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Statistical Correlation Analysis for Comparing Vibration Data From Test and Analysis

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STATISTICAL CORRELATION ANALYSIS FOR COMPARING VIBRATION DATA FROM TEST AND ANALYSIS

INTRODUCTION

Up until the last 30 years, structural analysis consisted largely of abbreviated and approximate calculations. Typically, the calculations represented empirical knowledge more than an understanding of structural behavior. Limited analytical capabilities also lead to limitations in testing. Without the knowledge of how a structure should respond to loads, the testing of a new design often consisted simply of putting it to its intended use. If it worked sufficiently well for a sufficiently long time, it was deemed successful and became a model for future structures of a similar nature.

This situation changed drastically as the result of three major developments. With the advent of the digital computer in the 1940s came the possibility of doing the large number of calculations required to determine accurately and in detail the stresses and deformations that a structure would experience when serving its intended functions. Next, the development of the finite element method in the 1950s provided algorithms, executable on digital computers, which could indeed calculate stresses and deformations in complex structures. Finally, software systems were developed to combine structural theory, finite element methods, and computer hardware into useful tools for structural analysis.

The NASTRAN software system (NASA STRuctural ANalysis), development of which was begun by NASA in 1965, is an example of such a system which has received wide usage. There were a number of reasons for its acceptance. First, it integrated into a unified set of software a sufficient number of algorithms and data types to carry out the majority of structural analyses. Second, NASTRAN included software to overcome many of the deficiencies of early computers, such as limited memory size, which would have otherwise limited the complexity of finite element models. This meant that the limitation on the complexity of an analyst's model shifted to the amount of computer time he could obtain. Finally, extensive effort went into providing good user interfaces, complete documentation, and wide dissemination. To enable wide use, NASTRAN is written mainly in a computer independent subset of FORTRAN, which permits it to run on 5 different makes of computers. The total capabilities provided by NASTRAN have contributed significantly to the present situation, where finite element analysis using digital computers is not only the dominant means of accomplishing structural analysis, but it is also widely used for analysis in heat transfer, aerodynamics, acoustics, control systems, potential theory, and actually any problem which can be solved by sets of linear equations.

The overall effect of this new tool has been to improve the quality of structural designs. With finite element techniques, the designer can be much more certain of reaching a desired tradeoff of structural efficiency, cost, and reliability than previously. However, the volumes of data produced by complex finite element analyses, now routinely performed, have created problems of interpretation, because of the human time required to assimilate large amounts of data. For the same reason, test data is often not completely compared to predicted analytical results. Often, if a structure goes through static and dynamic testing with no apparent problems, such as breakage or pronounced deflection or vibration, it is deemed adequate. When test data obviously disagrees

with results predicted by finite element analysis, a too frequent practice is to assume that the analytical data is wrong and to adjust its parameters until satisfactory agreement with test data is achieved.

There are a number of ways to increase the value of combined analytical and test data on structural behaviour. The work described here was undertaken to derive some of these improvements. Fundamentally, the two sets of data provide a means of cross checking, thereby reducing the probability of undetected errors in either set. A principal problem in doing cross checking is that there is not a commonly accepted measure of comparison between analytical and test data. Often, this means that a few hundred data points from both sources, regarded as critical, are plotted in some way, and if the data plots appear reasonably alike to the eye, or can be made to look alike by reasonable alterations to the analytical model, then agreement is decreed.

With the techniques described below, it is possible to use NASTRAN to place analytical results in a format in which they can be statistically compared as a group to equivalent groups of test data gathered by automated test systems. Statistical routines can then provide criteria describing overall agreement and identify areas of significant disagreement. This means that far more data can be evaluated with far less human labor. This technique can help identify whether disagreement is due to faulty test procedures or faulty modeling. However, another promising long range benefit of the statistical correlation of analytical and test data is that structural design can be further improved. There is presently no widely accepted and effective way of validating analytical results on real problems. Statistical comparisons with equivalent test data appear to provide an acceptable means for this validation. If this technique becomes widely used and improved, then it will gradually lead to improved analytical techniques, thus leading in turn to improved designs and eventually to improved structures.

OBJECTIVE

When designs need to qualify under narrow allowances, as is normally the case with aerospace structures, it is often necessary to compare structural vibration properties obtained from testing with those obtained from analysis.

In order for a comparison to be meaningful, it is necessary to define the basis on which the data will be compared. In general, they will be compared on the basis of like modes. A test mode and an analytical mode are alike if the amplitude of the standing wave pattern is "exactly" the same for both at all sample points. The bothersome qualifier in this definition of like modes is the word 'exactly'. Even if one were to assign a reasonable tolerance for defining the word 'exact', it would be rare to find a test mode that measured exactly the same as an analytical mode. A more realistic definition of modes being "alike" is to require that the pair correlate closely. This definition allows some engineering judgement for prescribing the tolerance of "closeness."

There are no exact solutions to the vibration characteristics of complex three dimensional structures. Highly capable analytical techniques are available, but they are liable to human error. Highly capable experimental equipment is also available, but human error can enter the experimental side from two sources: in fabricating the test article and in conducting the test. Once a like pair is found, it can be expected that the frequency at which this mode appears is different for analysis than it is for test. Therefore, the purpose of this enterprise is not to judge the correctness

of either set of data to represent a given design, but to point up differences and equip the responsible structural engineers with enough measures for them to be able to assess the areas of disagreement.

To illustrate how statistical comparison can help the structural engineer, consider the following example. After testing a collection of modes for likeness in a given frequency range, say 8 from test and 11 from analysis, it might be that 7 matches are found. Also, consider that one test mode and four analytical modes are not matched. In those that match, it is possible that the frequencies of the analytical modes are all higher than their test counterparts. It may also be that the one test mode without a match measures higher in frequency than all other test modes, while two of the analytical modes without matches measure lower in frequency than all other analytical modes, and the other two are in the middle range. Figure 1 depicts this example.

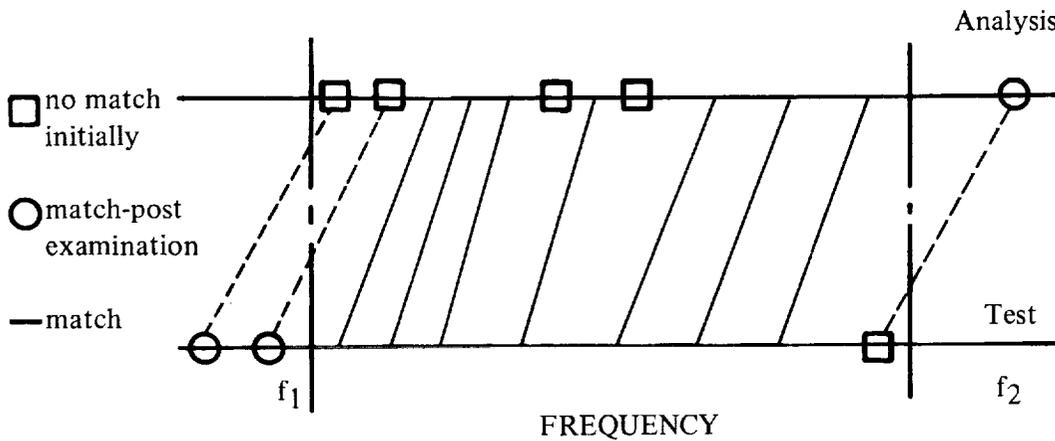


Figure 1

One would be inclined to look above the upper frequency bound of the analytical modes to find a match for the spinster test frequency, and to look below the lower frequency bound of the test modes to find matches for the mateless analytical modes. As for the two unpaired analytical modes in the middle frequency range, there is a possibility that analysis uncovered two modes that test failed to find. It might also be that one grid point stands out in five of the matching pairs of modes as the place where the modes show the greatest difference in their shapes. One might be suspicious of the analysis as having too low a value of mass at that point.

The happy ending to this story might be that the analytical mass defect was found, and the wanting test instrumentation was supplied so that the overall shift in frequency was erased, two middle range test modes were revealed, and 10 out of 11 matches were found in the frequency range on a second trial.

The limited amount of experimental data and the limited access in which to install sensors at interior points are factors that constrain the points at which comparisons can be made. There is a disproportionately large number of points at which analytical data is available for comparisons. The objective will be to bring about useful comparisons within the constraints of available data. The intent is to be able to identify the mode shapes from both of the sources; to say how closely any two mode shapes are related; to say at what frequencies the test mode and the analytical mode

of a closely related pair appear; to give the locations at which two modes diverge beyond a threshold; and to isolate the greatest divergence.

A correlary objective is to establish a communication basis between the records from analysis and the records from test. Once such a channel is established, then standardized data can be exchanged by means of a program. For instance, the arrays of generalized mass and generalized stiffness can be passed from analysis to test while the array of modal damping can be passed from test to analysis.

METHOD

Structural properties determined by either analysis or test can properly be regarded as non-deterministic and therefore random. For instance, in analysis the factors liable to random variation are: the interpretation of drawings, the modeling of elastic relations, the representation of joints, the modeling of mass properties, entering of data into the computer, transfer of data into, out of, and within a computer, computer behavior, and debugging methods. There will be as many analytical results as there are analysts. Similarly, variability in testing can arise from the quality of materials in fabrication, the machining of parts, the assembly of components, the mounting of sensors, the calibration of recorders, the reading of records, and the processing of data. The experimental results will be as individual as the number of teams conducting tests. Since it is the intention to compare two random records, a well proven stochastic tool to apply is the correlation function—or particularly—the correlation coefficient. Thus, the criterion for deciding whether two modes are the same can be mediated by how close to unity the correlation coefficient for them is. Statistical methods will be employed to compare test mode shapes with analytical mode shapes. Analytical and test measurements of mode shapes will be taken at the same set of structural locations, so that behavior will be compared at like points. At present, the comparisons in this study will be limited to undamped real modes, as opposed to damped complex modes. A test mode shape and an analytical mode shape will each be considered to be a statistical set of data. The number of test modes to be compared need not be the same as the number of analytical modes, so that all available modes from both sources within a specified frequency range can be considered. The primary tool for making comparisons will be the correlation coefficient.

According to James & James 'Mathematical Dictionary', the definitions of the statistical quantities that will be used in this analysis are as follows:

$$\text{Variance} = \sum_{i=1}^n (x_i - x')^2 p(x_i) = \sigma^2 \quad (1)$$

where n is the number of sample points in the statistical file,

$$x' \text{ is the mean} = \frac{1}{n} \sum_{i=1}^n x_i \quad (2)$$

and $p(x_i)$ is the probability of finding the sample x_i in any statistical record. Other statistical quantities will be introduced after discussing those introduced thus far.

The following interpretations will be given to these quantities for purposes of this analysis. Data from each mode is a distinct statistical record. The quantity x_i is the measurement of the departure from the equilibrium position at a given point "i" of a single vibration mode from an eigenvalue analysis. If x_i were measured in time from an undamped oscillation, it is known from the definition of a mode shape that there will be an equal number of positive excursions as negative excursions away from the equilibrium position of a mode. The mean of a time varying sample would be the equilibrium position, so x' would be zero. The x_i 's are not taken as time varying samples, but as the normalized envelopes of a finite number of extreme model positions for which the average is definitely not zero. The probability $p(x_i)$ is a quantity which varies from mode to mode. The function $p(x_i)$ for a mode is not known a priori, so it will be estimated by using the scheme of empirical probability density as described in Y. W. Lee's "Statistical Theory of Communications", page 125. The range of x_i depends on how a mode is normalized. For example, if a mode is normalized to its maximum component, the range is $-1 < x_i < +1$. For normalization according to a particular component or to mass, the ranges can be greater or less than unity. The range is divided into equal increments, Δx . Modal data is scanned for how many of the modal displacements fall within each increment; i.e, the number N_i in each increment Δx_i . The frequency ratio is constructed for each increment, by dividing the count in each increment N_i by the total number of modal data points n : N_i/n . According to Jacob Bernoulli's theorem on probability, the quantity $\frac{N_i/n}{\Delta x}$ stays within an ϵ neighborhood of $p(x_i)$ as n gets large and Δx grows small. It will be assumed that the number of samples of a mode shape n is sufficiently large to justify the use of the quantity $\frac{N_i/n}{\Delta x}$ as a reasonable approximation to the probability density function $p(x)$ for use in this algorithm. The probability that a model sample point "h" will fall within the range of

$$x < h < x + \Delta x \text{ is } \int_x^{x + \Delta x} p(x) dx$$

Because of the discretized nature of the available data the integral will be approximated in incremental form by

$$P(x_i < h < x_i + \Delta x) \approx \frac{N_i/n}{\Delta x} (x_i + \Delta x - x_i) \approx N_i/n \quad (3)$$

On occasion, a fault in a sensor or a recorder will arise which voids data for some point. This renders the probability null for finding data at that point. Instead of admitting a zero probability, this analysis will reduce the sample space "n" to the corresponding number of data points available in both analysis and test.

With the above provisions for this analysis, the statistical quantities reduce to:

Variance

$$\sigma^2 = \sum_{i=1}^n (x_i - x)^2 N_i/n \quad (4)$$

Standard Deviation

$$\sigma = +\sqrt{\sigma^2} = + \left[\sum_{i=1}^n (x_i - x')^2 N_i/n \right]^{1/2} \quad (5)$$

R.M.S (Root Mean Square)

$$\rho = [1/n \sum x_i^2 N_i/n]^{1/2}. \text{ If } x' = 0 \text{ then } \rho = \sigma.$$

Correlation Coefficient between two statistical files $x_i(a)$ and $x_i(e)$ is:

$$r_{ab} = \frac{\sum_{i=1}^n [x_i(a) - x'_a] \rho_a(x_i) [x_i(e) - x'_e] \rho_e(x_i) \cdot \rho_{ae}(x_a, x_e)_i}{\sqrt{\sum_{i=1}^n [x_i(a) - x'_a]^2 \rho_a(x_i) \sum_{i=1}^n [x_i(e) - x'_e]^2 \rho_e(x_i)}}$$

using $x'_a = x'_e = 0$, and using the frequency ratios for approximating probability causes "r" to simplify to:

$$r_{ab} = \frac{\sum_{i=1}^n x_i(a) x_i(e) \frac{N_a(x_i)}{n} \frac{N_e(x_i)}{n}}{\sqrt{\sum_{i=1}^n x_i(a)^2 \frac{N_a(x)}{n} \sum_{i=1}^n x_i(e)^2 \frac{N_e(x)}{n}}} = \frac{\sum_{i=1}^n x_i(a) x_i(e) \frac{1}{n^2} N_a(x_i) N_e(x_i)}{\sigma_a \sigma_e}$$

$$r_{ab} = \sum_{i=1}^n \frac{x_i(a)}{\sigma_a} \frac{x_i(e)}{\sigma_e} \frac{N_a(x_i) N_e(x_i)}{n^2} \quad (6)$$

Equation (6) can be interpreted as the total effect over the whole mode of multiplying the modal amplitude in the "a" set of data when scaled by its standard deviation, by the modal amplitude in the "e" set of data when scaled by the "e" standard deviation, for every pair of corresponding points, and summed for all n points. This method gives complete freedom to both the analyst and to the experimenter for organizing data in the manner of his choice (so long as it is uniform) and of normalizing to any convenient scheme independent of each other. When each set of data is scaled to its own standard deviation, both are placed on equal footings regardless of how the modal data was originally obtained.

All modes in both sets will be compared with each other, and the correlation coefficient will be computed for every combination.

Relative Deviation

It is instructive to determine where and by how much test and analytical mode shapes differ from one another. The approach here is to scale the modes so as to be highly sensitive to differences. Scaling by the RMS value for each mode will put both modes on such a footing that their differences will show a greater spread than they would if scaled by the variance. Using subscript "a" to indicate quantities belonging to analytical data and "e" to indicate quantities belonging to experimental data, the expression for relative deviation in the i^{th} sample of the j^{th} mode is written as:

$$(\text{Rel. Dev.})_{ij} = \left| \frac{x_i(a)_j}{\rho^a} - \frac{x_i(e)_j}{\rho^e} \right| \quad (7)$$

Relative deviation in a mode is the absolute value of the difference between the analytical modal displacement scaled by its modal RMS, and the experimental modal displacement scaled by its own modal RMS. An option will be given to specify what percentage of spread is to be displayed with the grid point identity. The default value of this spread is 5%.

Three other quantities will be computed which have been found to be useful by practicing test engineers. These quantities are defined in an internal GSFC memorandum written by D. J. Hershfeld dated January 8, 1971, entitled "Fitting Mode Shapes to Experimental Data." According to equation (2) of the memo (when transcribed into notation adapted in this report) the normalizing factor of the j^{th} mode is:

Normalizing Factor

$$C_j = \frac{\sum_{i=1}^n x_i(a)_j x_i(e)_j}{\sum_{i=1}^n x_i(a)_j^2} \quad (8)$$

The standard error, according to equation (5) of the memo in transcribed notation, is:

Standard Error

$$S = \left| \frac{1}{n} \left[\sum_{i=1}^n x_i(e)^2 N_e(x_i) - \sum_{i=1}^n x_i(a)^2 N_a(x_i) \right] \right|^{1/2} = \left| \sigma_e^2 - \sigma_a^2 \right|^{1/2} \quad (9)$$

Differences in mode shapes are computed by a common scaling of their absolute values by the standard error:

$$\text{Scaled Difference} = \left| [x_i(a) - x_i(e)] / S \right| \quad (10)$$

The tabulations of input modal arrays will be processed by this program. Listings will be made of modal masses, modal stiffnesses, and modal damping arrays versus frequency.

IMPLEMENTATION

In order to put this statistical correlation method of comparing test and analysis into operation, attention must be given to three distinct operations: a. the generation of the analytical vibration data and the transfer of its results, b. the sensing of the test vibration data and the transfer of its results, and c. the computation of the comparison between test and analysis and the acceptance of data from the two sources.

Analytical vibration data are expected to be implemented with NASTRAN. Output of the results is needed in non-standard form, so an ALTER packet was written to tailor the data and to translate the data to BCD for universal readability. These analytical data need further processing before computation can start and are passed to intermediate processors.

Two assemblies of test data are expected. They are: the list of points where test data were taken and the tabulation of mode shapes and frequencies in simple BCD format. They need to be transferred to files in the primary computer for computation.

The computation according to the theory outlined above is accomplished in a program called STATCORR. It expects input data in particular formats and allows the user to choose from a variety of output options.

Consideration has been given to analytical and test data coming from various sources. The STATCORR program will operate on data independent of its source, so long as it is entered according to a specified format. During this development, the analysis was done with NASTRAN and the tests were performed by the Environmental Test & Integration Branch at GSFC. References to specific analytical operations will pertain to capabilities in NASTRAN.

Provision was made for data coming from several runs, structures with symmetry, different normalizations, and non-uniform samples.

Liaison

At the outset, it is mandatory that comparisons be based on data gathered from identical locations. Liaison between test and analysis personnel prior to either the generation of the NASTRAN model or the instrumentation of the test article must establish the points and the component directions at which data is to be sampled. This set of locations will be referred to as the TESET vector. TESET will govern the location and orientation of test sensors and will govern the entries in the analytical partitioning vector. It is used in tabulating mode shapes from test and analysis, and it is the primary reference within STATCORR for sorting and reporting differences.

Equally important as matching data points is matching boundary conditions. The most difficult experimental boundary to enforce is clamped. The easiest to enact is free-free. Liaison between the test engineer and the analyst will help to uncover any disparity between the test set-up and the analytical boundary constraints.

Provision has been made for using symmetry. If the structure has symmetry that can be taken advantage of, liaison should define whether both test and analysis will collect data on only the basic segment. If so, agreement is needed on the naming of each plane of symmetry. Then, each test mode and each analytical mode must be tagged with SYM # PLAN parameters for the type of symmetry across each plane of symmetry. If only analytical data is based on symmetry, while test data is gathered over the whole structure, liaison is needed for three additional items. Octants of symmetry need to be identified. Each test point must be checked for the existence of an image point of reflection in the basic segment of analysis. Multiply-reflected image points must be provided with clones. A list of points with their individual component numbers belonging to each octant is organized by analysis, but should be double checked by the test engineer before proceeding.

Analysis

In NASTRAN, there are 5 options for eigenvalue analysis: Determinant, Inverse Power, Givens, Feer, and Hessenberg. All methods are manageable for use in conjunction with STATCORR. There is a problem, however, in transferring NASTRAN eigenvalue results into STATCORR. A DMAP ALTER has been written that manages this transfer. Modal frequencies, mass, and stiffness are delivered as part of the LAMA table in DTI format, using TABPCH. Partitioned mode shapes are delivered as a single matrix in DMI format using OUTPUT3. An explanation of the ALTER packet will follow subsequently. There are some precautions that should be observed with some of the 5 methods. With the Feer method one should check-point the eigenvalue run and exit after the READ module. Results should be examined for the acceptability of the last half of the roots extracted. If negative roots or vectors that fail to meet the orthogonality criterion are found, the PHIA matrix and LAMA table should be partitioned down to only the valid roots immediately after restarting; then one can proceed with the prepared DMAP ALTER route. Sometimes with the Determinant and the Inverse Power methods, several runs may be required before all the roots in a given frequency range are found. Data from any number of separate runs may be combined, but some roots may be repeated in different runs. A post-processor program (MERGE) has been provided to combine eigenvector data from the several runs, detect and eliminate duplicates, and sequence them in ascending order of frequencies. Modes may be normalized according to MASS, MAX, or POINT, but once a decision is made for a method of normalizing, it must be used exclusively for all analytical modes henceforth.

Partitioning is done using the DMAP module PARTN which requires a user supplied partitioning vector. The vector has been arbitrarily named TESET (standing for test set), but this name is imbedded in the DMAP statements of the ALTER packet, so it becomes necessary to use this name. DMI bulk data cards define the vector as a rectangular matrix of a single column, and the number of rows equal to order G of the structural model. This partitioning vector will be designed to serve a double duty. In addition to its duty of partitioning the PHIG matrix, TESET will serve the STATCORR program as a guide for correlating the sequence of test data with analytical data. The device employed to enable this secondary duty is that of constructing the DMI vector in ordered pairs. The first member of this pair is a NASTRAN internal sequence number which corresponds to a component of a test point. The second member of the pair is the Grid Point ID number belonging to the test point. The internal sequence number is actually the row

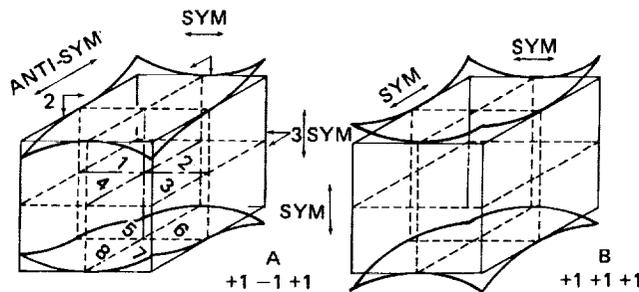
number of the equation of equilibrium for a given degree of freedom as they are organized in NASTRAN's system of matrices. The matrix of eigenvectors, PHIG, is the matrix to be partitioned, so the vector used to do the partitioning has to be the same order as the subject matrix. The final letter of standard NASTRAN matrix names gives its size; so in this case, the partitioning vector must be of order G; or briefly, the vector is G-sized. The format of the DMI input data requires that the first member of the pair is to be an integer, and second member of the pair is to be a real number. Consequently, in implementing this DMAP ALTER the user is required to first list the grid point identification number (ID) as a real number. Just placing a decimal point after the ID number makes it a real number. The internal sequencing used by NASTRAN for matrix operations could be different than that which the analyst originated with his grid point sequencing. The partitioning vector must be organized according to internal sequencing, so it is advisable to include DIAG 21 and 22 and CHPNT YES in the executive control packet, and then insert an ALTER to EXIT somewhere after the GP4 module. The detailed correspondence between internal and external sequencing for the various sets will be printed when DIAG 21 and 22 are activated. The internal sequence number of every corresponding entry on the DOF list will become the row number of the partitioning vector. The row numbers are required to appear in ascending sequence on the DMI cards.

