PROVIDING STRUCTURAL MODULES WITH
SELF-INTEGRITY MONITORING
SOFTWARE USER'S MANUAL

Prepared for

NASA
JET PROPULSION LABORATORY
Pasadena, California
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1.0 INTRODUCTION

National Aeronautics and Space Administration (NASA) Contract NAS7-961 [A Small Business Innovation and Research (SBIR) contract from NASA] involved research dealing with remote structural damage detection using the concept of substructures [1]. Several approaches were developed; the main two were: (1) the module (substructure) transfer function matrix (MTFM) approach and (2) modal strain energy distribution method (MSEDM). Either method can be used with a global structure; however, the focus was on substructures.

As part of the research contract, computer software was to be developed which would implement the developed methods. This was done and it was used to process all the finite element generated numerical data for the research. The software was written for the IBM AT personal computer. Copies of it were placed on floppy disks (see Section 4.0).

This report serves as a user's manual for the two sets of damage detection software. Sections 2.0 and 3.0 discuss the use of the MTFM and MSEDM software, respectively.
2.0 MODULE TRANSFER FUNCTION MATRIX METHOD

This method/approach is discussed in detail in Section 3.0 of Reference 1. The corresponding software consists of several programs. To discuss this, it is easiest to describe the process followed in doing the related part of the research.

The basic steps followed are given as follows:

a) obtain transient response of finite element model corresponding to undamaged and damaged states; this was done using COSMOS/M [2];

b) process transient response data to obtain corresponding data in MAC/RAN IV [3] format;

c) run program for determining the module transfer function matrix [MTFM] for the undamaged and damaged states; and

d) determine differences between the MTFM for the two states.

The above steps were followed for each damage level (state) for a given model.

The MTFM software was built around the computer code MAC/RAN IV. This code is a well developed digital time series analysis package. The most important part of it that is related to the subject research is its module (subroutine) TRANS; it is a multi-input, single-output (MISO) code. However, the research required a multi-input, multi-output (MIMO) code. To deal with this, a computer code was written that would execute TRANS for each required output (one at a time)--the code looped through TRANS the number of times needed. The TRANS output files were merged together to form a rectangular matrix corresponding to the MIMO problem.

The details of how to run the MTFM and damage indicator computer codes are described in Table 2.1. All the codes referenced in this table can be found on each of the 5-1/4-in. floppy disks entitled, "Structural Module Integrity Software, ANCO Engineers, Inc., Report 1311.05, August 1988, NASA Contract NAS7-961." Table 2.2 describes the contents of the floppies that is related to the MTFM method. Appendix A contains a listing of the contents of a floppy, including the source listings.

An example of an MTFM and damage indicator run is given in Table 2.3.
TABLE 2.1: RUNNING THE MTFM AND DAMAGE INDICATOR COMPUTER CODES

The codes were written to be used in connection with the finite element computer code COSMOS/M. The sequence followed in running the software package is given as follows:

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Start process using COSMOS/M output time histories corresponding to the undamaged and damaged substructure states.</td>
</tr>
<tr>
<td>2</td>
<td>Use macro NASAMAC.BAT - this macro reads the COSMOS/M output time histories and outputs time histories in MAC/RAN IV format.</td>
</tr>
<tr>
<td></td>
<td>To do:</td>
</tr>
<tr>
<td>2-1</td>
<td>Create NASAMAC.BAT --</td>
</tr>
<tr>
<td></td>
<td>INTRFS.EXE</td>
</tr>
<tr>
<td></td>
<td>MAC423 /R 10000 &lt;FRMCHK.SCF &gt;MACOUT.OUT</td>
</tr>
<tr>
<td></td>
<td>DEL MACOUT.OUT</td>
</tr>
<tr>
<td></td>
<td>NASADAM</td>
</tr>
<tr>
<td>2-2</td>
<td>Create NASADAM --</td>
</tr>
<tr>
<td></td>
<td>NASA.EXE *</td>
</tr>
<tr>
<td></td>
<td>NASAD</td>
</tr>
<tr>
<td></td>
<td>* NASA.EXE creates NASAD.BAT, NASAREN.BAT and MATRX.DAT.</td>
</tr>
<tr>
<td>2-3</td>
<td>Run NASAMAC.BAT</td>
</tr>
<tr>
<td></td>
<td>Input to INTRFS.EXE is given as follows:</td>
</tr>
<tr>
<td></td>
<td>a) Enter COSMOS plot filename to process</td>
</tr>
<tr>
<td></td>
<td>b) Enter output MACRAN.SCF filename - include extension .SCF</td>
</tr>
<tr>
<td></td>
<td>c) Enter output filename MACRAN.SDF filename - include extension .SDF</td>
</tr>
<tr>
<td></td>
<td>d) Enter the number of points in the time history</td>
</tr>
<tr>
<td></td>
<td>e) Do you want to truncate the number of points?</td>
</tr>
<tr>
<td></td>
<td>f) Enter the number of loads to use from COSMOS</td>
</tr>
<tr>
<td></td>
<td>g) Is there load data in the COSMOS plot file?</td>
</tr>
<tr>
<td></td>
<td>h) Enter the number of accelerations to use from COSMOS (this must be the total number of node points in the COSMOS output file)</td>
</tr>
<tr>
<td></td>
<td>i) Enter channel description for each acceleration used, e.g., --&gt;NODE1,TX; --&gt;NODE6,TX; --&gt;NODE9,TX</td>
</tr>
</tbody>
</table>
TABLE 2.1 (continued)

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
</table>
| 3    | Input for NASA.EXE --  
      | This program is used to create a batch file which is used to execute MAC/RAN once for each output channel*.  
      | Input is given as follows:  
      | a) Enter input MACRAN FILENAME - including extension .SDF  
      | b) Number of points (time history points)  
      | c) Number of points/segments (the number of segments refers to how many segments the time histories are broken up into; for this study four (4) segments were used)  
      | d) Enter output filename - no file extensions please  
      | e) Enter the number of input channels (<=10) (this is the number of inputs to use for the calculation of the transfer function matrix)  
      | f) Specify MAC/RAN channel to use for each input (in MAC/RAN, the first channel is time (values of time in time history); the remaining channels correspond to the node numbers and their order in the COSMOS output file, e.g., time, Node 1, Node 6, and Node 9 correspond to MAC/RAN Channels 1, 2, 3 and 4, respectively.  
      | g) Specify MAC/RAN channel for each output  
      | h) Is this a (d)amaged or (u)ndamaged run?  
      | (Enter "D" or "U")  
      | i) Enter a descriptive title for this run  

* MAC/RAN is a multi-input, single-output transfer function processor code.

4  
At this point in the process, a multi-input, multi-output transfer function matrix has been created for the substructure. One matrix is created for each run of INTRFS.EXE, either undamaged or damaged condition. A matrix for both damaged states must be obtained before proceeding with the analysis. The elements of the MTFM are plotted by editing the MTFM data file to obtain the needed data for the element, and then by using the plotting features in MAC/RAN
### TABLE 2.1 (continued)

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
</table>
| 5    | Run the program DAMAGE.EXE  
The final step in this process is to calculate the damage indicators. The results are plotted using the plotting features in MAC/RAN |
TABLE 2.2: CONTENTS OF FLOPPY DISK THAT ARE RELATED TO THE MTFM METHOD

### A:MTFM

<table>
<thead>
<tr>
<th>Type</th>
<th>File Size</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIR</td>
<td></td>
<td>1-29-89</td>
<td>11:01a</td>
</tr>
<tr>
<td>NASA</td>
<td></td>
<td>1-29-89</td>
<td>11:01a</td>
</tr>
<tr>
<td>DAMAGE</td>
<td></td>
<td>1-29-89</td>
<td>11:01a</td>
</tr>
<tr>
<td>INTERF</td>
<td></td>
<td>1-29-89</td>
<td>11:02a</td>
</tr>
<tr>
<td>TESTPD</td>
<td>File(s)</td>
<td>327680 bytes free</td>
<td></td>
</tr>
</tbody>
</table>

### A:MTFM NASSA

<table>
<thead>
<tr>
<th>Type</th>
<th>File Size</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>NASA</td>
<td>FOR</td>
<td>1-29-89</td>
<td>11:01a</td>
</tr>
<tr>
<td>MACRO1</td>
<td>FOR</td>
<td>1-29-89</td>
<td>11:01a</td>
</tr>
<tr>
<td>MACRDC</td>
<td>FOR</td>
<td>1-29-89</td>
<td>11:01a</td>
</tr>
<tr>
<td>MACROI</td>
<td>FOR</td>
<td>1-29-89</td>
<td>11:01a</td>
</tr>
<tr>
<td>FMKAP</td>
<td>FOR</td>
<td>1-29-89</td>
<td>11:01a</td>
</tr>
<tr>
<td>FILEX</td>
<td>FOR</td>
<td>1-29-89</td>
<td>11:01a</td>
</tr>
<tr>
<td>FILEC</td>
<td>FOR</td>
<td>1-29-89</td>
<td>11:01a</td>
</tr>
<tr>
<td>FILEH</td>
<td>FOR</td>
<td>1-29-89</td>
<td>11:01a</td>
</tr>
<tr>
<td>FILEC</td>
<td>FOR</td>
<td>1-29-89</td>
<td>11:01a</td>
</tr>
<tr>
<td>FILEA</td>
<td>FOR</td>
<td>1-29-89</td>
<td>11:01a</td>
</tr>
<tr>
<td>NASA</td>
<td>FOR</td>
<td>1-29-89</td>
<td>11:01a</td>
</tr>
</tbody>
</table>

FILE(S): 327680 bytes free
### TABLE 2.2 (continued)

#### A1\NTFM\DAMAGE

<table>
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<tr>
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<th>1-27-87</th>
</tr>
</thead>
<tbody>
<tr>
<td>MACWRT</td>
<td>1-1459</td>
<td>1-27-87</td>
</tr>
<tr>
<td>DAMAGE</td>
<td>1-27-87</td>
<td>1-27-87</td>
</tr>
</tbody>
</table>

#### A1\NTFM\INTERP

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<th>DIR</th>
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<th>1-27-87</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUT1</td>
<td>1-20-87</td>
<td>1-20-87</td>
</tr>
<tr>
<td>INTRF3</td>
<td>1-20-87</td>
<td>1-20-87</td>
</tr>
<tr>
<td>INTRF3</td>
<td>1-20-87</td>
<td>1-20-87</td>
</tr>
</tbody>
</table>

#### A1\NTM\TESTRD

<table>
<thead>
<tr>
<th>TESTRD</th>
<th>1-27-87</th>
<th>1-27-87</th>
<th>1-27-87</th>
</tr>
</thead>
</table>

*44921 bytes free*
The input to this set of programs is rather lengthy, therefore, the input and output listings for the problem discussed in Subsection 4.2.2 of Reference 1 is shown below. The COSMOS/M time history plot files used are FRMWWUX.PLT and FRMWWD2X.PLT for the undamaged and damaged states, respectively.

**INTRFS** - PROGRAM TO REFORM COSMOS FILE TO MACRAN FILE

**VIFAC-VIBRATION PACKAGE**

REVISION NO.: 1.00

ANCO ENGINEERS, INC. (C) Copyright 1984,1985,1986

ENTER COSMOS PLOT FILENAME TO PROCESS : FRMWWUX.PLT

ENTER OUTPUT MACRAN .SCF FILENAME - INCLUDE .SCF : FRMWWUX.SCF

ENTER OUTPUT MACRAN .SDF FILENAME - INCLUDE .SDF : FRMWWUX.SDF

ENTER THE NUMBER OF POINTS IN THE TIME HISTORY : 1024

DO YOU WANT TO TRUNCATE THE NUMBER OF POINTS? N

ENTER THE NUMBER OF LOADS TO USE FROM COSMOS : 0

IS THERE LOAD DATA IN THE COSMOS PLOTFILE? : N**

ENTER THE NUMBER OF ACCELERATIONS TO USE FROM COSMOS : 3

ENTER CHANNEL DESCRIPTION FOR EACH ACCELERATION USED

--> NODE1.TX

--> NODE6.TX

--> NODE9.TX

FILE HAS A TIME STEP OF : 2.0000E-02 SECONDS

READING IN ACCELERATION DATA

REFORMATTING TO COSMOS -.SCF FORMAT

Stop - Program terminated.

21:14:40

E:\
TABLE 2.3 (continued)

|      |   1   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|------|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|      |
|      |   1   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|      |   1   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 21:14:40 | E: | TYPE FRMWWUX.PL T | 1024 | 9 time d d 1 | 1 v i | 1 a 1 | 1 d d | 6 v 1 | 6 a 1 | 6 d d |
| 20000E-01 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 40000E-01 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 60000E-01 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 80000E-01 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 10000E+00 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 12000 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 14000 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 16000 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 18000 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 20000 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 1.9800 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 2.0200 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 3338E-04 | -3338E-02 | -4667E-01 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 2.0400 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 2.0600 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 2.0800 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 2.1000 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 2.1200 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 2.1400 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 2.1600 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 2.1800 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 2.2000 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 2.2200 | 0000 |      | 0000 | 0000 | 0000 | 0000 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |

2-8
<table>
<thead>
<tr>
<th>Time</th>
<th>Node 1, TX</th>
<th>Node 6, TX</th>
<th>Node 9, TX</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00E+00</td>
<td>0.00E+00</td>
<td>0.00E+00</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>2.00E-02</td>
<td>0.00E+00</td>
<td>0.00E+00</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>4.00E-02</td>
<td>0.00E+00</td>
<td>0.00E+00</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>6.00E-02</td>
<td>0.00E+00</td>
<td>0.00E+00</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>8.00E-02</td>
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</tr>
<tr>
<td>1.00E-01</td>
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</tr>
<tr>
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INTRFS - PROGRAM TO REFORM COSMOS FILE TO MACRAN FILE
VIPAC-VIBRATION PACKAGE   REVISION NO.: 1.00
ANCO ENGINEERS, INC. (C) Copyright 1984,1985,1986

ENTER COSMOS PLOT FILENAME TO PROCESS : FRMWWD2X.PLT

ENTER OUTPUT MACRAN .SCF FILENAME - INCLUDE .SCF : FRMWWD2X.SCF

ENTER OUTPUT MACRAN .SDF FILENAME - INCLUDE .SDF : FRMWWD2X.SDF

ENTER THE NUMBER OF POINTS IN THE TIME HISTORY : 1024
DO YOU WANT TO TRUNCATE THE NUMBER OF POINTS? N

ENTER THE NUMBER OF LOADS TO USE FROM COSMOS : 0

IS THERE LOAD DATA IN THE COSMOS PLOTFILE? : N**

ENTER THE NUMBER OF ACCELERATIONS TO USE FROM COSMOS : 3

ENTER CHANNEL DESCRIPTION FOR EACH ACCELERATION USED
--- NODE1,TX
--- NODE6,TX
--- NODE9,TX

FILE HAS A TIME STEP OF : 2.000E-02 SECONDS

READING IN ACCELERATION DATA

REFORMATTING TO COSMOS -.SCF FORMAT

Stop - Program terminated.

