MSC/NASTRAN AT THE UNIVERSITY OF MICHIGAN

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ABSTRACT

The University of Michigan's Engineering College was the first university group to sign up for MacNeal-Schwendler's new University Program which allows use of MSC/NASTRAN for educational purposes. Since implementation of the code on the University's Amdahl V-8 in April of 1981, a sequence of courses, television tapes and engineering summer conferences has been based on the use of MSC/NASTRAN. This has required the development of lecture notes, audio-visual aids and laboratory materials. Student reaction has been very favorable. MSC/NASTRAN has allowed completion of a number of student projects, including analyses of race car bodies, hydrofoils, sailboats and rocket motor cases. A total of 223 engineers will have been trained with MSC/NASTRAN in the 1981-82 school year, including engineering summer conferences.

INTRODUCTION

The Engineering College at The University of Michigan was founded in 1853 with a Civil Engineering curriculum. The College currently has 1,065 graduate students and 3,968 undergraduates enrolled in 11 departments and 7 interdisciplinary programs. Student motivation is excellent and the quality of the engineering student is rising, with 78 percent of our incoming freshmen from the top ten percent of their high school class.

The University is served by a centralized computing system with an Amdahl 470 V/8 computer. This large, mainframe computer has 16 megabytes of high speed memory of which 7 megabytes of virtual memory are available to the user. Secondary storage totals 2.2 million 4096 byte-pages on 3330 and 3350 type disks, with 32,767 pages per user. Tape drives include 14 STC 3650 1600/6250 BPI 9-track drives and 6 drives for lower densities. (Users are encouraged to use 6250 BPI density.) A newer, larger computer, Amdahl 5860, will be installed in the summer of 1982.

The operating system used is the Michigan Terminal System (MTS). The system simultaneously handles up to 400 remote terminal users. About 200,000 terminal and batch jobs are processed per month. The MTS was developed in the 1965-67 period under University and Advanced Research Project Agency (ARPA) support and has been under continual improvement since. MTS is currently used at eight universities in the U.S., Canada, Great Britain and Brazil.

A large and vocal community of 27,000 MTS users at The University of Michigan is supported by a newsletter, message system, lecture series, and extensive documentation. Many of the faculty feel that MTS is the best operating system offered anywhere.

FINITE ELEMENT INSTRUCTION

A course on finite difference and finite element methods was taught by Professor Eisley at The University as long ago as 1962. For many years thereafter, the teaching of finite elements was concentrated in the Aerospace, Civil and Naval Architecture Departments, with courses cross-listed in Applied Mechanics and Mechanical Engineering to allow easier registration by their students. At present, there are five finite element courses offered in the Engineering College, all at the senior and M.S. level. Four of the five courses emphasize structural mechanics but the fifth includes various fluid flow problems.

Finite element codes used at The University have included PS-2, ELAS75, SAP2, SAPIV, SAP6, NONSAP and now, MSC/NASTRAN. The codes were chosen for use in classroom teaching, for student projects and for research.

The senior author has probably been the dominant teacher of finite element methods at The University of Michigan over the past decade. A complete summary of this involvement is given in Table 1. Instruction in the short courses has been shared with Professors Sandstrom and Eisley. The courses involved include Aero 510 and Aero 610: "Finite Elements in Mechanics I, II," and Engineering Summer Conferences: "Finite Elements in Mechanical Design, A & B." In each case there is an introductory course based on linear static stress analysis and an advanced course based on dynamics and nonlinear methods. The material in these courses has been packaged several ways:

1) credit classes for local students
2) credit classes for remote industry students, closed circuit (live) TV
3) audit status for remote industry students, closed circuit TV
4) cassetted TV lectures for remote industry students
5) Engineering Summer Conferences in Ann Arbor open to the general public
6) Engineering conferences in Ann Arbor contracted to specific corporations or government.

The table ties together the enrollment patterns, the use of specific finite element (F.E.) codes, and the trend toward increased industrial training.

DECISION TO SWITCH TO MSC/NASTRAN

The University of Michigan is located near the large U.S. auto companies. About 40 percent of the students graduating from the Engineering College are employed by those companies. In 1979, Professor Anderson surveyed finite element users from a major automobile maker's firm. The primary goal was to report to the company on in-house training needs. A secondary goal was to determine the engineers' background and interests. The results (Figures 1 and 2) proved that the company was involved overwhelmingly in MSC/NASTRAN. Similar conclusions were drawn in discussions with another large automotive firm. Unfortunately, the University was training people to use codes in which the vehicle industry was not interested. The split between industry needs and University training was more than superficial, because many methods used in MSC/NASTRAN (e.g., inverse power eigenvalue extraction) differed from methods in the other codes and consequently were not being taught.

