRABIG
WRITE(IWRITE,7002) CFSMA,CPASMA,SMALL,FRASMA
7001 FORMAT(1X,4X,4X,20HINVERSE TR MAX,APPR=,E12.5,2X,6HEXACT=,E12.5,2X,6
1HERROE=,E12.5,2X,9HFRACTION=,F10.6/) 7002 FORMAT(1X,4X,2OHINVERSE TR MIN,APPR=,E12.5,2X,6HEXACT=,E12.5,2X,6
1HERROE=,E12.5,2X,9HFRACTION=,F10.6/) 99 CONTINUE
C ERRORS INVERSE TRANSFORMED
PRESS = SQRT(SUMSQ/DN)
MEMBER NAME SPITZ

IF(BF(1,L).EQ.0.) FRAERR = 0.
IF(BF(1,L).NE.0.) FRAERR = FMSE / DABS(BF(1,L))
WRITE(IWEITE,1702) FMSE,BF(1,L),FRAERR
20 CONTINUE

1700 FORMAT(1H ,4X,I4,3I,E16.6,2X,E15.5,4X,E15.6)
1701 FORMAT(1H0,12H*CONSEQUENCE,14,3I,15HDAX ERROR KNOT=,I4,7H VALUE=,E
116.6,3X,15MIN ERROR KNOT=,I4,7H VALUE=,E16.6/)
1702 FORMAT(1H ,20H MEAN SQUARE ERROR=,E15.6,11H ZEP VALUE=,L15.6,3X,1
1OHPFACTION =,F9.5/)

C SET COEFFICIENTS BEFCEE RETURNING , FLAGS ALSO
C
CALL REPLAC(BF,NCOEF2,IFIT)
IFIT = 0
NQUAD=1
MQ=1
LIFAIB=0

C SENSITIVITIES FOR THE FITTED SURFACES
C
DO 30 L=1,NCONS
   DO 30 J = 1,NPARA
      DZJ = Z1(J)-ZO(J)
      DZJ2 = Z2(J)-ZO(J)
      SENS(L,J) = ABS((B(L,J)+C(L,J)*DZJ)*DZJ)
      1 +ABS((B(L,J)+C(L,J)*DZJ2)*DZJ2)
      J1 = J+1
      IF(J1.GE.NPARA) GO TO 30
      DO 31 K = 1,NPARA
      SENS(L,J,K) = ABS( D(L,J,K) * (Z3(J)-ZO(J)) * (Z3(K)-ZO(K)) )
31 CONTINUE
30 CONTINUE
RETURN
END
SUBROUTINE RFIT3(ZF, CF, BF, ZFP, AMAT, NCOEF3, IFIT)
C READS CONSEQUENCES AND COORDINATES OF THE RANDOM KNOT-POINTS, SOLVES THE
C FITTED 3RD DEGREE SURFACE COEFFICIENTS AND SENSITIVITIES, EDITS COEFFICIENTS.
C CALCULATES CONSEQUENCES IN TEXAS IF TEST = 22 THROUGH 30
C
REAL*8 ZF, CF, BF, ZFP, AMAT, NPARAM, NCONS,
DIMENSION ZF(NPARAM, NCOEF3), CF(NPARAM, NCONS),
BF(NCOEF3, NCONS),
DIMENSION RKMEAN(6), RKC2(6), RKM2(6), RKM1(6)
DATA IREAD, IWRITE/5, 6/
C
CALL COMM
COMMCH/TRANSF/NTRAQ, JTYPE(7), LTRAQ(7), LTYPE(7), APA(17), EPA(7), ACO(7), BCO(7)
C
IF (NPARAM .GT. 4) WRITE(IWRITE, 1502) NPARAM
1502 FORMAT(1H0, 10X, 5H*PLEASE MAKE SURE THAT DIMENSION IN SUBROUTINE
1MAT3 IS ENOUGH FOR 14, 23d PARAMETERS, I CONTINUE/)
IF (TEST .GT. 21 .AND. TEST .LT. 31) GO TO 12
WRITE(IWRITE, 2000) IJOB, NCONS
2000 FORMAT(1H1, 10X, 7H*CONSEQUENCES IN RANDOM KNOT-POINTS, INPUT IN
1SUBROUTINE RFIT3 FOR IJOB, 14/1H, 7I, 5H*INDEX, 10X, 4H*KNOT, 6X, 13, 13H C
2CONSEQUENCES//)
C
DO 10 I = 1, NPARAM
READ(IREAD, J001) INDEX, KNOT, CONS(J), J = 1, NCONS
WRITE(IWRITE, 2002) INDEX, KNOT, CONS(J), J = 1, NCONS
C
CALL TRACO(CONS)
C
IF (NTRACC .GT. 4) WRITE(IWRITE, 2005) NTRACC
2005 FORMAT(1H2H*TRANSFORMED VALUES/5H+, 315, (6E16.6))
C
C CONSEQUENCES TRANSFORMED
DEFINE MATRIX CF

DO 11 L=1,NCONS
BKCONS = CONS(L)
BKMAX(L) = BKMAX(L) + BKCONS
BKMIN(L) = BKMIN(L) + BKCONS
IF(BKCONS.GT.BKMAX(L)) BKMAX(L) = BKCONS
IF(BKCONS.LT.BKMIN(L)) BKMIN(L) = BKCONS
CP(KNCT,L) = CONS(L)
11 CONTINUE
10 CONTINUE

C READ KNOT-POINT COORDINATES
WRITE(IWRITE,1621) JOB1
1621 FORMAT(1H1,1CX,J5H*RANDOM KNOT-POINT COORDINATES FOR JOB1,I4//)
WRITE(IWRITE,1622) INDEX, KNOT, (Z(L),L=1,NPARA)
WRITE(IWRITE,1623) INDEX, KNOT, (Z(L),L=1,NPARA)

C TRANSFORM KNOT-POINT COORDINATES
IF(NKAPA.GT.0) CALL TAPAZ(Z)
WRITE(IWRITE,2623) INDEX, KNOT, (Z(L),L=1,NPARA)
2623 FORMAT(1H,6X,15,4X,15,6E16.6))

C DEFINE MATRIX ZP AND CP
C
ZP(KNCT,1) = 1.000
ZFP(1,KNCT) = 1.000

C ORDER CP TERMS = A+B*Z+D*Z**3+E*Z**5+3*J+K*Z+J*K+P*Z**2+S*Z**2+Z+G*Z**Z
C 2+B*Z+Z**2+Z

C
DO 3 J=1,NPARA
J1 = J+1
J2 = J1 + NPARA
J3 = J2 + NPARA
JD = (2+J)*NPARA + 1 - J*J/2
JP = JD + ND
JG = JP + ND
JBEZF = 1 + 3*(NPARA + ND)
DZJ = Z(J-20)(J)
DZJ2 = DZJ*DZJ
ZP(KNOT,J1) = DZJ
ZP(KNOT,J2) = DZJ2
ZP(KNOT,J3) = DZJ*DZJ2
ZFP(J1, KNOT) = DZJ
ZFP(J2, KNOT) = DZJ2
ZFP(J3, KNOT) = ZP(KNOT, J3)

IF(J.GE.NPARA) GC TO 3

C
DO 4 K = J1, NPARA
K1 = K + 1
K2 = JD + K
DZK = Z(K) - Z0(K)
DZK2 = DZK* DZK
K4 = JG + K
ZP(KNOT, K2) = DZJ* DZK
ZP(KNOT, K3) = DZJ2* DZK
ZP(KNOT, K4) = DZJ* DZK2
ZFP(K2, KNOT) = DZJ* DZK
ZFP(K3, KNOT) = DZJ2* DZK
ZFP(K4, KNOT) = DZJ* DZK2
IF(J.GE.NPARA) GC TO 4

C
DO 5 M = K1, NPARA

JKMH IS USED TO LOCATE THE H-COEFFICIENTS OF H(JKM) *ZJ*ZK*ZH

JKMH = JKM + 1
JM = JHREF + JKM
DZM = Z(K) - Z0(K)
ZP(JM, KNOT) = ZP(KNOT, JM)
ZFP(JM, KNOT) = ZFP(KNOT, JM)
5 CONTINUE

C
IP(TEST GT. 21.AND.TEST LT. 31) GO TO 50
2 CONTINUE

C
IF(TEST LE. 21.GE.TEST.GE.31) GO TO 60
WRITE(IWRITE, 1706) TEST
DO 90 I = 1, NANKP
90 WRITE(IWRITE, 1705) I, (CF(I, J), J = 1, NCONS)
1705 FORMAT(1H ,16,6(2X, D15.6))
1706 FORMAT(6I3, TEST = , I3, 32H ARRAY CF AS CALCULATED BY TEXAS)
GO TO 60