21:27:32
E: \n
---
TABLE 2.3 (continued)

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TABLE 2.3 (continued)

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TABLE 2.3 (continued)

PROGRAM NASA - TO GENERATE A MACRAN BATCH FILE
VIPAC-VIBRATION PACKAGE  REVISION NO.: 1.00
ANCO ENGINEERS, INC. (C) Copyright 1984,1985,1986

ENTER INPUT MACRAN FILENAME (INCLUDING .SDF) : FRMWWD2X.SDF
NUMBER OF POINTS : 1024
NUMBER OF POINTS/SEGMENT : 256
ENTER OUTPUT FILENAME - NO FILE EXTENSIONS PLEASE : FRMW2D

ENTER THE NUMBER OF INPUT CHANNELS (<= 10) : 1
SPECIFY MACRAN CHANNEL TO USE FOR EACH INPUT
--> 3*

SPECIFY MACRAN CHANNEL FOR EACH OUTPUT
--> 4

IS THIS A (D)AMAGED OR (U)NDAMAGED RUN? : D
ENTER A DESCRIPTIVE TITLE FOR THIS RUN : FRMWB DAMAGED, XEMOT

Stop - Program terminated.

22:24:23
D:\

=====================================================================

2-13

ORIGINAL PAGE IS OF POOR QUALITY
3.0 MODAL STRAIN ENERGY DISTRIBUTION METHOD (MSEDM)

This method (modal strain energy distribution method) is discussed in detail in Section 6.0 of Reference 1. The corresponding software consists of several programs. The basic steps followed in using it are given as follows:

a) run a program to determine the strain energy in each finite element for each mode;

b) determine the level of damage associated with each mode; this can be done by using the damage indicator discussed in Reference 1; and

c) run program to determine possible locations of damage.

The details of how to run the MSEDM computer codes are described in Table 3.1. All of the codes referenced in this table can be found on each of the 5-1/4-in. floppy disks entitled, "Structural Module Integrity Software, ANCO Engineers, Inc., Report 1311.05, August 1988, NASA Contract NAS7-961." Table 3.2 describes the contents of the floppies that are related to the MSEDM. Appendix A contains related source code listings.

An example of an MSEDM run is given in Table 3.3.
TABLE 3.1: RUNNING THE MSED M COMPUTER CODES

The following three computer codes must be run in using the MSED M. The required inputs are listed for each code.

MODSTRN - This program computes element modal strain energies for a simply-supported beam due to bending deformation only. The user must input the number of elements and modes to use. The output element modal strain energies are contained in the file "MS.DD". This file is a binary file.

DAMIO - This program allows the user to input damage parameters to be used in damage assessment. Damage parameters are input on a mode-by-mode basis. The user also specifies the output file containing the damage parameters. This output file is an ASCII file.

MODSUM - This program performs the damage assessment based on the modal strain energies and the damage parameters. The user must input the file name containing the modal strain energies and the damage parameters. The user also specifies the damage fraction (g) used in assessing damage. Alternately, the user can select the option of summarizing the element strain energies for a given mode. In either case, output data is contained in the file "MODSUM.DD".
**TABLE 3.2: CONTENTS OF FLOPPY DISK THAT ARE RELATED TO THE MSEDM**

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<th>File</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTFSM</td>
<td>DIS</td>
<td>1-25-89</td>
<td>11:48a</td>
</tr>
<tr>
<td>MSEDM</td>
<td>DIS</td>
<td>1-29-89</td>
<td>11:48a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Files</td>
<td>874,000 bytes</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>Directory</th>
<th>File</th>
<th>Date</th>
<th>Time</th>
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</thead>
<tbody>
<tr>
<td>MSEDM</td>
<td>DIS</td>
<td>1-29-89</td>
<td>11:48a</td>
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<td></td>
<td></td>
<td>2 Files</td>
<td>874,000 bytes</td>
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</tbody>
</table>

**ORIGINAL PAGE IS OF POOR QUALITY**
### TABLE 3.3: EXAMPLE OF MSEDM

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<th>Description</th>
<th>Input Value</th>
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<td>MODSTRN</td>
<td>Damage file used.</td>
<td>DAMOUT3.DD</td>
</tr>
<tr>
<td></td>
<td>Problem title (= damage at N = 0.25 and N = 0.5).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of modes to use.</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Number of elements for simply supported beam</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Damage fraction.</td>
<td>0.4</td>
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<td>DAMIO</td>
<td>Damage file name.</td>
<td>DAMOUT3.DD</td>
</tr>
<tr>
<td></td>
<td>Problem title (= damage at N = 0.25 and N = 0.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of modes to use.</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Modal damage indicator values [scalars $D(\omega_i)$], and corresponding</td>
<td></td>
</tr>
<tr>
<td></td>
<td>critical values are listed below.</td>
<td></td>
</tr>
<tr>
<td>MODSUM</td>
<td>Damage file used.</td>
<td>DAMOUT3.DD</td>
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<tr>
<td></td>
<td>Problem title (= damage at N = 0.25 and N = 0.5)</td>
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<tr>
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<td>Damage fraction.</td>
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The output from the various computer codes are shown on the following pages:
TABLE 3.3 (continued)

SIMPLY SUPPORTED BEAM
DAMAGE FILE USED : DAMOUT3.DD
DAMAGE TITLE : DAMAGE AT N = 0.25 AND AT N = 0.5
NUMBER OF MODES : 12
NUMBER OF ELEMENTS : 60
DAMAGE FRACTION : 0.4000

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DAMAGE FILENAME : DAMOUT3.DD
DAMAGE AT N = 0.25 AND AT N = 0.5
NUMBER OF MODES : 12

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TABLE 3.3 (continued)

SIMPLY SUPPORTED BEAM
DAMAGE FILE USED : DAMOUT3.DD
DAMAGE TITLE : DAMAGE AT N = 0.25 AND AT N = 0.5
NUMBER OF MODES : 12
NUMBER OF ELEMENTS : 60
DAMAGE FRACTION : .4000

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* indicates possible modal element damage
TABLE 3.3 (continued)

SIMPLY SUPPORTED BEAM
DAMAGE FILE USED: DAMOUT3.DD
DAMAGE TITLE: DAMAGE AT N = 0.25 AND AT N = 0.5
NUMBER OF MODES: 12
NUMBER OF ELEMENTS: 60
DAMAGE FRACTION: .4000

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X indicates possible modal element damage
4.0 CONTENTS OF FLOPPY DISKS

A single floppy disk contains all the software necessary to solve either the module transfer function matrix* /damage assessment or modal strain energy distribution method problem defined in Reference 1. The software contained on the floppy is listed in Tables 2.2 and 3.2. Also, each floppy contains the input data for the two sample problems described earlier. The software on the floppies consists of the Fortran source listings and the corresponding executable codes.

The floppies are 5-1/4-in., 1.2 MByte, high density 96 TPI. Three floppy disks, with software, have been provided with this report.

* This is true provided that MAC/RAN IV has been installed on the microcomputer being used for these analyses.
5.0 REFERENCES


2. COSMOS/M, general purpose structural linear and nonlinear, static and dynamic finite element computer code; Structural and Analysis Corporation, Inc., Santa Monica, California.

APPENDIX A

SOURCE CODE LISTINGS FOR
MTFM AND MSED M APPROACHES
Contained in this appendix are the Fortran source code listings for the two damage assessment methods.
MODULE TRANSFER FUNCTION MATRIX (MTFM)
SOURCE CODE LISTINGS
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<th>Comment</th>
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<td>1.05p</td>
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**ORIGINAL PAGE IS OF POOR QUALITY**
C PROGRAM NASA - PURPOSE: TO CREATE A BATCH FILE WHICH WILL EXECUTE MACRAN SEVERAL TIMES

C

IMPLICIT INTEGER*2 (I-N)
DIMENSION ICHNI(10),ICHNO(14)
CHARACTER*80 KEY
CHARACTER*30 TITLE
CHARACTER*12 MFILI,MFIL10,MFIL2I,MFIL20
CHARACTER*12 MFIL3I,MFIL30,MFIL4I,MFIL40
CHARACTER*12 FILIN,FILOT1,FILOT2
CHARACTER*6 MFIL1,MFIL2,MFIL3,MFIL4,FILOT
CHARACTER*3 FX1,FX2,FX3,FX4,AYN
CHARACTER*1 ATYPE,FILET(12)
LOGICAL*2 EXISTS,IER
COMMON/NASADT/ICHNI,ICHNO,NINPUT,NOUTPT,FILIN,NPNTS
EQUIVALENCE (FILOT2,FILET(1))

C

CALL VCLEAR
CALL VCURXY(0,0)

C DISPLAY PROGRAM NAME TO USER
C

KEY = 'PROGRAM NASA - TO GENERATE A MACRAN BATCH FILE$'
CALL PRMPT(KEY,1.00)

C BEGINN HERE
C
C OPEN UP FILE CONTAINING NPTS
C
OPEN(31,FILE='INTRFS.DAT')
READ(31,8831) NPTS
8831 FORMAT(I4)
NPNTS = (NPTS+3)/4
IR = 7
10 CONTINUE
KEY = 'ENTER INPUT MACRAN FILENAME (INCLUDING .SDF) : '$
CALL KEYBD(KEY,R,I,FILIN,3,12,1,0,IR)

C SEE IF FILE EXISTS
C
INQUIRE(FILE=FILIN,EXIST=EXISTS)
IF(EXISTS) GO TO 15
IR = IR + 1
CALL VCURXY(0,IR)
WRITE(*,9010)
9010 FORMAT(IX,'FILE DOES NOT EXIST - PROGRAM ABORT!!')
STOP

C MAKE SURE IT HAS A .SDF EXTENSION
C
15 CONTINUE
IR = IR + 1
CALL VCURXY(0,IR)
WRITE(*,8543) NPTS,NPNTS
8543 FORMAT(1x,'NUMBER OF POINTS : ',I4,1x,'NUMBER OF POINTS/SEGMENT ; ',I4)
CALL VCURXY(0,IR)
CALL FILECH(FILIN,IER)
IF(IER) GO TO 20
IR = IR + 2
CALL VCURXY(0,IR)
WRITE(*,9002)
C FORMAT(1X,'NO .SDF EXTENSION - PROGRAM ABORT!!') STOP
C HERE IF OK
C 20 CONTINUE
IR = IR + 2
KEY = 'ENTER OUTPUT FILENAME - NO FILE EXTENSIONS PLEASE :$'
CALL KEYBD(KEY,R,I,FILOT,3,(6),0,IR)
C VERIFY NO EXTENSION AND GET CURRENT LENGTH
IFLEN = 6
CALL FILEX(FILOT,IFLEN)
NFLEN = IFLEN + 6
C NOW GET INPUT/OUTPUT CHANNELS
C 30 CONTINUE
IR = IR + 2
CALL VCURXY(0,IR)
KEY = 'ENTER THE NUMBER OF INPUT CHANNELS ( <= 10 ) :$'
CALL KEYBD(KEY,R,NINPUT,A,2,(2),O,IR)
IF(NINPUT.LE.10) GO TO 40
IR = IR + 1
CALL VCURXY(0,IR)
WRITE(*,9030)
9030 FORMAT(1X,'TOO MANY INPUT CHANNELS SPECIFIED'
) GO TO 30
40 CONTINUE
IR = IR + 2
CALL VCURXY(0,IR)
WRITE(*,9031)
9031 FORMAT(1X,'SPECIFY MACRAN CHANNEL TO USE FOR EACH INPUT'
) I R = IR + 1
CALL VCURXY(0,IR)
KEY = '-> $'
DO 45 IC=1,NINPUT
IR = IR + 1
CALL KEYBD(KEY,R,ICHNI(IC),A,2,(2),O,IR)
45 CONTINUE
C NOW GET OUTPUT CHANNELS
C 48 CONTINUE
CALL VCLEAR
IR = 2
CALL VCURXY(0,IR)
KEY = 'ENTER THE NUMBER OF OUTPUT CHANNELS ( <= 14 ) :$'
CALL KEYBD(KEY,R,NOUTPT,A,2,(2),O,IR)
IF(NOUTPT.LE.14) GO TO 50
IR = IR + 1
CALL VCURXY(0,IR)
WRITE(*,9040)
9040 FORMAT(1X,'TOO MANY OUTPUT CHANNELS SPECIFIED'
) GO TO 48
C NOW GET OUTPUT CHANNELS
C 50 CONTINUE
IR = IR + 2
CALL VCURXY(0,IR)
WRITE(*,9041)
FORMAT(1X,'SPECIFY MACRAN CHANNEL FOR EACH OUTPUT')
IR = IR + 1
CALL VCURXY(O,IR)
KEY = '--- $'
DO 55 IC = 1,NOUTPT
IR = IR + 1
CALL KEYBD(KEY,R,ICHNO(IC),A,2,(2),O,IR)
CONTINUE

SEE IF A DAMAGED OR UNDAMAGED CASE
IR = IR + 2
CALL VCURXY(O,IR)
CONTINUE
KEY = 'IS THIS A (D)AMAGED OR (U)NDAMAGED RUN? :$'
CALL KEYBD(KEY,R,I,ATYPE,3,(1),O,IR)
IF(ATYPE.EQ.'D' .OR. ATYPE.EQ.'d') GO TO 56
IF(ATYPE.EQ.'U' .OR. ATYPE.EQ.'u') GO TO 56
GO TO 54
56 CONTINUE

GET TITLE FOR THIS RUN
KEY = 'ENTER A DESCRIPTIVE TITLE FOR THIS RUN : $'
IR = IR + 2
CALL KEYBD(KEY,R,I,TITLE,3,(30),O,IR)

NOW START CREATING THE BATCH FILE
OPEN(6,FILE='NASAD.BAT',STATUS='NEW')
OPEN(7,FILE='NASAREN.BAT',STATUS='NEW')
OPEN(8,FILE='MATRX.DAT',STATUS='NEW')
WRITE(8,4010) NINPUT,NOUTPT,ATYPE,TITLE

ASSIGN GENERIC FILENAMES TO MACRAN FILES
MFIL1 = 'TRNSD1'
MFIL2 = 'TRNSD2'
MFIL3 = 'TRNSD3'
MFIL4 = 'TRNSD4'
FX1 = 'INP'
FX2 = 'OUT'
FX3 = 'SDF'
FX4 = 'DAT'
IL = 6

