REPORT TO THE CONGRESS

Use Of Numerically Controlled Equipment Can Increase Productivity In Defense Plants

Department of Defense

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

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

B-140389

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

This is our report on using numerically controlled equipment to increase productivity in defense plants.

We made our review 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.

Elmer B. Staats

Comptroller General
of the United States

Contents

ABBREVIATIONS

DOD	Department of Defense
GAO	General Accounting Office
NC	numerically controlled

GLOSSARY

Axis	One of the lines of direction or motion on a machine.
Contouring	A method of machining in which a control system makes a curve by keeping a cutting tool in constant contact with a workpiece while the tool moves.
Fixture	A work-holding device used for machining duplicate workpieces. A fixture differs from a jig in that it only holds a part in a fixed position in relation to tools.
Jig	A device that holds and locates a workpiece and guides, controls, or limits one or more cutting tools.
Point to point	A method of machining 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. This method is more restrictive than contouring.
Postprocessor	A special computer routine which converts general instructions into codes to operate a machine. Postprocessors are unique to each different combination of machine, control unit, language, and computer.

COMPTROLLER GENERAL'S
REPORT TO THE CONGRESS

USE OF NUMERICALLY CONTROLLED EQUIPMENT CAN INCREASE PRODUCTIVITY IN DEFENSE PLANTS
Department of Defense

D I G E S T

WHY THE REVIEW WAS MADE

A previous GAO survey showed how Department of Defense (DOD) industrial activities plan for and manage numerically controlled industrial equipment--a relatively new technology.

The report 1/ recommended that the DOD Secretary establish a group to coordinate and improve the military services' use of the equipment--controlled by punched tape or computers--and to work with industry in further developing the field of numerical control. DOD subsequently did so.

GAO made this review to assess the full extent of problems previously noted and to find methods for improvements.

FINDINGS AND CONCLUSIONS

Numerically controlled industrial equipment is expensive and complex. It includes drills, mills, lathes, machining centers, and other machines controlled automatically by punched tape or computers.

If properly managed, this equipment offers tremendous increases in productivity and savings in industrial operations--particularly for small-lot production. (See p. 2.)

Need to better define work of Government activities

The Government relies on private enterprise for goods and services except in certain situations, such as when production in its own plants is necessary to meet readiness requirements.

Original manufacturers and private machine shops could handle some of the numerical control work being done at DOD plants--at less cost in some cases.

Also, some DOD activities had unused numerically controlled machine capacities which others could use. DOD recognizes this situation but believes that some unused capacity must be maintained for emergencies. (See p. 6.)

Need to make work-mix studies

Once the type and amount of

1/ "Numerically Controlled Industrial Equipment: Progress and Problems" (B-140389, Sept. 24, 1974).

work to be done in DOD plants is decided, studies should be made to identify the more efficient production method for the work--conventional or numerically controlled machines.

Most DOD activities did not have effective procedures for making such studies. The activities' machines did not always suit their work. GAO's sample studies showed that some activities

--could effectively use more numerically controlled equipment;

--had overly elaborate, expensive equipment not required for the work; or

--had, or were ordering, numerically controlled equipment for which little work existed. (See p. 21.)

GAO prepared a step-by-step procedure which should assist activities in justifying procurements and in selecting the appropriate type and number of machines. (See app. I.)

If activities find that their machines and workloads are unsuited, procurement of additional machines is not necessarily the wisest solution. Management should first compare the costs and savings of all alternatives, including

--declaring equipment surplus and transferring it to others,

--continuing operations at less than full productivity, and

--having another activity do its numerical control work. (See p. 26.)

<u>Information on Government-owned numerically controlled machines</u>

GAO sent questionnaires to the 225 activities which had Government-owned numerically controlled equipment, asking for data on the management and use of the equipment. The data showed that:

--Many activities planned substantial future investments in numerically controlled equipment.

--Many different types of computer arrangements were used with varying amounts of turnaround time.

--Government activities did not develop postprocessors in-house to the extent that contractors did.

--A variety of different languages were in use, although languages seemed to be approaching standardization.

--Machine-use reporting systems were extremely diverse. Contractors seemed to use their numerically controlled machines more than did Government activities.

--Most activities did not consider manufacturers' recommended spare-parts kits appropriate. Those activities which bought kits spent more than those which developed kits through experience.

--Many activities had problems

getting repair parts quickly, partly due to cumbersome procurement systems.

--Activities generally used qualitative factors in selecting jobs for numerically controlled machines. Cost models or comparisons would be more helpful.

--Data package interchange could save programing time, but first, numerically controlled systems must become more standardized and records of parts programed must be more visible.

--Followup systems were not always used to assess whether numerical control was as productive as possible and to notify management of problems. (See p. 29.)

Costs of numerically controlled systems

The direct and support costs of numerically controlled systems are considerable but vary widely, depending on the machine system and type of work.

Realizing savings from numerical control requires that the critical factors involved be closely studied and managed. A cost model prepared by GAO to illustrate this important matter can be found on page 51.

The prime factor in keeping numerical control cost effective seems to be high use. To achieve a payoff over conventional production, numerically controlled machines should usually be used at least one full shift. (See p. 45.)

Obtaining the benefits of numerical control

Although numerical control offers many benefits in terms of cost savings, high tolerances, and ability to meet mobilization requirements, it is no panacea. To fully benefit, activities must closely plan for numerically controlled machines as a total production system. Thus far the cost savings achieved and the ability to meet mobilization requirements have been less than planned. (See p. 54.)

RECOMMENDATIONS

The Secretary of Defense should:

--Require that no justifications for new machines be approved unless the activity has adequately considered using the capacities of other activities in the geographical area.

--Insure that the necessary computer support and programers are available to meet mobilization requirements.

In addition, the triservice numerical control committee should insure that work-mix studies are made to achieve a better match of machines and work and to identify opportunities for cost-effective investments.

AGENCY ACTIONS AND UNRESOLVED ISSUES

DOD said it believed that the current guidance on capacities which activities need in emergencies is adequate and comprehensive. DOD also said that an activity's total production requirements and rates are used to determine the production equipment, and thus the capacity, needed in a mobilization, keeping in mind the items' make-or-buy situation.

GAO believes DOD's guidance is not definite because, as GAO's earlier report pointed out, both commands and installations interpret the guidance differently.

Also, DOD has no reasonable basis for determining an activity's total requirements because many activities do not know what items they will have to produce.

DOD also said that its existing procedures for soliciting bids from private machine shops are adequate and that the decision to make or buy an individual item cannot be viewed as an isolated case.

Although GAO agrees that a decision to make or buy an item should not be viewed as an isolated case, the decision should include more emphasis on the comparative costs of Government and commercial production since many commercial shops can provide items in the time required. With this increased emphasis, DOD could more economically use those capacities which are determined to be required for a mobilization but which are excess to peacetime needs.

In commenting on GAO's recommendation to use other activities' unused capacities before requesting in-house machining capability, DOD said it had made every attempt to achieve that goal. DOD recognizes, as does GAO, that work exchange may be inhibited by reprograming effort, the limited exchanges of numerical control data packages, and the lack of standardization in hardware and software.

DOD said its triservice numerical control committee, established as a result of GAO's previous report, had prepared a Draft DOD Instruction 4215.xx, "Management of Numerically Controlled Industrial Plant Equipment," as a major step toward improving the management of this equipment.

The draft instruction addresses:

--Planning (including personnel and computer support for peacetime and mobilization workloads and work-mix studies to improve the identification of the types of machines required).

--Economic justifications and followups.

--Utilization.

--Preventive maintenance and

spare-parts acquisitions.

--Inventory reporting.

--Standardization of hardware and software.

This instruction, when implemented, should be of great help to activities in better planning for and managing their numerically controlled machines.

MATTERS FOR CONSIDERATION BY THE CONGRESS

GAO's report provides information on the nature of numerically controlled equipment, its high costs, and the special management needed to make the most of this relatively new technology. Ultimately, such information should provide a basis for judging the thoroughness of research done to support requests for additional facilities and equipment.

This information may also be useful to the Congress in considering Senate bills 765 and 937 because numerically controlled equipment, and its associated use of computers, is important to improved productivity both in the Government and in private industry.

CHAPTER 1

INTRODUCTION

CONCEPTS OF NUMERICAL CONTROL

In a broad sense, a numerically controlled (NC) system is machinery controlled automatically by coded instructions. An NC system has two basic elements: (1) the machine which does the work and (2) an electronic control unit which directs the machine's motions. A few machines operate directly from computers or by magnetic tape, but most get instructions in the form of punched tape.

Most NC equipment is used for metalworking, but its uses include a wide variety of other manufacturing operations. Most of the machines in use are drills, mills, lathes, punches, and machining centers. Some machines are equipped with automatic tool changers, and a variety of other features, including multiple spindles and rotary tables, can be ordered. Photographs of typical new equipment are on pages 4 and 5.

Punched tapes are usually prepared with computer assistance within the Department of Defense (DOD). A part programer extracts from engineering drawings the information and dimensions, such as surface finishes, tolerances, and measurements, required to machine the part. He prepares a manuscript which shows the sequence of operations and which designates fixtures, cutting tools, feeds, and speeds. A computer assists in programing the part primarily by making calculations to position and control the cutter along the paths necessary to accurately machine the part. A postprocessor (a special computer program) converts general cutter-path instructions into punched-tape codes peculiar to the specific NC machine, and the computer then makes the tape. The operator places the fixture on the machine tool, loads the part in the fixture, places the cutter in the spindle and over the target, places the tape in the control unit, and starts the operation. The control unit then assumes command and guides the cutter in its predetermined path. The first tryout of the tooling and tape usually reveals errors. After errors are corrected, production will be consecutive.

When used under proper circumstances and applications, NC machines can manufacture superior and more economical products than can conventional machines. Numerical control applies best to shop operations requiring machining of parts in small lots or batches, because the economic break-even point for small lots comes much earlier with NC machines than with conventional machines. Also some very complex jobs can be done only on NC machines. Following are some other advantages of numerical control.

--Productivity increases because all machine functions are controlled automatically. Therefore metal is cut a greater percentage of the overall machining time.

--Storing and handling bulky jigs and templates is eliminated because they are replaced by tapes or punched cards.

--Jobs can be set up faster because guiding fixtures for newly designed parts do not have to be designed and manufactured, as is sometimes necessary for conventional machines.

--Repeat orders can be produced quickly because the tapes have already been made.

--Engineering changes to workpieces can be readily incorporated simply by changing instructions on the tape.

--Quality control is better because NC machines are more accurate and can produce closer tolerance parts. This means fewer parts are rejected and the amount of scrap is reduced.

--Parts handling can be reduced because more operations can be done by an NC machine with one setup than by a conventional machine.

Productivity increases on NC machines vary with the machines and the parts to be produced. Productivity increase ratios of 10 to 1 over conventional machines on some parts are not uncommon. But NC machines are expensive and complex; therefore they require close management. Their control systems contain thousands of solid-state electronic devices.

Thus maintenance problems are compounded and programers, operators, and other personnel need special training.

PREVIOUS REPORT ON NUMERICAL CONTROL

Our report, "Numerically Controlled Industrial Equipment: Progress and Problems" (B-140389, Sept. 24, 1974), described a variety of problems dealing with how DOD activities identify where NC machines can be used to increase productivity, plan for NC machine purchases, manage the machines in operation, and follow up on their benefits. We recommended that the Secretary of Defense establish a central group to coordinate and improve the military services' management and use of NC machines and to work with industry in developing the field of numerical control.

In response to that report, DOD established a triservice committee, composed of technically qualified personnel, to

--review existing DOD guidelines on numerical control;

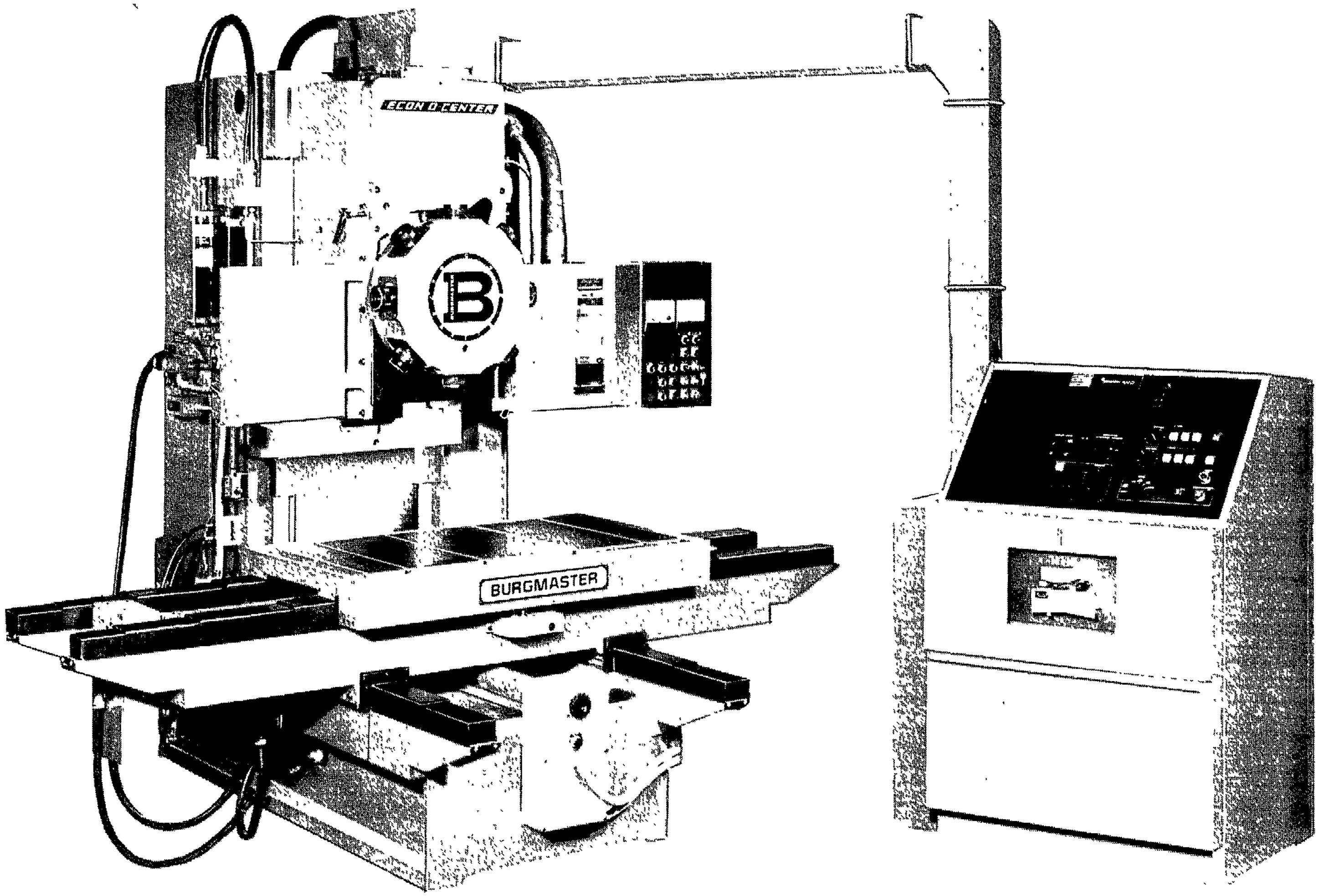
--improve the management and use of NC machines and their application to defense production;

--devote attention to equipment and software standardization;

--analyze the contribution and use of computers, controllers, and computer-aided manufacturing; and

--examine and correct existing regulations on maintaining NC machines and on training personnel in numerical control.

