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A SURVEY OF PRE- AND POSTPROCESSORS FOR NASTRAN

Gordon C. Everstine
and
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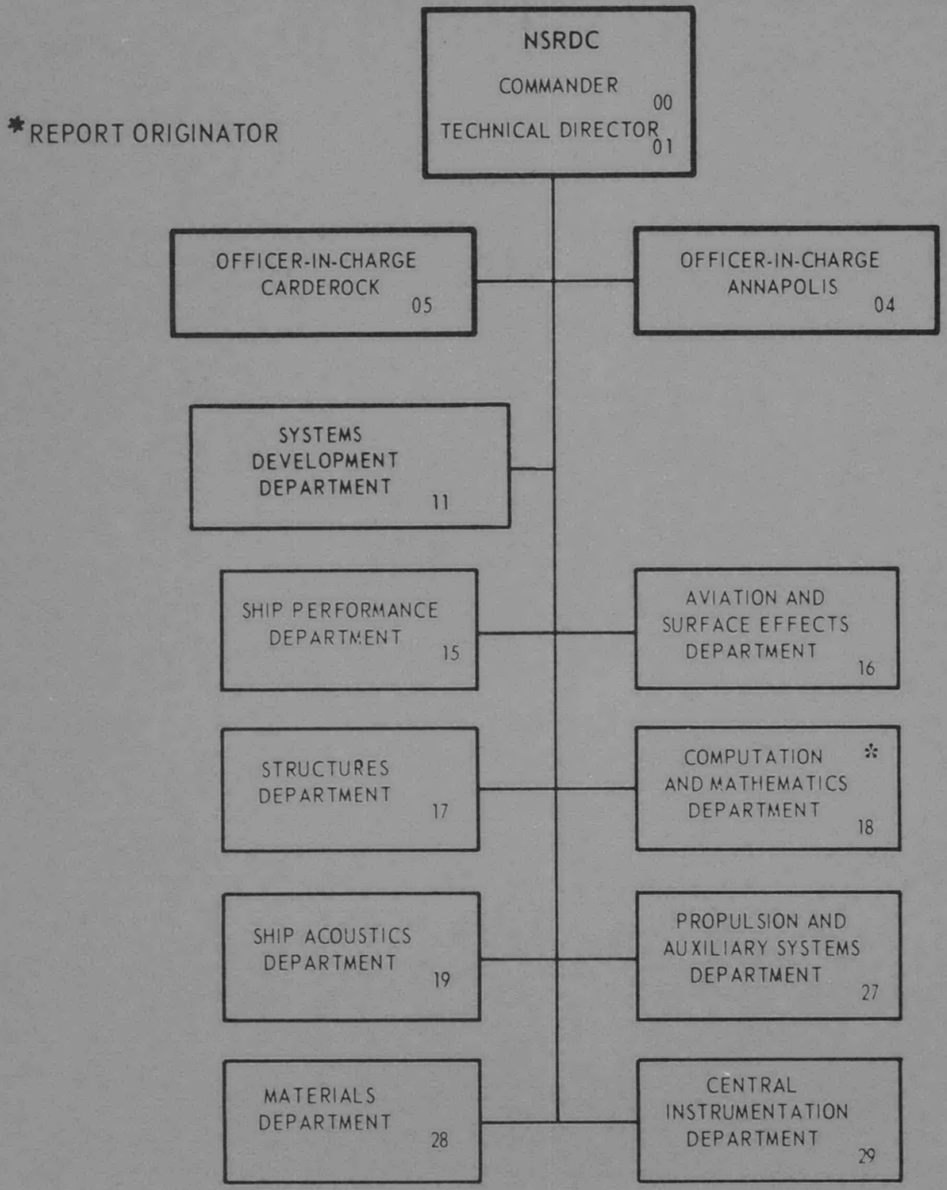

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This paper surveys various preprocessors and postprocessors developed for use with the NASA Structural Analysis Computer Program, NASTRAN. The following topics are included in the survey: automatic data generation, data checking and updating, conversion of data to NASTRAN format, grid point resequencing, partitioning vectors, radiation view factors, contour plotting, NASTRAN's General Purpose Plotter (NASTPLT), data transfer utilities,

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transient response to input accelerations, rigid links, processors for vehicle dynamics, antenna radiation, and structural modification reanalysis.

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PREFACE

This study was performed under the sponsorship of the Navy NASTRAN Systems Office (NNSO), Task Area ZF 0990101, Work Unit 1-1844-007. NNSO is funded in part by the Office of the Director of Navy Laboratories (DNL).

