094181

REPORT TO THE CONGRESS

Numerically Controlled Industrial Equipment: Progress And Problems

B-140389

Department of Defense

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

~~710729~~

094181

SEPT. 24, 1974

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-140389

To the Speaker of the House of Representatives
and the President pro tempore of the Senate

This is our report on the progress and problems with numerically controlled industrial equipment in the Department of Defense.

We made our examination pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53), and the Accounting and Auditing Act of 1950 (31 U.S.C. 67).

We are sending copies of this report to the Director, Office of Management and Budget; the Secretary of Defense; and the Secretaries of the Army, Navy, and Air Force.

Comptroller General
of the United States

Contents

ABBREVIATIONS

DOD Department of Defense

GAO General Accounting Office

NC numerically controlled

GLOSSARY

APT	Automatically programed tool language--The most powerful and comprehensive computer language in common use. It provides for multiaxis contouring motion by machine tools.
Axis	One of the lines of direction or motion on the machine.
Computer language	The set of symbols or signals and the rules for combining them which convey to a computer instructions or information to be processed.
Continuous path	A method of machining where the control system makes a curve by keeping the cutting tool in constant contact with the workpiece while the tool moves. Also known as contouring.
Feeds	The distance a drill, for example, moves into the work for each complete turn of the drill.
Fixture	A production-type, work-holding device used for machining duplicate workpieces. A fixture differs from a jig in that it only holds the work in a fixed position in relation to tools.
Jig	A production device that holds and locates a workpiece and guides, controls, or limits one or more cutting tools.
Machine control unit	An electronic unit which automatically reads the tape and converts the coded tape information into machine-tool instructions.
Manuscript	A form used to list the detailed instructions which can be transcribed directly by the tape preparation device or fed into a computer for further calculation.

Point-to-point	A system in which controlled motion is required only to reach a given end point with no path control during the transition from one end to the next. The most common application is a numerically controlled drill press.
Postprocessor	A special computer routine which converts general instructions into codes to operate the machine. Postprocessors are unique to each different combination of machine, control unit, language, and computer.
Preset tool	A cutting tool precisely positioned in a holder to insure positional relationship when assembled on a machine.
Punched tape	Tape into which a pattern of holes is punched to convey information. Tapes may be made of paper, mylar, or a combination of mylar and aluminum.
Speed	The velocity of a point on the circumference of the cutting tool in feet per minute.

COMPTROLLER GENERAL'S REPORT TO THE CONGRESS

NUMERICALLY CONTROLLED INDUSTRIAL EQUIPMENT: PROGRESS AND PROBLEMS
Department of Defense
B-140389

D I G E S T

WHY THE SURVEY WAS MADE

Numerically controlled (NC) industrial equipment includes drills, mills, lathes, etc., controlled automatically by punched tape. NC equipment is expensive and complex but offers tremendous productivity increases and savings in industrial operations--particularly for small-lot production. In 1973 the Department of Defense (DOD) owned $300 million worth of NC industrial equipment.

GAO surveyed how industrial activities identify where numerical control can increase productivity, plan for NC-machine purchases, manage numerical control, and follow up on its benefits. This survey, made in each military service and at two contractor plants, provides information on observed progress and problems.

GAO has a more detailed review underway covering the management of NC equipment.

FINDINGS AND CONCLUSIONS

DOD's role in advancing numerical control

Advancement of numerical control may be limited because users are confronted with many different NC systems and different standards. DOD could do more to develop the field and bring about more standardization. A more concerted, active DOD role in researching and developing the numerical control field and in working more closely with industry could directly benefit DOD, since it is a major numerical control user. (See p. 11.)

Systems for identifying a need for numerical control

Activities surveyed had no formal systems for identifying where numerical control could be economically used. They did not have adequate staffs to search out opportunities, did not make work mix studies, and usually bought NC equipment only when conventional equipment deteriorated or when new workloads were anticipated. Large amounts of equipment were planned for procurement, but very little was NC. (See p. 16.)

Planning for specific NC equipment

Once a need for numerical control has been identified, both short- and long-range plans should be made to get the most productivity. Plans should view numerical control as a total package, including computer support, organizational responsibilities, personnel, spare parts, and prompt installation. These matters may need increased attention. Also, justification documents do not seem adequate for sound planning. (See p. 21.)

Management of NC equipment in use

If NC equipment is properly managed,

use rates generally will be high. Use appeared lower than it could be, but it could increase if:

--Management had adequate data on equipment use.

--Activities had formal guidelines for determining which jobs should be done on NC equipment.

--Policies restricting multishift use were eliminated or clarified.

--Preventive maintenance programs were improved.

--Repair parts were acquired more quickly.

--Work interchange programs were improved.

Some indirect benefits of numerical control have not been taken advantage of.

--None of the activities had programs to reduce logistics support costs by stocking tapes instead of spare parts.

--Tape package exchange programs were not working.

--Higher skilled operators than may be needed are used. (See p. 28.)

Followup systems to assess benefits

Although all activities are required to have followup systems that show the actual savings from NC equipment, not all had such systems. Some systems in use produced questionable information. (See p. 43.)

RECOMMENDATIONS OR SUGGESTIONS

The Secretary of Defense should establish a DOD group to coordinate the services' use of numerical control and to work with industry in further developing the numerical control field. Such a group should:

--Develop and enforce a policy encouraging interservice standardization for NC hardware and software.

--Improve the systems for identifying opportunities for numerical control. Work mix studies should be made, and NC equipment should be considered when large amounts of conventional equipment are requested.

--Improve the planning for NC-machine purchases by developing guidelines on planning for numerical control as a total production system. Also, more input from higher levels is needed to insure more accurate justification documents.

--Study the possibilities of reducing inventories through numerical control and of exchanging NC data packages.

--Improve the management and use of numerical control by implementing the management improvements suggested on page 48.

--Establish uniform guidelines on developing systems which will more accurately disclose the true savings and costs of NC equipment.

The Secretary of Defense also should (1) work with the General Services Administration, the Atomic Energy Commission, and other Federal agencies having responsibilities for and interest in the future of numerical control and (2) consider to what extent DOD should sponsor research and development in the numerical control field. (See p. 47.)

AGENCY ACTIONS AND UNRESOLVED ISSUES

DOD plans to establish a triservice organization to improve the management and use of NC equipment, devote attention to equipment and software standardization; analyze the contribution of computers, controllers, and computer-aided manufacturing; and examine NC-equipment maintenance and personnel training. This offers potential to improve many areas noted in the survey.

DOD also plans to study whether spare-parts stockage for weapons can be economically reduced by numerical control.

Concerning its continuing work to develop the numerical control field, DOD pointed out it had pioneered numerical control to demonstrate its benefits to industry, and it believes that, if largely financed and monitored by industry, a more lasting program will develop.

DOD acknowledged that numerical control's effective application was a broad national matter requiring contributions from industry, universities, and Government agencies.

DOD also stated that such a program would require national leadership, possibly by the President's Commission on Productivity or by the Office of Technology Assessment. DOD also pointed out it was participating with a variety of organizations on how best to increase productivity through automated manufacturing.

MATTERS FOR CONSIDERATION BY THE CONGRESS

NC equipment can enhance productivity and can help improve the Nation's technology. This report, by informing the Congress of the progress and problems in moving toward more modern production techniques, should assist it in evaluating defense plant modernization programs and requests for additional plants and capabilities.

In addition, the Congress may wish to consider whether DOD should expand its research and development to take full advantage of the benefits of numerical control and whether more efforts are needed to promote industry and Government interests in working toward more standardization in the numerical control field.

CHAPTER 1

STATUS AND CONCEPTS OF NUMERICAL CONTROL

In a broad sense, a numerically controlled (NC) system is a machine that is controlled automatically by coded instructions. More precisely, it is a system in which programed numerical values, stored in some form of input medium, are automatically read and decoded to cause a corresponding movement of the machine which it is controlling. An NC system has two basic elements: the machine which does the work and an electronic control unit which directs the machine's motions. Both operate as an integrated unit. A few NC machines operate directly from computers, but most get instructions in the form of punched tape.

DESCRIPTIONS OF THE EQUIPMENT

The applications of numerical control are virtually limitless. It can be applied to any operation in which a tool or workpiece is moved from one point to another and stopped and then the work is done. Although most NC equipment is metalworking equipment, its applications include electronics manufacturing, glassmaking, food processing, material handling, drafting, and inspection.

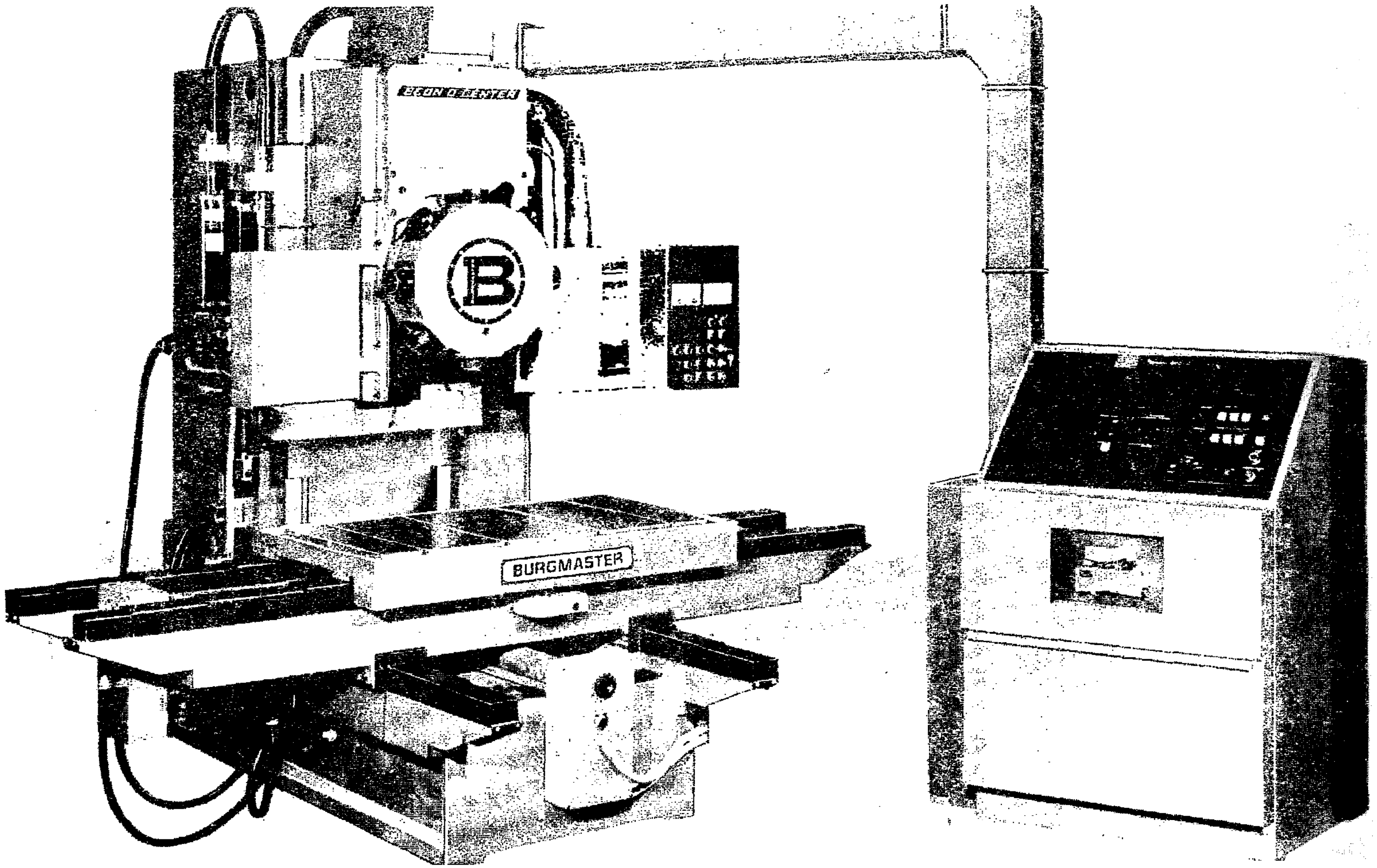
As metalworking equipment, NC equipment includes most types of conventional machines: drills, mills, lathes, punches, etc. Becoming more in use are NC machining centers which do a variety of metalworking operations. Photographs of typical new equipment follow.

As can be seen in the photographs, some machines are equipped with automatic tool changers. A variety of other features, including multiple spindles, multiple tables which allow raw parts to be loaded onto the machines while other parts are being worked, and automatic tool changers, can be built into the machinery.

