NASTRAN: A PROGRESS REPORT

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INTRODUCTION

During the interval since the first NASTRAN Users' Colloquium September 13-15, 1971 (ref. 1), the number of NASTRAN users has increased by about 50 percent. At the present time NASTRAN is installed on over 100 computers. Government users include, in addition to NASA centers, DOD, DOT, and the AEC. Users in the private sector include most aerospace firms, the automotive industry, architectural engineers, and those who use NASTRAN at computer data centers. A partial sampling of some interesting domestic NASTRAN applications is included in a NASTRAN benefits study which was conducted for the Office of Technology Utilization, NASA Headquarters (ref. 2). On the international scene NASTRAN has been made available by American firms at computer data centers world wide. NSMO has received expressions of interest in NASTRAN from firms in nearly every West European country, Japan, and Israel.

The purpose of this report is to inform NASTRAN users of significant NASTRAN-related events of the past year, to describe the present operation of the NASTRAN Systems Management Office (NSMO), to discuss the new capabilities and improvements incorporated in Level 15 of NASTRAN, and to discuss priorities for future levels of NASTRAN.

SIGNIFICANT MILESTONES

October 1971-September 1972

Four activities seem worthy of discussion as significant milestones: the NASTRAN Newsletter, the SPR Log, the generation of Level 15, and the 2nd NASTRAN Users' Colloquium including a NASA-Industry Working Session.

Newsletter

The first NASTRAN Newsletter was published August 20, 1971. Subsequent Newsletters were published December 7, 1971, March 13 and July 20, 1972. A variety of topics is normally included under NSMO Communications. Other items of user interest discussed in these Newsletters have included Level 15 Announcements, NASTRAN Publications, Level 12 Errors, DMAP Programs, and

Rigid Format Alter Packets. The Newsletter circulation is presently over 1,000 copies.

SPR Log

A computerized data base of information from all Software Problem Reports (SPR's) was created in February. The first released SPR Log was designated Log 16 and was distributed by NSMO to 21 organizations for evaluation and comment. Log 17 was generated in March and was sent to 16 additional organizations and to COSMIC for further distribution. Log 19 was generated in July and is presently available from COSMIC. SPR Logs 16 and 17 consist of two parts. The first part is an alphabetical sort of the NASTRAN module in which the error was discovered. This is a brief listing and should be used as an index to the second part which is a listing by assigned SPR number and includes a complete description of the error and its present status. In SPR Log 19 a third listing is included which lists by SPR number the Level 12 errors that have been corrected in Level 15.

The SPR Log is a valuable reference for any NASTRAN user group. It provides a rapid assessment of all previously reported errors in any NASTRAN module.

Level 15

The generation of Level 15 posed several formidable problems. Certain new capability and improvements which had been developed by the MacNeal-Schwendler Corporation (MSC) in their Level 11-based NASTRAN were scheduled to be incorporated in Level 15. These included a new GINO, efficiency improvements, heat transfer capability and several others. A contractural requirement stated that Level 15 would be built from NASA's Level 14 which was generated by the interim maintenance contractor, Computer Sciences Corporation (CSC), from Levels 12 and 13. In order to build Level 15 in a systematic, reproducible fashion and to retain all error corrections made by CSC in Level 14, the corresponding decks of both the MSC system and Level 14 were compared and the differences analyzed. Of a total of 939 decks 717 FORTRAN decks common to both systems were first compared line for line using a special purpose computer program. Either the Level 14 or the MSC deck was modified until a comparison showed perfect coincidence of the two decks. This computerized comparison effort resulted in changes to 307 decks from Level 14 and 370 decks from the MSC system. The remaining 222 decks were totally new design FORTRAN decks or were machine dependent and were not directly compared line for line. Of these, 125 decks were new additions from the MSC system, and 97 decks had been altered in both systems. For these decks the arduous task of hand comparison was performed. After thorough analysis and discussion, decisions were made which preserved nearly all previous error corrections and assured that the new decks would be free from previously reported errors. The Level 15 archive system was generated in May and incorporated all error corrections

which had been made by March 31. The completed code for each machine version was shipped to COSMIC early in July.