The triservice committee offers potential for improving the productivity of DOD industrial activities, helping to correct many of the problems noted, and using the successes of some activities to assist others.



Two-axis turret machining center. It selects one of its eight spindles in any sequence for drilling, tapping, boring, and milling. It costs about $45,000.
(Courtesy of Burgmaster Corp.)

Tape-controlled lathe provides fully automatic turning, facing, and boring. It can do roughing work and finishing, and costs about $80,000.

(Courtesy of American Tool Co.)

CHAPTER 2

NEED TO BETTER DEFINE WORK OF GOVERNMENT ACTIVITIES

Our earlier report on numerical control noted that activities lacked systems for identifying the more efficient production method--conventional machines or NC machines. However, some more basic issues--what work should be done by Government activities and which activities should do the work--should be resolved first.

Parts made on NC equipment by DOD activities could often be provided by original manufacturers and private machine shops in adequate response time and at lower costs.[1] Some DOD activities had excess NC machine capacities which others could use through a work exchange program.

GOVERNMENT MAKE-OR-BUY POLICY

Office of Management and Budget Circular A-76 requires the Government to rely on private enterprise for goods and services unless it would be in the national interest for a Government agency to provide the goods and services in-house. In-house operations are permitted when

--procurement from a commercial source would disrupt or materially delay an agency's program;

--combat support, military personnel training, or mobilization readiness would be impaired by commercial procurement;

--a commercial source is not available and cannot be developed in time to provide the product or service when needed and the product or service is not available from another Government agency; or

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[1]The costs for Government activities' work were taken from available cost accounting systems (without verification) and excluded depreciation and other fully allocated cost factors.

--procurement from a commercial source would be much more costly to the Government.

The circular also requires each Government agency to (1) issue instructions to insure that the policy is followed, (2) compile and maintain an inventory of its commercial and industrial activities, and (3) review its activities every 3 years to determine whether in-house operations should be continued.

DOD Directive 4151.1 states that, since maintenance support of military equipment is vital to sustain military power, the military services should have adequate programs for maintaining assigned equipment in accordance with military missions. The directive also states that:

> "The extent of facility capability and capacity within the Military Departments for depot support of mission essential equipment will be kept to the minimum required to insure a ready and controlled source of technical competence and resources necessary to meet military contingencies. Generally organic depot maintenance capacity will be planned to accomplish no more than 70% of the gross mission-essential depot maintenance workload requirements, with a facility capacity loading at a minimum rate of 85% on a 40-hour week, 1-shift basis."

The capacity needed to meet mobilization requirements should be the primary basis for determining the capacity needed in peacetime. However, the military services have no viable systems for determining the total production capacity needed in a mobilization. The services therefore use the DOD directive as a basis for setting activities' peacetime capacities, in general, at a one-shift, 40-hour week production level. This level often results in low usage of machines. (See pp. 13 to 16.)

The system for deciding whether to make parts in-house varies with activities, but the comparative costs of making parts in-house or out-house are seldom considered in the decision. Higher commands decide on the feasibility of manufacturing a weapon system in-house. Rework facilities make parts depending on codes assigned by higher commands and the availability of parts from contractors. If a part is coded "buy," the activity must try to get the part from a private contractor in the leadtime required; otherwise, the activity has to make the part.

In a December 1972 study, the Commission on Government Procurement found that, except for a few activities in which cost studies had been made, there was little support for recommendations to continue activities' in-house operations. The Commission recommended that legislation be enacted to state a policy of relying on private enterprise for goods and services as much as possible, within reasonable prices.

PARTS AVAILABLE FROM PRIVATE CONTRACTORS

Many parts that DOD activities made on NC machines were available from original manufacturers at lower costs. DOD officials said the parts were made in-house either because the activities needed the work to meet the requirements of DOD Directive 4151.1 or because contractors could not provide the parts in adequate leadtimes. DOD did not usually compare the costs of having parts made in-house and out-house.

Warner Robins Air Logistics Center made 38 parts needed for a C-130 aircraft modification. Lockheed-Georgia Company, Marietta, Georgia, the original manufacturer of the C-130, also made some parts for the modification. We compared Warner Robins' cost for making 6 of the 38 parts with Lockheed's stated prices for making the parts. The six parts were chosen because both activities made them on NC machines. If Warner Robins had bought the parts from Lockheed, it could have saved $155,000 between November 1972 and April 1973, as shown below.

Part number	Number of units	Cost per unit Warner Robins	Cost per unit Lockheed	Cost difference for all units
394109 -1	222	$ 366	$183	$ 40,626
-2	218	340	183	34,226
394110 -1	220	384	223	35,420
-2	219	343	223	26,280
3303526-5	954	53	43	9,540
-6	950	53	43	9,500
Total		$1,539	$898	$155,592

Lockheed could have provided the first 4 parts, except for 35 units, in the leadtimes required. It could have provided the fifth and sixth parts within the leadtimes, except for 523 units. Although Lockheed could have made all six parts at less cost, Warner Robins did not consider cost in deciding to make the parts in-house. An Air Force Logistics Command representative stated that the C-130 modification was mission essential and that the command had tried to schedule work for in-house facilities as required by DOD Directive 4151.1. It should be pointed out that about 30 percent of the Air Force's C-130 depot maintenance workload is done commercially. As stated on page 7, the DOD directive does not require that all mission-essential work be done in-house.

Although original manufacturers are not always interested in making parts for which the leadtimes are short and the required quantities are small, many private machine shops in these situations can respond to such needs. In effect, small machine shops are geared to producing a wide variety of parts in small quantities. Such shops can make some parts at less cost and some are anxious to do so.

The Sacramento Air Logistics Center made parts which private machine shops could have made at lower prices in the leadtimes required. The center did not check with the machine shops before deciding to make the parts in-house. Following are comparisons of the center's costs with private shops' prices.

--Recessed washers were made in 7 months in-house for $2,679. A machine shop quoted a total price of $195 and a leadtime of 1-1/2 months.

--Fillers were made in-house for $2,660. A machine shop would have made the fillers for $980 in the same leadtime.

--Other fillers were made in 1 month in-house for $8,369. Although a machine shop would have taken 2 months, it would have charged $1,045.

In contrast, the Norfolk Naval Shipyard's reported costs for producing parts were less than quotes from local machine shops, as shown below. Leadtimes for the machine shops were 15 to 30 days, which the shipyard said were too long.

--The shipyard made connectors for $20 each, excluding material. A machine shop quoted $45 each, excluding material.

--Tube sheets produced by the shipyard cost $1,698 each, excluding material. A shop quoted $6,000 each for one type of sheet and $8,500 for another type, excluding material.

--Fittings made at the shipyard cost $15 each; a machine shop quoted $60 each.

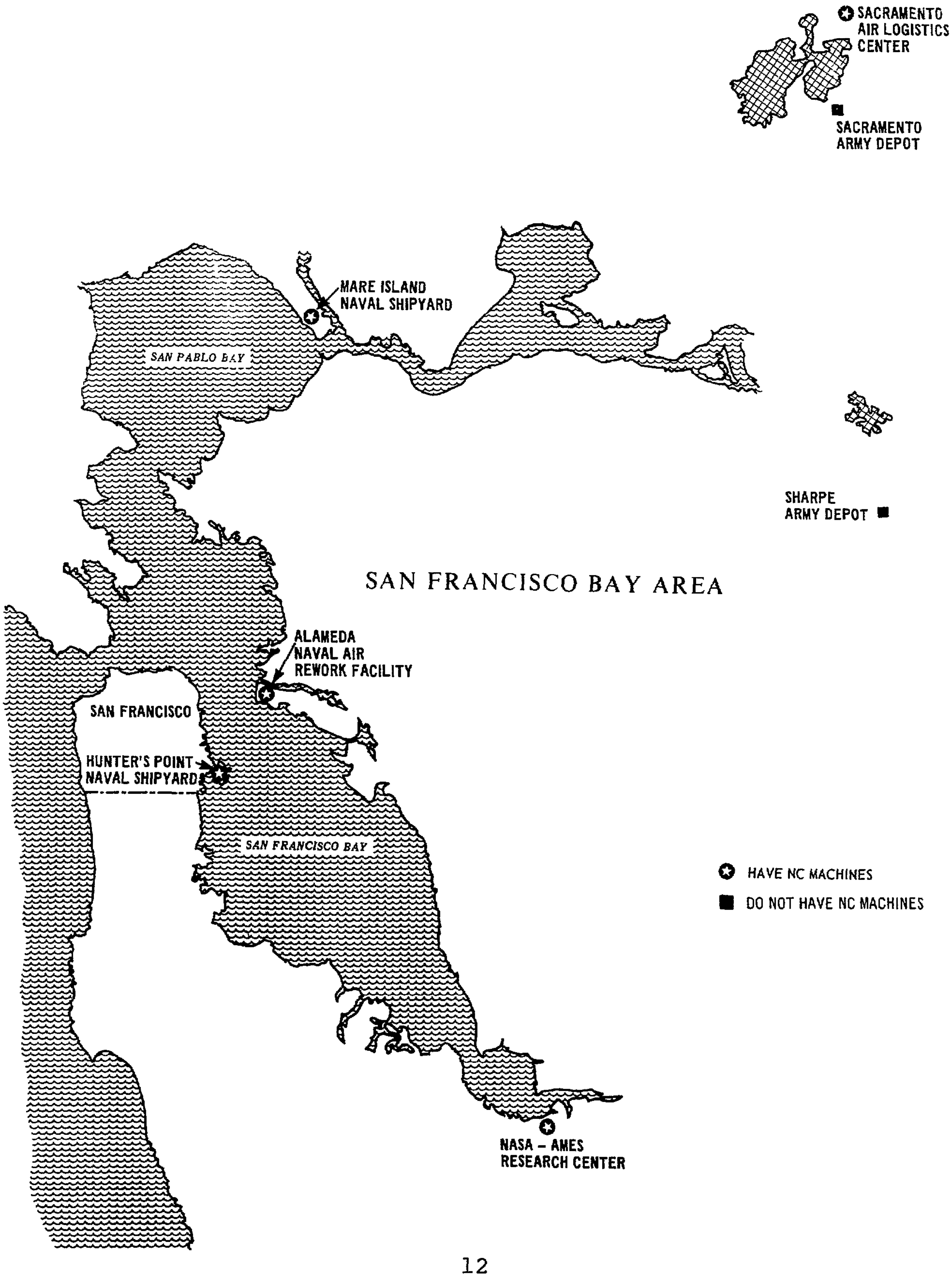
The shipyard made these parts on NC equipment. These machine shops would have made them on conventional equipment; however, many machine shops have NC equipment.

CAPACITY AVAILABLE AT OTHER GOVERNMENT ACTIVITIES

One of the justifications for producing work in-house, according to Circular A-76, is the unavailability of the product or service from a commercial source and from another Government activity. Also a 1967 DOD directive stated that each DOD component should request support from another component when the capabilities are available and when such support is to DOD's overall advantage. Components were to provide support to the extent that military requirements and capabilities permitted, and interservice and interdepartmental agreements were to be made. However, little numerical control work has been exchanged, either within a service or between services. By exchanging work among activities, the Government could reduce its investments in additional machines and present machines could be used more productively.

Many NC machines at Government activities were used for only part of one shift. Instead of relying on these activities with unused capacities to make parts, nearby activities were ordering similar NC machines. The types of machines planned are listed on page 30. These machines are estimated to cost $20 million and do not include machines ordered or planned by activities which currently have no NC machines. These procurements may not be necessary if the capacities of other activities are available. Rather than invest in new machines, activities should develop work exchange programs and take advantage of other activities' unused capacities.

Several geographical areas have duplicate NC capabilities among present and planned NC machines. For example, the map on page 12 shows the Government-operated activities within a 100-mile radius of the San Francisco Bay area which have NC machines and nearby industrial activities which have no NC machines but which may have workloads suitable for NC machines.