EXPLANATION OF THE PROCESS

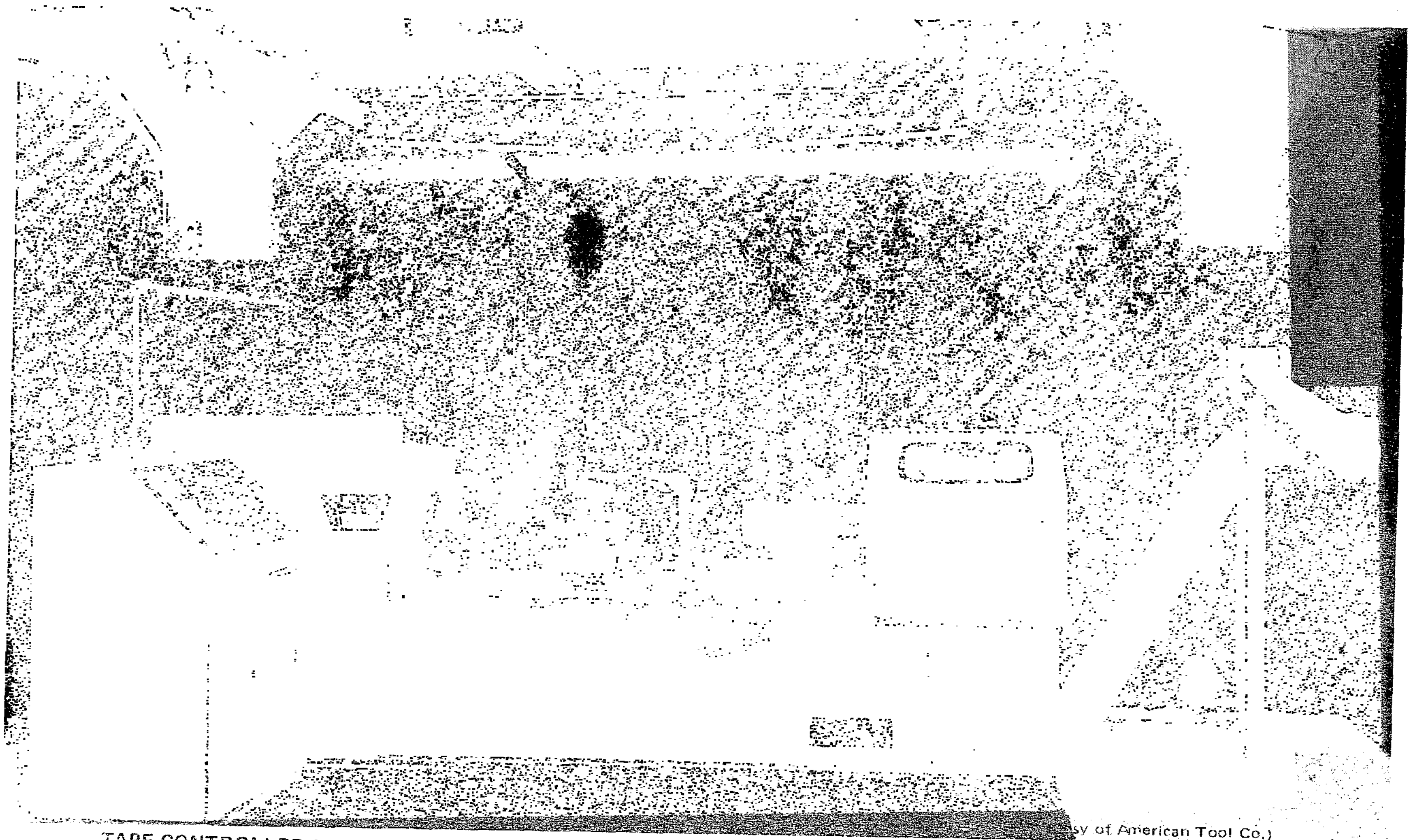
The product to be machined is first illustrated in an engineering drawing which specifies material types and conditions; surface finishes and tolerances; and part dimensions, such as length, width, height, radius, and curves.

The part programer then extracts from the engineering drawing all the information and dimensions required to machine the part. He prepares a manuscript which shows the



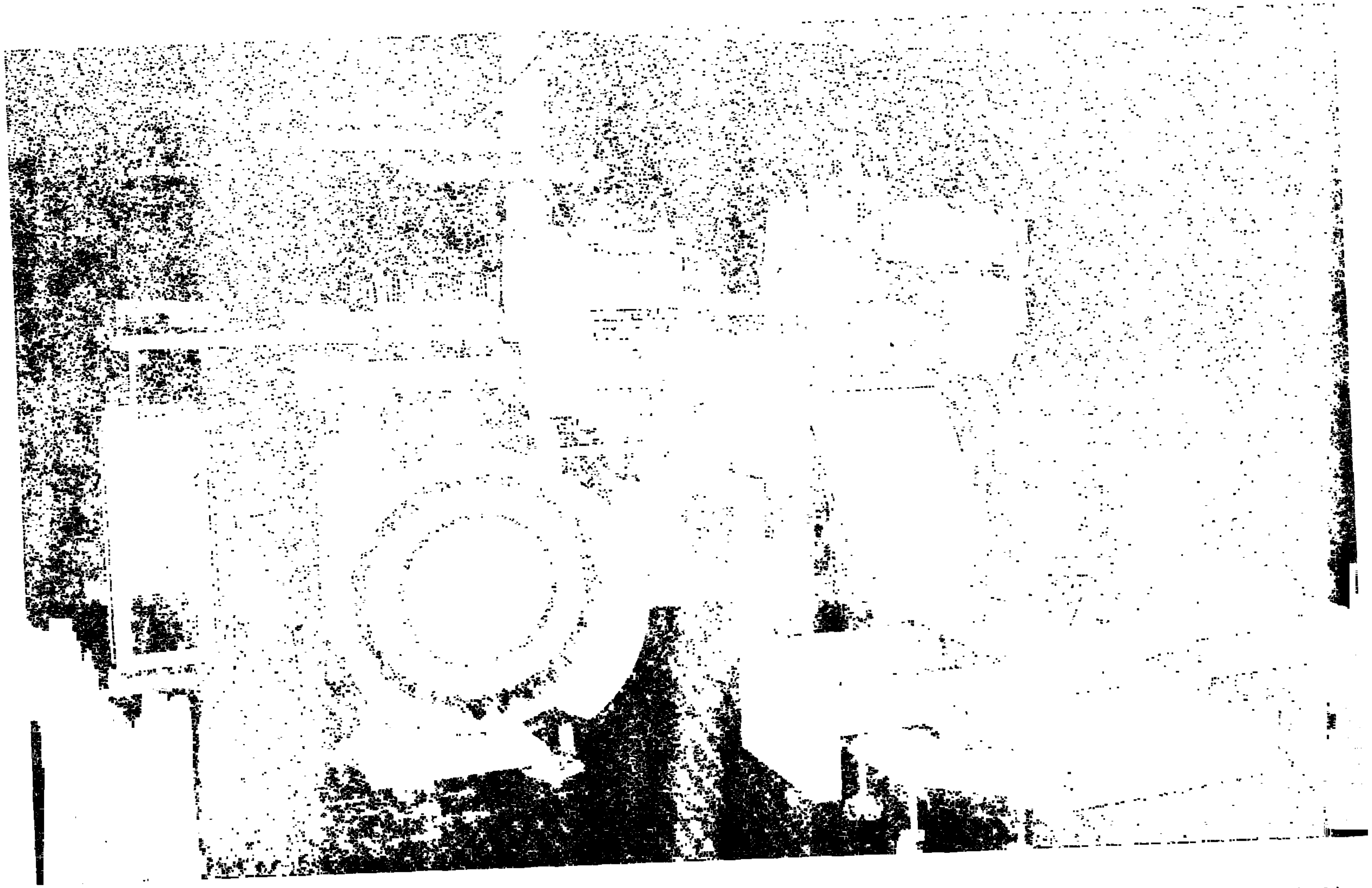
(Courtesy of Burgmaster Corp.)

TWO-AXIS TURRET MACHINING CENTER. IT SELECTS ONE OF ITS EIGHT SPINDLES IN ANY SEQUENCE FOR DRILLING, TAPPING, BORING, AND MILLING. COSTS ABOUT $45,000.



sy of American Tool Co.)

TAPE-CONTROLLED LATHE PROVIDES FULLY AUTOMATIC TURNING, FACING, BORING, AND FORM TOOLING. IT CAN DO ROUGHING WORK AND FINISHING. COSTS ABOUT $80,000.



(Courtesy of Sundstrand Corp.)

FIVE-AXIS MACHING CENTER WITH AN AUTOMATIC TOOL CHANGER HOLDING 60 TOOLS. IT MACHINES CONTOURS AND WORKS ON FIVE SIDES OF A PART WITH ONLY ONE SETUP. COSTS ABOUT $450,000.

sequence of operations, fixtures and cutting tools to be used, and feeds and speeds.

Computers usually assist in programing the part. Given points, lines, and curves as shown on the engineering drawing, computers make calculations to position and control the cutter. Postprocessors (special computer programs) convert general instructions into codes peculiar to the specific NC machine. The computer then makes the tape.

The operator's task is to place the fixture on the machine tool, load the part into this fixture, place the cutter into the spindle and over the target, place the tape in the control unit, and start the operation. The control unit then assumes command and guides the cutter in the predetermined path.

The first tryout of the tooling and tape usually reveals errors in tooling as well as in programing. When the errors have been corrected, production will be consecutive. The complete process is illustrated on the following page.

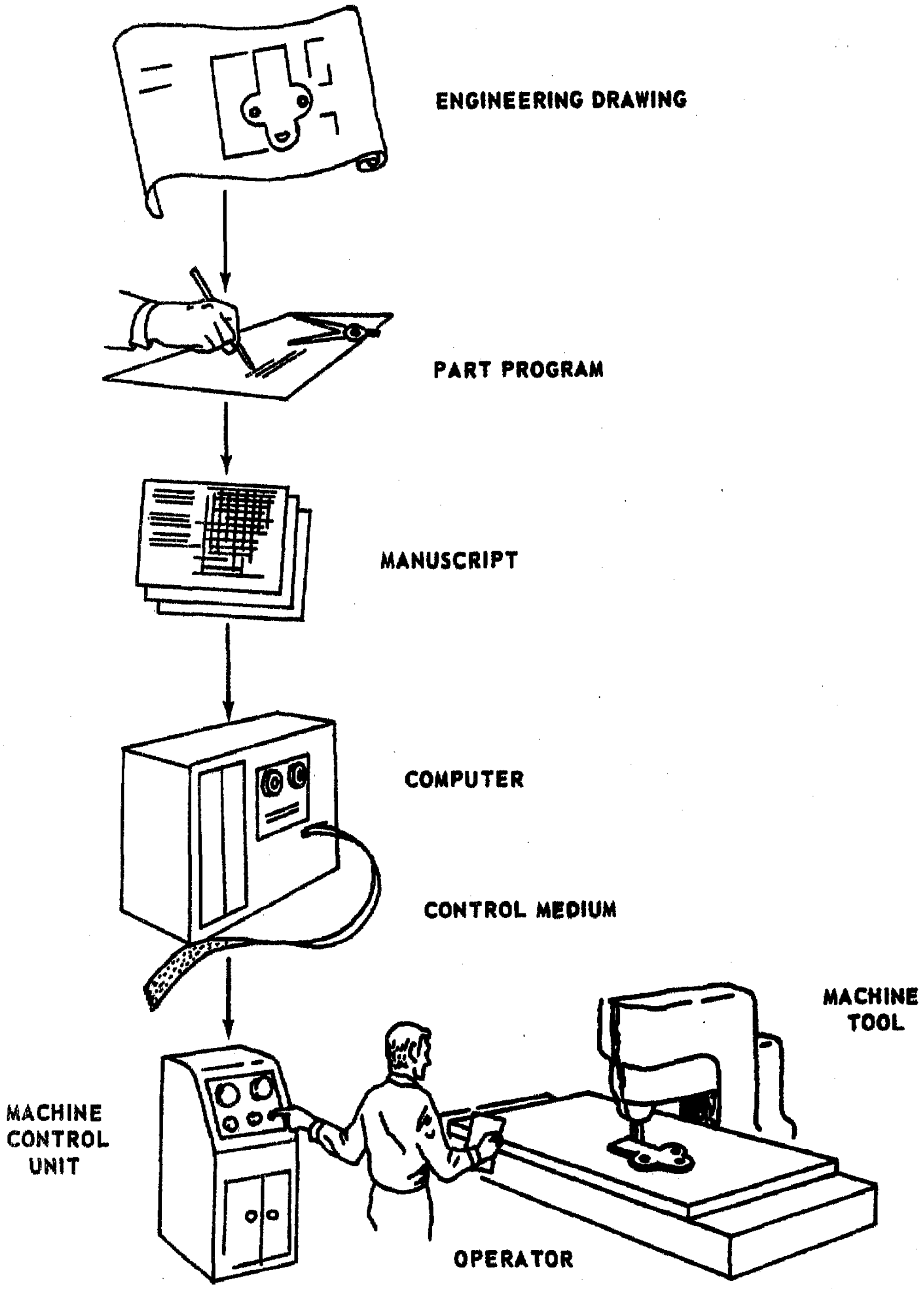
ADVANTAGES AND DISADVANTAGES

NC machines can manufacture superior and more economical products than can conventional machines. A common misconception about numerical control is that it applies to large-quantity production. Some numerical control is used in production lines, but it applies best to job-shop operations because the economic break-even point for small lots comes much earlier with NC equipment than with conventional machines. Also, some complex jobs can be done only on NC equipment. Following are some advantages of NC equipment.

--<u>Increased productivity</u>. Because all machine functions are controlled automatically, delays inherent in conventional machines are either eliminated or greatly reduced. This means metal is cut at a greater precentage of the overall machine-cycle time.

--<u>Reduced tool and fixture storage</u>. Because jigs, fixtures, and templates are greatly reduced, the primary storage remaining is that of tapes or punched cards.

--<u>Faster setup time</u>. Eliminating jigs and fixtures means jobs can be set up faster. Leadtime is also reduced materially, since jigs and fixtures for newly designed parts do not have to be designed and tested.


ENGINEERING DRAWING
PART PROGRAM
MANUSCRIPT
COMPUTER
CONTROL MEDIUM
MACHINE TOOL
MACHINE CONTROL UNIT
OPERATOR

--Reduced parts inventory. Tapes, instead of parts, can be stored. Because of the capability of NC equipment to reuse tapes, parts can be reproduced quickly.

--Speed of change. Engineering changes to workpieces can be incorporated almost immediately, simply by changing a few dimensions on the tape. In the conventional method, changes may take weeks to complete.

--Better accuracy and uniformity of parts. Tape control allows greater accuracy and repeatability. In fact, specifying tighter tolerances costs no more than loose tolerances. A side benefit of this advantage is reduced inspection requirements. Tapes can be certified periodically.