NOW LOOP OVER THE NUMBER OF OUTPUT CHANNELS TO PROCESS
DO 100 ICHN=1,NOUTPT
GET FIRST MACRAN FILENAME
CALL FILEM(MFIL1,MFIL1I,FX1,ICHN,IL)
OPEN(10,FILE=MFIL1I,STATUS='NEW')

NOW WRITE OUT FIRST MACRAN CARD
CALL MACRO1(FILIN,NINPUT,ICHNI,ICHNO(ICHN),TITLE,NPNTS)
CLOSE(10,STATUS='KEEP')
CALL FILEM(MFIL1,MFIL1O,FX2,ICHN,IL)
C GET SECOND MACRAN FILENAME
C
CALL FILEM(MFIL2,MFIL2I,FXI,ICHN,IL)
OPEN(10,FILE=MFIL2I,STATUS='NEW')

C WRITE OUT SECOND CARD
C
CALL MACRD2
CLOSE(10,STATUS='KEEP')
CALL FILEM(MFIL2,MFIL2O,FX2,ICHN,IL)

C GET THIRD MACRAN FILENAME
C
CALL FILEM(MFIL3,MFIL3I,FX1,ICHN,IL)
OPEN(10,FILE=MFIL3I,STATUS='NEW')

C WRITE OUT THIRD MACRAN CARD
C
CALL MACRD3
CLOSE(10,STATUS='KEEP')
CALL FILEM(MFIL3,MFIL3O,FX2,ICHN,IL)

C NOW ADD TO THE NASAD.BAT FILE
C
WRITE(6,6010) MFIL1I,MFIL1O,MFIL1O
WRITE(6,6060) MFIL2I,MFIL2O,MFIL2O
WRITE(6,6010) MFIL3I,MFIL3O,MFIL3O

C GET OUTPUT FILENAME
C
CALL FILEM(FILOT,FILOT1,FX3,ICHN,IFLEN)
CALL FILEM(FILOT,FILOT2,FX4,ICHN,IFLEN)

C WRITE OUT BATCH COMMANDS
C
WRITE(6,6020) FILOT1,FILOT1
WRITE(6,6030) FILOT2,FILOT2
WRITE(8,4020) (FILET(IFM),IFM=1,NFLEN)
CONTINUE
FORMAT(12A1)

100 IF(IFLEN.EQ.6) GO TO 150
CALL FILAD(FILOT,IFLEN)
CONTINUE

C FINISH OFF BATCH COMMANDS FOR NASA.BAT
C
WRITE(6,6070)

C CLOSE(6,STATUS='KEEP')

C NOW ADD TO NASAREN.BAT
C
WRITE(7,6050) FILOT,FILOT
CLOSE(7,STATUS='KEEP')

C END IT ALL
C
CLOSE(7,STATUS='KEEP')
CALL VCURXY(0,23)
STOP
C FORMAT SECTION

6010 FORMAT('MAC423 /R 10000 <',A12,' > D:',A12,'/DEL D:',A12)
6020 FORMAT('DEL',1X,A12,'/REX TRNSMD2.SDF',1X,A12)
6030 FORMAT('DEL',1X,A12,'/REX HD2.DAT',1X,A12)
6040 FORMAT('DEL',1X,A6,'01.BFT'
1 /'REX FORDI.DAT',1X,A6,'01.BFT')
6045 FORMAT('DEL',1X,A6,'01.DFT'
1 /'REX FORDI.DAT',1X,A6,'01.DFT')
6046 FORMAT('DEL',1X,A6,'02.DFT'
1 /'REX FORDO2.DAT',1X,A6,'02.DFT')
6050 FORMAT('DEL',1X,A6,'.BAT'
1 /'REX NASAD.BAT',1X,A6,'.BAT')
6060 FORMAT('MACTRN /R 10000 <',A12,' > D:',A12,'/DEL D:',A12)
6070 FORMAT('TESTRD.EXE'/'NASAREN.BAT')
END
SUBROUTINE MACRD3 - PURPOSE TO WRITE OUT 3RD MACRAN CARD

SUBROUTINE MACRD3
IMPLICIT INTEGER*2 (I-N)
WRITE(10,9010)
9010 FORMAT('FILIN TRNSMD2.SDF'
 1 /'FILOUT H02.DAT'
 2 /'CTAPE',52X,'-1'
 3 /'END'
 4 /)
RETURN
END
SUBROUTINE MACRD2
IMPLICIT INTEGER*2 (I-N)

WRITE OUT STUFF

WRITE(IO,9010)
9010 FORMAT('FILIN MATRXD2.SDF'
 1 /'FILOUT TRNSMD2.SDF'
 2 /'TRANS TAPE'
 3 /'END'
 4 /)
RETURN
END
SUBROUTINE MACRDI - PURPOSE TO WRITE OUT FIRST MACRAN CARD

SUBROUTINE MACRDI(FILIN,NINPUT,ICHNI,ICHNO,TITLE,NPNTS)
IMPLICIT INTEGER*2 (I-N)
DIMENSION ICHNI(IO)
CHARACTERZ12 FILIN
CHARACTER*30 TITLE

WRITE OUT FIRST COUPLE OF COMMENT CARDS

WRITE(10,9010) TITLE
9010 FORMAT('JBHEAD ',A30,5X,'TRANSFER FUNCTIONS')
WRITE(10,9020) FILIN
9020 FORMAT('FILIN',2X,A12)

NOW WRITE OUT CHANNEL NUMBERS

IF(NINPUT.GT.2) GO TO 50
WRITE(10,9030) ICHNO,(ICHNI(IL),IL=I,NINPUT)
GO TO 100
50 CONTINUE
WRITE(10,9030) ICHNO,(ICHNI(IL),IL=I,2)
NLINES = (NINPUT+I)/4
DO 60 IJ=I,NLINES
   IL = 3 + 4*(IJ-1)
   IK = IL + 3
   IF(IK.GT.NINPUT) IK = NINPUT
   WRITE(10,9040) (ICHNI(IM),IM=IL,IK)
60 CONTINUE
9030 FORMAT('FILIN',1X,'CCHAN',I4X,'I.',1X,3(gx,I2,'.'))
9040 FORMAT('FILIN',IX,'CCHAN',5X,4(gx,I2,'.'))

HERE FOR REST OF DATA

CONTINUE
WRITE(10,9050) NPNTS
9050 FORMAT(1 'FILOUT MATRXD2.SDF'
2/'PSD TRANS',11X,I4,'.',
3/'PSD TOUTMTFC'
4/'PSD RETAIN'
5/'END'
6/)
SUBROUTINE FILMAP - TO CONSTRUCT A FILENAME
CALLED FORM FILEM

SUBROUTINE FILMAP(FIL1,FIL2,FX,ANUM,ILEN)
IMPLICIT INTEGER*2 (I-N)
CHARACTER*1 ANUM(2),FX(3),FIL1(12),FIL2(12)

DO 10 I=1,ILEN
     FIL2(I) = FIL1(I)
10 CONTINUE
DO 15 I=1,2
     FIL2(ILEN+I) = ANUM(I)
15 CONTINUE
     FIL2(ILEN+3) = '.
DO 20 I=1,3
     FIL2(ILEN+3+I) = FX(I)
20 CONTINUE

CHANGE BLANKS TO ZEROES

NLEN = ILEN + 6
DO 30 I=1,NLEN
     IF(FIL2(I).EQ. ' ') FIL2(I) = '0'
30 CONTINUE
RETURN
END
SUBROUTINE TO CHECK ON FILE AND ITS LENGTH

SUBROUTINE FILEX(FILI, ILEN)
IMPLICIT INTEGER*2 (I-N)
CHARACTER*1 FILI(20)

GET LENGTH OF FILE

DO 5 I=1, ILEN
   IF(FILI(I).EQ.' ') GO TO 7
5 CONTINUE
   GO TO 8
7 CONTINUE
   ILEN = I-1

NOW SEE IF AN EXTENSION WAS ADDED

8 CONTINUE
   DO 10 I=1, ILEN
      IF(FILI(I).EQ.'.') GO TO 20
10 CONTINUE
   RETURN
20 CONTINUE
   ILEN = ILEN-1
   RETURN
END
SUBROUTINE FILEM - TO CONSTRUCT A FILENAME

SUBROUTINE FILEM(FILI,FIL2,FX,INUM,ILEN)
IMPLICIT INTEGER*2 (I-N)
CHARACTER*1 FIL1(12),FIL2(12),FX(3)
CHARACTER*2 ANUM

C WRITE OUT INUM TO ANUM
C
WRITE(ANUM,900) INUM
900 FORMAT(I2)
C
CALL FILCHG TO GET FILENAME
C
CALL FILMAP(FILI,FIL2,FX,ANUM,ILEN)
RETURN
END
SUBROUTINE FILECH - PURPOSE TO SEE IF A .SDF EXTENSION IS ON

SUBROUTINE FILECH(FILI,IER)
IMPLICIT INTEGER*2 (I-N)
CHARACTER*1 FILI(12)
LOGICAL*2 IER

C FIRST LOOK FOR A .
C
IER = .FALSE.
DO 10 I=1,12
   IF(FILI(I).EQ.' ') GO TO 20
10 CONTINUE
RETURN
20 CONTINUE
ILEN = I
IF(FILI(ILEN+I).NE.'S' .AND. FILI(ILEN+I).NE.'s')RETURN
IF(FILI(ILEN+2).NE.'D' .AND. FILI(ILEN+2).NE.'d')RETURN
IF(FILI(ILEN+3).NE.'F' .AND. FILI(ILEN+3).NE.'f')RETURN
IER = .TRUE.
RETURN
END
$NOFLOATCALLS

CHARACTER*80 KEY
CHARACTER*14 FLNAME

CALL VCLEAR
CALL VCURXY(0,0)
KEY = 'ENTER FILENAME TO DISPLAY : $'
CALL KEYBD(KEY,R,I,FLNAME,3,(14),0,5)
OPEN(7,FILE=FLNAME,FORM='UNFORMATTED')

CONTINUE
READ(7) FTR,FTI
WRITE(*,8000) FTR,FTI

8000 FORMAT(2X,1PE10.3,5X,1PE10.3)

GO TO 10
STOP
END
SUBROUTINE FILAD(FILOT,IFLEN)

IMPLICIT INTEGER*2 (I-N)
CHARACTER*1 FILOT(5)
IFL = IFLEN + 1
DO 10 I=IFL,6
   FILOT(I) = '0'
10 CONTINUE
RETURN
END
SUBROUTINE MACWRT(DAM,NFREQ,DELF,TITLE)
IMPLICIT INTEGER*2 (I-N)
COMPLEX DAM(7,2500),XDAM(7)
REAL*4 RDAM(16)
CHARACTER*4 ADAM(7)
CHARACTER*30 TITLE

C SET UP CHARACTER STRINGS
C
ADAM(1) = 'DAM1'
ADAM(2) = 'DAM2'
ADAM(3) = 'DAM3'
ADAM(4) = 'DAM4'
ADAM(5) = 'DAM5'
ADAM(6) = 'DAM6'
ADAM(7) = 'DAM7'
C
C OPEN UP OUTPUT DAMAGE.SCF FILE
C
OPEN(20,FILE='DAMAGE.SCF',STATUS='NEW')

C START WRITING OUT TO FILE
C
WRITE(20,9090) TITLE
9090 FORMAT('JBHEAD',1X,'COMPUTED DAMAGE - ',A30)
WRITE(20,9050)
WRITE(20,9000)
WRITE(20,9010)
WRITE(20,9020)
DO 20 I=1,6
   DO 10 IW=1,2
      WRITE(20,9030) ADAM(I)
   CONTINUE
20 CONTINUE
DO 30 I=1,16
   RDAM(I) = 0.0
30 CONTINUE
CALL GCURXY(IC,IR)
IR = IR + 1
CALL VCURXY(0,IR)
DO 100 IFQ=I,NFREQ
   RDAM(1) = FLOAT(IFQ-1) * DELF
   DO 40 I=1,6
      XDAM(I) = DAM(I,IFQ)
      RI = AIMAG(XDAM(I))
      RR = REAL(XDAM(I))
      RDAM(I*2) = RR
      RDAM(I*2+1) = RI
   CONTINUE
100 CONTINUE
WRITE(20,9040) (RDAM(I),I=1,16)
CLOSE(20,STATUS='KEEP')
$NOFLOATCALLS

SUBROUTINE DAMCOM(IFQ)
IMPLICIT INTEGER*2 (I-N)
COMPLEX*8 TFU(14,10),TFD(14,10)
COMPLEX*8 DAM(7,2500),AUX1,AUX2,AUX3,AUX4,AUX5
DIMENSION ILMI(14),ILMO(14)
COMMON/DAMC/TFU,TFD,DAM,ILMI,ILMO,NINPUT,NOUTPT
C
C ZERO OUT AUX
C
AUX1 = (0.,0.)
AUX2 = (0.,0.)
AUX3 = (0.,0.)
AUX4 = (0.,0.)
AUX5 = (0.,0.)
C
C COMPUTE DAMAGE
C
DO 20 KK=1,NOUTPT
   DO 19 IK=1,NOUTPT
      IF(KK.EQ.ILMO(IK)) GO TO 20
   CONTINUE
   DO 10 JJ=1,NINPUT
      DO 11 IJ=1,NINPUT
         IF(JJ.EQ.ILMI(IJ)) GO TO 10
      CONTINUE
      AUX1 = AUX1 + TFU(KK,JJ) * FTO(KK) * FTI(JJ)
      AUX2 = AUX2 + TFD(KK,JJ) * FTO(KK) * FTI(JJ)
      AUX3 = AUX3 + TFU(KK,JJ) * TFU(KK,JJ)
      AUX4 = AUX4 + TFU(KK,JJ) * TFD(KK,JJ)
      AUX5 = AUX5 + TFD(KK,JJ) * TFD(KK,JJ)
   CONTINUE
   CONTINUE
20   DAM(I,IFQ) = (AUX5 + AUX4) / (AUX4 + AUX3)
   DAM(2,IFQ) = (AUX4 + AUX3) / (AUX5 + AUX4)
   DAM(3,IFQ) = AUX3/AUX4
   DAM(4,IFQ) = AUX4 / AUX3
   DAM(5,IFQ) = AUX4 / AUX5
   DAM(6,IFQ) = AUX5 / AUX4
RETURN
END
$NOFLOATCALLS