Level 15 documentation was a pacing item throughout the year. The camera-ready mats were finished for the Theoretical Manual SP-221(01) in mid-April, for the User's Manual SP-222(01) in mid-June, for the Demonstration Manual SP-224(01) in mid-June, and for the Programmer's Manual SP-223(01) in early September. COSMIC agreed to provide complimentary copies of the Level 12 manuals to persons ordering Level 15 until the Level 15 manuals became available.

Pre-release copies of Level 15 were made available in June to selected NASA centers and industry on the basis that evaluation reports would be returned to NSMO in a timely manner and thus preclude the possibility of serious undiscovered errors existing in Level 15 when released through COSMIC. Some errors that were discovered through pre-release testing have already been reported in the Newsletter and included in the SPR Log.

1972 USERS' COLLOQUIUM

The 2nd NASTRAN Users' Colloquium was held at the Langley Research Center September 11-12. Papers were selected on the basis of abstracts received by NSMO by April 15. This volume contains a collection of the papers presented at the Colloquium.

An industry working session with representatives from several aerospace firms was held on the morning of the 13th. The purpose of this session was to provide the participants with an opportunity to formally apprise NSMO of their list of most needed NASTRAN improvements and new capabilities.

NSMO ACTIVITIES

The NSMO staff presently includes the following persons:

J. P. Raney, Head
D. J. Weidman
J. E. Walz
H. M. Adelman
J. L. Rogers, Jr.
Sylvia Harris, Secretary

The major areas of activity of NSMO staff members include user communications, maintenance functions, development and installation of new capabilities.

User Communication

One of the most important functions of NSMO requiring a greater than one man level of effort, is to provide open lines of communication with the users of NASTRAN. At present NSMO communications with NASTRAN users are handled in six ways:

Steering Committees: NSMO is represented on the Navy's NASTRAN Steering Committee and also serves on NASA's NASTRAN Advisory Group (NAG). Efforts to achieve a working interface with industry are also being made.

Newsletter: The NASTRAN Newsletter has been published by NSMO at a rate of about once every four months. The Newsletter provides a means of timely contact with NASTRAN users informing them of all maintenance activities and should be issued every two months.

NASTRAN Users' Colloquia: An annual colloquium provides a unique opportunity for users to share their experiences and evaluation of the NASTRAN system.

Talks and Papers: Last year the NSMO staff presented three papers and gave numerous presentations to groups at Langley and elsewhere.

SPR Log: The SPR Log, a spinoff of the maintenance activity, is essential as a guide to known errors in NASTRAN and can be used to identify and avoid potential pitfalls in previously untried applications or solution paths.

Telephone: The telephone is an expedient means of communication and, therefore, is in constant use. Telephone consultations alone account for most of the time devoted to user communications.

Maintenance

The maintenance activity currently requires a nearly two man level of effort on the part of NSMO. Monitoring the maintenance contractor, establishment schedules and work priorities, and arranging for government furnished computers are important aspects of NSMO maintenance activity.

Initial screening of all SPR's is done by NSMO. NSMO receives an average of about 10 to 12 error reports each month. After an evalution, and perhaps a computer verification of the reported error, a number and priority are assigned by NSMO and the SPR is then delivered to the maintenance contractor for in-depth evalution and correction.

Maintenance of the NASTRAN manuals is performed jointly by NSMO and the maintenance contractor. Two editors have been assigned to each manual - an

NSMO editor and a contractor editor. Changes of the manuals for Level 15 proved to be quite extensive because of many modifications and the addition of new capability incorporated in this new level of NASTRAN. It was therefore decided to print new manuals rather than attempting to issue updates to the existing Level 12 documentation. Documentation was the pacing item of work in the preparation of Level 15. NSMO hopes to devote a continuous high level of effort to NASTRAN documentation requirements and thereby eliminate a major peaking of this activity during the generation of later levels of NASTRAN.