50 CALL TEXAS
DO 51 L = 1, NCONS
RKCONS = CONS(L)
RKMEAN(L) = RKMEAN(L) + RKCONS
RKCH2(L) = RKCH2(L) + RKCONS * RKCONS
IF(RKCONS.GT.RKMAX(L)) RKMAX(L) = RKCONS
CP(KNOT, L) = CONS(L)
51 CONTINUE
GO TO 2

60 CONTINUE
WRITE(IWRITE, 30C0)
DO 100 I = 1, NCONS
EKAVE = RKMEAN(L) / NANKP
EKVAR = RKCH2(L) / NANKP - EKAVE * EKAVE
EKSD = SQRT(EKVAR)
100 IF(EKVAR.GT.0.) EKSD = SQRT(EKVAR)
MEMBER NAME  Bfit3

WRITE (IWRITE,3001) L,RKAVE,RKSD,RKMAX(L),RKBIN(L)
100 CONTINUE
3000 FORMAT('CHARACTERISTICS OF RANDOM KNOT POINT SAMPLE CONSEQUENCES
'/'O CONSEQUENCE MEAN VALUE STD DEVIATION MAXIMUM VALUE MINIMUM VALUE'/)
3001 FORMAT(1HG,5X,14,4I,G14.5,1L,G14.5,1X,G14.5,1L,G14.5)

WRITE (IWRITE,2100) DET3,ICOR
2100 FORMAT('DETERMINANT OF MATRIX ZFP*ZF=',315.6,'TIMES 1.0D',14)

C EDIT COEFFICIENTS
C EDIT 3RD DEGREE SURFACE COEFFICIENTS
C FIRST DEFINE A,B,C,E, D, F , G AND H COEFFICIENTS

2050 FORMAT(1H1,10X,59b**THE COEFFICIENTS OF THE FITTED 3RD DEGREE POLYNOMIALS**/1b,20X,I4,21,19HRANDOM KNOT-POINTS,I5,14H COEFFICIENTS//)
2051 FORMAT(1H0,12X,1HCONSEQUENCE,I4,//)
2052 FORMAT(1H ,7X,3HA =,*G15.6//)

C DO 141 L=1,NCONS
   J(L) =EF(1,L)
   JKMH = 0

C DO 101 J=1,NPARA
   J1 = J+1
   J2 = J1 + NPARA
   J3 = J2 + NPARA
   JD = (Z+J)*NPARA +1 -J*J1/2
   JP = JD +ND
   JG = JP +ND
   J3 = J2 +NPARA
   B(J1,L) = BF(J1,L)
   C(J2,L) = BF(J2,L)
   E(J3,L) = BF(J3,L)
   IF(J.EQ.NPARA) GO TO 101

C DO 102 K =J1,NPARA
   K1 = K+1
   K2 = JD + K
   K3 = JP + K
   K4 = JG + K
   D(K,L,K) = BF(K2,L)
   F(K,L,K) = BF(K3,L)
   G(K,L,K) = BF(K4,L)
   IF(K.EQ.NPARA) GO TO 102

C DO 103 M=K1,NPARA
   JKMH = JKMH +1
MEMBER NAME RFIT3

JM = JREFP+JAMH

138 CONTINUE

103 CONTINUE

102 CONTINUE

101 CONTINUE

141 CONTINUE

2053 FORMAT(10H B(J) =, (6G15.6))

2054 FORMAT(10H C(J) =, (6G15.6))

2055 FORMAT(10H L(J) =, (6G15.6))

DO 201 L=1,NCONS
    WRITE(IWRITE,2051) L
    WRITE(IWRITE,2052) A(L)
    WRITE(IWRITE,2053) B(L,J),J=1,NPARA
    WRITE(IWRITE,2054) C(L,J),J=1,NPARA
    WRITE(IWRITE,2055) D(L,J),J=1,NPARA

2056 FORMAT(5HO F(J2,5,H,K) =, (6G15.6))

2057 FORMAT(5HO G(J2,5,H,K) =, (6G15.6))

IF(NPARA.LT.2)
    GC TO 1202
    NPA = NPARA - 1
    DO 202 J=1,NPA
        J1=3+1
        WRITE(IWRITE,2056) J, (D(L,J,K),K=J1,NPARA)
        WRITE(IWRITE,2057) J, (C(L,J,K),K=J1,NPARA)
        WRITE(IWRITE,2058) J, (G(L,J,K),K=J1,NPARA)

202 CONTINUE

1202 CONTINUE

IF(NPANA.LT.2) GO TO 201

NAAA = NPANA - 2

2059 FORMAT(5HO H(J2,1,H,K2,5,H) =, (6G15.6))

DO 204 J = 1,NPPAA
    J1=J+1
    DO 204 K=J1,NPARA
        R1=K+1
        WRITE(IWRITE,2059) J,K, (H(L,J,K),K=R1,NPARA)

204 CONTINUE

201 CONTINUE

C CALCULATE AND EDIT FITTED SURFACE ERRORS: MAXIMUM AND MINIMUM, MEAN SQUARE ERROR, REFERENCE VALUE AND FRACTIONAL ERROR.

DN = NPANKP - NCOEP3

IF(DN.LE.0) DN = 1.0E-10

DO 157 L = 1,NCONS
    SUMSQ = 0.0
    BIG = -1.0E+49
    IBIG = 1
    SMALL = 1.0E+49
    ISMALL = 1
    WRITE(IWRITE,1690) L
    DO 155 IR = 1,NPANKP
        CPA = 0.0
        DO 153 IC = 1,NCOEP3
            CPA = CPA + DF(IR,IC) * BF(IC,L)
            I = CPA - CF(IR,L)
            IF(X.GT.BIG) IBIG = IR
            IF(X.GT.BIG) BIG = X
            IF(X.LE.SMALL) ISMALL = IB
MEMBER NAME: PIT3

IF (X.LT.SMALL) SMALL = X
WRITE(IWRITE, 1701) I, CPA, CF(IP, L), X
WRITE(IWRITE, 1700) I, CPA, CF(IP, L), X

155 SUMSC = SUMSQ + I * X
WRITE(IWRITE, 1701) I, CPA, CF(IP, L), X
IF (WTBACCC.LT.0) GO TO 99
C MAX EBCP CONSEQUENCES TO BE INVERSE TRANSFORMED

LYP = 0
DO 701 L = 1, NTBACU
   LL = LTB(A)(L)
   IF (LL.EQ.LL) GO TO 701
   LTYP = LTYPE(L)
   AC = ACC(L)
   BC = ECO(L)
   CFBIG = CF(IBIG, L)
   CFABIG = CFBIG + BIG
   CFSMA = CF(ISMALL, L)
   CFASMA = CFSMA + SMALL
   GO TO (110, 200, 300, 400, 500, 600, 700), LTYP
110 BCC = 1./BC
   CFBIG = CFBIG**BCC + AC
   CFABIG = CFABIG**BCC + AC
   CFSMA = CFSMA**BCC + AC
   CFASMA = CFASMA**BCC + AC
   GO TO 701
200 CSPM = EXP(CFABIG) + AC
   CFABIG = EXP(CPABIG) + AC
   CFSMA = EXP(CFSMA) + AC
   CFASMA = EXP(CFASMA) + AC
   GO TO 701
300 CFBIG = EC*ALOG(CFBIG) + AC
   CFABIG = EC*ALOG(CFABIG) + AC
   CFSMA = EC*ALOG(CFSMA) + AC
   CFASMA = EC*ALOG(CFASMA) + AC
   GO TO 701
400 CFBIG = EC*TAN(CFBIG) + AC
   CFABIG = EC*TAN(CFABIG) + AC
   CFSMA = EC*TAN(CFSMA) + AC
   CFASMA = EC*TAN(CFASMA) + AC
500 CONTINUE
600 CONTINUE
700 CONTINUE
701 CONTINUE
   IF (LTYP.EQ.0) GO TO 99
   BIG = CFABIG - CFBIG
   SMALL = CFASMA - CFSMA
   FRAEBIG = BIG/CFBIG
   FRAESMA = SMALL/CFSMA
   WRITE(IWRITE, 7001) CFABIG, CFBIG, BIG, FRAEBIG
   WRITE(IWRITE, 7002) CFSMA, CFASMA, SMALL, FRAESMA
7001 FORMAT (1H+, 4X, 20HINVERSE TR MAX, APPR=, B12.5, 2X, 6HEXACT=, B12.5, 2X, 6HERROR=, E12.5, 2X, 6HFACTION=, F10.6/)
7002 FORMAT (1H+, 4X, 20HINVERSE TR MIN, APPR=, B12.5, 2X, 6HEXACT=, B12.5, 2X, 6HERROR=, E12.5, 2X, 9HFACTION=, F10.6/)
99 CONTINUE
C ERRORS INVERSE TRANSFORMED