Several friends of the authors, including Donald Dewhirst and Louie Nagy, were very supportive of the "learnability" of MSC/NASTRAN and the quality of the documentation. When MacNeal-Schwendler offered MSC/NASTRAN to universities at a reduced rate, The University of Michigan was the first to sign up.

IMPLEMENTATION OF MSC/NASTRAN ON THE MICHIGAN TERMINAL SYSTEM

As with other large software packages, MSC/NASTRAN requires consideration of:

1) funding
2) installation
3) maintenance
4) training.

In the University environment, with its own history and its lack of profit motive, these steps are not straightforward.

Funding of the relatively modest fees for MSC/NASTRAN proved difficult. What is software? Is it equipment? Who will pay for subsequent years? (The individual user does not want to pay royalties and the MTS system does not allow the bookkeeping required at present.) Who will pay for disk storage? Ultimately, good will prevailed and four departments combined for the first year's payment (Aerospace, Civil, Naval Architecture and Mechanical). The second year's fee has already been secured as a part of a larger gift to the College.

Installation of MSC/NASTRAN was difficult. The MTS operating system is nonstandard. It was decided to use an IBM version of MSC/NASTRAN and to use a fake IBM operating system on the Amdahl. Such a fake operating system, VSS, was under development by the University of British Columbia. After receipt of the MSC/NASTRAN load module, a period of six months passed during which a student of Professor Anderson broke his sword on the problem - confronted with an experimental fake operating system (not yet formally debugged and released) and the largest software package to be installed on the Amdahl, outside of the operating system itself. Fortunately, Mike Alexander of the Computing Center, when informed of the seriousness of the need, stepped in and installed MSC/NASTRAN in several weeks of part time work. He did find and detect several software bugs in MTS and VSS that had hampered earlier efforts. In April of 1981, MSC/NASTRAN was up and running and Professor Anderson assigned a beam vibration problem to his advanced finite element class.

Maintenance and updating of MSC/NASTRAN is a special problem in a university. Many faculty believe that computer simulation now occupies a similar status as the experimental laboratory once did. Administrators, however, have had trouble in the concept that system programmers and counselors are equally as important as machinists once were. New proposals are descending upon our Dean's desk in regard to this.

Training is, of course, the University's prime business. A major problem however with acquisition of a large-scale program such as MSC/NASTRAN is that people want to use it with no investment in their own time. (Does this sound familiar - the rookie who wants to solve a transient vibration problem and has never done a static stress problem?) In the University, this creates a group of nontraditional students - those who want training now and don't want to wait for a course or pay tuition. Fellow professors constitute some of this cadre. One solution is the creation of a simulation laboratory as discussed under "maintenance," and staffed by professionals other than faculty. Another solution is the use of industry gift money for faculty updating and creation of special "in-house" short courses for in-house people.

In the first ten months of MSC/NASTRAN, we have not solved or even identified all the possible problems. The ability to handle MSC/NASTRAN seems assured, however.

UNIVERSITY COURSES USING MSC/NASTRAN

Two courses use MSC/NASTRAN at present:

1) Aerospace 510 "Finite Elements in Mechanics, I" 3 hr.

2) Aerospace 610 "Finite Elements in Mechanics, II" 3 hr.

Both courses are "co-listed" with Applied Mechanics and the first is co-listed with Mechanical Engineering. The courses are basically at the M.S. level. They are taught from bound notes prepared by Professor Anderson:

Vol. 1	"Finite Elements in Mechanics, I"	325 pages
Vol. 2	"Finite Elements in Mechanics, II"	237 pages
Vol. 3	"The University of Michigan MSC/NASTRAN Interactive Training Program"	212 pages
Vol. 4	Supplemental inserts to Vol. 3 above, containing dynamics and nonlinear problems.	68 pages

The computer problems assigned to students constitute a "laboratory" taken with the course. A teaching fellow is stationed at the Computing Center with a complete MSC User's Manual. Each student has an abbreviated set of manual pages in the bound Volume 3, above.

The laboratory problems documented to date are given in Table 2. An example of a problem statement is given as Table 3. Generally, the students are given a calendar week to finish such a problem.