New Capability

The selection and development of new capability also accounts for an expenditure of about a two man level-of-effort. In addition to monitoring contracts for the addition of solid isoparametric elements and of a family of linear strain elements, NSMO is installing inhouse a new isoparametric quadrilateral membrane element. A paper which describes this element is included in this volume. Significant time is required to evaluate and define new capability (including efficiency improvements) and to interface with the proposers of new capability for NASTRAN.

LEVEL 15
A Comparison With Level 12

The improvements and modifications to Level 12 that led to the generation of Level 15 generally may be described as providing functional capabilities, or efficiency improvements, or user conveniences. The more significant of these are summarized below. A significant effort was also made to correct as many serious program errors as possible.

Functional Capabilities

1. Dummy structural elements - Provision has been made for dummy structural elements to allow the user to investigate new structural elements with a minimum of difficulty. It is only necessary for the user to generate the code for the element matrices, and the procedures are such that a knowledge of Fortran is sufficient to accomplish the task of inserting a new element on a trial basis. These elements are still restricted to the six degrees of freedom currently in NASTRAN.

2. Substructuring - Substructuring procedures have been developed for both static and dynamic analysis. The basic matrix operations provided in Level 12 were used in the development of the substructuring procedures. Two new modules (INPUTT1 and OUTPUT1) were developed to provide the capability for writing matrices on tape and reading

matrices from tape in NASTRAN format. Also, the PARTN and MERGE modules were rewritten for improved efficiency and capability. At present, an auxilliary program PARTVEC is used to generate partitioning vectors.

3. Solid polyhedra elements - The basic solid polyhedron element is the tetrahedron analyzed for constant strain and uniform isotropic materials. The wedge and hexahedron are assembled from basic tetrahedron elements, and are also elementary constant strain elements.

4. Heat transfer - Linear steady-state heat transfer analysis has been added. The NASTRAN heat flow capability may be used either as a separate analysis to determine temperatures or to determine temperature inputs to be used in a later run for structural problems.

5. Acoustic analysis - This application includes the calculation of the vibration modes of a compressible fluid in cavities with slots.

6. Compressible fluids in axisymmetric tanks - Compressibility of the fluid and the effects of gravity on a free surface are both included in the formulation, as well as consideration of the elasticity of the tank wall.

7. Improved differential stiffness for plate elements - An improved formulation of the differential stiffness for plate elements has reduced the error for buckling analysis to less than 10 percent with two elements per halfwave.

8. Thermal bending - Provision has been made to include thermal bending moments created by the presence of thermal gradients in bars and plate elements.

Efficiency Improvements

A number of important improvements in efficiency have been made in Level 15.

1. General input/output routines (GINO) - Many improvements were made in the efficiency of this machine-dependent routine. The IBM FORTRAN version of GINO was completely replaced with an assembly language routine, which also assumes the task of managing the secondary storage space on the disc storage files.

2. Matrix packing - The logic of the matrix packing routine was substantially revised, and the CDC and IBM versions were replaced with assembly language routines for efficiency.

3. Multiply/add (MPYAD) - The inner loops of all multiply/add routines were rewritten in assembly language for all three machines for

improved efficiency. In addition, the sparse matrix routine (Method 2) was completely rewritten.

4. Single precision - Most of the matrix operation routines on the CDC machine were revised to use only single-precision arithmetic. Some key operations still remain in double precision, and may be converted later.

5. Eigenvalue extraction - Improved shift decision logic and symmetric decomposition is now used in the inverse power method of eigenvalue extraction.

6. Frequency response - The use of symmetric decompositions and symmetric equation solution routines is available on an optional basis in the solution of frequency response problems.

7. Equation solution - The inner loops of the equation solution routines have been rewritten for improved efficiency.

A tabulation of the execution (CPU) times for the NASTRAN demonstration problems for both Levels 12 and 15 which indicates the areas of greatest improvement in efficiency is given in the Appendix.

User Conveniences

1. Diagnostic output - A number of new types of diagnostic output have been provided as indicated in the following partial list.

   DIAG 8 - Print the size, form, type, and density of matrices as they are formed.