FMSE = SQRT(SUMSQ / DN)
   IF (EF(1, L).EQ.0.) FRAERR = 0.
   IF (BF(1, L).NE.0.) FRAEFP = FMSE / DABS(BF(1, L))
SENSE NAME BFI3

157 WRITE(1,WRITE,1702) PMSE, BF(1, L), FREAER, DN
1690 FORMAT(1H1, 10X, 'THIRD DEGREE FITTED SURFACE ERRORS'/,6X, 4HKNF, 6X,
113HAPPROXIMATON, 8X, 5HEACT, 10X, 10HDIFFERENCE, 5X, 15HFOR CONSEQUENCE
2E, 14X/)  
1700 FORMAT(1H1, 4X, 4X, 3X, E16.6, 2X, E15.64X, E15.6)
1701 FORMAT(1H0, 12H*CONSEQUENCE, 4X, 3X, 15HMAX ERROR KNOT=, I4, 7H VALUE=, E16.6, 5X, 15HMIN ERROR KNOT=, I4, 7H VALUE=, E16.6/)  
1702 FORMAT(1H, 20H, MEAN SQUARE ERROR=, E15.6, 11H AVE VALUE=, E15.6, 3X, 12H PROPORTION =, F9.5/250 WITH WAVKPP - WCO3P3 =, G10.3, 19 DEGREES 2 OF FREEDOM)  
C  
C SENSITIVITY CALCULATIONS  
C  
DO 210 L = 1, NCCNS  
DO 211 J = 1, NPARA  
J1 = J + 1  
DZJ1 = Z1(J) - ZO(J)  
DZJ2 = Z2(J) - ZO(J)  
DZJ3 = Z3(J) - ZO(J)  
SENS(L, J) = ABS((E(L, J) + DZJ1*(C(L, J) + DZJ1*E(L, J))) * DZJ1) + 1  
ABS((E(L, J) + DZJ2*(C(L, J) + DZJ2*E(L, J))) * DZJ2)  
IF(J .EQ. NPARA) GO TO 211  
C  
DO 212 K = J1, NPARA  
K1 = K + 1  
DZK3 = Z3(K) - ZO(K)  
SENSCH(L, J, K) = ABS(DZJ3 * DZK3 * (D(L, J, K) + DZJ3 * E(L, J, K) + DZK3 * G(L, J, K)))  
IF(K .EQ. NPARA) GO TO 212  
DO 213 M = K1, NPARA  
DZM3 = Z3(M) - ZO(M)  
213 SENSE(L, J, K, M) = DZJ3 * DZK3 * DZM3 * H(I, J, F, S)  
212 CONTINUE  
211 CONTINUE  
210 CONTINUE  
C  
C SET FLAGS BEFORE RETURNING.  
C  
EQ = 1  
EQAD = 1  
LMFAIR = 0  
IFIT = 0  
RETURN  
END
MEMBER NAME: SAMDIS

SUBROUTINE SAMDIS
C READS IN NEW PARAMETER DISTRIBUTIONS TO SAMPLE FROM
C IN JOBI 7,8
C CALLED BY DRIVER

*CALL CCMMI:
DATA IREAD, IWRITE/5,6/
WRITE(IWRITE,1019) JOBI
1019 FORMAT(1X,1H ,9X,6HJOBI =,I4,41H SAMPLES FROM THE FOLLOWING DISTRIBUTIONS,,/1H ,9X,43HDIFFERENT FROM KNOT SELECTION DISTRIBUTIONS/)
C READ SAMPLING DISTRIBUTION INFO
DO 11 I=1,NPARE
READ(IREAD,1004) K,NAMEA,NAMEB,JDIS,UDIS,UCDIS,UDDIS,JK
WRITE(IWRITE,1004)K,NAMEA,NAMEB,JDIS,UDIS,UCDIS,UDDIS,JK
IPAPA (K)=K
PNAMEA (K)= NAMEA
PNAMEE (K)= NAMEE
IDIS (K) = JDIS
ADIS(K) = UDIS
BDIS(K) = UDDIS
CDIS(K) = UDDIS
DDIS(K) = UDDIS
IF(IPAPA .LE. 0) GO TO 11
DO 12 LA = 1,12
JA= JJK(LA)
IF(JA .LE. K) GO TO 13
JK(K,JA)=1
GO TO 12
13 IF(JA .LE. 0) GO TO 12
JK(JA, K)=1
CONTINUE
11 CONTINUE
IF(NCCRR.LE.0) GO TO 16
DO 18 I=1,NCCH
READ (IREAD,1017) ITYPE(I),ILEAD(I),FLEAD(I),IDEP(I),FDEP(I)
WRITE(IWRITE,1017) ITYPE(I),ILEAD(I),FLEAD(I),IDEP(I),FDEP(I)
18 WRITE(IWRITE,1020) I
16 CONTINUE
WRITE(IWRITE,1020)
WRITE(IWRITE,1021)
WRITE(IWRITE,1022)
WRITE(IWRITE,1023)
WRITE(IWRITE,1024)
WRITE(IWRITE,1025)
WRITE(IWRITE,1026)
WRITE(IWRITE,1027)
WRITE(IWRITE,1028)
1002 FORMAT(12,1X,A4,A2,I2,4F11.5,1X,12I2)
1004 FORMAT(7H ,I4,4X,A4,A2,I6,6X,4G11.5,4X,12I3)
WRITE(IWRITE,1029)
1017 FORMAT(15,15,15,15,15,15,15,15)
1018 FORMAT(16X,1H,6X,16HECPRELATION TYPE,I4,11H LEAD PARA,I4,8H, VALUE=,1214.6,3X,14HDEPENDENT PARA,I4,15H SHIFTED MEAN=,214.6/)
1020 FORMAT(91HG DISTRIBUTION FIRST PARAMETER SECOND PARAMETER
1THIRD PARAMETER FOURTH PARAMETER/)
1021 FORMAT(86H 1=UNIFORM UPPER LIMIT LOWER LIMIT
1N/A N/A )
1022 FORMAT(86H 2=NORMAL MEAN VALUE STANDARD DEVIATION
1N/A N/A )
1023 FORMAT(86H 3=EXPONENTIAL LOWER LIMIT SCALE CONSTANT
1N/A N/A )
BERBER NAME SANDIS

1 N/A N/A

1024 FORMAT (66H 4=EXPONENTIAL UPPER LIMIT SCALE CONSTANT

1 N/A N/A)

1025 FORMAT (66H 5=NORMAL MEAN VALUE STANDARD DEVIATION

1 LOWER LIMIT N/A)

1026 FORMAT (66H 6=NORMAL MEAN VALUE STANDARD DEVIATION

1 UPPER LIMIT N/A)

1027 FORMAT (95H 7=BETA LOWER LIMIT UPPER LIMIT

1 MEAN STANDARD DEVIATION)

1028 FORMAT (86D 8=LOG NORMAL MEAN VALUE STANDARD DEVIATION

1 N/A N/A)

1029 FORMAT ('///4X,' FOR DISTRIBUTIONS 5 AND 6, THE VALUES FOR THE MEAN

AND STANDARD DEVIATION ARE THOSE FOR THE UNTRUNCATED NORMAL DISTRIBUTIONS.'///,'///4X,' FOR DISTRIBUTION 8, THE VALUES FOR MEAN AND STANDARD DEVIATION ARE THOSE OF THE LOGARITHM OF THE PARAMETER.'"
RETURN
END
**NAME** SAMPLE

