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NASTRAN BENEFITS ANALYSIS

VOLUME I

EXECUTIVE SUMMARY

Submitted to
NASA HEADQUARTERS
Washington, D. C.



15 FEBRUARY 1972

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COMPUTER SCIENCES CORPORATION

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COMPUTER SCIENCES CORPORATION

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Falls Church, Virginia 22046

Major Offices and Facilities Throughout the World

FOREWARD

This Final Report has been prepared by Computer Sciences Corporation, Systems Division, Systems Sciences Center, Falls Church, Virginia for NASA Goddard Space Flight Center, under Contract Number NAS5-11724, Work Order Number 79.

The Final Report consists of two volumes as follows:

Volume I - Executive Summary

Volume II - Final Technical Report

This is Volume I.

TABLE OF CONTENTS

<u>Section 1 - Introduction</u>	1-1
<u>Section 2 - NASTRAN Benefit Highlights</u>	2-1
<u>Section 3 - Conclusions</u>	3-1
<u>Section 4 - Summary of Selected NASTRAN Benefits and Usage Information</u> .	4-1

LIST OF TABLES

Table

1	NASTRAN Survey and Response Sample	1-3
2	NASTRAN Response Sample Characteristics	4-2
3	Some NASTRAN Response Set User-Survey Results	4-3
4	Computers and Plotters Used for NASTRAN by Response Set	4-4
5	Examples from Response Set of Typical NASTRAN Benefits	4-5
6	Response Set User Funds Expended for NASTRAN Applications	4-5
7	Maintenance Funds Saved by 27 Users in the Response Set	4-6
8	User Funds Expended by Response Set to Improve NASTRAN	4-6
9	Response Set Organizations Reported as Users of NASTRAN	4-7

SECTION 1 - INTRODUCTION

The NASA Structural Analysis Program (NASTRAN) is a general-purpose digital computer program designed to analyze the behavior of elastic structures under a range of loading conditions. NASTRAN, developed at NASA's Goddard Space Flight Center during the period 1965-1970 for use by NASA and the aerospace industry, is now working for automobile companies, electronics manufacturers, the construction industry, and for several non NASA government agencies. Some of the most important spinoffs from the space program are application programs for use with computers--NASTRAN is one of these programs.

Upon completion of the development phase at NASA Goddard Space Flight Center and release to the public in November of 1970, the management of NASTRAN was transferred to NASA's Langley Research Center (LaRC). The program is now being disseminated, under contract to NASA, by the Computer Software Management and Information Center (COSMIC) at the University of Georgia. The initial development costs of NASTRAN were about \$3,000,000, and annual maintenance and improvement costs, funded by NASA LaRC, are about \$400,000. A complete set of NASTRAN tapes and documentation can be purchased through COSMIC for an average of \$1700, depending on options required by the user. The NASTRAN Systems Management Office (NSMO) furnishes (essentially-free) program maintenance to purchasers of NASTRAN. The public users therefore, benefit from the fact that government development and maintenance expenditures have reduced the acquisition and operational costs of the program.

NASTRAN has wide analytical capability. It includes analysis of:

- Static response to various loads, thermal expansion, and deformation
- Dynamic response to transient loads, harmonic loads, and random excitation
- Mathematical manipulations and solutions for vibration, dynamic stability, and elastic stability analysis.

The purposes of this study were: to generate baseline data for future comparison of the costs and benefits of the program; to show the impact on and benefits to wide segments of government and industry from current use of NASTRAN; and, to indicate by example, ways in which potential users may benefit from application of this program to their individual needs.

The program is highly user-oriented in that it is systematically organized to do much of the work automatically, thus minimizing the engineer's burden. NASTRAN is operational on the Univac 1108, the IBM 360/370, and the CDC 6000 series machines. It has been well received by industry and is effecting savings for its users in design practices and applications.