SACRAMENTO
AIR LOGISTICS
CENTER
SACRAMENTO
ARMY DEPOT
MARE ISLAND
NAVAL SHIPYARD
SAN PABLO BAY
SHARPE
ARMY DEPOT
SAN FRANCISCO BAY AREA
ALAMEDA
NAVAL AIR
REWORK FACILITY
SAN FRANCISCO
HUNTER'S POINT
NAVAL SHIPYARD
SAN FRANCISCO BAY
HAVE NC MACHINES
DO NOT HAVE NC MACHINES
NASA – AMES
RESEARCH CENTER

The activities shown on the map had the following present and planned NC machines.

	Present NC machines		NC machines planned for next 3 years	
	Number	Cost	Number	Cost
National Aeronautics and Space Administration, Ames Research Center	6	$ 522,000	1	$ 50,000
Mare Island Naval Shipyard	22	3,630,939	4	[a]603,965
Alameda Naval Air Rework Facility	19	2,457,963	8	1,161,000
Hunter's Point Naval Shipyard (note b)	21	2,166,723	-	-
Sacramento Air Logistics Center	16	2,444,919	2	643,000
Sacramento Army Depot	-	-	(c)	-
Sharpe Army Depot	-	-	-	-
Total	84	$11,222,544	15	$2,457,965

[a]Decisions are tentative pending completion of a plant study.
[b]Closed; plans for its future use are uncertain.
[c]Our review showed a workload for NC machines. (See p. 25.)

Many machines of a different type can produce identical work. For instance, machining centers can do most work that drills do, and drills can do the drilling work done by machining centers. Therefore capability may be duplicate, depending on the parts to be made, even though machines are different. Following are examples of duplicate and similar machines at the four operating activities and the machines' use in 1973. We calculated the machines' use on the basis of hours used and converted the hours to the percent of time used on two shifts. As can be seen, many machines are underused.

Contour profile machines	Cost	Approximate percent use on two shifts in 1973
Ames Research Center:		
Cincinnati milacron, 30" x 120", hydrotel, 3-axis	$199,000	90
Cincinnati milacron, 28" x 120", hydrotel, 3-axis	131,000	90
Alameda Naval Air Rework Facility:		
Bridgeport mill, 3-axis (note a)	39,000	-
Bridgeport mill, 3-axis (note a)	160,000	-
Kearney and Trecker mill, 4-axis (note a)	193,000	-
Mill, 4-axis (note a)	195,000	-
Sacramento Air Logistics Center:		
Gorton mill, 30" x 12" x 15":	80,000	[b]41
Giddings and Lewis mill, 174" x 44" x 18"	275,405	[b]41
Kearney and Trecker mill, 172" x 60" x 18", 3-spindle	480,725	[b]66
Pratt and Whitney mill, 40" x 30" x 16", 4-axis	119,780	[c]57
Punch presses		
Sacramento Air Logistics Center:		
Weideman punch, 72" x 36"	117,959	[b]4
52" punch press (note a)	143,000	-

Punch presses (continued)	Cost	Approximate percent use on two shifts in 1973
Alameda Naval Air Rework Facility:		
Strippit punch, 10-gauge	$63,000	[c]11
Mare Island Naval Shipyard:		
Weideman punch, 14-gauge	54,236	(d)
Weideman punch, 11-gauge	72,122	[b]7
Point-to-point machining centers		
Ames Research Center:		
Kearney and Trecker, model EA	109,000	35
Cincinnati Cintimatic	25,000	35
Mare Island Naval Shipyard:		
Kearney and Trecker, model EA	94,923	[b]8
Kearney and Trecker, model EA	104,474	[b]13
Cincinnati Cintimatic	29,642	[b]50
Cincinnati Cintimatic	29,642	[b]46
Monarch, model 2N	56,516	[b]15
Alameda Naval Air Rework Facility:		
Cincinnati, Cim X	83,244	[b]11
Monarch, model 2NL	80,787	[b]20

Contour machining centers	Cost	Approximate percent use on two shifts in 1973
Sacramento Air Logistics Center:		
Giddings and Lewis, model 75-N/C-5V, 3-axis	$123,887	[b]40
Pratt and Whitney, model 3050, 4-axis	157,507	[b]17
Alameda Naval Air Rework Facility:		
Kearney and Trecker, MMII	293,096	[b]73

[a]Planned machines.
[b]Use for June to November 1973.
[c]Use for November 1973 (only data available).
[d]Not installed during period.

On the basis of the above statistics, we believe the overall productivity of the activities in the San Francisco Bay area, and probably other areas, could be improved through work exchange programs. Furthermore, our work-mix study at the Sacramento Army Depot (see p. 25) showed a workload for NC punch presses. Such machines with low use are at several nearby activities.

Although interchange programs offer many benefits, they should be considered in the light of the following matters.

--Many activities have unused NC machine capacities because of inadequate computer support or management problems rather than because of a lack of work. Others cannot use these capacities until such problems are corrected.

--Some unused capacities are legitimately used for nonproductive purposes, such as preventive maintenance. Also unused capacities may result when machines have no operator or are waiting for material, tools, or repair.

--To do work for others, an activity may have to add other shifts. This can complicate supervision and tape prove-out. Extra shifts would violate some service policies of having shifts available for mobilization. However, they could increase paybacks.

--Activities seem to be inherently reluctant to have their work done by others because they think it will be assigned low priority.

--NC machines with unused capacities are not necessarily unjustified, since paybacks can occur quickly with less than full use.

--Machine-use reporting systems are not adequate to pinpoint the unused capacities which could be used for other work. (See p. 34 for further discussion.)

CONCLUSIONS

Government activities made items in-house which could have been procured within the time required at less cost. The decision to make or buy an item should include more emphasis on the comparative costs of in-house and commercial production. In addition, Government activities requested machinery for in-house production without considering the existing duplicate capabilities of other Government activities. DOD recognizes this situation but believes that some unused capacity must be maintained for emergencies.

As discussed in chapter 5, high use of NC machines can make the difference between a quick payback and a loss. It therefore appears that DOD's usual practice of running machines on only one shift is self-defeating. Before requesting new NC machines, activities should be required to economically justify them in terms of how much they will be used and whether they are needed in view of already-existing unused capabilities. Justifications for new machines based solely on relieving multishift use of other NC machines should be carefully scrutinized to determine if more excess capability is really needed to meet mobilization requirements. Because our previous report on numerical control recommended that the policies on multishift use and reserve capacity be clarified, we are not making any further recommendations on that matter.

RECOMMENDATION

We recommend that the Secretary of Defense require that no justifications for new NC equipment be approved unless the activity has adequately considered using the capacities of other activities in the geographical area.

AGENCY COMMENTS AND OUR EVALUATION

In a letter dated February 14, 1975 (see app. V), DOD said it believed that the current guidance on capacities which activities need in emergencies is adequate and comprehensive. DOD also said that end items' production requirements and rates, as dictated by the scenarios for potential conflicts, are used to determine the production equipment needed in a mobilization, keeping in mind the items' make-or-buy situation. The total requirements for all the items assigned to an activity should then provide definitive guidance on the activity's mobilization capacity. We believe this guidance is not definitive. Our earlier report on numerical control pointed out the differing interpretations, at both the command and the installation levels, of DOD's policy concerning the reserve capacity needed for national emergencies. In addition, we believe DOD has no workable basis for determining an activity's total requirements because many activities do not know what items they will have to produce, and their justifications for new machines substantiate this.

DOD believed that its existing procedures for soliciting bids from private machine shops are adequate. Recognizing that it is possible to identify individual items that appear to have been made in-house at a higher cost than if they had been procured commercially, DOD said the decision to make or buy an individual item cannot be viewed as an isolated case. Instead, the decision should be made from the perspective of the total environment at that moment.

We agree that a make-or-buy decision should not be viewed as an isolated case. For those parts which we found could have been made at less cost commercially, we did not attempt to consider all the factors involved in a make-or-buy decision. We are merely pointing out that the decision should include more emphasis on the comparative costs of in-house and commercial production, since many commercial shops can provide the items in the time required. With this increased emphasis, DOD could more economically use those capacities which are determined to be required for a mobilization but which are excess to peacetime needs.

DOD said that our recommendation on using other activities' unused capacities before requesting in-house capacities had merit and that it had made every attempt to achieve that goal. In our opinion, DOD has made little progress in interservicing. In a previous report,[1] we pointed out that, excluding $2 billion worth of Navy shipyard work, interservice maintenance amounted to only 2 percent of the total $3 billion worth of depot maintenance done in fiscal year 1971. The situation has not changed; for example, only 2 percent of the Navy's depot maintenance workload planned through 1980 will be done by another service. Not all of this maintenance work, of course, is done by NC machines. But some is, and it is extremely important that activities with NC machines not have duplicate capabilities because of the machines' high costs and the need to use them sufficiently in order to achieve a savings.

Recognizing that numerical control work exchange between activities may be inhibited by reprograming effort, the limited exchanges of numerical control data packages, and the lack of standardization in hardware and software, DOD stated that the triservice numerical control committee is trying to make some inroads toward standardization. DOD's point that the lack of standardization continues to impede data package exchanges is well taken. As the triservice committee pursues its objectives, we suggest it direct attention to parts which one activity needs that may already have been programed by another activity. Even if the parts had not been programed, having another activity with underused capacity do the work could be more economical than buying a new machine. In addition, work exchange would help to avoid duplicate capabilities at nearby activities, provide more economical production to activities that cannot justify NC equipment, and insure reasonable peacetime productivity.

We also received comments on this report from the General Services Administration, the Energy Research and Development Administration (previously the Atomic Energy Commission), and the National Aeronautics and Space Administration. These agencies generally stated that our report's findings on increasing productivity through numerical control were constructive and timely. (See apps. VI to VIII.)

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[1]"Potential for Greater Consolidation of the Maintenance Workload in the Military Services" (B-178736, July 6, 1973).

CHAPTER 3

NEED TO MAKE WORK-MIX STUDIES

After an activity determines the type and amount of work to be done in-house, it must select the more economical production method--NC or conventional equipment. For the activity to achieve the proper match of workloads with production methods, it must analyze its workloads.

Activities did not have effective procedures for analyzing their workloads; they usually bought NC equipment only when conventional equipment deteriorated or when new workloads were anticipated. Properly made work-mix studies could help in justifying NC machine purchases and in determining the types, sizes, and number of machines most suitable for an activity.

We made sample work-mix studies at five activities to determine whether their workloads were suited to their production methods. Also our consultant prepared a step-by-step procedure for activities to use in assessing their workloads. The procedure, included as appendix I, could be used by activity personnel with technical expertise in numerical control or, with outside assistance, by those activities not familiar with numerical control. The procedure takes only a few days.

PROCEDURES USED IN WORK-MIX STUDIES

Work-mix studies should include reasonably thorough statistical analyses of parts. The following features of the parts sampled should be determined.

1. Lot size.

2. Hours (including setup time) for conventional and NC machining.

3. Programing time.

4. Repeatability of parts.

5. Percent of work by operation, such as milling.

6. Size of the part.

7. Number of sides on the part that need work. (This relates to the need for rotary tables or heads.)

8. Different tools. (This relates to the need for automatic tool changers.)

9. Number of axes required.

10. Material.

At each of the activities where we made sample work-mix studies, we reviewed:

--The production shop with conventional machines.

--The production shop with NC machines.

--The numerical control part-programing section.

--The planning section which assigns job orders to the NC or conventional machine shop area.

Within each of these four operations, we reviewed parts to determine whether they were suitable for NC or conventional equipment and what types of equipment were best suited to the work.

RESULTS OF SAMPLE STUDIES

Warner Robins Air Logistics Center

Our work-mix study at this activity showed that much of the work being done on conventional machines was better suited for NC machines and that the NC machines appeared to be overly elaborate and expensive in relation to the work.

The activity has 89 conventional machines (that have functions comparable to those of NC metal-cutting machines) with 59 operators and 8 NC machines with 8 operators. Of the jobs sampled in the conventional machine shop, 61 percent (which used 91 percent of the staff-hours) could have been done at less cost on NC machines. An almost identical situation was found among the jobs awaiting scheduling by the planning section. Some of these jobs could have been done on the present NC machines but were not scheduled for them for such reasons as:

--The NC machine shop had a 3-month backlog of work, based on one shift.

--The part-programing section was slow, primarily due to inadequate computer support.

--The costs of NC machining were thought to be much higher than those of conventional machining.

--There were more conventional machine operators than NC machine operators.

Of the jobs determined to be suitable for NC machines, about 80 percent were milling jobs and about 16 percent were turning (lathe) jobs. No jobs were noted which required tapping or boring. Also most of the jobs were for relatively small aluminum parts. (The median size was 10 x 4 x 3 inches.) On the basis of these characteristics, relatively light and inexpensive NC profile milling machines appeared to be most appropriate. The cost of such machines is about $35,000 to $50,000 each.

Two of the NC machines on hand, relatively large lathes, were being declared excess. They appeared to be too large for the activity's turning work. Also, the activity had made large investments in machining centers having automatic tool changers and rotary tables. Since 80 percent of the work was profile milling and none involved tapping and boring--important features of machining centers--these machines seemed overly elaborate. Further, most of the parts examined had no requirements for automatic tool changers or rotary tables. As a result, the activity had machines which cost an average of $210,000 when most of the work could be done effectively with machines costing as little as $35,000.

Sacramento Air Logistics Center

This activity had an unusually high proportion of NC machines and operators in the production area--11[1] NC machines with 13 operators and 20 conventional machines with 20 operators. About 20 percent of the parts sampled in the conventional area were better suited for NC machines.

More NC machines were on hand and on order than the volume and type of work required. Of the 11 on-hand NC machines, 6 were not operating at the time of our study. The activity had requested the following NC metal-cutting machines.

--A $230,000 profile mill similar to already-installed machines that had light workloads.

--A $130,000 four-axis turret lathe that did not appear to have enough potential work.

--A $500,000 honeycomb mill which appeared to be of questionable need because records showed no past or future requirement for its capability.