**SUBROUTINE** SAMPLE

**C** SAMPLES INPUT PARAMETERS

**C**

*CALL COMMON*

**C**

COMMON/NEWREF/ZONENW(12)
COMMON/CTRL/JOBSV
DO 311 J=1,NPANA
L=IDIS(J)
GO TO (320,325,330,330,9335,9340,9345,9350),L
320 U=FLTRNF(0)
Z(J)=BDIS(J)+O*(ADIS(J)-BDIS(J))
IF(NCOEF.GT.0) CALL MSHIFT(ZO)
GO TO 311
325 U=FLTRNF(0)
W=1./U
GA=((2.*ALOG(W))**.5)*COS(6.2831853*W)
Z(J)=ADIS(J)+GA*BDIS(J)
IF(NCORR.GT.0) CALL MSHIFT(ZO)
GO TO 311
330 U=FLTRNF(0)
Z(J)=ADIS(J)-EDIS(J)*ALOG(U)
IF(L.EQ.4) Z(J)=ADIS(J)+BDIS(J)*ALOG(U)
IF(NCORR.GT.0) CALL MSHIFT(ZO)
GO TO 311
C THE SAMPLING GENERATED FOR THE BETA DISTRIBUTION IS DONE USING A
C PAIR OF GAMMA RANDOM VARIATES WHICH IN TURN USE EXPONENTIAL, AND
C THEREFORE, THE UNIFORM RANDOM VARIATE.
9335 U=FLTRNF(0)
V=FLTRNF(0)
W=1./U
GA=((2.*ALOG(W))**.5)*COS(6.2831853*W)
Z(J)=ADIS(J)+GA*BDIS(J)
IF(Z(J).LT.CDIS(J)) GO TO 9335
IF(NCORR.GT.0) CALL MSHIFT(ZO)
GO TO 311
9340 U=FLTRNF(0)
V=FLTRNF(0)
W=1./U
GA=((2.*ALOG(W))**.5)*COS(6.2831853*W)
Z(J)=ADIS(J)+GA*BDIS(J)
IF(Z(J).GT.CDIS(J)) GO TO 9340
IF(NCORR.GT.0) CALL MSHIFT(ZO)
GO TO 311
C
\[ \begin{align*}
\text{NAME} = w = 1/\theta \\
\text{GA} = \left((2 \times \text{ALOG}(w))^{0.5}\right) \times \cos(6.2831853 \times \theta) \\
\text{BN} = \text{ABIS}(J) + \text{GA} \times \text{BDIS}(J) \\
Z(J) = \exp(\text{EN}) \\
\text{IF}(\text{NCORB.GT.0}) \text{ CALL MSHIFT(20)}
\end{align*} \]

CONTINUE
RETURN
FUNCTION GAMRN (ALAM, ETA)
\[ \begin{align*}
N &= \text{ETA} \\
F &= \text{ETA} - N \\
\text{IF}(F = 0) \text{ GO TO 8100}
\end{align*} \]

8010 P = FLTBNF(0) \\
\text{IF}(P < P / (F + 2.71828)) \text{ GO TO 8120}
\[ Y = C^{**}(1/F) \]
\text{IF}(F > \exp(-Y)) \text{ GO TO 8100}
GO TO 8050
8100 Y = 0. \\
GO TO 8070
8120 S = FLTBNF(0) \\
\[ Y = 1 - \text{ALCG}(S) \]
\text{IF}(S > Y^{**}(F - 1)) \text{ GO TO 8010}
8050 IF(N.EQ.0) \text{ GO TO 8150}
8070 Z = 1.0 \\
DO 6080 I = 1, N
8080 Z = Z * FLTRBF(0) \\
\[ Y = Y - \text{ALCG}(Z) \]
8150 GAMRN = Y / ALAN
RETURN
END
*CALL COMP

I1 = Z(1) - 500.
I2 = Z(2) + 1.368
I3 = Z(3) + 23.6
I4 = Z(4) - 1760.
I5 = Z(5) - 1.
I6 = Z(6) + 5.
CONS(1) = 26.76 + 2.5089 * X1 - 5703.5 * X2 - 27.273 * X3 + 1.1287 * X4
CONS(2) = 4324. + 2.5756 * X1 - 2633.2 * X2 - 21.455 * X3 + 1.0810 * X4
CONS(3) = 3814. + 0.66222 * X1 - 1919.6 * X2 - 7.2727 * X3 + 0.34442 * X4
CONS(4) = 5923. + 2.0311 * X1 - 1959.6 * X2 - 4.5455 * X3 + 0.99574 * X4
CONS(5) = 0.
CONS(6) = 0.
LSAV = L
DO 71 L = 1, N
IF (INDEX.EQ.0) ETA(L) = CONS(L)
IF (INDEX.EQ.1) ETA(1, L) = CONS(L)
IF (INDEX.EQ.2) ETA(2, L) = CONS(L)
IF (INDEX.EQ.3) ETA(3, L) = CONS(L)
IF (INDEX.EQ.4) ETA(4, L) = CONS(L)
IF (INDEX.EQ.5) ETA(5, L) = CONS(L)
IF (INDEX.EQ.6) ETA(6, L) = CONS(L)
IF (INDEX.EQ.7) ETA(7, L) = CONS(L)
IF (INDEX.EQ.8) ETA(8, L) = CONS(L)
IF (INDEX.EQ.9) ETA(9, L) = CONS(L)
IF (INDEX.EQ.10) ETA(10, L) = CONS(L)
IF (INDEX.EQ.11) ETA(11, L) = CONS(L)
IF (INDEX.EQ.12) ETA(12, L) = CONS(L)
IF (INDEX.EQ.13) ETA(13, L) = CONS(L)
IF (INDEX.EQ.14) ETA(14, L) = CONS(L)
IF (INDEX.EQ.15) ETA(15, L) = CONS(L)
IF (INDEX.EQ.16) ETA(16, L) = CONS(L)
IF (INDEX.EQ.17) ETA(17, L) = CONS(L)
IF (INDEX.EQ.18) ETA(18, L) = CONS(L)
IF (INDEX.EQ.19) ETA(19, L) = CONS(L)
IF (INDEX.EQ.20) ETA(20, L) = CONS(L)
IF (INDEX.EQ.21) ETA(21, L) = CONS(L)
IF (INDEX.EQ.22) ETA(22, L) = CONS(L)
IF (INDEX.EQ.23) ETA(23, L) = CONS(L)
IF (INDEX.EQ.24) ETA(24, L) = CONS(L)
IF (INDEX.EQ.25) ETA(25, L) = CONS(L)
IF (INDEX.EQ.26) ETA(26, L) = CONS(L)
IF (INDEX.EQ.27) ETA(27, L) = CONS(L)
IF (INDEX.EQ.28) ETA(28, L) = CONS(L)
IF (INDEX.EQ.29) ETA(29, L) = CONS(L)
IF (INDEX.EQ.30) ETA(30, L) = CONS(L)
IF (INDEX.EQ.31) ETA(31, L) = CONS(L)
IF (INDEX.EQ.32) ETA(32, L) = CONS(L)
IF (INDEX.EQ.33) ETA(33, L) = CONS(L)
IF (INDEX.EQ.34) ETA(34, L) = CONS(L)
IF (INDEX.EQ.35) ETA(35, L) = CONS(L)
IF (INDEX.EQ.36) ETA(36, L) = CONS(L)
IF (INDEX.EQ.37) ETA(37, L) = CONS(L)
IF (INDEX.EQ.38) ETA(38, L) = CONS(L)
IF (INDEX.EQ.39) ETA(39, L) = CONS(L)
IF (INDEX.EQ.40) ETA(40, L) = CONS(L)
IF (INDEX.EQ.41) ETA(41, L) = CONS(L)
IF (INDEX.EQ.42) ETA(42, L) = CONS(L)
IF (INDEX.EQ.43) ETA(43, L) = CONS(L)
IF (INDEX.EQ.44) ETA(44, L) = CONS(L)