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A SURVEY OF PRE- AND POSTPROCESSORS FOR NASTRAN

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ABSTRACT

This paper surveys various preprocessors and postprocessors developed for use with the NASA Structural Analysis Computer Program, NASTRAN. The following topics are included in the survey: automatic data generation, data checking and updating, conversion of data to NASTRAN format, grid point resequencing, partitioning vectors, radiation view factors, contour plotting, NASTRAN's General Purpose Plotter (NASTPLT), data transfer utilities, transient response to input accelerations, rigid links, processors for vehicle dynamics, antenna radiation, and structural modification reanalysis.

INTRODUCTION

The development over the last few years of structural analysis computer programs has enabled the engineer to solve complicated structural engineering problems, in contrast with the previous situation in which he was limited to the study of only very simple approximations to the real structure. Early programs generally addressed either particular types of analyses or limited classes of structures, or both, and hence would now probably be classified as special purpose.

More recently, this fragmented approach to computer structural analysis has given way to the development of so-called general purpose computer programs. Of the programs which address primarily linear problems, the most widely used is probably the NASA Structural Analysis Program, NASTRAN [1-6]. NASTRAN's success is probably due to a combination of its wide-ranging capability, its convenience of use, and its availability.

In the opinion of T.G. Butler [7], the original NASTRAN project manager at NASA, one consequence of the existence of computer programs such as NASTRAN will be a shift in emphasis away from mechanical testing in favor of analysis as a proof of design. This in turn will result in an increased need and justification for the development of preprocessors and postprocessors to aid the user in both the preparation of data and the interpretation of results. With respect to NASTRAN, this prediction has certainly been realized (as evidenced in part by the number of references listed at the end of this paper).

In view of the length of time that NASTRAN has been publicly available (over four years) and the proliferation of NASTRAN-related computer software development, there seemed to be a need for a survey of the work performed to date. It is thus the object of this paper to survey the pre- and postprocessors that have been developed for use with NASTRAN and briefly describe the capabilities of each.

In what follows, it is assumed that the reader has at least a rudimentary knowledge of NASTRAN's capabilities and how to use it. With the exception of the following section, in which the survey's scope is defined, a separate section is devoted to each of 14 areas in which NASTRAN-related processors have been written.

SCOPE OF SURVEY

For the purposes of this survey, we consider a preprocessor or postprocessor to be any computer program peripheral to NASTRAN which interfaces with NASTRAN to perform some useful job not already performed by NASTRAN. In general, a processor must satisfy the following three requirements in order to be included: (1) its interface with NASTRAN must be operational, (2) it must be documented, and (3) it must be available to the general public. In some cases, availability involves interaction with a commercial computer service.

Specifically excluded from this survey are the many so-called one-shot processors which were never intended to be used by anyone other than the developer. For some jobs, such processors are often invaluable. The first requirement above also excludes processors developed for programs other than NASTRAN, even those processors which could be easily adapted to NASTRAN format. The more general scope is addressed by other papers in this volume.

While we have attempted to be as comprehensive as possible in this survey, we were unable to obtain copies of some relevant documentation, and hence had to omit several processors. Even for those programs included, many are receiving continued development, so that our descriptions may soon be out-of-date. Hopefully this survey will have served its purpose if it does nothing more than collect a list of references in one place and possibly identify those hotbeds of NASTRAN-related development.

Finally, since the authors have not personally executed all the computer programs described, the paper is,of necessity, an uncritical survey.

DATA GENERATING PREPROCESSORS

As finite element users have long recognized, the preparation of input data usually involves considerable drudgery. Data generation for finite element programs covers a wide range of applications. The range of data generation computer programs surveyed for this paper is correspondingly wide, both in terms of program capability and in the way that the programs are used.

Background

Data generation programs are labor saving devices which are used to eliminate the tedium and manual effort usually associated with the preparation of point-by-point structural data for finite element programs like NASTRAN. The effort required to write a program which will generate most of the geometric and connecting data for a structure is seldom more than that required for computing and transcribing the data by hand. Moreover, the resulting idealization will have fewer errors. A useful program may be written which generates only one particular structural idealization, but if certain attributes of the model (e.g., dimensions) are made parameters rather than constants, the program will be capable of generating various families of structural idealizations. The degree to which the parameterization is carried out depends, to some extent, on whether the program developer expects to encounter similar problems in the future.

Some organizations which make heavy use of finite element programs have concluded that significant savings could be realized by developing one general purpose data generation program and making it available to all their engineers, rather than having each engineer put together his own generators.