The introductory course, Aero 510, requires a term project to be done in groups of 1 to 3. They choose topics appropriate to the number of participants and to their pooled resources of computer money and disk space. A new wrinkle this year is that the instructor estimates the commercial value of each problem had it been done to completion and perfection. The students enjoy this - some larger groups had projects up in the $5000 range (4500 d.o.f.). The level of modeling ability is very good at this M.S. level.

At the beginning of the term, each student is told he has a computer budget of $100 (Aero 510) or $110 (Aero 610) to complete the term's work. At this point, the $100 has been proven adequate for Aero 510, including the project, and the Aero 610 number is in doubt.

SHORT COURSES FOR PRACTICING ENGINEERS

The Engineering College has had a strong Engineering Summer Conference program for years. In finite elements, the same material offered to University students during the term is repackaged for summer short courses. These are:

8219 - Finite Elements in Mechanical Design
A: Static Linear Analysis July 19-23, 1982

8220 - Finite Elements in Mechanical Design
B: Dynamics and Nonlinear Analysis July 26-30, 1982.

Similar training materials are used as for school year courses. A major difference in philosophy occurs by using more case studies and industrial speakers. Laboratory work is emphasized and is 45 percent of the effort.

A new type of training for "casual" users has emerged in contracted short courses. A mid-career professional growth short course is offered each summer to selected Bendix engineers. This month-long "refresher" course allows engineers aged 30-50 to hear about new technical developments (such as microprocessors) and about professional growth topics. The engineers form groups to work on a project of their own choosing to demonstrate the teamwork principles they have learned. Finite element technology, taught by Professors Eisley and Anderson, is one of six to eight technical areas. Each year, however, more than one-third of the engineers choose finite elements as their subject for team projects. This is remarkable since more attendees are electrical engineers than any other type!

The mid-career refresher course described above is solely for Bendix employees. The idea has proven so successful that a second session sponsored by the SAE will be open to the public in June of 1982.

RESEARCH ON INVERSE PERTURBATION IN DYNAMIC REDESIGN

Acquistion of MSC/NASTRAN has allowed the University to do research using DMAP procedures. A joint program between Aerospace and Naval Architecture and Marine Engineering is underway to allow efficient dynamic redesign using MSC/NASTRAN. We wish to achieve mode and frequency goals, typically under a least change criterion. Attention is concentrated on plate-like structures such as sheet metal vehicles and thin-walled die castings. The ultimate goal is to have a DMAP sequence which will be usable by a broad group of engineers, not just researchers (i.e., sailor-proof).

Special requirements for a good dynamic redesign are:

1) algorithm must be programmable in DMAP;

2) algorithm must be stable with respect to a variety of frequency and mode change requests;
3) the data input should be simple and compatible with existing MSC/NASTRAN format;
4) the user should have to intervene in the process as little as possible, or not at all.

This research project has been funded by the National Science Foundation and special encouragement given by United Aircraft and Ford Motor Co.

CONCLUSIONS

Ongoing training in Finite Element Methods with MSC/NASTRAN at The University of Michigan is substantial. The use of MSC/NASTRAN in our training programs is consistent with industry needs. Both the magnitude and the quality of this effort is enhanced by the quality of the University of Michigan's faculty, students and computing capacity.

The use of MSC/NASTRAN for basic research at universities is now underway and should prove to be of substantial benefit to both the academic and industrial communities.

TABLE 1

Enrollments in Finite Element Classes Aero 510, Aero 610
and Engineering Summer Conferences

		CREDIT	NONCREDIT					
		University	Industry					
		UM Students	Live TV Credit	Live TV Audit	Cassette TV Audit	Open Short Course	Contract Short Course	F.E. Progran Used
70-71	INTRO.	14					15 Bendix	
	ADV.	--						
72-73	INTRO.	22						PS-2
	ADV.	--						
73-74	INTRO.	10						
	ADV.	8						
74-75	INTRO.	17						ELAS-7
	ADV.	9						
75-76	INTRO.	20	5	33				
	ADV.	10	2	11				
76-77	INTRO.	39	-	--				SAPIV
	ADV.	10	-	--				
77-78	INTRO.	35	7	34		50		
	ADV.	11	2	15				
78-79	INTRO.	46	2	20	39 Trane	40		
	ADV.	16	3	21	15 Trane			
79-80	INTRO.	53	7	9		--	40 Bendix	SAP6
	ADV.	--	-	--				
80-81	INTRO.	65	13	6	19 Gdyr.	41	36 Bendix	
	ADV.	34	1	2				
81-82	INTRO.	45	13	6	13 GE		70 Bendix/SAE	MS
	ADV.	24	9	3				NASTRA
	TOTALS	488	64	160	86	131	146	