71 CONTINUE
L = LSAV
RETURN
END
MEMBER NAME TEXOUT

SUBROUTINE TEXOUT

C TEXOUT PUNCHES AND PRINTS TEST CONSEQUENCES FROM TEXAS.
C
*CALL COMMP
C
1700 FORMAT (36H1 TEST CONSEQUENCE OUTPUT -TEXAS //)
1701 FORMAT (3I2,2X,(6E12.6))
1702 FORMAT (5H ,3I5, (6E16.6))
WRITE (6,1700)
INDEX = 0
J=0
K=0
WRITE (7,1701) INDEX, J, K, (ZETA0 (L) ,L=1, NCONS)
WRITE (6,1702) INDEX, J, K, (ZETA0 (L) ,L=1, NCONS)
DO 61 J=1,NPARA
INDEX = 1
WRITE (7,1701) INDEX, J, K, (ZETA1 (L,J) ,L=1, NCONS)
WRITE (6,1702) INDEX, J, K, (ZETA1 (L,J) ,L=1, NCONS)
INDEX = 2
WRITE (7,1701) INDEX, J, K, (ZETA2 (L,J) ,L=1, NCONS)
WRITE (6,1702) INDEX, J, K, (ZETA2 (L,J) ,L=1, NCONS)
IF(NQ.LE.1) GO TO 72
INDEX=3
WRITE (7,1701) INDEX, J, K, (ZETA3 (L,J) ,L=1, NCONS)
WRITE (6,1702) INDEX, J, K, (ZETA3 (L,J) ,L=1, NCONS)
INDEX=4
WRITE (7,1701) INDEX, J, K, (ZETA4 (L,J) ,L=1, NCONS)
WRITE (6,1702) INDEX, J, K, (ZETA4 (L,J) ,L=1, NCONS)
72 CONTINUE
IF(J.EQ.NPARA) GO TO 81
JPI=J+1
INDEX=0
84 CONTINUE
INDEX=INDEX+11
DO 82 K=JPI,NPARA
IF(LMPAIR.GT.0) GO TO 86
83 CONTINUE
IF(INDEX.EQ.42) GO TO 85
IF(INDEX.EQ.43) GO TO 87
IF(INDEX.EQ.44) GO TO 88
WRITE (7,1701) INDEX, J, K, (ZETA11 (L,J,K) ,L=1, NCONS)
WRITE (6,1702) INDEX, J, K, (ZETA11 (L,J,K) ,L=1, NCONS)
GO TO 82
85 CONTINUE
WRITE (7,1701) INDEX, J, K, (ZETA22 (L,J,K) ,L=1, NCONS)
WRITE (6,1702) INDEX, J, K, (ZETA22 (L,J,K) ,L=1, NCONS)
GO TO 82
87 CONTINUE
WRITE (7,1701) INDEX, J, K, (ZETA33 (L,J,K) ,L=1, NCONS)
WRITE (6,1702) INDEX, J, K, (ZETA33 (L,J,K) ,L=1, NCONS)
GO TO 82
88 CONTINUE
WRITE (7,1701) INDEX, J, K, (ZETA44 (L,J,K) ,L=1, NCONS)
WRITE (6,1702) INDEX, J, K, (ZETA44 (L,J,K) ,L=1, NCONS)
82 CONTINUE
IF(NQ.LE.1) GO TO 73
IF(INDEX.LT.44) GO TO 84
83 CONTINUE

K = 0
MEMBER NAME TEXTOUT
81 CONTINUE
RETURN
86 IF (JK(J,K) .EQ. 1) GO TO 83
   GO TO 82
END
SUBROUTINE TRACO(DCONS)

C TRANSFORMS KNCT-POINT CONSEQUENCES
C CALLED BY DELVAR,BFIT2,BFIT3
C
*CALL COMMP

COMMON/ZFANSF,MTRAPA,MTRACO,JTRA(7),JTYPE(7),LTRA(7),LTYPE(7),APA(17),EPA(7),ACO(7),ECO(7)
DIMENSION DCONS(6)
DO 10 I=1,NTRACO
   LL = LTRA(I)
   LTYP = LTYPE(I)
   AC = ACO(I)
   BC = BCO(I)
   DCONST = DCONS(LL) - AC
   GO TO (160,200,300,400,500,600,700),LTYP
100 DCONS(LL) = DCONST**BC
   GO TO 10
200 DCONS(LL) = ALOG(DCONST)
   GO TO 10
300 DCONS(LL) = EXP(DCONST/BC)
   GO TO 10
400 DCONS(LL) = ATAN(DCONST/BC)
   GO TO 10
500 CONTINUE
600 CONTINUE
700 CONTINUE
10 CONTINUE
RETURN
END
SUBROUTINE TRANM
C CALCULATES APPROXIMATE CENTRAL MOMENT FOR TRANSFORMED PARAMETERS
C IF NTRAFA.GT.0, CALLED BY DRIVER
*CALL COMRF
COMMON/TRANSF/NTRAFA,NTRACO,JTRA(7),JTYPE(7),LTRA(7),LTYPE(7),APA(17),EPA(7),ACO(7),BCO(7)
COMMON/SVZC/ZOSV(14)
DO 2C J=1,NTRAFA
   JTYP = 0
   DO 10 I=1,NTRAFA
      JJ = JTRA(I)
      IF(JJ.NE.J) GO TO 10
      JTYPEF = JTYPEF(I)
      AP = APA(I)
      BF = BPA(I)
      ZBEF = ZOSV(JJ) - AP
      ZPLUS = ZREF + SQRT(CM2(JJ))
      GO TO (100,200,300,400,500),JTYP
100 ZREF = ZREF ** BP
      ZPLUS = ZPLUS ** BP
      GO TO 9
200 ZREF = ALCG(ZREF)
      ZPLUS = ALCG(ZPLUS)
      GO TO 9
300 ZREF = EXP(ZREF/EP)
      ZPLUS = EXP(ZPLUS/BP)
      GO TO 9
400 ZREF = ATAN(ZREF/BP)
      ZPLUS = ATAN(ZPLUS/BP)
      GO TO 9
500 ZBEF = ZREF/ (ZREF + AP - BP)
      ZPLUS = ZPLUS/ (ZPLUS + AP - BP)
9 SDZ = AES(ZPLUS - ZREF)
10 CONTINUE
   IF(JTYP.EQ.0) GO TO 20
   WRITE(6,1000) J
1000 FORMAT(1WH I PARAMETER,J3,J3H TRANSFORMED/) 
C APPROXIMATE MOMENTS FOR TRANSFORMED PARAMETERS 
CM2(J) = SDZ * SDZ
CM3(J) = 0.
CM4(J) = 3. * CM2(J) * CM2(J)
IF(NCOB.GE.0) GO TO 20
C CM11 MAY BE ORDERS OF MAGNITUDE WRONG FOR TRANSFORMED, MAKE ZERO FOR CORRE.
   DO 7 KM = 1,NCOFA
      DO 8 KKM = 1,NPARA
         IF(IILEAD(KK).EQ.J ) CM11(J,KKM) = 0.
         IF(IILEAD(KK).EQ.J ) CM11(KKM,J) = 0.
         IF(IDEP(KK).EQ.J ) CM11(J,KKM) = 0.
         IF(IDEP(KK).EQ.J ) CM11(KKM,J) = 0.
7 CONTINUE
8 CONTINUE
7 CONTINUE
20 CONTINUE
RETURN
END
SUBROUTINE TRAPA(DZPA)
C TRANSFORMS KNOT-POINT AND SAMPLED POINT COORDINATES
C CALLED BY DRIVER, RFIT2, RFIT3
C
*CALL CCBEF
COMMON/TRANSF/NTAPA,NTRACO,JTRA(7),JTYPE(7),LTRA(7),LTYPE(7),APA(17),BPA(7),ACO(7),ECO(7)
DIMENSION DZPA(14)
DO 1C I=1,NTAPA
JJ = JTRA(I)
JTP = JTYPE(I)
AP = APA(I)
BP = BPA(I)
DAPA = DZPA(JJ) - AP
GO TO (100,200,300,400,500),JTP
100 DZPA(JJ) = DAPA ** BP
GO TO 10
200 DZPA(JJ) = ALOG(DAPA)
GO TO 10
300 DZPA(JJ) = EXP(DAPA/BP)
GO TO 10
400 DZPA(JJ) = ATAN(DAPA/BP)
GO TO 10
500 DZPA(JJ) = DAPA/ (DZPA(JJ) - BP)
10 CONTINUE
RETURN
END
SUBROUTINE VARI(BEE, NY)