Although most generation programs have been developed from heuristic considerations, Kamel and Eisenstein [8] have investigated techniques for forming an acceptable finite element mesh from a more theoretical viewpoint. These techniques are used to model arbitrary surfaces with triangular elements. The determination of the best mesh for a particular structure is still largely an art, and the generation programs considered here either constrain the user to a predefined mesh pattern or require that he determine the appropriate mesh. Although in some situations one might like to have a data generation program and an analysis program combined into a fool-proof "black box", the fact that engineering judgment is required to create a suitable mesh is sufficient to rule out existing programs for such a combination. Eppink [9] has studied some of the Navy's data generation requirements and has offered guidelines for the development of systems to generate complete models of ships and other large complex structures.

Techniques for generating data vary widely among programs. Most generation programs, however, use a combination of three techniques: (1) a parametric description of the model, (2) a compiler or other facility for user-defined generating algorithms, and (3) a digitization of points on the model by electromechanical means.

A generator which employs the first technique, a parametric description of the model, will accommodate structures with one basic form. Each particular individual structure can be generated by assigning specific values to a set of parameters. For example, a program for generating rectangular plates might have length, width, thickness, and the number of elements on each side as parameters. By themselves, these generators are most applicable when the user has many similar structures to analyze. However, a combination of several of these generators, each generating a basic geometric shape, can be used effectively for general problems.

Facilities for user-defined generating algorithms, the second technique, function as compilers or translators which assemble the required computer instructions from statements given by the user. Although these programs can be similar to FORTRAN or ALGOL compilers, they have additional features which automatically perform sequences of operations which occur frequently in data generation.

A typical compiler could readily process commands such as the following:

> Generate ten grid points beginning with number 105 and increment each grid number by ten. Let the coordinates of the first grid point be (1.0, 1.0, 0.0) and increment the first component by .5 for each successive grid point.

This type of generation program is usually very flexible and can be applied to any structural problem, although it does require the user to invent the generation procedure. A good deal of ingenuity may be required to use this type of program effectively for complex structures.

The third technique used in generation programs employs electromechanical digitizing equipment. Here the user is permitted to scan a scale drawing of the structure with a digitizing device and automatically record the positions of grid points for the model. Stand-alone digitizers can be used for this purpose, but they tend to be cumbersome whenever supplementary information is required. If the digitizing device is connected to a computer and a graphic display device, so as to permit the user and the generation program to interact, generators can be developed which are quite flexible and can be used for a broad range of applications. Interactive computer graphics systems are sometimes used for this type of generator, utilizing a cathode ray tube (CRT) as both the digitizer and the display device. The high initial cost of digitizing and display equipment usually limits their use to those organizations which have a high volume of applications. Stand-alone digitizers are now used in repetitive applications like ship certification by the U.S. Coast Guard, while interactive graphics equipment tends to be used for combined design and analysis applications.

Regardless of the technique employed by the generation program, some programs will be easy to use and will come close to minimizing the effort required to prepare finite element data, and others will not. For programs which require only small amounts of user data, the input data format and data organization will not be a significant factor. The user will probably find the general purpose programs easier to use if the data are organized so that values are specified in about the same sequence as would occur in manual preparation, or if the order can be chosen by the user. Programs with a variety of data cards invite less confusion if they allow key-word or free-field specification of the data, or if they adopt one general format which is used for all data cards.

Except for some of the large general purpose programs, data generators are usually easy to modify. If a user finds a program that comes close to generating the required structure or if he finds a program that is acceptable but doesn't generate the data in NASTRAN format, he is usually only a few FORTRAN statements away from having the program he needs.

Survey of Available Data Generation Programs

All the programs summarized in this section do generate NASTRAN data, but in the absence of sufficient common characteristics to group the programs, summaries are listed alphabetically by author.* All programs will generate grid point and connection cards and, unless noted otherwise, are written in FORTRAN. Little information is given in the references on the cost of running these programs; however, judging from programs used by the authors, the computer costs for generation of the model should be small when compared to either the cost of manual data preparation or to the computer cost of the NASTRAN analysis.

(1) GRIDXY, J.M. Brophy, Frankford Arsenal [10]

This program was developed to idealize small arms cartridge cases using NASTRAN's triangular and trapezoidal ring elements. It may be used, however, for any thick-walled axisymmetric problem. The user is required to divide the structure into subregions which are bounded by four straight lines or polynomial curves. Parameters are then specified to define the idealization for each subregion. Several types of mesh variation are possible within each subregion. Varying pressure loads are converted into the required FORCE cards. The program operates on CDC 6000 computers.