**IMPILCIT INTEGER*2 (I-N)**
**COMPLEX*8 TFU(14,10),TFD(14,10)**
**COMPLEX*8 DAM(7,2500)**
**DIMENSION ILMI(14),ILMO(14)**
**CHARACTER*80 KEY**
**CHARACTER*30 TITLE**
**CHARACTER*20 TFUF,TFDF**
**CHARACTER*1 ATYPE**
**COMMON/DAMC/TFU,TFD,DAM,ILMI,ILMO,NINPUT,NOUTPT**

CALL VCLEAR
CALL VCURXY(0,0)
IR = 0

C GET EACH FILENAME,OPEN IT UP AND READ HEADER INFO
C
TFUF = 'HWUMAT.DAT'
OPEN(6,FILE=TFUF,FORM='UNFORMATTED')
READ(6) TITLE,NFREQ,NINPUT,NOUTPT,ATYPE,DELF
WRITE(*,9000) TITLE,NINPUT,NOUTPT,NFREQ,DELF
9000 FORMAT(1X,A30)
1 /1X,'NUMBER OF INPUT CHANNELS':',I4
2 /1X,'NUMBER OF OUTPUT CHANNELS':',I4
3 /1X,'NUMBER OF FREQUENCY POINTS':',I4
4 /1X,'FREQUENCY STEP SIZE':',1PE10.3,' Hz'
IR = IR + 6
CALL VCURXY(0,IR)
IF(ATYPE.EQ.'U' .OR. ATYPE.EQ.'u') WRITE(*,9010)
IF(ATYPE.EQ.'D' .OR. ATYPE.EQ.'d') WRITE(*,9015)
9010 FORMAT(IX,'UNDAMAGED'
9015 FORMAT(IX,'DAMAGED'
IR = IR + 2
CALL VCURXY(0,IR)

C GET DAMAGED TF FILENAME
C
TFDF = 'HWDMAT.DAT'
OPEN(7,FILE=TFDF,FORM='UNFORMATTED')
READ(7) TITLE,NFREQ,NINPUT,NOUTPT,ATYPE,DELF
WRITE(*,9000) TITLE,NINPUT,NOUTPT,NFREQ,DELF
IR = IR + 6
CALL VCURXY(0,IR)
IF(ATYPE.EQ.'U' .OR. ATYPE.EQ.'u') WRITE(*,9010)
IF(ATYPE.EQ.'D' .OR. ATYPE.EQ.'d') WRITE(*,9015)
IR = IR + 2

C SEE ABOUT ROW/COLUMN ELIMINATION
C
PAUSE
CALL VCLEAR
IR = 0
CALL VCURXY(0,IR)
DO 40 I=1,14
   ILMI(I) = 0
   ILMO(I) = 0
40 CONTINUE
KEY = 'HOW MANY INPUT CHANNELS DO YOU WANT TO ELIMINATE? : $'
CALL KEYBD(KEY,R,IELMI,A,2,(2),0,IR)
IR = IR + 1
IF(INELMI.EQ.0) GO TO 75
CALL VCURXY(0,IR)
WRITE(*,9200)
FORMAT(IX,'ENTER CHANNELS TO ELIMINATE')
IR = IR + 1
CALL VCURXY(0,IR)
DO 50 I=1,IELMI
  KEY = '___$'
  CALL KEYBD(KEY,R,ILMI(I),A,2,(2),0,IR)
  IR = IR + 1
50 CONTINUE
CONTINUE
IR = IR + 1
KEY = 'HOW MANY OUTPUT CHANNELS DO YOU WANT TO ELIMINATE? : $'
CALL KEYBD(KEY,R,IELMO,A,2,(2),0,IR)
IF(INELMO.EQ.0) GO TO 100
IR = IR + 1
CALL VCURXY(0,IR)
WRITE(*,9200)
IR = IR + 1
CALL VCURXY(0,IR)
DO 80 I=1,IELMO
  KEY = '___$'
  CALL KEYBD(KEY,R,ILMO(I),A,2,(2),0,IR)
  IR = IR + 1
80 CONTINUE
CONTINUE
IR = IR + 1
KEY = 'NOW READ IN ALL THE DATA, ONE FREQ POINT AT A TIME AND COMPUTE
C DAMAGE FOR THAT FREQ POINT
C
NTOT = NINPUT + NOUTPT
DO 150 IFQ=1,NFREQ
  DO 110 IO=1,NOUTPT
    READ(6) (TFU(IO,I),I=1,NINPUT)
    READ(7) (TFD(IO,I),I=1,NINPUT)
110 CONTINUE
150 CONTINUE
CALL DAMCOM(IFQ)
C CALL MACWRT TO WRITE OUT DATA
C
CALL MACWRT(DAM,NFREQ,DELF,TITLE)
C END IT ALL
C
CALL GCURXY(IC,IR)
IR = IR + 1
CALL VCURXY(0,IR)
STOP
END
A:OMETRD\TESTRD
DIR

Volume \ drive A has no label
Directory of  A:\OMETRD\TESTRD

TESTRD FOR 14:00:00 1/5/91
IMPLICIT INTEGER*2 (I-N)
COMPLEX*8 HW(30), FT(30)
DIMENSION ADAT(30), ODAT1(30), ODAT2(30), FREQD(2)
CHARACTER*12 FLNAME
CHARACTER*1 ADUM, ATYPE
CHARACTER*30 TITLE

C
C READ IN DATA FROM FILE
C
OPEN(8, FILE='MATRX.DAT')
READ(8, 5000) NINPUT, NOUTPT, ATYPE, TITLE
5000 FORMAT(I5, 2X, I5, 2X, A1/A30)
C
C NOW READ IN EACH FILENAME AND OPEN UP A CHANNEL
C
DO 2 I=1, NOUTPT
   READ(8, 5010) FLNAME
   ICHN = I + 20
   OPEN(ICHN, FILE=FLNAME)
2 CONTINUE

CLOSE(8, STATUS='KEEP')
C
C OPEN UP OUTPUT FILE
C
IF(ATYPE.EQ.'U' .OR. ATYPE.EQ.'u') GO TO 4
OPEN(6, FILE='HWDMAT.DAT', STATUS='NEW', FORM='UNFORMATTED')
GO TO 5
4 CONTINUE
OPEN(6, FILE='HWUMAT.DAT', STATUS='NEW', FORM='UNFORMATTED')
5 CONTINUE
C
C READ IN FIRST RECORD AND GET THE NUMBER OF FREQ RECORDS
C
READ(21, 9000) NREC
9000 FORMAT(/30X, I5)
   NFREC = (NREC-1)/2
   NRECD = NREC + 2
   REWIND 21
   NLINE = (NREC+3)/4
C
C READ CHANNEL 21 AND COMPUTE # OF FREQ POINTS
C
DO 11 I=1, NRECD
   READ(21, 9001) ADUM
11 CONTINUE
   NFREQ = 0
12 CONTINUE
   DO 13 I=1, NLINE
      READ(21, 9001, END=14) ADUM
13 CONTINUE
   NFREQ = NFREQ + 1
   GO TO 12
14 CONTINUE
   REWIND 21
   WRITE(*, 4010) NFREQ
4010 FORMAT(1X, I5, ' FREQUENCY POINTS READ')
C READ IN FIRST TWO FREQ VALUES AND COMPUTED DELTA FREQ
C
DO 21 I=1,NRECD
READ(21,9001) ADUM
21 CONTINUE
DO 22 I=1,2
READ(21,5800) FREQD(I)
DO 22 IL=2,NLINE
READ(21,9001) ADUM
22 CONTINUE
5800 FORMAT(24X,E11.3)
REWIND 21
DELF = FREQD(2) - FREQD(1)
WRITE(*,5810) DELF
5810 FORMAT(1X,'FREQUENCY STEP SIZE : ',1PE10.3,' HZ')
C
C READ OVER DUMMY DATA IN EACH FILE
C
DO 6 IFL=1,NOUTPT
ICHN = 20 + IFL
DO 10 I=1,NRECD
READ(ICHN,9001) ADUM
10 CONTINUE
6 CONTINUE
9001 FORMAT(A1)
C
C NOW WRITE OUT HEADER INFO
C
WRITE(6) TITLE,NFREQ,NINPUT,NOUTPT,ATYPE,DELF
C
C NOW LOOP OVER EACH FILE, READING A ROW AT EACH FREQ POINT
C
DO 30 IFL=1,NOUTPT
ICHN = IFL + 20
DO 15 IW=I,NLINE
II = (IW-1) * 4 + 1
JJ = II + 3
READ(ICHN,9010,END=100) (ADAT(K),K=II,JJ)
15 CONTINUE
C
C NOW PLACE IN COMPLEX ARRAY
C
DO 18 IW=1,NFREC
HW(IW) = CMPLX(ADAT(IW*2),ADAT(IW*2+1))
18 CONTINUE
WRITE(6) (HW(I),I=1,NFREC)
30 CONTINUE
9010 FORMAT(24X,4(E11.3,1X))
GO TO 20
100 CONTINUE
DO 105 IFL=1,NOUTPT
ICHN = 20 + IFL
CLOSE(ICHN,STATUS='KEEP')
105 CONTINUE
STOP
END
A:ANTFM
DIR

Volume 3 drive A has no label
Directory of A:ANTFM

OUT1 3CC 1478 1-29-80 8:57 P.M.
INTREFS 001 7660 1-07-87 10:45 A.M.
SUBROUTINE OUT1
PARAMETER(NTIME=5000)
IMPLICIT INTEGER*2 (I-N)
DIMENSION XIN(24,NTIME)
CHARACTER*12 MACOUT,MACBIN,MACIN
CHARACTER*8 CHANDES(24)
COMMON/NASA/XIN,CHANDES,NTOT,NPTS,DT,MACIN,MACOUT,MACBIN
NREC = NTOT + 1

WRITE OUT FIRST SET OF CTAPE CARDS
OPEN(4,FILE=MACOUT,STATUS='NEW')
WRITE(4,9001) MACIN
9001 FORMAT('JBHEAD',IX,'TIME HISTORIES FROM COSMOS FILE - ',A12)
WRITE(4,9000) MACBIN
9000 FORMAT('FILOUT ',A12)
WRITE(4,9010)
9010 FORMAT('CTAPE',2X,'NASA 1311.05')
WRITE(4,9020) NREC
9020 FORMAT('CTAPE',2X,'COSMOS/M',15X,I2,'.')
WRITE(4,9030)
9030 FORMAT('CTAPE',2X,'TIME')
DO 10 I=I,NTOT
WRITE(4,9040) CHANDES(I)
10 CONTINUE
WRITE(4,9040)
9040 FORMAT('CTAPE',2X,A8)

WRITE OUT DATA
IF(NREC.GT.4) GO TO 200

HERE IF LESS THAN 4 OUTPUT CHANNELS
DO 110 I=I,NPTS
TIME = (I-I) * DT
WRITE(4,9050) TIME,(XIN(IFN,I),IFN=I,NTOT)
110 CONTINUE
WRITE(4,9090)
RETURN

CONTINUE
NREC = NREC-4
NLINE = (NREC+3)/4
DO 210 I=I,NPTS
TIME = (I-I) * DT
WRITE(4,9050) TIME,(XIN(IFN,I),IFN=I,3)
DO 215 IP = I,NLINE
II = (IP-1) * 4 + 4
JJ = II + 3
IF(JJ.GT.NTOT) JJ = NTOT
WRITE(4,9060) (XIN(IFN,I),IFN=II,JJ)
215 CONTINUE
210 CONTINUE
WRITE(4,9090)
RETURN
9090 FORMAT('END')
9050 FORMAT('CTAPE',19X,4(1PE11.3,1X))
9060 FORMAT('CTAPE C',17X,4(1PE11.3,1X))
THIS PROGRAM TAKES THE OUTPUT DATA (*.PLT) FILE FROM COSMOS AND PREPARES AN INPUT FILE (*.SCF) FOR MACRAN.

NASA PROJECT JOB # 1311.058

THE PROGRAM WILL OPEN A MAXIMUM OF 25 CHANNELS. TIME WILL ALWAYS BE CHANNEL 1 FOLLOWED BY 10 INPUT CHANNELS AND THE OUTPUT CHANNELS (MAXIMUM = 14). THE PROGRAM ALSO CREATES A BATCH FILE NAMED NASAMAC.BAT, WHICH UPON EXECUTION, BESIDES PERFORMING THE AFOREMENTIONED TASK WILL CALL MACRAN AND CONVERT THE ASCII (*.SCF) FILE TO A BINARY (*.SDF) FILE.

DEFINITION OF VARIABLES

TIME : DISCRETE TIME SERIES
XLOD : INPUTS FROM COSMOS
XOUT : OUTPUTS FROM COSMOS

NTIME : PARAMETER FOR VARIABLE DIMENSION, SET TO MAXIMUM OF 5000 POINTS.
NPTS : NO OF POINTS IN THE TIME HISTORY
ICHANO : NO. OF OUTPUT CHANNELS
ICHANI : NO. OF INPUT CHANNELS

USER INPUTS

NAME OF THE INPUT FILE NAME : (*.PLT)
NAME OF THE MACRAN ASCII FILE : (*.SCF)
NAME OF THE MACRAN BINARY FILE : (*.SDF)
NO OF POINTS IN THE TIME HISTORY : NPTS

NOTES

1. THE SOURCE CODE HAS BEEN PROGRAMMED TO ACCEPT 5000 TIME POINTS, MADE AVAILABLE TO IT FROM COSMOS PLOT FILE (*.PLT). SHOULD IT BE NECESSARY TO INCREASE THIS LIMIT CHANGE THE VALUE OF 'NTIME=' APPEARING IN THE PARAMETER STATEMENT OF THE MAIN PROGRAM -- REFORM, AND THE FIVE SUBROUTINES IT CALLS NAMELY; OUT1, OUT2, OUT3, OUT4, AND OUT5. THIS HAS TO BE DONE BY EDITING THE SOURCE PROGRAM --- INTRFS.FOR .

2. ITS IMPERATIVE THAT THE USER ACQUAINTS HIMSELF WITH THE COSMOS PLOT FILE AND IS FAMILIAR WITH THE INPUTS AND THE OUTPUTS SPECIFIED IN THE COSMOS RUN. THE CODE IS WRITTEN FOR TEN INPUTS (STRESSES, DISPLACEMENTS). IT CONSIDERS ACCELERATION AS ITS OUTPUTS ONLY. IT IS RECOMMENDED THAT THE USER MAKES A NOTE OF THESE PARAMETERS AND UTILIZES ONLY THE NON-ZERO QUANTITIES IN THE SECOND MACRO. THIS WILL PRECLUDE ERRONEOUS TRANSFER FUNCTIONS RESULTING FROM DIVISION OR MULTIPLICATION OF ZERO.