Since it has become available to the public, NASTRAN has been accepted for use in solving structural analysis problems by a number of government agencies, industrial companies, and by the academic community. Primary industrial users include aerospace companies, automobile manufacturers, consulting engineer firms, and the construction industry. These users are developing unique applications for NASTRAN within their own organizations. Many of these companies report that they would not have attempted these uses, had NASTRAN not been in existence.

This NASTRAN Benefits Analysis Study explores the acceptance of NASTRAN as depicted by a sample set of NASTRAN users. A list of 205 persons was selected for interview from what was believed were users of NASTRAN. The data reported herein of the impact and benefits to NASTRAN users were derived from mailed questionnaires, telephone interviews and personal interviews. One hundred fifty two usable responses were received. The composition of the survey list and the response sample are shown in Table 1. The response number for service bureaus is higher than that for the mailing list because several organizations thought to be industry were in fact service bureaus. A detailed breakdown of the response from the 205 person survey list is as follows:

158 users or potential users
51 no response
7 address unknown
7 absolute non-users
3 consultants (made no return)
226

Table 1. NASTRAN Survey and Response Sample

Population	Total No. in Popula- tion	Industry		Government		Academic	Service Bureaus
		Aero- Space	Non Aero- Space	NASA	Non NASA		
Survey List	205	84	63	16	16	14	12
Response Sample	152	53	49	14	13	8	15

The additional 21 names (226-205) were obtained where others joined in the personal or telephone interview, and by joint signatures on some of the mailed returns. Of the 158 users or potential users, 36 were classified as potential users which are defined as those who have obtained the tapes and/or documentation, and are evaluating the program for their use. They, in general, furnished some usable data such as computers and plotters available, comments on documentation, sample problems tried, etc. They did not contribute to the NASTRAN tangible benefits or the applications lists. The 158 returns were composed of the following:

50	mail return, only
41	telephone interview, only
61	mail return and telephone interview
<u>6</u>	personal interview
158	

Six of the 158 did not provide usable data, for example, service bureaus with proprietary claims. Thus, the response sample is 152 as listed in Table 1. The 77 user organizations (potential user organizations not included) in the response sample set, as listed in Table 9 represent a high proportion of all installations using NASTRAN. Seventy-five percent of those who obtained NASTRAN from COSMIC are on this list. The exact number of NASTRAN installations is difficult to determine because of proprietary service bureau-customer relationships and the fact that the response set is only a portion of the entire population.

The 116 users (152-36) of the response set (representing the 77 user organizations) reported approximately 200 applications of NASTRAN for structural design and engineering. Among the examples reported are:

- Design and analysis of aircraft fuselages, wings, and tail assemblies
- Design and analysis of automobile frames and other components of motor vehicles
- Design and analysis of high speed railroad tracks
- Design and analysis of turbine engines
- Design and analysis of space vehicles and related launch facilities.

Volume I emphasizes the benefits obtained from NASTRAN. In Volume II, the complete methodology, results and conclusions of the survey are presented. This study is applicable to NASTRAN usages prior to the issue of NASTRAN level 15 by the NASTRAN Systems Management Office.

SECTION 2 - NASTRAN BENEFIT HIGHLIGHTS

This section presents examples reported by the response set which demonstrates that NASA has produced a technological tool of great significance to the public sector. The use of NASTRAN has immediate cost savings benefits and the limits of its future potential are unknown. Since NSMO at NASA LaRC provides program maintenance, this is a considerable savings to users of the program as shown below. The illustrations which follow contain the name of the user, the application by the user or the impact of NSMO maintenance services, and the users estimate of the benefits received.