(2) FEM, R.C. Burk and F.H. Held, McDonnell Douglas Astronautics Company - East [11]

In its normal mode of operation the Finite Element Modeling (FEM) program accepts nodal geometry data which have been digitized from scale drawings using an interactive graphics system, although nodal data may also be entered from pre-punched cards or other generation programs. Once the nodal geometry has been defined, the user may define the finite element mesh by pointing out the nodal points associated with each element. The user may also specify pressure loads and symmetry constraints in a similar manner. When generation is complete, the model may be transferred to an output file in either NASTRAN format or that of several other finite element programs. The FEM program has been implemented using an inexpensive Computek interactive graphics terminal and digitizing tablet and runs on an XDS SIGMA 7 computer.

(3) AXIS, SHELBY, COONS, and MOVE, W.L. Cook, Goddard Space Flight Center [12]

Three stand-alone data generation programs, AXIS, SHELBY, and COONS,

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* Some of these programs are part of larger pre- and post-processor packages, in which case they will also be reviewed in other appropriate sections of this paper.

generate shells of revolution, shells described by the translation of a plane curve along an arbitrary axis in space, and Coons' surfaces, respectively. The programs generate grid point cards, quadrilateral connection cards, and, if desired, the cards to define a varying pressure load. The fourth program, MOVE, will generate a complete structural model from the data cards for one segment of the model which can then be replicated, translated, and rotated as required to form the complete structure. These programs were written for the IBM 360 computers in FORTRAN IV, except for MOVE which is in PL/1.

(4) PING, P.C. Huang and J.P. Matra, Jr., Naval Ordnance Laboratory [13]

The Planform Input Generator (PING) program is a preprocessor which develops NASTRAN finite element models for missile lifting surfaces. The types of wing planforms which PING handles include sweptback, delta, diamond, cylindrical, and builtup. The program can also generate the transition region between two meshes of different density. One useful application of this capability is the modeling of a cutout patch in which the cutout boundary has more grid points than are on the patch boundaries.

PING was written in FORTRAN for the CDC 6000 series of computers. The second phase of the same NOL project which produced PING will result in a program called BING (body input generator) for the automatic modeling of the axisymmetric shell bodies to which the wings are attached.

(5) SAIL II, M.W. Ice, Boeing Computer Services [14,15]

The SAIL II language is a FORTRAN-like data generation language which is translated into FORTRAN and compiled into an executable data generation program.

The user normally supplies the program with a complete NASTRAN deck (Executive, Case Control, and Bulk Data) which has SAIL II statements instead of the usual Bulk Data. Any FORTRAN statements included in the deck will become part of the SAIL II generation program. Any NASTRAN Bulk Data contained in the deck will be included with the SAIL II generated data. All the usual compiler-type capabilities are present in the SAIL II language including looping and subroutine definition.

SAIL II operates on BCS's IBM 360, 370 computers and is set up so that the generation phase and the NASTRAN analysis phase may be executed in the same run.

(6) -----, M.S. Katow and B.M. Cooper, Jet Propulsion Laboratory [16]

From a set of NASTRAN GRID cards which describe the surface of a structure, this program permits the user to specify graphically the finite element connectivity of the model. This program has been written using the UNIVAC 1108-EXEC 8 Graphics Programming Library subroutines and operates on the UNIVAC 1557/1558 graphics system on the 1108. An illustration in the referenced paper shows the CBAR connections being defined for a large antenna, but it appears that connections for most of the available NASTRAN elements could be defined similarly. The program may also be used for visual data checking of any NASTRAN model. (See next section.)

(7) IGFES, W. Lorensen, Watervliet Arsenal [17]

The preprocessor portion of this program permits the user to define a two-dimensional finite element mesh using either an interactive graphics terminal or punched data cards. The user divides his structure conceptually into four-sided subregions and defines the bounding curves for each subregion. The program will determine appropriate interpolation functions which are then used to locate grid points in the interior of each subregion. Several rectangular and triangular mesh patterns may be selected for each subregion. The program will ensure that grid points are not duplicated along boundaries which are common to several subregions. To be used interactively, the program requires a Tektronix 4002 storage tube display connected to an IBM 360/44. When the program is run using punched card specifications, the generated mesh can be plotted using CALCOMP plotters.