488
UNIV.

587 INDUSTRY

TABLE 2

Computer Laboratory Problems

NUMBER	PHYSICAL CASE	ELEMENT(S)
1	Plane Stress	QUAD4 or QUAD8
2	Cantilever Beam, Stress	BAR
3	Plate, Stress	QUAD4 or QUAD8
4	Gear Tooth Stress	HEXA
5	Cantilever Beam Modes	BAR
6	Cantilever Beam, Frequency Response	BAR
7	Cantilever Beam, Transient	BAR
8	Stepped Column Buckling	BAR
11	Transient Heat Conduction	HEXA, QUAD4, ELAS2

TABLE 3

Typical Laboratory Problem Statement

Problem 4. Solid.

Consider a spur gear with "pitch circle" radius of 100 mm (3.937 in.) and with 20 teeth. A tooth on the gear is subjected to a line load by the mating tooth as contact is made (Fig. 1). This steady running load is modeled as a line load of 600 N/mm acting at the pitch circle radius. The load is assumed to act in the +y direction for simplicity.

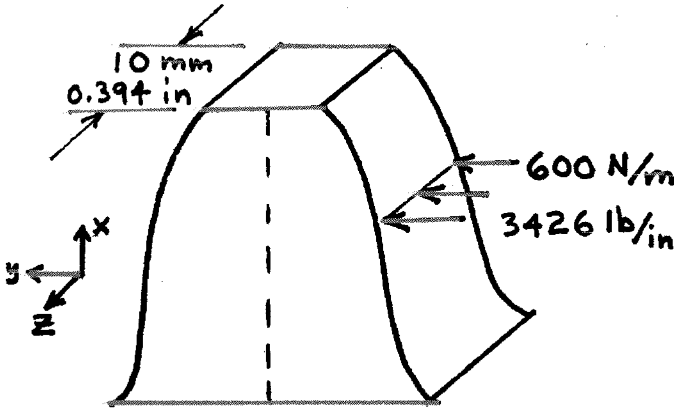

Fig. 1. Spur gear tooth under steady running load.

The side view of the tooth is shown in more detail in Fig. 2. The tooth is "cylindrical," i.e., it can be swept out by straight line generators.

The gear is made of steel with properties:

$E = 206,840.$ mPa (30.0×10^6 psi)

$G = 79,550.$ mPa (11.5×10^6 psi)

$\nu = 0.3$

A) Find the maximum stress in the gear tooth for the case of uniform line load shown in Fig. 1.

B) Find the maximum stress in the gear tooth for the case of gear misalignment, where the full 6000 N (1,349 lb.) acts at one side of the tooth (Fig. 3).

C) Compare the two cases above to see how much conservation needs to be included in the design to prevent short term failure due to misalignment and before the gears "wear in."