Symmetry

As a special analytical case, an analyst likes to take advantage of symmetry of a particular structure for the economy and improved definition of modes. Cyclic symmetry is automated within NASTRAN, but reflective symmetry is not. Mode shapes analyzed via cyclic symmetry can automatically be described either for the whole structure, or for just a segment. The only additional processing needed for such modes, before they would be ready for STATCORR, is partitioning. On the other hand, modes analyzed via reflective symmetry require additional processing in order to prepare the modes for STATCORR. Eigenvalue analyses employing reflective symmetry may cause the analytical data to be delivered in the form of several runs, depending on the available combinations of symmetry and anti-symmetry. The post processor program for analytical data, mentioned above in the discussion of DET and INV methods, will operate, as explained before, by combining all modes, eliminating duplicates, and sequencing both frequency and GP list. In addition, the analyst will supply 3 parameters that will act like flags to the STATCORR program for indicating the symmetry status with respect to each of the bounding planes of symmetry. Each of the three parameters can carry the values -1 , 0 , or $+1$ for the symmetry status. "0" denotes "absence of symmetry" such as for the face plane of a plate. Positive 1 denotes symmetric behavior about the plane of symmetry. Negative 1 denotes anti-symmetric behavior about the plane of symmetry. Names given to these three parameters are SYM1PLAN, SYM2PLAN, and SYM3PLAN. Values for these symmetry parameters must always be supplied, if modal data is based upon information gathered on the basis of only a basic segment of a structure. If data from both test and analysis are flagged for OK having symmetry, STATCORR tests for the existence of symmetry for one file and anti-symmetry for the other file occurring simultaneously with respect to any one of the three planes. When such an unlikeness occurs, the algorithm immediately declares the correlation coefficient to have the value zero, and suspends calculations for both variance and RMS. Likeness amongst all three parameters between the two sets simultaneously indi-

cates to STATCORR that only the correlation coefficient for the basic segment need be calculated, because it is equal to that for the complete structure. RMS is also the same for the whole structure as it is for the basic segment. However, variance of the whole structure is equal to the number of octants of symmetry multiplied by the variance of the basic segment. Standard deviation of the whole structure is equal to the square root of the number of octants of symmetry multiplied by the standard deviation of the basic segment.

To illustrate how the correlation coefficient has values alternating between zero and that for the basic segment, a pair of free parallelepipeds with 3 planes of symmetry will be used. Modes



involving translations in only one coordinate will provide enough detail to be realistic without obscuring the concepts with complications.

Symmetry parameters SYM1PLAN, SYM2PLAN, and SYM3PLAN for the two solids being compared have the values +1, -1, +1 for solid A and +1, +1, +1 for B. A set of modes conforming to these parameters is diagrammed to create a mental image.

The correlation coefficient between the two structures is

$$r = \frac{\sum_{i=1}^n x_i y_i}{\left[\sum_{i=1}^n x_i^2 \right]^{1/2} \left[\sum_{i=1}^n y_i^2 \right]^{1/2}} = \frac{(xy)_1 + (xy)_2 + (xy)_3 + (xy)_4 \dots \dots \dots (xy)_8}{\left[x_1^2 + x_2^2 + x_3^2 + \dots \dots x_8^2 \right]^{1/2} \left[y_1^2 + y_2^2 + y_3^2 + \dots \dots y_8^2 \right]^{1/2}}$$

where $\sum_{i=1}^{n_s} x_i y_i = (XY)_s$, $\sum_{i=1}^{n_s} x_i^2 = X_s$, and $\sum_{i=1}^{n_s} y_i^2 = Y_s$.

Substitute the equivalent, signed basic segment portion for octants 2 and above.

$$r = \frac{(xy)_1 + (xy)_1 + [(-x)y]_1 + [(-x)y]_1 + (xy)_1 + (xy)_1 + [(-x)y]_1 + [(-x)y]_1}{[8x_1]^{1/2} [8y_1]^{1/2}}$$

$$= \frac{0}{8\sigma_x \sigma_y} = 0.$$

If, however, both A and B were symmetric with respect to all 3 planes of symmetry, the correlation coefficient can be represented in terms of basic segment data as follows:

$$r = \frac{8(xy)_1}{8^{1/2} \sigma_x 8^{1/2} \sigma_y} = \frac{8(xy)_1}{8 \sigma_x \sigma_y} = \frac{(xy)_1}{\sigma_x \sigma_y} \quad \text{q.e.d.} \quad (11)$$

This concept is built into the correlation algorithm of STATCORR. A table of correlation coefficients for various symmetry permutations clearly shows the oscillation between two values.

<u>SYMMETRY PARAMETERS</u>	<u>CORRELATION COEFFICIENT</u>	<u>SYMMETRY PARAMETERS</u>	<u>CORRELATION COEFFICIENT</u>
S O O : x A O O : y	0	S A O : x A A O : x	0
A O O : x S O O : x	0	A A O : x A A O : y	BASIC
A O O : x A O O : y	BASIC	S A S : x S S S : y	0
S O O : x S O O : y	BASIC	S S S : x S S S : y	BASIC
S A O : x S S O : y	0	A S S : x S A A : y	0
S S O : x S S O : y	BASIC	A S A : x A S A : y	BASIC
A S O : x A A O : y	0	S A S : x S A A : y	0
A S O : x A S O : y	BASIC	A A A : x A A A : y	BASIC

Variance. The variance is given by

$$\sigma^2 = \sum_{i=1}^n x_i^2$$

$$\sigma^2 = X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8$$

which, in terms of equivalent basic segment for the parallelepiped, becomes:

$$\sigma^2 = 8 X_1 = 8 \sigma_1^2, \text{ or } \sigma_{\text{whole}}^2 = 2^p \sigma_{\text{basic}}^2 \quad (12)$$

where p = the number of planes of reflective symmetry.

Standard Deviation. Similarly,

$$\sigma = (\sigma^2)^{1/2} = (8 \sigma_1^2)^{1/2} = 2\sqrt{2} \sigma_1 \text{ or } \sigma_{\text{whole}} = 2^{p/2} \sigma_{\text{basic}}$$

Root Mean Square

$\rho = \sigma/\sqrt{n}$, where m equals the sample points in the basic segment and n= 8 m.

$$\rho_{\text{basic}} = \sigma_{\text{basic}}/\sqrt{m}, \text{ but } \sigma_{\text{whole}} = 2\sqrt{2} \sigma_{\text{basic}}$$

$$\rho_{\text{whole}} = 2\sqrt{2} \sigma_{\text{basic}}/\sqrt{8m} = \sigma_{\text{basic}}/\sqrt{m} = \rho_{\text{basic}} \quad (13)$$

$$\rho_{\text{whole}} = \rho_{\text{basic}}$$

Normalization Factor

$$C = \frac{\text{Same numerator as "r"}}{\sigma_a^2}$$

Using the results leading up to equation (11), one can conclude that when there is unlikeness in the symmetry parameters, the numerator is zero, causing C to be null. When there is likeness amongst all of the symmetry parameters,

$$C = \frac{8(XY)_1}{8X_1} = \frac{(XY)_1}{X_1} \quad (14)$$

$$C_{\text{whole}} = C_{\text{basic}}$$

Standard Error

$$S = \left[\frac{1}{n} (\sigma_e^2 - \sigma_a^2) \right]^{1/2}$$

then $\sigma_e^2 = 8X_1(e)$ and $\sigma_a^2 = 8X_1(a)$. Make these substitutions.

$$S = \left[\frac{8}{8m} (X_1(e) - X_1(a)) \right]^{1/2} = \left[\frac{1}{m} (\sigma_e - \sigma_a)_{\text{basic}} \right]^{1/2}$$

$$S_{\text{whole}} = S_{\text{basic}} \tag{15}$$

The final alternate of reflective symmetry is the case in which analytical properties are determined by only modeling a basic segment, while test uses the entire structure. The scheme will be to limit the calculations to only those quantities that are necessary. It was discovered during the development of this method that it was not necessary to deploy the basic segment geometry into a mode shape over all 8 octants. By planning ahead, it is possible to arrange that every instrumented point on the test article, when reflected back to the basic segment, will define an image point in the basic segment which is a member of the grid of points used in the analysis. It is possible that several external test points reflect back to a common image point in the basic segment, but in the operation of the processor program, it is necessary to provide a unique point in the basic segment for every instrumented point. A multiply-reflected point violates this requirement. This dilemma is solved by setting up clones of grid points in the NASTRAN bulk data. Thus, the total set of points used by analysis in the basic segment must embrace all of the instrumented points. Those will be of three kinds: direct, image, and cloned points. The direct points correspond to the instrumented points in the basic segment on the test article. The image points are those having no corresponding points in the basic segment, and that, when reflected by an appropriate number of times from the basic segment, thus will coincide in ID and location with a unique instrumented point outside of the basic segment on the test article. A cloned point is a grid point in the basic segment with a unique grid point ID number, which has duplicate coordinates of a multiply-reflected direct or image point, but has no structural function. There are as many clones at a point as there are multiplicities of instrumented reflections to a point. Clones are fully constrained points that have no elements connected to them. The point whose coordinates are being cloned is called a parent point. It is usual for the analysis to have more data points than the test data has, so it is necessary to partition the analytical mode shapes down to contain data corresponding to only those points that were instrumented on the test article. Partitioning vector TESET earmarks all direct, image, and cloned points so that when TESET acts on the matrix of analytical mode shapes, PHIG, the modal deflections for instrumented points only will be retained in the matrix PHITE. But PHITE, at this raw stage, is not ready for comparison with test data, because modal data from the basic segment has to be reflected out to the instrumented points with correct signs. The signs of the deflections of instrumented points to be assigned to image and cloned points, depend on their location and the type of symmetry being simulated by an analytical run. A way has been devised to communicate these particulars to the processor program which will enable it to convert PHITE to make it ready for STATCORR. The same parameters that described the type of symmetry for the case of both sources using symmetry will serve equally well for this case. Parameters SYM1PLAN, SYM2PLAN and SYM3PLAN must be supplied so that they will be output to the postprocessor. In order to so communicate a location, a convention must be adapted. The following is the convention used for identifying the octants. Octant # 1 is the basic segment. Octant # 2 is the reflection of the basic segment about the first plane of sym-

metry. By-pass, momentarily, the definition of octant # 3 and define octant # 4 as the reflection of the basic segment about the second plane of symmetry. Octant #3 lies in between octants 2 and 4. It is a double reflection of the basic segment about the first and second planes of symmetry. Octant # 5 is the reflection of the basic segment about the third plane of symmetry. Rather than define octants 6, 7, and 8 as a series of precise double and triple reflections, it is easier to picture them as lying under octants 2, 3, and 4, just as octant # 5 lies under the basic octant. It remains to set a procedure for reporting the locations of instrumented points. This is done by reorganizing the data, already contained in the TESET vector, into an 8 columned matrix which will be named DOFLIST. Columns one through eight of DOFLIST refer to octant locations one through eight. Direct points are tabulated in ascending sequence of internal DOF number in column one. Image points and parents of cloned points reflected from octant # 2 are tabulated in ascending sequence of internal DOF number in column two. Similarly, tabulations follow for octants 3 through 8. Tabulations are omitted for any octant for which symmetry is absent (i.e., SYM#PLAN is zero). The essential difference between TESET and DOFLIST will be stressed at this juncture. TESET is a vector tabulation of internal degrees of freedom vs. instrumented grid point numbers including clone IDs. DOFLIST is an 8 columned matrix tabulation of internal degrees of freedom vs. all instrumented grid point numbers except that parent IDs are used for clones.

By definition, if SYM2PLAN is equal to -1 , the reflection with respect to the second plane is anti-symmetric, and the vertical displacements in octant # 4, as shown in Figure 2, are of the opposite sign from those in the basic segment. Similarly, if SYM3PLAN is equal to $+1$, the vertical displacements in octant 5 would also be of opposite sign from those of the basic segment. To determine the sign for octants # 3, 6, 7, and 8, the parameters must be used in particular ways. Thus, the sign of displacements in octant # 3 depend on the types of symmetry across both the first and second planes of symmetry. If one were symmetric and the other anti-symmetric, the vertical displacements for octant # 3 would be of opposite sign to the basic. This discussion deals with a given point in the basic segment which is paired with its image point in the reflected octant; therefore all such pairs of displacements are equal in magnitude. Symmetry and anti-symmetry for 3 translational and 3 rotational degrees of freedom will be defined with respect to a plane of symmetry, and then is translated to items of action pertaining to the correlation coefficient under the option of "symmetry for analysis and whole structure for test." Consider, for discussion purposes, that the plane of symmetry is a coordinate plane and, it is oriented vertically. Designate one of the other two coordinate planes to be the horizontal plane, and the remaining one to be transverse.

For the moment, language will be adapted for describing the modal displacements in terms of this convention for the 3 planes. Displacements perpendicular to the plane of symmetry can be described as being towards or away from the plane of symmetry. Displacements perpendicular to the horizontal plane can be described as being up or down. Displacements perpendicular to the transverse plane can be described as back and forth. The goal is to define the behavior of the reflection with respect to the plane of symmetry for each of the 6 displacement components at a Grid Point, for either the symmetric or the anti-symmetric case.

When data is collected on a whole structure with respect to a single fixed coordinate system with coordinate planes imbedded in the frame of the planes of symmetry, it is unaware of the descriptions: twd/away, up/down, back/forth. Therefore, when analytical symmetric data is converted from the basic segment to modal behavior in the seven other octants, it must take into account

the way that displacements will appear in the fixed coordinate system of the whole. As an example, according to Table S, the symmetric behavior involving displacements perpendicular to the plane of symmetry will result in the basic and image points both moving synchronously toward or synchronously away from the plane of symmetry. In terms of the coordinate system of the whole, the displacements involve the same coordinate axis. Since they are both moving toward the plane of symmetry, they are moving towards each other; that is, they bear opposite signs.

Table S

IMAGE VS BASIC MOTIONS WITH RESPECT TO PLANES OF SYMMETRY

DIRECTION OF MOTION	RELATIONSHIPS
TRANS \perp P/S	Both twd \rangle - Symmetric Both away \rangle - Symmetric One twd & one away - AntiSym
ROT'N \perp P/S	Δ vert/ Δ forth: Both Δ up or Both Δ down with Both Δ forth \rangle - Symmetric One Δ up & one Δ down with Both Δ forth \rangle - AntiSym
TRANS \perp H/P	Both up \rangle -Symmetric Both down \rangle -Symmetric One up & one down - AntiSym
ROT'N \perp H/P	Δ across/ Δ forth: Both Δ twd \rangle - Symmetric Both Δ away \rangle - Symmetric with Both Δ forth One Δ twd & one Δ away \rangle - AntiSym with Both Δ forth
TRANS \perp T/P	Both forth \rangle - Symmetric Both back \rangle - Symmetric One forth & one back - AntiSym
ROT'N \perp T/P	Δ across/ Δ up: Both Δ twd or Both Δ away \rangle - Symmetric with Both Δ up One Δ twd & one Δ away \rangle - AntiSym with Both Δ up

Consequently, adaptation of basic segment data to octant # 2 symmetrical modal behavior, requires that the sign be changed for those components which are perpendicular to the plane of symmetry. Currently, it is recognized that only translational data is measured in test, but Table U will

be prepared for sign changes not only for the 3 translational components, but also for the three rotational components. In order to implement this conversion, certain restrictions must be placed on the analytical model. Only the basic coordinate system will be allowed to be used for grid points in the basic segment which correspond to instrumented test points. Its coordinate planes must be parallel to planes of reflective symmetry. To report how the basic coordinate system is oriented to the planes of symmetry, a vector is required to be constructed on DMI cards called IDCORD. The basic coordinate system ID (non-zero) is entered as an integer in the row position, and the translational component which is perpendicular to the 1st plane of symmetry is entered as a real number, followed by the translational component, which is perpendicular to the 2nd plane of symmetry. The size of the matrix to be entered on the "O" card is: rows = ID # + 1, columns = 1. If a small number is used for the coordinate system ID, it will eliminate the unnecessary processing of zeroes. The card will have the appearance of that shown in Figure 3, page 18.

Table U

ACTION TABLE FOR CONVERTING BASIC SEGMENT DATA
SIGN OF DISPLACEMENT

OCTANT LOCATION OF IMAGE POINT	TYPE & SEQUENCE OF REFLECTION SYM1 SYM2 SYM3			FOR COMPONENT NO.						COMP PERP TO TP P/S		
				1	2	3	4	5	6	1ST	2ND	3RD
				2	3	1	5	6	4	1	2	3
2	+1			CHNG	NOOP	NOOP	NOOP	CHNG	CHNG			
	-1			NOOP	CHNG	CHNG	CHNG	NOOP	NOOP			
4	+1			NOOP	CHNG	NOOP	CHNG	NOOP	CHNG			
	-1			CHNG	NOOP	CHNG	NOOP	CHNG	NOOP			
5		+1		NOOP	NOOP	CHNG	CHNG	CHNG	NOOP			
		-1		CHNG	CHNG	NOOP	NOOP	NOOP	CHNG			
3	+1	-1		CHNG	NOOP			NOOP	CHNG			
	-1	+1		NOOP	CHNG			CHNG	NOOP			
	+1	+1				NOOP				CHNG		
	-1	-1				CHNG				NOOP		
6	+1		-1	CHNG		NOOP	NOOP			CHNG		
	-1		+1	NOOP		CHNG	CHNG			NOOP		
	+1		+1		NOOP				CHNG			
	-1		-1		CHNG				NOOP			
8		+1	-1		CHNG	NOOP				NOOP	CHNG	
		-1	+1		NOOP	CHNG				CHNG	NOOP	
		+1	+1		NOOP			CHNG				
		-1	-1		CHNG			NOOP				
7	+1	-1	-1	CHNG				NOOP				
	-1	+1	+1	NOOP				CHNG				
	+1	-1	+1		NOOP				CHNG			
	-1	+1	-1		CHNG				NOOP			
	+1	+1	-1			NOOP				CHNG		
	-1	-1	+1			CHNG				NOOP		

Notice that the octants are not entered in ascending sequence. The scheme used here was to work towards increasing complexity starting with octants involving only a single reflection, then double, and finally triple reflection.

DMI	IDCORD	0	2	1	1	ID + 1	1
DMI	IDCORD	1	ID	PERP 1ST	PERP 2ND		
			(INTEGER)	(REAL)	(REAL)		

Figure 3

What action needs to be taken to convert a component in the basic segment to a modal displacement for an image point in an external octant has been worked out for either type of symmetry, for all six component displacements, and for the three distinct orientations of the basic coordinate system. The action to be taken is, either to change the sign of that component or not. If the sign is to be changed, the notation in the table is CHNG. If the sign is to be left unchanged, the entry in the table is expressed in computer jargon as NOOP, meaning no operation.

Certain components can participate in only certain types of multiple reflections. Null entries are mutually exclusive. The processor program will accomplish the actions tabulated here, so that the analytical mode shapes delivered to the STATCORR program will represent whole structure behavior at those image points corresponding to instrumented points outside the basic segment.

CODES

DMAP ALTER's; (STATDMAP)

In reviewing the design of the DMAP ALTER packet, one sees that its principal function is to transfer important data blocks from the NASTRAN runs to the STATCORR program. It uses the punch file for all output. It manages the partitioning of the eigenvectors to the order of test modes.

A DMAP ALTER packet must be included with each analytical run in order to provide the data sets and parameters necessary to prepare the output properly for operating the STATCORR program. A listing of the ALTER packet is contained in this report on pages 22 through 26. As of this writing, the packet is compatible with NASTRAN Rigid Format Series P. It was intended to be self explanatory by supplementing it with comment statements. It is stored in the user library account ULIB1 in the Design Engineering Branch under the filename DRA0:[NASCAT.UTILITY] STATDMAP.LIS;1. Analysts who wish to implement this ALTER can access this file, then copy and merge it into the executive control of their own jobs. Scanning the left hand margins of STATDMAP, the reader will notice that there are several subdivisions. Each subdivision will be called a packet according to an identifier. Each ALTER packet subdivision is readily distinguished by a title. The first packet is entitled FREQUENCY DATA and uses the margin identifier \$F. PARTITIONED MODE SHAPES is the title of the second packet, identified by \$P. The third packet is entitled SYMMETRY FOR BOTH, using \$\$ at the margin. Finally, the ANALYTICAL

SYMMETRY ONLY packet uses identifier \$W. Packets F and P are always used. When data comes from a basic segment of symmetry for both analysis and test, packets F, P, and S are used. The entire set of ALTER packets is needed when the test data is based on the whole structure, but analysis uses a basic segment only. Packet \$F delivers the LAMA table from a NASTRAN eigenvalue execution to the punched output file using the DMAP utility module, TABPCH. Although the entire LAMA table is exported, the preprocessor program selects only three entries for each mode. These are words 5, 6, and 7 in Record 2 of LAMA giving the cyclic frequency, generalized mass, and generalized stiffness, respectively. Packet \$P instructs the user how to set up his DMI cards for defining the partitioning vector TESET. Module PARTN employs TESET to partition the matrix of eigenvalues PHIG from the analytical size down to experimental size. Module OUTPUT 3 delivers test-sized eigenvectors PHITE and vector TESET to the punch output file in DMI format.

Packet \$S provides a place for the analyst to catalog which of the planes of symmetry he named first, second, and third. There are options for rectangular, cylindrical or spherical coordinate systems, so the user is advised to erase the unused options to avoid the clutter. The primary purpose of packet \$S is to define the type of reflective symmetry which was simulated for a given computer run. Each time a run is made with a different set of boundary conditions at the planes of symmetry, the appropriate entries should be made for the SYM # PLAN parameters. These parameters are not used at all in the NASTRAN execution. DMAP is being used as a transfer agent to pass the values of these parameters into the post-processor program in a self-contained package so that none of the pertinent data goes adrift or gets mixed with the wrong set. Module PARAM is set up for the user to input their values, and module PRTPARM transfers them to the output file. All other previous output has been sent to the punch output file, and these parameters should be no exception. This is done by intercepting the print output from PRTPARM just long enough to route it to the FORTRAN logical unit for punch output, and then restoring it. PARAM statement S4 directs the parameters to the punch output, and S7 restores it to print output.