   DIAG 13 - Print the amount of working storage available for each module.

   DIAG 14 - Print the rigid format for all nonrestart runs.

   DIAG 16 - Print details of the iteration steps for the real inverse power method of eigenvalue extraction.

2. User tapes - Two new modules (OUTPUT2 and INPUTT2) have been provided to allow the user to read information from tapes that have been written with external FORTRAN programs and to write information on tapes inside of NASTRAN that can be read by external FORTRAN programs. This provides an important interface between NASTRAN and other programs.

3. Partitioning matrices - Two new modules (VEC and UPARTN) have been provided to make it more convenient for the user to partition matrices in terms of the set notation that is used internally in NASTRAN.

4. Table printer - A new formatted table printer has been provided for the printing of selected NASTRAN tables in readable formats.

5. Matrix punching - A new module (OUTPUT3) has been provided to permit the user to punch matrices on DMI or bulk data cards.

6. Transliterator - Provision has been made to accept either 026 or 029 character sets, either as intermixed cards of these types or even as intermixed characters on a card.

PRIORITIES FOR FUTURE LEVELS OF NASTRAN

A new level of NASTRAN is generated when the bookkeeping associated with error corrections, system improvements, and new capability becomes excessive. At the present time well-defined plans for future release of NASTRAN include an intermediate version of Level 15 (Level 15 1/2) with major new capability, and Level 16.

Level 15 1/2 - January 1973

1. Complete Heat Transfer allows for analysis of steady state and transient heat transfer. Inputs include convection, conduction, and radiation.

2. Fully Stressed Design Module automatically sizes the ROD, BAR, TRMEM, QDMEM, TRPLT, QDPLT, TRIA1, QUAD1, TRIA2, and QUAD2 elements to provide maximum stress in each element.

3. Space Shuttle Improvements which include grid point force balance information and output of the element forces for the element listed under the Full Stressed Design Module.

4. Error Corrections

Level 16 - June 1973

1. Solid Isoparametric Elements developed by Universal Analytics, Inc.

2. Linear Strain Elements developed by Bell Aerospace Company.

3. New Structural Matric Assembler

4. Complete Single/Double Precision Option

5. Extensive Efficiency Improvements

6. Error Corrections

Planning for FY 1974 has only recently commenced; however, it appears reasonably certain that at least a major update of Level 16 will occur before July 1, 1973.

SUMMARY

The NASTRAN Systems Management Office has operated over the last year with a staff of five professionals who divide their time between user communications, maintenance, and new capability. Accomplishments of interest to NASTRAN users have included publishing four Newsletters, distribution of the new SPR Log, generation of Level 15, and organizing the 2nd NASTRAN Users' Colloquium. During FY '73 a major update of Level 15 is planned to incorporate a complete heat transfer capability. Level 16 is targeted to be released in June and will include major efficiency enhancements and new linear strain and solid isoparametric elements.

REFERENCES

1. "NASTRAN: Users' Experiences," TM X-2378, September 1971.

2. "NASTRAN Benefits Analysis," CR-125882, February 15, 1972.