--A $500,000 five-axis machining center. We felt that five-axis capability was needed, but we were not certain that the particular machine on order was the appropriate type and size. In a letter to the Commander, Sacramento Air Logistics Center, we questioned the need for the machine. He replied that a reevaluation of the workload had indicated cost savings from the machine were doubtful and that the order had been canceled.

Problems in the part-programing section had caused a backlog of work. The section had 7,000 hours of backlogged work, most of which was waiting to be programed. The problem resulted partly from inadequate computer support but mostly from insufficient manpower.

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[1]Does not include three machines not installed at the time of our study and two non-metal-cutting machines.

Sacramento Army Depot

At the time of our study, this activity had no NC machines. The metal-working section had 19 operators who worked 22 conventional machines which had NC counterparts. Lot sizes, the type of work, and the fact that a high proportion of the parts involved repeat orders indicated that NC machines could replace several conventional machines.

--All the punch press work sampled was suitable for NC machines.

--Of the lathe work, 83 percent was suitable for NC machines.

--Of the milling work, 98 percent was suitable for NC machines.

Several studies had been made at the depot to justify NC machine purchases; however, depot management had the common misunderstanding that NC machines were for extremely large lot sizes, which were not found at the depot. After the last study, made in February 1972, proposals were made for five NC machines. We felt that only three of the machines were needed for the workload. Also, the other two machines seemed too large for the average type of work, and one of them had expensive, high-tolerance features that might not be required.

Norfolk Naval Shipyard

The type and mix of the nine NC machines at the shipyard did not appear suited to the work. The machines were too large, of a restrictive point-to-point variety, or too sophisticated.

The shipyard's machine shop had 235 machinists. Half of the work was not the type that would even be considered for NC machines. Only 1 percent of the work was done on NC machines, while 27 percent of the work would be suitable and 12 percent was marginal. Almost all of these jobs involved lathe work.

The present two NC lathes could absorb the work presently done on conventional lathes that is suitable for numerical control, since the NC lathes have been used only 25 percent of their capacities on two shifts. These lathes, however, appeared to be larger and more expensive than needed for the type of work. We felt that smaller NC lathes would be highly desirable for the shipyard's part families, such as valve stems.

Alameda Naval Air Rework Facility

The facility has 16[1] NC machines and 42 conventional machines which have functions comparable to those of NC machines. Conventional machine use was extremely low. Of the conventional work sampled, 74 percent could have been done on the NC machines and probably would have been if the appropriate NC machines had not been so heavily loaded.

Two machining centers were loaded on a full three-shift basis; an additional machining center being installed should relieve this heavy workload. The other NC machines were used only part of one shift, principally because they were point-to-point machines and therefore restrictive.

At the time of our study, 126 parts were in the programing section or awaiting NC machining. Of these, 44 percent were repeat orders which did not need additional programing and which therefore would result in maximum savings. The part-programing section, which used a stand-alone minicomputer, was comparatively efficient and well organized.

FACTORS TO CONSIDER BEFORE
REALINING MACHINES WITH WORK

Work-mix studies show whether present machines are suited to present work; they do not show what management actions should be taken if machines do not match the work. Before buying more suitable machines, management should com-

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[1]Does not include three non-metal-cutting machines.

pare the costs and savings of all alternatives, such as whether:

--Another activity could use an unneeded machine.

--Dismantling, transporting, and installing an unneeded machine at another activity which needs the machine would be more cost effective than having that activity buy a new machine.

--A machine not needed by another activity should be stored in place or shipped to a storage depot.

--An activity with unused NC machine capacity could take on other activities' work rather than declare the machine excess.

--A marginal-value machine and its workload could be transferred to another activity.

--Continuing operations at less than full productivity would be more cost effective than declaring an inappropriate machine excess and buying a more appropriate one.

--An activity's future workload is planned to increase or decrease.

After considering all of these factors, an activity with a workload for NC machines should (1) analyze costs and follow any other procedures needed to justify and obtain the machines or (2) have another activity with unused capacity do its numerical control work.

CONCLUSIONS

Present machines are not always suited to present workloads. Some activities need additional NC machines, and some have overly elaborate machines and unneeded options. Moreover, most activities do not analyze workloads adequately to prevent such conditions, nor do they reassess workloads to determine whether changes are needed. Therefore work-mix studies, as described in this chapter and in appendix I, could greatly assist the justification process by identifying the amount of work suited to NC machines and the appropriate type and size of machines and options, such as automatic tool changers and rotary tables.

RECOMMENDATION

We recommend that the triservice committee insure that work-mix studies are made to achieve a better match of machines and work and to identify opportunities for cost-effective investments. (Our guide for work-mix studies, as shown in appendix I, should assist the committee in implementing this program.)

AGENCY COMMENTS AND OUR EVALUATION

In commenting on our report (see app. V), DOD said the triservice committee had prepared a Draft DOD Instruction 4215.xx, "Management of Numerically Controlled Industrial Plant Equipment," as a major step toward improving the management of this equipment. The instruction, which has not yet been approved, addresses several areas, including work-mix studies to improve the identification of the types of NC machines required. The instruction is discussed further on page 43.

The General Services Administration, in commenting on our report (see app. VI), suggested that we reiterate a point made in our earlier report--that most DOD activities do not have properly trained staffs to make work-mix studies. We agree that this is an important point. But we believe that most activities with experience in NC equipment could follow the work-mix guidelines presented in appendix I with little difficulty. Those activities which experience difficulty could obtain the triservice committee's help in obtaining a better match of machines and work.

CHAPTER 4

INFORMATION ON THE UNIVERSE OF GOVERNMENT-OWNED NC MACHINES

Our earlier report pointed out activities' many problems in planning for and managing NC machines. To get a more in-depth look at machine management, we sent questionnaires to the 225 activities which had Government-owned NC machines. This chapter summarizes our analysis of the questionnaires.[1]

PLANS FOR ADDITIONAL MACHINES

At the time of our earlier report, most activities had few or no plans for acquiring additional NC machines but were ordering much conventional equipment. Our questionnaires asked the activities whether they planned to buy additional NC machines in the next 3 years and, if so, the quantity, type, and approximate cost. Of the DOD activities,[2] 68.1 percent responded "Yes" and 6.4 percent responded "Perhaps." About half of the contractors responded "Yes," but many of those responses concerned machines to be acquired with private funds. Therefore we did not analyze the contractors' responses to this question.

The following table shows the types of equipment which the DOD activities plan to buy.

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[1]Some respondents did not answer all questions. Unless otherwise indicated, the number of unanswered questions was small and analyses were based on the total number of answers.

[2]"DOD activities," as used in this chapter, refers to activities owned and operated by the services or DOD agencies. "Contractors" refers to all other activities which may be wholly or partly Government-owned by DOD, the Energy Research and Development Administration (formerly the Atomic Energy Commission), the National Aeronautics and Space Administration, and the General Services Administration.

Type of machine	Number	Cost (000 omitted)
Lathe	42	$ 5,861
Machining center	39	8,536
Mill	24	2,344
Drill	13	885
Punch	3	705
Grinder	4	522
Borer	2	350
Other	3	314
Total	130	$19,517

Some of these machine classifications may not be precise because many machines perform a variety of functions. For instance, since mills may do boring and tapping, they may be classified as machining centers. For our analysis, we accepted the activities' machine classifications. Regardless of some misclassifications, a large investment in NC machines is planned. The above machines do not include those which will be operated by contractors or those which may be purchased by Government activities which had no NC machines when we mailed the questionnaires.

COMPUTER SUPPORT

We pointed out in our earlier report that many activities did not have adequate computer support and postprocessors. Computer support and postprocessors reduce programing time and are essential for the more sophisticated NC machines.

Types of computer arrangements

Through the questionnaires, we analyzed the types of computer support which activities used and compared the average time which the various types of computers took to program a part and return it to the programer (turnaround time). Government activities most often used in-house electronic data processing departments, and contractors most often used terminals to remote computers. Many activities had no computer support. Following are the types of computer support used and the types which can achieve turnaround time of 1 hour or less.

Type of support (note a)	Activities which use this type of support		Activities which achieve turnaround time of 1 hour or less	
	Government	Contractor	Government	Contractor
	(percent)			
None	18.8	20.8	-	-
Minicomputers	24.9	4.9	100.0	80.0
Terminals to remote computers	18.8	39.6	77.8	65.3
In-house electronic data processing departments or large computers with no locations specified (assumed to be outside production departments)	33.3	22.2	23.5	29.0
Other in-house	-	4.2	-	75.0
Commercial service center	4.2	8.3	50.0	33.3
Total	100.0	100.0	54.3	53.2

[a]Some activities have multiple arrangements and are duplicated among the categories.

As shown above, about 50 percent of the activities can achieve turnaround time of 1 hour or less. However, this calculation was based on the shortest time mentioned by the activities which stated a range of turnaround time, such as "1 to 4 hours." By using the longest time mentioned, only 37.2 percent of the Government activities and 26.8 percent of the contractors can achieve turnaround time of 1 hour or less. Further, about 40 percent of the activities with computer support have a turnaround time of over 8 hours.

Manual programing

Activities may have to manually program parts if they have inadequate or no computer support. Although manual programing may be efficient for some parts, it is very tedious and inefficient for most parts, especially in contouring work.

We asked all activities to state the percentage of their programing done manually for point-to-point and contouring work and found that:

--20.9 percent of the Government activities and 38.9 percent of the contractors did all of their point-to-point programing manually.

--13.5 percent of the Government activities and 10 percent of the contractors did all of their contour programing manually.

Sources of postprocessors

The questionnaire asked about the sources of the activities' postprocessors, and we developed the data shown below.

Source	Postprocessors	
	Government	Contractors
	(percent)	
Machine and/or control unit manufacturer	47.8	41.5
Computer manufacturer or source of computer support	14.2	10.4
Other computer service company	19.0	5.6
In-house	7.5	[a]36.2
Another activity	11.5	6.3
Total	100.0	100.0

[a]About half of these postprocessors were developed by contractors which normally sell postprocessors along with control units.

As noted above, many postprocessors were obtained from the machine manufacturers, generally at no additional cost over the price of the machines. Some activities, especially Government activities, exchanged postprocessors. The key difference between Government and contractor procedures for acquiring postprocessors not available with the machine systems was that contractors developed more postprocessors in-house; Government activities depended more on computer service companies to develop them.

LANGUAGES USED FOR PART PROGRAMING

Our earlier report showed that full development of numerical control's potential may be limited unless greater standardization or uniformity is achieved. Most NC systems appeared to be unique for one reason or another, and one of the unique features was part-programing languages. We asked the activities to indicate what languages they used. Their responses were:

Language	Activities Government	Contractor
	(percent)	
APT	42.0	60.4
ADAPT	2.0	8.2
UNIAPT	22.0	3.0
COMPACT II	8.0	6.0
SPLIT	-	4.5
QUICKPOINT	4.0	.7
AUTOSPOT	4.0	-
Other	18.0	17.2
Total	100.0	100.0

Since some activities are programed in more than one language, they are duplicated among the languages listed. Apparently APT and versions of APT are the most popular languages.

MACHINE-USE REPORTING

During our earlier review, many different machine-use reporting systems were in use and some activities had no systems. The categories of machine use that were recorded also varied. Many activities applied a factor to the number of hours available for work to allow for maintenance and other items and then compared use against this allowance. Some reported only their standard hours.

Our questionnaires asked for descriptions of the activities' reporting systems, including the bases for their statistics (staff-hours, power meters, etc.), the way the data is entered into the systems and compiled, the types of reports generated, the categories used in the reports, the data used to make up the categories, and the number of shifts on which the data is based.

This question was not completely answered. Some activities, such as schools with DOD equipment on loan and DOD storage facilities, had no need for reporting systems. Of the activities which answered the question, 23 percent of the Government-operated activities and 11 percent of the contractors said they had no reporting systems. The Government activities with no systems had 56 NC machines estimated to be worth $5.7 million; the contractors had 71 Government NC machines estimated to be worth $11 million.

Only 96 questionnaire responses were clear enough for us to determine whether the basis for machine-use reporting was staff-hours or meters. Our analysis follows.

Basis	Activities Government	Contractor
	(percent)	
Staff-hours	44.0	84.5
Power meters	48.0	9.9
Both	8.0	5.6
Total	100.0	100.0

Many of the machines we observed had at least one type of meter, such as a power meter, a spindle meter, or a meter which measured actual cutting time. But, as shown in the preceding table, using meters for reporting has not been generally accepted.

We asked each activity to state each machine's productive use in 1973. Because of the diversity of machines, the use rates shown below should be considered only in broad, rough terms. Also, the data is based on about two-thirds of the Government-owned machines because some machines had no reporting systems and some were in storage.

Productive use was over	Cumulative percent of machines Government	Contractor
500 hours	87.4	91.4
1,000 hours	75.3	78.0
2,000 hours	43.9	49.7
3,000 hours	9.0	30.1
4,000 hours	1.7	11.6
5,000 hours	.4	5.7

The percent of time an NC machine is used does not necessarily indicate poor or good operations. NC machines with low use may be paying for themselves because of the productivity increases over conventional machines. And NC machines with high use may not be doing the most appropriate work for numerical control.

PURCHASE OF SPARE-PARTS KITS

If activities do not have essential spare parts when they are needed, the parts must be procured. And when NC machines are waiting for parts, the activities must either resort to less productive conventional machines or delay production.

Most manufacturers recommend spare-parts kits for their machines, but most NC users do not buy the kits. Following are the activities' responses to our question: "Do you usually purchase the manufacturer's spare parts kits for the machine tool and control unit?"

Response	Percent response Government	Contractor
Yes	29.5	19.6
No	70.5	78.1
Selectively or seldom	-	2.3
Total	100.0	100.0

The reasons given for not buying the kits follow.