- Ford Motor Co. - Quality assurance analysis of automobile frames - saved \$12,000,000 per year
- Ford Motor Co. - NASA LaRC program maintenance - saved \$40,000 per year
- NASA Manned Spacecraft Center - NASA LaRC program maintenance - saved \$40,000 per year
- Itek Corp.- NASA LaRC program maintenance - saved \$10,000 per year
- CHI Corp. - New business generated - \$18,000 per year
- Westinghouse Electric, Defense and Space Center - NASA LaRC program maintenance - saved \$30,000 per year
- General Dynamics/Convair Aerospace - NASA LaRC program maintenance - saved \$40,000 per year
- NASA Kennedy Space Center - Analysis of Mobile Service Structure Platforms - shortened development time by 10 weeks
- NASA Kennedy Space Center - Analysis of Skylab launcher pedestal - shortened development time by 6 weeks
- Fairchild Industries - NASA LaRC program maintenance - saved \$8,000 per year

- Jet Propulsion Laboratory - NASA LaRC program maintenance - saved \$15,000 per year
- NASA Goddard Space Flight Center - NASA LaRC program maintenance - saved \$30,000 per year
- NASA Marshall Space Flight Center - NASA LaRC program maintenance - saved \$40,000 per year
- Raytheon Co. - NASA LaRC program maintenance - saved \$35,000 per year
- NASA Ames Research Center - NASA LaRC program maintenance - saved \$30,000 per year
- Esso Production Research Co. - NASA LaRC program maintenance - saved \$20,000 per year
- Sperry Rand Corp., Space Support Division - NASA LaRC program maintenance - saved \$30,000 per year
- NASA LaRC - Viking Launch Vehicle and Payload - shortened development time by 3 months
- NASA LaRC - Reliability analysis of Viking Launch Vehicle and Payload - saved 500 man hours
- NASA LaRC - Analysis of Sandwich Plate - shortened development time by 6 weeks
- Sperry Rand Corp., Space Support Division - Analysis of Antenna Tower - shortened development time by 3 months.

SECTION 3 - CONCLUSIONS

The conclusions apply to the data received in the response set. As a result of the NASTRAN Benefits Analysis Study, it is concluded that:

- There is a widespread use and acceptance of the program. As many as 186 separate applications are reportedly in progress and at least 55 more are in the planning stage.
- NASTRAN is considered to be essential to the structural analysis community. Two-thirds of current NASTRAN applications would not have been attempted without it.
- Significant benefits are reported in areas of quality assurance, reliability analysis, and shortening of job development times.
- For 50 NASTRAN applications, for which sufficient data were provided, users reported spending a total of \$529,000. An extrapolation of these figures over the 186 applications reported suggests approximately \$1.5 million spent to date ($\frac{186}{50} \times 529,000$).
- 37 users have reported a total expenditure of \$232,000 of their own funds for improvement and adaptations of NASTRAN.
- Most of the users stated that they received a benefit from NASA maintenance of the NASTRAN program; however, a smaller number provided a monetary estimate of its value. This monetary benefit was estimated for 27 applications and saved the users \$234,000. Extrapolated over the 186 applications, plus the 55 planned, the savings are conservatively estimated at \$2,500,000 ($\frac{186+55}{27} \times 234,000$).
- NASTRAN is contributing to new product development. The number of responses was few but the following are examples:

A non-aerospace company - More Sophisticated Analysis Capability -
\$5,000,000.

An aerospace company - Hypersonic Wing Study - \$650,000.

- The interest of the user community in the development of NASTRAN is evidenced by 116 improvements and 35 future applications which have been recommended by users.
- Seven of eight cost comparisons between the same application with NASTRAN and another available program were favorable to NASTRAN. Computer costs in each case were equal or greater for NASTRAN but the personnel costs (programmers, analysts, and engineers) to conduct the application were much less.
- 667 persons, primarily engineers, were estimated by the users in the response set, to be engaged in NASTRAN work at the time the study was undertaken.
- NASTRAN applications have widespread acceptance and 21 service bureaus or corporations are marketing NASTRAN services.

Some of the facts mentioned above are recapitulated.