3. TO EXECUTE THIS PROGRAM RUN --- NASAMAC.BAT

A-29
$\text{NOFLOATCALLS}$

\begin{verbatim}
PARAMETER(NTIME=5000)
  IMPLICIT INTEGER*2 (I-N)
CHARACTER*120 ALINE
CHARACTER*12 MACIN,MACOUT,MACBIN
  CHARACTER*4 ATIME
CHARACTER*3 AYN
CHARACTER*80 KEY
DIMENSION XIN(24,NTIME)
CHARACTER*8 CHANDES(24)
COMMON/NASA/XIN,CHANDES,NTOT,NPTS,DT,MACIN,MACOUT,MACBIN

C CLEAR SCREEN, DISPLAY PROMPT ,ETC

CALL VCLEAR
CALL VCURXY(O,O)
KEY='INTRFS - PROGRAM TO REFORM COSMOS FILE TO MACRAN FILE $'
CALL PRMPT(KEY,1.00)
CALL GCURXY(IC,IR)
IR = IR + 1

C GET INPUT AND OUTPUT FILENAMES

KEY = 'ENTER COSMOS PLOT FILENAME TO PROCESS : $'
CALL KEYBD(KEY,R,I,MACIN,3,(12),0,IR)
IR = IR + 2
KEY = 'ENTER OUTPUT MACRAN .SCF FILENAME - INCLUDE .SCF : $'
CALL KEYBD(KEY,R,I,MACOUT,3,(12),0,IR)
IR = IR + 2
KEY = 'ENTER OUTPUT MACRAN .SDF FILENAME - INCLUDE .SDF : $'
CALL KEYBD(KEY,R,I,MACBIN,3,(12),0,IR)

C GET THE NUMBER OF POINT IN THE TIME HISTORY

IR = IR + 2
KEY = 'ENTER THE NUMBER OF POINTS IN THE TIME HISTORY : $'
CALL KEYBD(KEY,R,NPTS,A,2,(4),0,IR)
IR = IR + 1
KEY = 'DO YOU WANT TO TRUNCATE THE NUMBER OF POINTS? $'
CALL KEYBD(KEY,R,IYN,AYN,4,(3),0,IR)
NEWPT = NPTS
IF(IYN.EQ.O) GO TO 30
IR = IR + 1
KEY = 'ENTER NEW NUMBER OF POINTS : $'
CALL KEYBD(KEY,R,NEWPT,A,2,(4),0,IR)
CONTINUE

30 CONTINUE

C OPEN UP INPUT COSMOS FILE AND .SCF MACRAN FILE

OPEN(2,FILE=MACIN)

C GET INPUT AND OUTPUT CHANNEL Assignments

IR = IR + 2
KEY = 'ENTER THE NUMBER OF LOADS TO USE FROM COSMOS : $'
CALL KEYBD(KEY,R,NFORC,A,2,(2),0,IR)
IR = IR + 2
IF(NFORC.NE.O) GO TO 20
KEY = 'IS THERE LOAD DATA IN THE COSMOS PLOTFILE? : $'
CALL KEYBD(KEY,R,IREWD,AYN,4,(3),0,IR)
IR = IR + 2
CONTINUE

20 CONTINUE
\end{verbatim}
C GET CHANNEL DESCRIPTIONS FOR EACH LOAD INPUT

C

IF(NFORC.EQ.0) GO TO 8
CALL VCURXY(0,IR)
WRITE(*,8020)

8020 FORMAT(1X,'ENTER A CHANNEL DESCRIPTION FOR EACH FORCE USED'
) CALL VCURXY(0,IR)
DO 5 IW=1,NFORC
   IR = IR + 1
   CALL VCURXY(0,IR)
   KEY = ' --> $
   CALL KEYBD(KEY,R,I,CHANDES(IW),3,(8),0,IR)
5 CONTINUE
8 CONTINUE
CALL VCLEAR
CALL VCURXY(0,0)
IR = 2
KEY='ENTER THE NUMBER OF ACCELERATIONS TO USE FROM COSMOS : $
CALL KEYBD(KEY,R,NACC,NACC,(2),0,IR)
IR = IR + 2
CALL VCURXY(0,IR)
WRITE(*,8030)

8030 FORMAT(1X,'ENTER CHANNEL DESCRIPTION FOR EACH ACCELERATION USED'
) IP = NFORC + 1
NTOT = NFORC + NACC
DO 15 IW=IP,NTOT
   IR = IR + 1
   CALL VCURXY(0,IR)
   KEY = ' --> $
   CALL KEYBD(KEY,R,I,CHANDES(IW),3,(8),0,IR)
15 CONTINUE

C READ PAST FIRST HEADER IN MACIN, COMPUTE DELTA T AND COMPUTE
C THE NUMBER OF POINTS IN THE FILE
C
IR = IR + 2
CALL VCURXY(0,IR)
WRITE(*,7010) MACIN

7010 FORMAT(1X,'READING COSMOS PLOTFILE : ',A12) CALL VCURXY(0,IR)
READ(2,26) ALINE
26 FORMAT(A)
READ(2,9010) TIME1
READ(2,9010) TIME2

9010 FORMAT(1X,E10.3)
DT = TIME2 - TIME1
WRITE(*,7000)

7000 FORMAT(80X)
CALL VCURXY(0,IR)
WRITE(*,7020) DT

7020 FORMAT(1X,' FILE HAS A TIME STEP OF : ',PE10.3,' SECONDS'
) IR = IR + 2
CALL VCURXY(0,IR)

C
C NOW REWIND FILE AND READ IN DATA

A-31
C
REWTND 2
IF((NFORC.EQ.0).AND.(IREWD.EQ.0)) GO TO 100
IF(NFORC.EQ.0) GO TO 50
READ(2,26) ALINE
WRITE(*,7040)
7040 FORMAT(1X,'READING IN LOAD DATA FROM COSMOS PLOTFILE ',')
   IR = IR + 2
   CALL VCURXY(0,IR)
   DO 40 I=1,NPTS
       READ(2,9030) (XIN(IFN,I),IFN=I,NFORC)
   CONTINUE
40 CONTINUE
   GO TO 100
9030 FORMAT(12X,10(E10.3,1X))
9040 FORMAT(12X,3(22X,E10.3,1X))
C HERE IF NO FORCES NEEDED BUT MUST BE READ OVER
C
50 CONTINUE
   READ(2,26) ALINE
   WRITE(*,7050)
7050 FORMAT(1X,'SKIPPING OVER LOAD DATA IN COSMOS PLOTFILE'
   IR = IR + 2
   CALL VCURXY(0,IR)
   DO 60 I=1,NPTS
       READ(2,26) ALINE
   CONTINUE
60 CONTINUE
C HERE TO READ ACCELERATIONS, IF ANY
C
100 CONTINUE
   IF(NACC.EQ.0) GO TO 200
   READ(2,26) ALINE
   WRITE(*,7060)
7060 FORMAT(1X,'READING IN ACCELERATION DATA'
   IR = IR + 2
   CALL VCURXY(0,IR)
   NLINO = (NACC+2)/3
   IP = 1
103 CONTINUE
   IAC1 = (IP-1) * 3 + 1 + NFORC
   IAC2 = IAC1 + 2
   IF(IAC2.GT.NTOT) IAC2 = NTOT
   DO 105 I=1,NPTS
       READ(2,9040) (XIN(IFN,I),IFN=IAC1,IAC2)
   105 CONTINUE
   IF(IP.EQ.NLINO) GO TO 110
   IP = IP + 1
   READ(2,26) ALINE
   GO TO 103
110 CONTINUE
C HERE WHEN ALL DONE READING IN DATA
C TIME TO REFORMAT TO MACRAN -.SCF FORMAT
C
200 CONTINUE
   WRITE(*,7070)
7070 FORMAT(1X,'REFORMATTING TO COSMOS -.SCF FORMAT'
   IR = IR + 2
   CALL VCURXY(0,IR)
   NPTS = NEWPT
   CALL OUT1
C
C HERE TO WRITE OUT REST OF MACRO

OPEN(6,FILE='NASAMAC.BAT',STATUS='NEW')
WRITE(6,19)