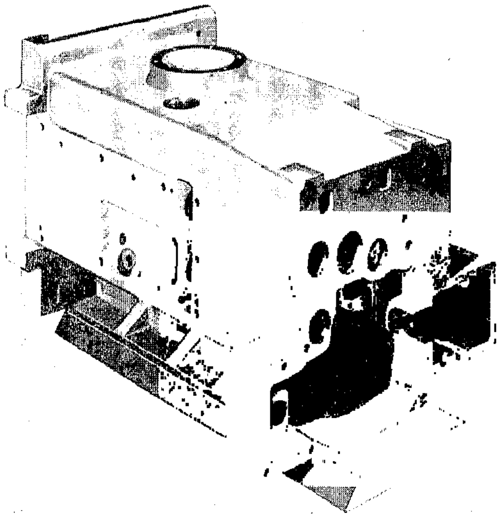
--Better quality control. With NC equipment, parts are no longer similar; they are identical. This aids assembly and reduces long and costly hand finishing. Fewer parts are rejected, so scrap is reduced.

--Reduction of parts handling. NC equipment permits more operations on a single machine with one setup. For instance, doing drilling, reaming, profiling, and contouring on a three-axis machining center could eliminate transferring parts among many machines.

--Reduced skill levels. Because the programer and the NC machine do most of the work that experienced, well-trained machinists do on conventional machines, an NC machine operator generally does not need as high a skill level.

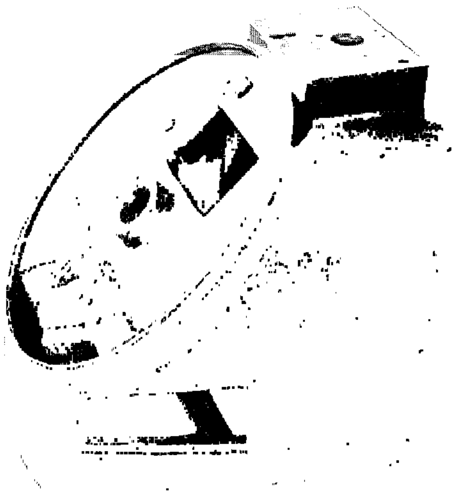
Examples of parts produced more economically by an NC machining center are on the following page. The hours shown include both setup time and machining time.

But numerical control has its disadvantages; it is expensive and complex. Control systems can contain thousands of solid-state electronic devices. Such complexity compounds maintenance problems--not only preventive maintenance but also training of mechanics in the technology of electronics. Programers, operators, and NC-machine coordinators have to be hired and trained. Finally, organizational structures may have to change to coordinate NC production with design and planning departments.



MODEL SA KNEE
(Lot size - 20)

Conventional	21.7 hrs.
Numerical control	5.7 hrs.
Percent savings	74

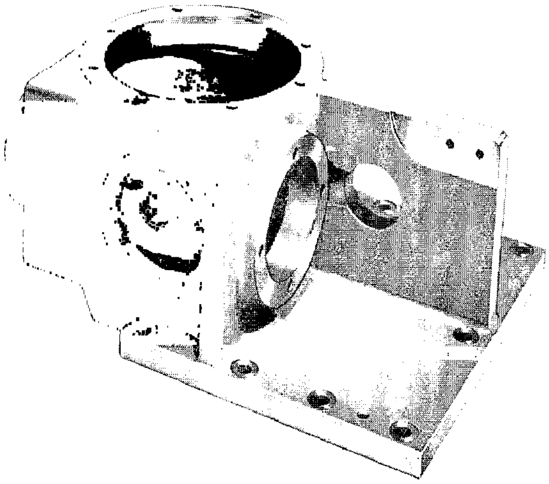


TOOL MAGAZINE HOUSING
(Lot size - 15)

Coventional	23.2 hrs.
Numerical control	3.8 hrs.
Percent savings	84

SPINDLE HEAD
(Lot size - 10)

Conventional	30.9 hrs.
Numerical control	12.3 hrs.
Percent savings	60



GEAR BOX
(Lot size - 10)

Conventional	9.2 hrs.
Numerical control	3.2 hrs.
Percent savings	65

Courtesy of Kearney & Trecker Corp.

GROWTH OF NUMERICAL CONTROL

During 1972 NC machine shipments totaled $167 million and accounted for 15 percent of the total metalworking-equipment shipments. The graph on page 10 depicts the growth of NC machine tool installations.

Most NC equipment used by the Government is industrial plant equipment, and the Department of Defense (DOD) owns most of it. In June 1973 the equipment was distributed among the services and contractors as follows:

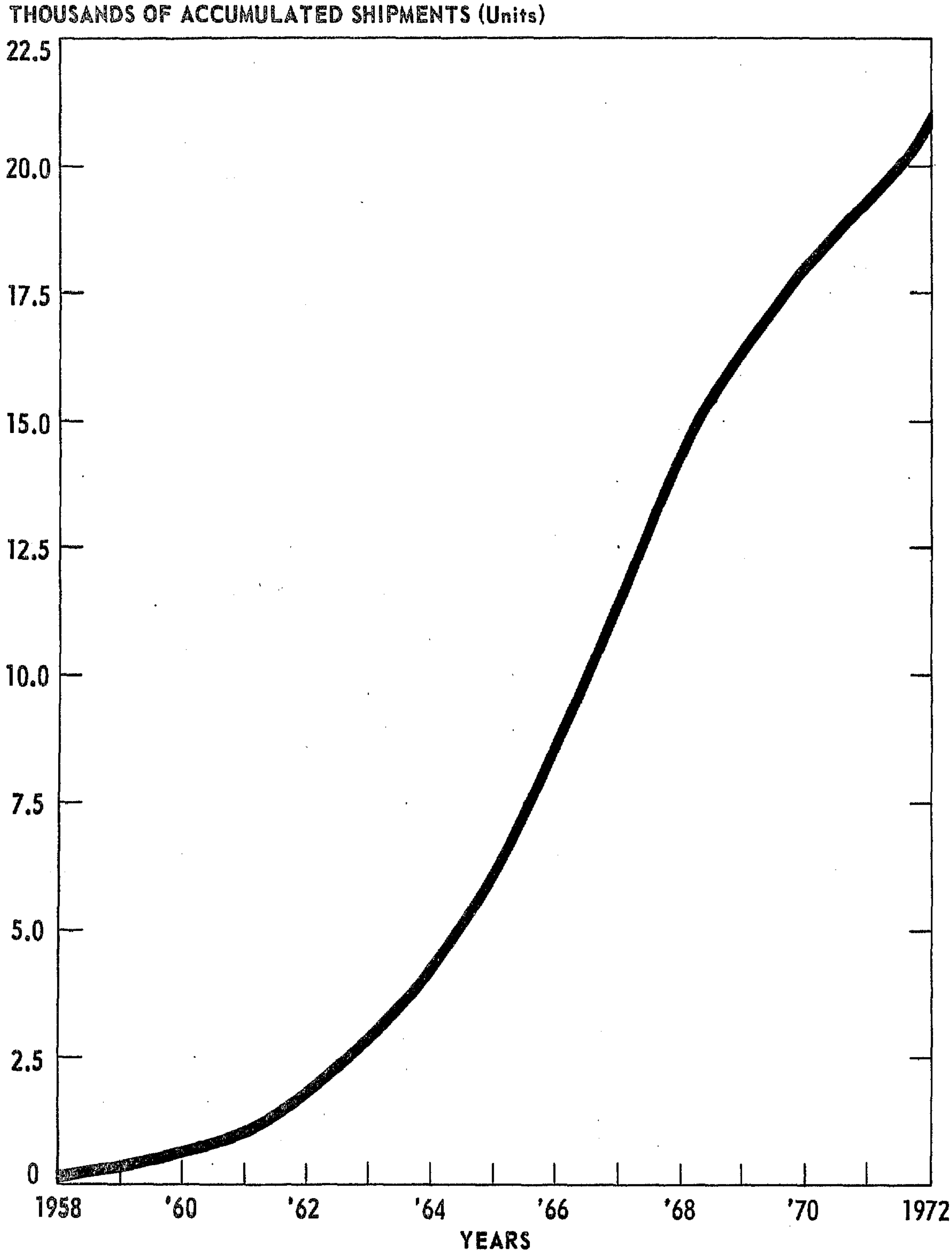
	Government operated		Contractor operated (note a)		Total	
	Units	Cost (millions)	Units	Cost (millions)	Units	Cost (millions)
Defense agencies (note b)	109	$11.7	535	$ 92.9	644	$104.6
Air Force	54	7.8	419	78.9	473	86.7
Army	192	22.6	27	3.8	219	26.4
Navy	376	45.6	176	37.0	552	82.6
Total	731	$87.7	1,157	$212.6	1,888	$300.3

[a]Categorized by the service which administers the equipment contract.

[b]Primarily the Defense Contract Administration Services, the Defense Industrial Plant Equipment Center, and the Defense Supply Agency.

Other Government owners of NC equipment include the Atomic Energy Commission, which has 400 units costing $40 million; the National Aeronautics and Space Administration, which has 80 units costing $10 million; and the General Services Administration, which has 17 units costing $1.4 million.

GROWTH OF NC MACHINE TOOL INSTALLATIONS



SOURCE: DEPARTMENT OF COMMERCE STATISTICS

CHAPTER 2

DOD's ROLE IN ADVANCING NUMERICAL CONTROL

Today's users of numerical control are confronted with a proliferation of machines, components, and software and with different standards. In our opinion, more concerted Federal leadership is needed to promote numerical control's productivity-enhancing features and to encourage industry standardization, particularly in the tooling and software areas. Because DOD is a major user of numerical control, it could be the prime benefactor of advancements in the field.

DOD ROLES

Shortly after World War II, the Air Force was faced with machining and inspecting complex aircraft assemblies accurately and on a repeatable basis. In 1948 the Air Force awarded a development contract to the Parson's Corporation which had conceived the idea that punched cards could direct machines to produce templates for inspecting helicopter plates. In 1949 the corporation was joined by the Massachusetts Institute of Technology. Development work continued, and the Massachusetts Institute of Technology was later awarded a contract which, in 1952, resulted in a successful three-motion milling machine. The following 3 years were devoted to refining hardware and developing mathematical techniques to prepare tapes. In 1955 the Air Force began awarding contracts, totaling $35 million, for the manufacture of 100 NC milling machines.

After the early development years, industry surpassed the Government in purchasing NC machines. In 1973 the Government owned about 2,400 of the estimated 21,000 industrial NC machines in use. Therefore, even though the Government does not own most of the NC equipment, it certainly owns a significant amount. And many privately owned NC machines are used for Government contract work.

In recent years the services have sponsored several studies on problems with numerical control, but most developments have been prompted by industrial associations and societies. One recent study sponsored by the Air Force (conducted by The Boeing Aerospace Company) tested a newly developed machine accessory which can be installed on existing machines. It automatically programs, senses, and adjusts feeds and speeds. The concept for the accessory, designated "Low Cost Retrofitable Adaptive Control," had been worked on for 15 years, but cost and implementation problems had prevented its widespread use. The study showed that the device can reduce cutting time by 37 percent, significantly reduce cutter breakages, and maintain normal tolerances. Moreover, it was demonstrated that the device would achieve a payback on its costs in about 6 months on a two-shift operation.

Also, the Manufacturing Methods and Technology Group, a DOD group organized for the services to exchange ideas on new technology, has funded several studies on some areas of numerical control. However, DOD has no centralized groups to coordinate the development of numerical control.

NUMERICAL CONTROL'S VARYING CHARACTERISTICS

As in the early development years of automatic data processing, the numerical control field has expanded into a variety of machines and support equipment and different standards. The uniqueness of most NC systems has caused problems which may limit full development of the field.

The primary characteristics of NC systems which vary are:

--Machines. Several companies produce the same kind of machine with different specifications. Even within the same brand name, there are differences in models, horsepower, tools, table sizes, power, feeds and speeds, spindle sizes, automatic tool changers, etc.

--Control units. Several companies build control units for their machines but most subcontract for control units. Subcontractors may update control units even though machines remain the same. Also, activities may update control units. Therefore different control units may be used for identical machines.

--Computer support. Different activities and contractors buy different computer support. Some use minicomputers, some have terminal hookups with large computers, some use installation computers without terminals, and some have no computer support.

In addition to a variety of brands, models, etc., over 50 computer languages are in use, many of which are proprietary. Also, automatic tool changers operate from codes that differ by manufacturer, and at least 30 configurations of toolholders are on different machines.

As a result of these varying characteristics and standards:

--Tapes cannot be exchanged between Government producers of the same part or between Government and industry producers of the same part.

--Shops have to deal with many different manufacturers in solving problems and in getting repair parts.

--Postprocessors are difficult to obtain because they have to be designed for the specific machine, control unit, language, and computer.

--Tooling inventories are increased unnecessarily. Because of different toolholders and codes, spare tools have to be made up for each machine even though several machines may use the same tool.

--Training is difficult. Programers have to be trained in many languages and machines, and maintenance training varies for different machines and control units.

As can be seen, the lack of numerical control commonality causes problems. In no way do we want to restrict competition or innovation; and, in fact, we believe greater agreement on NC software and hardware could stimulate and improve competition in the field.

The Government has made some attempts toward commonality and standardization. Government officials have participated in technical associations and societies, and some multiple buys of machines have been made so activities could have similar equipment. Several DOD-industry conferences have been held which have endorsed APT1/ as a standard language. Currently, the Numerical Control Society is making a study for the Army to determine which language best suits certain workloads. An Army representtive has told us that after the study is completed, the Army will specify what language is best suited for its installations. Further, the Air Force and the Army have studied acquiring standard data packages (see p. 39) from contractors for parts which the services may later produce.

The chief organizations working toward standarization have been the Electronics Industries Association and the Aerospace Industries Association. They have issued standards for the size, spacing of holes, and tolerances of

---

1/See glossary.

punched tapes. They have also issued many technical standards specifying such requirements as positioning accuracy for different types of machines.

POTENTIAL DEVELOPMENTS

In the long range, numerical control is only the beginning of more advanced concepts in which design and production functions will be completely preplanned and preprogramed with the aid of computers.

In the short range, numerical control can become the major means of automating the production of items in small batches. Experts estimate that three-fourths of all metalworking production consists of batch quantities of less than 50 pieces. Such lot sizes are common to all Government and private activities ranging from small machine shops to large plants. Therefore, with numerical control's proved savings, it could have a great economic impact.