Reason	Percent response Government	Contractor
Kits contain unneeded parts and lack needed parts	21.9	24.5
Better to replace parts as they fail	37.5	32.4
Too expensive	15.6	25.5
Cannot determine needed parts	9.4	2.9
Other	15.6	14.7
Total	100.0	100.0

The 41 Government activities which estimated how much they had invested in spare parts had a total of $907,034 invested. As shown below, those activities which bought kits had a much higher average investment in spare parts for each machine than those which did not buy kits.

	Number of machines	Total investment in spares	Average per machine
Government activities with kits	174	$488,207	$2,806
Government activities without kits	270	418,827	1,551

We asked the activities which did not buy the kits how they decided which spare parts to buy. Following are typical answers.

--We use past experience with the same or similar machines.

--We receive good service during the warranty period, which gives us time to determine our spare-parts requirement from actual experience.

--We purchase spare parts as indicated by the breakdown history of specific parts.

--We buy replacements as parts fail.

Many activities told us that spare parts were difficult to obtain for many of the older machines. To overcome this, parts were exchanged between contractors' different plants or were manufactured in-house.

DELAYS IN GETTING REPAIR PARTS

The questionnaires asked the activities whether getting parts quickly was a problem. Responses were that 38.6 percent of the Government activities and 41.3 percent of the contractors had problems. We also asked the activities to describe the procedures they used and the time it took to get a part after a request was made from the shop. Rather than stating an average time, many respondents gave a time range, depending on various circumstances, including

--what internal priority was assigned to the part,

--whether the manufacturer had the item in stock, and

--what the part cost.

We compared the time it took to obtain parts at activities which said they had problems with the time it took at activities which did not have problems.

Days to obtain parts	Activities which	
	Had problems	Had no problems
	(percent)	
1	19.3	35.1
2 to 7	44.5	46.0
8 to 14	13.3	13.5
15 to 21	2.4	2.7
22 to 31	3.6	2.7
Over 31	16.9	-
Total	100.0	100.0

Even though some delays were caused by uncontrollable factors, such as unavailability of the parts, inadequate procurement systems also were contributing causes. One activity described its procurement procedures as follows:

> A request is made of Plant Services Production Control to procure parts. Since most parts are not stocked in the Federal supply system, form 1348-6 must be processed, which takes an average of 3 to 5 weeks, and then form 244 is submitted to base supply. The usual time for delivery of parts is 90 to 120 days, but it can take as long as 1 year depending on the manufacturer's leadtime.

In contrast, the following procedures were in effect at an activity which said it had no problems.

> After a material request is received from the shop, the material-ordering section immediately phones an order to the vendor and has parts shipped by air. Delivery takes 1 to 20 days and averages 3 to 15 days.

PROCEDURES FOR SELECTING JOBS FOR NC MACHINES

Activities generally lacked formal guidelines for determining what jobs should be done on NC machines rather than conventional machines. They generally did not make formal cost comparisons for different production methods. The following summarizes the frequency of the factors mentioned in response to our request to: "Describe how you decide which jobs will be done on NC. (Include criteria, personnel responsible, and procedures to insure that jobs are put on NC when they should be.)"

Selection factor	Percent of activities which mentioned factor Government	Contractor
Machine load	62.2	35.6
Lot size	51.4	46.5
Cost of job	51.4	46.5
Part complexity	37.8	43.6
Possibility of repeat orders	27.0	5.0
Tolerances	24.3	31.7
Other costs (note a)	21.6	25.7
Size of part	10.8	15.8

[a]Activities mentioned setup costs, tooling savings, and tooling costs.

Other selection factors mentioned were use of present machines, safety, and kind or amount of machining. Only one activity--a contractor--indicated that it used a form (see app. II) to compare NC methods with conventional production methods. Key features are the comparison of tooling costs, machine run times, inspection costs, and part complexities. We believe such cost comparisons would assist all activities in selecting jobs for NC machines.

EXCHANGE OF DATA PACKAGES

We pointed out in our earlier report that exchanging numerical control data packages (engineering drawings, cutter-line listings, tooling data, etc.) could save programing time if an activity had to produce a part that another had already programed.

We asked the activities to:

"Describe your system, if any, for exchanging NC tapes or NC packages with other activities and/or contractors. Include in your discussion any available statistics on numbers of tapes or packages exchanged, with whom, and resulting savings."

Of the 225 activities which received questionnaires, only 41 said they had exchanged data packages; no exchanges had been made between industry and Government activities.

Data package exchange	Number of activities
Between similar Government activities	11
Between different plants of contractors	14
Between contractors and subcontractors	16
Total	41

FOLLOWUP SYSTEMS TO ASSESS BENEFITS

Although activities are generally required to have followup systems that show the actual savings from NC equipment, not all did. The questionnaires asked the activities to "describe your system for determining whether your NC equipment is providing the savings you predicted on your justification." The responses are summarized below.

	Percent of activities	
	Government	Contractor
No system	47.7	38.6
Partial system	2.3	2.6
Have system:		
One-time followup	22.7	27.2
More than one followup	27.3	31.6
Total	100.0	100.0

CONCLUSIONS

Many areas in the management and use of numerical control need further development, resolution, and/or coordination to bring about the most benefits. Responses to our questionnaires showed that the following areas need to be improved.

--Many different types of computer arrangements are in use with varying amounts of turnaround time. More appreciation of adequate computer arrangements could bring about increased productivity and enhance future development of numerical control.

--Government activities have not developed postprocessors to the extent that contractors have. Through coordination, more expertise could be built up within the Government to avoid the expense and delay often accompanying outside procurements of postprocessors.

--Utilization reporting systems are extremely diverse. More uniformity should be sought.

--Most activities do not consider manufacturers' recommended spare-parts kits appropriate. Those which bought kits spent more on spare parts than those which developed kits through experience. With the appropriate coordination, experience gained on needed parts could be passed on to activities without experience so they could judge what parts to buy with a new machine.

--Many activities have problems getting repair parts quickly, partly due to cumbersome procurement systems. With proper emphasis on the productivity lost when NC machines are down, streamlined methods could be devised and hard-to-get parts could be interchanged.

--Activities generally did not use cost models or comparisons in selecting jobs for NC machines. Such comparisons should be developed to better select jobs.

--Data package interchange can save programing time, but NC systems must become more standardized and records of parts programed must be more visible before this can be achieved on a broad scale. Also, early plans should be made for the Government's acquiring data packages to insure that they are available when needed and to resolve ownership questions.

--Followup systems are not always used to assess whether NC machines are as productive as possible and to notify management of problems so that decisions can be made on whether to improve productivity or replace equipment.

Because DOD has established the triservice coordinating committee, we are not making recommendations for improving numerical control's management and use at this time. Rather, we hope that the information in this chapter will add to the committee's insight and aid in its efforts to improve the field of numerical control.

AGENCY COMMENTS AND OUR EVALUATION

In its comments (see app. V), DOD said the triservice committee is trying to resolve the problems we identified in our earlier report and in this report through our questionnaires. Draft DOD Instruction 4215.xx, which the committee prepared, currently addresses the following major areas of numerical control's management:

--Planning (including work-mix studies and personnel and computer support for peacetime and mobilization workloads).

--Economic justifications and followups.

--Utilization.

--Preventive maintenance and spare-parts acquisitions.

--Inventory reporting.

--Planning for standardization of hardware and software.

This instruction, when implemented, should be of great help to military and nonmilitary activities, in better planning for and managing their NC machines. As suggested by the Energy Research and Development Administration (see app. VII), an exchange of information between the triservice committee and its counterparts elsewhere in the Government and in private industry would be advisable.

CHAPTER 5

COSTS OF NUMERICAL CONTROL

The primary consideration of numerical control involves its high cost, both for the basic machine and the necessary support. Therefore, before NC machines are purchased, the activities which request and approve them should fully understand these costs and the critical factors which can lead to savings or losses with NC machines.

During the next 3 years, Government-operated activities that already have NC machines plan to buy $20 million worth of NC machines, and the Government will undoubtedly buy additional machines for (1) contractor-operated, Government-owned plants, (2) Government-operated activities with no present NC machines, and (3) contractor plants that are partly Government owned. One of the most common justifications for buying these machines will be their cost effectiveness. For example, an NC machine can outproduce its conventional counterpart by 3 or 4 to 1. But if NC machines are not properly managed and sufficiently used, they can result in a higher overall cost than conventional machines.

INCREASED COSTS

There is no absolute method for predicting all costs associated with an NC installation. These costs vary widely and depend on many circumstances, such as the type and size of the machine, part-programing practices, and maintenance services. But activities must recognize that such costs exist, that they are high, and that management must be alert to them to make wise investment decisions and to keep NC machines as cost effective as possible. Some of the major cost considerations of NC machines follow.

--Acquisition costs. NC machines may cost several times as much as their conventional counterparts. This, however, may be of little consequence if the alternative to buying one NC machine is to buy several conventional machines. The cost of an NC machine ranges from $30,000 to over $1 million.

--Installation. The cost to install any large machine is high. Special foundations, for example, must be prepared. But stable foundations are of greater consequence for NC machines than for conventional machines because of NC machines' closer tolerance output and automatic operations. Foundations for relatively small NC machines may cost only a few thousand dollars. However, for large machines, the cost may range from $50,000 to $100,000. Coupled with the foundation costs may be costs for removing other machines and for losing productive time while NC and conventional machines are inoperable. If the alternative to installing an NC machine is installing several conventional machines, foundation costs for the NC machine may be less and may result in savings.

--Training. Training costs vary depending on the complexity and number of NC machines. Equipment suppliers usually give initial maintenance training and include it in the contract price. Training costs for programers, planners, and liaison personnel depend on the policy of the suppliers and the existing in-house capabilities and usually are higher than training costs for conventional machines.

--Part programing. Part-programing time is an added cost with NC machines. The programing time required is difficult to calculate unless details are known about the availability of computer support, types of machines, lot sizes, complexity of parts, and number of machines. Programing time for each machine seems to decrease somewhat as activities obtain more machines. Annual salaries for programers generally range from $12,000 to $15,000 plus fringe benefits.

--Computer support. Computer support should be available to save programing time. Its costs can vary depending on the types of machines, such as point-to-point machines or contouring machines. Rented terminals, a popular source of support, may cost about $1,200 a year minimum and, for more frequent use, perhaps an additional $150 to $500 to program a part.

A dedicated minicomputer system, another popular source of support, can cost $60,000 to $80,000 plus another $1,000 a year for maintenance.

--Special tooling. Special tool holders and adapters may be costly, especially for automatic tool-changing machines. These costs can vary depending on the commonality of machines at one location. For instance, one activity paid $30,000 for tooling for its first five-axis automatic-tool-changing machining center but estimated only $15,000 for a second identical machine's tooling.

--Postprocessors. Many postprocessors are included in the price of the machine system. The costs for having postprocessors developed outside an activity average $3,500, not including in-house calibrations and adjustments, which can take several months.

--Maintenance and repair parts. The cost for NC machines' maintenance and repair parts may be higher than that for conventional machines because NC machines involve electronics and higher accuracies. According to a Small Business Administration study, these costs are about $3,000 a machine each year. Also, productivity is lost when the machines are being repaired.

--Inspection equipment. Equipment to inspect and repair NC machines can be costly. In addition to electronic and other circuit-testing equipment, special alinement-checking equipment--such as high-accuracy optical devices and laser interferometers--often must be procured.

SAVINGS FROM NUMERICAL CONTROL

The savings from investing in NC machines also depend on a variety of circumstances. Direct labor is usually the largest single savings mentioned in justifications for NC machines. Laborsavings from NC machines are calculated on the basis of equivalent machine-hours on conventional machines, a productivity increase for NC machines, and a shop labor rate. Since these factors are often unsupported and can be easily adjusted to result in a favorable justification, actual savings may not be as estimated.

--Conventional machine-hours are estimates of the time to produce the work conventionally. If conventional machines are to be replaced, actual savings occur only through eliminating operators and/or sustaining the projected use of the NC machine.

--The productivity increase ratio is normally stated as reduced floor-to-floor time when NC machines, rather than conventional machines, produce parts. Productivity ratios in justification documents may be as great as 10 to 1. These ratios, however, vary according to the type of machine; machine features, such as automatic tool changers; and the specific items being machined. The Numerical Control Society surveyed numerical control's average productivity increases over conventional machines for different types of machines and manufacturers. The productivity increases for two types of manufacturers and the average increase for all manufacturers surveyed are shown below.

Manufacturer of	Average productivity increase from NC machines					
	Drilling	Boring	Turning	3-axis milling	5-axis milling	Punching
	(percent)					
Aircraft and parts	149	125	193	287	293	300
Missiles and ordnance	115	106	93	258	420	350
Average for all manufacturers surveyed	113	84	107	197	267	185

--Most justifications use the standard shop labor rate which includes both direct and indirect labor. Since indirect labor includes nonvariable overhead items, it is likely that actual laborsavings from numerical control are not as great as the rate used. The savings are actually the conventional machinists' direct pay rates and fringe benefits, which may total only about $7.50 an hour.

The following other savings from numerical control may or may not be significant, depending on the specific machine, parts, use of the machine, and management efficiency.

--Scrap savings. Savings from reducing reworked and scrapped parts can be significant. After a tape has been successfully tested and the first part has been successfully machined, the chances of errors in machining later parts are remote. The chances of scrapping the first part depend, to a large extent, on the computer program diagnostics and the verification equipment and procedures, in addition to the part programers' abilities. Some means of plotting the tool path before machining the first part is therefore highly recommended. Verifying the tool path also reduces the checkout time normally required on the machine.

--Tooling. The savings from producing parts without special jigs and fixtures depend to a high degree on whether the jigs and fixtures have already been made for conventional machines. If the alternative to using NC machines is preparing jigs, etc., real savings result; if they have already been prepared, no savings result.

