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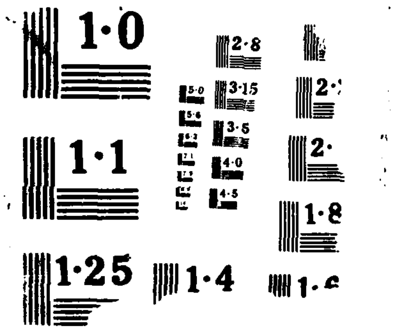
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Choosing a PC-Based Finite Element Code for Packaging Design Applications

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Luann J Cutler

PACKAGING AND ENGINEERING DIVISION
DEPUTY FOR MUNITIONS AND ARMAMENT EQUIPMENT
ARMAMENT DIVISION
EGLIN AIR FORCE BASE, FLORIDA 32542-5000

MAY 1988

FINAL REPORT FOR PERIOD APRIL-SEPTEMBER 1987

Armament Division

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FOR THE COMMANDER

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Associate Deputy for
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This technical note documents the evaluation of four PC-based finite element programs (SUPERSAP, NISA II-PC, COSMOS/M, and PAL2) for use in packaging engineering. There is a growing need for design analyses before committing to prototype fabrication of containers and cushioning. Similar analyses are crucial during the development of munitions and equipment; analysis can uncover design flaws overlooked by the developer. A PC-based finite element program which can be used on the Zenith Z-248 and Computervision Personal Designer workstations in conjunction with the resident CADD software would provide design engineers a powerful combination of design and analysis tools. Requirements for the program are defined in terms of performance capabilities, hardware and software interfaces, and usability. Though the requirements were tailored toward packaging engineering, they are generally suitable for other engineering applications. Each program was numerically rated against criteria derived from the above general requirements to obtain an overall rating. The results and conclusions address the ratings and preference ranking of the programs for packaging design applications.

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ANVIL	Manufacturing and Consulting Services, Inc.
AutoCAD	Autodesk, Inc
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CADKEY	Micro Control Systems, Inc
CADWrite, CGA EGA, IBM, IBM(AT, PC, PCJr)	International Business Machines, Inc
Calcomp	California Computer Products, Inc
COSMOS, COSMOS/M	Structural Research & Analysis Corp
Crossroads	McDonnell Douglas Corp
Designer, Personal Designer	Computervision Corp
HP (74XX, 75XX)	Hewlett-Packard Co
JDL 850	JDL, Inc
Logimouse	Logitech, Inc
Micro CADAM	CADAM, Inc
Microsoft Mouse MS-DOS	Microsoft Corp
Mouse Systems	Mouse Systems Corp
NASTRAN	NASA
NISA, NISA II-PC	Engineering Mechanics Research Corp
PAL2	MacNeal-Schwendler Corp
Prime	Prime Corp
SUPERSAP	Algor Interactive Systems, Inc
VAX	Digital Equipment Corp
VersaCAD	T&W Systems, Inc
Z-248	Zenith Data Systems Corp

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PREFACE

This evaluation effort was conducted in-house by the Packaging Engineering Division, Deputy for Munitions and Armament Equipment, Armament Division, Eglin Air Force Base, Florida 32542-5434. Ms Luann J. Cutler (AD/YNES) was the principal investigator. This effort was conducted from 1 April to 15 September 1987.

The use of trade names or manufacturer's names in this document does not constitute indorsement of any commercial product.

The findings in this technical note are not to be construed as an official Department of the Air Force position. The conclusions and recommendations of this report identify a preferred solution for a particular set of requirements, and may not be appropriate for other applications.

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COSMOS, COSMOS/M	Structural Research & Analysis Corp
Crossroads	McDonnell Douglas Corp
Designer, Personal Designer	Computervision Corp
HP (74XX, 75XX)	Hewlett-Packard Co
JDL 850	JDL, Inc
Logimouse	Logitech, Inc
Micro CADAM	CADAM, Inc
Microsoft Mouse MS-DOS	Microsoft Corp
Mouse Systems	Mouse Systems Corp
NASTRAN	NASA
NISA, NISA II-PC	Engineering Mechanics Research Corp
PAL2	MacNeal-Schwendler Corp
Prime	Prime Corp
SUPERSAP	Algor Interactive Systems, Inc
VAX	Digital Equipment Corp
VersaCAD	T&W Systems, Inc
Z-248	Zenith Data Systems Corp

TABLE OF CONTENTS

LIST OF TABLES

SECTION I

INTRODUCTION

1. BACKGROUND

The Packaging Engineering Division, Deputy for Munitions and Armament Equipment, Armament Division (AD/YNEP), at Eglin Air Force Base, Florida, designs, develops, and tests containers and packaging for military munitions and equipment. The Engineering Directorate (AD/YNE) oversees contractor engineering activities for munitions and equipment acquisition efforts. The Deputy for Engineering (AD/EN) supports these and other engineering functions by collocating engineers within each directorate and division, and by maintaining a central group of engineers with expertise in specific disciplines.