Many other benefits from numerical control could occur within DOD. Considering numerical control in developing weapons systems could have large payoffs, since the systems could be produced faster, cheaper, and better. DOD could benefit from numerical control's inherent advantages, such as fewer jigs and fixtures, increased productivity, reduced inspections, less scrapping, and increased accuracy.

In addition, because of numerical control's ability to reproduce parts quickly, DOD could reduce logistics support by stocking tapes instead of parts. Many low-demand, insurance-type spare parts would not have to be stocked, so DOD could save substantially. For instance, the Navy's Ships Parts Control Center has $517 million invested in insurance-type spare parts. Stocking tapes instead of spare parts for those parts which are suitable for NC manufacturing would reduce investments by millions of dollars.

Another benefit of numerical control in developing weapons would be planning for the exchange of tape packages or other numerical control data between original producers and Government repair facilities. Such exchanges have been attempted but have had little success, partly because of the many different characteristics of numerical control. Also, some contractors consider data packages, including tapes, as proprietary. These questions should be identified and resolved in the contractual phases of procuring weapons systems.

Other numerical control benefits could result from greater sharing among DOD activities or between contractors and DOD activities. For instance, the Government could establish numerical control centers on a geographic basis, to provide for the more sophisticated production items and to enable pooling of smaller volume workloads from other activities. Also, centralized computer support shared by Government activities through terminals could have many advantages: adequate computer facilities would be available for all users; tape programs could be stocked and controlled at one point and shared; more expertise could be built up to provide software; and information, production parts, repair parts, and software could be exchanged.

To develop these areas and to identify others, DOD should emphasize numerical control research and development; work more closely with private industry; and most importantly, bring about a greater degree of standardization of NC hardware and software.

CHAPTER 3

SYSTEMS FOR IDENTIFYING

A NEED FOR NUMERICAL CONTROL

DOD got an early start in modernizing its machining capabilities through numerical control development, but to date it has continued to buy large quantities of conventional machines without critically analyzing the pros and cons of NC machines versus conventional machines. DOD has no formal systems for identifying where numerical control could be economically used. Activities did not have adequate staffs to search out opportunities, did not make work mix studies, and usually bought NC equipment only when conventional equipment deteriorated or when new workloads were anticipated.

INDUSTRY AND DOD PURCHASES

Over the past 10 years, the number of DOD purchases of NC equipment has decreased while the number of private industry purchases has increased, as shown below.

	Purchases by		
	DOD	Industry	Total
1963	163	865	1,028
1964	146	1,171	1,317
1965	126	1,707	1,833
1966	185	2,383	2,568
1967	197	2,474	2,671
1968	184	2,559	2,743
1969	117	2,106	2,223
1970	72	1,746	1,818
1971	53	1,134	1,187
1972	67	1,527	1,594
Total	1,310	17,672	18,982

In the early 1950s, DOD bought almost all the NC production equipment sold, but because of accelerated sales to industry, its purchases now represent about 4 percent. (See p. 18, fig. 1.) From 1970 through 1972, DOD spent $31 million for 192 NC machines and $49 million for 3,356 conventional machines. The trend of NC purchases is shown on page 18, figure 2.

This analysis is not presented to suggest that DOD should have continued to purchase larger quantities of NC equipment merely because private industry has done so. Rather, taken together with other matters presented in this report, the data indicates that, unlike private industry, DOD may not have fully exploited the technology it pioneered.

PRESENT SYSTEMS

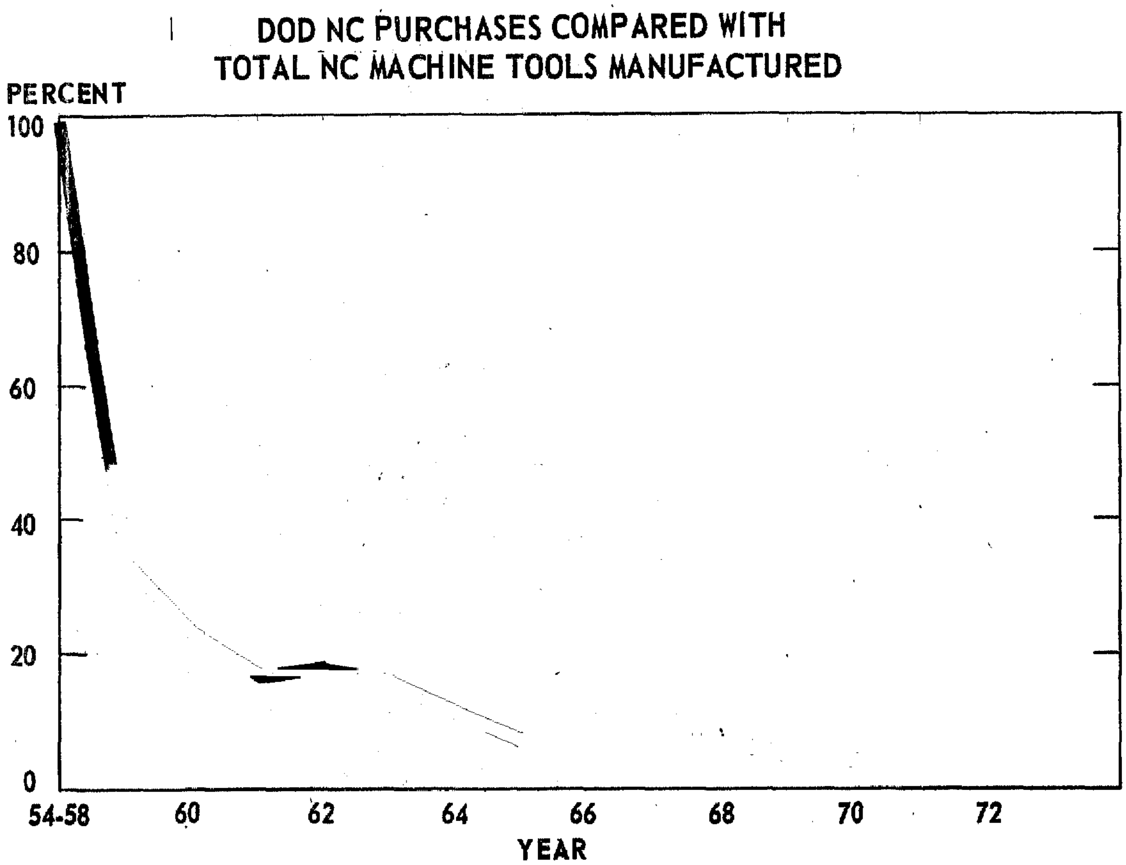
Some activities did not have enough staff to make work mix studies or similar analyses to identify opportunities for using NC equipment to increase productivity. Our survey indicated that most requests for NC equipment originated at the shop level. Such equipment was to replace deteriorated conventional equipment or to meet new workload requirements.

A joint study on productivity in the Federal Government1/ stated that a well-staffed, centralized organization oriented toward identifying productivity-improving investments was a key to a good capital investment program. Few of the activities visited by the joint team appeared to be well staffed with personnel to investigate potential productivity-increasing opportunities. The team observed that management tended to rely on operating personnel to identify investment needs and that "the primary emphasis was on replacement of isolated items of deteriorated equipment and facilities. Increased productivity did not seem to be the primary motivating factor."

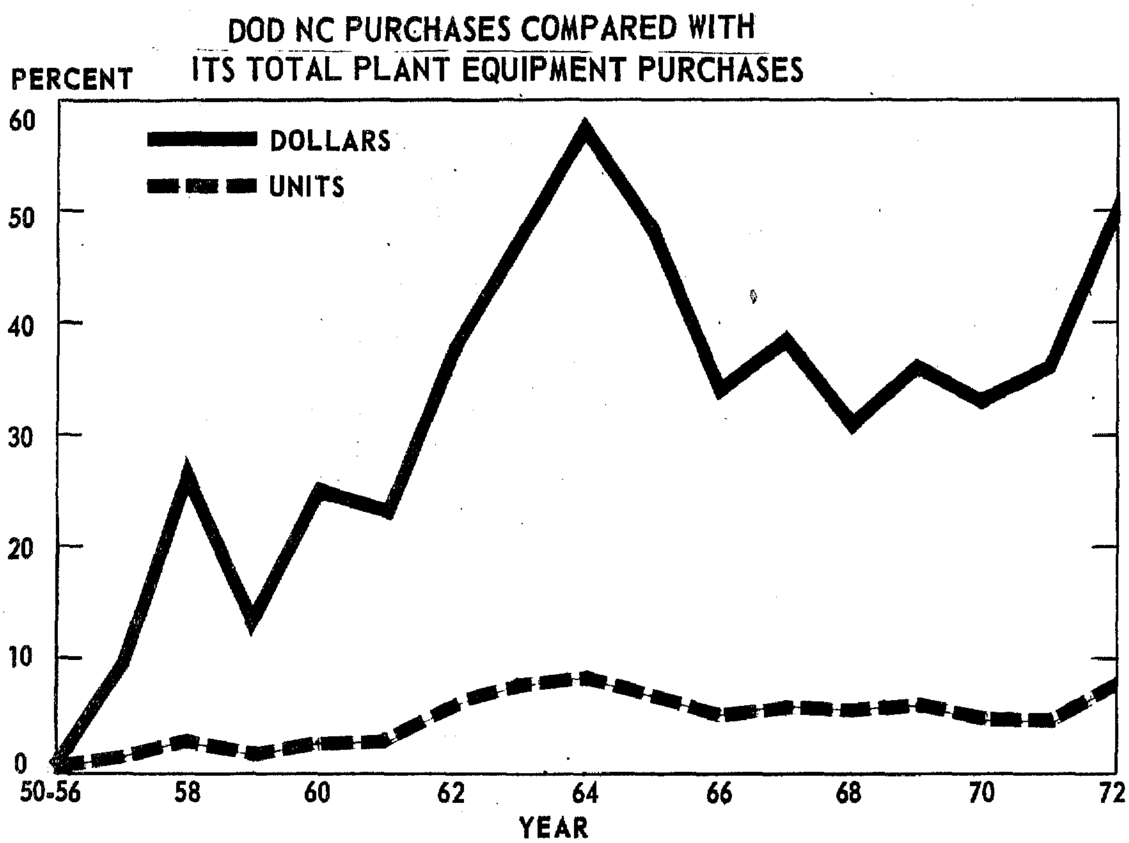
Several activities we visited said that a desirable approach to identifying where NC equipment was needed would be work mix studies but that resources had not been available to make the studies. Examples of actual practices, as described by activity personnel, follow.

--Norfolk Naval Air Rework Facility. The Production Engineering Department is responsible for establishing a need for equipment to improve operations. Only one person is assigned to this function for the machine shop. Actually, shop personnel request equipment and the Engineering Department representative prepares specifications and justification documents.

1/Phase III--"Summary Report on Measuring and Enhancing Productivity in the Federal Government," June 1973, by the Office of Management and Budget, the Civil Service Commission, GAO, and the Bureau of Labor Statistics.



(Figure 1)



(Figure 2)

--Rock Island Arsenal. Foremen in the shops identify problems with current machines and submit requests for replacements. Shop heads decide on priorities and submit requests to the Plant Engineering Division, which decides whether machines requested should be NC or conventional machines.

At each Government-operated activity we visited, we obtained justifications for several NC machines. Problems with present equipment, such as an inability to hold tolerances or other breakdowns, and expected increases in workloads appeared to be the primary factors in motivating the purchases. Although productivity was sometimes mentioned as part of a justification, it was rarely the primary factor for recommending new equipment.

CONVENTIONAL EQUIPMENT ON ORDER

The Government-operated activities had much industrial equipment planned, but very little was NC equipment, as shown below.

	Planning period	Total equipment planned	NC equipment planned	Percent
Norfolk Naval Air Rework Facility	1974-75	17	11	64.7
Norfolk Naval Shipyard	1973-75	111	-	-
Rock Island Arsenal	1974-75	90	1	1.1
Oklahoma City Air Materiel Area	1975-77	155	21	13.5

The table shows that the Norfolk Naval Air Rework Facility is planning a higher concentration of NC equipment than are the others. This is apparently because its parent command, the Naval Air Systems Command, encourages the rework facilities to achieve 75 percent of shop production through NC equipment and requires them to explain why conventional equipment is requested instead of NC equipment. We heard of no similar requirements in the other services and commands.

INDEPENDENT STUDIES ON POTENTIAL FOR NUMERICAL CONTROL

Several studies have indicated that activities could achieve more productivity by converting to NC machines but that systems are not adequate to identify opportunities for such machines. Following are summaries of some of the studies.

--U.S. Army Management Engineering Training Agency. At an Army depot's machine shop, the Agency categorized, primarily through discussions with shop personnel, major workloads on conventional machines by work function, such as drilling and milling. The Agency studied a sample of work in the major functional areas from the standpoints of conventional machine versus NC machine run time, the types of NC machines which could do the work, and the volume of work. It concluded that two NC machines could be productively used.

One machine suggested was an NC punch, costing about $65,000, which would save 10,000 man-hours a year. Considering only the savings on labor, the punch would pay for itself in about 6 months. Another machine suggested was an NC milling machine, costing about $40,000, which would save about 4,800 man-hours a year. The labor savings would amortize the initial cost of this machine in about 10 months.

The Agency felt that the depot's in-house capability was not adequate to identify productivity projects. Only one depot representative was available to do such work, and he spent only 30 percent of his time on the machine shop. He used this time to scan DOD lists of excess equipment.

--U.S. Army Production Equipment Agency. At an Army depot, the Agency sampled shop orders which showed large man-hour requirements and found many potential applications for NC machines. For the sheet metal shop, an NC punching and shearing machine could replace conventional machines and yield a payback in 4.7 years. For the machine shop, the Agency suggested an NC lathe, a turret drill, and a machining center, which would yield quick paybacks.