--Inspection. Because NC machines can produce almost identical parts, fewer parts have to be inspected. Also, fewer checkpoints on parts are required. However, few activities modified their inspection procedures after they bought NC machines. But since many parts made on NC machines require high tolerances, inspection costs might increase if the parts were made conventionally.

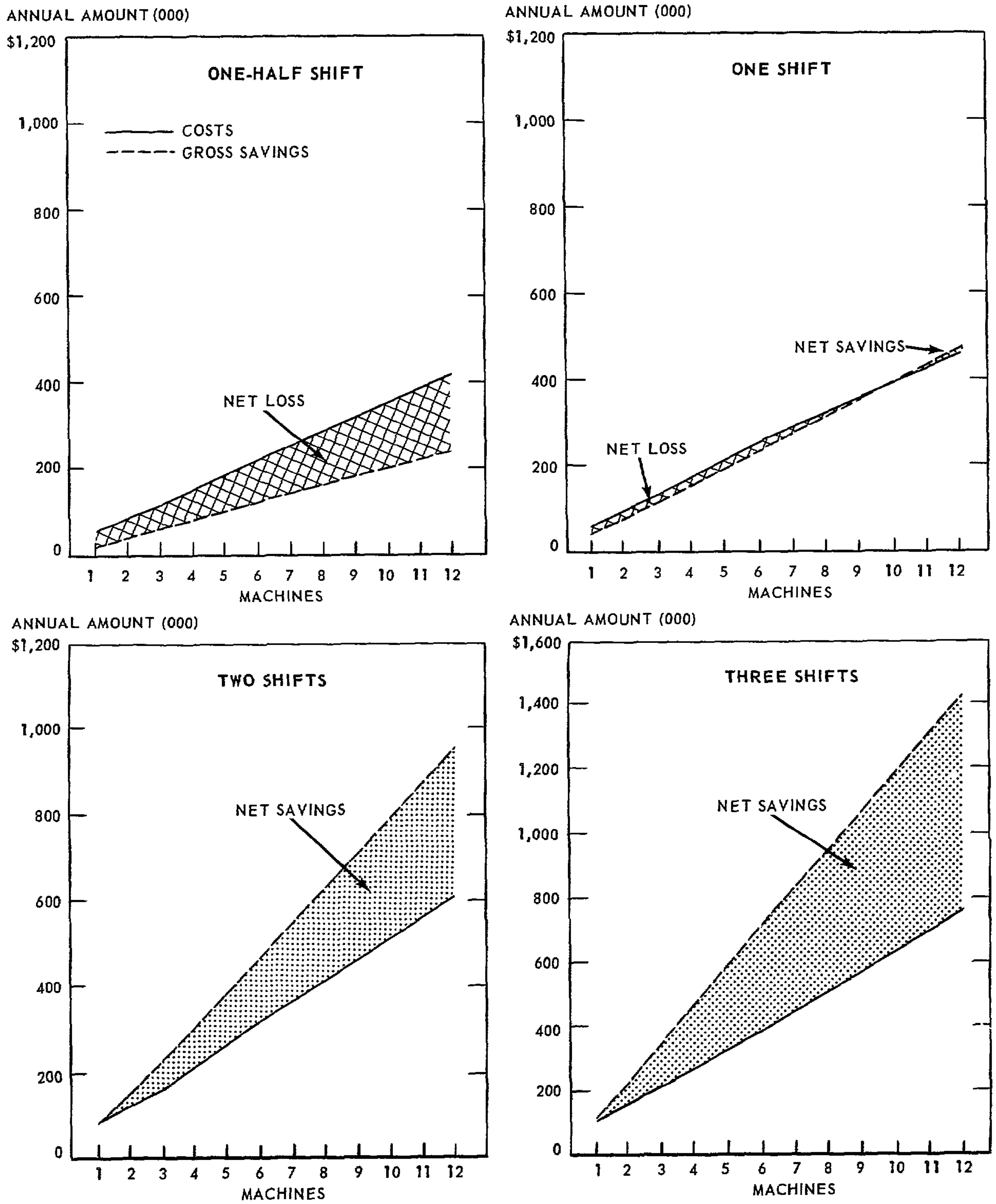
--Other savings. Other savings that cannot be readily measured result from (1) improved response time to manufacture parts, but this depends largely on the efficiency of the programing functions, (2) better manufacturing control in that machining times are more readily estimated, (3) better quality products, and (4) relief from shortages of experienced machinists--a critical problem at many activities.

COST-SAVINGS MODEL

Achieving a saving or a loss on NC machines depends partly on how many machines an activity has and how often they are used. As the number of NC machines at an activity increases, the support costs for each machine can be expected to decrease. If a facility has only a few NC macines and is running them on part of the shift, the overall efficiency of the operation, considering the equipment investment and support services, is likely to be poor. Savings therefore are proportional to the number of machining hours used.

For example, if one NC machine can produce the same amount of work as three conventional machines, the NC machine working an 8-hour shift can produce the work of three 8-hour shifts on conventional machines. If NC machines work two or even three shifts a day, the savings double or triple, respectively. The greatest savings can therefore be realized when the maximum number of technically suitable NC machines are operating a maximum number of shifts. Conversely, NC machines operating on too few shifts can result in a net loss. An example of the savings or loss, depending on the number of NC machines at an activity and the number of shifts worked each day, is illustrated on the following page.

The cost lines shown in the graphs represent the investment cost and yearly operating costs, including tooling, part programing, data processing, and maintenance. Savings are those obtained on labor, tooling, and scrap. The figures shown are representative of aircraft activities in which the average cost of an NC machine is $204,000.


ANNUAL AMOUNT (000)
ONE-HALF SHIFT
COSTS
GROSS SAVINGS
NET LOSS
MACHINES
ONE SHIFT
NET SAVINGS
NET LOSS
MACHINES
TWO SHIFTS
NET SAVINGS
MACHINES
THREE SHIFTS
NET SAVINGS
MACHINES

Some of the major assumptions used for the figures follow; appendix IV shows more details on assumptions and calculations used.[1]

--An NC machine's life is amortized over 10 years.

--Salary costs for personnel include direct salaries and fringe benefits.

--The productivity ratio is 3 to 1.

--Computer costs assume a dedicated minicomputer with a 7-year life.

--An investment in conventional machines is considered a sunk cost.

As shown in the graphs, a one-shift operation is uneconomical unless an activity has at least 10 NC machines. The adverse effect of a partial-shift operation is even greater; the loss on 12 machines over 1 year is approximately $180,000. The savings on a two-shift operation increase impressively as the number of NC machines increases above one, and maximum savings are gained by a full three-shift operation (5-day week).

It should be noted that the lines shown on the graphs for the savings depict efficient operations. Activities should not assume that, merely by installing several NC machines, they will obtain operating savings. If the machines are not used enough, an activity will not come close to breaking even.

CONCLUSIONS

Numerical control can be a cost-effective operation or can result in additional costs that cannot be recovered. As shown through the model and discussion of cost elements,

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[1]Sources: GAO questionnaires, actual costs at selected activities, and previous studies on numerical control.

the break-even point and amount of profit or loss depend on many variables that should be analyzed and managed properly. To achieve the most cost-effective operation of NC machines, activities should (1) adequately and accurately justify procurements of the machines and (2) use the machines at least as much as planned. In fact, if these two things are done, investments in NC machines will almost always be cost effective.

CHAPTER 6

IS DOD OBTAINING THE INTENDED BENEFITS FROM NUMERICAL CONTROL ACQUISITIONS?

Although numerical control offers many benefits in terms of cost savings, high tolerances, and ability to meet mobilization requirements, it is no panacea. To fully benefit, activities must closely plan for and manage numerical control as a total production system. Thus far the cost savings achieved and the mobilization requirements met have been less than optimum. From an overall view, unless the management and use of numerical control are improved, its benefits will not be obtained.

Buying NC machines differs from buying conventional machines. As a production system, numerical control requires:

- --Adequate computer support so that parts can be programed quickly and efficiently.
- --Personnel adequately trained in numerical control to plan for its work, program parts, operate the machines, follow up on and correct maintenance and downtime problems, and act as liaisons between departments involved with numerical control operations.

COST SAVINGS

Many activities have had little success in achieving cost savings from numerical control. In their justifications for buying NC machines, activities frequently cited quick payback periods and high productivity. These justifications are normally based on ideal production systems; i.e., adequate computer support, trained personnel, and minimal downtime. Such ideals have not always been met.

As demonstrated in chapter 5, NC machines should generally be run at least a full shift to achieve paybacks. Since this was not always the case, DOD did not fully obtain numerical control's cost benefits.

HIGH TOLERANCES

NC machines can produce parts at high tolerances by certain inherent capabilities. But this assumes that appropriate machines and features are available, that they are suited to the work, and that the machines are operating. Here again, this has not always been the case. Obviously, if machines are down or if parts are produced conventionally because inadequate computer support or programers caused long leadtimes, the high-tolerance work may have to be done tediously by conventional machines.

MOBILIZATION READINESS

Mobilization readiness requires that DOD facilities be able to meet higher levels of production until industry can increase its production--generally considered to be about 6 months. Some activities attempt to reserve shifts for higher production in the event of mobilization. NC machines, depending on their management, could either assist in mobilization or be a clear-cut detriment to higher production.

Since jobs can be set up faster on NC machines than on conventional machines, response time can be shorter, and short response time would obviously be helpful in meeting mobilization requirements. However, because of inadequate computer support; inappropriate NC equipment; and a shortage of trained personnel, particularly part programers, leadtimes to produce parts have often been longer on NC machines than on conventional machines. Therefore, in the event of mobilization, activities' leadtimes for higher production levels would have to include time to acquire programers and to train them in the intricacies of the particular machine, computer, and programing language.

It seems unlikely that NC machines could quickly meet higher production requirements because, as stated previously, their use has been less than optimum at the present peacetime production level. For instance, the Norfolk Naval Shipyard has been able to achieve only about one-half-shift use of its NC machines because of inoperable postprocessors, inadequate computer support, and other problems. Potentially good part candidates for numerical control have been diverted to conventional machines and produced more quickly. If higher production levels were required, it would be more expedient for the shipyard to divert most of the additional work to conventional machines. Therefore, the use of NC machines would likely not increase.

Another example of the current inability to build up to higher production levels through numerical control can be found at Warner Robins Air Logistics Center. The center has four programers and eight NC machines (including two lathes recently declared excess) that were acquired between March 1971 and August 1972. Since the NC operations began, only 46 parts have been programed. The lack of adequate computer support hampered the programers' ability to program parts within the allotted leadtime. Programing time was concentrated on large-lot production orders to occupy the machines and allow programers sufficient time to program other parts. Consequently, many parts which were prime candidates for numerical control were produced conventionally. Even though the air logistics centers plan a computer-linked system dedicated to numerical control, Warner Robins' programers will have to take additional training to be able to use the system and language.

Another factor which has prevented numerical control from meeting readiness requirements is the lack of data package exchange. To make such exchanges possible, ownership of data packages has to be resolved and NC systems have to be more standardized. If these areas were improved, programing time and leadtime could be reduced to allow for more production.

If NC machines were properly managed, they could offer much to the readiness posture.

- --NC machine operators do not need such extensive skills as conventional machine operators, so a more ready labor market could be available.
- --Numerical control data packages could be acquired from industry and quickly converted to tapes, so Government NC machines would be capable of meeting higher production requirements in a mobilization.

--Inventories of spare parts could be reduced, since tapes could be stored to quickly respond to requirements for the parts.

--New parts could be set up more quickly because NC machines often do not require special fixtures and tool design and manufacture.

--Repeat orders could be produced quickly.

CONCLUSIONS

To achieve numerical control's benefits of cost effectiveness and mobilization readiness, management must be dedicated to planning for and acquiring the necessary support. Numerical control must be managed as a total production system involving a number of varied in-house operations. Merely buying or retaining machines will not fill these needs; numerical control is no panacea. NC machines are only one link in the total chain of production.

RECOMMENDATION

We recommend that the Secretary of Defense insure that the necessary computer support and programers are available to meet mobilization requirements.

AGENCY COMMENTS AND OUR EVALUATION

As stated on page 43, DOD said its Draft DOD Instruction 4215.xx addresses planning for personnel and computer support needed to meet peacetime and mobilization workloads. When this support is available and personnel are appropriately trained, NC equipment should be of great benefit in meeting mobilization requirements.

CHAPTER 7

SCOPE OF REVIEW

At the following activities, we toured shops, discussed policies and procedures, and analyzed instructions and other documents relating to the management and use of NC equipment.

Warner Robins Air Logistics Center, Warner Robins, Georgia

Lockheed-Georgia Company, Marietta, Georgia

Naval Air Rework Facility, Alameda, California

Mare Island Naval Shipyard, Vallejo, California

Sacramento Air Logistics Center, Sacramento, California

Rock Island Army Arsenal, Rock Island, Illinois

Norfolk Naval Shipyard, Portsmouth, Virginia

Naval Air Rework Facility, Norfolk, Virginia

We made limited inquiries at the Naval Weapons Station, Yorktown, Virginia; the Aerojet-General Corporation, Sacramento; and the Kansas City area office, Atomic Energy Commission (Bendix Corporation), Kansas City, Missouri. We also obtained data from DOD and service headquarters and from the Defense Industrial Plant Equipment Center, Memphis.

We mailed questionnaires to 225 activities which had Government-owned NC machines at the time of mailing, and we received 214 responses. Activities covered included contractor plants, Government-owned activities, National Aeronautics and Space Administration and General Services Administration facilities, and 17 Atomic Energy Commission plants.

Mr. James J. Childs, a leading numerical control consultant and author of numerous numerical control articles and textbooks, made work-mix studies and prepared guidelines for activities to use in assessing their workloads. (See app. I.)