Annual Cost Savings to Users

\$12,000,000 - quality assurance

2,500,000 - program maintenance

\$14,500,000

New Product Development

\$5,650,000

User Funds Spent to Date for Applications and Improvements

\$ 232,000 - improvements

1,500,000 - applications

\$1,732,000

Other important findings from the study are that the response set of users is almost unanimous in its opinion that NASTRAN has caused a substantial reduction in real operating costs and therefore, a great increase in productivity. Four primary factors listed as increasing productivity were:

- (1) Analyses have been accomplished which would not have been done without NASTRAN.
- (2) More complete and accurate results have been obtained.
- (3) Job completion time has been shortened.
- (4) Communications between engineers and programmers have improved because of the standardization of terminology and mathematical approaches developed in NASTRAN.

SECTION 4 - SUMMARY OF SELECTED NASTRAN BENEFITS AND USAGE INFORMATION

This section contains selected tables and information from the benefits and usage sections of Volume II which are of wide general interest. The data reported are that obtained from the response set users. No extrapolations are used in this section.

Prior to discussion of the results, a brief narrative of how the information was obtained and analyzed follows. The survey list of 205 persons, believed to be NASTRAN users, was developed from the following resources: a list of purchasers of NASTRAN tapes and documentation from COSMIC; the addressees of the NASTRAN NEWS LETTER; the attendees of the NASTRAN colloquium; a list of respondees for NASTRAN usage data in the first NASTRAN NEWS LETTER; selected personnel at NASA Headquarters, NASA Goddard Space Flight Center, NASA Langley Research Center; and contractors who had worked on the initial NASTRAN development. The type data required to show NASTRAN benefits and usage was determined. A mail questionnaire, and a supplemental questionnaire for telephone and personal interview only, were developed and approved by NASA. The questionnaires were mailed and the interviews conducted. The data were collected and tabulated. Table 2 shows the characteristics of the various NASTRAN populations. The number of the users in columns 3-9 has been normalized so that the comparisons are readily apparent. The characteristics of the response sample closely approximate the other populations. The collected data were checked, cross tabulated to find obvious errors, analyzed, and displayed in the various tables and graphs of Volume II in order to present the results of the study. No statistical manipulations of the data were conducted.

Table 3 presents a cross-section of some NASTRAN user survey results. A greater number of applications, improvements and recommendations, etc. come from the aerospace industry. This was clearly expected since this industry has been exposed to and worked with NASTRAN for a much longer period than the other organizations with the exception of NASA. Table 4 presents the number of computer and plotting installations used for NASTRAN work by the response sample. As mentioned in

Table 2
NASTRAN Response Sample Characteristics

Population	Total No. in Pop.	Industry		Government		Academic	Service Bureaus	Affiliation Unidenti- fied
		Aero- space %	Non Aero- space %	NASA %	Non NASA %			
COSMIC Pur- chasers of Tapes and Documenta- tions (users)	69	40	28	16	6	5	5	0
Colloquium (users and non-users)	264	35	19	16	14	5	11	0
News Letter (users and non- users)	784	36	32	7	8	10	4	3
Responded to 1st News Letter (and a user)	129	35	28	8	9	4	5	11
Survey List	205	41	30	8	8	7	6	0
Response Sample (Set)	152	35	32	9	9	5	10	0

Table 3. Some NASTRAN Response Set User-Survey Results

	Number of NASTRAN applications	User-Made NASTRAN adaption	Improvements to NASTRAN recommended by users	Applications which would have been developed <u>without</u> NASTRAN	Applications used but would <u>not</u> have been attempted <u>without</u> NASTRAN	Planned or in-process NASTRAN applications	Provides techniques not previously available	Handles complex and large problems readily	Recommended future applications
Aerospace Industry	93	19	52	26	67	25	34	6	18
Non-Aerospace Industry	26	0	20	10	16	12	1	4	9
Government - NASA	24	11	13	5	19	8	3	8	2
Government - Other Agencies	19	3	17	10	9	5	0	2	5
Computer Service Bureaus	17	4	12	7	10	5	8	1	1
Academic Institutions	7	0	2	4	3	0	0	0	0

Section 1, the program can be run on only IBM, CDC, or Univac machines. A few users have expressed interest in having a version for General Electric, Burroughs, Honeywell, and others but no one has undertaken such a conversion. A total of 130 computers are available because some organizations had more than one.