--Logistics Management Institute. The Institute studied the feasibility of using NC machines aboard U.S. Navy tenders and repair ships. Its February 1970 report stated that NC machines were economically advantageous and technically feasible for certain metalcutting operations. The report concluded that, of the benefits from using NC machines both afloat and ashore, improved response time would be the most meaningful to the Navy.

CHAPTER 4

PLANNING FOR SPECIFIC NC EQUIPMENT

TOTAL PACKAGE PLANNING

Management should plan for NC equipment as a total package by planning the role of computers; organizational responsibilities; adequate numbers of trained personnel to program, operate, and maintain the equipment; the content of spare-parts kits; and prompt installations. However, because management at the activities was not adequately trained in numerical control, planning was not adequate.

Computer support

Several activities have had NC machines for years but only recently have gotten adequate computer support and postprocessors, which are essential for the more sophisticated NC machines. The key advantage of computer support and postprocessors is reduced programing time.

Some production departments initially used base computers (normally in comptroller departments or otherwise separate from production), but it sometimes took 2 to 3 days to get programing results. Also, many tape programs had to be rerun 5 to 10 times to correct programing errors. To reduce programing time and thereby increase productivity, most activities have begun to use computer terminals or have purchased minicomputers. The following summarizes computer problems and progress at some activities.

--The Norfolk Naval Shipyard got its first NC machine in 1958, the majority in 1967, and the last of nine in 1968. Until 1973 all programing was done manually. Because of the long leadtime required, parts were made conventionally, so NC machines were used only half a shift a day.

In mid-1970 the shipyard requested a minicomputer, but the request was denied because it was higher command policy that computers should not be in production departments. In 1971 the shipyard requested a three-dimensional coordinate-measuring machine (which has a minicomputer), and the request was approved for the production department. Seventy percent of the minicomputer's capacity will be available for programing assistance, and postprocessors were expected late in 1973. When the minicomputer and postprocessors are fully operational, use of NC machines is expected to double to one full shift a day.

--<u>The Oklahoma City Air Materiel Area</u> received its first NC machine in 1958 and now has 18. It has enough postprocessors, and the machine shop has been using base computers to assist in programing. Because turnaround time is slow, several days elapse before a program is completed.

Because of these problems, air materiel areas are working out arrangements for a centralized computer at the San Antonio Air Materiel Area. Each air materiel area will have a ready-access terminal, and turnaround time will be only 30 minutes; therefore, more jobs will be feasible for numerical control and productivity should increase.

--<u>The Norfolk Naval Air Rework Facility</u> installed its first NC machine in 1963 and the majority between 1968 and 1970. Beginning in 1968, programing was done with computers at several activities not related to the rework facility. These arrangements were unsatisfactory because of the slow turnaround time. In 1972 the facility bought a minicomputer; however, it had to buy new postprocessors, which became fully operational in 1974.

--<u>Rock Island Arsenal</u> got its first NC machine in 1958. It now has 36, half of which it got before 1967. The machines were programed manually until 1971 when the arsenal entered a time-sharing contract with UNIVAC. In 1972 the arsenal got a minicomputer that (1) will serve as a terminal with a large computer at Picatinny Arsenal, Dover, New Jersey, on a time-sharing basis and (2) operates several NC machines directly--the only application of direct numerical control in DOD. These latest computer arrangements will save one-half of the expense of the UNIVAC contract. However, new postprocessors had to be purchased.

<u>Organizational responsibilities</u>

In planning for NC machines, management must designate organizational responsibilities, including where the machines will be placed and whether full-time NC-machine coordinators will be assigned.

Some activities placed their NC machines throughout their plants near related work and component supervision.

Such an arrangement is beneficial, particularly for the first NC machines. Other activities grouped their machines in single locations. The benefits of this arrangement, which seems to be preferred, increase as the number of machines increases, because (1) supervision of advanced NC-machine work is much different from that of conventional machine work and (2) the NC machines are convenient for programers to monitor tape preparation and first-piece production.

Selecting the initial location of the equipment is important, since relocating it is expensive, causes downtime, and necessitates recalibration. Following are examples of changes in NC-machine locations.

--The Norfolk Naval Shipyard has all of its NC machines in two sections of the machine shop, except one NC punching machine which is in the sheet metal shop. A recent modernization study of the machine shop shows that all of its NC machines will be moved and grouped adjacent to the programing area. The goal is to change the organizational structure so that one supervisor will be responsible for all aspects of numerical control. The sheet metal shop will keep its NC punching machine, which differs in concept from other NC cutting machines, and will also keep programing responsibility.

--The Norfolk Air Rework Facility's NC machines are assigned to the Metals Division, which includes the programing section. The facility had planned to place one machine in the Power Plant Division, but a recent consolidation study recommended that all present and future NC machines be placed in the Metals Division, to increase the efficiency of both machines and personnel.

The major addition to an activity's organizational structure to accommodate NC machines is the coordinator. He usually oversees machine selection, justification, parts programing, and maintenance and is the contact for information on and problems applicable to numerical control. His responsibilities include establishing procedures to insure the maximum work for NC machines and coordinating the processing of NC-machine job orders from planning through completion. At two activities we visited, the NC-machine coordinators also had other responsibilities.

A March 1973 joint shipyard conference recommended that shipyards assign NC-machine coordinators within shops and engineering, planning and estimating, and design divisions.

The Army Materiel Command is studying where the coordinator should be in an organization.

Support personnel

The numerical control planning process should include plans for acquiring and training enough personnel to program, operate, and maintain the machines. Such personnel should be available when the NC machines are installed or shortly afterward.

We noted no major problems in planning for enough trained personnel. For the most part, contracts for new NC machines called for factory training for support personnel.

Spare-parts kits

Another point to consider in procuring NC machines is what spare parts to buy. Most manufacturers recommend spare-parts kits, but activities usually do not purchase those recommended because they are often expensive, ranging up to 15 percent of the price of the machines. Some activities buy modifications of the recommended kits on the basis of experience with other machines.

In some cases, not buying the spares caused downtime. For example, at the Oklahoma City Air Materiel Area, a mill was down 4 weeks because of a faulty circuit board. Earlier, it had been down 4 weeks because of a defective relay switch. These parts were included in the manufacturer's recommended spare-parts kit but were not stocked. The Oklahoma City Air Materiel Area now stocks these parts.

An alternative to the problem of not being able to purchase the recommended, expensive spare-parts kits would be to stock spare parts for several machines at a central location. By doing so, activities could reduce duplicate investments in spare parts and could acquire parts more quickly. For instance, Sundstrand machining centers (see photo, p. 4) were recently purchased for three naval air rework facilities. Norfolk Naval Air Rework Facility personnel said that they had only the minimum recommended spare parts, which cost $9,000, but would like to have more. They said that, if they had more machining centers, they would be able to justify additional spare parts.

The Norfolk facility coordinator said that the other two rework facilities had essentially the same spare parts as the Norfolk facility had. We were told that a nearby activity--the National Aeronautics and Space Administration's Langley Research Center--was also getting a Sundstrand machining center of the same model as the rework facilities had. In June 1973 there were 31 other Sundstrand machining centers at DOD activities and contractors. Currently, however, there is no system to control spare parts for several activities and no information system to enable an activity to identify and request needed spare parts from another activity.

Installation delays

The planning process should also insure installation of the machinery shortly after it arrives. The manufacturer normally provides foundation drawings and other technical data before delivery to allow for site preparation. Most activities experience little delay in installing the equipment, but some had delays of 6 months or more.

Some of the longest delays occurred at the Norfolk Naval Air Rework Facility. After the facility receives certified drawings from the contractor, it makes location drawings and forwards them and a work request to the Public Works Center. The Public Works Center reviews the drawings and decides whether it will do the work in-house or under contract. If Public Works decides to do the work, the job is scheduled but may be delayed for higher priority work. For example, a jig borer received in May 1972 had been waiting 15 months to be installed. The contractor had sent incorrect drawings and corrected them in August 1972. In December the work request went to Public Works. The machine was still not installed 8 months later. Reasons cited by the Public Works Center for delays were shortages of manpower and materials and higher priority work.

JUSTIFICATION PROCEDURES

Documents and procedures for justifying procurements of NC equipment need to be improved. Justification documents are not based on accurate data and do not show all costs and savings.

As noted in the "Summary Report on Measuring and Enhancing Productivity in the Federal Government," (see p. 17) good investment decisions depend largely on the adequacy of project justifications and adequate justifications depend on good cost-benefit analyses. The joint team found that activities had little or no documentation to support proposals for projects and that cost-benefit analyses were often poorly prepared.

At the activities we visited, most of the NC equipment had been justified on the Machine Tool Replacement Analysis Worksheet (DD Form 1106). The DD 1106's prime function is to provide a clear summary to both technical and administrative personnel who will evaluate the equipment request. It analyzes the operating cost of present and proposed equipment and estimates annual savings. We looked at five main categories on the DD 1106s and found that the reliability of the documents varied and that most had little backup data.

--The productivity increase ratio is supposed to be developed by engineering studies and estimates from manufacturers. But some activities did not indicate how they had developed the ratio or included such statements as "prior experience on similar machines" but gave no supporting details.

--Machine load is the known and anticipated workload of present equipment and the number of hours the proposed equipment would be used in a year. One activity analyzed parts from machines to be replaced until it found enough man-hour savings to show a 5-year payback for the proposed machine. Another activity estimated the proposed machine's load at 2.5 shifts a day and calculated what the equivalent man-hours would have been on its present machines. The person who prepared justifications at another activity said he gathered most of the data from discussions with operators and maintenance personnel.

--Under "tooling," activities were to calculate major differences between the tooling costs for the present equipment and those expected for proposed equipment. One activity said that a $65,000 saving on conventional machines would result from tooling. However, the saving was based on the average cost to tool a conventional machine and apparently did not consider that tooling was already available. Because no new workload was expected for the NC machine, it appeared to us that the $65,000 was a sunk cost and not a savings. Another activity said there would be no additional tooling costs for conventional machines.

--Savings from other operations was the reduced inspection time, reduced assembly time, etc., inherent in NC machines. One activity showed no savings in this category. Another indicated that eliminating assemblies was a major factor but showed only inspection savings on the justification. Other activities gave no data supporting savings in this category.

--Activities are specifically required to show other NC-machine costs or savings under "other cost." Although most activities had increased costs for computer support, programers, training, and postprocessors, none had indicated these costs on their justifications.

CHAPTER 5

MANAGEMENT OF NC MACHINES IN USE

Once NC machines are installed and operational, good management is essential to achieve the expected benefits. One key result of good planning and management is proper equipment use. NC-machine use appeared to be less than it could be, and management did not always have adequate, uniform data on such use. Some of the problems were

--a lack of criteria for what work should be on NC machines,

--management policies limiting multishift use,

--inadequate preventive maintenance programs,

--delays in getting repair parts, and

--a lack of programs to exchange work between activities.

Some indirect benefits of numerical control were not being achieved because the activities

--had no programs to reduce stocks of spare parts carried in inventories,

--did not exchange tape packages to save programing effort, and

--had not taken advantage of NC machines' ability to use lower skilled operators.

USE OF NC MACHINES

Since NC machines are more expensive and more productive than conventional machines, it is important that their workloads be properly scheduled. In private industry a NC machine is often in operation 75 percent of the time on two and three shifts. Use rates may run as high as 90 percent, and one source said "The cardinal rule of keeping the machine cutting is mandatory in numerical control if payback in a reasonable time is anticipated."1/

1/Charles J. Vlahos, "Fundamentals of Numerical Control" (New YOrk: Verlan Publications, Incorporated, 1968).

At the activities we visited, actual NC-machine use rates were low in relation to potential use. Low use does not necessarily mean that machines are not recouping their investments. Sometimes the productivity gain on certain parts is so great that a machine returns most of the investment on a few runs. For example, the Oklahoma City Air Materiel Area manufactured 400 hinges because the contractor could not deliver them for 6 to 9 months. It took 1,246 hours of NC milling compared with 8,400 hours of conventional milling. This saved 7,154 hours, or about $92,000. The specific mill used was not identified, but the activity's mills ranged in cost from $45,000 to $290,000.

Within the Government activities, there appeared to be differing ideas on the number of shifts which NC machines should be run and no clear policy on the reserve machine capacity needed for national emergencies. According to several literature sources, industry commonly uses its NC machines on two or three shifts. At the Government activities we visited, most NC machines were used on only one shift. Further acquisition of some NC machines was justified solely on relieving multishifts on other NC machines. Unnecessarily limiting the number of shifts may contribute to decreased economic returns or to procuring machines that may not be needed.

The DOD maintenance policy representative of the Office of the Deputy Assistant Secretary (Production Engineering and Materiel Acquisition) said that DOD policy called for having two or three shifts available for reserve capacity because of the inability of industry to build up quickly in an emergency. Also, a Naval Air Systems Command representative told us that, although there were no headquarters guidelines, another machine generally should be bought if an NC machine was used over one shift and that two shifts must be reserved for immediate mobilization capacity. His reasoning was that the output of NC machines was much greater than conventional equipment and therefore more critical. He acknowledged that he had difficulty with this policy because activities felt that it prevented adequate paybacks.

In contrast, a Naval Ship Systems Command representative said that one shift was the minimum target use and that no policies restricted multishift use. He said the Defense Industrial Plant Equipment Center maintained reserve equipment for emergencies.

These informal and differing policies indicate a need for clear guidance on multishift use and reserve capacity. Multishift use of NC machines could reduce conventional-machine workloads and could preclude investments in additional equipment.

MANAGEMENT INFORMATION ON EQUIPMENT USE

Management must have accurate and timely data on equipment use to exercise effective control. The activities had different systems for recording use and recorded different factors, as indicated below.