19 FORMAT('INTRFS.EXE')
WRITE(6,1911) MACOUT

1911 FORMAT('MAC423 /R 10000 <',A12,1X,'>MACOUT.OUT')
WRITE(6,1912)

1912 FORMAT('DEL MACOUT.OUT')
WRITE(6,1913)

1913 FORMAT('NASADAM')
CLOSE(6)

C HERE WHEN DONE

C STOP
END
MODAL STRAIN ENERGY DISTRIBUTION METHOD (MSEDM)
SOURCE CODE LISTINGS
```
AT: \MSED\M

> DIR

Volume 0 Device 0 Label:
D:\_P\P0\Q\Q0\Q000\Q00000\Q000000

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```
C CLEAR SCREEN, ETC

C

CALL VCLEAR
CALL VCURXY(0,0)
KEY = 'DAMIO - PROGRAM TO CREATE/EDIT DAMAGE PARAMETERS$
CALL PRMPT(KEY,1.00)
IR = 6
IR = IR + 1
KEY = 'DO YOU WANT TO (C)REATE OR (E)DIT A DAMAGE FILE? : $
CALL KEYBD(KEY,R,I,IEDCR,3,(1),0,IR)

C HERE FOR FILE CREATION

C

CALL VCLEAR
IR = 0
CALL VCURXY(0,IR)
KEY = 'DAMAGE TITLE : $
CALL KEYBD(KEY,R,I,DAMTTL,3,(60),0,IR)
IR = IR + 1
KEY = 'NUMBER OF MODES USED : $
CALL KEYBD(KEY,R,NMODES,A,2,(2),0,IR)
IR = IR + 2
CALL VCURXY(0,IR)
WRITE(*,9010)
9010 FORMAT(I1,'MODE',5X,'D(W)',IOX,'Dcrit(W)'
IR = IR + 1
CALL VCURXY(0,IR)
WRITE(*,9002)
9002 FORMAT(' NO.'
IR = IR + 1

C

C NOW READ IN DATA

C

IST = IR
IEND = IR + 9
DO 20 IM=1,NMODES
CALL VCURXY(0,IR)
IF(IR.EQ.IST) WRITE(*,9200) IM
IF(IR.NE.IST) WRITE(*,9201) IM
KEY = '$'
CALL KEYBD(KEY,DAM(IM),I,A,1,(10),9,IR)
CALL KEYBD(KEY,DAMCRT(IM),I,A,1,(10),23,IR)
IR = IR + 1
IF(IR.LE.IEND) GO TO 20
DO 15 IER=IST,IEND
   CALL VCURXY(0,IER)
   WRITE(*,9000)
15    CONTINUE
IR = IST
20    CONTINUE
IR = 20

C GET OUTPUT FILENAME AND WRITE IT OUT

C

KEY = 'ENTER OUTPUT DAMAGE FILENAME : $'
CALL KEYBD(KEY,R,I,DAMFIL,3,(20),0,IR)
OPEN(5,FILE=DAMFIL,STATUS='NEW')
WRITE(5,8000) DAMFIL,DAMTTL,NMODES
WRITE(5,8010)
DO 30 I=1,NMODES
  WRITE(5,8020) I,DAM(I),DAMCRT(I)
30 CONTINUE
9201 FORMAT(1X,1X,I3\)
9200 FORMAT(1X,I3\)
9000 FORMAT(40X\)
8000 FORMAT('DAMAGE FILENAME : ',A20/A60/'NUMBER OF MODES : ',I2)
8010 FORMAT('MODE',S5,'D(W)',IOX,'Dcrit(W)')
8020 FORMAT(1X,I2,5X,F7.3,7X,F7.3)
STOP
END
SUBROUTINE MODSSUM
IMPLICIT INTEGER*2 (I-N)
DIMENSION ES(100,20)
CHARACTER*80 KEY
CHARACTER*40 TITLE

C C GET CURSOR 
C CALL GCURXY(IC,IR)
IR = IR + 1
C
C C OPEN UP FILE 
C READ(5) TITLE,NELM,NMODES
DO 10 I=1,NMODES
   READ(5) (ES(J,I),J=1,NELM)
10 CONTINUE
KEY = 'ENTER WHICH MODE TO SUMMARIZE : $
CALL KEYBD(KEY,R,IMODE,A,2,(3),O,IR)
IR = IR + 1
C
C C OPEN UP MODSUM.DD FILE 
C OPEN(6,FILE='MODSUM.DD',STATUS='NEW')
WRITE(6,8000) TITLE,NMODES,NELM
8000 FORMAT(A40,
     1  /'NUMBER OF MODES : ',I2,
     2  /'NUMBER OF ELEMENTS : ',I3)
WRITE(6,8010) IMODE
8010 FORMAT(//2OX,'SUMMARY
     1 FOR MODE NUMBER : ',I2)
WRITE(6,8020)
8020 FORMAT(//'ELEMENT',5X,'MODAL STRAIN',
     1  /'NO. ',5X,' ENERGY')
DO 20 I=1,NELM
   WRITE(6,8030) I,ES(I,IMODE)
20 CONTINUE
8030 FORMAT(3X,I3,5X,1PE10.3)
STOP
END
C PROGRAM MODSTRN - COMPUTE MODAL STRAIN ENERGY MODE BY MODE

IMPLICIT INTEGER*2 (I-N)
DIMENSION XTRN(200),XAVG(200)
CHARACTER*80 KEY
CHARACTER*40 TITLE
COMMON/XDAT/XTRN,XAVG

C CLEAR SCREEN, DISPLAY PROGRAM

KEY = 'MODSTRN - PROGRAM TO COMPUTE MODAL STRAIN ENERGY $
CALL VCLEAR
CALL VCURXY(0,0)
CALL PRMPT(KEY,1.00)
CALL GCURXY(IC,IR)
IR = IR + 1

C GET USER INPUTS

KEY = 'ENTER DESCRIPTION OF RUN : $
CALL KEYBD(KEY,R,I,TITLE,3,(40),0,IR)
IR = IR + 1
KEY = 'ENTER THE NUMBER OF ELEMENTS TO USE : $
CALL KEYBD(KEY,R,NELM,A,2,(2),O,IR)
IR = IR + 1
KEY = 'ENTER THE NUMBER OF MODES TO USE : $
CALL KEYBD(KEY,R,NMODES,A,2,(2),O,IR)
IR = IR + 1
CALL VCURXY(0,IR)

C OPEN UP BINARY FILE CONTAINING DATA

OPEN(6,FILE='MS.DD',STATUS='NEW',
     FORM='UNFORMATTED')
WRITE(6) TITLE,NELM,NMODES

C COMPUTE STRAIN ENERGY FOR 100 PTS FROM 0 TO 1

XLM = 1.0 / NELM
NELMP1 = NELM + 1
XPI = 4.0 * ATAN(1.0)

C LOOP OVER NUMBER OF MODES

DO 100 IMODE=1,NMODES
  XMX = 0.0
  XCOFF = 1.0
  DO 10 I=1,NELMP1
    XL = FLOAT(I-1) * XLM
    XS = FLOAT(IMODE) * XPI
    XSN = SIN(2*XS*XL)
    XTRN(I) = XCOFF * (XL/2 - XSN/(4.0 * XS))
  10 CONTINUE

C COMPUTE ELEMENT STRAIN ENERGY

A-39
DO 15 I=1,NELM
  XAVG(I) = (XTRN(I+1) - XTRN(I))/0.1
  IF(ABS(XAVG(I)).GT.XMX) XMX = XAVG(I)
  CONTINUE
C SCALE TO UNITY
C
DO 20 I=1,NELM
  XAVG(I) = XAVG(I) / XMX
  CONTINUE
C NOW WRITE IT OUT
C
WRITE(6) (XAVG(I),I=1,NELM)
  CONTINUE
  STOP
  END
$NOFLOATCALLS
IMPLICIT INTEGER*2 (I-N)
DIMENSION ES(100,20),DAM(20),DAMCRT(20)
CHARACTER*80 KEY
CHARACTER*60 DAMTTL
CHARACTER*40 TITLE
CHARACTER*20 FLNME,DAMFIL
CHARACTER*3 PDAM(IOO),ISM
CHARACTER*27 FMT
CHARACTER*2 FM
CHARACTER*1 AES(IOO,20),FF,FMTM(27),FMM(2)
DIMENSION ESMX(20),LESMX(20)
COMMON/DAT/ES,AES,ESMX,LESMX,DAM,DAMCRT,PDAM
EQUIVALENCE (FMT,FMTM(1)),(FM,FMM(1))

C DEFINE FORMFEED
C
FF = CHAR(12)
FMT = '(7X,I2,SX, I(AI,3X),IOX,A3)'
FM = ' 1'

C DISPLAY PROGRAM TO USER
C
CALL VCLEAR
CALL VCURXY(0,0)
KEY = 'MODSUM - PROGRAM TO SUMMARIZE STRAIN ENERGY DATA$'
CALL PRMPT(KEY,1.00)
CALL GCURXY(IC,IR)
IR = IR + 1

C GET FILENAME CONTAINING DATA
C
KEY = 'ENTER FILENAME CONTAINING MODAL STRAIN ENERGIES : $'
CALL KEYBD(KEY,R,I,FLNME,3,(20),0,IR)
OPEN(5,FILE=FLNME,FORM='UNFORMATTED')
IR = IR + 1

C SEE IF USER WISHES TO SUMMARIZE MODAL STRAIN ENERGIES
C FOR ALL ELEMENTS
C
KEY='DO YOU WANT TO SUMMARIZE STRAIN ENERGIES FOR A MODE? : $'
CALL KEYBD(KEY,R,I,ISM,4,(3),O,IR)
IF(I.EQ.1) CALL MODSSUM

C GET FILENAME CONTAINING DAMAGE INFO
C
KEY = 'ENTER FILENAME CONTAINING DAMAGE DATA : $'
CALL KEYBD(KEY,R,I,DAMFIL,3,(20),0,IR)
OPEN(7,FILE=DAMFIL)

C GET DAMAGE FRACTION
C
KEY = 'ENTER DAMAGE FRACTION ( <= 1 ) : $'
CALL KEYBD(KEY,FR,I,A,1,(10),0,IR)

C READ IN DATA

A-41
READ(5) TITLE,NELM,NMODES
WRITE(9111) NMODES
FMTM(11) = FMM(1)
FMTM(12) = FMM(2)
FORMAT(12) READ(7,7010) DAMTTL
FORMAT(/A60/1X/1X)
DO 10 I=1,NMODES
READ(5) (ES(J,I),J=1,NELM)
READ(7,7020) DAM(I),DAMCRT(I)
CONTINUE
FORMAT(SX,FT.3,?X,F7.3)
C NOW DETERMINE MAX STRAIN ENERGIES FOR EACH MODE
C
DO 30 I=1,NMODES
XMX = 0.0
DO 20 J=1,NELM
IF(ES(J,I).LE.XMX) GO TO 20
XMX = ES(J,I)
LMX = J
20 CONTINUE
ESMX(I) = XMX
LESMX(I) = LMX
CONTINUE
C INITIATE AES
C
DO 35 I=1,NMODES
DO 34 J=1,NELM
AES(J,I) = ' '
CONTINUE
34 CONTINUE
35 CONTINUE
C NOW SORT IT ALL OUT
C
C BEGIN BY FINDING ELEMENTS WITH LOW STRAIN ENERGIES
C
DO 100 I=1,NMODES
IF(DAM(I).GT.DAMCRT(I)) GO TO 50
ESMXL = FR * ESMX(I)
DO 40 J=1,NELM
IF(ES(J,I).LE.ESMXL) AES(J,I) = 'x'
40 CONTINUE
GO TO 100
C
HERE FOR ELEMENTS WITH HIGH STRAIN ENERGIES
C
50 CONTINUE
DO 60 J=1,NELM
AES(J,I) = 'x'
CONTINUE
60 CONTINUE
100 CONTINUE
C
C NOW DETERMINE IF ANY ONE ELEMENT MIGHT HAVE DAMAGE
C
DO 110 IL=1,NELM
PDAM(IL) = 'YES'
DO 120 IM=1,NMODES
   IF(AES(IL,IM).EQ.' ') PDAM(IL) = 'NO'
120  CONTINUE
110  CONTINUE

C NOW SUMMARIZE DATA
C
OPEN(6,FILE='MODSUM.DD',STATUS='NEW')
NPG = (NELM + 39)/40 + 1
IPAGE = 1
WRITE(6,9000) TITLE,IPAGE,NPG,DAMFIL,DAMTTL,NMODES,NELM,FR
9000  FORMAT(//4X,A40,16X,'Page ' ,I1,' of ' ,I1,
1   /4X,'DAMAGE FILE USED : ',A20
1   /4X,'DAMAGE TITLE : ',A60
1   /4X,'NUMBER OF MODES : ',I2,
2   /4X,'NUMBER OF ELEMENTS : ',I2,
3   /4X,'DAMAGE FRACTION : ',F6.4)
WRITE(6,9010)
9010  FORMAT(/4X,'MODE',3X,'MAXIMUM ELEMENT',3X,'ELEMENT',
1   /4X,'NO.',3X,'STRAIN ENERGY ',3X,'NO./')
   DO 200 I=1,NMODES
      WRITE(6,9020) I,ESMX(I),LESMX(I)
200  CONTINUE
WRITE(6,9021) FF
9020  FORMAT(5X,I2,6X,1PE10.3,8X,I2)
WRITE(6,9021) FF
9021  FORMAT(A1)
   IPAGE = 2
   WRITE(6,9000) TITLE,IPAGE,NPG,DAMFIL,DAMTTL,NMODES,NELM,FR
WRITE(6,9035)
9035  FORMAT(//20X,'ELEMENT DAMAGE SUMMARY')
WRITE(6,9040)
9040  FORMAT(/4X,'ELEMENT',27X,'MODE',27X,'POSSIBLE',
1   /4X,'NO.',27X,'NO.',28X,'DAMAGE')
   WRITE(6,9050) (I,I=I,NMODES)
9050  FORMAT(13X,15(I2,2X))
   DO 70 J=1,NELM
      WRITE(6,FMT) J,(AES(J,I),I=I,NMODES),PDAM(J)
      IF(MOD(J,40).NE.0) GO TO 70
      WRITE(6,9060)
      IPAGE = IPAGE + 1
      WRITE(6,9021) FF
      WRITE(6,9000) TITLE,IPAGE,NPG,DAMFIL,DAMTTL,NMODES,NELM,FR
WRITE(6,9035)
WRITE(6,9040)
WRITE(6,9050) (I,I=I,NMODES)
70  CONTINUE
WRITE(6,9060)
9060  FORMAT(//15X,'x indicates possible modal element damage')

C
C ALL DONE
C
STOP
END
APPENDIX B

SELECTED MATERIAL FROM MAC/RAN IV USER'S MANUAL
This manual corresponds to MAC/RAN IV Version 2.0

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B-3
The MAC/RAN IV System is a proven program for the analysis of time series data. Originally developed by Measurement Analysis Corporation of Los Angeles, MAC/RAN was acquired by University Software Systems in 1970. The program has been continuously refined and improved since that time and has served data processors and analysts in a wide variety of applications.

MAC/RAN IV differs from MAC/RAN III in a number of ways. Once an industry standard in the mainframe computer world of the 1970s, the advent of supermini, mini, and microcomputers led to the complete restructuring of MAC/RAN III. MAC/RAN IV can now take full advantage of the greater high speed memory (if available) of modern computers, virtual memory operating systems, and fast mass storage devices. A new, more compact data file structure, along with its direct access allows MAC/RAN to run efficiently on desktop microcomputers as well as the largest of mainframes. The Data File Manager controllers (replacing the EXEC "cards" of MAC/RAN III) reflect this change in data access and structure.

The first three chapters of this manual describe the terms and concepts used in MAC/RAN IV along with the structure of the program. Chapter 4 describes the Data File Manager. Chapters 5 through 15 describe the MAC/RAN IV processors. It is recommended that the user first carefully read Chapters 1 through 4 and study the examples (and possibly the Standard Test Case of Appendix B) to get a feel for the processing sequences. Chapters 5 and up may be referenced as needed.

The PREP (Chapter 5) and PSD (Chapter 8) Processors are particularly powerful and offer many attractive features. PREP contains the digital filters and PSD does spectral averaging (as opposed to simple frequency transformation in FOUR) along with coherency, cross spectra, and transfer function computation. Each computational processor has a section that describes the method or procedures that it uses.

MAC/RAN generally operates in a batch mode and is, in fact, designed to process large streams and many channels (up to 25 at one time) of data efficiently and with minimum user interference. However, if desired, MAC/RAN can now operate on a controller by controller basis, directly from the computer console. The main differences between this mode of operation and a truly interactive one, is that the user must have a grasp of the control language as MAC/RAN does not supply menus or help lists; the reference manual provides the information. The other difference from truly interactive operation is that the plots generated are not immediately displayed, but are written to a file for later postprocessing or output, depending on equipment and installation. Thus MAC/RAN IV remains essentially hardware independent during its operation.
CHAPTER 1 - INTRODUCTION

A. BACKGROUND

1. Time Series Analysis

A series of data values that are compiled with respect to their chronological occurrences can be considered a time series. This means that a data value or perhaps an ensemble of values are associated with one instant in time that in most cases precedes and succeeds another pairing or ensemble of values. A simple example might be recording the value of several stocks on a daily basis.

Time series analysis means applying analytic methods to better understand time histories of values or to reduce them into a form where conclusions can more readily be made from the data. Some typical examples of time series analysis might be plotting the data values with respect to their time occurrences, limiting the rates at which these values change (smoothing or filtering), or correlating one set of data points with another.

More often, one is concerned with a transformation of time series data into another domain such that more involved investigation can be facilitated. The most common of these transformations is the Fourier transform which in some sense calculates the frequency content of a time history of values. This transformation is a very powerful tool and is used extensively for many purposes, including power estimation, spectral display and analysis, certain types of correlation, and even mathematical integration and differentiation, among many others. Thus, time series analysis is a very broad term that includes many frequency domain techniques to deal with a wide spectrum of phenomena. These techniques are also applicable to situations that do not involve a time basis, since an analogy can be made with a time series.

2. Solving Time Series Problems

A typical way to solve isolated time series problems is to develop individual, non-integrated programs. This usually requires some research into the techniques employed, a choice of algorithms, and then the time consuming tasks of programming and debugging on a computer. With an arbitrary collection of programs to do the different kinds of signal and data analyses required, problems of compatibility are likely. For example, output from one program may not have the proper format for input to another program. Thus, programs and/or data may have to be partially rewritten nearly every time they are used. Frequent
program and data changes increase the probability for human error. Corrections are costly and time-consuming; more significantly, undetected errors may cause distorted or incorrect results.

3. MAC/RAN as a Time Series Tool

MAC/RAN incorporates sophisticated algorithms and data preparation techniques in its processors. This minimizes the signal processing expertise and computer coding necessary to analyze data correctly. All data entered into MAC/RAN remains in a standard data format that allows continuous processing through various modules or selective output at any time during a program run. In addition MAC/RAN processes multiple channels simultaneously for greater throughput.

MAC/RAN allows any one, several, or all of its state-of-the-art processing procedures to be specified within the same program run. The MAC/RAN driver and management software handle the delegation of tasks and data to the necessary modules by way of a command language. Thus, a command file can be easily edited to alter existing sequences of procedures, parameters, or input data. This avoids the rewriting of special software that is required to accommodate any adjustments needed to obtain the desired results.

MAC/RAN is not a programming language nor a set of subroutines from which one constructs his own data reduction system; instead, it is a self-contained data reduction system that provides flexibility in the choice of any specific processing procedures required at any given time.

B. SYSTEM FEATURES

1. Flexibility

As a package of state-of-the-art processing procedures, MAC/RAN performs a wide variety of basic computations to properly reduce time series data. Any one, several, or all of the basic processors (plus the Data File Manager) may be specified within the same program to solve a given problem. Figure 1-1 illustrates the MAC/RAN system.

Processors include:

- Data File Manager. (FILIN, FILOUT, MERGE)
- Data Preparation Processor (PREP)
- Fourier Analysis Processor (FOUR)
- Power Spectral Density Processor (PSD)
- Plugboard Simulation Processor (PLUG)
- Display Processor (PLOT)
- Input/Output Port (CTAPE)
- Convolution and Filtering Processor (CONFIL)
- Time and Frequency Analysis Processor (SPEC)
- Amplitude Statistics Processor (AMSTAT)
- Shock Spectrum Analysis Processor (SHOCKS)
- Linear Systems Analysis Processor (TRANS)