Packet \$W instructs the user how to set up his DMI cards for tabulating the image points in the octants for matrix DOFLIST and for the IDCORD card. Module OUTPUT3 delivers the DOFLIST matrix and the IDCORD vector to the punch output file in DMI format. Once again, DMAP is being used strictly as a transfer agent to pass the data from the user to the processor program.

Statement F1 is inserted at position 103 of RF3 after the READ module has output LAMA. It picks up data block LAMA, which is a table, and sends it to the punch output file in DTI format. Parameter 1 is given the BCD value "FN" to use in setting up the continuation cards.

Statement P1 does a row partition on the matrix of eigenvectors, PHIG. It is inserted at R.F. 3 statement # 111 after the matrix PHIG has been checkpointed. The position of the column partitioning vector is left deliberately unspecified, while TESET is entered at the position of the row partitioning vector (RP). TESET has values at internal sequence positions of the G set which correspond to the degrees of freedom of points that were instrumented on the test article. PARTN separates the rows into two sub matrices according to whether there is a value in the partitioning vector for that row or not. The symbolic name of the partition matching the row of RP without values is A_{11} , and that, matching the rows of RP with values is A_{21} . Since our interest is in the A_{21} partition only, all positions of the output data blocks from PARTN are left purged, except the second. The name given to the A_{21} partition is PHITE. Giving a positive value of the

parameter SYM in the first position indicates a non-symmetric partition. The positive value given to parameter, TYPE, in the second position indicates that the output partitions are real single precision matrices. PHIG is a real single precision matrix so any of its partitions will be the same. The value 2 for the 3rd and 4th positions indicates that their forms will be general rectangular.

Statement P2 picks up data blocks PHITE and TESET and writes them on the punch output file in DMI format. Parameter P1 in the first position is negative to indicate that data being output should be sent to the FORTRAN logical unit. BCD value, MOD, is assigned to the second parameter for use in setting up continuation cards for the PHITE matrix, and BCD value, DOF, is assigned to the third parameter for use in setting up continuation cards for the TESET vector.

The explanation for why ALTER 125 was selected for inserting packet P will be delayed until after the explanation of statement S8. Statements S1, S2, and S3 define parameters SYM#PLAN through the module PARAM using logical operator MPY (multiply). In each instance, variable parameter IN1 is multiplied by the constant 1 to produce the output value. In effect, the value given to the variable parameter IN1 is the value of the output.

Statement S4 uses the module PARAM to change the value of the parameter which controls the printing of NASTRAN output (OUTTAP) that is located in the system common block (SYSTEM) of NASTRAN. The purpose of S4 is to change the OUTTAP assignment from the value of the FORTRAN logical unit for printing to the value of the FORTRAN logical unit for punching. The logical operator SYST uses the value for the 3rd parameter to catalog the sequence number of the parameter in the system common block. Referring to Section 2.4.1.8 of the Programmer's Manual, one finds that the sequence number for parameter OUTTAP is 2, so 2 is entered as the value for the third parameter. SYST uses the value of the 4th parameter to catalog the assignment number of the FORTRAN logical unit. These FORTRAN assignments are arbitrary and depend upon the decision of the systems programmer at the time that NASTRAN is installed on a computer. The punch output was assigned to FORTRAN logical unit 77 at the time that NASTRAN was installed on the computer used for developing this method, so in order to direct the output data blocks of a module under the management of system common block, named OUTTAP, to go to the punch buffer, 77 is entered as the value for the 4th parameter. The BCD value DUM given to the 2nd parameter is meaningless, because this parameter is not used in the operation of the logical operator SYST.

Statements S5, S6, and S7 involve module PRTPARM. The value 0 assigned to the 1st parameter enables the module to operate as a parameter printer. The particular BCD values assigned to the 2nd parameter discriminate amongst all possible parameters and will select only those having the indicated BCD names.

Statement S8 uses the module PARAM in the same sense as in statement S4 to assign the FORTRAN logical unit 6 to the system common block parameter OUTTAP. Making this temporary reassignment of a major regulation item should be treated gingerly so as not to interfere with normal operations. Rapid restoration is imperative. Care must be exercised when PARAM logical operator SYST is put into operation. Since the printer output block is involved, care must be taken to ensure that anything destined for the print buffer has been already sent there, so that only those things that are governed by parameter OUTTAP during this temporary assignment are routed to the punch buffer. Statement 125 occurs after module OFP has directed OEIGS, LAMA, and DQM1 to the print buffer and before new quantities from SDR2 are being readied for print-

ing. Thus diverting OUTTAP temporarily to punch at statement 125 does not endanger the printing of any important quantities.

Statement W1 is inserted at position 128 to isolate it from those in packet S, as well as, to make sure that it would not be caught in a bypass caused by a conditional jump. It picks up the data blocks delivered by the analyst in the bulk data in DMI format, and writes them on the punch output file in DMI format once again. Parameter P1 in the 1st position is negative to indicate that the data output should be sent to the FORTRAN logical unit. The BCD value, LIS, is assigned to the 2nd parameter, and FRM to the 3rd parameter for use in setting up the continuation cards.

-----STATCORR PREP-----
-----DMAP ALTER PACKET-----

-----FOR USE WITH RIGID FORMAT SERIES P-----

ALTER 103

THIS DMAP ALTER PACKET IS DESIGNED TO PROVIDE OUTPUT TO PROCESSORS WHICH IN TURN PREPARE THE ANALYTICAL INPUT TO THE STATISTICAL CORRELATION PROGRAM ***STATCORR*** FOR COMPARING ANALYTICALLY DERIVED MODAL DATA WITH EXPERIMENTALLY DERIVED MODAL DATA. SUBPACKETS ***F*** AND ***P*** WILL ALWAYS BE USED. SUBPACKET ***S*** IS DESIGNED FOR USE WHEN BOTH ANALYTICAL AND EXPERIMENTAL DATA ARE REPORTED FOR ONLY A SINGLE SEGMENT OF REFLECTIVE SYMMETRY IN ONE, TWO, OR THREE COORDINATE DIRECTIONS. SUBPACKET ***W*** IS DESIGNED FOR THE CASE WHEN REFLECTIVE SYMMETRY IS USED WITH ANALYSIS BUT NOT WITH TEST.

*****FREQUENCY DATA*****

F1

TABPCH LAMA,,,//FN *

F WORD 5 IN EACH ENTRY OF RECORD 2 OF THE LAMA TABLE GIVES THE CYCLIC FREQUENCY FOR A MODE.
F WORD 6 IN EACH ENTRY OF RECORD 2 OF THE LAMA TABLE GIVES THE GENERALIZED MASS FOR A MODE.
F WORD 7 IN EACH ENTRY OF RECORD 2 OF THE LAMA TABLE GIVES THE GENERALIZED STIFFNESS FOR A MODE.

*****PARTITIONED MODE SHAPES*****

P

ALTER 111

SP

SP PHIC IS PARTITIONED TO THAT SET OF FREEDOMS WHICH ARE TO BE INSTRUMENTED ON THE TEST ARTICLE.

SP

SP THE PARTITIONING VECTOR TESET IS INPUT USING DMI. THE PRECEDING EIGENVALUE RUN SHOULD INCLUDE DIAG 21,22 TO GIVE THE CORRELATION BETWEEN THE INTERNAL D.O.F.'S AND THE EXTERNAL NUMBERING. THE PARTITIONING VECTOR IS ORGANIZED ACCORDING TO INTERNAL SEQUENCING. MODULE PARTN IS ORGANIZED TO DO A ROW PARTITION AMONGST THE DEGREES OF FREEDOM IN ORDER TO PRESENT A DESCRIPTION OF THE MODAL BEHAVIOR ONLY IN TERMS OF THE INSTRUMENTED D.O.F.'S.

SP

SP THE ZERO CARD OF DMI HAS THESE ENTRIES: FIELD 1, DMI; FIELD 2, TESET;

```

**P FIELD 3,ZERO
**P FIELD 4, 2--TO INDICATE THAT THE MATRIX BEING BUILT IS RECTANGULAR;
**P FIELDS 5 & 6, 1--TO INDICATE SINGLE PRECISION IN AND SINGLE PRECISION
**P OUT; FIELD 7, BLANK; FIELD 8, G-SIZE; FIELD 9, 1--TO INDICATE A
**P SINGLE COLUMN OUTPUT.
**P **P P
**P THE NEXT DATA CARD OF DMI HAS THESE ENTRIES: FIELD 1, DMI; FIELD 2,
**P TESET; FIELD 3, 1--TO INDICATE DATA FOLLOWING PERTAINS TO COLUMN 1
**P OF THE OUTPUT MATRIX;
**P FIELD 4, THE INTERNAL SEQUENCE NUMBER, IN INTEGER FORMAT, OF
**P THE FIRST INSTRUMENTED D.O.F. ACCORDING TO THE DIAC 21 TABULATION;
**P FIELD 5, THE EXTERNAL GRID POINT ID NUMBER CORRESPONDING TO THE
**P FIRST DOF. IT IS TO BE WRITTEN AS A REAL NUMBER, I.E. GP ID
**P FOLLOWED BY A PERIOD.
**P FIELD 6, THE SECOND INSTRUMENTED D.O.F. PER DIAC 21; INTEGER.
**P FIELD 7, THE EXTERNAL GRID POINT ID NUMBER CORRESPONDING TO THE
**P SECOND DOF. IT IS TO BE WRITTEN AS A REAL NUMBER.
**P CONTINUE IN A SIMILAR MANNER UNTIL ALL INSTRUMENTED POINTS HAVE
**P BEEN ENTERED. IN THE CASE OF SUBPACKET ***W*** THE GRID POINT
**P NUMBERS INCLUDE CLONES AND IMAGES.
**P1
PARTN PHIG,,TESET/,PHITE,,/C,N,+1/C,N,1/C,N,2/C,N,2 *
**P
**P MATRIX PHITE HAS BEEN PARTITIONED FROM THE PHIG DATA BLOCK. PHITE
**P CONTAINS MODAL DATA FOR ONLY THOSE DOF THAT WERE INSTRUMENTED. *
**P
**P2
OUTPUT3 PHITE,TESET //C,N,-1/C,Y,N1=VCT /C,Y,N2=DOF *
**P
**P PHITE AND TESET ARE OUTPUT IN DMI FORMAT AS PUNCH FILES.
**P IF THE USER WANTS THE
**P DMI CARD IMAGES TO BE WRITTEN TO A DISK FILE INSTEAD OF BEING PUNCHED,
**P THE USER MUST SUPPLY THE APPROPRIATE JOB CONTROL LANGUAGE STATEMENTS.
*
*
*****SYMMETRY FOR BOTH*****
*
**S THE ANALYST SHOULD SUBSTITUTE THE PROPER ENTRIES FOR EACH OF THE
**S VARIABLES REPRESENTED IN *X*X*X*X* FORMAT IN THE NEXT PARAGRAPH.
*
*
*
**S
**S IF THE ANALYSIS IS TO BE CONFIKED TO ONLY ONE SEGMENT OF REFLECTIVE
**S SYMMETRY AND SIMULTANEOUSLY IF TEST RESULTS WILL ALSO BE REPORTED
**S FOR ONLY ONE SEGMENT, THEN THE TYPE OF MODES BEING PRODUCED IN EACH
**S RUN MUST BE INDICATED IN THE FOLLOWING THREE PARAMETER STATEMENTS.
**S FOR RECORD PURPOSES, THE FIRST PLANE OF SYMMETRY IS PERPENDICULAR
**S TO THE *A*A*A*A* AXIS AND CUTS THAT AXIS AT *A*A*A*A* (RECTANGULAR),
**S OR IS AN R:Z PLANE THRU THETA = *T*T*T*T* , PHI = 0 (CYLINDRICAL),
**S OR IS A PLANE THRU THETA = 0 , PHI = 0 (SPHERICAL).
**S THE SECOND PLANE OF SYMMETRY IS PERPENDICULAR TO THE *B*B*B*B* AXIS
**S AND CUTS THAT AXIS AT *B*B*B*B* (RECTANGULAR), OR IS AN R:Z PLANE
**S THRU THETA = [*T*T*T*T* + PI/2] , PHI = 0(CYLINDRICAL), OR IS A PLANE
**S THRU THETA = PI/2, PHI = 0 (SPHERICAL).
**S THE THIRD PLANE OF SYMMETRY IS PERPENDICULAR TO THE *C*C*C*C* AXIS
**S AND CUTS THAT AXIS AT *C*C*C*C* (RECTANGULAR), OR IS PERPENDICULAR
**S TO THE Z AXIS AND CUTS THAT AXIS AT Z = *V*V*V*V* (CYLINDRICAL),
**S OR IS A PLANE AT PHI = PI/2 FOR ALL THETA (SPHERICAL).

```

```

$S
$
$S
$S THE DESIGNATION FOR A SYMMETRICAL REFLECTION W.R.T. AN AXIS IS +1;
$S ENTER IN1 = +1 ON THE PARAM CARD IN PLACE OF XXX.
$S THE DESIGNATION FOR ANTI-SYMMETRIC REFLECTION W.R.T. AN AXIS IS -1;
$S ENTER IN1 = -1 ON THE PARAM CARD IN PLACE OF XXX.
$S THE DESIGNATION FOR ABSENCE OF SYMMETRY WITH RESPECT TO AN AXIS IS 0;
$S ENTER IN1 = 0 ON THE PARAM CARD IN PLACE OF XXX.
$
$S
$SS$ALTER 125
$S1
$
$
$
$S VALUES OF SYM*PLAN WILL CHANGE EVERY TIME THE CONSTRAINTS
$S OF SYMMETRY CHANGE.
$
$
$
$S1$PARAM //C,N,MPY/V,Y,SYM1PLAN/V,N,IN1=XXX/V,N,IN2=1 $
$S
$S THIS STATEMENT SAYS WHETHER THE MODE SHAPE IS SYMMETRIC OR ANTI-
$S SYMMETRIC OR HAS NO SYMMETRY WITH RESPECT TO PLANE 1.
$S
$S2
$S2$PARAM //C,N,MPY/V,Y,SYM2PLAN/V,N,IN1=XXX/V,N,IN2=1 $
$S
$S THIS STATEMENT TELLS WHAT KIND OF SYMMETRY PERTAINS TO PLANE 2.
$S
$S3
$S3$PARAM //C,N,MPY/V,Y,SYM3PLAN/V,N,IN1=XXX/V,N,IN2=1 $
$S
$S THIS STATEMENT TELLS WHAT KIND OF SYMMETRY PERTAINS TO PLANE 3.
$
$S4
$S4$PARAM //C,N,SYST/V,N,DUM/C,N,2/C,N,77 $
$S
$S CHANGES THE FORTRAN LOGICAL UNIT FOR THE SYSTEM COMMON DATA BLOCK,
$S CALLED OUTPUT, FROM ITS USUAL VAX VALUE
$S OF 6 TO THE VAX VALUE RESERVED FOR PUNCH WHICH IS 77, SO THAT IT CAN
$S BE WRITTEN TO THE SAME DISK FILE AS THE CHKPNT DICTIONARY AND THE
$S OUTPUT3 FILES.
$S
$S5
$S5$PRTPARM //C,N,0/C,N,SYM1PLAN $
$S
$S6
$S6$PRTPARM //C,N,0/C,N,SYM2PLAN $
$S
$S7
$S7$PRTPARM //C,N,0/C,N,SYM3PLAN $
$S
$S8
$S8$PARAM //C,N,SYST/V,N,RUM/C,N,2/C,N,6 $
$S
$S RESTORES THE FORTRAN LOGICAL UNIT FOR OUTPUT BACK TO THE VAX VALUE
$S OF 6 NOW THAT THE NEED FOR ASSIGNING IT TO 77 IS OVER.
$
$

```

*
 *** *****ANALYTICAL SYMMETRY ONLY*****
 \$W
 \$W USE SUBPACKET **W** IF EXPERIMENTAL DATA COMES FROM THE WHOLE STRUCTURE
 \$W BUT ANALYTICAL DATA COMES FROM A BASIC SEGMENT OF SYMMETRY. THE
 \$W ANALYTICAL BASIC SEGMENT WILL CONTAIN POINTS CORRESPONDING TO THOSE
 \$W TEST POINTS IN THE BASIC SEGMENT. IN ADDITION THE ANALYTICAL BASIC
 \$W SEGMENT WILL CONTAIN POINTS WHICH ARE REFLECTED IMAGES OF ALL TEST POINTS
 \$W WHICH ARE LOCATED OUTSIDE OF THE BASIC SEGMENT. THE PARTITIONING
 \$W VECTOR ***TESET*** WILL INCLUDE THE DIRECT POINTS PLUS ALL CLONED AND
 \$W IMAGE POINTS. ALL REFLECTED POINTS
 \$W MUST BE TALLIED FOR ***STATCORR*** TO PROCESS THE DATA
 \$W CORRECTLY. THIS TALLY IS COMMUNICATED IN THE FORM OF AN EIGHT
 \$W COLUMNED MATRIX CALLED ***DOFLIST***
 \$W
 \$W
 \$W
 \$W WARNING. WARNING. BE SURE THAT CLONED GRID POINTS
 \$W ARE INCLUDED IN THE BULK DATA AND ARE FULLY CONSTRAINED.
 \$W
 \$W
 \$W
 \$W EACH OF THE 8 COLUMNS IS RESERVED FOR A PARTICULAR OCTANT. THESE
 \$W ARE THE DEFINITIONS OF THE OCTANTS.
 \$W OCTANT 1 IS THE BASIC SEGMENT. OCTANT TWO IS THE REFLECTION OF THE
 \$W BASIC SEGMENT ABOUT SYM1PLAN. OCTANT FOUR IS THE REFLECTION OF THE
 \$W BASIC SEGMENT ABOUT SYM2PLAN. OCTANT THREE IS IN BETWEEN OCTANTS
 \$W TWO AND FOUR. OCTANT FIVE IS THE REFLECTION OF THE BASIC SEGMENT
 \$W ABOUT SYM3PLAN. OCTANTS SIX, SEVEN, AND EIGHT ARE ROTATED AWAY
 \$W FROM OCTANT FIVE IN THE SAME SENSE THAT OCTANTS TWO, THREE, AND
 \$W FOUR ARE ROTATED AWAY FROM OCTANT ONE.
 \$W DATA FOR TALLYING THE IMAGE POINTS REFLECTED FROM EACH OCTANT IS
 \$W ORGANIZED IN DMI INPUT. COLUMN ONE IS RESERVED FOR LISTING ALL
 \$W POINTS PLUS COMPONENT DIRECTIONS WHICH ARE COMPANIONS
 \$W OF THE INSTRUMENTED POINTS IN THE
 \$W BASIC SEGMENT. COLUMN TWO IS RESERVED FOR LISTING ALL UNIQUE
 \$W POINTS OR PARENTS OF CLONES
 \$W IN THE BASIC SEGMENT WHICH ARE REFLECTIONS OF INSTRUMENTED
 \$W POINTS FROM OCTANT #2. SIMILARLY, COLUMN THREE IS RESERVED FOR
 \$W LISTING ALL UNIQUE POINTS OR PARENTS OF CLONES IN THE BASIC SEGMENT
 \$W WHICH ARE REFLECTIONS OF
 \$W INSTRUMENTED POINTS FROM OCTANT #3. COL 4 LIST FOR OCTANT 4 AND
 \$W SO FORTH THRU COL 8 FOR OCTANT 8.
 \$W EXAMPLES OF EACH OF THE NINE DMI LOGICAL CARDS FOR THIS MATRIX
 \$W EXPRESSED IN FREE FIELD FORMAT ARE:
 \$W DMI,DOFLIST,0,2,1,1,BLANK,G-SIZE,8,BLANK
 \$W DMI,DOFLIST,1,INT DOF #,GP #,INT DOF #,GP #,INT DOF #,GP #,CONT'N
 \$W DMI,DOFLIST,2,INT DOF #,GP #,INT DOF #,GP #,INT DOF #,GP #,CONT'N
 \$W DMI DOFLIST,3,INT DOF #,GP #,INT DOF #,GP #,INT DOF #,GP #,CONT'N
 \$W DMI ETC FOR COLUMNS 4 THRU 8.
 \$W NOTICE THAT THE CONTENT OF CARDS FROM COLUMN ONE ET SEQ. ARE
 \$W PAIRED QUANTITIES. THE FIRST OF THE PAIR IS THE ROW NUMBER
 \$W WHICH IS THE INTERNAL DEGREE OF FREEDOM NUMBER WRITTEN AS AN
 \$W INTEGER. THE SECOND OF THE PAIR IS A REAL NUMBER FORM OF
 \$W THE GRID POINT ID CORRESPONDING TO THE INTERNAL DOF .
 \$W PAIRS FOR A GIVEN COLUMN
 \$W OVERFLOW ONTO CONTINUATION CARDS UNTIL ALL POINTS FOR AN OCTANT
 \$W ARE TALLIED. DATA FOR THE SUCCEEDING COLUMN CONSTITUTE A NEW
 \$W LOGICAL CARD STARTING WITH THE COLUMN NUMBER THEN FOLLOWED BY ITS

```

$W SUBSEQUENT PAIRS.
$W
$W
$W
$W A SECOND DMI VECTOR NAMED ***IDCORD*** IS PUT INTO THE BULK DATA
$W TO SPECIFY THE ORIENTATION OF BASIC COORDINATE PLANES WITH THE
$W PLANES OF SYMMETRY. VALUE #1 IS THE BASIC COMPONENT THAT IS
$W PERPENDICULAR TO THE 1ST PLANE OF SYMMETRY. VALUE #2 IS THE
$W BASIC COMPONENT THAT IS PERPENDICULAR TO THE 2ND PLANE OF
$W SYMMETRY. SET VALUE #2 = 0.0 IF THERE IS ONLY ONE PLANE OF
$W SYMMETRY. NO ENTRY IS MADE FOR THE THIRD COMPONENT REGARDLESS
$W OF THE EXISTENCE OF A THIRD PLANE OF SYMMETRY.
$W
$W
$W
$W W$ALTER 126
$W1
$W1$OUTPUT3 DOFLIST, IDCORD//C,N,-1/C,Y,LIS/C,Y,FRM 3
$W
$W POST PROCESSOR WILL APPLY THE APPROPRIATE SIGN TO THE
$W REFLECTED DISPLACEMENTS
$W ACCORDING TO THE COMBINATION OF IN1 PARAMETERS ENTERED IN STATEMENTS
$W S1, S2, AND S3.
$
ENDALTER

```

MERGE

In case eigenvectors have been obtained from several disjoint NASTRAN runs, it is possible to combine these vectors into a single set for use with STATCORR. Probably some overlap of frequency ranges would occur with consequent duplication of vectors. The pre-processor program MERGE accepts files of eigenvectors from several runs and discards all duplicates. It reassembles the resulting into a sequence according to ascending frequencies and delivers them as a single file. MERGE operates interactively and the user responds to the on-line prompts.


```

100 C PROGRAM MERGE
200 C
300 C THIS PROGRAM WILL MERGE TWO MATRIX FILES WITH THE SAME NUMBER
400 C OF COLUMNS INTO A SINGLE MATRIX WITH THE SAME NUMBER OF COL-
500 C UMNS AND A TOTAL NUMBER OF ROWS EQUAL TO THE SUM OF THE NUMBER
600 C OF ROWS IN THE ORIGINAL TWO MATRICES.
700 C A CORRESPONDING COLUMN IN EACH MATRIX (NOT NECESSARILY THE SAME
800 C COLUMN NUMBER) MUST BE IN ASCENDING SORT, AND A SORTED MERGE WILL
900 C BE DONE BASED ON THE RESPECTIVE CORRESPONDING COLUMNS.
1000 C IF DESIRED, DUPLICATED ROWS WILL BE DELETED; A MAXIMUM RELATIVE
1100 C DIFFERENCE (EPSILON) MAY BE SPECIFIED FOR DEFINING "EQUALITY"
1200 C OR A DEFAULT VALUE MAY BE USED.
1300 C IF DESIRED, ROWS CONTAINING TERMS BELOW A MAXIMUM THRESHOLD VALUE
1400 C WILL BE DELETED; THE THRESHOLD VALUE MAY BE SPECIFIED, OR A
1500 C DEFAULT VALUE MAY BE USED.
1600 C IF DESIRED, ROWS CONTAINING TERMS ABOVE A MINIMUM CEILING VALUE
1700 C WILL BE DELETED; THE CEILING VALUE MAY BE SPECIFIED, OR A
1800 C DEFAULT VALUE MAY BE USED.
1900 C ADDITIONAL MATRIX PAIRS THAT ARE ASSOCIATED RESPECTIVELY WITH THE
2000 C ORIGINAL MATRIX PAIR MAY ALSO BE MERGED TOGETHER, BASED ON THE
2100 C SORTED MERGE OF THE ORIGINAL PAIR. IN THIS CASE, COLUMNS OF AN
2200 C ASSOCIATED MATRIX MUST CORRESPOND TO ROWS OF THE ORIGINAL MATRIX
2300 C WITH WHICH IT IS ASSOCIATED. ANY DELETED DUPLICATE, BELOW-
2400 C THRESHOLD, OR ABOVE-CEILING ROWS OF THE ORIGINAL MATRIX WILL
2500 C RESULT IN CORRESPONDINGLY DELETED COLUMNS OF THE ASSOCIATED
2600 C MERGED MATRIX.