Naval Air Rework Facility	Norfolk Naval Shipyard	Oklahoma City Air Material Area	Rock Island Arsenal
Cutting time	Run time	Run time	Run time
Tape proveout	Mechanical repair	Accuracy tests	
Setup	Electrical repair	Scheduled maintenance	
Warmup	Lubrication	Unpredictable repair	
Cleanup	Preventive maintenance	Awaiting parts	
No work		No work	
No operator		No operator	
No tooling		Down mechanically	
Maintenance:		Waiting tools	
Mechanical		All other reasons	
Control			
Preventive			

Most activities had machine power meters, but only the Norfolk shipyard used them for use data. The other activities computed use data from man-hour records. Also, some of the data recorded is questionable.

--The air materiel area run time, which is based on operator time, includes time in which the operator is doing non-NC-machine work, such as loading pallets or deburring parts on conventional machines.

--The rework facility data covered only 8 of the 10 machines in use.

--The shipyard run time, which is based on meters, includes nonproductive time. We were told that the meters might be turned on for an entire shift, regardless of whether work was being done.

Improved management visibility through more in-depth information could help to increase machine use and efficiency. For instance, if information were available to show time spent loading and unloading parts, management might find that multiple tables, which allow raw parts to be loaded while another part is being machined, would be a wise investment. The number of delays due to errors in tapes could alert management to the need to improve advance tape testing. Additional categories of information (see app. I) could help management improve production in other ways.

CRITERIA FOR SELECTING WORK

The activities lacked systematic procedures for screening jobs and selecting good candidates for NC machines. In discussing selection criteria, personnel usually referred to complexity, multiple tooling and setup time, the possibility of reruns, and other theoretical characteristics of desirable NC-machine jobs. No activity had quantified and documented selection criteria, and only one activity had compared costs of the different machining methods.

Procedures for scheduling workloads did not appear adequate. Job planners usually selected jobs for NC machines, but we were told that some planners were not adequately trained on NC machines. Some activities relied heavily on shop personnel to spot potential NC-machine work being done conventionally. In contrast, the two large, private contractors we visited, which do considerable Government work and which have both privately owned and Government-owned NC machines, said that decisions on what work should be done on NC machines were normally made when products were designed and that therefore shop personnel did not become involved in selecting work for NC machines.

Of the Government activities, the Oklahoma City Air Materiel Area's selection system was one of the better systems we observed, as follows:

--Planners screened all work requests for potential NC-machine candidates and based their decisions on (1) whether the part had been done on NC machines previously, (2) complexity, (3) tolerances, (4) lot sizes, and (5) leadtime available to program.

--Candidates were sent to the Methods and Standards Division, where a cost comparison was made considering setup and machining hours. Parts having NC-machine hours equal to or less than conventional-machine hours were tentatively scheduled for NC machines.

--The candidates were scrutinized by a preplanning team composed of the NC-machine coordinator, programers, schedulers, shop foremen, quality control personnel, and workload controlers and planners. Firm decisions to use NC machines were made if the part was appropriate for NC machines and if scheduling the part was feasible.

Even though these procedures seemed to be better than those of the other activities, the air materiel area had no written guidelines on what factors should be considered in selecting parts or in comparing costs. The only documentation produced was a work order which stated the hours for NC machines and conventional machines.

Following are summaries of the systems at the other Government activities.

--Norfolk Naval Shipyard. Shop planners initially decided whether a job should be done on NC machines. We were told that the planners had no formal orientation or written criteria about NC machines and that many jobs were missed. A planning supervisor said that NC machines were usually used if the parts were already programed, if the work was complex, and if leadtime requirements were short. Other jobs might be informally selected when programers toured the shops and observed conventional-machine work.

--Norfolk Naval Air Rework Facility. Job planners decided whether work should be done on NC machines by determining whether the job was already programed and by considering the possibility of reruns, lot size (generally 24 or more), and machine time available. However, the shop superintendent and programers also identified jobs being done conventionally and converted them to NC machines.

--Rock Island Arsenal. Again, shop planners made the initial decision. We were told that the planners had extensive orientation on NC machines and had been instructed to load NC machines first. Steps had been taken to document the capabilities of NC machines in use. Other criteria include quantity of parts required (usually 25 or more), tooling, setup time, run time, probability of repeat orders, tolerances, and complexity. The most emphasis was given to scrutinizing new work. In one case, the activity analyzed the NC-machine potential for all parts in a new weapons system.

The lack of good systems for selecting NC-machine work indicates that many jobs may be missed and that production may not be as economical as possible. In our opinion, if cost comparisons were uniformly made, most qualitative factors (such as complexity) now used would automatically be taken into account in calculating man-hours for the different machining methods.

PREVENTIVE MAINTENANCE PROGRAMS

The activities' preventive maintenance programs varied, and some were inadequate. "Fundamentals of Numerical Control"1/ describes the importance of preventive maintenance.

> "Numerical control maintenance problems are largely extensions of conventional machine problems. However, they differ in that they require immediate attention. As can be expected, downtime is costly for any numerical control machine, so users must make every effort to be prepared for any future breakdowns * * * preventive maintenance is a must; every effort should be made to set such a program up. Once set up, it should be diligently executed.
>
> "Because of the inherent nature of numerical control, there arises an immediate need for reorientation and education of maintenance personnel. This alone can have a significant influence on the profit potential of a numerically controlled machine."

Guidelines being developed for naval shipyard preventive maintenance programs state that such programs and effective management are absolutely necessary and that every possible precaution must be taken to prevent unscheduled downtime for adjustment, maintenance, or repair of NC machines.

All activities have guidelines for preventive maintenance programs, and most have a manufacturer's inspection schedule for each machine. However, these guidelines were not always followed. Descriptions of the programs at the Government activities follow.

--Oklahoma City Air Materiel Area. This activity used manufacturers' checklists for mechanical preventive maintenance. Activity officials told us that, although they felt the program was adequate, it could

---

1/See footnote, p. 28.

be improved through additional factory training. Electrical preventive maintenance was a problem because they did not have equipment to make recommended tests. Electrical problems usually were identified when parts produced failed to meet specifications.

--Norfolk Naval Shipyard. Although the Naval Ship Systems Command required a preventive maintenance program for all industrial plant equipment, shipyard personnel said they had no preventive maintenance programs for NC equipment due to the lack of skilled manpower. As noted earlier, additional guidelines are being drafted for all shipyards covering basic requirements for NC-machine maintenance; however, these guidelines will not improve the programs unless skilled manpower is adequate.

--Norfolk Naval Air Rework Facility. Maintenance representatives told us that mechanical and hydraulic components of all machines had periodic maintenance but that, due to a lack of manpower, only two machines received electrical preventive maintenance. Other officials indicated that mechanical and hydraulic maintenance was also inadequate.

--Rock Island Arsenal. The arsenal had tried to follow the manufacturers' recommended preventive maintenance but felt that it caused unnecessary downtime for inspections, etc. Accordingly, the arsenal periodically checked obvious items, such as filters, and made limited inspections of other mechanical functions. The arsenal's Chief of Servo Mechanics and Repair said that electrical preventive maintenance was not needed for control units, so none was done.

The contractors' programs seemed to be better than those of the Government activities. One contractor had experienced downtime because it had to use maintenance personnel for other work. But both contractors felt that they had enough skilled personnel, and both had in-depth checklists for each machine and each control unit. The checklists were developed in-house on the basis of manufacturers' recommendations and experience with the equipment. Maintenance personnel indicated that preventive maintenance was done regularly according to plans.

An adequate preventive maintenance program for both mechanical and electrical components is one key to maintaining high productivity. Because of the high initial cost and the adverse effect on productivity of unscheduled maintenance, preventive maintenance should be emphasized and requirements should be clarified.

DELAYS IN PROCURING REPAIR PARTS

Several activities complained of inordinate delays in acquiring needed repair parts because of cumbersome procurement systems. Such delays caused costly machine downtime. Some examples follow.

--Rock Island Arsenal. A maintenance representative said that most manufacturers had an exchange program whereby parts could be obtained in a week or less. However, he pointed out that the Government's paper processing to order parts took about 30 days. At the time of our visit, several machines were down waiting for parts. A lathe costing $220,000 had been down for 1-1/2 weeks because of a defective part. The manufacturer had been contacted and promised delivery 1 day after he received the order.

--Norfolk Naval Shipyard. A $135,000 turret lathe was down for 5 months awaiting a $2,200 coder. Of this time, 2 to 3 months was due to initiating and processing the part order. The procedures for ordering parts involved section supervisors, shop detailers, maintenance shops, the production engineering department, and the supply department.

--Norfolk Naval Air Rework Facility. One machining center costing $280,000, which was programed for two shifts, had been down for 5 weeks due to a faulty lead screw costing $4,000. We were told that items over $2,500 required special approval and therefore contributed to lengthy downtime.

WORK INTERCHANGE AMONG ACTIVITIES

DOD has policies and instructions to encourage work interchange among activities, but actual interchange was rare even though most activities had extensive idle capacities. Most activities believed that work interchange was theoretically feasible but would cause scheduling problems. Several were receptive to accepting work from other activities but were generally against having others do work for them.

A 1967 DOD directive requires that each DOD component request support from another component when the capabilities are available and when such support is to DOD's overall advantage. It directs that each DOD component provide support to the extent that military requirements permit and capabilities exist or can be made available and that the interservice and interdepartmental agreements be executed at the lowest command levels possible.

The NC-machine coordinator in the Air Force Logistics Command told us that there was no policy for exchanging numercial control work between air materiel areas and that work interchange occurred infrequently. The Oklahoma City Air Materiel Area told us it had done seven or eight emergency numerical control jobs for another air materiel area and had done work for several subcontractors so they could meet completion dates.

An Army Materiel Command representative indicated that work interchange among arsenals was not likely because workloads peaked at the same time. The Army Missile Command (a subordinate of the Army Materiel Command), which has no metalworking capacity, generally contracts for machine work but is encouraged to use Army arsenals. Rock Island Arsenal representatives said that 6 to 10 percent of the arsenal's workload, including numerical control work, was for Army commands and other facilities. Also, they seemed receptive to having other activities do work for Rock Island Arsenal during workload peaks, but did not know what numerical control capabilities were available at other activities.

Naval Air Systems Command representatives said that a naval air rework facility might request another facility to do work in emergencies or to produce a part if the other facility had already programed the part. Norfolk Naval Air Rework Facility personnel said the facility had done some jobs for the National Aeronautics and Space Administration and indicated they were receptive to accepting work from other facilities but not to having others do their facility's work.

The Naval Ship Systems Command NC-machine coordinator said that shipyards were encouraged to exchange work, but he had no statistics on how much had been exchanged. The Norfolk shipyard's NC-machine coordinator saw no advantages in using another activity's numerical control because the shipyard is a repair yard with critically short leadtime requirements. Yet the Norfolk shipyard had done several numerical control jobs for the National Aeronautics and Space Administration and had helped other shipyards in programing parts.

Extensive work interchange programs between similar activities and between different nearby activities would require planning and coordination and perhaps additional shifts to avoid scheduling and work priority problems. However, such programs could have important advantages. For instance, a Norfolk shipyard representative said that the shipyard needed NC contouring milling capabilities but could not justify procuring the machinery. The Norfolk Naval Air Rework Facility, 15 miles away, has three contour milling machines which are used one and two shifts with idle time on both shifts.

Work interchange could allow an activity to absorb work from smaller, nearby activities. For instance, in the Norfolk area, many activities have industrial equipment but may not have large enough workloads to acquire NC equipment. To our knowledge, such activities, including Langley Air Force Base, Yorktown Naval Weapons Station, and Oceana Naval Air Station, have not requested NC work from either the Norfolk Shipyard or the Norfolk Naval Air Rework Facility.

Work interchange could also avoid duplicate capabilities at similar activities. For example, three naval air rework facilities have machining centers costing $450,000 each. The Norfolk facility's machining center, and perhaps the other facilities' centers, is not being used to the fullest capacity.

Improved work interchange programs should be studied to increase use of and savings from NC equipment, help avoid purchases of unneeded equipment, and provide a means for more economical production to activities that cannot economically justify NC equipment.

PROGRAMS TO REDUCE OR ELIMINATE PARTS INVENTORIES

NC machine leadtime to produce repeat orders is substantially less than conventional machine leadtime. Therefore, inventories can be reduced by storing tapes instead of parts. Storing tapes can avoid procuring insurance-type spare parts which manufacturers may not be able to produce later and can preclude scrapping parts later found to be not needed.

The activities said that they produced no parts solely for maintaining stock levels but that they produced parts to meet known requirements for a year or more. The Government activities have not studied the feasibility or economy of reducing production lots for NC work. In fact, the personnel who order parts and designate lot sizes do not know whether the parts have been or will be produced on NC machines.

Eliminating low-demand, insurance-type spare parts has been considered but not pursued. A Rock Island Arsenal representative suggested to command headquarters that the arsenal dedicate several NC machines to producing spare parts for the Tank-Automative Command. The brief analysis supporting this suggestion indicated that the tank command's spare-parts inventory could be greatly reduced and that large savings could result. We were told that the suggestion was not accepted because it would cause cumbersome management problems between the arsenal and the tank command.

Some studies have tried to identify what types of data should exist in numerical control data package so that Government activities could reproduce spare parts originally made by contractors. However, the feasibility of storing data packages instead of spare parts has not been studied.

We are not certain that reductions in inventory levels are entirely feasible with numerical control, since activities theoretically are not producing for stock. However, producing spare parts for a year or more is not very different from maintaining a certain stock level. If normal stock levels and procurements of insurance-type spare parts could be reduced through numerical control, savings could result. More studies on these matters are needed.

TAPE PACKAGE EXCHANGE

The lack of numerical control commonality (standardization) prevents contractors and Government activities that produce the same or similar parts from exchanging machine tapes. Studies made by industry and Government activities have concluded that exchanging tapes offers no benefits but that exchanging data packages would save programing time. Since programing represents a major part of the cost of an NC job, exchanging programs can reduce programing effort and can therefore lead to large savings.

Norfolk shipyard officials told us that the shipyard had not exchanged any tape packages with other shipyards, except in one instance when an exchange program was being tested. At a March 1973 conference, the shipyard recommended that the tape catalog system be discontinued and that they instead be urged to "open greater lines of communications to exchange programs and programing services."