(8) NARFEM, M.A. Martens, et al., Space Division, North American Rockwell [18,19]

The NARFEM program, while not a compiler, does provide certain incrementing and data manipulation facilities which are under user control. There is also a capability for parametric description of surfaces of revolution. The complete finite element model of a structure can be generated during one application of the program, or the structure can be segmented and the model generated by invoking the program repeatedly. Grid point data supplied for an earlier segment do not need to be redefined for subsequent segments. The program requires data in fixed-field format and can generate data in the format required by several finite element programs including NASTRAN. The program will also accept certain data prepared for one finite element program and translate it to the format required by another program.

The program operates on IBM 360, 370 computers and can optionally produce CRT plots of the generated structure.

(9) DATGEN, P.M. Meyer, Naval Ship Research and Development Center [20]

This program is used primarily to generate deck and hull models for ship structures from a parametric description. The user may locate stiffeners, holes, and rectangular cutouts within a deck as well as specify various loadings and boundary conditions on the structure. The present version of the program will generate both plane surfaces and simply warped surfaces.

The program operates on CDC 6000 series computers and requires data in fixed-field format.

(10) CUTUP, J. McKee and E. Marcus, Naval Ship Research and Development Center [21,22]

The CUTUP program provides a convenient mechanism for linking several simple data generation modules in order to generate NASTRAN Bulk Data for a complete structure. The program automatically manages such details as unique grid point numbering on module boundaries, communication of geometric data and properties between modules, and automatic propagation of the finite element mesh density between modules.

The user normally supplies a complete NASTRAN deck (Executive, Case Control, and Bulk Data) which has generation options in the Executive or Case Control decks and data generation specifications (in NASTRAN Bulk Data format) in the Bulk Data deck. Each of these specifications may be used as a "super" element, thereby generating a variety of data, including plates, spheres, cones, Coons' surfaces, stiffeners, and boundary constraints. Any NASTRAN Bulk Data cards included in the deck will become a part of the CUTUP-generated data. SC-4020 plots of the generated structure are produced upon request.

CUTUP operates on CDC 6000 series computers with the NASTRAN linkage editor and is set up so that the generation phase and the NASTRAN analysis phase may be executed in the same run.

(11) GENDA, R.D. Rockwell, Naval Ship Research and Development Center [23-25]

To use this program, the user defines, in integer coordinates, the boundaries of a finite element mesh which is topologically equivalent to a segment of the model to be idealized. A triangular mesh is implied for this pseudostructure with grid points located at each coordinate point. Then, given the boundary curves on the actual structure, the program maps the integer mesh into the structural space. The process is then repeated until the complete structure has been generated. The program as described is primarily for generating intersecting cylinders, but could be easily modified to accommodate other structures.

The program requires fixed field data specifications and generates connection cards and coordinate cards according to user-prescribed formats. The program operates on CDC 6000 series computers and can produce SC-4020 CRT plots.

(12) NASTRAN.LINK0-2, SCI-TEK, Inc. [26]

The data generation portion of this preprocessor will accept simple user-defined generation procedures which are limited to incrementation of grid point coordinates and identification numbers. The program also has the facility to generate geodesic dome structures from parametric specifications.

Finally, several generators were reviewed which were tied very closely to particular structures. These programs may be used to generate models of structures such as small-water-plane-area twin hull ships [27], threaded connections found at the breech ring in artillery [28], and the fuselage and wings of aerospace vehicles [29].

DATA CHECKING AND UPDATING

Regardless of how NASTRAN input data are generated, the data must be checked for errors prior to a complete NASTRAN execution. The most comprehensive checks on NASTRAN data are performed, of course, by NASTRAN itself. However, at many installations, the central memory requirements to run NASTRAN and the passive nature of the NASTRAN plot package (as extensive as it is) are not conducive to efficient routine data checking and undeformed model plotting. In this section we describe several stand-alone capabilities which aid in the checking, display, and modification of NASTRAN data.

We have identified ten such NASTRAN preprocessors and listed them in Table 1. Since all involve computer graphics and hence are machine-dependent, the computer hardware requirements are listed in the table. However, since the ideas used are applicable to other machines, some of the programs could probably be adapted to different hardware without major effort. For interactive programs, which are usually strongly machine-dependent, the conversion effort required could be considerable.

Four of the programs, the first three and Cronk's, have extracted NASTRAN's input file processor, geometry processor, and structural plotter in order to duplicate both the data checking performed in the NASTRAN preface and the undeformed structural plotting. They thus have all the plotting versatility that NASTRAN has. The principal advantage that this type of program has over NASTRAN is that less central memory is required, which results in faster turn-around time.

However, reduced memory benefits are negated by passive graphics. Thus the most useful preprocessors of this type use interactive graphics. All those listed will perform substructure plotting (with magnification) and allow for view rotation.