Most munitions containers are currently designed with extruded aluminum shapes. Engineered extrusions improve producibility and reduce production costs by eliminating the need for attaching functional, structural, or protective members and hardware. Current extrusion designs represent a conservative and readily producible design baseline in terms of alloys, ease of manufacture, and end-product performance. Other design agencies are adopting many features of these designs as a sort of empirical standard. Future design improvements will require trade-offs between alloys, strength requirements, dimensional relationships, tolerances, and manufacturing costs. Finite element modeling (FEM) techniques can help the packaging design engineer quantify the effects of departing from "standard" designs, and identify design limits. Ultimately, the design profile must be extrudable as well as structural. Finite element analyses of new design concepts could eliminate the cost, time, and technical risk associated with the "cut-and-try" approach. Methodical use of FEM for dynamic analyses of partial or complete container structures could help engineers identify and eliminate potential structural failure modes as well as over- or under-protection of container payloads.

Project engineers must ensure that contractor designs are structurally sound, within design and interface constraints, producible, and adequately documented by specifications, drawings, and technical orders. Availability of in-house finite element modeling capabilities can decrease the engineer's dependence on contractor-generated analyses. In-house conceptual studies could reduce the scope and technical risk of engineering efforts by identifying and eliminating undesirable design approaches or concepts. Also, an independent analysis of a more mature design can be used to validate or challenge the contractor's analysis.

Engineers in the central offices are often tasked to conduct specific analyses of concepts, materials, and designs. Such analyses lend themselves to finite element modeling techniques. A program capable of analyzing the range of problems encountered in packaging should be capable of analyzing the various structural and mechanical aspects of life-cycle conditions imposed on a munition, component, or piece of equipment.

The Packaging Engineering Division has an IBM PC-compatible Zenith Z-248 computer and a Computervision Designer CAD/CAM system with multiple workstations. Computervision Personal Designer stand-alone CADD systems are scheduled to be added within a year. The Engineering Deputate and Directorate have several Z-248 systems. Engineering software, such as CADKEY and AutoCAD, have also been ordered for the Z-248.

2. OBJECTIVE

The purpose of this report is to document the evaluation and recommendation of PC-based finite element codes for packaging engineering applications, as well as for general engineering applications in munitions and equipment development.

3. PRESENTATION

The evaluation process has three distinct, sequential stages. First is definition of requirements, followed by definition of evaluation criteria based on these requirements, then the evaluation of candidates against these criteria. The three primary sections of this report encompass these evaluation stages. A fourth section includes a brief description of the finite element programs considered. The conclusions are based on the results of the evaluation process.

SECTION II

REQUIREMENTS

1. HARDWARE COMPATIBILITY

The initial requirement is that the Finite Element Modeling (FEM) program be capable of running on a Zenith Z-248, which is fully compatible with the IBM PC. The Z-248s used by the various engineering organizations are equipped with MS-DOS, 20MB (megabyte) hard disks, two 360KB "floppy" disk drives each, 512 KB RAM, EGA graphics cards, monochrome or color monitors, and near-letter-quality printers. All of the programs considered require 640 KB RAM and the 8087 or 80287 coprocessor. These system modifications have been ordered to support FEM and other software packages. Other peripherals, such as a plotter, mouse, or tablet, can be added as needed to improve the systems. Demonstration software, including a trial version of the program (if provided), must be operable on a PC-compatible computer.

The FEM program will also be transferred to the Engineering Division's Personal Designer workstations as they are purchased in 1988. These workstations are IBM PC-AT machines, modified to run Computervision CADD software and to support 19-inch color monitors and digitizer tablets. Each machine will have a 40 MB hard disk, 1 MB RAM, and two 520 KB "floppy" disk drives. The CV 1280 HP high-resolution graphics card replaces the standard graphics card (EGA, CGA, etc.). Graphics pre- and post-processing would use the Computervision PDFEM, making the FEM program's modeling capability unnecessary. The program's built-in capability would be needed, however, for continued use on the Z-248s.

2. CAPABILITIES

The primary requirement is that the program be capable of analyzing the kinds of engineering problems of interest to packaging design and munitions/equipment project engineers. Specific packaging examples are: comparison of strengths of existing extrusion profiles and structural shapes; strengths and failure analyses of new extrusion designs and shapes; evaluation of effects of different materials properties (particularly different aluminum alloys); evaluation of the effects of shock, impact, pressure, loading, and vibration on individual members and partial or complete structures; prediction of changes in performance at temperature extremes; determination of design limits for and effects of deformation; analysis of plastics, composites, and elastomers; and determination of the effects of external load conditions on the contents of the package. Many of these applications are common to the munition or piece of equipment, in and out of containers. For munitions and equipment, there is often a greater variety of materials and multiple load conditions to consider.