The naval air rework facilities have no written procedures for exchanging numerical control programs, but they have a list of programs for two NC machines which all the facilities have in common. We were told that if one activity needed a part that was programed by another activity, the activity which had programed the part would be requested to send the tape, tape printout, fixture drawings, and tooling information. Norfolk rework facility representatives told us that they had exchanged only a few programs in the last 2 years because (1) the facilities did not have the same NC machines, (2) the workload for a major component was assigned to only one facility, and (3) the list of programs was for only two NC machines.

The Oklahoma City Air Materiel Area and the Norfolk rework facility rework different models of J-57 engines. However, they had not tried to exchange data. We showed each activity a list of parts which the other had programed. It did not seem that the activities produced identical parts, but the Norfolk rework facility noted that some of Oklahoma City Air Materiel Area's parts were similar to the facility's parts. Norfolk then contacted the air materiel area to identify additional jobs for Norfolk's NC equipment.

Air materiel areas and Army activities had no program package exchange program between their related activities because, we were told, they have very little work and equipment in common.

The Oklahoma City Air Materiel Area studied potential exchange with a contractor. It compared how the contractor had produced selected parts with how the Oklahoma City Air Materiel Area would produce the parts and concluded that, if it received a data package from the manufacturer, it could produce the part and substantially reduce programing time. Later, an Oklahoma City Air Materiel Area conference defined the contents of numerical control data package as (1) engineering and/or numerical control drawings, (2) tool lists, (3) preset tool data, (4) fixture drawings and machine setup estimates, (5) a programing manuscript, (6) a configuration of automated data processing equipment, and (7) an identification of the machine and control unit. To reproduce a part from a data package, the Oklahoma City Air Materiel Area would change the manuscript to compensate for different languages; change tool functional data; and compensate for diversities in control systems, tool adaptors, cutting-tool designs, etc.

Although attempts at exchanging data packages have been made within a given service, they have not been successful and no programs exist between services or between industry and the Government. Before such programs can be started, the question of proprietary contractor data packages must be solved and greater standardization must be achieved. It seems that proper studies could help design systems to achieve savings through tape package exchange.

OPERATOR SKILL LEVELS

The NC machine and the programer do much of the work that formerly required a skilled and experienced machinist. NC-machine operators do not have to be as fully qualified as conventional-machine operators. With most numerical control installations, the operator's function is largely that of an overseer with such other duties as inserting tapes, changing tools, and loading and unloading workpieces.

In many countries, the ability to use lower skills is a major selling factor of NC machines because skilled conventional machinists are difficult to acquire. In the activities we visited, experienced, well-trained machinists were used to operate the NC machines. At one activity, extensive recruiting was being done to hire machinists. Although categorzing the numerical control operation as requiring lower skill and wage levels could have economic benefits, this would likely be a disincentive to an effective numerical control operation. An alternative would be to use lower skilled personnel and view the numerical control operation as a way to advance to higher job levels, such as programing.

We selected machines having comparable complexities at each activity and found that the experience requirements, job titles, and grade levels of the machines' prime operators varied, as follows:

	Experience required	Job title	Wage grade
Norfolk Naval Shipyard	2 years' apprenticeship on conventional machinery	Machinist	WG-10
Norfolk Naval Air Rework Facility	2 years' experience on conventional machinery	Machinist	WG-10
Rock Island Arsenal	4 years' apprenticeship on conventional machinery	Machinist	WG-11
Oklahoma City Air Material Area (note a)	Conventional machine operator at WG-10 level	NC machine operator	WG-12

a/Prime operators are not designated. Operators are required to have 6 months' minimum training on NC machines at the WG-10 level and then may be promoted to WG-12. Most NC machine operators are WG-12s.

The Oklahoma City Air Materiel Area's job descriptions were written to cover NC-machine skills; however, the other activities' descriptions did not mention NC-machine skills. Also, the descriptions mentioned skills not required for NC machines. For example, a Norfolk shipyard job description for an NC-machine operator describes "typical work performed" as:

--Selects appropriate cutting tools and installs and alines them in machines.

--Operates machines, controlling the speeds and feeds. Brings various tools to bear in successive operations and makes various test cuts and roughing and finishing cuts.

--Checks dimensions at various stages, using such precision-measuring instruments as height gauges, depth gauges, calipers, verniers, and micrometers of various types.

--Typically works from blueprints and specifications of finished pieces to be obtained but may also work from oral instructions or from workpieces to be replaced or duplicated.

--Uses shop mathematics to made calculations.

Regardless of whether reduced skill levels can be beneficially used, job descriptions should cover NC-machine duties and wage levels should be comparable among the services.

CHAPTER 6

FOLLOWUP SYSTEMS TO ASSESS BENEFITS

Knowing the actual results of NC equipment in use can help to determine future equipment needs and to identify management actions needed to increase productivity. Most activities were required to have followup systems to show actual savings and benefits, but not all had such systems. Further, the systems in use varied widely among the services and did not include all costs and benefits.

The "Summary Report on Measuring and Enhancing Productivity in the Federal Government" (see p. 17) recommended that management require systematic feedback on completed projects to demonstrate that the benefits claimed were achieved or, if not, to evaluate the reasons why not. Followup of implemented projects was virtually nonexistent in most agencies the joint team visited. This appeared to stem from a lack of (1) appreciation of the value of such information, (2) systems to generate followup information, and (3) requirements for followup.

The shipyards appear to have a followup system that fairly accurately reports benefits. The Naval Ship Systems Command requires each shipyard to sample jobs and report savings every 6 months. At the time of our survey, the sampling involved (1) selecting six completed job orders on each machine, (2) comparing NC machining hours with conventional machining hours shown in production records or estimates, (3) multiplying savings in man-hours by hourly shop labor rates, and (4) projecting the sample savings to the 6-month period using meter readings. The shipyards submit as a single item the total costs which relate only to numerical control, such as the cost of tape preparation and computer support. The command then prepares semiannual and annual composite reports for each shipyard.

At a joint shipyard conference in March 1973, Norfolk Shipyard personnel stated that data being submitted did not account for programing or tool setup time and that the shipyard's cost accounting system was not adequate to calculate true savings. A July 1973 Naval Ship Systems Command instruction mechanized the reporting system and designated in more depth the savings and cost factors. For instance, the samples are now to include savings from reduced tools, power, setups, and scrap. However, the system still appears to have several problems.

--The basis for total use is power meters. We were told that machines often were not producing work when they were running. Thus the time the machines were not producing work was included in the savings computations when man-hours were projected to total power meter use.

--One machine is not included because the reporting system relates only to machines acquired under the Shipyard Modernization Program.

--The system does not account for past savings. The latest reports show a composite payback period of 11 years for the Norfolk Shipyard, yet some of the machines have already returned the investment several times.

A 1971 Naval Air Systems Command instruction requires that naval air rework facilities maintain production records to verify savings from equipment investments over $10,000. The records are to be kept long enough to evidence increased production and/or savings. The Norfolk rework facility has not yet started accumulating the data, but it is developing a system which would require operators to fill out data sheets.

A 1973 Air Force Logistics Command instruction requires that the air materiel areas prepare benefit reports on each NC machine that was approved through the Defense Plant Modernization Program. The instruction requires that a benefit report be prepared 6 months after the machine is installed to confirm the benefits stated in original justifications and to explain significant deviations.

At the time of our survey, the Oklahoma City Air Materiel Area had not yet received any NC machines through the modernization program. It had made a study to demonstrate savings; it used two methods of computing savings on 19 randomly selected items of varying lot sizes produced during the last 3 years. One method, using an arbitrary 3-to-1 productivity ratio for NC machines, computed $99,400 in laborsavings. The other, using cost comparisons of actual NC-machine time and estimated conventional-machine time, multiplied by the average conventional shop rate, computed savings of $2 million but appeared to contain errors.

--The average conventional shop rate used was 2-1/2 times the actual shop rate shown in justification documents.

--Major cost elements, including programing, tape preparation and testing, and computer support, were not computed.

--Such savings as reduced setups, jigs, fixtures, and scrap were not calculated.

An Army Materiel Command regulation requires that its activities calculate in a one-time report (Form DD 1651--Industrial Equipment Modernization Program Post Analysis Report) actual net operating savings a year after equipment is operational. The forms, which are forwarded to the Army Plant Equipment Agency, compare the justification documents item by item with actual experience in the year. When actual savings are less than 85 percent of the estimated savings shown on the justification, the activity must explain the reasons for the deviation.

As noted previously, much of the data in the justifications is questionable. Also, the data in the DD 1651s may not be accurate. For example, in 1973 the Army Audit Agency reviewed eight DD 1651s at Rock Island Arsenal and found overstatements in indirect labor rates and therefore in the actual net operating savings. When corrected, the actual savings for three of the eight items were reduced to below the 85-percent criterion and therefore required explanation.

The contractors we visited also used DD 1651s to report actual savings but prepared the forms 15 months after the machines were operational.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

DOD had a major role in initiating the use of numerical control and in developing its early stages. But DOD has not continued that role and, unlike private industry, may not have fully exploited the technology it pioneered. In addition, the services have had a variety of problems, many of which appear to be beyond the capability of individual activities to correct. These conditions suggest that DOD needs to take a more coordinated, active role. With the proper attention, numerical control could become the major means of automating small-lot production, significantly improve productivity, reduce inventories, and improve readiness by providing greater surge capabilities in time of emergency.

Because NC equipment is both more productive and more expensive than conventional equipment, it requires special attention to achieve its benefits. The service activities we visited did not give adequate attention to NC equipment.

--Most activities did not have good systems for finding opportunities for NC equipment to economically replace conventional equipment. NC equipment was usually prompted when conventional equipment broke down or new workloads were anticipated. Also, much conventional equipment was on order. Staffing did not appear adequate to do work mix studies to identify the most economical production techniques.

--The planning process for specific machines could be improved. NC equipment should be planned for as a total package by considering computer support; organizational responsibilities; adequate numbers of trained personnel to program, operate, and maintain the equipment; contents of spare-parts kits; and prompt installations. Also, the planning for NC equipment should include adequate justification documents. Justifications we examined did not seem to include all costs and benefits of NC equipment and were not always accurate.

--Many aspects of managing NC equipment need further attention because proper management can make the difference between a quick payback period and a loss. Although the extent NC equipment is used is not an exacting measure of productivity, making greater use of it should improve investment returns. In our opinion, use was less than it could be because of a lack of criteria for what work should be done on NC equipment, unclear policies on the number of shifts NC equipment should be used, inadequate preventive maintenance programs, delays in getting repair parts, and lack of work exchange among activities. Some indirect benefits of NC equipment also were not being achieved; the activities had no programs to reduce stocks and spare parts, tape exchange programs were not working, and higher skilled operators than may be needed were used. In addition, management did not always have adequate use data.

--The activities did not always have adequate followup systems to help determine future NC-equipment needs and to identify management actions needed to increase productivity. Most activities made some attempts to follow up on the actual benefits of NC equipment, but the data did not seem adequate for management to decide whether investments were sound or to pinpoint problem areas. Also, the emphasis on the need for such data seemed to vary among the activities.

Some of the activities have made progress in these areas. But the activities have no way to draw on the experiences of the others or to work together in solving common problems.

RECOMMENDATIONS

We recommend that the Secretary of Defense establish a centralized DOD group to provide guidance on numerical control to the service activities and their contractors and to serve as an information clearinghouse and focal point for numerical control planning and management. The group could assist in developing the full potential of numerical control by encouraging and coordinating research and by working toward industry standardization. Specifically, the group should:

--Develop and enforce a policy encouraging interservice standardization for both NC hardware and software.

--Improve the systems for identifying opportunities for numerical control. Work mix studies should be made, and NC equipment should be considered when large amounts of conventional equipment are requested.

--Improve the planning for NC-machine purchases by developing guidelines on planning for NC as a total production system. In addition, perhaps higher command levels should give more input to preparing accurate justification documents.

--Establish a Government-wide inventory of NC spare parts and require activities to consider that inventory when they procure new machines.

--Clarify the policies on multishift use and reserve capacity of NC equipment to obtain maximum use of such equipment. More in-depth management information on use is also needed.

--Improve the management of numerical control. The activities need (1) more training on NC equipment, (2) criteria and procedures, including cost comparisons, for determining what work should be done on NC equipment, (3) adequate preventive maintenance programs, (4) authority to give priority to procuring needed repair parts, and (5) better systems for exchanging work between similar activities and between services.

--Study the possibilities of reducing inventories through numerical control and of exchanging NC data packages.

--Establish uniform guidelines on developing followup systems which will more accurately disclose the true savings and costs of NC equipment.

We also recommend that the Secretary of Defense (1) work with the General Services Administration, the Atomic Energy Commission, and other Federal agencies having responsibilities for and interest in the future of numerical control and (2) consider to what extent DOD should sponsor research and development in the numerical control field.

AGENCY COMMENTS AND OUR EVALUATION

The General Services Administration's Director of the Office of Management Systems and Special Projects commented on this report by letter dated March 27, 1974. (See app. III.) He said that the report should help DOD managers in making proper decisions on acquiring and using industrial equipment and suggested that the report be sent to and read by those managers. This, he believed, would ultimately lead to increased productivity in the Federal sector by helping many DOD equipment managers overcome their reluctance to acquire NC equipment because of their lack of familiarity with it.

In a letter dated May 16, 1974 (see app. II), the Assistant Secretary of Defense (Installations and Logistics) said DOD could do more regarding the management and economical use of DOD-owned NC production equipment. The Assistant Secretary said that to achieve this, DOD would establish a triservice coordinating group of technically qualified personnel to:

--Review existing DOD guidelines.

--Develop improvements in the management and use of NC equipment and its application to defense production.

--Devote attention to equipment and software standardization.

--Analyze the contribution and use of computers, controllers, and computer-aided manufacturing.

--Examine the use of NC tools in DOD-owned plants.