WORK-MIX STUDIES: A BASIS FOR JUSTIFYING AND SELECTING EQUIPMENT

Prepared for:

U.S. General Accounting Office

Prepared by:

James J. Childs, President
James J. Childs Associates
Alexandria, Virginia

A representative and properly executed work-mix study can be very helpful in justifying NC equipment and in determining the most suitable size and type of NC equipment. The key to a work-mix study is a reasonably thorough, statistical analysis of the parts selected for the sample.

Neither the random-sampling technique nor the analysis need be overly detailed or time consuming as long as the sample is felt to be reasonably representative of the average type of work in the shop. If the results of the sampling are felt to be not representative, a second or even third sampling may be made. In most cases gathering the sample material should not exceed 2 or 3 man-days. The actual time required depends on the size and complexity of the activity and the type of work.

Experience has shown that, at most Government activities, a sample of 20 to 50 parts is generally suitable. If an activity has NC equipment, a sample of about 10 parts may be taken from each of the following sections.

1. The planning section where the jobs are reviewed and scheduled for NC or conventional machines.

2. The conventional shop.

3. The NC shop.

4. The part-programing section.

If an activity has no NC equipment, only the first two sections can be reviewed.

Samples taken from the different sections may be combined or handled separately. One of the purposes of sampling the planning section and the conventional shop area is to determine what percentage of the work in these areas is technically and economically suitable for NC machines.

FORMAT FOR GATHERING DATA

A format that may be used as a guide for recording the sample statistics found in all four sections of an activity is shown on the following page. Other columns, such as de-

APPENDIX I

1	2	3	4		5		6	7		8		9	10	11					12	13	14	15	16	17	18	19
			Unit hours (including set-up averaged)		Total hours		Estimated part-prog. time	Estimated holding fixture design & mfg. (hours)		Total hours		Percent chance of repeat or similar parts	Recom-mend NC	Percent operations					Size	Sides to machine	Recom-mend rotary table	Differ-ent tools	Recommend tool changer	Recom-mend 4 or 5 axes	Material	Recommend type machine
Part no.	Part name	Lot size	Conv.	NC	Conv.	NC	(hours)	Conv.	NC	Conv.	NC	parts	NC	Mill	Drill	Tap	Bore	Turn	(inches)	machine	table	tools	changer	5 axes	Material	type machine
PLANNING SECTION																										
XXXX-1	Angle	22	2	.6	44	13	8	-	-	44	21	5	Yes	100					16x1x1	3	No	2	No	No	Alum.	NC profiler
2XXX-A	Bracket	1	50	8	50	8	20	-	12	50	40	5	Yes	90	10				25x6x6	6	Yes	5	No	No	Alum.	Mach. center
3XXX-2	Fitting	1	24	5	24	5	8	-	8	24	21	10	Yes	70	30				4x4x2	4	No	5	No	Yes	Alum.	Mach. center
23XXX-A	Angle	8	2	.6	16	5	5	-	-	16	10	20	Yes	100					16x1x1	3	No	5	No	No	Steel	NC profiler
24XXX-T	Expander	10	3.5	3.0	35	30	8	-	-	35	38	1	No	-	10			90	1x1/2D	NA	NA	NA	NA	NA	Steel	Lathe
256XX-Q	Gage	1	24	10	24	10	15	-	-	24	25	-	No	80	20				6x3x2	-	No	-	No	-	Steel	----
XXX-1	Fitting	8	85	20	680	160	30	-	12	680	202	10	Yes	100					23x9x2	2	No	5	No	No	Alum.	NC profiler
2XX-XX	Fitting	100	7	2.5	700	250	40	10	24	710	314	-	Yes	95	5				4x4x4	6	Yes	12	Yes	No	Steel	Mach. center
3XX-XX	Belcrank	2	6	3	12	6	12	-	-	12	18	-	No	80	20				1x1x1/4	-	No	-	No	-	Alum.	----
4XX-4T	Panel	2	2	1	4	2	6	-	-	4	8	-	No	70	30				3x1x1/4	-	No	-	No	-	Alum.	----
XX-XXX-2	Plate	15	12	5	180	75	15	-	-	180	90	10	Yes	60	40				10x8x1	2	No	25	Yes	No	Plastic	Mach. center
CONVENTIONAL SHOP																										
XX-XX-XX	Eccentric	12	5	1.5	60	18	3	-	-	60	21	20	Yes	15	10			75	1/4x1D	NA	NA	NA	NA	NA	Alum.	NC lathe
6X-42-X	Cover	10	.5	.3	5	3	6	-	-	5	9	-	No	60	40				3x3x1/8	1	No	-	No	-	Alum.	----
7XXXXX	Bolt	540	.14	.12	76	65	2	-	-	76	67	10	No					100	2x1/2D	NA	NA	NA	NA	NA	Brass	----
8XXXX-1	Roller	540	.17	.16	92	86	8	-	-	92	94	10	No					100	2x1/4D	NA	NA	NA	NA	NA	Alum.	----
9XXXX-2	Guide	6	9	2	54	12	5	-	-	54	17	1	Yes	80	20				4x2x1	4	No	6	Yes	No	Alum.	Mach. center
5XX-2	Support	46	2	.7	92	32	2	-	-	92	34	10	Yes	90	10				5x2x1	2	No	4	No	No	Alum.	NC profiler
65XX-2	Plate	20	120	6	2400	120	20	-	25	2400	165	1	Yes	95	5				65x9x1/4	1	No	2	No	No	Alum.	NC profiler
80XXX-A	Fitting	15	2.8	1	42	15	3	-	-	42	18	10	Yes	80	20				3x2x2	5	No	4	No	No	Alum.	NC profiler
30XXX-2	Quadrant	10	60	15	600	150	40	-	20	600	210	5	Yes	65	5			30	10x10x3	6	Yes	20	Yes	No	Alum.	Mach. center--lathe
30XXX-3	Quadrant	17	65	15	1105	255	45	-	25	1105	325	5	Yes	50				50	6x6x7	2	No	10	Yes	No	Alum.	Mach. center--lathe
6TXXX-4	Longeron	12	17	5	204	60	6	-	-	204	66	10	Yes	100					12x4x4	2	No	2	No	No	Alum.	NC profiler
XXX-X2X	Fitting	3	10	2	30	6	12	-	-	30	18	1	Yes	100					16x2x1	-	No	-	No	No	Alum.	NC profiler
XX4-X2X	Fitting	10	16	12	160	120	30	-	-	160	150	1	No	70	30				4x4x3	-	No	-	No	No	Alum.	----
XXX-53X	Fitting	4	100	40	400	160	40	-	20	400	200	10	Yes	90	10				28x6x4	5	No	8	No	No	Alum.	NC profiler
NC SHOP																										
XXX-XXXX	Guide	540		.8		432	8		-		440		Yes	85	15				5x3x1/4	1	No	2	No	No	Alum.	NC profiler
16XXX-2	Plate	270		.5		135	10		5		150		Yes	60	40				20x12x1/4	1	No	4	No	No	Alum.	NC profiler
16TXX-5	Sprocket	50		7.5		375	15		10		400		Yes	80	20				4x4x1	2	No	2	No	No	Steel	NC profiler
20TXX-6	Fitting	210		10		2100	80		40		2220		Yes	100					14x6x4	6	Yes	18	Yes	No	Alum.	Mach. center
20TXX-7	Fitting	210		10		2100	10		30		2140		Yes	100					14x6x4	6	Yes	18	Yes	No	Alum.	Mach. center
XXX-XX	Guide	480		3		1440	15		20		1475		Yes	85	15				9x1x1	6	No	7	No	No	Alum.	Mach. center
PART-PROGRAMING SECTION																										
10XXX-2	Ring segment	12		2		24	15		8		47		Yes	60				40	16x16x2	1	No	4	No	No	Alum.	NC profiler
16XXX-3	Ring segment	270		1.8		486	15		-		501		Yes	90	10				22x22x2	1	No	4	No	No	Alum.	NC profiler
XXXXX-3	Guide	90		2		180	18		-		198		Yes	85	15				23x3x2	3	No	2	No	No	Alum.	NC profiler
XXXXX-7	Guide	45		3		135	18		-		153		Yes	85	15				37x3x2	3	No	2	No	No	Alum.	NC profiler
XXXXX-11	Guide	45		4		180	18		-		198		Yes	85	15				60x3x2	3	No	2	No	No	Alum.	NC profiler
XXXXX-13	Guide	45		3		135	18		-		153		Yes	85	15				60x3x2	3	No	2	No	No	Alum.	NC profiler
XXXXX-15	Guide	45		2		90	18		-		108		Yes	85	15				37x3x2	3	No	2	No	No	Alum.	NC profiler
2XXX-2	Frame	10		16		160	25		6		191		Yes	100					24x6x3	6	Yes	5	No	No	Alum.	Mach. center
2XXX-3	Frame	17		16		272	5		6		283		Yes	100					24x6x3	6	Yes	5	No	No	Alum.	Mach. center
XXPXX-2	Plate	1080		.20		216	3		3		222		Yes	80	20				3x2x1	1	No	2	No	No	Alum.	NC profiler
XXXX-1Q	Channel	90		.35		32	2		-		34		Yes	100					28x2x1	2	No	2	No	No	Alum.	NC profiler
XXXX-2Q	Channel	90		.35		32	2		-		34		Yes	100					43x2x1	2	No	2	No	No	Alum.	NC profiler
XXXX-3Q	Channel	90		.35		32	2		-		34		Yes	100					65x2x1	2	No	2	No	No	Alum.	NC profiler
3QTXY	Corner fitting	30		10		300	40		16		356		Yes	100					16x6x4	6	Yes	6	Yes	No	Alum.	Mach. center
43UT	Corner fitting	30		10		300	40		16		356		Yes	180					14x6x4	6	Yes	6	Yes	No	Alum.	Mach. center

APPENDIX I

medium-size lots, because different parts can be machined by changing a tape. Very large quantities of relatively simple parts are most economically produced on specialized equipment, either especially designed for the part or on equipment requiring lengthy setups, such as automatic bar machines.

The chief reason for the larger lot sizes shown in the NC shop and the part-programing section on page 61 is that this activity programed parts manually, which meant that larger lot sizes than normal were required to balance the excessive time required to prepare tapes and therefore justify the NC method.

Columns 4, 5, 7, and 8--estimated hours, conventional versus NC machines

The unit hours, in this instance, include the averaging of any setup time involved. As can be seen, most of the parts being machined conventionally at this activity would have been better suited for numerical control. One reason why conventional machines were used more was the heavy backlog (3 months) in the NC machine shop and an additional 1-month backlog in the part-programing section. It should be pointed out that most of the NC machines were operating on one shift.

Column 6--estimated part-programing time

The estimated hours shown in this column should reflect the time to program the sample parts when operating under a reasonably efficient part-programing system. This means computer-assisted part programing and ready access to the computer by a remote terminal or a dedicated on-site computer.

Although this activity programs parts manually now, it plans to have computer-assisted programing shortly by a remote terminal connection to a large general-purpose computer.

Column 9--Percent chance of repeat or similar orders

Since the same tape may be used for repeat orders of the same part, a bonus savings is realized on repeat orders because the part does not have to be reprogramed or checked out again at the machine tool site. Also, since computer programs are designed to take advantage of parts that have the same sired chip load,[1] may be added. By comparing the chip load with the material to be machined, the horsepower size and spindle ranges could be determined. Also, not all of the columns need to be filled in for all the sections. For example, there would be no need to compare the time to make a part conventionally and by numerical control if the part had already been selected for numerical control.

Since the data shown was obtained at an aircraft repair activity, some of the conclusions are peculiar to aircraft machining. For example, most of the parts are aluminum and involve profile milling.

EXPLANATION OF FORMAT AND ANALYSIS

Columns 1 and 2--part number and description

All parts should be clearly identified, and each different part should be considered separately. If a part, for example, has a left- and right-hand configuration, it should be considered as two distinct parts.

Column 3--lot size

This is probably one of the strongest factors in deciding for or against NC machines. If the quantity of parts in the lot is small (e.g., one to five pieces) and the work on the part is very simple, such as drilling a few holes or milling several straight cuts, the part is probably not a good numerical control candidate. If the part is simple and the quantity is relatively large (more than 20 pieces), it could be considered a reasonable numerical control candidate. If the part is complex and the quantity is small (even one piece), it should also be considered a reasonable numerical control candidate. As a general rule, the more complex a part, the lower the lot size required to make the part suitable for NC machines.

Unfortunately, the erroneous impression still exists that numerical control is best suited for large quantities. In fact, numerical control is geared especially for small- and

---

[1] Amount of material removed by the cutter.

Further calculations may be made to determine the productivity increase to be realized by using NC machines instead of conventional machines. The productivity ratio comparing NC machines with conventional machines may be calculated by dividing the conventional hours of workload by the comparable numerical control hours for any of the operations. The figures for milling operations follow.

Conventional					NC				
Hours	x	%			Hours	x	%		
44	x	100	=	44.00	21	x	100	=	21.00
50	x	90	=	45.00	40	x	90	=	36.00
24	x	70	=	16.80	21	x	70	=	14.70
16	x	100	=	16.00	10	x	100	=	10.00
(Calculations omitted)									
160	x	70	=	112.00	150	x	70	=	105.00
400	x	90	=	360.00	200	x	90	=	180.00
	Total hours			5,646.00		Total hours			1,485.90

$\frac{5,646.00}{1,485.90} = 3.80 =$ Productivity ratio in favor of NC machines. This means that NC machines can produce 3.8 times the output of conventional machines in the same time and that one NC milling machine can do the work of 3.8 conventional machines.

Column 12--size

After determining the most suitable type of NC machine required, the table size, or x and y travel of the machine (assuming a mill or machining center) should be determined on the basis of the part dimensions shown in column 12. These dimensions need not be exact; figures to the nearest inch are satisfactory.