The program must therefore have linear static and dynamic capabilities, nonlinear static capabilities, and preferably, nonlinear dynamic capabilities as well. It must have a variety of two- and three-dimensional elements and some generic types for modeling curvilinear surfaces and "black box" contents. It must be able to handle assemblies of different materials, and preferably, some directional or non-uniform material properties. It must be able to handle voids and spaces within a structure.

The program must have a built-in library of materials with provisions for tailoring and adding entries, or a means to store and retrieve user-specified materials properties. Both manual and automatic mesh generation capabilities are desirable.

Though no minimum requirements for numbers of elements, nodes, and degrees of freedom can be specified due to their interrelationships and dependence on element type, a program having relatively large problem size limits is preferred. Engineers can develop larger and more complicated models as their familiarity with and confidence in the program increase. A large-capacity program should be able to handle nearly all problems of interest. The occasional problem which exceeds the capacity of the program or the computer could be presented for solution on a larger computer with a large-capacity FEM program such as NASTRAN.

Speed of solution is not critical, as full-time use of the Z-248s is not anticipated and problems can be run in background mode on the Personal Designer. A program which uses bandwidth-reduction, wavefront calculation, or efficient memory allocation techniques should be expected to operate faster or have a larger problem capacity than a program which does not.

3. SUPPORT

Since the engineers are not expected to use the program continuously, it must have adequate documentation, and on-screen help to facilitate relearning. A tutorial program is also desirable. The company offering the program must have provisions for maintenance, upgrades, formal training, and user-support service. The ability to link or convert to a mainframe FEM program, such as NASTRAN, is desirable in the event of an occasional problem which exceeds the program or machine limits.

4. GRAPHICS AND OUTPUT

The program must have built-in three-dimensional geometry construction and model generation capabilities and the ability to link with Computervision's Personal Designer. The ability to link with Cadkey or AutoCAD, which may be used on the Z-248, is also desirable.

The program must have several means of presenting output data. Specific presentation requirements include: deflections and stresses by node or element, preferably both; original and deformed geometric representations; normal projection and isometric views; sectioning; both wireframe and solid-body representations; tabulated data per user specifications, to include applied and reaction forces; options for labeling and coding graphics; and provisions for printing and plotting (such as screen dump) within interactive programming. Animation is desirable.

SECTION III

EVALUATION PROCEDURE

1. METHOD

The evaluation method parallels Air Force source selection evaluation procedures used for awarding research, development, or production contracts. Candidate FEM programs were numerically graded individually against preselected evaluation criteria, which were weighted in order of importance. The author was the sole evaluator.

2. CRITERIA

Evaluation criteria included the four categories identified under the requirements section, costs, and the evaluator's opinion, which included information and recommendations from other sources.

Criteria were weighted in the following order of importance: capabilities (30 possible points), graphics and output (25), support (15), opinion (15), hardware compatibility (10), and costs (5), for a total of 100 points. Specific factors under each criterion were weighted in the same manner. A middle rating (such as 3 of a possible 5) indicates that the program satisfies the basic or minimum requirement for a particular factor. A higher rating reflects extra or more impressive capabilities, whereas, a lower rating reflects deficiencies. Nice-to-have features, such as animation and mainframe-FEM linkage, were assigned low weights (1-2) to prevent overcompensation for deficiencies in meeting major requirements.

Three specific factors included under the opinion category were the company's cooperation, independent articles and information from other sources, and user recommendations. A company that promptly and courteously responded to inquiries was considered likely to provide prompt and courteous service to its customers after the sale. Comparative information was obtained from magazine articles and other private or company reports. Users consulted were current users of one of the programs in question, and those who had investigated one or more of the programs for particular applications.

SECTION IV

CANDIDATE PROGRAMS

A number of FEM programs have been advertised or reviewed in engineering and computer magazines. Four companies, whose programs were adapted or developed specifically for IBM-PC and compatible machines, responded to information requests. Programs marketed by those four companies were evaluated.

a. SUPERSAP

SUPERSAP offers separate and combined software modules for mechanical (structural and dynamic) and heat transfer analysis. It was originally developed on a Prime computer system, and is available for use on Prime and VAX machines as well as PC/compatibles. The company, Algor Engineering Inc, a subsidiary of Algor Interactive Systems Inc, Essex House, Essex Square, Pittsburgh PA 15206, offers to contract with users to run all or part of a problem via time-sharing on a Prime computer in Pittsburgh. The program has open architecture, is not copy protected, and permits files transfer between all supported computer systems. Source code is available. Special engineering services offered include conducting complete finite element analyses for customers and developing custom FEM programming. SUPERSAP is the company's primary software product. The information package included a demonstration diskette, and an interactive demo disk and documentation for the SUPERDRAW II modeling routine. A combination tutorial and trial analysis program is available for purchase.