```

```

100      PROGRAM MERGE
200      C
300      CHARACTER*8 MATRIX1, MATRIX2
400      CHARACTER*1 YESNO
500      REAL SORTLIST(2,100)
600      INTEGER MTXKEY(200), ROWKEY(200)
700      C
800      DO 100 ISET=1,1000000
900      C      ASK IF ANOTHER SET IS DESIRED
1000     TYPE 1000
1100     ACCEPT 2000, YESNO
1200     IF (YESNO .NE. 'Y') GOTO 150
1300     C      REQUEST NAMES & OPEN MATRIX FILES (LOG. UNIT NOS. 1&2)
1400     CALL GETKEYMTX(MATRIX1, MATRIX2, KROW1, KROW2,
1500     *          KCOL1, KCOL2, *100)
1600     C      REQUEST KEY COLUMNS FOR SORTED MERGE, & READ THEM INTO ARRAY
1700     CALL GETSORTCOL(MATRIX1, MATRIX2, KROW1, KROW2,
1800     *          KCOL1, KCOL2, SORTLIST)
1900     C      GENERATE KEY LISTS FOR MERGING
2000     CALL KEYLIST(SORTLIST, KROW1, KROW2, MTXKEY, ROWKEY)
2100     C      SET TOTAL NUMBER OF ROWS (PRIOR TO DELETIONS)
2200     KOUT = KROW1 + KROW2
2300     C      CULL DUPLICATE VALUES
2400     CALL DELDUPES(SORTLIST, MTXKEY, ROWKEY, KROW1, KROW2, KOUT)
2500     C      CULL BELOW-THRESHOLD VALUES
2600     CALL DELTHRESH(SORTLIST, MTXKEY, ROWKEY,
2700     *          KROW1, KROW2, KOUT, *100)
2800     C      CULL ABOVE-CEILING VALUES
2900     CALL DELCEILING(SORTLIST, MTXKEY, ROWKEY,
3000     *          KROW1, KROW2, KOUT, *100)
3100     C      MERGE KEY MATRICES INTO OUTPUT MATRIX & CLOSE MATRIX FILES
3200     CALL MERGEKEY(MTXKEY, KOUT)
3300     C      MERGE ASSOCIATED MATRIX PAIRS
3400     CALL ASSOCIATE(MTXKEY, KROW1, KROW2, KOUT)
3500     100 CONTINUE
3600     150 STOP 'END OF MATRIX SET REQUESTS'
3700     C
3800     1000 FORMAT(/, ' MERGE ANOTHER KEY MATRIX SET? (Y OR N): ', $)
3900     2000 FORMAT(A1)
4000     END

```

```

100      SUBROUTINE ASSOCIATE(MTXKEY, KROW1, KROW2, KOUT)
200      C
300      C      MERGE ASSOCIATED MATRIX PAIRS
400      C
500      INTEGER MTXKEY(200)
600      CHARACTER*1 YESNO
700      C
800      DO 100 IASSOC=1,1000000
900      C      ASK IF ANOTHER ASSOCIATED MATRIX PAIR IS DESIRED
1000     TYPE 1000
1100     ACCEPT 2000, YESNO
1200     IF (YESNO .NE. 'Y') GOTO 150
1300     C      OPEN ASSOCIATED MATRIX PAIR (LOGICAL UNIT NOS. 182) AND
1400     C      CHECK FOR VALID DIMENSIONS.
1500     CALL GETASCMTX(KROW1, KROW2, MROW, NCOL, *100)
1600     C      MERGE ASSOCIATED PAIR INTO OUTPUT MATRIX FILE & CLOSE FILES
1700     CALL MERGEASC(MTXKEY, KOUT, MROW, NCOL)
1800     100 CONTINUE
1900     C      NO MORE ASSOCIATED MATRIX REQUESTS
2000     150 TYPE *, 'END OF ASSOCIATED MATRIX REQUESTS'
2100     RETURN
2200     C
2300     1000 FORMAT(/, ' MERGE ANOTHER ASSOCIATED PAIR OF MATRICES? (Y OR N): '
2400     *      ,*)
2500     2000 FORMAT(A1)
2600     END

```

```

100      SUBROUTINE DELDUPES(SORTLIST,MTXKEY,ROWKEY,KROW1,KROW2,KOUT)
200      C
300      C   DELETE ROWS WHERE THE MERGING TERM IS A DUPLICATE (WITHIN
400      C   RELATIVE DIFFERENCE EPSILON) OF THE NEXT TERM.
500      C
600      INTEGER MTXKEY(200), ROWKEY(200)
700      REAL SORTLIST(2,100)
800      CHARACTER*1 YESNO
900      C
1000     C   ASK IF DUPLICATE DELETION IS DESIRED
1100     TYPE 1000
1200     ACCEPT 2000, YESNO
1300     IF (YESNO .NE. 'Y') RETURN
1400     C   SET DEFAULT EPSILON & REQUEST INPUT VALUE TO REPLACE IT
1500     EPS = 1.0E-5
1600     TYPE 3000, EPS
1700     ACCEPT *, EPS
1800     C   CULL OUT DUPLICATE VALUES
1900     KOUT = KROW1 + KROW2
2000     DO 100 I=1,KROW1+KROW2-1
2100         VTHIS = SORTLIST(MTXKEY(I),ROWKEY(I))
2200         VNEXT = SORTLIST(MTXKEY(I+1),ROWKEY(I+1))
2300         DIFF = ABS(VNEXT-VTHIS)
2400         C   DETERMINE RELATIVE DIFFERENCE
2500         C   IF (DIFF .EQ. 0.0) THEN
2600             RELDIFF = 0.0
2700         ELSE
2800             RELDIFF = DIFF/MAX(ABS(VNEXT),ABS(VTHIS))
2900         END IF
3000         IF (RELDIFF .LE. EPS) THEN
3100             MTXKEY(I) = -MTXKEY(I)
3200             KOUT = KOUT - 1
3300         END IF
3400     100 CONTINUE
3500     RETURN
3600     C
3700     1000 FORMAT(/,' DELETE DUPLICATE VALUES? (Y OR NO): ',*)
3800     2000 FORMAT(A1)
3900     3000 FORMAT(6X,'ENTER VALUE FOR EPSILON. ", " FOR DEFAULT ',
4000     * 1PE8.1,' : ',*)
4100     END

```

```

100      SUBROUTINE DELTHRESH(SORTLIST, MTXKEY, ROWKEY, KROW1, KROW2, KOUT, *)
200      C
300      C   DELETE ROWS WHERE THE MERGING TERM IS BELOW A GIVEN THRESHOLD
400      C   VALUE.
500      C
600      INTEGER MTXKEY(200), ROWKEY(200)
700      REAL SORTLIST(2,100)
800      CHARACTER*1 YESNO
900      C
1000     C   ASK IF THRESHOLD CULLING IS DESIRED
1100     TYPE 1000
1200     ACCEPT 2000, YESNO
1300     IF (YESNO .NE. 'Y') RETURN
1400     C   SET DEFAULT THRESHOLD & REQUEST INPUT VALUE TO REPLACE IT
1500     THRESH = 1.0
1600     TYPE 3000, THRESH
1700     ACCEPT *, THRESH
1800     C   CULL OUT BELOW-THRESHOLD ROWS
1900     DO 100 I=1, KROW1+KROW2
2000     IF (MTXKEY(I) .LT. 0) GOTO 100
2100     IF (SORTLIST(MTXKEY(I), ROWKEY(I)) .GE. THRESH) GOTO 150
2200     MTXKEY(I) = -MTXKEY(I)
2300     KOUT = KOUT - 1
2400     100 CONTINUE
2500     C   CHECK TO SEE IF ANY ROWS REMAIN
2600     IF (KOUT .EQ. 0) THEN
2700     TYPE *, 'NO MERGING:'
2800     TYPE *, 'ALL TERMS ARE LESS THAN THRESHOLD VALUE:', THRESH
2900     CLOSE(UNIT=1)
3000     CLOSE(UNIT=2)
3100     RETURN 1
3200     END IF
3300     C   ALL REMAINING TERMS ARE GREATER THAN OR EQUAL TO THRESHOLD
3400     150 RETURN
3500     C
3600     1000 FORMAT(/, ' DELETE VALUES BELOW A THRESHOLD? (Y OR N): ', *)
3700     2000 FORMAT(A1)
3800     3000 FORMAT(6X, 'ENTER VALUE FOR THRESHHOLD. ", " FOR DEFAULT ',
3900     *      1PE8.1, ' : ', *)
4000     END

```

```

100      SUBROUTINE DELCEILING(SORTLIST,MTXKEY,ROWKEY,KROW1,KROW2,KOUT,*)
200      C
300      C      DELETE ROWS WHERE THE MERGING TERM IS ABOVE A GIVEN CEILING
400      C      VALUE.
500      C
600      INTEGER MTXKEY(200), ROWKEY(200)
700      REAL SORTLIST(2,100)
800      CHARACTER*1 YESNO
900      C
1000     C      ASK IF CEILING CULLING IS DESIRED
1100     TYPE 1000
1200     ACCEPT 2000, YESNO
1300     IF (YESNO .NE. 'Y') RETURN
1400     C      SET DEFAULT CEILING & REQUEST INPUT VALUE TO REPLACE IT
1500     CEIL = 1.0E+35
1600     TYPE 3000, CEIL
1700     ACCEPT *, CEIL
1800     C      CULL OUT ABOVE-CEILING ROWS
1900     DO 100 I=1,KROW1+KROW2
2000     IF (MTXKEY(I) .LT. 0) GOTO 100
2100     IF (SORTLIST(MTXKEY(I),ROWKEY(I)) .GT. CEIL) THEN
2200     MTXKEY(I) = -MTXKEY(I)
2300     KOUT = KOUT - 1
2400     END IF
2500     100 CONTINUE
2600     C      CHECK TO SEE IF ANY ROWS REMAIN
2700     IF (KOUT .EQ. 0) THEN
2800     TYPE *, 'NO MERGING:'
2900     TYPE *, 'ALL TERMS ARE GREATER THAN CEILING VALUE:',CEIL
3000     CLOSE(UNIT=1)
3100     CLOSE(UNIT=2)
3200     RETURN 1
3300     END IF
3400     C      ALL REMAINING TERMS ARE LESS THAN OR EQUAL TO CEILING
3500     150 RETURN
3600     C
3700     1000 FORMAT(/,' DELETE VALUES ABOVE A CEILING? (Y OR N): ',*)
3800     2000 FORMAT(A1)
3900     3000 FORMAT(6X,'ENTER VALUE FOR CEILING. ", " FOR DEFAULT',
4000     *      1PE8.1,' : ',*)
4100     END

```

```

100      SUBROUTINE GETASCMTX(KROW1,KROW2,MROW,NCOL,*)
200      C
300      C OPEN ASSOCIATED MATRIX PAIR (LOGICAL UNIT NOS. 182) AND
400      C CHECK FOR VALID DIMENSIONS.
500      C
600      CHARACTER FILNAM1*35, FILNAM2*35, MATRIX1*8, MATRIX2*8
700      C
800      C GET NAMES OF ASSOCIATED MATRIX PAIR
900      C FIRST MATRIX:
1000     1 TYPE 1000, '1> ', '1'
1100     ACCEPT 2000, FILNAM1
1200     OPEN(UNIT=1,NAME=FILNAM1,TYPE='OLD',READONLY,
1300     * CARRIAGECONTROL='LIST',ERR=1)
1400     READ(1,3000) MATRIX1,MROW1,NCOL1
1500     C SECOND MATRIX:
1600     2 TYPE 1000, '2> ', '2'
1700     ACCEPT 2000, FILNAM2
1800     OPEN(UNIT=2,NAME=FILNAM2,TYPE='OLD',READONLY,
1900     * CARRIAGECONTROL='LIST',ERR=2)
2000     READ(2,3000) MATRIX2,MROW2,NCOL2
2100     C CHECK FOR VALID DIMENSIONS
2200     TYPE 4000, '1> ', MATRIX1,MROW1,NCOL1
2300     TYPE 4000, '2> ', MATRIX2,MROW2,NCOL2
2400     IF ((NCOL1.NE.KROW1) .OR. (NCOL2.NE.KROW2)) THEN
2500     TYPE 5000, 'NO MERGING DONE FOR THIS ASSOCIATED PAIR'
2600     CLOSE(UNIT=1)
2700     CLOSE(UNIT=2)
2800     RETURN 1
2900     ELSE IF (MROW1 .NE. MROW2) THEN
3000     TYPE 6000, 'NO MERGING DONE FOR THIS ASSOCIATED PAIR'
3100     CLOSE(UNIT=1)
3200     CLOSE(UNIT=2)
3300     RETURN 1
3400     ELSE
3500     C MATRICES ARE OK
3600     MROW = MROW1
3700     NCOL = NCOL1 + NCOL2
3800     RETURN
3900     END IF
4000     C
4100     1000 FORMAT(1H ,A3,'ENTER NAME OF ASSOCIATED MATRIX FILE ',A1,' : ',*)
4200     2000 FORMAT(A35)
4300     3000 FORMAT(A8,2I8)
4400     4000 FORMAT(6X,A3,A8,' IS A ',I8,' ROW BY ',I8,' COLUMN MATRIX')
4500     5000 FORMAT(6X,'# OF COLUMNS DOES NOT MATCH # OF ROWS OF KEY MATRIX',
4600     * /,6X,A40)
4700     6000 FORMAT(6X,'MATRICES HAVE DIFFERENT # OF ROWS',/,6X,A40)
4800     END

```

```

100      SUBROUTINE GETKEYMTRX(MATRIX1, MATRIX2, KROW1, KROW2, KCOL1, KCOL2, *)
200      C
300      C      GET KEY MATRIX FILENAMES, OPEN THEM (FORTRAN LOGICAL UNIT
400      C      NOS. 182), READ HEADER RECORDS, AND CHECK FOR COMPATIBLE SIZES.
500      C
600      CHARACTER*35 FILNAM1, FILNAM2
700      CHARACTER*8  MATRIX1, MATRIX2
800      C
900      C      FIRST MATRIX:
1000     1      TYPE 2000, '1', '1'
1100     1      ACCEPT 6000, FILNAM1
1200     1      OPEN(UNIT=1, NAME=FILNAM1, TYPE='OLD', READONLY,
1300     *      CARRIAGECONTROL='LIST', ERR=1)
1400     *      READ(1, 3000) MATRIX1, KROW1, KCOL1
1500     C      SECOND MATRIX:
1600     2      TYPE 2000, '2', '2'
1700     2      ACCEPT 6000, FILNAM2
1800     2      OPEN(UNIT=2, NAME=FILNAM2, TYPE='OLD', READONLY,
1900     *      CARRIAGECONTROL='LIST', ERR=2)
2000     *      READ(2, 3000) MATRIX2, KROW2, KCOL2
2100     C      CHECK FOR SAME NUMBER OF COLUMNS
2200     IF (KCOL1 .NE. KCOL2) THEN
2300         CLOSE(UNIT=1)
2400         CLOSE(UNIT=2)
2500         TYPE 7000, '1> ', MATRIX1, KROW1, KCOL1
2600         TYPE 7000, '2> ', MATRIX2, KROW2, KCOL2
2700         TYPE *, 'NO MERGING DONE:'
2800         TYPE *, 'MATRICES HAVE DIFFERENT NO. OF COLUMNS'
2900         RETURN 1
3000     END IF
3100     RETURN
3200     C
3300     2000  FORMAT(1X, A1, '>' ENTER FILENAME OF KEY MATRIX ', A1, ': ', $)
3400     3000  FORMAT(A8, 2I8)
3500     6000  FORMAT(A35)
3600     7000  FORMAT(6X, A3, A8, ' IS A ', I8, ' ROW BY ', I8, ' MATRIX')
3700     END

```

```

100      SUBROUTINE GETSORTCOL(MATRIX1,MATRIX2,KROW1,KROW2,
200      *                                KCOL1,KCOL2,SORTLIST)
300      C
400      C      DETERMINE KEY COLUMNS FOR SORTED MERGE, AND READ THEM
500      C      INTO SORTING ARRAY, SORTLIST.
600      C
700      REAL SORTLIST(2,100)
800      CHARACTER*8 MATRIX1, MATRIX2
900      C
1000     C      FIRST MATRIX:
1100     1      TYPE 7000, '1> ', MATRIX1,KROW1,KCOL1
1200     TYPE 8000
1300     ACCEPT *, MRGCOL1
1400     IF ((MRGCOL1.LT.1) .OR. (MRGCOL1.GT.KCOL1)) GOTO 1
1500     C      SECOND MATRIX:
1600     2      TYPE 7000, '2> ', MATRIX2,KROW2,KCOL2
1700     TYPE 8000
1800     ACCEPT *, MRGCOL2
1900     IF ((MRGCOL2.LT.1) .OR. (MRGCOL2.GT.KCOL2)) GOTO 2
2000     C      READ MERGE COLUMNS INTO SORTING ARRAY
2100     DO 100 J=1,MRGCOL1
2200     DO 100 I=1,KROW1
2300     READ(1,9000) SORTLIST(1,I)
2400     100     CONTINUE
2500     DO 200 J=1,MRGCOL2
2600     DO 200 I=1,KROW2
2700     READ(2,9000) SORTLIST(2,I)
2800     200     CONTINUE
2900     RETURN
3000     C
3100     7000  FORMAT(6X,A3,A8,' IS A ',I8,' ROW BY ',I8,' COLUMN MATRIX')
3200     8000  FORMAT(9X,'ENTER COLUMN NO. TO USE FOR SORTED MERGE: ',I)
3300     9000  FORMAT(E16.8)
3400     END

```

```

100      SUBROUTINE KEYLIST(SORTLIST,KROW1,KROW2,MTXKEY,ROWKEY)
200      C
300      C      GENERATE KEY LISTS FOR SORTED MERGING
400      C
500      REAL SORTLIST(2,100)
600      INTEGER MTXKEY(100), ROWKEY(100)
700      C
800      I1 = 1
900      I2 = 1
1000     DO 100 I=1,KROW1+KROW2
1100         IF (I1 .GT. KROW1) THEN
1200             C      END OF COLUMN FOR MATRIX 1 REACHED; SET KEY FOR MATRIX 2
1300             MTXKEY(I) = 2
1400             ROWKEY(I) = I2
1500             I2 = I2 + 1
1600         ELSE IF (I2 .GT. KROW2) THEN
1700             C      END OF COLUMN FOR MATRIX 2 REACHED; SET KEY FOR MATRIX 1
1800             MTXKEY(I) = 1
1900             ROWKEY(I) = I1
2000             I1 = I1 + 1
2100         ELSE IF (SORTLIST(1,I1) .LE. SORTLIST(2,I2)) THEN
2200             C      SET KEY FOR MATRIX 1
2300             MTXKEY(I) = 1
2400             ROWKEY(I) = I1
2500             I1 = I1 + 1
2600         ELSE
2700             C      SET KEY FOR MATRIX 2
2800             MTXKEY(I) = 2
2900             ROWKEY(I) = I2
3000             I2 = I2 + 1
3100         END IF
3200     100 CONTINUE
3300     RETURN
3400     END

```

```

100      SUBROUTINE MERGEASC(MTXKEY, KOUT, MROW, NCOL)
200      C
300      C   MERGE ASSOCIATED MATRIX PAIR INTO OUTPUT FILE & CLOSE FILES
400      C
500      INTEGER MTXKEY(200)
600      CHARACTER FILNAM3*35, MATRIX3*8
700      C
800      C   GET NAME OF NEW ASSOCIATED OUTPUT (MERGED) MATRIX
900      TYPE 1000
1000     ACCEPT 2000, FILNAM3
1100     TYPE 3000
1200     ACCEPT 4000, MATRIX3
1300     OPEN(UNIT=3, NAME=FILNAM3, TYPE='NEW', CARRIAGECONTROL='LIST')
1400     C   MERGE MATRIX PAIR INTO OUTPUT MATRIX
1500     WRITE(3,5000) MATRIX3, MROW, KOUT
1600     DO 100 J=1, NCOL
1700     DO 100 I=1, MROW
1800         READ( ABS(MTXKEY(J)) , 6000 ) TERM
1900         IF (MTXKEY(J) .GT. 0) WRITE(3,7000) TERM
2000     100 CONTINUE
2100     C   FINISHED: CLOSE FILES & RETURN
2200         CLOSE(UNIT=1)
2300         CLOSE(UNIT=2)
2400         CLOSE(UNIT=3)
2500         RETURN
2600     C
2700     1000 FORMAT(/, ' ENTER NAME OF NEW (MERGED) MATRIX FILE: ', $)
2800     2000 FORMAT(A35)
2900     3000 FORMAT(6X, ' ENTER MATRIX NAME: ', $)
3000     4000 FORMAT(A8)
3100     5000 FORMAT(A8, 2I8)
3200     6000 FORMAT(E16.8)
3300     7000 FORMAT(1PE16.8)
3400     END

```

```

100      SUBROUTINE MERGEKEY(MTXKEY, KOUT)
200      C
300      C      MERGE KEY MATRICES INTO OUTPUT MATRIX & CLOSE FILES
400      C
500      INTEGER MTXKEY(200)
600      CHARACTER*8 MATRIX1, MATRIX2, MATRIX3, FILNAM3*35
700      C
800      C      GET NAME OF OUTPUT KEY MATRIX & OPEN NEW FILE
900      TYPE 1000
1000     ACCEPT 2000, FILNAM3
1100     TYPE 3000
1200     ACCEPT 4000, MATRIX3
1300     OPEN(UNIT=3, NAME=FILNAM3, TYPE='NEW', CARRIAGECONTROL='LIST')
1400     C      MERGE KEY MATRICES INTO OUTPUT MATRIX
1500     REWIND 1
1600     REWIND 2
1700     READ(1, 5000) MATRIX1, KROW1, KCOL1
1800     READ(2, 5000) MATRIX2, KROW2, KCOL2
1900     WRITE(3, 5000) MATRIX3, KOUT, KCOL1
2000     DO 100 J=1, KCOL1
2100     DO 100 I=1, KROW1+KROW2
2200         READ( ABS(MTXKEY(I)) , 6000 ) TERM
2300         IF (MTXKEY(I) .GT. 0) WRITE(3, 7000) TERM
2400     100 CONTINUE
2500     C      FINISHED: CLOSE FILES & RETURN
2600     CLOSE(UNIT=1)
2700     CLOSE(UNIT=2)
2800     CLOSE(UNIT=3)
2900     RETURN
3000     C
3100     1000 FORMAT(/, ' ENTER NAME OF NEW (MERGED) MATRIX FILE: ', *)
3200     2000 FORMAT(A35)
3300     3000 FORMAT(6X, ' ENTER MATRIX NAME: ', *)
3400     4000 FORMAT(A8)
3500     5000 FORMAT(A8, 2I8)
3600     6000 FORMAT(E16.8)
3700     7000 FORMAT(1PE16.8)
3800     END

```

STATCORR

The statistical correlation program STATCORR was written for implementation on the GSFC Code 750 VAX-11/780 computer system, and the analysis was done using the Code 750 VAX version of Level 17.5 NASTRAN. The empirical testing was performed by the GSFC Environmental Test & Integration Branch and test mode shapes, frequencies, and damping were determined using the standard in-house processing software on a PDP-11/35 computer system.