One preprocessor listed in Table 1, HIDE, is unique in that it contains a hidden-line capability, i.e., only portions of structural elements that can be seen from the user's viewpoint are plotted. As a NASTRAN preprocessor, HIDE is slightly less convenient to use in that the user must also input the FORTRAN formats indicating how the data are to be read.

Finally, NARFEM, FEM, and the Katow-Cooper preprocessors, while capable of being used alone for data checking and updating, contain additional capability such as data generation and are also covered in that section of this survey.

CONVERSION OF DATA TO NASTRAN FORMAT

Since no single computer program satisfies all the needs of structural analysts, most users have occasion to convert input data from the format used for one program to that of another. The automation of such a conversion by means of a short FORTRAN program is usually a simple job. As a result, most conversion programs are written as the need arises and never documented. Two examples of documented programs can be cited. First, Anderson and Buell [37] have written a preprocessor called NASTIE to convert from SAMIS

Table 1 - Summary of Data Checking and Updating Preprocessors

Program Name	Developer	Computer	Graphics Hardware	NASTRAN Preface-Type Checking	Active or Passive Graphics	Modify Data at Console	Hidden Line Capability
Smith I [30]	NASA-LRC	CDC 6000	DD 80 B	Yes	Passive	N.A.	No
Smith II [31]	NASA-LRC	CDC 6000	CDC 250 CRT	Yes	Active	Yes	No
SAGE [32]	Israel Aircraft	XDS Sigma 7	Tektronix 4002A or 4010	No	Active	Yes	No
IDEAL [33,34]	NSRDC	CDC 6000	CDC 1700 CDC 274 CRT	No	Active	Yes	No
FASTDRAW [35]	McDonnell Douglas Automation	IBM 360/ 195	XDS Sigma 7 Computek or Tektronix	No	Active	Yes	No
Cronk [36]	Convair	CDC 6000	CDC 1700 CDC 274 CRT	Yes	Active	Yes	No
NARFEM [18,19]	North Amer. Rockwell	IBM 370	IMLAC PDS-1	No	Active	Yes	No
Katow-Cooper [16]	JPL	UNIVAC 1108	UNIVAC 1557/1558	No	Active	Yes	No
HIDE [24,25]	NSRDC	CDC 6000	SC 4020	No	Passive	N.A.	Yes
FEM [11]	McDonnell Douglas Astronautics	IBM 360 UNIVAC 418	IBM 2250 DEC 340	No	Active	Yes	No

(N.A. = Not Applicable)

format to NASTRAN format. Second, Giles and Dutton [38] wrote a routine to convert input data from McDonnell Douglas's Automated Structural Design (ASD) program [39] to NASTRAN format.

GRID POINT RESEQUENCING

The structural matrices formed during a NASTRAN analysis are normally both symmetric and sparse. For a given structure, the locations of nonzero terms in the matrices are determined solely by the choice of numbers (labels) assigned to the grid points. NASTRAN, like all finite element programs, has a solution algorithm whose speed depends on the grid point sequence. In NASTRAN's case, a combination band/active-column algorithm is used, i.e., the solver operates fastest for those matrix topologies exhibiting small bandwidth and few active columns. For example, in bandwidth-dependent routines, the number of calculations required (and hence the computer running time) is of order NB^2 for large N and B, where N and B are the matrix order and bandwidth, respectively.

Although proper grid point sequencing is essential to the user, NASTRAN burdens the user with supplying his own sequence. Since this is often an excessive burden (particularly when automatic data generators are used), several algorithms have been devised to automatically resequence grid point numbers to reduce both computer running time and core storage.

Three of these algorithms have been coded into NASTRAN preprocessors. One of the most widely used resequencers is the BANDIT program [40,41], which uses the Cuthill-McKee bandwidth reduction strategy [42]. Levy [43,44] has developed an iterative algorithm to reduce matrix wavefront. It has been implemented into a program called WAVEFRONT [45] and applied successfully to NASTRAN data. Another bandwidth reduction algorithm was developed by Cook and called BANDAID [12]. Unlike BANDIT and WAVEFRONT, which are in FORTRAN, BANDAID was written in PL/1. BANDIT will run on all NASTRAN computers; WAVEFRONT requires some conversion to run on machines other than the UNIVAC 1108.

Input to these preprocessors is the NASTRAN data deck. Output includes a set of SEQGP bulk data cards for insertion into the NASTRAN deck.

The algorithms used in these programs, as well as several other approaches, are reviewed in a survey article by Cuthill [46].