--Examine and correct existing regulations regarding NC-equipment maintenance and personnel training.

We believe this group offers potential for improving the productivity of DOD industrial activities, correcting many of the problems we noted, and using the successes of some activities to help others. We intend to maintain surveillance over the work of the group. Also, on the basis of more in-depth work underway, we may later offer to the group suggestions on specific numerical control management areas which we feel need its immediate attention.

Regarding our proposal that spare-parts stockage policies be examined to fully recognize numerical control's capabilities, DOD said that this matter would be studied for feasibility and economy. DOD acknowledged that instances may exist when stocks of insurance-type spare parts could be reduced, provided that prompt and effective exchange of tapes and availability of machines can be demonstrated as being cost effective. We agree that cost and feasibility studies are needed before DOD can decide whether numerical control offers potential for reducing such stocks.

In answer to our general concern that DOD had not continued its pioneer role in the numerical control field, DOD pointed out that its early role was intended to develop the field and demonstrate numerical control's benefits to industry. DOD believes that, if largely financed and monitored by private industry, a more lasting program will develop. We believe DOD could give more input to the program since DOD is a major user of NC equipment and benefits from privately owned NC equipment used under defense contracts.

Acknowledging that numerical control is now a national matter in which it has a major interest, DOD said numerical control can best be advanced through cooperative efforts of all interested groups. DOD also said a program to advance numerical control would require national leadership, possibly by the President's Commission on Productivity or by the Office of Technology Assessment. DOD is currently working with industries, universities, and Government agencies (including GAO) in seeking ways to increase productivity through greater use of automated manufacturing. We agree that an effective program would require both national leadership and participation by all interested groups, including the Atomic Energy Commission which is a major NC-equipment user.

MATTERS FOR CONSIDERATION BY THE CONGRESS

NC equipment can enhance productivity and can help improve the Nation's technology. This report, by informing the Congress of the field of NC and the progress and problems in moving toward more modern production techniques, should assist it in evaluating defense plant modernization programs and requests for additional plants and capabilities.

In addition, the Congress may wish to consider whether DOD should expand its research and development to take full advantage of the benefits of numerical control and whether more efforts are needed to promote industry and Government interests in working toward more standardization in the numerical control field.

CHAPTER 8

SCOPE OF SURVEY

At the Office of the Secretary of Defense and at military services' headquarters, we discussed policies and procedures relating to NC equipment and other types of industrial plant equipment. We also held discussions with headquarters representatives of the National Aeronautics and Space Administration and the Atomic Energy Commission.

At two contractor plants and the following Government-operated industrial activities, we toured shops; discussed policies and procedures; and briefly analyzed reports, instructions, and other documents on managing and using NC equipment.

--Norfolk Naval Shipyard, Portsmouth, Virginia

--Naval Air Rework Facility, Norfolk, Virginia

--Rock Island Arsenal, Rock Island, Illinois

--Oklahoma City Air Materiel Area, Oklahoma City, Oklahoma

We also studied literature in the field of NC-equipment management and gathered information from the Defense Industrial Plant Equipment Center, Memphis, Tennessee; the Army Management Engineering Training Agency and the Army Plant Equipment Agency, Rock Island, Illinois; the Department of Commerce; the Machine Tool Builders Association; several NC machine manufacturers; and the Numerical Control Society. Further, we contracted with Mr. James J. Childs, a leading consultant and author of several texts on NC equipment.

POTENTIAL CATEGORIES OF MACHINE USE

- etup
- oad and unload
- anual (NC) operation:
  - Chip cutting
  - Positioning
  - Tool change
  - Feed and speed adjustments
  - Pallet change
- rt inspection:
  - On machine
  - Off machine
- ool and fixture proofing
- C tape proveout
- eventive maintenance:
  - Lubrication
  - Periodic cleaning
  - Periodic replacements
  - Periodic test and checks
- orrective maintenance:
  - Electrical
  - Electronic
  - Mechanical
  - Hydraulic
  - Pneumatic
- achine overhaul
- nip removal
- elays:
  - Operator time out
  - Not scheduled (no work)
  - Supervision delay
  - Inspection delay
  - Material-handling equipment
  - Cutting tools:
    - Not available
    - Broken, faulty
    - Sharpening, presetting
    - Procuring

Delays (continued):
  - Fixtures:
    - Not available
    - Faulty, defective
    - Repair or rework
    - Procuring
  - NC tapes:
    - Not available
    - Tape error
    - Reprograming
    - Procuring
  - Material, workpieces:
    - Not available
    - Faulty
    - Cleaning
    - Secondary operations
    - Procuring
    - Need material handler
  - Secheduled shutdown:
    - Lunch breaks
    - Holiday, vacation
  - Nonscheduled shutdown:
    - Operator not available
    - Strike
  - Instruction
  - Recordkeeping
  - Other

ASSISTANT SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

INSTALLATIONS AND LOGISTICS

16 MAY 1974

Mr. Fred J. Shafer
Director, Logistics and
Communications Division
U. S. General Accounting Office
Washington, D. C. 20548

Dear Mr. Shafer:

Reference is made to our earlier letter to you dated 27 March 1974, wherein we indicated a final response to your draft report on "Progress and Problems With Numerically Controlled (N/C) Machines" (OSD Case 3778) would be provided subsequent to review of all agency comments. Our comments on the report's findings and recommendations are as follows:

It is agreed that the Department of Defense could do more as regards the mangement and economical utilization of defense-owned numerically controlled (N/C) production equipment. To this end, we plan to establish a tri-Service coordinating group composed of technically qualified personnel from the Military Departments for the purpose of reviewing existing DoD guidelines. The group will develop, as needed, improvements in the mangement and utilization of defense-owned numerically controlled production equipment and their application to defense production. This group will also devote its attention to the equipment/software standardization aspect where it is feasible to do so. The contribution and use of computers, controllers and the more complex issue of computer aided manufacturing will be a part of our overall analysis. The utilization of N/C tools in defense-owned plants, their maintenance and personnel training will be examined and corrections to existing regulations will be made where appropriate.

The report's suggestion that current DoD spare parts stockage policies for its weapons be re-evaluated in order to more fully recognize the N/C capability in reducing pre-production leadtimes will be studied for feasibility and economy. Instances may exist wherein the procurement of insurance-type spares could be reduced provided the effective exchange and prompt availability of computer tapes and supporting N/C tools can be demonstrated as cost effective.

In regard to your general concern that DoD has not continued its earlier major role in the N/C field, it should be noted that this was intended to only "prime the pump" and to demonstrate to private industry the benefits that could be realized through use of N/C machines. As evidenced by the greatly increased procurements of N/C equipment by private industry this effort was successful. We have been of the opinion that a more lasting program will develop if largely financed and monitored by private effort and need.

The continued effective application of N/C is now a national matter in which the Department of Defense has a significant, but nonetheless corollary interest. The solution of the future problems of advancing N/C technology and improving its use in U.S./defense manufacturing can best be achieved through the coordinated, cooperative, efforts of machine tool makers, users, universities and interested Government agencies. A program of this scope will require national leadership from an organization capable of addressing this technology in the total U.S. economic interest. One such agency is the President's Commission on Productivity or the Office of Technology Assessment. In this regard, and in the interest of national defense, the Department of Defense is currently participating with concerned industry associations, educational institutions and other Government agencies, including the Assistant Comptroller General in seeking a resolution on how best to increase national productivity through greater use of automated manufacturing.

Sincerely,

A. I. Mendolia

ARTHUR I. MENDOLIA
Assistant Secretary of Defense
(Installations & Logistics)

UNITED STATES OF AMERICA
GENERAL SERVICES ADMINISTRATION
Office of Federal Management Policy
Washington, DC 20405

MAR 27 1974

Mr. Werner Grosshans
Logistics & Communications Division
U.S. General Accounting Office
441 G Street, N.W.
Washington, DC 20548

Dear Mr. Grosshans:

My staff reviewed your draft report entitled, "Progress and Problems with Numerically Controlled Industrial Equipment." Enclosed are our comments concerning this draft report per your request.

Sincerely,

(Signed)
GORDON T. YAMADA
Director
Office of Management Systems
and Special Projects

Enclosure

GAO note: Numbers in brackets are page numbers in this final report.

Keep Freedom in Your Future With U.S. Savings Bonds

COMMENTS ON THE NC DRAFT REPORT

Overall the report is informative, clearly documented, and readily understandable. Further, this report should assist DOD managers to make proper decisions concerning the acquisition and utilization of industrial equipment. Accordingly, when the final report is published, every effort should be taken to assure that it is disseminated to and read by these managers. This should result in improved acquisition policies and greater utilization of NC equipment, which will ultimately lead to increased productivity in the Federal sector.

[5]

I was happy to see that on page 12 the report stated the most common misconception concerning NC equipment, i.e., NC equipment should primarily be used for large quantity production. The report goes on to state that in fact NC equipment best applies to job-shop operations because the breakeven point for small lots comes much earlier with NC rather than with conventional equipment.

This is an excellent point and worth reiterating in the [pp. i to iii] DIGEST (pages 1-4), since it would assist in restructuring the thinking of higher level executives who may only read the DIGEST portion of the report.

The report indicates that most DOD agencies:

- Do not have properly trained staff to conduct workmix studies and to perform conventional versus NC equipment tradeoff studies.

- Do not currently have sufficient guidance from headquarter levels in these areas.

Nevertheless, assuming these problems are overcome, the root of the problem will still exist since workloads are very erratic and historically workload forecasts have been grossly inaccurate in DOD.

Perhaps the report should include some analysis of the viewpoints held by the vast majority of equipment managers. For example, the overwhelming majority of DOD facilities do not have NC equipment. Thus, few equipment managers have experience with or exposure to the NC equipment environment. This lack of understanding or working knowledge often causes the manager to fear the acquisition and installation of NC equipment. Since these same managers play an important role in the equipment analysis and selection process they may tend to "weight" the data in favor of conventional equipment. In situations, when the analysis indicates that NC equipment would be economical, they may opt for conventional equipment.

In summary, the more equitable use of NC equipment is inhibited by the ingrained bias of most DOD equipment managers.

[See GAO note.]

[5 to 7]

On pages 12 and 13, some of the advantages cited are too encompassing, tend to be an overstatement, and may be misleading.

[8]

On page 14, another disadvantage of NC equipment is that it requires significantly longer time to acquire and install than does conventional equipment.

GAO note: The deleted comments relate to matters which were discussed in draft report but omitted from this final report.

PRINCIPAL OFFICIALS OF THE DEPARTMENT OF DEFENSE AND THE DEPARTMENTS OF THE ARMY, NAVY, AND AIR FORCE RESPONSIBLE FOR ADMINISTRATION OF ACTIVITIES DISCUSSED IN THIS REPORT

	Tenure of office	
	From	To
DEPARTMENT OF DEFENSE		
SECRETARY OF DEFENSE:		
James R. Schlesinger	Apr. 1973	Present
Elliot L. Richardson	Jan. 1969	Apr. 1973
Melvin R. Laird	Jan. 1969	Jan. 1973
DEPUTY SECRETARY OF DEFENSE:		
William P. Clements	Jan. 1973	Present
Kenneth Rush	Feb. 1972	Jan. 1973
Vacant	Jan. 1972	Feb. 1972
David Packard	Jan. 1969	Dec. 1971
ASSISTANT SECRETARY OF DEFENSE (INSTALLATIONS AND LOGISTICS):		
Arthur I. Mendolia	Apr. 1973	Present
Hugh McCullough (acting)	Feb. 1973	Apr. 1973
Barry J. Shillito	Jan. 1969	Feb. 1973
DEPARTMENT OF THE ARMY		
SECRETARY OF THE ARMY:		
Howard Calloway	May 1973	Present
Robert F. Froehlke	July 1971	May 1973
Stanley R. Resor	July 1965	June 1971
UNDER SECRETARY OF THE ARMY:		
Herman R. Staudt	Oct. 1973	Present
Vacant	June 1973	Oct. 1973
Kenneth F. Belieu	Aug. 1971	June 1973
Thaddeus R. Beal	Mar. 1969	July 1971

	Tenure of office From	To
DEPARTMENT OF THE ARMY (continued)		
ASSISTANT SECRETARY OF THE ARMY (INSTALLATIONS AND LOGISTICS):		
Vincent P. Huggard (acting)	Apr. 1973	Present
Dudley C. Mecum	Oct. 1971	Apr. 1973
J. Ronald Fox	June 1969	Sept. 1971
DEPARTMENT OF THE NAVY		
SECRETARY OF THE NAVY:		
J. William Middendorf	June 1974	Present
J. William Middendorf (acting)	Apr. 1974	June 1974
John W. Warner (acting)	May 1972	Apr. 1974
John H. Chafee	Jan. 1969	Apr. 1972
UNDER SECRETARY OF THE NAVY:		
Vacant	June 1974	Present
J. William Middendorf	June 1973	June 1974
Frank Sanders	May 1972	June 1973
John W. Warner	Feb. 1969	Apr. 1972
ASSISTANT SECRETARY OF THE NAVY (INSTALLATIONS AND LOGISTICS):		
Jack L. Bowers	June 1973	Present
Charles L. Ill	July 1971	May 1973
Frank Sanders	Feb. 1969	June 1971
DEPARTMENT OF THE AIR FORCE		
SECRETARY OF THE AIR FORCE:		
John L. Lucas	July 1973	Present
Dr. Robert C. Seamans, Jr.	Jan. 1969	July 1973
ASSISTANT SECRETARY OF THE AIR FORCE (INSTALLATIONS AND LOGISTICS):		
Richard J. Keegan (acting)	Aug. 1973	Present
Lewis E. Turner (acting)	Jan. 1973	Aug. 1973
Philip N. Whittaker	May 1969	Jan. 1973

AN EQUAL OPPORTUNITY EMPLOYER

UNITED STATES
GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U. S. GENERAL ACCOUNTING OFFICE

U.S.MAIL

THIRD CLASS

Mr. T. E. Sullivan
Transportation
Room ~~5049~~
5033