C
C SUBROUTINE VARI CALCULATES TERMS IN ANALYTICAL VARIANCES OF THE CONSEQUENCES
C IF CORRELATED INPUT PARAMETERS PRESENT
C CALLED BY MAIN, ONLY IF NCORE.GT.0

* CALL COMMP
DIMENSION BEE(6,12)
DO 196 L=1, NCONS
   VAR = 0.
   DO 197 J=1, NY
      IF (J.EQ. NY) GO TO 197
      JPI = J+1
      DO 198 K= JPI, NY
         VAB = VAP + 2.*BEE(L,K)*CH11(J,K)*BEE(L,J)
      198 CONTINUE
   197 CONTINUE
   SDZET(L) = SQRT(SDZET(L)**2 + VAR)
196 CONTINUE
RETURN
END
SUBROUTINE WEIERR
C CALCULATES ERRORS OF THE WEIGHTED MQ SURFACE IN ITS KNOT-POINTS
C THE SURFACE GOES THROUGH THE REFERENCE POINT EXACTLY
C EDITS THE ERRORS FOR ALL CONSEQUENCES
C CALLED BY DRIVER IF NQUAD= 4 AND RANGE.GT.0
C RADSQ(J),S MUST BE KNOWN BEFORE CALLED
C WEIER CALLS WEIPOL
C
C COMMON/WEIGHT/KOFIT,RANGE,RADSQ(12),RANGEP
DIMENSION DXC(6)
DATA IWRITE/6/
INDEX=0
J = 0
K=0
WRITE(IWRITE,1000)
WRITE(IWRITE,1010) INDEX,J,K,(ZETA0(I),I=1,NCONS)
WRITE(IWRITE,1011) (SDZET(I),I=1,NCONS)
1000 FORMAT(1H1,9X,39h*ERRORS OF THE WEIGHTED 3-Q SURFACES */110,81,52
+FIRST THE REFERENCE POINT VALUES OF THE CONSEQUENCES/1H ,6H INDEX
2,7H J K,9X,13H CONSEQUENCES///)
1010 FORMAT(1H1,315,6E14.4)
1011 FORMAT(15HSTANDARD DEV.S,1X,6E14.4)
WRITE(IWRITE,1012)
1012 FORMAT(1H0,9X:THEN ERRORS IN THE KNOT-POINTS///)

DO 1 J=1,NPARA
1 2(J) = 20(J)
DO 2 JWE=1,NFARA
2 3(JWE) = 3(JWE)
INDEX=1
CALL WEIPOL
DO 3 L=1,NCONS
3 DXC(L) = APZETA(L) - ZETA1(L,JWE)
WRITE(IWRITE,1010) INDEX,JWE,KWE,(DXC(I),I=1,NCONS)
INDEX=2
Z(JWE) = Z2(JWE)
INDEX=1
CALL WEIPOL
DO 4 L=1,NCONS
4 DXC(L) = LPZETA(L) - ZETA2(L,JWE)
WRITE(IWRITE,1010) INDEX,JWE,KWE,(DXC(I),I=1,NCONS)
INDEX=3
KWE = 0
Z(JWE) = Z3(JWE)
INDEX=1
CALL WEIPOL
DO 5 L=1,NCONS
5 DXC(L) = APZETA(L) - ZETA3(L,JWE)
WRITE(IWRITE,1010) INDEX,JWE,KWE,(DXC(I),I=1,NCONS)
INDEX=1
JPI = JPI+1
IF(JPI.GT.NPARA) GO TO 21
DO 20 KWE= JPI,NPARA
20 INDEX=11
Z(KWE) = Z3(KWE)
DO 7 L=1,NCONS
7 DXC(L) = APZETA(L) - ZETA11(L,JWE,KWE)
WRITE(IWRITE,1010) INDEX,JWE,KWE,(DXC(I),I=1,NCONS)
MEMBER NAME WEIER

INDEX = 44
Z(KWE) = Z4(KWE)
CALL WEIFOL
DO 8 L = 1, NCONS
8 DXC(L) = APZETA(L) - ZETA44(L, JWE, KWE)
WRITE (IWRITE, 1010) INDEX, JWE, KWE, (DXC(I), I = 1, NCONS)
Z(KWL) = Z0(KWE)
20 CONTINUE
21 CONTINUE
INDEX = 4
KWE = 0
Z(JWE) = Z4(JWE)
CALL WEIFOL
DO 6 L = 1, NCONS
6 DXC(L) = APZETA(L) - ZETA4(JWE)
WRITE (IWRITE, 1010) INDEX, JWE, KWE, (DXC(I), I = 1, NCONS)
JPI = JWE + 1
IF (JPI.GT.NPARA) GC TO 31
DO 30 KWE = JPI, NPARA
INDEX = 22
Z(KWE) = Z3(KWE)
CALL WEIFOL
DO 9 L = 1, NCONS
9 DXC(L) = APZETA(L) - ZETA22(L, JWE, KWE)
WRITE (IWRITE, 1010) INDEX, JWE, KWE, (DXC(I), I = 1, NCONS)
INDEX = 33
Z(KWE) = Z4(KWE)
CALL WEIFOL
DO 10 L = 1, NCONS
10 DXC(L) = APZETA(L) - ZETA33(L, JWE, KWE)
WRITE (IWRITE, 1010) INDEX, JWE, KWE, (DXC(I), I = 1, NCONS)
Z(KWE) = Z0(KWE)
30 CONTINUE
31 CONTINUE
Z(JWE) = Z0(JWE)
2 CONTINUE
RETURN
END
SUBROUTINE WEIPOL
C CALCULATES RESPONSE SURFACE CONSEQUENCES WITH WEIGHTED COEFFICIENTS
C CALLED BY FLIYQ (IF NQUAD=4 AND RANGE.GT.0.)
C WEIGHTING SPECIFIED BY INPUT VARIABLE RANGE
C
*CALL COMP*
COMMON/WEIGHT/NOFIT,RANGE,RADSQ(12),RANGEP
DIMENSION WEIGR(12),WQ3(12),WQ4(12)
DO 330 J=1,NPARA
ZZA =Z(J)
ZZJ =ZZA - Z(J)
ZZ3 =ZZA - Z3(J)
ZZ4 =ZZA - Z4(J)
RINV = RADSQ(J)
ARGUM = ZZJ*ZZJ*RINV
IF(ARGUM.GT.80.) ARGUM =80.
WEIGR(J) = EXP(-ARGUM)
ARGUM = ZZ3*ZZ3*RINV
IF(ARGUM.GT.80.) ARGUM =80.
WQ3(J) = EXP(-ARGUM)
ARGUM = ZZ4*ZZ4*RINV
IF(ARGUM.GT.80.) ARGUM =80.
WQ4(J) = EXP(-ARGUM)
330 CONTINUE
DO 341 L=1,NCONS
APZETA(L) = ZETA0(L)
DO 342 J=1,NPARA
ZZJ = Z(J) - ZO(J)
DTERM = 0.
WEIGR = WEIGR(J)
AWEIGH = 1. -WEIGR
WQJ3 = WQ3(J)
WQJ4 = WQ4(J)
C JUMP OVER 343 LOOP
IF(J.EQ.NPARA) GO TO 344
JP1 = J+1
DO 343 K=JP1,NPARA
ZZK = Z(K) - ZO(K)
WQK3 = WQ3(K)
WQK4 = WQ4(K)
QWE1 = QWE1 + WQJ3 * WQK3
QWE2 = QWE2 + WQJ4 * WQK3
QWE3 = QWE3 + WQJ3 * WQK4
QWE4 = QWE4 + WQJ4 * WQK4
QSUM = QWE1 + QWE2 + QWE3 + QWE4
QWE1 = QWE1 * QSUM
QWE2 = QWE2 * QSUM
QWE3 = QWE3 * QSUM
QWE4 = QWE4 * QSUM
DTERM = DTERM + (QWE1*DQ(L,1,J,K) + QWE2*DQ(L,2,J,K) +
+ QWE3*DQ(L,3,J,K) + QWE4*DQ(L,4,J,K) )*ZZK
343 CONTINUE
344 CONTINUE
C
WBSUM = 1./(WEIGBB + WQJ3 + WQJ4)
BQSUM = (WEIGBB*B(L,J) + WQJ3*BQ(L,1,J) + WQJ4*BQ(L,3,J) )*WBSUM
CQSUM = (WEIGBB*C(L,J) + WQJ3*CQ(L,1,J) + WQJ4*CQ(L,3,J) )*WBSUM
MEMBER NAME