Since the resequencing algorithm must be tailored to the approach used for equation solving, these preprocessors will probably have to be modified when NASTRAN's Level 16 is released. That version of NASTRAN will contain a new equation solver [47].

PARTITIONING VECTORS

Substructure analysis using NASTRAN's standard release Level 15 requires that the user generate manually the partitioning vectors used to merge the structural matrices. For realistic nontrivial problems, this approach is both time-consuming and error-prone.

Although future releases of NASTRAN will provide some automation in the generation of partitioning vectors, at least one such preprocessor has been developed for the current version of NASTRAN. Called PVEC [48], the program uses the Phase I Checkpoint tape and a few additional input cards to generate the partitioning and other matrices used by NASTRAN in Phase II.

RADIATION VIEW FACTORS

The NASTRAN Thermal Analyzer (standard release version 15.5) includes the capability to perform complete thermal analyses on structures. In order to simulate the radiative heat transfer between surfaces, NASTRAN requires the user to input the view factors (also called shape factors, form factors, configuration factors) between those surfaces. A NASTRAN preprocessor called VIEW [49,50] has been developed which automates the computation of these factors. Output from VIEW includes RADLST and RADMTX bulk data cards for inclusion in the NASTRAN deck.

VIEW was adapted from an earlier view factor program called RAVFAC [51], which is not a NASTRAN preprocessor. VIEW was developed for use on the IBM 360 and contains some machine language code.

CONTOUR PLOTTING

To assist in the interpretation of the large volumes of output frequently produced by structural analysis programs, it is useful for the analyst to be able to plot contours of certain variables. For NASTRAN, several contour-plotting postprocessors have been developed.

Giles and Blackburn [29] report one such program which reads NASTRAN Bulk Data and punched output to generate contours for stresses, displacements, or eigenvectors (vibration or buckling).

Another such NASTRAN postprocessor called CONPLT [24,25] can produce two kinds of plots: (1) contour plots for each of several surfaces, including substructure enlargement, and (2) line graphs for user specified groups of nodal or elemental ID numbers. The latter amounts to X-Y plots where the list of grid or element ID's appears along the X-axis. CONPLT was written for the CDC 6000 computers and the SC-4020 plotter.

The IGFES system [17] discussed earlier with respect to data generation also includes an output package with several alternatives for display of NASTRAN results. The graphics capability consists of contour plots, perspective plots, and X-Y plots of some dependent variable versus one of the principal coordinates. IGFES is implemented on a Tektronix 4002 storage display connected to an IBM 360/44 and interfaces with NASTRAN via an OUTPUT2 file.

Finally, contour plotting capabilities have also been incorporated directly into the NASTRAN Plot Module by Kelly [52], although this is not a NASTRAN postprocessor. As a NASTRAN enhancement, the program will run on all the NASTRAN computers and plotters.

NASTPLT

No discussion of NASTRAN graphics postprocessors would be complete without some mention of the NASTRAN General Purpose Plotter package, NASTPLT [2,3]. This package is normally used at installations with plotting hardware not recognized by NASTRAN (e.g., plotters attached on-line to a computer). To use NASTPLT, a separate program (a postprocessor) must be written to interpret NASTRAN's plot tape and create the appropriate plotter commands. The plot tape consists of a sequence of elementary plot operations, each of which must, in turn, be translated into the appropriate commands to drive the plotter.

Although the writing of such a translator postprocessor is relatively straightforward, the authors are not aware of any documented NASTPLT applications.

DATA TRANSFER UTILITIES

Since NASTRAN is currently operational on the computers of three different manufacturers (IBM, CDC, UNIVAC), a compatibility problem arises in attempting to transfer data between dissimilar computers. Although BCD punched cards or their images can be used, the numerical precision obtained is inadequate for some applications. For example, the NASTRAN DMI bulk data card can pass a maximum of only ten significant digits. To overcome this problem, Rogers [53,54] has developed a pair of utilities which interface with the NASTRAN user tapes in such a way that no precision is lost. Typically, the RDUSER utility reads the OUTPUT2 binary tape and generates a BCD tape. The latter is then transferred to a dissimilar computer where WRTUSER converts it to an INPUTT2 binary tape readable by NASTRAN. These utilities find application, for example, in substructuring problems being run on two or more different computers.

A second type of utility, available from Boeing Computer Services [55], reads data from the NASTRAN Checkpoint tape (NPTP). Called NFETCH, the subroutine can be used to store data in either an in-core array or an external file. This routine, developed before NASTRAN's OUTPUT2 module became available, is essentially superceded by OUTPUT2, although the user must explicitly list in advance each NASTRAN data block to be written by OUTPUT2, instead of checkpointing the run.