b. NISA II-PC

NISA II-PC offers separate software modules for static, dynamic, and heat transfer analyses. The modules may be purchased separately or combined in various packages which include other software options. This PC version is derived from the NISA-II mainframe program, both developed by Engineering Mechanics Research Corporation, P.O. Box 696, Troy MI 48099. The program is noted for its composite materials modeling capabilities, which include several special element types, laminate and fiber orientation definitions, and structural and failure analyses. The company offers related software programs for fatigue, fracture, 3D fluid flow analyses, and structural optimization. Consulting services are available. Software use is by license. The information package included three demonstration diskettes. A 200-node/20-element trial program is available for purchase.

c. COSMOS/M

COSMOS/M is available in several combinations of its linear static, linear dynamic, advanced dynamic, nonlinear, and heat transfer modules, plus other software options This self-contained FEM package was developed specifically for PC and compatible machines. It also supports VAX, Prime, Computervision, and other computers. The company, Structural Research and Analysis Company, 1661 Lincoln Blvd, Suite 100, Santa Monica CA 90404, has developed a mainframe version of the program, and offers an optional add-on Motorola 68020 CPU board which enables the PC to match the speed and problem size capabilities of mainframe machines. The program can also model fluid, electro-magnetic, and acoustic fields. The company offers consultation services and hot-line support. The software must be licensed, and is provided with a security locking device. The information package included three demonstration diskettes. The company also provided their 100-node/40-element trial program with documentation, at no charge.

d. PAL2

PAL2 is a self-contained stress and vibration analysis package offered by MacNeal-Schwendler Corporation, 815 Colorado Blvd, Los Angeles CA 90041-1777. A heat transfer program is offered separately, as are other software options. The company is known for its version of the NASTRAN mainframe program. Free telephone consultation is available. The information package included a demonstration diskette. A 25-node trial program with full documentation is available for purchase.

More specific details of the candidate programs are addressed in the evaluation results section.

SECTION V

EVALUATION RESULTS

1. CAPABILITIES

Ratings in this category are summarized in Table 1. COSMOS/M and NISA II possess excellent combinations of required and desired capabilities. SUPERSAP has very good attributes, but fewer of the nice-to-have features. PAL2 is deficient in many respects.

All four programs have linear static and dynamic capabilities; PAL2 was the only program with no nonlinear features. SUPERSAP and NISA specify problem size limits of 10,000 degrees of freedom. With the use of substructuring, they are otherwise limited by machine memory. COSMOS permits 5000 degrees of freedom, and 3000 elements or 2000 nodes per substructure; a large problem can be broken into any number of substructures, such that the limiting factor becomes computer memory. PAL2 is limited to 2000 degrees of freedom for a static analysis, and 150 for a dynamic analysis.

Element types, summarized in Table 2, proved to be one of the main discriminating factors. COSMOS has the best variety of elements. Though NISA has fewer basic types of elements, it has more options under each type, including a collection of composite elements. SUPERSAP has a good selection of basic structural elements, but currently lacks composite and special-purpose elements. PAL2 has a very limited selection of elements.

COSMOS has a built-in materials library and accepts user-defined properties. It has provisions for isotropic, orthotropic, temperature-dependent, and composite material properties. SUPERSAP offers an optional interactive materials library. The program accepts isotropic, orthotropic, and anisotropic properties. NISA did not claim to have a materials library. It has the same materials property provisions as COSMOS, plus time-dependent properties for dynamic analysis. PAL2 has no library feature, and allows only isotropic materials properties.

Options for applied loads are compared in Table 3. SUPERSAP and COSMOS have almost identical load option listings. NISA has a slightly different but equally impressive listing. PAL2 offers the fewest options, though it satisfies the basic needs for structural analysis.

PAL2 uses only manual mesh generation, where the other three programs have both manual and automatic mesh generation features. NISA can analyze crack initiation, propagation and fracture failure. SUPERSAP can model crack propagation. NISA also has optional program modules for fatigue and fluid analyses, and structural design optimization. COSMOS can analyze fluid, acoustic and electromechanical field problems. Using the optional 68020 CPU increases the COSMOS problem size limit to over 20,000 degrees of freedom and significantly increases calculation speed. PAL2 has no noteworthy additional capabilities.