Figure 1-1. MAC/RAN System
2. **Simplified Programming Requirements**

This modular construction of MAC/RAN provides a simplified approach to processing time series data. The Data File Manager controls the flow of data from processor to processor in order to compute the functions specified in any given run. This feature significantly reduces the amount of control information the user must supply to link each specified processor.

3. **Integrated System Capability**

Through MAC/RAN's package of general programs, the complete processing for a given data set of time histories can be obtained with a single computer run; in contrast, a non-integrated system would extend the processing over a long period of time with individual computer runs required for each of the individual functions. However, the independence of the processors, even though they can be combined into a single package, allows any given total processor operation to be repeated any number of times in a single run. This flexibility in control of processing can be implemented by the control language parameters.

4. **Data Format Compatibility**

Throughout the system, every intermediate data format is the same; thus, input to any given processor is in the same format. Consequently, after data is initially fed into the MAC/RAN System, it need never be manually handled again. This greatly simplifies bookkeeping details and increases the efficiency of the overall processing procedure.

5. **Display Capability**

A special processor is devoted to providing printed and/or plotted outputs of any data or any intermediate functions stored in the standard MAC/RAN format. Inherent within the display processor is the ability to select logarithmic or decimal scales, plus the basic linear scale and scale increment selections in numerically simple values.

C. **SYSTEM CONFIGURATION**

The MAC/RAN General Process Chart, shown in Figure 1-2, illustrates the flow of data through the system, and the interrelationship between the various stages of processing. These stages are described by symbols representing software, hardware and people.
1. **Input**

Input to MAC/RAN consists of a control file and data to be analyzed for the desired processors.

2. **Control**

Control of processing is maintained by the System Manager, invisible to the user, through the parameters in the control file.

3. **Output**

Generally, a computational processor prints its operational information and the channel statistics of the output data. This processed data is written out as a Standard Data File (SDF). The Display Processor (PLOT, not considered computational) may be used at any time to print or plot data from the SDF of any MAC/RAN processor. Some computational processors optionally print and plot their own output during execution.

Figure 1-2. MAC/RAN General Process Chart
CHAPTER 2 - SYSTEM OPERATION

A. GENERAL

MAC/RAN consists of a System Executive, a Data File Manager and various processors that do the time series analysis. In addition, there are two special processors that handle I/O and communicate MAC/RAN results to the user, respectively. User inputs to MAC/RAN are a Standard Control File (SCF) and (in most cases) one or more data files. These data files can contain multiple channels of data that are to be processed simultaneously, if desired.

The system operation follows the user commands placed in the input control file. The System Executive recognizes these user specified commands and transfers control to the data file manager or one of the processors.

The MAC/RAN Executive takes care of system initialization, control file information, calls the required processors, and constantly updates the channel statistics during processing. During the course of the processors' computations, the Executive also decides when to write the output data to the appropriate disk file.

The Data File Manager can combine input data files, select or combine channels, and edit the data to be processed. Editing features are start and stop time specification, leading or trailing zero padding, specification of number of points desired, and decimation. Interpolation is possible using the PREP Processor.

B. STANDARD CONTROL FILE (SCF) FORMAT

A Standard Control File consists of various control records, or rows of control information, from which the System Executive drives MAC/RAN. These control records must conform to a standard format of seven fields per record.

The first three fields are alphanumeric and generally contain processor names and processor functions (controllers) as well as annotation information. Field 2 is used only for continuation with certain processors. Fields 4 through 7 are numeric (except when the JBHEAD controller is used). Numbers in these fields can be placed anywhere if a decimal point is supplied, otherwise they must be right justified. Generally, blanks in numeric fields are interpreted as zeros. A complete description of the specific control record formats are given in the following chapters.

The control field format is shown below. The arrows mark the beginning of the field that follows.
Control Field Format:

<table>
<thead>
<tr>
<th>i</th>
<th>f1</th>
<th>f2</th>
<th>f3</th>
<th>i</th>
<th>f4</th>
<th>f5</th>
<th>f6</th>
<th>i</th>
<th>f7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>24</td>
<td>36</td>
<td>48</td>
<td>60</td>
<td>71</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Record 1  
Record 2

C. MAC/RAN STANDARD DATA FILE (SDF) FORMAT

All data files generated by the system are written in a standard binary format. The first record of a SDF stores channel names and statistics. The subsequent records store channel data. The channel statistics consist of the mean value, variance, maximum value, minimum value, number of channel data points, and sampling rate.

All MAC/RAN processors generate channel statistics when they output a SDF file. The channel (or function) names are defined by the user and they provide annotation for plots. If no names are entered, MAC/RAN supplies them as DATA1, DATA2, etc. If the names are properly chosen, then the plots will be easily identifiable.

D. DEFINITION OF TERMS EMPLOYED

1. General

Controller - A MAC/RAN control word or a part of a control record that specifies control information to the system; e.g., "PLUG" or "FILTLOW" (in the PREP Processor). It must be capitalized.

Control Field - One of seven specific areas of a control record where MAC/RAN control parameters are placed.

Control File - A disk file that contains the control records to drive MAC/RAN in its specific tasks.

Control Group - Adjacent control records with the same controller in a MAC/RAN control file.

Control Record - A record in the MAC/RAN control file that contains a controller and optionally, other control parameters.

DFM - The Data File Manager.

2-2
2. Mathematical

A time series \( x_i \) will be assumed to be sampled at equal spaced intervals separated in time by an amount \( \Delta t \), so that the continuous form of \( x_i \), \( x(t) \), is related to it by

\[
x(t) = x(i\Delta t) = x_i
\]

(2.1)

Without loss of generality, \( i \) will be assumed to have the range 0,1,...,N-1 for a total of N values.

The series \( y_i \) will frequently be used to represent either a second series, or the original series \( x_i \) after some operation such as digital filtering.

Fourier transforms will be denoted with capital letters. For example, the Fourier transform of \( x(t) \) will be written as \( X(f) \) where \( f \) is frequency in Hz. The Fourier transform of \( x_i \) will be written \( X_k \) where

\[
f_k = k\Delta f
\]

(2.2)

and \( \Delta f \) is the frequency interval in Hz. Usually,

\[
f_k = \frac{1}{N\Delta t}
\]

(2.3)

The sampling rate \( f_s \) is usually input to the program rather than \( \Delta t \), but their relation is quite simple.
The maximum frequency, \( f_N \), sometimes referred to as the Nyquist frequency is

\[
f_N = \frac{f_s}{2} = \frac{1}{2\Delta t}
\]  

(2.5)
CHAPTER 12 - DISPLAY PROCESSOR (PLOT)

A. FUNCTION

The Display Processor provides a convenient means for listing and/or plotting output from any data file in the MAC/RAN SDF format. Any function or combination of functions from a file computed with the MAC/RAN System and written on disk in the SDF format may be saved and later printed or plotted by the Display Processor.

B. INPUT/OUTPUT SPECIFICATIONS

1. Input

   a. Control Inputs to the Display Processor include:
      - Printer and/or plot selection
      - Multiple plot selection
      - Plot widths and lengths
      - Plot data intervals
      - Plot scale selection - linear, log, or db

   b. Control Inputs to Data File Manager (DFM). The FILIN controller (and optional FILIN CCHAN Controller) is required to describe input disk files.

   c. Data Input. Input may consist of one or more channels of time series data in MAC/RAN SDF format.

2. Output

   Any desired listing and/or plots with one to 24 curves per plot may be specified. As indicated above, SDFs that have been produced by any computational processor in standard format may be reprinted or replotted at any time.

C. CONTROL RECORDS

Control records for the Display Processor may be input in any order with the exception of multiplot continuation records which must follow the multiplot definition record (see C.1.g below). All control records are optional.

1. Format

   The basic format of each record is shown in the following figure.
a. **Plot/Print Record**

Field 1 - PLOT
Field 3 - Print and single plot output options

Blank → Print and plot
PLOT → Plot only - (left adjusted)
PRINT → Print only - (left adjusted)

b. **Individual Print Selection Record**

Field 1 - PLOT  
Field 3 - PRINTIND

If print is requested through Record (a), a simultaneous printout of all input data channels is nominally produced. If the Individual Print Selection Record is input, however, a separated printout of the independent variable along with each dependent variable is produced rather than the simultaneous printout.

c. **Independent Variable Selection Record**

Field 1 - PLOT  
Field 3 - INDE - (left adjusted)

Independent channel number (numerical 1-25) -  
(columns 16-17, right adjusted)

The independent data channel for printing and for the individual plots is nominally Channel 1. This may be overridden by specifying the independent variable through this controller.
d. **Plot Type and Log Plot Cycle Size Selection Record**

**Field 1** - PLOT
**Field 3** - LOG - (left adjusted)

Nominal plot type (numerical 1-8) - (column 23)
1  •  Linear x, linear y
2  •  Linear x, log y
3  •  Log x, linear y
4  •  Log x, log y
5  •  Linear x, 10 log\(_{10}(y)\)
6  •  Linear x, 20 log\(_{10}(y)\)
7  •  Log x, 10 log\(_{10}(y)\)
8  •  Log x, 20 log\(_{10}(y)\)

The nominal plot type (type 1 unless specified by this record) is used for all plots for which no specific plot type is requested (see the SCALE record and MULT record below).

**Field 4** - Log cycle size in inches for x-axis (floating point). If not specified, 2.0 is used.

**Field 5** - Log cycle size in inches for y-axis. If not specified, 2.0 is used.

---
e. **Scale Selection Record**

**Field 1** - PLOT
**Field 3** - SCALE - (left adjusted)

Dependent channel number, dependent variables only (numerical 2-25). (Columns 16-17, right adjusted.) Defines variable number for which the Scale Selection Record parameters apply. If this field is blank, the record parameters are applied to all individual plots.

Plot Type - (numerical 1-8) - (column 23).
Specified plot type is used for plots implied by above channel number field. If blank, nominal plot type is used (see C.1.d above).

**Field 4** - Origin for x-axis (floating point)

**Field 5** - Maximum value for x-axis (floating point)

If Fields 4 and 5 are not specified, processor selects x-axis scales.
Field 6 - Origin for y-axis (floating point)
Field 7 - Maximum value for y-axis (floating point)

If Fields 6 and 7 are not specified, processor selects y-axis scales.

f. **Plot Axis Name Record**

Field 1 - PLOT
Field 3 - NAME (left adjusted)
12-character name field (columns 12-23)

Specifies a 12-character label for plot axes for channel numbers given in Fields 4 through 7. If not specified for a channel, the name (ID) field on the data file is used.

Fields - Channel numbers to which specified name field applies.

Field 4-7 - Channel numbers

**g. Multiple Plot Definition Records**

The Multiple Plot Definition Records define a single plot containing multiple dependent variables plotted against a single independent variable on the same set of axes. Only one multiplot may be requested in one execution of the Display Processor.

Field 1 - PLOT
Field 3 - MULT (left adjusted)

Independent Channel Number - (numerical 1-25) - (columns 16-17, right adjusted). Specifies independent variable for multiplot. If omitted, the nominal independent variable is used (see C.1.c).

Number of dependent channels to be plotted - (numerical 1-24) - (columns 20-21, right adjusted). If blank, all data channels except the independent channel are plotted.

Plot Type - (numerical 1-8) - (column 23). If omitted, the nominal plot type is used (see C.1.d).

Field 4 - Origin for x-axis (floating point)
Field 5 - Maximum value for x-axis (floating point)
If Fields 4 and 5 are not specified, processor selects x-axis scales.

Field 6 - Origin for y-axis (floating point)
Field 7 - Maximum value for y-axis (floating point)
If Fields 6 and 7 are not specified, processor selects y-axis scales.

1) **Multiplot Continuation Record**

Field 1 - PLOT  
Field 2 - C  
Field 3 - MULT (left adjusted)  
Fields - Dependent data channels to be plotted - (numerical 1-25) - columns 34-35, 46-47, 58-59, 70-71). If specific dependent data channels are not specified, the first n channels (not including the independent channel) are used where n is specified by the Multiple Plot Definition record above. If fewer than n channels are explicitly requested, the remainder are automatically selected starting from the first variable (omitting the independent channel and avoiding duplication). As many Multiplot Continuation Records as necessary may be input.

2) **Multiplot Name Record**

Field 1 - PLOT  
Field 2 - C  
Field 3 - NAME (left adjusted)  
12-character label (columns 12-23) for y-axis of multiplot. If not specified, the name field is selected based on the first requested dependent channel.
D. EXAMPLE

<table>
<thead>
<tr>
<th></th>
<th>78</th>
<th>24</th>
<th>38</th>
<th>48</th>
<th>60</th>
<th>71</th>
</tr>
</thead>
<tbody>
<tr>
<td>f1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f2</td>
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<td>f3</td>
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<td>f4</td>
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<td>f5</td>
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<td></td>
</tr>
<tr>
<td>f6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PLOT
PLOT INDE 2
PLOT SCALE 15 4 10. 1000.
PLOT LOG 3
PLOT NAME EARLY TIMES 2
PLOT MULT 10 5 10. 53. 6. 900.
PLOT CMULT 4 7 12 6
PLOT CMULT 21
PLOT CNAMESCOINCIDENCE

Explanation:

Record | Effect
-------|-------------------------------------------------------------
1       | Produce multiple print and individual plots.
2       | Use Channel 2 for independent variable.
3       | Use plot type 4 (log-log) on the individual plot of Channel 15. Scale the y-axis on the Channel 15 plot using 10. as the origin and 1000. as the maximum value.