Three data files are required to input analytical mode shape data to the STATCORR program: 1) the LAMA matrix file, which contains data from the NASTRAN LAMA table (frequency, mass, and stiffness vectors) and mode symmetry information; 2) the PHITE matrix file, which contains the eigenvectors generated by the NASTRAN run; 3) the grid point list file, obtained from the TESET vector. All the data required to build these files is contained in the NASTRAN punch file produced by using the DMAP ALTER package discussed earlier.

Since the NASTRAN analysis and the statistical correlation are performed on the same computer system, the NASTRAN punch file is immediately available for processing (to generate the analytical input files to STATCORR) by the appropriate intermediate processor programs MERGE,LAMA, UNPACKDMI, GRDPTLIST, discussed subsequently. These processor programs read the NASTRAN punch file and produce input files in the format required for input to STATCORR.

One data file for each experimental mode is required to input experimental mode shape data to the STATCORR program. Each experimental data file contains all data (frequency, damping, symmetry, gridpoint IDs, and mode shape data) to describe one experimental mode. The in-house Modal Survey processing program has the capability of generating various ASCII data files containing the necessary grid-point ID, frequency, damping, and mode-shape information, which can be further processed to generate files in the appropriate format for input to the STATCORR program.

Since the experimental mode data is stored on a different computer system, it was necessary to provide a method of data transfer between the Code 750 VAX-11/780 computer and the Environmental Test & Integration Branch PDP-11/35 computer. Because rapid, convenient file transfer was desired and the two computer systems had no similar storage media to permit simple volume transfer between the machines, a remote terminal emulator program with ASCII file transfer capability was adapted for use on the PDP-11/35. This permits the PDP computer to be used as a remote (dial-up) terminal to the VAX-11/780, allowing direct transfer of ASCII text files via phone line between the VAX and PDP computers.

For a user's guide describing the execution of NASTRAN, STATCORR, and the associated preprocessing programs, please refer to NASA Technical Memorandum 86044. Also included is a working example using the SPARTAN-1 model, and FORTRAN source code listings of the STATCORR program and the preprocessing programs TESETDMI, UNPACKDMI, LAMA, and GRDPTLST.

PROGRAM STATCORR

C

PARAMETER (MAXMODE= 200)
 PARAMETER (MAXDOF = 1000)
 COMMON /LIMITS/ MXMD,MXDF
 DATA MXMD/MAXMODE/, MXDF/MAXDOF/

REAL FREQAN(MAXMODE), FREQEX(MAXMODE)
 REAL DISPAN(MAXDOF,MAXMODE), DISPEX(MAXDOF,MAXMODE)
 REAL MASS(MAXMODE),STIFF(MAXMODE),DAMP(MAXMODE)
 REAL CORREL(MAXMODE,MAXMODE), C(MAXMODE,MAXMODE)
 REAL S(MAXMODE,MAXMODE)
 REAL RMSA(MAXMODE,MAXMODE), RMSE(MAXMODE,MAXMODE)
 REAL AVECT(MAXDOF),EVECT(MAXDOF),DIFF(MAXDOF),DIFABS(MAXDOF)
 INTEGER IDDOFA(MAXDOF,MAXMODE),IDDOFE(MAXDOF,MAXMODE)
 INTEGER ICOMP A(MAXDOF,MAXMODE), ICOMPE(MAXDOF,MAXMODE)
 INTEGER NDOFA(MAXMODE),NDOFE(MAXMODE)
 INTEGER IDDOF I(MAXDOF),ICOMP I(MAXDOF)
 INTEGER NAFIT(MAXMODE),MEFIT(MAXMODE)
 INTEGER ASYMM(3,MAXMODE),ESYMM(3,MAXMODE)
 CHARACTER*10 AHEADER(4),EHEADER(4),HEADER(32)
 CHARACTER*9 CDATE
 CHARACTER*1 YESNO
 LOGICAL PRTAN,PRTEX,LSYMM,LPRINT

COMMON /WHEN/ CDATE

C

DATA PRTAN,PRTEX,LSYMM,LPRINT/4*.FALSE./
 DATA AHEADER/2*' NASTRAN',2*' TEST'/
 DATA EHEADER/2*' TEST', 2*' NASTRAN'/
 DATA HEADER/'# OF CP'S', ' CORREL', 2*' ', 2*' RMS',
 * ' MAX REL', ' GRID', ' MODE', 'FREQUENCY',
 * ' MODE', 'FREQUENCY', ' COMPARED', ' COEFF',
 * ' CA', ' S', '(NASTRAN)', '(TEST)',
 * 'DIFFERENCE', ' POINT', 12*' _____'/'

C

C

PRINT SECTION 1 HEADER
 CALL DATE(CDATE)
 PRINT 8000, CDATE
 PRINT 4000

C

CHECK FOR SEPARATE PRINT FILE
 TYPE 5000
 ACCEPT 7000, YESNO
 IF (YESNO.EQ.'Y') LPRINT = .TRUE.
 IF (LPRINT) PRINT 5500, YESNO

C

GET ANALYTICAL FREQ, MASS, STIFFNESS, MODE-SHAPE, & DOF LISTS
 CALL GETAN(FREQAN,MASS,STIFF,ASYMM,DISPAN,NAN,
 * IDDOFA,ICOMP A,NDOFA,LPRINT)

C

GET EXPERIMENTAL FREQ, DAMPING, MODE-SHAPE, & DOF LISTS
 CALL GETEXP(FREQEX,DAMP,ESYMM,DISPEX,MEX,IDDOFE,ICOMPE,
 * NDOFE,LPRINT)

C

DETERMINE SYMMETRY, MODE-SHAPE DUMP, & THRESHOLD OPTIONS
 CALL OPTIONS(LSYMM,PRTAN,PRTEX,RTHRESH,LPRINT)

C

PRINT INPUT SUMMARY
 CALL INPSUM(NAN,FREQAN,MASS,STIFF,ASYMM,MEX,FREQEX,DAMP,ESYMM)
 SORT DOF LISTS & MODE SHAPE MATRICES (BASED ON DOF SORT)
 CALL DOFSORT(IDDOFA,ICOMP A,NDOFA,DISPAN,NAN)
 CALL DOFSORT(IDDOFE,ICOMPE,NDOFE,DISPEX,MEX)

C

COMPUTE CORRELATION COEFFICIENTS & RMS VALUES FOR ALL
 C POSSIBLE ANALYTICAL/EXPERIMENTAL PAIRS

```

DO 100 N=1,NAN
DO 100 M=1,MEX
C   GET VECTORS TO BE COMPARED & THEIR DOF INTERSECTION SET
    CALL GETVEC(DISPAN(1,N),NDOFA(N),AVECT)
    CALL GETVEC(DISPEX(1,M),NDOFE(M),EVECT)
    CALL INTERSECT(AVECT,EVECT,IDDOFA(1,N),IDDOFE(1,M),
*           ICOMP(1,N),ICOMPE(1,M),
*           NDOFA(N),NDOFE(M),IDDOFI,ICOMPI,NDOFI,
*           ASYMM(1,N),ESYMM(1,M),LSYMM)
C   COMPUTE CORR COEFFS & RMS VALUES FOR THIS PAIR
    CALL CORRMS(AVECT,EVECT,NDOFI,CORREL(N,M),
*           C(N,M),S(N,M),RMSA(N,M),RMSE(N,M))
100 CONTINUE
C   PRINT CORRELATION COEFFICIENT TABLE
    CALL CORRtbl(CORREL,NAN,MEX)
C   DETERMINE BEST MATCH FOR EACH EXPERIMENTAL & ANALYTICAL MODE
    CALL MATCH(CORREL,NAN,MEX,NAFIT,MEFIT)
C   FOR EACH MATCHED PAIR, GET X/RMS DIFFERENCES & PRINT SUMMARY
C   PRINT ANALYTICAL MODE SHAPE HEADER
    PRINT 8000, CDATE
    PRINT 1000, AHEADER, HEADER
DO 200 N=1,NAN
    M = NAFIT(N)
C   GET VECTORS TO BE COMPARED & THEIR DOF INTERSECTION SET
    CALL GETVEC(DISPAN(1,N),NDOFA(N),AVECT)
    CALL GETVEC(DISPEX(1,M),NDOFE(M),EVECT)
    CALL INTERSECT(AVECT,EVECT,IDDOFA(1,N),IDDOFE(1,M),
*           ICOMP(1,N),ICOMPE(1,M),
*           NDOFA(N),NDOFE(M),IDDOFI,ICOMPI,NDOFI,
*           ASYMM(1,N),ESYMM(1,M),LSYMM)
C   CALCULATE INDIVIDUAL DIFFERENCES
    CALL RMSDIFF(AVECT,EVECT,NDOFI,RMSA(N,M),RMSE(N,M),
*           CORREL(N,M),S(N,M),DIFF,DIFABS)
C   PRINT SUMMARY FOR THIS PAIR, WITH MAX DIFF & > THRESHOLD
    CALL PRINT(N,FREQAN(N),M,FREQEX(M),NDOFI,CORREL(N,M),
*           C(N,M),S(N,M),RMSA(N,M),RMSE(N,M),
*           DIFF,DIFABS,IDDOFI,ICOMPI,RTHRESH)
200 CONTINUE
C   PRINT EXPERIMENTAL MODE SHAPE HEADER
    PRINT 8000, CDATE
    PRINT 3000, EHEADER, HEADER
DO 300 M=1,MEX
    N = MEFIT(M)
C   GET VECTORS TO BE COMPARED & THEIR DOF INTERSECTION SET
    CALL GETVEC(DISPEX(1,M),NDOFE(M),EVECT)
    CALL GETVEC(DISPAN(1,N),NDOFA(N),AVECT)
    CALL INTERSECT(AVECT,EVECT,IDDOFA(1,N),IDDOFE(1,M),
*           ICOMP(1,N),ICOMPE(1,M),
*           NDOFA(N),NDOFE(M),IDDOFI,ICOMPI,NDOFI,
*           ASYMM(1,N),ESYMM(1,M),LSYMM)
C   CALCULATE COMBINED RMS AND INDIVIDUAL DIFFERENCES
    CALL RMSDIFF(AVECT,EVECT,NDOFI,RMSA(N,M),RMSE(N,M),
*           CORREL(N,M),S(N,M),DIFF,DIFABS)
C   PRINT SUMMARY FOR THIS PAIR, WITH MAX DIFF & > THRESHOLD
    CALL PRINT(M,FREQEX(M),N,FREQAN(N),NDOFI,CORREL(N,M),
*           C(N,M),S(N,M),RMSA(N,M),RMSE(N,M),
*           DIFF,DIFABS,IDDOFI,ICOMPI,RTHRESH)
300 CONTINUE
C   PRINT ANALYTICAL &/OR EXPERIMENTAL MODE-SHAPE VECTORS
    CALL PRINTPHI(NAN,NDOFA,IDDOFA,ICOMP,DISPAN,PRTAN,
*           MEX,NDOFE,IDDOFE,ICOMPE,DISPEX,PRTEX)

```

```

      STOP 'FORTRAN STOP -- PROCESSING COMPLETED'
C
1000  FORMAT(1H0,'4. ANALYTICAL MODE SHAPES AND THEIR BEST',
*      ' EXPERIMENTAL MATCHES:',/0',12(A10,1X),2(/12(1X,A10)))
3000  FORMAT(1H0,'5. EXPERIMENTAL MODE SHAPES AND THEIR BEST'
*      ' ANALYTICAL MATCHES:',/0',12(A10,1X),2(/12(1X,A10)))
4000  FORMAT(1H0,' 1. INTERACTIVE DIALOG:')
5000  FORMAT(/,' IS A SEPARATE OUTPUT LISTING FILE TO BE PRINTED?',
*      '(Y OR N): ',S)
5500  FORMAT(/,' IS A SEPARATE OUTPUT LISTING FILE TO BE PRINTED?',
*      '(Y OR N): ',A1)
7000  FORMAT(A1)
8000  FORMAT(1H1,'NASTRAN MODAL ANALYSIS - MODAL SURVEY STATISTICAL',
*      ' CORRELATION', /1X,A9)
      END

```

```

SUBROUTINE CORRMS(AVECT,EVECT,NDOFI,CORREL,CA,S,RMSA,RMSE)
C
C COMPUTE CORRELATION COEFFICIENTS & RMS VALUES
C
REAL AVECT(*),EVECT(*)
C
C INITIALIZE RMS'S & CORR COEFFS
RMSA = 0.0
RMSE = 0.0
CORREL = 0.0
CA = 0.0
S = 0.0
IF (NDOFI.EQ. 0) RETURN
C COMPUTE VARIANCES OF ANALYTICAL & EXPERIMENTAL VECTORS
C NOTE: THE FINAL VALUES COMPUTED HERE FOR THE "VARIANCES"
C ARE NOT TRUE VARIANCES. TO OBTAIN VARIANCES, THE VALUES
C VARA, VARE, & VARAE SHOULD BE EACH MULTIPLIED BY 1/NDOFI .
C THESE VALUES ARE NOT REPORTED, BUT ARE USED ONLY TO
C CALCULATE CORREL, CA, S, RMSA, & RMSE. THE 1/NDOFI FACTOR
C IS NOT INCLUDED, SINCE IT APPEARS IN BOTH THE NUMERATOR AND
C DENOMINATOR OF CORREL & CA; THE EXTRA ARITHMETIC OPERATIONS
C WOULD SIMPLY INTRODUCE UNNECESSARY ERROR IN THE RESULTS.
C THE 1/NDOFI FACTOR IS INCLUDED IN THE CALCULATIONS OF
C S, RMSA, & RMSE.
VARA = 0.0
VARE = 0.0
VARAE = 0.0
DO 100 N=1,NDOFI
VARA = VARA + AVECT(N)*AVECT(N)
VARE = VARE + EVECT(N)*EVECT(N)
VARAE = VARAE + AVECT(N)*EVECT(N)
100 CONTINUE
C COMPUTE CORRELATION COEFFICIENT FOR THIS PAIR OF VECTORS
IF (VARAE .NE. 0.0) CORREL = VARAE/SQRT(VARA*VARE)
C COMPUTE CORREL COEFF (REFERENCED TO ANALYTICAL VECTOR)
IF (VARA .NE. 0.0) CA = VARAE/VARA
C COMPUTE ROOT OF MEAN SQUARE DIFFERENCE
S = SQRT( ABS(VARE-CA*CA*VARA)/NDOFI )
C COMPUTE RMS VALUES
C NOTE: FOR THIS APPLICATION, RMS = STD.DEV. = SQRT(VARIANCE) .
RMSA = SQRT(VARA/NDOFI)
RMSE = SQRT(VARE/NDOFI)
RETURN
END

```

```

SUBROUTINE CORRTEL(CORREL,NAN,MEX)
C
C PRINT AN NAN X MEX TABLE OF THE ANALYTICAL VS. EXPERIMENTAL
C CORRELATION COEFFICIENTS.
C
COMMON /LIMITS/ MAXMODE,MAXDOF
COMMON /WHEN/ CDATE
REAL CORREL(MAXMODE,MAXMODE)
CHARACTER CDATE*9
C
DO 200 MFIRST=1,MEX,16
DO 200 NFIRST=1,NAN,50
    MLAST = MIN( MEX, MFIRST+15 )
    NLAST = MIN( NAN, NFIRST+49 )
C PRINT HEADER FOR ONE PAGE OF THE TABLE
    PRINT 1000, CDATE
    PRINT 2000
    PRINT 3000, (M,M=MFIRST,MLAST)
DO 100 N=NFIRST,NLAST
    PRINT 4000, N, (CORREL(N,M),M=MFIRST,MLAST)
100 END DO
200 END DO

RETURN

1000 FORMAT(1H1,'NASTRAN MODAL ANALYSIS - MODAL SURVEY STATISTICAL ',
* 'CORRELATION', /1X,A9,
* /1H0,'3. CORRELATION COEFFICIENTS FOR ANALYTICAL VS. ',
* 'EXPERIMENTAL COMPARISONS:')
2000 FORMAT('0ANALYTICAL',24X,'EXPERIMENTAL MODES')
3000 FORMAT(3X,'MODES',3X,15,15I7)
4000 FORMAT(1X,16,4X,16(1X,F6.3))
END

```

```

SUBROUTINE DOFSORT( IDDOF, ICOMP, NDOF, DISP, NMODES)
C
C
C
C
C
COMMON /LIMITS/ MAXMODE, MAXDOF
REAL DISP( MAXDOF, MAXMODE)
INTEGER IDDOF( MAXDOF, MAXMODE), ICOMP( MAXDOF, MAXMODE), NDOF( MAXMODE)
C
DO 200 J=1, NMODES
  IF ( NDOF(J) .EQ. 1) GOTO 200
  DO 100 I=1, NDOF(J)-1
  DO 100 K=I+1, NDOF(J)
    IF ( IDDOF(K, J) .LT. IDDOF(I, J) ) THEN
      CALL SWAP( IDDOF(I, J), IDDOF(K, J) )
      CALL SWAP( ICOMP(I, J), ICOMP(K, J) )
      CALL SWAP( DISP(I, J), DISP(K, J) )
    ELSE IF ( ( IDDOF(K, J) .EQ. IDDOF(I, J) ) .AND.
      *      ( ICOMP(K, J) .LT. ICOMP(I, J) ) ) THEN
      CALL SWAP( IDDOF(I, J), IDDOF(K, J) )
      CALL SWAP( ICOMP(I, J), ICOMP(K, J) )
      CALL SWAP( DISP(I, J), DISP(K, J) )
    END IF
  100 CONTINUE
  200 CONTINUE
RETURN
END

```

```

SUBROUTINE GETAN(FREQS, MASS, STIFF, ASYMM, SHAPES, NMODES,
*                IDDOF, ICOMP, NDOFS, LPRINT)
C
C   GET FREQUENCY, MASS, STIFFNESS & SYMMETRY VECTORS;
C   MODE-SHAPE MATRIX; AND GRID POINT LIST.
C
COMMON /LIMITS/ MAXMODE, MAXDOF

REAL FREQS(MAXMODE), MASS(MAXMODE), STIFF(MAXMODE)
REAL SHAPES(MAXDOF, MAXMODE)
INTEGER ASYMM(3, MAXMODE)
INTEGER IDDOF(MAXDOF, MAXMODE), ICOMP(MAXDOF, MAXMODE)
INTEGER NDOFS(MAXMODE)
CHARACTER*35 FRQFIL, SHPFIL, DOFFIL
CHARACTER*8 FRQMTX, SHPMTX
LOGICAL LPRINT

C
C   GET FILE NAMES
10  TYPE 1000
    ACCEPT 2000, FRQFIL
    OPEN(UNIT=1, NAME=FRQFIL, TYPE='OLD', READONLY, ERR=10)
    IF (LPRINT) PRINT 1500, FRQFIL
20  TYPE 3000
    ACCEPT 2000, SHPFIL
    OPEN(UNIT=2, NAME=SHPFIL, TYPE='OLD', READONLY, ERR=20)
    IF (LPRINT) PRINT 3500, SHPFIL
30  TYPE 4000
    ACCEPT 2000, DOFFIL
    OPEN(UNIT=3, NAME=DOFFIL, TYPE='OLD', READONLY, ERR=30)
    IF (LPRINT) PRINT 4500, DOFFIL
C   READ FREQUENCY FILE
    READ(1, 7000) FRQMTX, NFREQS, NCOLS
    IF (NCOLS .NE. 6) THEN
40  TYPE 5000, FRQMTX, NCOLS
        IF (LPRINT) PRINT 5000, FRQMTX, NCOLS
        CLOSE(UNIT=1)
        CLOSE(UNIT=2)
        CLOSE(UNIT=3)
        STOP
    END IF
    IF (NFREQS .GT. MAXMODE) PRINT 6000, NFREQS, MAXMODE
    NMODES = MIN(NFREQS, MAXMODE)
    DO 100 I=1, 6
    DO 100 J=1, NFREQS
        IF (J .GT. MAXMODE) THEN
            READ(1, 8000) DUMMY
        ELSE IF (I .EQ. 1) THEN ! GET FREQUENCY LIST
            READ(1, 8000) FREQS(J)
        ELSE IF (I .EQ. 2) THEN ! GET MASS LIST
            READ(1, 8000) MASS(J)
        ELSE IF (I .EQ. 3) THEN ! GET STIFFNESS LIST
            READ(1, 8000) STIFF(J)
        ELSE IF (I .EQ. 4) THEN ! GET PLANE 1 SYMMETRY LIST
            READ(1, 8000) SYMM
            ASYMM(1, J) = NINT(SYMM)
        ELSE IF (I .EQ. 5) THEN ! GET PLANE 2 SYMMETRY LIST
            READ(1, 8000) SYMM
            ASYMM(2, J) = NINT(SYMM)
        ELSE IF (I .EQ. 6) THEN ! GET PLANE 3 SYMMETRY LIST
            READ(1, 8000) SYMM
            ASYMM(3, J) = NINT(SYMM)