TABLE 1. PROGRAM CAPABILITIES

CHARACTERISTIC	SUPER SAP	NISA II	COSMOS/M	PAL2
LINEAR	STATIC, DYNAMIC	STATIC, DYNAMIC	STATIC, DYNAMIC	STATIC, DYNAMIC
NONLINEAR (5)	STATIC, DYNAMIC, MATERIAL, GEOM (4)	MATERIAL, GEOM (3)	STATIC, DYNAMIC, MATERIAL, GEOM, GAP, FRICTION (5)	NONE (0)
SIZE (5)	10K DOF (LIMITED BY TIME & MEMORY) (5)	10K DOF (LIMITED BY MEMORY) (5)	5K DOF, 3K ELEM, 2K NODES PER SUBSTRUCT (LIM BY MEMORY) (4)	2K DOF STATIC 150 DOF DYN (2)
ELEMENTS (5)	GOOD VARIETY NO COMPOSITES (3)	EXC VARIETY SEVERAL COMPOSITES (4)	EXC VARIETY - INCL COMPOSITE (5)	FEWEST TYPES (1) -NO COMPOSITES
MATERIALS (5)	LIBRARY OPTIONAL (4) ISO/ORTHO/ANISO	NO LIBRARY (4) ISO/ORTHO/TEMP-DEP/ TIME-DEP (DYN)	LIBRARY OR DEFINABLE ISO/ORTHO/TEMP-DEP/ COMPOSITE (5)	NO LIBRARY (1)
LOADING (5)	EXC OPTIONS (5)	EXC OPTIONS (5)	EXC OPTIONS (5)	FAIR OPTIONS (3)
MESH GEN (3)	AUTO & MANUAL (3)	AUTO & MANUAL (3)	AUTO & MANUAL (3)	MANUAL/CADD (1)
FAILURE (+1)	CRACK PROP (1)	FRACTURE, CRACK INIT AND PROPAGATION (1)		
OTHER (+1)		FATIGUE AND FLUID MODULES OPTIONAL, STRUCTURAL DESIGN OPTIM OPTION (1)	OVER 20K DOF WITH COPROCESSOR OPTION; ELECTRIC, ACOUSTIC, FLUID FIELDS (1)	
TOTAL RATING (30)	25	26	28	8

TABLE 2. ELEMENT TYPES

ELEMENT	SUPERSAP	NISA II	COSMOS/M	PAL2
Truss	X		X	
Spar		X	X	
Link	X			
Beam	X	X	X	X
Plane Stress	X	X	X	X
Plane Strain	X	X	X	X
Plate	X		X	X
Membrane	X			
Pipe	X		X	
Elbow			X	
Mass	X	X	X	X
3-D Solid	X	X	X	
Boundary	X		X	
Shell	X	X	X	
Composites		X	X	
Curved Beam			X	X
Stiffness			X	X
Damping				X
Spring		X	X	X
Gap		X	X	
Friction			X	

TABLE 3. LOADING OPTIONS

LOAD TYPE	SUPERSAP	NISA II	COSMOS/M	PAL2
Point Force	X	X	X	X
Moment	X	X	X	X
Distr. Load		X	X	
Pressure	X	X	X	X
Linear Accel	X	X	X	
Angular Accel	X	X	X	X
Thermal	X	X	X	
Displacement	X	X	X	X
Nodal Force-Displ History		X		
Stress-Strain Limits		X		
Centrifugal	X		X	
Crit Buckling	X		X	
Gravity	X		X	X

2. GRAPHICS AND OUTPUT

Ratings for graphics and output features are summarized in Table 4. The SUPERSAP and COSMOS geometry and model creation capabilities were considered above average because they are integral to the FEM programs and are fully three-dimensional. Both offer solid modeling via interactive input and file editing. NISA has comparable modeling features, but as a separately-priced program module. The PAL2 demo appeared to use an internal model creation capability, though the company literature did not describe it. The literature and demo emphasized the use of AutoCAD for model creation, and their AutoFEM software link to complete the finite element model preparation.

All companies claimed that their package would interface with "all" or "popular" CADD systems. SUPERSAP's interface option links with Computervision's Personal Designer, Cadkey, AutoCAD, VersaCAD CADWrite, ANVIL, Crossroads, MicroCADAM, any other International Graphics Exchange Standard (IGES)-compatible system, and any system using the AutoCAD DXF format. NISA's interface option is claimed to link with all CADD systems. Its demo highlighted its compatibility with Cadkey, and its information package emphasized its compatibility with CADAM. It links to both Computervision systems via IGES. COSMOS is fully interfaced with AutoCAD and Personal Designer, via optional translator packages. It also has an optional IGES translator package for any IGES-compatible CADD system, including Cadkey. A Computervision applications engineer has stated that PAL2 is one of the FEM programs that is fully compatible with the Personal Designer. The PAL2 literature did not identify specific system interface capabilities.

The IGES link (NISA II) was considered the minimum acceptable CADD interface for the Personal Designer. The SUPERSAP link was rated slightly above average due to its ability to also interpret DXF format, as used by AutoCAD. PAL2 was similarly rated due to lack of information concerning its own capabilities, and its reliance on third-party software for CADD interfaces. The COSMOS links were rated above average because they are specifically tailored for certain CADD systems, including Personal Designer, and have an IGES-format link for the remainder.