TRANSIENT RESPONSE TO INPUT ACCELERATIONS

Wingate *et al*.[56] have developed a transient analysis postprocessor which allows the user to prescribe (1) input acceleration forcing functions, and (2) nonzero initial conditions when a modal formulation is used. The standard NASTRAN release provides neither of these capabilities.

Not having the first capability, however, is merely an inconvenience to a user since it can be overcome by placing a large mass at the appropriate point and applying an input force equal to the product of the total mass and the desired input acceleration. In contrast, the lack of the second is truly a program deficiency (although NASTRAN's direct approach has no such restriction).

The procedure developed requires a NASTRAN normal mode analysis, in which the modes and other data blocks are written onto a user tape. This tape is then the input to the postprocessor. The time integration is performed with a fourth-order Runge-Kutta procedure.

RIGID LINKS

Occasionally the finite element analyst must include rigid links in his model. Typical applications include offset plates, connections between beam and plate elements, or any situation in which a very stiff member is desired. Since the inclusion of a high stiffness member might cause matrix ill-conditioning problems, the NASTRAN user generally defines rigid links using multipoint constraint (MPC) equations. To automate the generation of the necessary MPC cards, Anderson [57] has written a NASTRAN preprocessor called RIGID. For each rigid link, RIGID generates the six constraint equations required to fix the distance between any two grid points.

A similar capability is also available to clients of the Structural Dynamics Research Corporation as part of SDRC's package of processors [58].

PROCESSORS FOR VEHICLE DYNAMICS

Here we describe a package of SDRC-developed processors which were intended primarily to aid in the dynamic analysis of vehicle systems (e.g., automobiles) [58].

Several preprocessor modules are included in the package. One generates rigid links and is described in the preceding section. Another module was written to generate NASTRAN concentrated mass elements (CONM2) to account for rotatory inertia in the beam element (BAR). A third module generates constraint relationships (MPC's) to transform the effects of isolation elements (such as mounts and bushings) to the vehicle coordinate axes (fore-aft, side to side, verticle).

To facilitate the description of subsystem properties for a NASTRAN analysis, two interface modules were written: (1) a substructuring interface module to generate symmetric substructures, to reorder substructure matrices if component and system sequencing differs, and to insert substructures into NASTRAN via binary buffered files (INPUTT4); and (2) a modal modeling interface module which accepts modal information either from experiment or from finite element computer programs.

Although the overall vehicle dynamics capability developed by SDRC goes beyond that mentioned here, we have emphasized only those modules considered to be NASTRAN pre- or postprocessors.

ANTENNA RADIATION

The program described in this section is of such scope and size that it probably ought not be considered a NASTRAN postprocessor. Rather, NASTRAN might be considered a preprocessor to it. In any case, a general purpose program for the analysis of reflecting antenna systems has been developed by Cook [59].

Called the General Antenna Package, the program determines the effects of structural deformation on the radiation properties of reflecting surfaces such as antennas. The mathematical model chosen for the radiation problem is analogous to that used for the structural problem, providing compatibility between the two parts of the analysis. The role played by NASTRAN is the calculation of the structural deformation, which in turn is used as input to the radiation step.

Although the General Antenna Package possesses wide-ranging capability, a more complete discussion of it here would be beyond the scope of this paper.

STRUCTURAL MODIFICATION REANALYSIS

Frequently the engineering designer is interested in assessing the effect on a structure of changes in the various member components of the structure. Rather than reanalyzing the entire structure following some change, it is often more economical to determine only the change in the solution relative to that of some reference configuration whose solution is known. Various procedures have been proposed for this computation, some exact and some approximate.

Levy [60] has proposed an exact method of solution based on a parallel element approach. Since the implementation was designed to accept input specifically in NASTRAN format, Levy's program is treated here as a NASTRAN postprocessor. Examples presented demonstrated substantial computational advantages to the post-processing approach over complete reanalysis when at least two changes are considered.

CONCLUDING REMARKS

We have discussed some 35 preprocessors and postprocessors which have been developed to interface with the NASTRAN structural analysis computer program. The number, diversity, and high quality of these processors attest to the wide acceptance that NASTRAN is achieving throughout government and industry. This in turn helps to justify the development of nontrivial pre- and postprocessors. Moreover, the availability of a number of useful processors should also influence NASTRAN's popularity. All these interrelationships thus promote a higher quality, more efficient approach to structural analysis and provide a common ground for increased communication throughout the user community.

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