```

```

        END IF
        CONTINUE
100  C   READ MODE-SHAPE FILE
        READ(2,7000) SHPMTX,NDISPS,NSHAPES
        IF (NSHAPES .NE. NFREQS) THEN
            NMODES = MIN( NFREQS, NSHAPES, NMODES )
            TYPE 9000, NFREQS,NSHAPES,NMODES
            IF (LPRINT) PRINT 9000, NFREQS,NSHAPES,NMODES
        END IF
        IF (NDISPS .GT. MAXDOF) PRINT 10000, NDISPS,MAXDOF
        DO 200 J=1,NMODES
        DO 200 I=1,NDISPS
            IF (I .LE. MAXDOF) READ(2,8000) SHAPES(I,J)
            IF (I .GT. MAXDOF) READ(2,8000) DUMMY
200  C   READ DOF ID FILE
        NDOFS(1) = 0
        DO 300 I=1,1000000
            IF (I .LE. MAXDOF)
                *   READ(3,11000,END=350) IDDOF(I,1),ICOMPA(I,1)
                IF (I .GT. MAXDOF) READ(3,11000,END=350) IDUMMY,IDUMMC
                NDOFS(1) = NDOFS(1) + 1
300  C   CONTINUE
350  C   IF (NDOFS(1) .NE. NDISPS) THEN
            TYPE 12000, NDISPS,NDOFS(1)
            IF (LPRINT) PRINT 12000, NDISPS,NDOFS(1)
            CLOSE(UNIT=1)
            CLOSE(UNIT=2)
            CLOSE(UNIT=3)
            STOP
            ENDIF
            NDOFS(1) = MIN(NDOFS(1),MAXDOF)
            IF (NMODES .EQ. 1) RETURN
            DO 500 J=2,NMODES
                NDOFS(J) = NDOFS(1)
                DO 400 I=1,NDOFS(J)
                    IDDOF(I,J) = IDDOF(I,1)
                    ICOMPA(I,J) = ICOMPA(I,1)
400  C   CONTINUE
500  C   CONTINUE
        CLOSE(UNIT=1)
        CLOSE(UNIT=2)
        CLOSE(UNIT=3)
        RETURN
C
1000  FORMAT(/,' ENTER ANALYTICAL LAMA MATRIX FILENAME: ',*)
1500  FORMAT(/,' ENTER ANALYTICAL LAMA MATRIX FILENAME: ',A35)
2000  FORMAT(A35)
3000  FORMAT(' ENTER ANALYTICAL MODE-SHAPE MATRIX FILENAME: ',*)
3500  FORMAT(' ENTER ANALYTICAL MODE-SHAPE MATRIX FILENAME: ',A35)
4000  FORMAT(' ENTER ANALYTICAL GRID POINT LIST FILENAME: ',*)
4500  FORMAT(' ENTER ANALYTICAL GRID POINT LIST FILENAME: ',A35)
5000  FORMAT(' FREQUENCY MATRIX ',A8,' HAS ',I6,' COLUMNS.'
        *   ' SHOULD BE 6 COLUMNS.')
6000  FORMAT(' **** WARNING: FREQUENCY VECTOR HAS ',I3,' ENTRIES.',
        *   '/15X,'ONLY THE FIRST',I5,' WILL BE USED.')
7000  FORMAT(A8,2I8)
8000  FORMAT(E16.8)
9000  FORMAT(' **** WARNING: UNEQUAL NUMBER OF FREQUENCIES AND '
        *   'MODE SHAPES. ',
        *   '/15X,'NUMBER OF FREQUENCIES:',I6,

```

```
*      /15X,'NUMBER OF MODE SHAPES:',16,
*      /15X,'ONLY THE FIRST',15,' WILL BE USED.')
```

10000 FORMAT(' **** WARNING: MODE-SHAPE VECTORS HAVE ',13,' ENTRIES.',

```
*      /15X,'ONLY THE FIRST',16,' WILL BE USED.')
```

11000 FORMAT(18,1X,11)

12000 FORMAT(' **** ERROR: UNEQUAL NUMBER OF MODE-SHAPE POINTS AND ',

```
*      'D.O.F. ID'S. ',16,' 8 ',16)
```

END

```

SUBROUTINE GETEXP(FREQEX,DAMP,ESYMM,DISPEX,MEX,
*                IDDOFE,ICOMP,NDOFE,LPRINT)
C
C   GET EXPERIMENTAL FREQUENCY & DAMPING LISTS, MODE-SHAPE MATRIX,
C   AND D.O.F. LIST.
C
COMMON /LIMITS/ MAXMODE,MAXDOF

REAL FREQEX(MAXMODE),DAMP(MAXMODE),DISPEX(MAXDOF,MAXMODE)
REAL DUMMY(5)
INTEGER ESYMM(3,MAXMODE)
INTEGER IDDOFE(MAXDOF,MAXMODE),ICOMP(MAXDOF,MAXMODE)
INTEGER NDOFE(MAXMODE)
CHARACTER*35 MSFILE
LOGICAL LPRINT

C
C   PROCESS MODE-SHAPE FILES
C   TYPE *, ' ' ! SKIP A LINE
C   IF (LPRINT) PRINT *, ' '
C   MEX = 0
C   DO 200 J=1,MAXMODE
C       GET NEXT EXPERIMENTAL MODE-SHAPE FILE
C       TYPE 1000
C       ACCEPT 2000, MSFILE
C       IF (MSFILE .EQ. 'NONE') GOTO 250
C       OPEN(UNIT=10,NAME=MSFILE,TYPE='OLD',READONLY,ERR=10)
C       IF (LPRINT) PRINT 1500, MSFILE
C       GET FREQUENCY, DAMPING & SYMMETRY FOR THIS MODE-SHAPE
C       READ(10,*) FREQEX(J)
C       READ(10,*) DAMP(J)
C       READ(10,*) (ESYMM(K,J),K=1,3)
C       GET MODE-SHAPE DISPLACEMENTS & D.O.F.'S
C       DO 100 I=1,MAXDOF
C           READ(10,*,END=150)
C           *                IDDOFE(I,J),ICOMP(I,J),DISPEX(I,J)
C           NDOFE(J) = I
C       100 CONTINUE
C       PRINT 5000, MAXDOF,MAXDOF
C       150 MEX = J
C       CLOSE(UNIT=10)
C       200 CONTINUE
C       TYPE 6000, MAXMODE
C       IF (LPRINT) PRINT 6000, MAXMODE
C       250 IF (LPRINT .AND. (MSFILE .EQ. 'NONE')) PRINT 1500, MSFILE
C       IF (MEX .EQ. 0) THEN
C           TYPE *, ' **** ERROR: NO EXPERIMENTAL MODE-SHAPE REQUESTS'
C           IF (LPRINT) PRINT *,
C           * ' **** ERROR: NO EXPERIMENTAL MODE-SHAPE REQUESTS'
C       STOP
C       END IF
C       RETURN

C
C   1000 FORMAT(' ENTER NEXT EXPERIMENTAL MODE-SHAPE FILENAME. ',
C   *          ' ("NONE" IF NO MORE) : ',0)
C   1500 FORMAT(' ENTER NEXT EXPERIMENTAL MODE-SHAPE FILENAME. ',
C   *          ' ("NONE" IF NO MORE) : ',A35)
C   2000 FORMAT(A35)
C   5000 FORMAT(' **** WARNING: MODE-SHAPE VECTOR HAS',16,' OR MORE',
C   *          ' ENTRIES.',/13X,' ONLY THE FIRST',16,' WILL BE USED.')
C   6000 FORMAT(' **** NO MORE EXPERIMENTAL MODE-SHAPE FILES PERMITTED.'
C   *          ' MAXIMUM IS ',14)

END

```

```
      SUBROUTINE GETVEC(DISP,NDOF,VECT)
C
C   COPY VECTOR OF LENGTH NDOF FROM PERMANENT VECTOR TO
C   WORKING VECTOR.
C
      REAL DISP(*),VECT(*)
C
      IF (NDOF .EQ. 0) RETURN
      DO 100 I=1,NDOF
          VECT(I) = DISP(I)
100      CONTINUE
      RETURN
      END
```

```

SUBROUTINE INPSUM(NAN,FREQAN,MASS,STIFF,ASYMM,
*           MEX,FREQEX,DAMP,           ESYMM)
C
C   PRINT A SUMMARY OF THE ANALYTICAL & EXPERIMENTAL FREQUENCIES,
C   MASS, STIFFNESS, DAMPING, AND SYMMETRY VECTORS.
C
REAL FREQAN(*),MASS(*),STIFF(*)
REAL FREQEX(*),DAMP(*)
INTEGER ASYMM(3,*),ESYMM(3,*)
LOGICAL NOSYMA(3),YESYMA(3),NOSYME(3),YESYME(3),FIRST
CHARACTER CDATE*9
COMMON /WHEN/ CDATE
DATA NOSYMA,YESYMA,NOSYME,YESYME/12*.FALSE./, FIRST/.TRUE./
C
C   PRINT HEADER
C   PRINT 8000, CDATE
C   PRINT 1000
C   PRINT ANALYTICAL SUMMARY
C   PRINT ANALYTICAL HEADER
C   PRINT 2000
C   PRINT SUMMARY DATA
C   PRINT 3000, (I,FREQAN(I),MASS(I),STIFF(I),
*             (ASYMM(J,I),J=1,3), I=1,NAN)
C   CHECK FOR INCONSISTENT ANALYTICAL "UNDEFINED" SYMMETRY
C   DO 200 IAXS=1,3
C       DO 100 MODE=1,NAN
C           IF (ASYMM(IAXS,MODE).EQ.0) NOSYMA(IAXS)=.TRUE.
C           IF (ASYMM(IAXS,MODE).NE.0) YESYMA(IAXS)=.TRUE.
100      CONTINUE
C           IF (NOSYMA(IAXS).AND.YESYMA(IAXS)) PRINT 6000, IAXS
200      CONTINUE
C   PRINT EXPERIMENTAL SUMMARY
C   PRINT EXPERIMENTAL HEADER
C   PRINT 4000
C   PRINT SUMMARY DATA
C   PRINT 5000, (I,FREQEX(I),DAMP(I),
*             (ESYMM(J,I),J=1,3), I=1,MEX)
C   CHECK FOR INCONSISTENT EXPERIMENTAL "UNDEFINED" SYMMETRY
C   DO 400 IAXS=1,3
C       DO 300 MODE=1,MEX
C           IF (ESYMM(IAXS,MODE).EQ.0) NOSYME(IAXS)=.TRUE.
C           IF (ESYMM(IAXS,MODE).NE.0) YESYME(IAXS)=.TRUE.
300      CONTINUE
C           IF (NOSYME(IAXS).AND.YESYME(IAXS)) PRINT 6000, IAXS
400      CONTINUE
C   CHECK FOR INCONSISTENT ANA VS. EXP "UNDEFINED" SYMMETRY
C   DO 500 IAXS=1,3
C       IF ( (NOSYMA(IAXS).AND.YESYME(IAXS)) .OR.
*         (YESYMA(IAXS).AND.NOSYME(IAXS)) ) THEN
C           IF (FIRST) PRINT 7000
C           FIRST = .FALSE.
C           PRINT 6000, IAXS
C           END IF
500      CONTINUE
C   RETURN
C
1000  FORMAT(1H0,'2. SUMMARY OF FREQUENCY, MASS, STIFFNESS,',
*          ' DAMPING, & SYMMETRY:')
2000  FORMAT(//,5X,'ANALYTICAL MODES:')
*      /1H0,4X,'MODE ', ' FREQUENCY ', ' MASS ',
*      ' STIFFNESS ', ' SYMMETRY '

```

```

*          /,5X,'-----',4(1X,'-----'))
3000  FORMAT(<NAN>(/5X,I3,1X,3(1PE16.8),3X,3I3),/)
4000  FORMAT(//,5X,'EXPERIMENTAL MODES:',
*          /1H0,4X,'MODE FREQUENCY  DAMPING  SYMMETRY',
*          /,5X,'-----',3(1X,'-----'))
5000  FORMAT(<MEX>(/5X,I3,1X,2(1PE11.3),1X,3I3),/)
6000  FORMAT(10X,'***WARNING: INCONSISTENT UNDEFINED SYMMETRY',
*          ' FOR PLANE',I2)
7000  FORMAT(//,5X,'ANALYTICAL VS. EXPERIMENTAL SYMMETRY:')
8000  FORMAT(1H1,'NASTRAN MODAL ANALYSIS - MODAL SURVEY STATISTICAL ',
*          'CORRELATION', /1X,A9)
END

```

```

SUBROUTINE INTERSECT(AVECT,EVECT, IDDOFA, IDDOFE, ICOMP A, ICOMPE,
*                   NDOFA, NDOFE, IDDOFI, ICOMPI, NDOFI,
*                   ASYMM, ESYMM, LSYMM)
C
C COPY INTERSECTION SET OF VECTORS IDDOFA & IDDOFE TO VECTOR
C IDDOFI. NDOFI IS THE LENGTH OF THE INTERSECTION SET.
C REDUCE AVECT & EVECT VECTORS TO CONTAIN ONLY THE CORRESPONDING
C INTERSECTION SET OF TERMS, I.A.W. THE MASTER SET IDDOFI.
C IF THE INTERSECTION SET IS NULL (NO EQUIVALENT D.O.F ID'S),
C THE VALUE RETURNED FOR NDOFI IS 0 .
C IF SYMMETRY IS TO BE CONSIDERED, AND ANALYTICAL & EXPERIMENTAL
C SYMMETRY ARE NOT THE SAME, THE VALUE RETURNED FOR NDOFI IS 0 .
C
REAL AVECT(*),EVECT(*)
INTEGER IDDOFA(*),IDDOFE(*),IDDOFI(*)
INTEGER ICOMP A(*),ICOMPE(*),ICOMPI(*)
INTEGER ASYMM(3),ESYMM(3)
LOGICAL LSYMM
C
IA = 1
IE = 1
NDOFI = 0
IF (LSYMM) THEN
C SYMMETRY IS TO BE CONSIDERED:
C IF A & E ARE UNLIKE, LEAVE INTERSECTION SET AS NULL
IF (ASYMM(1) .NE. ESYMM(1)) RETURN
IF (ASYMM(2) .NE. ESYMM(2)) RETURN
IF (ASYMM(3) .NE. ESYMM(3)) RETURN
END IF
C
DO 100 I=1,NDOFA+NDOFE
IF ((IA.GT.NDOFA) .OR. (IE.GT.NDOFE)) GOTO 150
IF ( ( IDDOFA(IA) .EQ. IDDOFE(IE) ) .AND.
*   ( ICOMP A(IA) .EQ. ICOMPE(IE) ) ) THEN
NDOFI = NDOFI + 1
IDDOFI(NDOFI) = IDDOFA(IA)
ICOMPI(NDOFI) = ICOMP A(IA)
AVECT(NDOFI) = AVECT(IA)
EVECT(NDOFI) = EVECT(IE)
IA = IA + 1
IE = IE + 1
ELSE IF ( IDDOFA(IA) .LT. IDDOFE(IE) ) THEN
IA = IA + 1
ELSE IF ( IDDOFE(IE) .LT. IDDOFA(IA) ) THEN
IE = IE + 1
END IF
100 CONTINUE
150 RETURN
END

```

```

SUBROUTINE MATCH(CORREL, NAN, MEX, NAFIT, MEFIT)
C
COMMON /LIMITS/ MAXMODE, MAXDOF

DIMENSION CORREL(MAXMODE, MAXMODE), NAFIT(MAXMODE), MEFIT(MAXMODE)
C
C DETERMINE BEST EXPERIMENTAL MODE-SHAPE MATCH (HIGHEST
C CORRELATION COEFFICIENT) FOR EACH ANALYTICAL MODE-SHAPE.
C
DO 200 N=1, NAN
  BEST = -1.0
  DO 100 M=1, MEX
    IF (ABS(CORREL(N, M)) .GT. BEST) THEN
      BEST = ABS(CORREL(N, M))
      NAFIT(N) = M
    END IF
    CONTINUE
  CONTINUE
100
200
C
C DETERMINE BEST ANALYTICAL MODE-SHAPE MATCH (HIGHEST
C CORRELATION COEFFICIENT) FOR EACH EXPERIMENTAL MODE-SHAPE.
C
DO 400 M=1, MEX
  BEST = -1.0
  DO 300 N=1, NAN
    IF (ABS(CORREL(N, M)) .GT. BEST) THEN
      BEST = ABS(CORREL(N, M))
      MEFIT(M) = N
    END IF
    CONTINUE
  CONTINUE
300
400
RETURN
END

```

```

SUBROUTINE OPTIONS(LSYMM, PRTAN, PRTEX, RTHRESH, LPRINT)
C
C DETERMINE SYMMETRY, MODE-SHAPE DUMP, & THRESHOLD OPTIONS
C
LOGICAL LSYMM, PRTAN, PRTEX, LPRINT
CHARACTER*1 YESNO
C
C DETERMINE IF SYMMETRY IS TO BE CONSIDERED
TYPE 1000
ACCEPT 2000, YESNO
IF (YESNO .EQ. 'Y') LSYMM = .TRUE.
IF (LPRINT) PRINT 1500, YESNO
C
C DETERMINE IF ANALYTICAL AND/OR EXPERIMENTAL MODE-SHAPE
C VECTORS ARE TO BE PRINTED
TYPE *, ' ' !SKIP A LINE
IF (LPRINT) PRINT *, ' '
TYPE 3000, 'ANALYTICAL'
ACCEPT 2000, YESNO
IF (YESNO .EQ. 'Y') PRTAN = .TRUE.
IF (LPRINT) PRINT 3500, 'ANALYTICAL', YESNO
TYPE 3000, 'EXPERIMENTAL'
ACCEPT 2000, YESNO
IF (YESNO .EQ. 'Y') PRTEX = .TRUE.
IF (LPRINT) PRINT 3500, 'EXPERIMENTAL', YESNO
C
C GET RELATIVE DEVIATION THRESHOLD. DEFAULT IS 5.0 %
RTHRESH = .05
TYPE 4000, RTHRESH
ACCEPT *, RTHRESH
TYPE 5000, RTHRESH
IF (LPRINT) THEN
PRINT 4500, .05, RTHRESH
PRINT 5000, RTHRESH
END IF

RETURN
C
1000 FORMAT(/, ' IS ANALYTICAL VS. EXPERIMENTAL SYMMETRY TO BE ',
* ' CONSIDERED? (Y OR N): ', @)
1500 FORMAT(/, ' IS ANALYTICAL VS. EXPERIMENTAL SYMMETRY TO BE ',
* ' CONSIDERED? (Y OR N): ', A1)
2000 FORMAT(A1)
3000 FORMAT(' PRINT ', A12, ' MODE-SHAPE VECTORS? (Y OR N): ', @)
3500 FORMAT(' PRINT ', A12, ' MODE-SHAPE VECTORS? (Y OR N): ', A1)
4000 FORMAT(// ' RELATIVE DEVIATIONS GREATER THAN A THRESHOLD',
* ' VALUE WILL BE PRINTED.',
* // ' THE DEFAULT THRESHOLD IS ', F6.3,
* // ' ENTER DESIRED THRESHOLD. ", " FOR DEFAULT: ', @)
4500 FORMAT(// ' RELATIVE DEVIATIONS GREATER THAN A THRESHOLD',
* ' VALUE WILL BE PRINTED.',
* // ' THE DEFAULT THRESHOLD IS ', F6.3,
* // ' ENTER DESIRED THRESHOLD. ", " FOR DEFAULT: ', F6.3)
5000 FORMAT(' RELATIVE DEVIATIONS GREATER THAN ', 2PF7.2,
* ' % WILL BE PRINTED.')
END

```

```

SUBROUTINE PRINT(N1,FREQ1,N2,FREQ2,NDOF,CORREL,C,S,RMSA,RMSE,
*      DIFF,DIFABS,IDDOF,ICOMP,RTHRESH)
C
C      PRINT CORRELATION INFORMATION FOR MODES N1,N2 COMPARISON
C
      DIMENSION DIFF(*),DIFABS(*),IDDOF(*),ICOMP(*)
      DIMENSION ID(30000)
C
C      DETERMINE MAXIMUM DIFFERENCE & DIFFS > THRESHOLD
      DIFMAX = 0.0
      IDMAX = 0
      NDIFF = 0
      IF (NDOF .GT. 0) THEN
          DIFMAX = ABS(DIFF(1))
          IDMAX = IDDOF(1)
          DO 100 N=1,NDOF
              IF (ABS(DIFF(N)) .GT. DIFMAX) THEN
                  DIFMAX = ABS(DIFF(N))
                  IDMAX = IDDOF(N)
              END IF
              IF (ABS(DIFF(N)) .GT. RTHRESH) THEN
                  NDIFF = NDIFF + 1
                  ID(NDIFF) = N
              END IF
          CONTINUE
100      END IF
C
C      PRINT SUMMARY LINE FOR THIS MATCHED PAIR
      PRINT 1000, N1,FREQ1,N2,FREQ2,NDOF,CORREL,C,S,
*      RMSA,RMSE,DIFMAX,IDMAX
      IF (NDOF .EQ. 0) RETURN
C
C      PRINT ALL DIFFS > THRESHOLD , DEFAULT IS 5%
      IF (NDIFF .GT. 0) THEN
          PRINT 2000, RTHRESH,( IDDOF(ID(N)), ICOMP(ID(N)),
*      DIFF(ID(N)), N=1,NDIFF)
          PRINT 3000, ( IDDOF(ID(N)), ICOMP(ID(N)), DIFABS(ID(N)),
*      N=1,NDIFF)
          END IF
      RETURN
C
1000  FORMAT('0',I6,2(F15.6,I7),4X,F9.3,2X,5(1PE11.3),I9)
2000  FORMAT(21X,'RELATIVE DEVIATIONS (XA/RMSA-XE/RMSE) > ',
*      2PF7.2,'% : (GRID ID/DEVIATION)',
*      20(/21X,5(I9,'-',I1,'/',1PE10.3)))
3000  FORMAT(21X,'SCALED DIFFERENCES ( (XA-XE)/S ) > THRESHOLD :',
*      '(GRID ID/DIFFERENCE)'
*      20(/21X,5(I9,'-',I1,'/',1PE10.3)))
      END