NAME = BQDM + CQDM*ZZJ + DTERM
APTETA(L) = APTETA(L) + ATERM *ZZJ

CONTINUE
CONTINUE
RETURN
END
SUBROUTINE ZTRAP
C TRANSFORMS SYSTEMATIC KNOT-POINT COORDINATES FOR JOBI.GT.1. IF
C NTRAPA.GT.0
C CALLED BY DRIVER BEFORE 48
*CALL COMMF
COMM/TTRANSF/MTTRAPA,MTTRACC,MTTRA (7),MTTYPE (7),MTTRA (7),MTTYPE (7),APA (17),BPA (7),ACC (7),BCO (7)
JTYPE = 0
DO 10 I=1,NTRAPA
JJ = JTYPE (I)
IF (JJ .NE. L) GO TO 10
JTYPE = JTYPE (I)
AP = APA (I)
BP = EPA (I)
DPAC = ZO (JJ) - AP
DPA1 = Z1 (JJ) - AP
DPA2 = Z2 (JJ) - AP
DPA3 = Z3 (JJ) - AP
DPA4 = Z4 (JJ) - AP
GO TO (100,200,300,400,500), JTYPE
100 ZO (L) = LPAO ** BP
Z1 (L) = DPA1 ** BP
Z2 (L) = DPA2 ** BP
Z3 (L) = DPA3 ** BP
Z4 (L) = DPA4 ** BP
GO TO 10
200 ZO (L) = ALOG (DPA0)
Z1 (L) = ALOG (DPA1)
Z2 (L) = ALOG (DPA2)
Z3 (L) = ALOG (DPA3)
Z4 (L) = ALOG (DPA4)
GO TO 10
300 ZO (L) = EXP (DPA0/BP)
Z1 (L) = EXP (DPA1/BP)
Z2 (L) = EXP (DPA2/BP)
Z3 (L) = EXP (DPA3/BP)
Z4 (L) = EXP (DPA4/BP)
GO TO 10
400 ZO (L) = ATAN (DPA0/BP)
Z1 (L) = ATAN (DPA1/BP)
Z2 (L) = ATAN (DPA2/BP)
Z3 (L) = ATAN (DPA3/BP)
Z4 (L) = ATAN (DPA4/BP)
GO TO 10
500 ZO (L) = DPA0/ (ZO (JJ) - BP)
Z1 (L) = DPA1/ (Z1 (JJ) - BP)
Z2 (L) = DPA2/ (Z2 (JJ) - BP)
Z3 (L) = DPA3/ (Z3 (JJ) - BP)
Z4 (L) = DPA4/ (Z4 (JJ) - BP)
10 CONTINUE
IF (JTYPE.EQ.0) GO TO 12
WRITE (6,2603) Z2 (L) ,Z4 (L) ,ZO (L),Z3 (L) ,Z1 (L)
2603 FORMAT (1S1 TRANSFORMED VALUES,5E14.6/)
This sample problem performs Task 14 (JOBI=14) for a problem of six input parameters and two consequence variables. Use of random knot points, least-squares fitting, a transformation for an input parameter, and a statistical criterion for conditional distributions is demonstrated in this example.

The first two pages contain the listing of the input cards for Task 14. Five consequence variables are input on the consequence cards (cards 9-48) but only the first two are used since the variable NCONS is given value 2 on the first card. The last input card specifies a lower limit for consequence 2 as having the mean value 350.0 and a standard deviation 50.0, to be used in calculating the conditional distributions. The physical meanings of the consequence variables are various damage potential indicators of a postulated accident in a fast breeder reactor.

In the output listing that follows, the first page indicates sizes and addresses of certain arrays important for the dynamic allocation of space, and are used internally by the code. With the aid of the definitions given in Chapters II and III and the comments found in the output itself, most of the output is self-explanatory. For example, the knot-point coordinates are given in terms of both original and transformed input parameters. Helpful comments may also be found in the program listing.

The errors of the fitted response surfaces in the knot points are listed so that the adequacy of the approximations can be assessed. In the output the coefficients of the response-surface polynomials, Eq. 2, are relevant to the transformed input parameters (rather than the original untransformed ones) when a transformation is used.

The probability distributions are presented as histogram tables with 12 categories (intervals). Category 1 includes all cases below the lower limit; category 12 includes all cases above the upper limit.

The distributions are also plotted in 26 categories, each one-half of the above 12 categories, except for the end categories (0 and 13) that cover the lower and upper tails.
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TRANSFORMATIONS FOR CONSEQUENCES

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FOR DISTRIBUTION 8, THE VALUES FOR THE MEAN AND STANDARD DEVIATION ARE THOSE OF THE LOGARITHM OF THE PARAMETER.

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SIMULT EXECUTED. RETURN TO CALLING PROGRAM.

DETERMINANT OF 2FP*2F = .471196E-12 TIMES 1.00 0
### Fitted Surface Errors

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**Consequence 1**

- Max Error Knot: 31
- Value: 0.662626E+01
- Min Error Knot: 35
- Value: -0.595143E+01

- Mean Square Error: 0.547556E+01
- Ref Value: 0.204303E+03
- Fraction: 0.02679
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**CONSEQUENCE 2** MAX ERROR KNOT= 30 VALUE= 0.5C207SC+07 MIN ERROR KNOT= 29 VALUE= -0.5E5328E+02

MEAN SQUARE ERROR= 0.485655E+02 MSE VALUE= 0.15437D+04 FRACTION = 0.32499
JOBI 14 IS JOB1 4 WITH 2ND DEGREE SURFACE FITTED TO RANDOM KNOT-POINTS
THE COEFFICIENTS OF THE POLYNOMIALS

\[ A(J) + (Z(J) - Z0(J)) \sum J \]

\[ C(J) * (Z(J) - Z0(J))^2 \sum J \]

\[ D(J,K) * (Z(J) - Z0(J)) * (Z(K) - Z0(K)) \sum J,K (K > J) \]

IN MULTIQUADRANT CASE (NQUAD=4) IQ INDICATES THE QUADRANT IN Z(J)/Z(K) -PLANE

CONSEQUENCE 1

\[ A = 204.368 \]

\begin{array}{cccccccc}
B(J) & 1403.87 & 86291.6 & 3.53502 & 0.245221E+09 & -.705580E-09 & 2223.28 \\
C(J) & 2895.01 & 0.234570E+08 & 0.134572E-01 & 0.325878E+15 & 0.342230E-20 & -.98501.9 \\
D(1,K) & 374570. & 61.6717 & 0.267006E+10 & -.816630E-08 & -.377.558 \\
D(2,K) & 3071.85 & -.105899E+12 & -.581802E-06 & -.103936. \\
D(3,K) & -.107566E+08 & -.661825E-10 & -1.23739 \\
D(4,K) & -.391765E-02 & -.782847E+10 \\
D(5,K) & -.646701E-09 & & & & & \\
\end{array}

CONSEQUENCE 2

\[ A = 1943.67 \]

\begin{array}{cccccccc}
B(J) & 7258.42 & 42444. & 39.6644 & 0.102024E+10 & -.444121E-08 & -.5085.57 \\
C(J) & -6944.4 & 0.241114E+08 & -1.20749 & 0.187902E+16 & 0.143508E-16 & -.65711. \\
D(1,K) & 694894. & 218.332 & -.135357E+10 & -.366119E-07 & -71194.4 \\
D(2,K) & 12581.1 & -.424856E+12 & -.232051E-09 & -.104686E+09 \\
D(3,K) & -.107038E+09 & -.935219E-10 & -322.539 \\
D(4,K) & .261972E-01 & -.493666E+11 \\
D(5,K) & .115681E-06 & & & & & \\
\end{array}
## SENSITIVITIES