APPENDIX

Execution Times (CPU Seconds): Level 15 vs. Level 12

Demonstration Problems		IBM 360 Series					CDC 6000 Series			UNIVAC 1100 Series	
		Model 95		Model 67	Model 65	Model 75	6400	6600		1108	
No.	Form & Version	Level 12	Level 15	Level 12	Level 15	Level 15	Level 15	Level 12	Level 15	Level 12	Level 15
1-1	U	60	-	108	56	-	46	31	36	72	30
1-1A	R	30	7	102	-	-	26	24	-	24	17
1-1B	R	108	15	294	-	-	-	90	37	72	41
1-2	U	84	-	264	114	-	--	72	22	60	55
1-2A	R	48	10	144	-	-	41	36	-	30	25
1-3	U	114	-	336	152	-	-	120	94	96	86
1-3	I	NA	22	NA	-	-	-	NA	85	NA	-
1-4	U-1	1020	139	1464	-	-	-	666	323	1020	510
1-4	I-1	NA	67	NA	-	-	-	NA	316	NA	-
1-4A	R-1	60	8	174	-	-	-	30	23	30	29
1-4	U-2	380	179	-	-	-	-	-	429	-	-
1-4	I-2	NA	84	NA	-	-	-	NA	421	NA	-
1-4A	R-2	-	48	-	-	-	-	-	25	-	-
1-5	U	660	111	1800	-	-	-	-	422	1080	477
1-6	U	48	10	132	-	-	-	30	30	24	22
1-7	U	60	21	270	-	-	-	120	127	90	115
1-8	U	NA	16	NA	-	-	-	NA	90	NA	47
1-9	U	NA	-	NA	128	-	148	NA	-	NA	76
1-10	U	-	-	-	254	-	34	-	-	-	18
1-11	U	-	30	-	-	-	-	-	81	-	83
1-12	C	NA	-	NA	44	-	-	NA	21	NA	18
2-1	U	72	-	168	66	-	42	30	26	24	24
3-1	U-1	720	105	3900	-	-	-	828	366	660*4	422
3-1	I-1	NA	92	NA	-	-	-	NA	362	NA	-
3-1	U-2	610	228	-	-	-	354	-	-	-	-
3-1	I-2	NA	510	NA	-	-	-	NA	1062	NA	-
3-2	U	NA	-	NA	-	157	-	NA	276	NA	405
3-3	U	NA	79	NA	-	-	-	NA	274	NA	354
3-4	C	NA	-	NA	-	182	-	NA	109	NA	107
4-1	U	168	31	486	-	-	164	144	-	90*2	102
5-1	U	408	-	1134	498	-	725	486	-	318*3	287

Demonstration Problems		IBM 360 Series					CDC 6000 Series			UNIVAC 1100 Series	
		Model 95		Model 67	Model 65	Model 75	6400	6600		1108	
No.	Form & Version	Level 12	Level 15	Level 12	Level 15	Level 15	Level 15	Level 12	Level 15	Level 12	Level 15
6-1	U	1714	353	5214*1	-	-	-	1956	323	270*3	1361
7-1	U	228	-	606	-	265	-	216	196	204	188
7-1	I	NA	-	NA	-	245	-	NA	176	NA	-
7-2	U-1	-	-	-	-	919	-	-	1225	-	765
7-2	U-2	-	-	-	-	388	-	-	1481	-	386
8-1	U-1	134	-	467	-	138	376	126	-	138	115
8-1	I-1	NA	-	NA	-	134	-	NA	127	NA	-
8-1	U-2	732	-	-	-	628	-	-	1354	-	-
8-1	I-2	NA	-	NA	-	940	-	NA	510	NA	-
9-1	U	90	-	372	-	66	57	30	40	36	24
9-2	U	396	81	1026	-	-	-	378	316	105	318
9-2	I	NA	78	NA	-	-	-	NA	307	NA	-
9-3	U	NA	286	NA	-	-	-	NA	464	NA	422
10-1	U	204	-	570	-	117	114	120	140	66	54
11-1	U	162	-	420	117	-	-	96	61	84	70
11-1A	R	36	8	114	-	-	24	18	-	18	16
11-2	U	942	271	2484	-	-	-	882	487	510*5	495
11-2	I	NA	124	NA	-	-	-	NA	504	NA	-
12-1	U	348	75	1032	-	-	-	336	147	294	167

FORMS
- I = INPUT generated deck
- U = UMF generated deck
- R = Restart deck
- C = Card deck
- NA = Not Applicable

VERSIONS
- 1-4 Version 1 = 5 x 50 elements; 2 = 5 x 60 element
- 3-1 Version 1 = 10 x 20 elements; 2 = 20 x 40 elements
- 7-2 Version 1 = 3 harmonics; 2 = 5 harmonics
- 8-1 Version 1 = 10 x 10 elements; 2 = 20 x 20 elements

- *1 25 loading increments
- *2 3 loading increments
- *3 4 loading increments
- *4 3 modes
- *5 20 modes