```

```

SUBROUTINE PRINTPHI(NAN, NDOFA, IDDOFA, ICOMP, DISPAN, PRTAN,
*
MEX, NDOFE, IDDOFE, ICOMPE, DISPEX, PRTEX)
C
COMMON /LIMITS/ MAXMODE, MAXDOF
COMMON /WHEN/ CDATE

REAL DISPAN(MAXDOF, MAXMODE), DISPEX(MAXDOF, MAXMODE)
INTEGER IDDOFA(MAXDOF, MAXMODE), IDDOFE(MAXDOF, MAXMODE)
INTEGER ICOMP(MAXDOF, MAXMODE), ICOMPE(MAXDOF, MAXMODE)
INTEGER NDOFA(MAXMODE), NDOFE(MAXMODE)
LOGICAL PRTAN, PRTEX
CHARACTER CDATE*9

C
IF (PRTAN) THEN ! PRINT ANALYTICAL MODE-SHAPE VECTORS
C
PRINT HEADER
PRINT 5000, CDATE
PRINT 1000
C
PRINT ALL VECTORS
DO 100 I=1, NAN
PRINT 2000, I, (IDDOFA(J, I), ICOMP(J, I), DISPAN(J, I),
*
J=1, NDOFA(I))
100
CONTINUE
END IF

C
IF (PRTEX) THEN ! PRINT EXPERIMENTAL MODE-SHAPE VECTORS
C
PRINT HEADER
PRINT 5000, CDATE
PRINT 3000
C
PRINT ALL VECTORS
DO 200 I=1, MEX
PRINT 4000, I, (IDDOFE(J, I), ICOMPE(J, I), DISPEX(J, I),
*
J=1, NDOFE(I))
200
CONTINUE
END IF

RETURN
C
1000 FORMAT(1H0, '6. ANALYTICAL MODE-SHAPE VECTORS ',
*
'(GRID PT/DISPLACEMENT)')
2000 FORMAT(1H0, 'ANALYTICAL MODE', I4,
*
200(/5X, 5(I9, '-', I1, '/', 1PE10.3)))
3000 FORMAT(1H0, '7. EXPERIMENTAL MODE-SHAPE VECTORS ',
*
'(GRID PT/DISPLACEMENT)')
4000 FORMAT(1H0, 'EXPERIMENTAL MODE', I4,
*
200(/5X, 5(I9, '-', I1, '/', 1PE10.3)))
5000 FORMAT(1H1, 'NASTRAN MODAL ANALYSIS - MODAL SURVEY STATISTICAL ',
*
'CORRELATION', /1X, A9)
END

```

```

SUBROUTINE RMSDIFF(AVECT,EVECT,NDOFI,RMSA,RMSE,CORREL,
*
S,DIFF,DIFABS)
C
C CALCULATE RELATIVE (TO RMS) DIFFERENCE BETWEEN ANALYTICAL &
C EXPERIMENTAL DISPLACEMENT FOR EACH GRID POINT.
C CALCULATE ABSOLUTE DIFFERENCE SCALED TO ANALYTICAL.
C
REAL AVECT(*),EVECT(*),DIFF(*),DIFABS(*)
C
IF (NDOFI .EQ. 0) RETURN
DO 100 I=1,NDOFI
  IF (CORREL .GE. 0.0) THEN
    DIFF(I) = 0.0
    IF ( (RMSA .NE. 0.0) .AND. (RMSE .NE. 0.0) )
*      DIFF(I) = AVECT(I)/RMSA - EVECT(I)/RMSE
    DIFABS(I) = 0.0
    IF (S .NE. 0.0)
*      DIFABS(I) = (AVECT(I) - EVECT(I)) / S
  ELSE IF (CORREL .LT. 0.0) THEN
C CORRECT FOR 180-DEGREE PHASE SHIFT
    DIFF(I) = 0.0
    IF ( (RMSA .NE. 0.0) .AND. (RMSE .NE. 0.0) )
*      DIFF(I) = AVECT(I)/RMSA + EVECT(I)/RMSE
    DIFABS(I) = 0.0
    IF (S .NE. 0.0)
*      DIFABS(I) = (AVECT(I) + EVECT(I)) / S
  END IF
100 CONTINUE
RETURN
END

```

C
C
C

SUBROUTINE SWAP(I,J)

INTERCHANGE THE VALUES IN TWO 4-BYTE VARIABLES

ITEMP = I
I = J
J = ITEMP
RETURN
END

READING CORRELATION RESULTS

The printed output listing generated by interactive execution of the statistical correlation program STATCORR contains seven functionally-defined sections. Sections 6 and 7 are optionally requested by the user.

Section 1 echoes the interactive dialog between the user and the program, providing a record of the analytical and experimental data files used in the correlation run, symmetry consideration, requests for mode shape vector listings, and requested threshold for deviation reporting.

Section 2 provides a summary which describes the analytic and experimental modes being compared, including frequency, mass, stiffness, and symmetry characteristics for each analytical mode, and frequency, damping, and symmetry characteristics for each experimental mode. Inconsistencies in undefined symmetry are reported in this section; where undefined symmetry with respect to any plane exists (a "0" symmetry code), symmetry should be undefined with respect to that plane for all modes, both analytical and experimental. If symmetry has been defined for any mode (a "+1" or "-1" symmetry code), with respect to a particular plane, but has not been defined with respect to that plane for another mode, a warning message will be printed for the user's benefit, so that he may take appropriate action, if required.

Section 3 reports the correlation coefficients computed for all mode comparisons. Each analytical mode is compared with each experimental mode. The correlation coefficients are printed in a matrix format, with each row referring to a particular analytical mode, and each column referring to a particular experimental mode. The integers labeling the rows and columns refer to the mode identification numbers reported in Section 2 (i.e., row 1 refers to analytical mode 1 described in Section 2; column 3 refers to experimental mode 3). As an example, the correlation coefficient shown in (row 2, column 3) is calculated (according to eqn(6)) by comparing analytical mode shape 2 with experimental mode shape 3. The magnitudes of the correlation coefficients range from 0.9 (no correlation) to 1.0 (perfect correlation). Negative correlation coefficients indicate a phase reversal (180-degree phase shift) between the analytical and experimental modes being compared. In determining which modes compare most favorably (highest correlation coefficient), absolute values of the correlation coefficients are compared. It is mathematically possible for a 0.0 correlation coefficient to be calculated, but from a practical standpoint this is not a likely occurrence. However, exact zero values may be reported in Section 3 when symmetry characteristics are considered (in accordance with the user's affirmative response to the symmetry query in Section 1); in any case where the analytical and experimental modes being compared have unlike symmetry, that correlation coefficient is set equal to 0.0, rather than being calculated.

Section 4 shows a summary of the correlation results for the analytical modes. For each analytical mode, the experimental mode that best matches it (based on the correlation coefficients listed in Section 3) is shown. This summary is reported in a table format, where each row of the table corresponds to a different analytical mode. Columns 1 & 2 identify the analytical mode and its characteristic frequency, and columns 3 & 4 give the mode number and frequency of the experimental mode which compares most favorably with this analytical mode. These mode numbers and frequencies correspond to those reported in Section 2. Column 5 shows the number of sample points (grid points on the structure) whose displacements were used to calculate the statistical data reported in this row. The Correlation Coefficient, Normalization Factor(CA) and Standard Error(S), calculated according to equations (6), (D), and (9), respectively, for this analytical and experimental mode pair, are given in columns 6, 7, and 8. The RMS values for the two mode shapes are shown in columns 9 and 10, to indicate the respective scaling used to determine the relative differences between the analytical and experimental mode shape displacements at individual grid points. Column 11 shows the maximum relative difference encountered for this mode shape pair, and column 12 shows the grid point at which this occurs. If there are any grid points which have (for a particular analytical mode as compared to its best experimental match) relative deviations greater than the percentage specified by the user (in Section 1), those grid points and the fractional values of their relative deviations are listed immediately following the row which gives the statistical report for that analytical mode. A report is also given of the standard errors at those same grid point locations. When symmetry characteristics are being compared by STATCORR, it is possible that there will be no experimental modes with the same symmetry parameters as a particular analytical mode. Should this occur, all the statistical data will be reported as zeroes in the row corresponding to that analytical mode.

Section 5 shows a summary of the correlation results for the experimental modes. For each experimental mode, the analytical mode that best matches it (based on the correlation coefficients reported in Section 3) is shown. This summary lists exactly the same format as Section 4, except that columns 1 & 2 identify the experimental mode and its characteristic frequency, while columns 3 & 4 give the mode number and frequency of the analytical mode which best compares with that experimental mode.

Section 6 (optionally requested by the user during the Section 1 dialog) provides a listing of the mode-shape displacements (eigenvectors) for all analytical modes. This listing shows, for each mode, all of the grid point identification numbers and the displacement associated with each grid point.

Section 7 (optionally requested by the user during the Section 1 dialog) provides a listing of the mode-shape displacements for all experimental modes. This listing is in the same format as Section 6.

LAMA

The table of modal frequencies, masses, and stiffnesses output from NASTRAN are converted by processor program LAMA from table format to matrix format to satisfy the input needs of STATCORR. LAMA operates interactively and prompts the user for the input file name and the output file name.


```

100      PROGRAM LAMATABLE
200      C
300      PARAMETER (MAXEIG = 300)
400
500      CHARACTER LAMA*8
600      REAL FREQ(MAXEIG),GMASS(MAXEIG),STIFF(MAXEIG),SYMM(3)
700      REAL REC2(7*MAXEIG)
800      C
900      DATA LUN_P, LUN_M /1, 2/  !! PUNCH & MATRIX FILE LOG UNIT #'S
1000     C
1100     C      POSITION PUNCH FILE TO 1ST CARD OF RECORD 2 OF LAMA TABLE
1200           CALL FINDREC2(LUN_P,LAMA)
1300     C      READ RECORD 2 OF LAMA TABLE INTO ARRAY REC2
1400           CALL READREC2(REC2,NVALUES,LUN_P,MAXEIG)
1500     C      EXTRACT FREQUENCY, MASS, & STIFFNESS VECTORS FROM REC2
1600           NEIGENS = NVALUES/7
1700           DO 100 I=1,NEIGENS
1800             FREQ(I) = REC2(7*I-2)
1900             GMASS(I) = REC2(7*I-1)
2000             STIFF(I) = REC2(7*I)
2100     100      CONTINUE
2200     C      DO ASCENDING SORT OF FREQ VECTOR; SLAVE SORT MASS & STIFF VECTORS
2300           CALL SORT(NEIGENS,FREQ,GMASS,STIFF)
2400     C      CHECK PUNCH FILE FOR SYMMETRY PARAMETERS
2500           CALL READSYM(SYMM,LUN_P)
2600     C      CLOSE PUNCH FILE
2700           CLOSE(UNIT=LUN_P)
2800     C      WRITE MATRIX FILE
2900           CALL WRITEMTX(NEIGENS,FREQ,GMASS,STIFF,SYMM,LUN_M,LAMA)
3000      STOP
3100      END

```

```

100      SUBROUTINE FINDREC2(LUN_P,LAMA)
200      C
300      CHARACTER PFILE*80,LAMA*8,LINE*80
400      C
500      C   OPEN PUNCH FILE
600      10  TYPE 1000, 'ENTER INPUT PUNCH FILE NAME:'
700      ACCEPT 2000, PFILE
800      OPEN(UNIT=LUN_P,NAME=PFILE,TYPE='OLD',READONLY,ERR=10)
900      C   POSITION FILE TO LAMA TABLE
1000     TYPE 1000, 'ENTER NAME OF LAMA TABLE:'
1100     ACCEPT 3000, LAMA
1200     DO 100 I=1,1000000
1300         READ(LUN_P,2000,END=125) LINE
1400         IF ((LINE(1:4).EQ.'DTI*') .AND. (LINE(9:16).EQ.LAMA))
1500             *   GOTO 150   !! LAMA TABLE FOUND
1600     CONTINUE
1700     C   TABLE NOT FOUND; START OVER
1800     125  TYPE *, '**** LAMA TABLE NOT FOUND'
1900     CLOSE(UNIT=LUN_P)
2000     GOTO 10
2100     C   POSITION PUNCH FILE TO RECORD 2 OF LAMA TABLE
2200     150  DO 200 I=1,1000000
2300         READ(LUN_P,4000,END=225) LINE(1:24),IREC
2400         IF ((LINE(1:4).EQ.'DTI*') .AND. (LINE(9:16).EQ.LAMA)
2500             .AND. (IREC.EQ.2)) GOTO 250   !! RECORD 2 FOUND
2600     CONTINUE
2700     C   RECORD 2 NOT FOUND; START OVER
2800     225  TYPE *, '**** RECORD 2 OF LAMA TABLE NOT FOUND'
2900     CLOSE(UNIT=LUN_P)
3000     GOTO 10
3100     C   POSITION FILE TO REREAD 1ST CARD OF RECORD 2
3200     250  BACKSPACE LUN_P
3300     RETURN
3400     C
3500     1000  FORMAT(1X,A30,1X,*)
3600     2000  FORMAT(A80)
3700     3000  FORMAT(A8)
3800     4000  FORMAT(A24,I16)
3900     END

```

```

100
200 C SUBROUTINE READREC2(IREC2,NVALUES,LUN_P,MAXEIG)
300 INTEGER IREC2(7*MAXEIG),ITEMP(4)
400 CHARACTER*6 CTEMP(4)
500 C
600 C READ 1ST CARD OF LAMA TABLE RECORD 2
700 READ(LUN_P,1000) IREC2(1),IREC2(2)
800 NVALUES = 2
900 C READ REMAINING CARDS UNTIL 'ENDREC' FOUND
1000 DO 200 I=1,1000000
1100 READ(LUN_P,2000,END=225) (CTEMP(J),ITEMP(J),J=1,4)
1200 DO 100 J=1,4
1300 IF (CTEMP(J).EQ.'ENDREC') GOTO 250
1400 NVALUES = NVALUES + 1
1500 IREC2(NVALUES) = ITEMP(J)
1600 IF (CTEMP(J)(6:6).EQ.'-')
1700 * IREC2(NVALUES) = -IREC2(NVALUES)
1800 IF (NVALUES.EQ.7*MAXEIG) GOTO 225
1900 100 CONTINUE
2000 200 CONTINUE
2100 C END OF RECORD 2 OF LAMA TABLE NOT FOUND
2200 225 TYPE 3000, NVALUES
2300 PAUSE 'TYPE "CONTINUE" OR "STOP"'
2400 C CHECK TO SEE IF # OF RECORD 2 ENTRIES IS DIVISIBLE BY 7
2500 250 IF (MOD(NVALUES,7).NE.0) TYPE 4000, NVALUES
2600 RETURN
2700 C
2800 1000 FORMAT(40X,2I16)
2900 2000 FORMAT(8X,4(A6,I10))
3000 3000 FORMAT(1X,'*** WARNING: END OF RECORD 2 NOT REACHED.',
3100 * /1X,'
3200 4000 * FORMAT(1X,'*** WARNING: # OF RECORD 2 ENTRIES',I4)
3300 * ' NOT DIVISIBLE BY 7')
3400 END

```

```

100      SUBROUTINE READSYM(SYMM,LUN_P)
200      C
300      CHARACTER*80 RECORD
400      REAL SYMM(3)
500      LOGICAL LSYM1,LSYM2,LSYM3
600      C
700      REWIND LUN_P !START SEARCH FROM TOP OF FILE
800      C SET SYMMETRY DEFAULTS
900          SYMM(1) = 0.0
1000         SYMM(2) = 0.0
1100         SYMM(3) = 0.0
1200      C SEARCH PUNCH FILE FOR SYMMETRY DEFINITION RECORDS
1300          DO 100 I=1,1000000
1400              READ(LUN_P,1000,END=150) RECORD
1500              IF (RECORD(21:28) .EQ. 'SYM1PLAN') THEN
1600                  LSYM1 = .TRUE.
1700                  DECODE(2,2000,RECORD(47:48)) SYMM(1)
1800                  TYPE *, 'PLANE 1 SYMMETRY:', SYMM(1)
1900              ELSE IF (RECORD(21:28) .EQ. 'SYM2PLAN') THEN
2000                  LSYM2 = .TRUE.
2100                  DECODE(2,2000,RECORD(47:48)) SYMM(2)
2200                  TYPE *, 'PLANE 2 SYMMETRY:', SYMM(2)
2300              ELSE IF (RECORD(21:28) .EQ. 'SYM3PLAN') THEN
2400                  LSYM3 = .TRUE.
2500                  DECODE(2,2000,RECORD(47:48)) SYMM(3)
2600                  TYPE *, 'PLANE 3 SYMMETRY:', SYMM(3)
2700              END IF
2800          100 CONTINUE
2900      C REPORT NON-DEFINED SYMMETRY
3000      150 IF (.NOT. LSYM1) TYPE 3000, '1'
3100          IF (.NOT. LSYM2) TYPE 3000, '2'
3200          IF (.NOT. LSYM3) TYPE 3000, '3'
3300      RETURN
3400      C
3500      1000 FORMAT(A80)
3600      2000 FORMAT(F2.0)
3700      3000 FORMAT(1X,'PLANE ',A1,' SYMMETRY NOT SPECIFIED')
3800      END

```

```

100      SUBROUTINE SORT(N,FREQ,GMASS,STIFF)
200      C
300      REAL FREQ(N),GMASS(N),STIFF(N)
400      C
500      C   PERFORM ASCENDING SORT OF FREQ VECTOR
600      C   SLAVE SORT GMASS AND STIFF VECTORS
700      C
800      IF (N .EQ. 1) RETURN
900      C
1000     DO 100 I=1,N-1
1100     DO 100 K=I+1,N
1200         IF (FREQ(K) .LT. FREQ(I)) THEN
1300             TEMP = FREQ(I)
1400             FREQ(I) = FREQ(K)
1500             FREQ(K) = TEMP
1600             TEMP = GMASS(I)
1700             GMASS(I) = GMASS(K)
1800             GMASS(K) = TEMP
1900             TEMP = STIFF(I)
2000             STIFF(I) = STIFF(K)
2100             STIFF(K) = TEMP
2200         END IF
2300     100 CONTINUE
2400     RETURN
2500     END

```

```

100      SUBROUTINE WRITEMTX(N, FREQ, CMASS, STIFF, SYMM, LUN_M, LAMA)
200      C
300      CHARACTER MFILE*40, LAMA*8
400      REAL FREQ(N), CMASS(N), STIFF(N), SYMM(3)
500      C
600      C      OPEN MATRIX FILE
700          TYPE 1000, 'ENTER OUTPUT MATRIX FILENAME:'
800          ACCEPT 2000, MFILE
900          OPEN(UNIT=LUN_M, NAME=MFILE, TYPE='NEW',
1000         *      CARRIAGECONTROL='LIST')
1100      C      WRITE MATRIX FILE HEADER
1200          IROWS = N
1300          JCOLS = 6
1400          WRITE(LUN_M, 3000) LAMA, IROWS, JCOLS
1500      C      WRITE VECTORS AS THREE COLUMNS OF MATRIX
1600          WRITE(LUN_M, 4000) FREQ      !! COLUMN 1
1700          WRITE(LUN_M, 4000) CMASS    !! COLUMN 2
1800          WRITE(LUN_M, 4000) STIFF    !! COLUMN 3
1900          WRITE(LUN_M, 4000) (SYMM(1), I=1, N) !! COLUMN 4
2000          WRITE(LUN_M, 4000) (SYMM(2), I=1, N) !! COLUMN 5
2100          WRITE(LUN_M, 4000) (SYMM(3), I=1, N) !! COLUMN 6
2200      CLOSE(UNIT=LUN_M)
2300      RETURN
2400      C
2500      1000  FORMAT(1X, A30, 1X, $)
2600      2000  FORMAT(A40)
2700      3000  FORMAT(A8, 2I8)
2800      4000  FORMAT(1PE16.8)
2900      END

```

UNPACKDMI

The data blocks of mode shapes and component degrees of freedom as output from NASTRAN are in a special format called DMI. This format is not acceptable to STATCORR, so these data must be reformatted. The pre-processor program UNPACKDMI is used to take modes and freedoms out of DMI format. The output of the modes from this program will be in final form for STATCORR. The output of freedoms will need further processing by another pre-processor. UNPACKDMI operates interactively and prompts the user for responses.


```

100      PROGRAM UNPACKDMI
200      PARAMETER (MAXMTXSIZ = 100000)
300      CHARACTER MATNAM*8, FLAG*1, CONTID*3
400      REAL ARRAY(MAXMTXSIZ)
500      LOGICAL ALL, EOF
600      DATA LUN / 10 /
700
800      C
900      C      DO 500 NFILE=1,1000000
1000     C          GET NEXT FILENAME
1100     C          CALL GETFIL(LUN,*499)
1200     C          ALL = .FALSE.
1300     C          EOF = .FALSE.
1400     C          DO 400 NMATRIX=1,1000000
1500     C              GET NEXT MATRIX NAME
1600     C              IF (.NOT. ALL) THEN
1700     C                  TYPE 1000
1800     C                  ACCEPT 2000, MATNAM
1900     C                  IF (MATNAM .EQ. '*ALL ') ALL = .TRUE.
2000     C                  END IF
2100     C              SEARCH FILE FOR MATRIX & GET DIMENSIONS
2200     C              CALL FNDMTX(MATNAM,MROWS,NCOLS,CONTID,LUN,ALL,EOF)
2300     C              IF (EOF) GOTO 399
2400     C              IF (MROWS*NCOLS .GT. MAXMTXSIZ) THEN
2500     C                  TYPE *, 'MATRIX IS TOO LARGE', MATNAM,MROWS,NCOLS
2600     C                  TYPE *, 'INCREASE PARAMETER MAXMTXSIZ IN UNPACKDMI'
2700     C                  GOTO 399
2800     C              ENDIF
2900     C              UNPACK MATRIX INTO ARRAY
3000     C              CALL UNPACK(ARRAY,MROWS,NCOLS,CONTID,LUN,ALL,EOF)
3100     C              REDUCE SQUARE DIAGONAL MATRIX TO VECTOR ?
3200     C              IF (MROWS .EQ. NCOLS) THEN
3300     C                  TYPE 6000, MATNAM
3400     C                  ACCEPT 4000, FLAG
3500     C                  IF (FLAG .EQ. 'Y')
3600     C                      *      CALL REDUCE(MATNAM,ARRAY,MROWS,NCOLS)
3700     C                      END IF
3800     C              WRITE UNPACKED MATRIX TO NEW FILE
3900     C              CALL WRTMTX(MATNAM,ARRAY,MROWS,NCOLS)
4000     C              IS ANOTHER MATRIX IN THIS FILE DESIRED ?
4100     C              399      IF (ALL .AND. EOF) GOTO 450
4200     C              IF (.NOT. ALL) THEN
4300     C                  TYPE 3000
4400     C                  ACCEPT 4000, FLAG
4500     C                  IF (FLAG .NE. 'Y') GOTO 450
4600     C                  END IF
4700     C              CONTINUE
4800     C              NO MORE MATRICES DESIRED FROM THIS FILE
4900     C              CLOSE (UNIT=LUN)
5000     C              IS ANOTHER FILE DESIRED ?
5100     C              499      TYPE 5000
5200     C              ACCEPT 4000, FLAG
5300     C              IF (FLAG .NE. 'Y') GOTO 550
5400     C              CONTINUE
5500     C              STOP 'NO MORE FILES REQUESTED.'
5600     C
5700     C      1000      FORMAT(' ENTER MATRIX NAME. ("*ALL" FOR ALL MATRICES): ',9)
5800     C      2000      FORMAT(A8)
5900     C      3000      FORMAT(' DO YOU WANT ANOTHER MATRIX IN THIS FILE ? (Y OR N): ',9)
6000     C      4000      FORMAT(A1)
6100     C      5000      FORMAT(' DO YOU WANT ANOTHER FILE ? (Y OR N): ',9)
6200     C      6000      FORMAT(' REDUCE DIAG MATRIX ',A8,' TO A VECTOR ? (Y OR N): ',9)
END