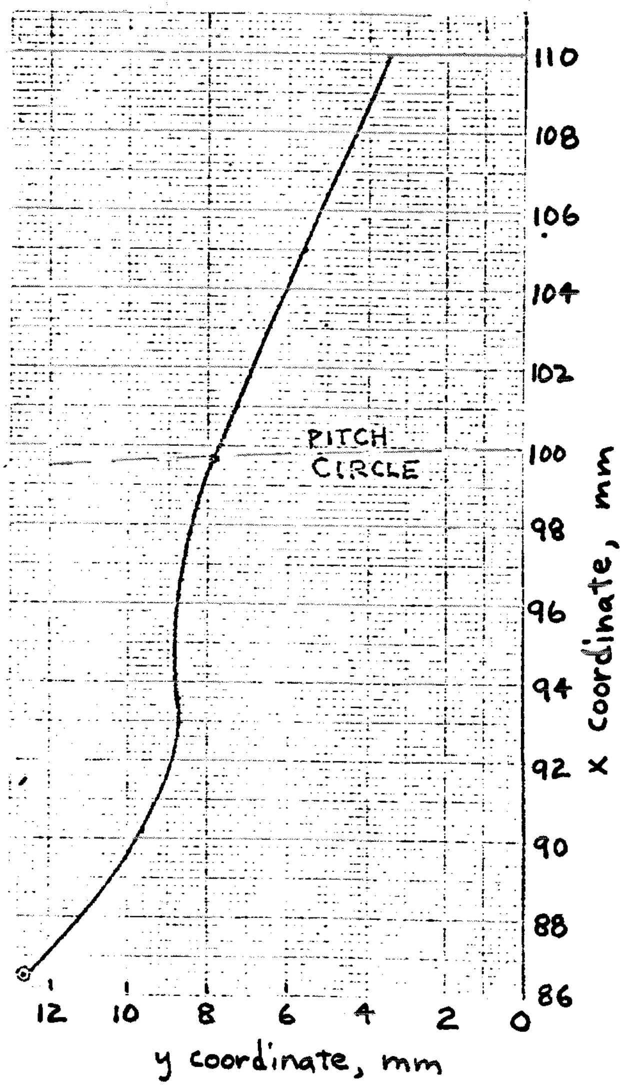

Fig. 2. Contour of spur gear tooth.

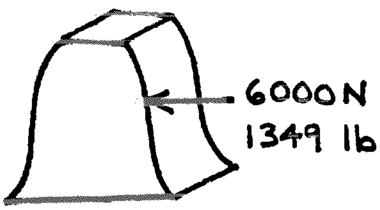

Fig. 3. Eccentric load.

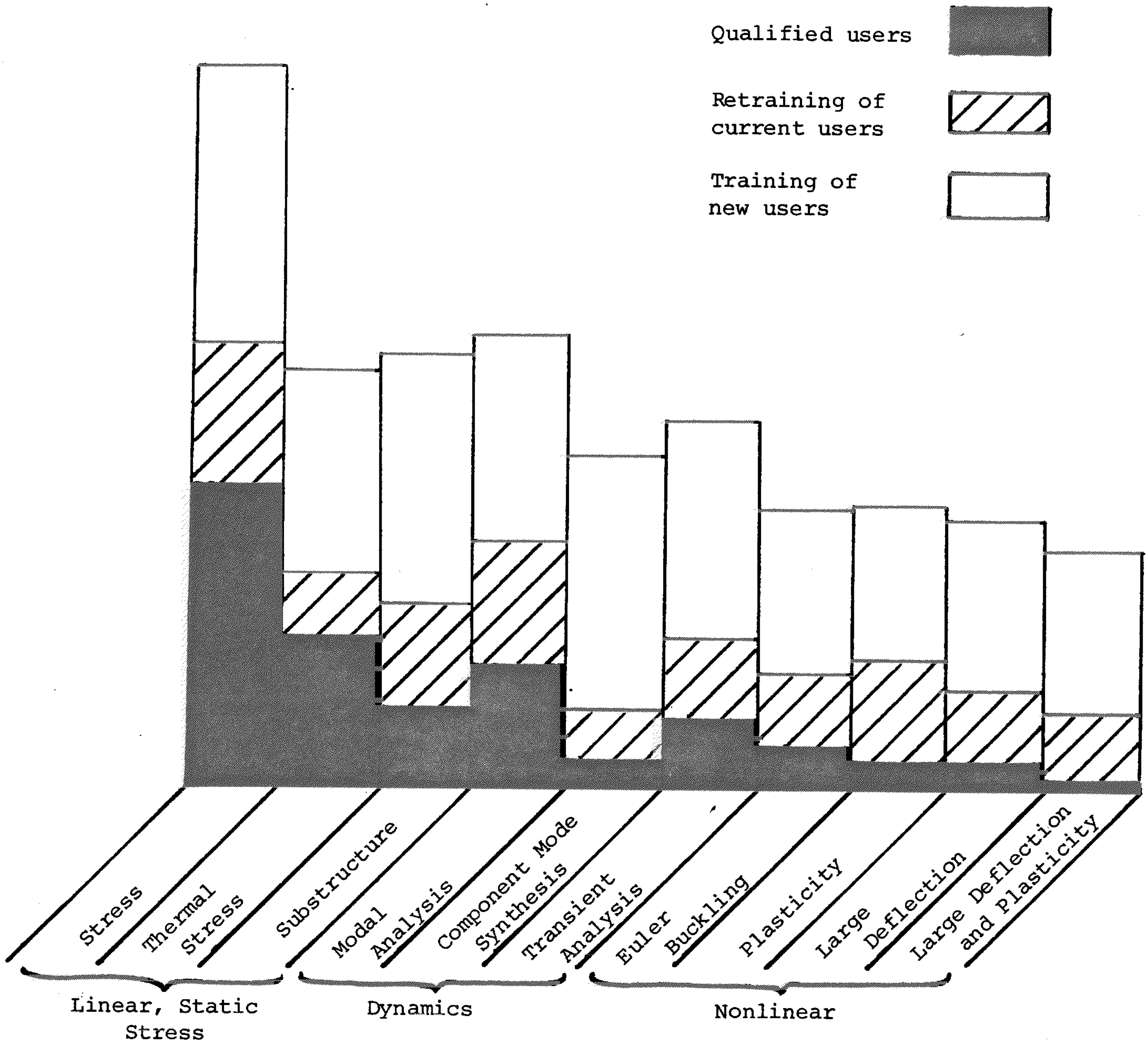

Fig. 1. Usage and desire for training in F. E. M. topics. Survey taken over a broad cross-section of automotive engineers.