The ratings for data presentation reflect the quality and versatility of graphics output presented in the demonstration programs. The PAL2 presentations were very primitive. The COSMOS graphics were presentation-quality. NISA and SUPERSAP had good output graphics. PAL2 is the only program of the four which does not have animation.

3. SUPPORT FEATURES

Ratings for important support features are summarized in Table 5. COSMOS's documentation was rated excellent based on the descriptive literature and limited-version program manual. SUPERSAP's documentation was rated very good based on the detail and completeness of the information package and its condensed manual for SUPERDRAW II. NISA's literature was

TABLE 4. GRAPHICS AND OUTPUT FEATURES

CHARACTERISTIC	SUPERSAP	NISA II	COSMOS/M	PAL2
Modeling (7)	6	4	6	2
CV-Intfc (7)	4	3	6	4
PC-Intfc (2)	2	2	2	1
Presentation of Data (7)	4	5	6	2
Animation (+2)	2	2	2	0
Total Rating (25)	18	16	22	9

TABLE 5. SUPPORT FEATURES

FEATURE	SUPERSAP	NISA II	COSMOS/M	PAL2
Document'n (5)	4	3	5	1
O-L Help (5)	3	3	5	0
Tutorial (2)	2	1	2	1
Co. Support (2)	2	2	2	1
FEM Link (1)	1	1	1	1
Total Rating (25)	12	10	15	4

fairly informative, but not very detailed. The company did claim that its documentation is "thorough...and well-written." The information package for PAL2 was of little value; most information was obtained from telephone discussions with the company and with PAL2 users.

COSMOS has an excellent on-line help utility which describes the command in question and prompts the user for required entries. NISA has on-line help; the company claims it is not extensive. SUPERSAP has on-line help; the company advises that some modules are fully supported. PAL2 does not have on-line help. SUPERSAP and COSMOS have tutorial programs as well as a collection of sample programs. NISA and PAL2 do not have tutorials. They rely on the sample problems for self-training.

All four companies offer formal training courses or user seminars. Algor (SUPERSAP) offers two formal classes at seven sites, and will tailor an on-site course offering to suit the user. EMRC (NISA) has monthly course offerings at three locations (Michigan, East and West Coast). SRAC (COSMOS) offers two to three classes per year in Los Angeles. MSC (PAL2) currently offers two courses at three sites (Dallas, Milwaukee, and New York); Atlanta is being considered as a fourth site.

EMRC and SRAC were considered likely to provide good user support, since both companies phoned regularly to offer information and answer questions, and responded promptly to inquiries. Algor was also considered likely to offer good support. Once the company realized its product was being seriously considered for purchase, a representative sent more information and began calling regularly. MSC was considered likely to offer fair support because inquiries were eventually directed to the "right" representative, who could discuss the information lacking in the descriptive literature.

All companies offer a mainframe FEM link, usually via an internal file translator. SUPERSAP and PAL2 will feed directly into their own company's mainframe code, SAP4 and NASTRAN, respectively. NISA and COSMOS will feed directly into their own mainframe versions, and will link to both ANSYS and NASTRAN.

4. HARDWARE COMPATIBILITY

Hardware compatibility ratings are summarized in Table 6. SUPERSAP and COSMOS appear to be universally compatible with PC-compatible hardware. NISA also seems universally compatible, but it may create serious software problems. The single NISA demo disk could not be executed from the floppy disk drive, and could not be copied into a user-specified hard disk directory; it had to be loaded onto the hard disk via backup mode, where it overwrote some DOS (disk operating system) files, which prevented using other resident programs. Once loaded, it did not execute properly. PAL2 does not support a plotter, and will only support a PC-compatible dot matrix printer. It apparently relies on the CADD program capabilities for input and output.

TABLE 6. HARDWARE COMPATIBILITY

DEVICE	SUPERSAP	NISA II	COSMOS/M	PAL2
Printers	Any PC-compatible, AutoCAD-compatible, DXF-CAD-compatible	Any PC-compatible	Any PC-compatible, color optional; Parallel Epson, IBM, or JDL	PC-compatible dot-matrix only
Plotters	HP74XX, 75XX; Calcomp (several); Tektronix 4662, 4663; Any AutoCAD/DXF-compatible	Any PC-AT-compatible; Tektronix 4696	HP7545 serial, color optional; JDL 850; HP74XX, 75XX; Any AutoCAD-compat.	None
Mouse	Microsoft, Mouse Systems, compatibles	Any PC-compatible	Microsoft, Logimouse	
Other	Digitizers: Calcomp, Bit Pad One, others	Any PC-compatible digitizer or tablet	Optional 68020 coprocessor	
Demo Runs?	Yes	No	Yes	Yes
TOTAL Rating (10)	10	3	10	5

5. COSTS

Comparative costs of the programs are shown in Table 7. SUPERSAP would be the least expensive, at $1965 for the basic software, materials library, internal graphics, CAD link, and tutorial. Upgrades are free for the first year, and optional thereafter, at an annual cost of $393 (20% of the original software purchase price). The cost of basic PAL2 software with the AutoFEM link would be $2290. Prices of the additional third-party software required for operation, upgrades and maintenance, installation, and other options, were not available. COSMOS would cost $3595 for the basic software (without AutoCAD), Personal Designer interface, and installation fee; annual maintenance and upgrade fee would be $779 (30% of purchase price). NISA would cost $7500 for the basic software, CADD interface, and installation fee; annual maintenance and upgrades would be $975 (15% of purchase price). The 17% GSA discount was not included.