```

```

100      SUBROUTINE FNDMTX(MATNAM, MROWS, NCOLS, CONTID, LUN, ALL, EOF)
200      CHARACTER MATNAM*8, RECORD*80, FLD1TO3*24, CONTID*3
300      LOGICAL ALL, EOF
400      C
500      IF (.NOT. ALL) THEN
600          REWIND LUN
700          EOF = .FALSE.
800          END IF
900      C
1000     C SEARCH FOR DESIRED MATRIX & GET DIMENSIONS
1100     FLD1TO3 = 'DMI ' // MATNAM // ' 0'
1200     DO 100 I=1, 1000000
1300         READ(LUN, 1000, END=199) RECORD
1400         IF (ALL) FLD1TO3(9:16) = RECORD(9:16)
1500         IF (RECORD(1:24) .EQ. FLD1TO3) THEN
1600             IF (ALL) MATNAM = RECORD(9:16)
1700             READ(RECORD, 2000) MROWS, NCOLS, CONTID
1800             CONTID(1:1) = '*'
1900             GOTO 150
2000         ENDIF
2100         100 CONTINUE
2200         .150 RETURN
2300     C
2400     C END OF FILE; NEXT MATRIX NOT FOUND
2500     199 EOF = .TRUE.
2600         IF (ALL) TYPE *, 'END OF FILE REACHED'
2700         IF (.NOT. ALL) TYPE *, MATNAM, 'MATRIX HEADER CARD NOT FOUND'
2800         RETURN
2900     C
3000     1000 FORMAT(A80)
3100     2000 FORMAT(56X, 218, A3)
3200     END

```

```

100      SUBROUTINE GETFIL(LUN,*)
200      CHARACTER FILNAM*40
300      C
400      C   GET NEXT FILENAME
500          TYPE 1000
600          ACCEPT 2000, FILNAM
700      C   OPEN FILE
800          OPEN(UNIT=LUN, NAME=FILNAM, TYPE='OLD', READONLY, ERR=199)
900          RETURN
1000     C
1100     C   NEW DMI FILE NOT FOUND
1200     199   TYPE *, FILNAM, 'FILE NOT FOUND'
1300         RETURN 1
1400     C
1500     1000  FORMAT(' ENTER NAME OF NEXT DMI FILE: ',*)
1600     2000  FORMAT(A40)
1700     END

```

```

100      SUBROUTINE REDUCE(MATNAM, MATRIX, MROWS, NCOLS)
200      CHARACTER*8 MATNAM
300      REAL MATRIX(MROWS, NCOLS)
400      C
500      C   CHECK FOR SQUARE MATRIX
600      IF (MROWS .NE. NCOLS) THEN
700          TYPE *, MATNAM, 'NOT A SQUARE MATRIX. NO REDUCTION DONE.'
800          RETURN
900      ENDIF
1000     C
1100     C   REDUCE TO (1 X NCOL) ROW VECTOR USING DIAGONAL VALUES
1200     DO 100 N=1, NCOLS
1300         MATRIX(N, 1) = MATRIX(N, N)
1400     CONTINUE
1500     MROWS = 1
1600     RETURN
1700     END

```

```

100      SUBROUTINE UNPACK(MATRIX,MROWS,NCOLS,CONTID,LUN,ALL,EOF)
200      CHARACTER*72 RECORD
300      CHARACTER*16 FLDID(2:5),CARDID*8,CONTID*3
400      EQUIVALENCE ( RECORD(1:1),CARDID(1:1) )
500      EQUIVALENCE ( RECORD(9:9),FLDID(2)(1:1) )
600      CHARACTER*6 FMT(6),REAL,INTGR,BLANK
700      REAL MATRIX(MROWS,NCOLS)
800      LOGICAL ALL,EOF
900      DIMENSION VALUE(4),IVALUE(4)
1000     EQUIVALENCE (VALUE(1),IVALUE(1))
1100     DATA FMT(1)/'(8X,',' , FMT(6)/'(8X)'/
1200     DATA REAL/'E16.8,',' , INTGR/'I16,',' , BLANK/'A16,','
1300     C
1400     C      ZERO THE MATRIX
1500         DO 100 I=1,MROWS
1600         DO 100 J=1,NCOLS
1700             MATRIX(I,J) = 0.0
1800     100     CONTINUE
1900     C
2000     C      PROCESS THE DMI CARDS FOR THIS MATRIX
2100         DO 400 K=1,1000000
2200             READ(LUN,1000,END=425) CARDID,FLDID
2300             IF (CARDID.EQ.'DMI ') THEN
2400     C                 THIS IS HEADER CARD OF NEXT MATRIX; THIS MATRIX DONE.
2500                     IF (ALL) BACKSPACE=LUN
2600                     GOTO 450
2700             ELSE IF (CARDID.EQ.'DMI* ') THEN
2800     C                 THIS IS A COLUMN IDENTIFIER CARD
2900                     READ(RECORD,2000) JCOL,IROW,VALUE(1)
3000                     MATRIX(IROW,JCOL) = VALUE(1)
3100                     IROW = IROW + 1
3200             ELSE IF (CARDID(1:3).EQ.CONTID) THEN
3300     C                 THIS IS A ROW/VALUE CARD
3400     C                 DETERMINE TYPE OF CONTENTS IN FIELDS 2:5
3500                     DO 200 L=2,5
3600                         IF (FLDID(L)(13:13).EQ.'E') THEN
3700                             FMT(L) = REAL
3800                         ELSE IF (FLDID(L)(16:16).EQ.' ') THEN
3900                             FMT(L) = BLANK
4000                         ELSE
4100                             FMT(L) = INTGR
4200                         ENDIF
4300     200     CONTINUE
4400     C                 READ CARD IN APPROPRIATE FORMAT
4500                     READ(RECORD,FMT,ERR=201) VALUE
4600     C                 PROCESS FIELDS 2:5
4700     201     DO 300 L=2,5
4800                     IF (FMT(L).EQ.REAL) THEN
4900                         MATRIX(IROW,JCOL) = VALUE(L-1)
5000                         IROW = IROW + 1
5100                     ELSE IF (FMT(L).EQ.INTGR) THEN
5200                         IROW = IVALUE(L-1)
5300                     ELSE IF (FMT(L).EQ.BLANK) THEN
5400                         CONTINUE
5500                     ENDIF
5600     300     CONTINUE
5700             ELSE
5800     C                 THIS IS A NON-DMI CARD; THIS MATRIX DONE
5900                     READ(RECORD,1000)CARDID,FLDID
6000                     GOTO 450
6100             ENDIF

```

```
6200      400      CONTINUE
6300      C      END OF FILE
6400      425      EOF = .TRUE.
6500      C      END OF MATRIX
6600      450      RETURN
6700      C
6800      1000     FORMAT(AB,4A16)
6900      2000     FORMAT(24X,2I16,E16.8)
7000      END
```

```

100      SUBROUTINE WRITMX(MATNAM, MATRIX, MROWS, NCOLS)
200      CHARACTER MATNAM*8, NAME*12
300      REAL MATRIX(MROWS, NCOLS)
400      C
500      NAME = MATNAM//'.MTX'
600      OPEN(UNIT=50, NAME=NAME, TYPE='NEW', CARRIAGECONTROL='LIST')
700      C      WRITE HEADER RECORD TO ASCII FILE
800              WRITE(50, 1000) MATNAM, MROWS, NCOLS
900      C      WRITE MATRIX TO ASCII FILE ( 1 VALUE PER RECORD )
1000             WRITE(50, 2000) MATRIX
1100      CLOSE (UNIT=50)
1200      TYPE *, 'MATRIX FILE WRITTEN WITH MROWS, NCOLS:'
1300      TYPE *, NAME, MROWS, NCOLS
1400      RETURN
1500      C
1600      1000  FORMAT(A8, 2I8)
1700      2000  FORMAT(1PE16.8)
1800      END

```

GRDPTLST

The freedoms output from processor UNPACKDMI are input to processor GRDPTLST to put them into final format for STATCORR. GRDPTLST operates interactively and prompts the user for the input file name and the output file name.

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```

100      PROGRAM GRDPTLST
200      C
300      C   THIS PROGRAM WILL READ THE TESET (DOF ID VS. GRID POINT ID)
400      C   MATRIX FILE OBTAINED FROM THE NASTRAN PUNCH FILE AND GENERATE
500      C   A GRID POINT ID LIST FILE, USING THE NON-ZERO ENTRIES OF THE
600      C   TESET MATRIX.
700      C
800      CHARACTER*35 MTXFIL, GPFIL, MTXNAME*8
900      C
1000     C   GET TESET MATRIX FILENAME
1100     10  TYPE 1000, 'ENTER GRID POINT ID MATRIX FILENAME:'
1200     ACCEPT 2000, MTXFIL
1300     OPEN(UNIT=1, NAME=MTXFIL, TYPE='OLD', READONLY, ERR=10)
1400     READ(1,3000) MTXNAME, MROWS, NCOLS
1500     IF (NCOLS .NE. 1) STOP 'ERROR: SHOULD BE ONLY ONE COLUMN'
1600     C   GET GRID POINT LIST FILENAME
1700     TYPE 1000, 'ENTER GRID POINT ID OUTPUT LIST FILENAME:'
1800     ACCEPT 2000, GPFIL
1900     OPEN(UNIT=2, NAME=GPFIL, TYPE='NEW', CARRIAGECONTROL='LIST')
2000     C   GENERATE LIST FILE FROM NON-ZERO MATRIX ENTRIES
2100     NIDS = 0
2200     DO 100 MDOF=1, MROWS
2300         READ(1,5000) GRDPT
2400         IF (GRDPT .NE. 0.0) THEN
2500             IGRDPT = INT(GRDPT)
2600             COMP = GRDPT - FLOAT(IGRDPT)
2700             ICOMP = NINT(10.0*COMP)
2800             IF (ICOMP .GT. 6) THEN
2900                 IGRDPT = IGRDPT + 1
3000                 ICOMP = 0
3100             END IF
3200             WRITE(2,6000) IGRDPT, ICOMP, MDOF
3300             NIDS = NIDS + 1
3400         END IF
3500     100  CONTINUE
3600     CLOSE(UNIT=1)
3700     CLOSE(UNIT=2)
3800     TYPE *, NIDS, 'ENTRIES WRITTEN TO GRID POINT LIST'
3900     STOP
4000     C
4100     1000  FORMAT(1X, A44, 1X, 6)
4200     2000  FORMAT(A35)
4300     3000  FORMAT(A8, 2I8)
4400     4000  FORMAT(1X, A8, ' IS A ', I8, ' ROW BY ', I8, ' COLUMN MATRIX')
4500     5000  FORMAT(E16.8)
4600     6000  FORMAT(I8, '-', I1, I12)
4700     END

```

FUTURE REQUIREMENTS

1. If the practice of comparing analysis with test, as outlined here, for certifying a design should become commonplace, one could imagine that the demand for additional information would increase. Instead of depending on a comparative analysis to indicate that differences do exist, and roughly where, engineers increasingly might require comparative analysis to predict more precisely where differences arise and their causes. An extension of the existing method in this direction would be to apply a correlation function using a correlation displacement variable. Consider the expression

$$\phi(P,r,s) = \int_{V_p} T(x_p, y_p, z) \times A[(x_p - r, y_p - s)z] dV.$$

ϕ measures the best correlation of a test function T at a particular point $P(x_p, y_p, z_p)$ with an analytical function A in the neighborhood of $P: [V_p]$ as the analytical function is evaluated at displacement distances (r and s) away from P in x and y . The motivation for considering such a quantity is to explore a point at which earlier results of a correlation coefficient showed consistent differences over a number of modes at one location of the structure. Since tests are limited as to the intensity of data obtainable in a small region, the test coordinate can be held constant in one or two dimensions while the analysis mesh is intensified in the region to provide enough definition to step through values of r and s to find what location in the vicinity of P shows greater correlation of A with T at P . Such a spatial correlation function might prove helpful in exploring a design defect or an analytical modeling error of a structure.

2. Another extension is to equip the correlation to make comparisons on the basis of mode shapes defined in the complex domain. Correlation with a damping displacement variable could prove useful in refining the damping away from average modal considerations to spatial distributions of damping.

3. Currently, the analysis presumes that any particular point on the test article, instrumentation can detect only one component direction of behavior. If multi-axis behavior at a test point can be provided, the component at an analytical point can be implemented by adding one more digit after the decimal point of the real number representing a grid point. The processor program can discriminate to the nearest integer by multiplying by 10, and then rounding off. Thus, the real value in TESET and DOFLIST can reflect correspondence in keeping with increased experimental detail.

4. Processing of analytical data in preparation for STATCORR is handled in discrete operations. If a number of different analytical runs are being processed at the same time for later assembly as STATCORR input, their separate results might get uncoordinated, so that a symmetric mode shape, adjusted for sign at certain image points might be identified with a wrong frequency or modal stiffness. With further effort, the several operations could be combined with automated bookkeeping to eliminate the risk of getting results scrambled.

5. Human error can be further reduced if the entire analysis were made interactive with computer prompts. Then when STATDMAP is accessed from USERLIB, the whole sequence of orderly information train could be set in motion to keep all relations coordinated.

6. STATCORR can be readily extended to comparisons of static loadings. First of all, the mean, x' , has entirely different meaning in statics than in modal analysis. x' for statics cannot be prescribed as the equilibrium position. The non-zero mean must be reintroduced into the stochastic quantities. Scaling was meaningful for eigenvalues because the method of normalizing could be arbitrary. The relative deviation of equation (7) should use actual unscaled response data for identifying magnitudes of difference.

7. The implementation of the option for comparing symmetrically based analysis against samples over the entire test article was restricted to the use of basic coordinates only. A logical extension is to allow any number of rectangular coordinates for defining direct and image points. Enough extra work would be involved to implement more than one coordinate system, that it may be tolerable to limit the first extension of rectangular coordinates whose planes are parallel to the planes of symmetry. In a second extension, all types of coordinates can be logically admitted.

USER MANUAL SUMMARY

This document is intended to serve as a guide for comparing analytical modes with test when using NASTRAN, STATCORR and its associated processors, in conjunction with the test data.

First, select one of three bases of comparison: (1) whole vs. whole in which both the analytical modeling and the test instrumentation involves the whole structure; (2) symmetric vs. symmetric in which the analytical modeling and the test instrumentation involves only a basic segment of reflective symmetry; and (3) symmetric vs. whole in which the analysis is based upon modeling of only a basic segment of reflective symmetry and the test is based upon instrumenting the whole structure.

USER MANUAL SUMMARY

STEP/ROUTE	WHOLE/WHOLE	SYM/SYM	SYM/WHOLE
LIASION	Establish (a) coordinate system location, (b) model locations of instrumented points (c) component directions at each location, (d) identification number of each point.	Analytical model should contain a grid point corresponding to each instrumented point within the basic segment. Test should have additional instrumentation outside the basic segment to sense phase relationship with respect reflected segment to ascertain the type of modal symmetry across planes of symmetry.	Analytical model should contain a grid point corresponding to each direct point, image point, and cloned point which is instrumented on the test article.
	Determine the precise boundary condition at every test support point and include that boundary behavior at corresponding points in the analytical model. Special care should be taken to ensure that boundary elasticity be measured at an apparent firm boundary point.	Agree on which plane will be called the 1st plane of symmetry; which the second plane of symmetry; and which the 3rd plane of symmetry. Agree on how each plane is to be defined in terms of the basic coordinate system.	Agree on which plane will be called the 1st plane of symmetry; which the second plane of symmetry; and which the 3rd plane of symmetry. Agree on how each plane is to be defined in terms of the basic coordinate system.
STRUCTURAL ANALYSIS	Precede Eigenvalue Run with CHKPNIT YES and DIAG 21, 22 commands, then take an exit after GP4 has executed using the ALTER packet: ALTER 53, EXIT 5, ENDALTER. Use listings of DIAG 21 and 22 to construct partitioning vector IESEI.	Agree on which plane will be called the 1st plane of symmetry; which the second plane of symmetry; and which the 3rd plane of symmetry. Agree on how each plane is to be defined in terms of the basic coordinate system.	Check to see that instrumented points when reflected back to the basic segment will coincide with a point of the analytical model. When instrumented points in different octants all reflect back to the same point in the model, agreement on its multiplicity will establish the number of clones needed. Each clone bears the number of a particular instrumented point.
	Merge CHKPNIT dictionary after ID card for a RSTRI run. Remove ALIER for exiting after GP4. Remove DIAG 21 and 22. Add DIAG 14. Reconsider use of CHKPNIT; generally advised if model is large. If mass of model checks O.K., disable GPUG with: ALTER 40, PARAM //AADDX/Y,GRDPNT/-1/0 \$. Add DMI cards to BULK DATA for IESEI vector. Follow instructions in packet XXXPXXX for the preparation of IESEI data. For an explanation of these instructions see page ??? of the STACORR report. Fetch DMAP ALTER file DRAO:INASCAT-UTILITY-STACORR.DEMO:ISTATDMAP.LIS. Edit file to suit the route before merging.	Delete packets XXXSXXX and XXXMXXX	Use DIAG 21 and 22 data to construct the matrix DOFLIST.
	Delete packets XXXSXXX and XXXMXXX	Delete packet XXXMXXX.	If coord system is rectangular, enter data at locations: KAKAKAA, ABABAB, & ACACACAC. Remove phrases pertaining to cylindrical and spherical coordinate systems. If coord system is cylindrical, enter data at locations ATATAT. Remove phrase pertaining to rectangular and spherical coord systems. Enter

values of INI for parameters SYMPLAN that indicate the kind of symmetry being imposed by the SPC case in Case Control. Remove \$\$\$ from in front of DMAP statements S1 thru S8. Remove \$\$\$ from ahead of ALIER 125. If coord system is spherical, remove phrases pertaining to rectangular and cylindrical coord systems.

Add DMI cards to Bulk Data for DOELISI matrix. Follow instructions in packet AAMAX for the preparation of DOELISI data. For an explanation of these instructions see page ??? of the STACORR report.
Add DMI cards to Bulk Data for IDCORR. Follow instructions in packet AAMAX for preparation of IDCORR data.
Remove \$M1\$ from ahead of DMAP statement M1.
Remove \$M2\$ from ahead of ALIER 128.
Merge ALIER into EXECC. Check to see that ENDALIER is only at the very end of ALIER packet.

Merge ALIER into EXECC. Check to see that ENDALIER is only at the very end of ALIER packet.

If a printout of only new Bulk Data is wanted during a RSTRT run, set ECHO = UNSORT in Case Control. Put a NASIRAN card ahead of the EXECC with FILES = (NPTP,OPTP) if checkpoint and restart files are to be directed to disk instead of tape. NASIRAN data is ready for eigenvalue run. Prepare system job control language commands for CHKPM1, RSTRT, & PUNCH. \$ABSIGN(old problem tape file) FOR008, \$ASSIGN(new problem tape file) FOR009, \$ASSIGN(punch file) FOR077. Make as many eigenvalue runs as is necessary to span the frequency range.

Change INI values for parameters SYMPLAN to correspond to symmetry according to new SPC set. Make as many eigenvalue runs as is necessary to model every type of symmetry over the frequency range.

If the DMAP ALIER executed successfully, the following messages will be found in the job listing:
USER INFORMATION MESSAGE 4015 Table named LAMA punched onto cards.
USER INFORMATION MESSAGE 4103 OUTPUT3 has punched matrix data block WHITE onto DMI cards.
USER INFORMATION MESSAGE 4103 OUTPUT3 has punched matrix data block IESET onto DMI cards.
USER INFORMATION MESSAGE 4103 OUTPUT3 has punched matrix data block DOELISI onto DMI cards.
USER INFORMATION MESSAGE 4103 OUTPUT3 has punched matrix data block IDCORR onto DMI cards.

PROCESSOR Fetch the MERGE processor from the directory DRAD:[NASCAT.UTILITY.STACORR.OLD]MERGE.EXE.

MERGE
Input data LAMA, IESET, and PHITE for all cases.
Sorted on frequency.
Merged.
Duplicates removed.
Output.
Send kappa and mu.
Input SYMPLAN vs. PHITE for every symmetric case.
SYMPLAN is attached to each PHITE.
Sorted on frequency.
Merged.
Duplicates removed.
Output.
Input DOELISI, IDCORR.
Output for whole.

STRUCTURAL Check that sensors match in location and orientation. Method is the same regardless of existence of symmetry.
TEST
Excite the structure for steady state modal response.
Record frequencies, phase angles, modal displacement data.
Stop excitation and measure decay data for damping.
Process.. Scale to forcing input. Check for best response at a frequency over various forcings. Cull best and assemble.
Check phase angle for symmetry.
Assign SYMPLAN and attach to MS data. Record zeta.
Transcribe modal test data into the required format for STACORR using in-house Modal Survey Program. Set up one data file per mode containing frequency, damping, symmetry planes, GP id's, and modal vector.

CORRELATION Fetch the Statistical Correlation Program from the utility directory INASCAI.UTILITY.STATCORR3STATCORR.EXE.
ANALYSIS Input--Analytical files are: LAMA.IBL, PHIE.MIX, GROPE.LIS.
STATCORR Experimental files are: EXPMOD4.INP. One for each mode. Enter NONE after filename of last experimental mode.
Parameters: 1. Is analytical vs. experimental symmetry to be considered? (Y or N):
2. Is a print wanted for analytical mode-shape vectors? (Y or N):
3. Is a print wanted for experimental mode-shape vectors? (Y or N):
4. Relative deviations greater than a threshold value will be printed.
The default is 0.050.
Enter desired threshold: ','. For default press RETURN key.

INTERPRET Per program READCORR.
STATCORR OUTPUT

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16. Abstract A theory is developed for comparing vibration modes obtained by NASTRAN analysis with those obtained experimentally. Both are treated as random data sources. Because many more analytical modes can be obtained than experimental modes, the analytical set are treated as expansion functions for putting both sources in comparative form. Three dimensional symmetry was developed for three general cases—non-symmetric whole model compared with a non-symmetric whole structural test, symmetric analytical portion compared with a symmetric experimental portion, an analytical symmetric portion with a whole experimental test. Theory was coded and a statistical correlation program was installed as a utility. Theory was established with small classical structures.			
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