Table 4. Computers and Plotters Used for NASTRAN By Response Set

Computer	Number
IBM 360 Series	65
IBM 370 Series	15
Univac 1108	15
Univac 1106	1
CDC 6000 Series	34
Total	130

Plotter	Number
Stromberg Carlson 4020	21
Stromberg Carlson 4060	1
Cal Comp	19
EAI 3500	1
DDI	2
Total	44

Since costs and benefits are of prime interest in this volume, the following tables present a few details. Table 5 illustrates some of the typical benefits which accrued to NASTRAN users. Table 6 shows the user funds spent by the response sample for NASTRAN applications by type organizations and with the cost breakdown between personnel and computer. The aerospace industry leads with funds expended. Table 7 lists the funds which 27 users of the response sample estimated they had saved because NSMO provided program maintenance. The aerospace industry leads with funds saved. Table 8 lists funds spent by the response sample to improve NASTRAN. The various NASA agencies have been working with NASTRAN longer than other organizations, and they have spent more to date for improvements because in the early phases of the program more were required. Finally, Table 9 lists the 77 organizations in the sample response which are using NASTRAN. Where large corporations are listed more than once at different locations, each location has a group of people using NASTRAN and in almost each instance, a separate computer installation.

Table 5. Examples from Response Set of Typical NASTRAN Benefits

Aerospace Industry

Structural damping study	Shortened development time 8 weeks
Dynamic stress concentration analysis	Shortened development time 4 weeks

Government - NASA

Analysis of mobile service platforms	Saved 3 man weeks in safety analysis, and shortened development 10 weeks
Analysis of skylab launch pedestal	Saved 12 man weeks in safety analysis, and shortened development time 6 weeks
Viking launch vehicle payload	Saved 12 man weeks in reliability analysis and shortened development time 3 months

Industry - Non-Aerospace

Automobile frame dynamics	Saved \$12,000,000 per year in quality assurance analysis
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Table 6. Response Set User Funds Expended for NASTRAN Applications

Type of Organization	Number of Applications	Programmer Analysts Costs	Engineering Costs	Computer Costs	Total Costs
Industry Aerospace	31	\$16,350	\$161,850	\$117,125	\$295,325
Industry Non-Aerospace	9	6,100	52,800	49,300	108,200
Government - NASA	8	21,500	40,700	57,500	119,700
Government - Non-NASA	2	0	3,400	2,400	5,800
TOTAL	50	\$43,950	\$258,750	\$226,325	\$529,025

Table 7. Maintenance Funds Saved by 27 Users in the Response Set

Type Organization	Number of Applications	Funds Saved
Industry - Aerospace	9	\$151,500
Industry - Non-Aerospace	13	125,000
Government - NASA	4	45,000
Service Bureaus	1	2,400
TOTAL	27	\$323,900

Table 8. User Funds Expended by Response Set to Improve NASTRAN

Type Organization	Number of Improvements/ Adaptations	Estimated Cost to Users
Industry - Aerospace	19	\$ 80,900
Government - NASA	11	147,500
Government - Non-NASA	3	No Estimate
Service Bureaus	4	3,600
TOTAL	37	\$232,000