6. OPINION

Table 8 summarizes the opinion ratings of each program. The evaluator rated EMRC (NISA) and SRAC (COSMOS) high in company cooperation. Both companies phoned regularly to offer additional information, responded promptly to inquiries, and provided user references. Algor (SUPERSAP) was rated average because it took some prodding to get information and references. MSC (PAL2) was rated low because the company was very reluctant to respond to inquiries or to offer references.

Machine Design magazine featured an article on finite element codes in its April 9, 1987 issue ("Fighting it Out in Finite Elements," by Nancy E. Rouse). It mentioned each of the four programs considered here. The article highlighted comparisons between COSMOS run on a PC and reliable mainframe programs run on a VAX 11/785. COSMOS results for benchmark linear static and mode shape frequency problems were within the ranges of mainframe solutions. COSMOS solution times on a regular PC-AT averaged about three times longer than the others on the VAX; with the coprocessor option, however, solution times were generally faster than the VAX.

The article noted SUPERSAP and PAL2 as specific PC-based programs evolved from mainframe programs; it otherwise made no distinctions between mainframe and PC programs, noting that substructuring, superelement, and wavefront techniques can effectively eliminate problem size limits for the PC.

The article emphasized the importance of nonlinear capabilities, again mentioning COSMOS, and NISA for both its composite materials modeling and fatigue and fracture analysis (ENDURE module) capabilities. NISA was also said to be "well-known in the auto industry." The article described the need for integral pre- and post-processing capabilities as finite element and optimization analyses move from mainframe to desktop computers. One reason is that batch-mode mainframe analysis programs relied on special

TABLE 7. PROGRAM COSTS

ITEM	SUPERSAP	NISA II	COSMOS/M	PAL2
Software	$995	$6000	$1995 $4500 w/ AutoCAD	$1995
Options	Materials Library $225	Fatigue Module $1500	IGES Interface $600	AUTOFEM Modeler $295
	Model, CAD Link, & Animation $595	CAD Link $500	Mainframe FEM Link $600	Engrg Formulas $895
	Heat Transfer Pkg $500	Heat Transfer Pkg $1000	Heat Transfer Pkg $1500	
	Advanced Programming Manual $75		AUTOSTAR Modeler $600	
Maintenance	20% per year *	15% per year	30% per year	Unknown
Support	Consultation $395 per year		Included in mx fee	
	Training $595/class			
Other	Tutorial $75	Installation $1000	Installation $1000	
	* First year free		68020 PC Opt $3595	
Total Rating (5)	5	3	4	2

TABLE 8. OPINION RATING

CATEGORY	SUPERSAP (Algor)	NISA II (EMRC)	COSMOS/M (SRAC)	PAL2 (MSC)
Cooperation (3)	2	3	3	1
Literature (5)	2	3	4	1
Other Sources (7)	5	3	6	1
Total (15)	9	9	13	3

model building and pre- and post-processing codes. Secondly, shape optimization programs in particular must be closely coupled with pre/post-processors to allow the mesh and model parameters to change with the model. Third, the rapid evolution in the analysis codes makes it almost impossible for independent vendors to keep their processor codes up-to-date. The last reason given is database complexity, which makes transitions between model, pre-processing, analysis, and post-processing more difficult.

Based on the content of this article, the programs were rated in the following descending order of merit: COSMOS, NISA, SUPERSAP, PAL2. Point ratings in Table 8 (literature) reflect this order.

At least three government or industry sources were consulted for comments and recommendations on each program. These sources had evaluated two or more of these candidate programs and are currently using the one they chose. Some sources admitted to compromising capability for cost when making their final choice, but all are reasonably satisfied with the program chosen. Sources included the Air Force Astronautics Laboratory (AFAL, Edwards AFB CA), AFWAL (Wright-Patterson AFB OH), Aviation Systems Command (AVSCOM, St Louis MO), General Offshore Corporation (Fort Lauderdale FL), Rome Air Development Center (RADC, Griffiss AFB NY), and Sverdrup Technology (Technical and Engineering Acquisition Support Contractor for Eglin AFB FL). These sources are arbitrarily identified by letters for the following discussion.