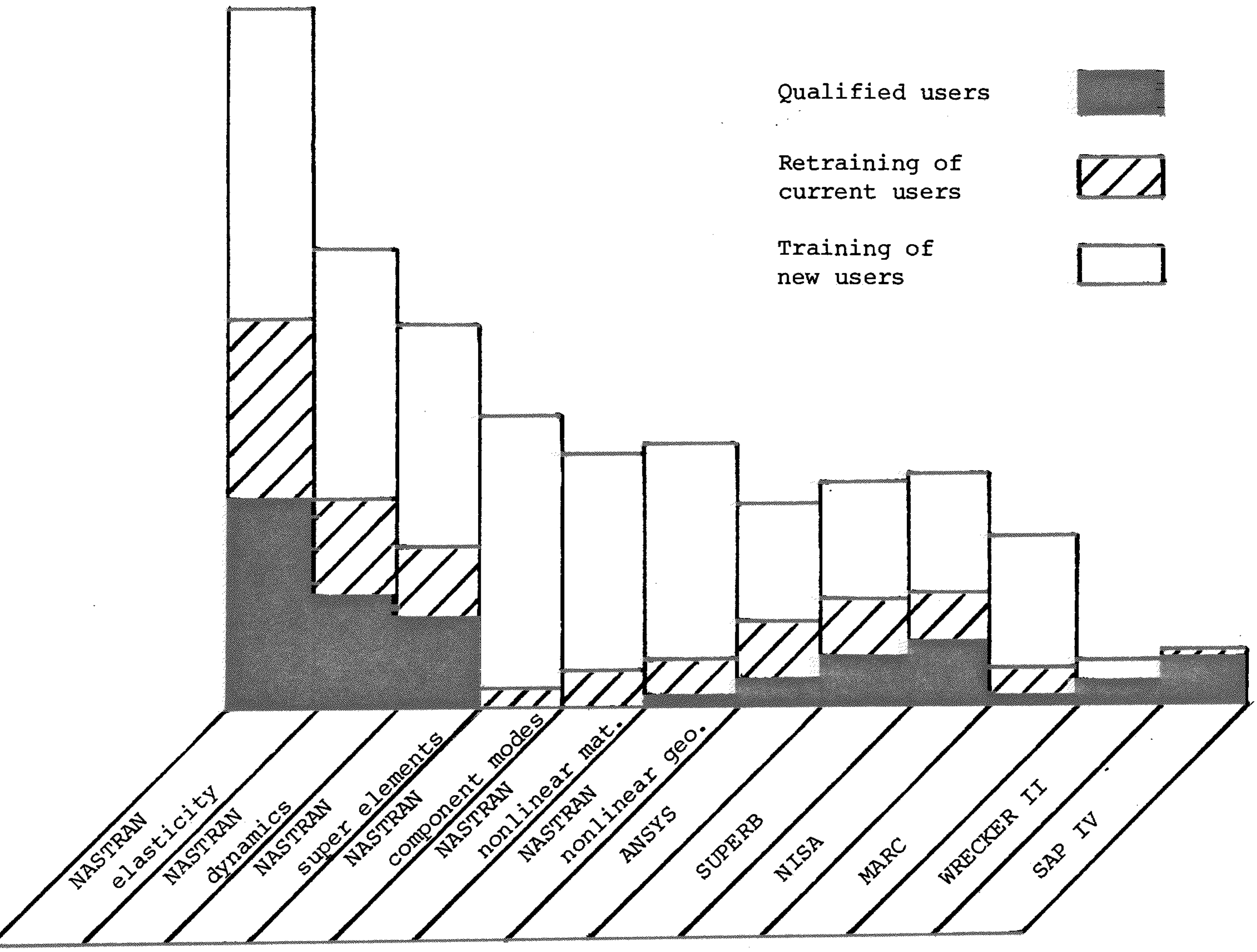

Fig. 2. Usage and desire for training on specific finite element codes.