4       | Plot all unspecified plots as log-linear. (In this case, all except Channel 15).
5       | Label the Channel 2 axes (in this case, the independent axis) as "EARLY TIMES."
6-8     | Produce a multiple plot of the five dependent channel numbers 4, 7, 12, 6, and 21 versus the independent channel number 10. Scale the x-axis using 10. and 53. and y-axis using 6. and 900. as the origins and maximum values. Note: the plot type will be type 3 as specified on Record 4.
9       | Label the y-axis on the multiplot as "COINCIDENCE."
CHAPTER 15 - LINEAR SYSTEMS ANALYSIS PROCESSOR (TRANS)

A. FUNCTION

The Linear Systems Analysis Processor (TRANS) operates on spectral density matrices from order 2 up to a maximum of 24. Frequency response functions, coherence functions (ordinary, multiple, and partial) and associated confidence limits are computed for single-input/single-output and for multiple-input/single-output linear systems.

B. INPUT/OUTPUT SPECIFICATIONS

1. Input

   a. Control Input to Linear Systems Analysis Processor. These include:

      o Specification of output channel
      o Plot option for coherence and frequency response functions
      o Plot option for confidence limits
      o Computation option for complete ordinary coherence matrix

   b. Control Inputs to Data File Manager (DFM). FILIN Record required to describe the special spectral density format input file.

   c. Data Input. The special spectral density file as generated by either the Time and Frequency Analysis Processor (SPEC) or the Power Spectral Density Processor (PSD).

2. Output

   Output from the TRANS Processor includes plots and listings of the frequency response (provided in terms of gain in db and phase in degrees) and coherence functions. Optionally, the resulting transfer functions may be output to SDF.

C. CONTROL RECORDS

TRANS normally requires very little input, as all the information it needs for default execution is on SDF. In summary, the record formats are as follows:

15-1
<table>
<thead>
<tr>
<th>Record No.</th>
<th>Field 3</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>blank</td>
<td>Call TRANS</td>
</tr>
<tr>
<td>2</td>
<td>CONF</td>
<td>Set confidence intervals</td>
</tr>
<tr>
<td>3</td>
<td>PCON</td>
<td>Plotting of confidence intervals</td>
</tr>
<tr>
<td>4</td>
<td>OUT</td>
<td>Defines output function</td>
</tr>
<tr>
<td>5</td>
<td>ORDC</td>
<td>Ordinary coherence matrix</td>
</tr>
<tr>
<td>6</td>
<td>SCAL</td>
<td>Scaling of plots</td>
</tr>
<tr>
<td>7</td>
<td>TAPE</td>
<td>SDF output of the transfer functions</td>
</tr>
</tbody>
</table>

1. **Format**

   a. **Record No. 1 (Optional)**

      Default calling of TRANS. Not required if any other TRANS record is used.

      Field 1 - TRANS

   b. **Record No. 2 (Optional)**

      Used only if it is desired to change the default confidence limits

      Field 1 - TRANS  
      Field 3 - CONF  
      Field 4 - Confidence interval for coherence functions

          $0 \rightarrow 0.95$ (95%) is assumed

      Field 5 - Confidence interval for frequency response functions

          $0 \rightarrow 0.95$ (95%) is assumed

   c. **Record No. 3 (Optional)**

      This record causes the confidence intervals to be plotted

      Field 1 - TRANS  
      Field 2 - PCON

   d. **Record No. 4 (Optional)**

      Used only if the output function is other than number one

      Field 1 - TRANS  
      Field 3 - OUT  
      Field 4 - Output channel number ($0 \rightarrow$ function number 1)
### Record No. 5 (Optional)

Used only if it is desired to print and plot the ordinary coherence between all possible input functions in addition to the ordinary coherence between the inputs and the output.

Field 1 - TRANS
Field 3 - ORDC

### Record No. 6 (Optional, up to 25 may be employed)

Field 1 - TRANS
Field 3 -

<table>
<thead>
<tr>
<th>Subfield</th>
<th>Columns</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>8-11</td>
<td>The letters of SCAL.</td>
</tr>
<tr>
<td>ii</td>
<td>12-15</td>
<td>GAIN (gain is the only function whose plotting may be varied).</td>
</tr>
<tr>
<td>iii</td>
<td>16-17</td>
<td>One or two digits which indicate which data function is to be plotted. For example, GAIN 02 would say that gain two is to be specially plotted. If left blank, all types of functions as defined by subfield ii are scaled according to this record.</td>
</tr>
<tr>
<td>iv</td>
<td>18-19</td>
<td>Used only if it is desired to define a second dependent variable, in which case the field contains one or two digits indicating the second function.</td>
</tr>
<tr>
<td>v</td>
<td>20-23</td>
<td>A single digit to indicate the plot type:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
</tr>
</tbody>
</table>

The balance of the special plotting records is as follows:
Field | Columns | Linear | Log
--- | --- | --- | ---
4 | 24-35 | $x_{\text{min}}$ | ---
5 | 36-47 | $x_{\text{max}}$ | number of cycles
6 | 48-59 | $y_{\text{min}}$ | ---
7 | 60-71 | $y_{\text{max}}$ | number of cycles

**g. Record No. 7 (Optional)**

This is used only if it is desired to output the transfer functions onto SDF.

Field 1 - TRANS
Field 3 - TAPE

If there are more than twelve input functions, only the first twelve transfer functions will be output. Output is in the form of real and imaginary parts. In order for this output to be useful, the "RETAIN" option in PSD will probably have to be requested if PSD was used to set up the input matrix. Otherwise, the number of frequency points will not be commensurate with MAC/RAN FFT lengths. That is, it may not be possible to inverse transform the transfer functions if the "RETAIN" option is not requested.

2. **Example**

<table>
<thead>
<tr>
<th>1</th>
<th>78</th>
<th>24</th>
<th>36</th>
<th>48</th>
<th>60</th>
<th>71</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_1$</td>
<td>$f_3$</td>
<td>$f_4$</td>
<td>$f_5$</td>
<td>$f_6$</td>
<td>$f_7$</td>
<td></td>
</tr>
</tbody>
</table>

**FILIN**  Filename
**TRANS**
**END**

**Explanation:** This is the default execution of TRANS. Filename is the special spectral density matrix input to TRANS. The standard output will consist of plots and listings of frequency response between the output (default is function no. 1) and all the inputs in addition to the coherence functions. No SDFs of the output transfer functions are generated, hence there is no need for a FILOUT controller. The END controller terminates the run.
D. Method

The computational procedures described here will be for computing parameters of a mathematical model assuming a p input \( x_i(t), i = 1,2,\ldots,p \) and single output \( y(t) \) linear system. The system parameters to be computed are:

- Frequency response functions between each of the inputs and the output.
- Ordinary coherence functions between the inputs and the output, and between all pairs of variables as an option.
- The multiple coherence function between the output and all of the inputs.
- Partial (conditional) coherence functions between each input and the output while conditioning on the other inputs.

Chapter 9 of DTSA discusses this problem and lists important references.

1. Computational Procedures

The computational procedures necessary for these options subdivide into three groups:

- **a.** Power and cross-spectral density function computational routines.

- **b.** A procedure for simultaneously handling \( p + 1 \) variables to efficiently obtain the spectral density functions among all these variables.

- **c.** The complex variable arithmetic and matrix operations to compute the multidimensional linear system parameters.

The spectral density functions can be computed by the PSD or SPEC Processors. In either case a \( (p + 1) \) by \( (p + 1) \) set of power and cross-spectral density functions is generated and employed as the input data for this processor.

The first operation performed by this processor is a sorting procedure. The spectral density functions are each supplied as a function of frequency. The Linear Systems Analysis Processor eventually must operate on the \( (p + 1) \) by \( (p + 1) \) spectral density matrices, one matrix for each frequency value.
The data operated on by the program will be a set of spectral density matrices at frequencies indexed by \( k \) as follows:

\[
\begin{bmatrix}
G_{yy}(k) & G_{y1}(k) & G_{y2}(k) & \cdots & G_{yp}(k) \\
G_{1y}(k) & G_{11}(k) & G_{12}(k) & \cdots & G_{1p}(k) \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
G_{py}(k) & G_{p1}(k) & G_{p2}(k) & \cdots & G_{pp}(k)
\end{bmatrix}
\]

\[k = 0, 1, \ldots, m\]  

(15.1)

The frequency index \( k \) can represent special frequency values

\[f_k = \frac{kf_c}{m}\]

(15.2)

where \( f_c \) is the Nyquist cut-off frequency. More generally, \( k \) can represent the frequency values

\[f_r = f_l + k\Delta f\]

(15.3)

where

\[f_l = \text{Beginning frequency}\]
\[\Delta f = \text{Frequency increment}\]  

(15.4)

Note: \( m \) might denote the maximum lag value if frequency points from (15.2) are used, but might only denote the maximum frequency index if (15.3) is used.

2. **Computation of Frequency Response Functions**

The mathematical model assumed is indicated in the block diagram of Figure 15-1.

The \( p \) input variables and the output variable are assumed to be zero mean, stationary, Gaussian processes whenever any statistical distribution results are discussed. The quantities \( H_{iy}(f) \), \( i = 1, 2, \ldots, p \) are the frequency response function (transfer function) characteristics of the linear systems through which the variables are passing to make up \( y(t) \).
Figure 15-1. Multiple-Input/Single-Output Linear System
The variables $x_i(t)$, $i = 1, 2, \ldots, p$ and $y(t)$ are assumed to be discrete (digitized) sequences of $N$ points each. The notation for the $N$ discrete points may be

$$
x_{1n} = x_1(n\Delta t) \\
x_{2n} = x_2(n\Delta t) \\
\vdots \\
x_{pn} = x_p(n\Delta t) \\
y_n = y(n\Delta t) 
$$

where $\Delta t$ is the sampling (digitizing) interval.

The matrix equation to be solved to determine the frequency response function is

$$
\begin{bmatrix}
G_{1y} \\
G_{2y} \\
\vdots \\
G_{py}
\end{bmatrix}
= 
\begin{bmatrix}
G_{11} & G_{12} & \cdots & G_{1p} \\
G_{21} & G_{22} & \cdots & G_{2p} \\
\vdots & \vdots & \ddots & \vdots \\
G_{p1} & G_{p2} & \cdots & G_{pp}
\end{bmatrix}
\begin{bmatrix}
H_{1y} \\
H_{2y} \\
\vdots \\
H_{py}
\end{bmatrix}
$$

(15.6)

where the function argument has been omitted for notational simplicity (e.g., $G_{11}$ is written instead of $G_{11}(k)$). It is understood that (15.6) is a function of the frequency index $k$. The matrix and vectors in (15.6) are complex valued and hence require complex arithmetic operations for correct manipulation. In particular,

$$
G_{11} = C_{11} - jQ_{11}
$$

(15.7)

where $C = C(k)$ and $Q = Q(k)$ are the appropriate co-spectral and quadrature spectral density functions at index value $k$.  

15-8

B-27
The solution to (15.6) is

\[
\begin{bmatrix}
H_{1y} \\
H_{2y} \\
\vdots \\
H_{py}
\end{bmatrix} =
\begin{bmatrix}
G_{11} & G_{12} & \cdots & G_{1p} \\
G_{12} & G_{22} & \cdots & G_{2p} \\
\vdots & \vdots & \ddots & \vdots \\
G_{p1} & G_{p2} & \cdots & G_{pp}
\end{bmatrix}^{-1}
\begin{bmatrix}
G_{1y} \\
G_{2y} \\
\vdots \\
G_{py}
\end{bmatrix}
\tag{15.8}
\]

or in simpler notation

\[
H_{xy} = (G_{xx})^{-1} G_{xy} \tag{15.9}
\]

An individual frequency response function is given by

\[
H_{iy} = \sum_{i=1}^{p} G_{i1} G_{iy} \quad i = 1, 2, \ldots, p \tag{15.10}
\]

3. Computation of Coherence Functions

The ordinary coherence functions between the output \(y\) and each input \(x_i\) are computed by

\[
\gamma_{iy} = \frac{|G_{iy}|^2}{G_{ii} G_{yy}} = \frac{C_{iy}^2}{G_{ii} G_{yy}} \quad i = 1, 2, \ldots, p \tag{15.11}
\]

The multiple coherence function between the output \(y\) and all of the inputs \(x_1, x_2, \ldots, x_p\) is computed by

\[
\gamma_{yx} = 1 - [G_{yy}, G_{yy}]^{-1} \tag{15.12}
\]

where \([G_{yy}, G_{yy}]^{-1}\) denotes the first diagonal element of the inverse matrix \((G_{yy})^{-1}\) associated with \(G_{xx}\) of (15.1).

Ordinary and multiple coherence functions for the set of inputs \(x_1\) alone are defined by considering the \(p\) by \(p\) spectral matrix of the inputs.
The ordinary coherence function between any two inputs \( x_i \) and \( x_j \) is computed by

\[
\gamma_{ij} = \frac{|G_{ij}|^2}{G_{ii} G_{jj}} = \frac{C_{ij}^2 + Q_{ij}^2}{G_{ii} G_{jj}}
\]  
(15.14)

To obtain the partial coherence function between any input, say \( x_1 \), and the output conditioned on the remaining \((p - 1)\) inputs, \( G_{y|x} \) is partitioned as indicated below.

\[
G_{y|x} = \begin{bmatrix}
G_{yy} & G_{y1} & G_{y2} & \cdots & G_{yp} \\
G_{1y} & G_{11} & G_{12} & \cdots & G_{1p} \\
G_{2y} & G_{21} & G_{22} & \cdots & G_{2p} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
G_{py} & G_{p1} & G_{p2} & \cdots & G_{pp}
\end{bmatrix}
= \begin{bmatrix}
\sum yy & \sum y1 \\
\sum 1y & \sum 11
\end{bmatrix}
\]  
(15.15)

Then compute the conditional spectral matrix

\[
G_{y|x}^{-1} = \sum yy - \sum y1 \left( \sum 11 \right)^{-1} \sum 1y
\]  
(15.16)

This procedure requires the equivalent of the inversion of the \((p-1)\) by \((p-1)\) complex valued matrix \( \Sigma_{ij} \). An individual element \( G_{iy|x} \) of the \(2\times2\) matrix \( G_{y|x}^{-1} \) can be written in terms of real and imaginary parts as

\[
G_{y|x}^{-1} = \begin{bmatrix}
G_{yy} & G_{y1} \\
G_{1y} & G_{11}
\end{bmatrix}
\]
The partial coherence function between the input $x_1$ and the output $y$, conditioned on the other $(p-1)$ inputs, is now computed by

$$G_{1y} l_p = C_{1y} l_p - JQ_{1y} l_p$$  \hspace{1cm} (15.17)$$

$$\gamma_{1y} l_p = \frac{|G_{1y} l_p|^2}{G_{11} l_p G_{yy} l_p} = \frac{2}{G_{11} l_p G_{yy} l_p}$$  \hspace{1cm} (15.18)$$

Similar results apply for $x_2$ by interchanging $x_2$ with $x_1$, for $x_3$ by interchanging $x_3$ with $x_2$, etc.

In the special case of a single-input/single-output linear system, all coherence functions are identical. This can be verified by examining (15.17) for partial coherence and (15.12) for multiple coherence. Upon substituting in values when $p = 1$, these equations will both reduce to (15.11).

4. Confidence Limit Computations

In addition to the computation of the basic parameter estimates, the confidence limits for the different coherence functions and for the frequency response functions are computed. Confidence limits are supplied for gain and phase of the frequency response functions.

The degrees of freedom, $n$ are given by

$$n = 2B_s T$$

where $B_s$ is the effective spectral resolution bandwidth and $T$ is the effective record length. For the special case of the single-input/single-output system, $p = 1$ the equations apply to ordinary coherence functions.

For a complete definition and interpretation of the confidence limits, see DTSA.

5. Number of Digits of Precision Plot

Equation (15.18) is not solved explicitly. Rather, a simultaneous equation solution is employed. The computations are performed in a manner that also produces an estimate of the accuracy of results from a numerical viewpoint. In particular, it estimates the number of decimal digits which are significant in the results. As there is one such result for each frequency point, it is essentially a function of frequency for this application. A plot is produced of the digits function, and it is, in fact, the last plot produced by the processor.