Table 9. Response Set of 77 Organizations Reported as Users of NASTRAN

Aerojet Solid Propulsion Company	Sacramento, California
A.O. Smith Corporation	Milwaukee, Wisconsin
Argonne National Laboratory	Argonne, Illinois
Atlantic Research Corporation	Costa Mesa, California
AVCO, Lycoming Division	Stratford, Connecticut
Bell Aerospace Company	Buffalo, New York
Bell Helicopter	Fort Worth, Texas
Bell Telephone Laboratory	Whippany, New Jersey
Boeing Aerospace Company	Seattle, Washington
Boeing Computer Service	Kent, Washington
CHI Corporation	Cleveland, Ohio
Computer Sciences Corporation	Richland, Washington
Computer Sciences Corporation	Los Angeles, California
COMSAT Laboratory	Clarksburg, Maryland
Control Data Corporation	Minneapolis, Minnesota
Control Data Corporation	Chicago, Illinois
COSMIC	Athens, Georgia
Esso Production and Research	Houston, Texas
Fairchild Industries	Germantown, Maryland
Ford Motor Company	Dearborn, Michigan
Franklin Institute	Philadelphia, Pennsylvania
General Dynamics/Convair	Fort Worth, Texas
General Dynamics/Convair	San Diego, California
General Dynamics Corporation	Pomona, California

Table 9. Response Set of 77 Organizations Reported as Users of NASTRAN
(continued)

General Motors Research Laboratory	Warren, Michigan
Georgia Institute of Technology	Atlanta, Georgia
Goodyear Aerospace Corporation	Akron, Ohio
B. F. Goodrich	Akron, Ohio
Grumman Aerospace Company	Bethpage, New York
Hercules	Magna, Utah
Hercules	Cumberland, Maryland
Itek Corporation	Lexington, Massachusetts
JET Propulsion Laboratory	Pasadena, California
Johns Hopkins University	Silver Spring, Maryland
Lockheed Georgia Company	Marietta, Georgia
Lockheed California Company	Burbank, California
Louisiana Tech. University	Ruston, Louisiana
Los Alamos Scientific Laboratory	Los Alamos, New Mexico
LTV Aerospace Corporation	Dallas, Texas
MacNeal - Schwendler	Hampton, Virginia
Martin - Marietta Corporation	Denver, Colorado
McDonnell-Douglas Aircraft Corp.	St. Louis, Missouri
McDonnell-Douglas Automation Co.	St. Louis, Missouri
McDonnell Douglas	Huntington Beach, California
McDonnell Douglas	St. Louis, Missouri
NASA Goddard	Greenbelt, Maryland
NASA Ames	Moffett Field, California

Table 9. Response Set of 77 Organizations Reported as Users of NASTRAN
(continued)

NASA Houston	Houston, Texas
NASA Lewis	Cleveland, Ohio
NASA MSFC	Huntsville, Alabama
NASA Kennedy	Cape Kennedy, Florida
NASA Langley	Langley, Virginia
Naval Air Development Center	Warminster, Pennsylvania
Naval Ship Research and Development Center	Washington, D.C.
North American Rockwell Space Div.	Downey, California
Northrop Services Incorporated	Huntsville, Alabama
Old Dominion University	Norfolk, Virginia
Perkin Elmer Corporation	Danbury, Connecticut
Pioneer Services Incorporated	Chicago, Illinois
Pratt & Whitney Aircraft	West Palm Beach, Florida
Raytheon Company	Sudbury, Massachusetts
Research Analysis Corporation	McLean, Virginia
Sandia Laboratories	Albuquerque, New Mexico
SCI-Tech.	Wilmington, Delaware
Sperry Rand	Huntsville, Alabama
Structural Dynamics Research Corp.	Cincinnati, Ohio
Teledyne Brown	Huntsville, Alabama
Teledyne Ryan	San Diego, California
Teledyne Computer Center	Toledo, Ohio
Texas Instruments	Dallas, Texas

Table 9. Response Set of 77 Organizations Reported as Users of NASTRAN
(continued)

TRW Systems	Redondo Beach, California
United Aircraft Sikorsky Division	Stratford, Connecticut
Watervliet Arsenal	Watervliet, New York
Westenhoff & Novick	Chicago, Illinois
Westinghouse Telecomputer	Pittsburgh, Pennsylvania
Westinghouse Defense and Space Center	Baltimore, Maryland
Westinghouse, Research and Development Center	Pittsburgh, Pennsylvania