COSMOS received the most favorable comments of all. Users at Source A are particularly happy with the program, recent improvements, and company support. They wanted a PC-based code with built-in pre- and post-processing to use instead of NASTRAN or ANSYS, which need time-consuming pre- and post-processing via a separate code. Applications include gas nozzle flow systems, high-temperature materials, and high-stress locations. They like COSMOS's internal graphics since they don't yet have a CADD package for their Z-248s; they have ordered AutoCAD, which should provide an "excellent combination with COSMOS."

Other COSMOS users include TRW, Hughes, McDonnell-Douglas, and Auburn University. Source B considered COSMOS a very good program, but chose SUPERSAP for its lower cost. Source C considered the prime version of COSMOS too expensive in 1985. Source D also considered COSMOS a good program, noting that its graphics capabilities are much better than those of PAL2.

SUPERSAP was the next favored program. Source B uses SUPERSAP for framework and cargo equipment analyses, and considers it "great for the price," since cost was their main concern. They liked COSMOS (better post-processor and better manuals) and NISA in particular. Source C uses SUPERSAP for analyzing turbines and blades. They are happy with its performance, noting it has the best flexibility and capability for the price. Tiernay Turbines is another user. Source A considered SUPERSAP but chose COSMOS for its greater capabilities.

NISA was third in preference. Source E uses the VAX version, and may purchase the PC version in FY88. Applications are primarily structural and vibration analyses of line-replaceable units. They currently do not have a CADDS package or interface, though they use CADAM-compatible files for eventual tie-in to CADAM. Source E's users consider NISA a very good program, but company service is below their expectations.

Source F also uses the VAX version of NISA. They have the PRIME version but rely primarily on the VAX for analysis of radar structures, micro-circuit stress, and thermal and dynamic effects on printed circuit boards. Users particularly like the program's internal graphics and the option to purchase object code. They claim the program has some flaws and is complex, but is not as difficult to use as NASTRAN. Complaints are that the company gives mediocre support, and that there are problems in getting program updates.

Source B considered NISA a very good program but too costly. Source D preferred PAL2 and COSMOS over NISA.

PAL2 was the least preferred program. Source D chose PAL2 primarily for its compatibility with NASTRAN, which is commonly used for aircraft and stores aerodynamic and structural analyses. They anticipate possible use of PAL2 for pre- and post-processing for NASTRAN analysis. They consider PAL2 user-friendly and note that its graphics capability is improving. Sources B and C both considered PAL2 too limited for their needs. Other sources almost universally called it a "toy" and did not give it serious consideration.

The relative values of the "other sources" ratings in Table 8 reflect the merit and convictions of these sources' positive and negative comments on the programs.

7. OVERALL RATINGS

The cumulative ratings are shown in Table 9. COSMOS/M is the highest rated, followed by SUPERSAP, NISA II, then PAL2. COSMOS led the ratings in five categories and was above average in the sixth (cost). PAL2 is clearly out of contention due to its shortfalls in each rating category.

TABLE 9. OVERALL RATINGS

CATEGORY	SUPERSAP	NISA II	COSMOS/M	PAL2
Capabilities (30)	25	26	28	8
Graphics & Output (25)	18	16	22	9
Support (15)	12	10	15	4
Opinion (15)	9	9	13	3
Hardware Compat (10)	10	3	10	5
Costs (5)	5	3	4	2
Total (100)	79	67	92	31

SECTION VI

CONCLUSIONS

The results of this evaluation show that COSMOS/M best suits the requirements of the Packaging Engineering Division. It was rated highly against each criterion; this is an indication of its overall suitability for general engineering usage.

SUPERSAP satisfies all requirements identified for this evaluation. It should be seriously considered for purchase for this application if cost becomes a critical concern.

NISA II-PC satisfies most requirements identified. It has a few particularly good features, but these are more than offset by some perceived undesirable features. Its relatively high cost may not be justified. It should not be considered for purchase for this application.

PAL2 should not be considered for purchase for this application. It has very limited capabilities which do not satisfy the minimum requirements for this application. Further, the costs of the additional software needed to run the program on the Personal Designer and Z-248 may make it the least cost-effective of the four programs considered.

The PC-based FEM market is very competitive. Two of the companies considered (Algor for SUPERSAP and SRAC for COSMOS) are particularly receptive to user feedback on their products and are currently completing software and documentation upgrades which will improve and expand their program capabilities.

SECTION VII

RECOMMENDATIONS

COSMOS/M should be purchased for use by the Packaging Engineering Division. An Armament Division-wide site license should be negotiated if any of the other engineering activities wish to use the program.

SUPERSAP should be purchased and licensed if funding is not sufficient to purchase and license COSMOS.

REFERENCE

Nancy E. Rouse, "Fighting it Out in Finite Elements," Machine Design, April 1987

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