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<th>CONSEQUENCE 2</th>
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CONSEQUENCES VS PARAMETERS
NINE EQUALLY SPACED VALUES FROM 12(J) THROUGH 21(J)

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CONSEQUENCE VERSUS PARAMETER SKETCH

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CONSEQUENCE VERSUS PARAMETER SKETCH

CONSEQUENCE 3

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CONSEQUENCE VERSUS PARAMETER SKETCH
CONSEQUENCE VERSUS PARAMETER SKETCH

PARAMETER CONSEQUENCE SKETCH

1.40E+06 183.2
1.25E+06 187.9
1.00E+06 193.0
5.74E+06 204.4
1.12E+06 210.7
5.28E+06 217.4
4.65E+06 224.5
1.50E+06 231.1

5 PIZZO

CONSEQUENCE VERSUS PARAMETER SKETCH

PARAMETER CONSEQUENCE SKETCH

2.50E+11 226.4
3.10E+11 220.5
3.70E+11 214.8
4.30E+11 209.5
4.90E+11 204.4
5.50E+11 199.5
6.10E+11 195.0
6.70E+11 188.7

5 TAPPIS

CONSEQUENCE VERSUS PARAMETER SKETCH

PARAMETER CONSEQUENCE SKETCH

0.50E+00 167.0
0.89E+00 181.5
0.97E+00 194.7
1.00E+00 204.4
1.03E+00 211.3
1.05E+00 215.5
1.07E+00 215.9

1 RAMPS

CONSEQUENCE VERSUS PARAMETER SKETCH

PARAMETER CONSEQUENCE SKETCH

1.70E+03 140.0
2.05E+03 154.5
2.29E+03 168.7
2.43E+03 181.5
2.58E+03 194.4
2.73E+03 208.8
2.89E+03 219.9
3.05E+03 230.5
3.21E+03 241.7

CONSEQUENCE VERSUS PARAMETER SKETCH
**CONSEQUENCE VERSUS PARAMETER SKETCH**

**PARAMETER** | **CONSEQUENCE** | **SKETCH**
--- | --- | ---
0.2535E+11 | 2148. | *
0.3166E+11 | 2079. | *
0.3798E+11 | 2023. | *
0.4429E+11 | 1977. | *
0.5060E+11 | 1944. | *
0.5691E+11 | 1921. | *
0.6322E+11 | 1911. | *
0.7585E+11 | 1923. | *

--- | --- | --- | --- | --- | --- | --- | --- | --- | ---

**CONSEQUENCE VERSUS PARAMETER SKETCH**

**PARAMETER** | **CONSEQUENCE** | **SKETCH**
--- | --- | ---
0.9500 | 1915. | *
0.9930 | 1942. | *
0.9975 | 1956. | *
1.000 | 1956. | *
1.005 | 1944. | *
1.010 | 1911. | *
1.012 | 1880. | *
1.016 | 1828. | *
1.020 | 1763. | *

**PARAMETER** | **TRANSFORMED**
--- | ---
0.5249E-06 | 1970. | *
0.5499E-06 | 1999. | *
0.5748E-06 | 2030. | *
0.5997E-06 | 2064. | *
MOMENTS OF THE PARAMETERS

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<th>PARAMETER</th>
<th>MEAN</th>
<th>CM2</th>
<th>CM3</th>
<th>CM4</th>
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ANALYTICAL MOMENTS NOT EXACT FOR TRANSFORMED PARAMETERS

APPROXIMATIVE RELATIONS USED
CM1 = TRANSFORMED REFERENCE POINT Z0(J)
CM2 = (IZ(Z0+SD)-TP(Z0))**2
CM3 = 0.
CM4 = 3.* CM2 * CM2

| 1  | BANDP | .244356E-03 | .734410E-03 | 0. | 1.68937E-05 |
| 2  | DOFLB | -.435090E-02 | .115602E-06 | 0. | .400901E-13 |
| 3  | CFUEL | 5.07842     | 16.0345     | 0. | 771.318     |
| 4  | LAMBDA| .500000E-06 | .149769E-14 | 0. | .672922E-29 |
| 5  | VZERO | .506000E+11 | .966400E+20 | 0. | .27671E+47 |
| 6  | VAPRES| 1.0053C     | .33751E-04  | 0. | .348602E+08 |

ANALYTICAL CROSS CENTRAL MOMENTS OF THE PARAMETER PAIRS

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MOMENTS OF THE ANALYTICAL RESPONSE SURFACE CONSEQUENCES

QUADRATIC MODEL

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<th>MEAN VALUE</th>
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<td>0.304904E+03</td>
<td>0.194367E+04</td>
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CONS1 CONS2 CORREL COEFF LIN CORREL COEFF

|     | LIN         | 0.88382566  | 0.90091288 |
|     | CORREL COEFF|              |            |

END OF MOMENT OUTPUT IN JOB 2
CRITERIA INPUT FOR CONDITIONAL DISTRIBUTIONS

NSB = 10000  NSC = 0  TOLE = '  NCOND = 1

NCRT = 1  LCRIT = 0  JDIS = 2  ADIS = 350.0000  BDIS = 50.0000  CDIS = 0.0  DDIS = 0.0
**DISTRIBUTIONS OF THE RESPONSE SURFACE CONSEQUENCES, * WORK 13**

**CATEGORIES DEFINED BY ANALYTICAL MOMENTS**

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<th>NUMBER OF SAMPLES = 40000</th>
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**NUMBER OF SIMULATION CYCLES = 40000**

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<th>ACCURACY</th>
<th>PERCENT</th>
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**CATEGORY 2 MEAN = 0.192290E+04 | STANDARD DEVIATION = 0.304504E+03 | SCALE = 3.50**

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<th>COUNTS</th>
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<th>ACCURACY</th>
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### Joint Distributions of Polynomial Consequences

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**End of Joint Distributions in Job 3**
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*Note: The diagram represents the probability distribution for each consequence unit.*
CONDITIONAL DISTRIBUTIONS OF CONSEQUENCES - JOB 4 - WORK NUMBER = 13

SELECTIVE SIMULATION OF POLYNOMIAL CONSEQUENCES

LIMIT FOR UNCONDITIONAL SIMULATION CYCLES NSA = 40000
LIMIT FOR UNRELIEVED CONDITIONAL SIMULATION CYCLES NSB = 10030
LIMIT FOR RELIEVED CONDITIONAL SIMULATION CYCLES NSC = 0 WITH TOLERANCE = 0.01

1 ACTUAL CONDITIONS

CONSEQUENCE 1 LIMIT TYPE = 0
CONSEQUENCE 0 LIMIT TYPE = 0
CONSEQUENCE C LIMIT TYPE = 0
CONSEQUENCE 0 LIMIT TYPE = 0

LIMIT TYPE 0 MEANS LOWER LIMIT, 1 MEANS UPPER LIMIT

TOLERANCE AS A FRACTION OF STANDARD DEVIATION

NUMBERS OF SIMULATION CYCLES
UNCONDITIONAL NC = 40000
CONDITIONAL ND = 1530
RELIEVED CONDITIONS NE = 1558

FRACTION SATISFYING CONDITIONS = ND/NC = 0.038250
FRACTION SATISFYING RELIEVED CONDITIONS = NE/NC = 0.038950

FOR POLYNOMIAL CONSEQUENCES WITH UNRELIEVED CRITERIA
STATISTICS FOR ND = 1530 RESPONSE SURFACE CONSEQUENCES

SAMPLE CONDITIONAL MEAN AND OTHER CHARACTERISTICS IN JOB 4 (RESPONSE SURFACE CONSEQUENCES)
OF WORK 13

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### Joint Distributions of Polynomial Consequences

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#### Consequence Number 2: Horizontal

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**Probability and Accuracy (Standard Deviation)**
### Conditional Distributions of the Response Surfs

**Probability Per Unit of Consequence 1**

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**Probability Per Category Sketch in Half Category Intervals**

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**Consequence 1**

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The diagram illustrates the probability distribution across different consequence values, with markers indicating the probability values at various points.
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ACKNOWLEDGMENTS

The author is indebted to K. A. El-Sheikh, D. R. Ferguson, C. Mueller and L. Mync for stimulating comments and discussions as well as to J. Fletcher, R. D. George, J. M. Kyser and F. G. Prohammer for their cooperation in the computational aspects of the methodology.
REFERENCES