APPENDIX I

general configuration, programing time for parts similar to those already programed can be a fraction of the time it took to program the original. The likelihood of a repeat or similar part therefore weighs heavily in the economic comparison between conventional and NC machines.

Column 10--recommend NC

The decision to make a part conventionally or by numerical control depends on the data in columns 3, 8, and 9. The decision should be made after a technical and economic evaluation and should not consider workloads or backlogs; instead, it should be assumed that conditions are satisfactory.

In the sample shown, 64 percent of the parts and 94 percent of the workload in the conventional shop and planning section were suitable for NC machines.

Column 11--percent operations

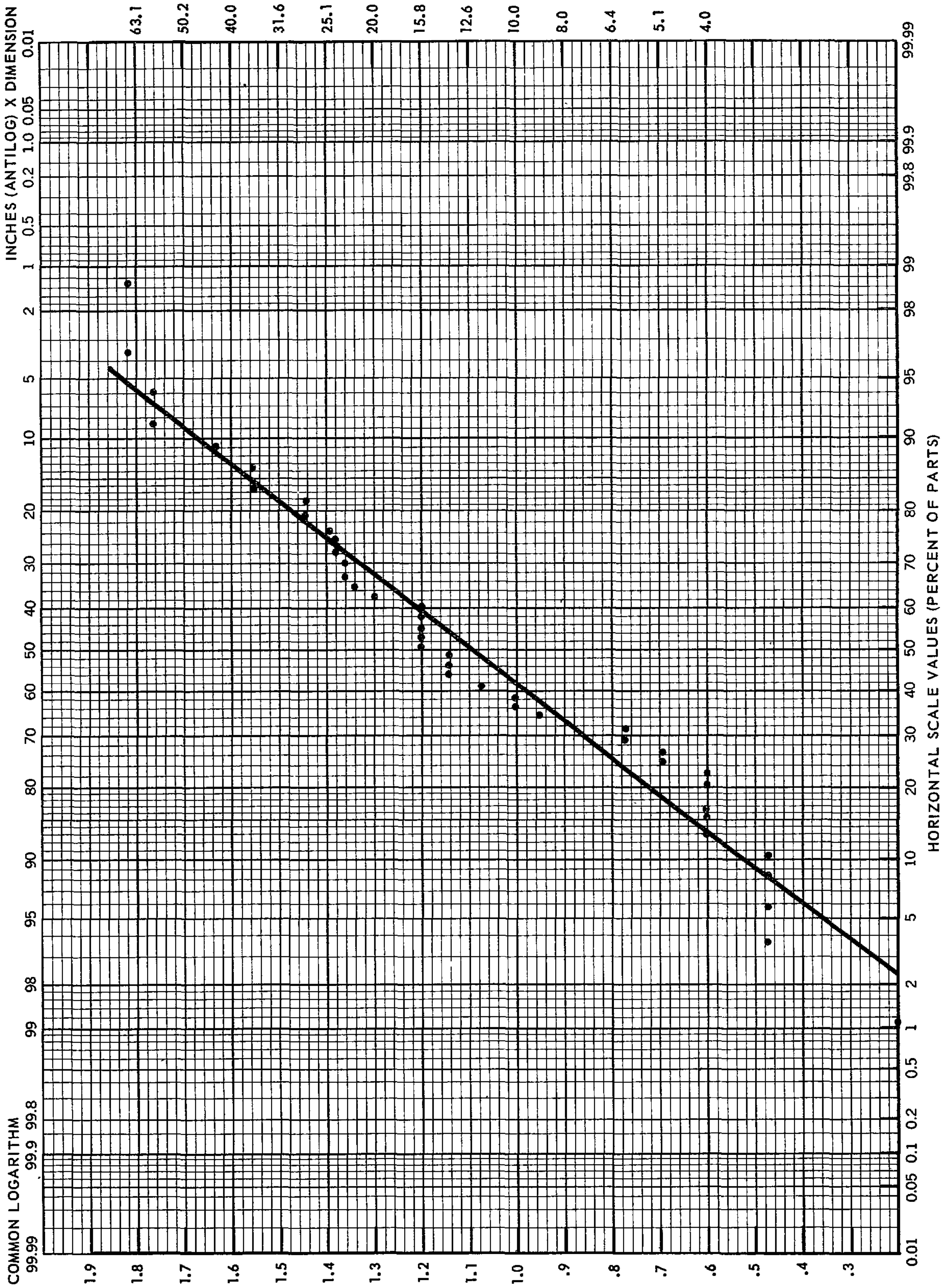
This column describes the breakdown of the types of machining operations; the breakdown may be approximate and can be determined by inspecting engineering drawings.

At this activity, milling operations accounted for 81 percent of the workload, drilling accounted for 5.5 percent, and turning accounted for 13.5 percent. These percentages are calculated by multiplying each of the percentages for any one type of operation in column 11 by the corresponding hours in column 8, adding these products, and then dividing the sum by the total number of hours. For example, the calculation for profile milling would be as follows:

Conventional hours	X	%		
44	x	100	=	44.00
50	x	90	=	45.00
24	x	70	=	16.80
16	x	100	=	16.00
(Calculations omitted)				
160	x	70	=	112.00
400	x	90	=	360.00
6,999				5,646.00

$\frac{5,646}{6,999}$ = 81% of the conventional hours involve milling.

APPENDIX I


INCHES (ANTILOG) X DIMENSION
63.1 50.2 40.0 31.6 25.1 20.0 15.8 12.6 10.0 8.0 6.4 5.1 4.0
COMMON LOGARITHM
1.9 1.8 1.7 1.6 1.5 1.4 1.3 1.2 1.1 1.0 .9 .8 .7 .6 .5 .4 .3
HORIZONTAL SCALE VALUES (PERCENT OF PARTS)
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01

The cost of an NC machine increases as its size increases. A machine having an x travel of approximately 50 inches and a y travel of approximately 30 inches may cost three to four times the cost of a machine having comparable features and an x travel of 30 inches and a y travel of 11 inches. A machine having an x travel of 144 inches and a y travel of 48 inches may cost 12 to 20 times more than a 30- by 11-inch machine. One reason for the geometric increase is that, as the size increases, practically everything else increases, including almost every portion of the frame, the drives, and the requirement for maintaining accuracies over longer ranges. Another reason is that the smaller sizes are more popular and are consequently produced in larger quantities at much lower costs.

The object in determining the proper size of a machine is to have the smallest machine which could do a reasonable percentage of the workload. If, for example, a 30- by 12-inch profile milling machine costing $35,000 could handle 85 percent of the workload but a 96- by 28-inch machine costing $200,000 would be needed to handle the remaining workload, obviously the $35,000 machine would make more sense. If a larger machine is necessary for a mandatory response requirement, only one large machine should be installed.

A statistical route known as a log normal distribution, or curve, is helpful in calculating the proper size of a machine. This curve approximates the distribution of the part sizes normally found in a machine shop. That is, most of the parts fall within a fairly narrow and low size range, while the balance has a much higher and generally much larger range. Using the example shown on page 61 and considering only milling and machining-center parts, the part sizes that constitute a large percentage of the workload may be calculated by a formula for the standard deviation of a log normal distribution. An easier and broader approach involves a graphical solution, as follows:

<u>Step 1</u>

Obtain a piece of probability scale graph paper as shown on page 67.

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X dimension	Common logarithm	Horizontal scale values (percent of parts)
1	.0000	1.19
3	.4771	3.57
3	.4771	5.95
3	.4771	8.33
3	.4771	10.71
4	.6021	13.09
4	.6021	15.47
4	.6021	17.85
4	.6021	20.23
4	.6021	22.61
5	.6990	24.99
5	.6990	27.37
6	.7782	29.75
6	.7782	32.13
9	.9542	34.51
10	1.0000	36.89
10	1.0000	39.27
12	1.0792	41.65
14	1.1461	44.03
14	1.1461	46.41
14	1.1461	48.79
16	1.2041	51.17
16	1.2041	53.55
16	1.2041	55.93
16	1.2041	58.31
16	1.2041	60.69
20	1.3010	63.07
22	1.3424	65.45
23	1.3617	67.83
23	1.3617	70.21
24	1.3802	72.59
24	1.3802	74.97
25	1.3979	77.35
28	1.4472	79.73
28	1.4472	82.11
37	1.5682	84.49
37	1.5682	86.87
43	1.6335	89.25
60	1.7782	91.63
60	1.7782	94.01
65	1.8129	96.39
65	1.8129	98.77

Step 2

List the dimensions for any one of the axes in ascending or descending order (in this case the x dimensions) in a column, as shown on page 69. Then note the common logarithm (base 10) beside each of the dimensions, also as shown on page 69.

Step 3

Divide the horizontal scale of the graph paper into equal increments depending on the number of figures listed in the x dimension column. For example, since there are 42 numbers, each increment would be 1/42 = 0.0238 or 2.38%. To plot at the midpoints of the increments, the plot points along the horizontal scale (% of parts) would start at $\frac{0.0238}{2}$ = 0.0119, or 1.19%; the next horizontal plot point would be 0.0119 + 0.0238 = 0.0357, or 3.57%; the next would be 0.0357 + 0.0238 = 0.0595, or 5.95%, etc. The horizontal scale values which correspond to the x dimensions, and common logarithm values, are shown on page 69.

Step 4

List the scale for the common logarithm column along the left-hand vertical axis of the graph paper. A corresponding machine tool dimension scale of antilogs may be noted along the right-hand vertical axis.

Step 5

Plot points for the horizontal scale values (percent of parts) versus the corresponding values in the log column. For example, the horizontal scale value for a point 36.89 percent would be plotted as a log value of 0.9542 shown on the left-hand vertical scale.

Step 6

Draw an "average" line through the points. This may be done visually.

needed work on four or more sides. The bulk of the contour milling is usually done on one or two sides of airframe parts. The decisions, therefore, that are shown in column 14 are based on the size of the part as well as the number of sides to be machined.

Of the 42 milling and machining-center parts shown on page 61, 8, or approximately 20 percent, were found suitable for a rotary table. However, three of the six NC machines at this activity had rotary tables. It should be pointed out, however, that these machines also had automatic tool changers, and the combination of an automatic tool changer and a rotary table is a fair bargain and usually go together. The question is whether an automatic-tool-changing machining center is justified at all.

<u>Column 15--different tools</u>

The number of different tools needed helps to indicate whether an automatic tool changer should be considered. The lot size should also be considered, since presetting tools would not be warranted for very small lots of relatively simple parts.

An automatic tool changer may add $20,000 to $50,000 to the cost of an NC machine. It may also reduce floor-to-floor machining time significantly (up to 40 percent) when compared with a manual tool-changing NC machine and should therefore be carefully considered.

<u>Column 17--recommend 4 or 5 axes</u>

A positive determination would depend on whether (1) a part had a continuously changing angular cut(s) involving two or more axes or there were cuts involving an angular attitude or (2) point-to-point operations requiring angular attitudes were required. Many airframe parts, which have changing angular cuts, can be machined far more readily with a multiaxis machine than with a machine restricted to x, y, and z motions. The part-programing and data processing costs are also often lower when a part can be programed for a multiaxis machine. However, the added axes are expensive and must be weighed in accordance with the anticipated multiaxis workload requirements.

Step 7

The horizontal scale represents the percentage of parts that fall within the dimensions as read on the right-hand vertical scale. The figures on the vertical left-hand scale must be converted back to inches by the antilog. For example:

--50 percent of the parts correspond to a log value (read on the left-hand vertical scale) of 1.08. The antilog of 1.08 = 12 inches. This means that 50 percent of the parts are 12 inches or less in size along the X dimension.

--75 percent of the parts correspond to a log value of 1.32.
The antilog of 1.32 = 21 inches.

--25 percent of the parts correspond to a log value of 0.78.
The antilog 0.78 = 6 inches.

--90 percent of the parts correspond to a log value of 1.66.
The antilog of 1.66 = 45.7 inches. This means that 90 percent of the parts are 45.7 inches or less in size along the X dimension.

As can be seen, the use of the graphical method offers an infinite range of percentage values which may correspond to maximum part dimensions. The y, or second longest, dimension may be calculated by the same graphical approach.

Column 13--sides to machine

The number of sides to machine on a part should indicate whether a rotary table or rotary head is needed. If a part is cubic and needs a relatively large number of operations on four or more sides, it usually is a reasonable candidate for a rotary table. Such parts include valve bodies, pump housings, and cylinder blocks. On the other hand, if a part needs work on four or more sides and is of a relatively long and large configuration, it is not likely to be a good candidate for a rotary table. For example, a 6- by 1- by one-half-foot airframe part would be a poor candidate even if it

APPENDIX II

APPENDIX II

ESTIMATED COST COMPARISON OF NUMERICAL
CONTROL VS. CONVENTIONAL MACHINING

RELEASE QUANTITY ________ ________ ________ ________ ________ ________

FIN. PARTS DATE ________ ________ ________ ________ ________ ________

	CONVENTIONAL (Hours)	NUMERICAL CONTROL (Hours)
MACHINING:		
a) Set-up		
b) Run		
c) Machine Efficiency (Percent)		
d) Factored Run Time X Total Quantity +		
e) Scrap & Rework ( ) Set Ups		
Total		
TOOLING:		
a) Process Planning		
b) Part Programing		
**c) Liaison & Tape Approval		
d) Tool Code		
e) Tool Design (Set Dwgs, Setup Sheets)		
f) Tool Fabrication & Tool Inspection		
g) Material		
Total		
INSPECTION:		
*a) Bench Cost		
b) Gages		
1 - Design		
2 - Fabrication		
Total		
PRODUCTION CONTROL:		
a) Lead Time		
b) Transportation, Dispatch & Service Personnel		
c) Lot Size		
d) Handling Cost & Damage		
Total		
TOTAL NUMBER OF PARTS TO BE FABRICATED — PRODUCTION HOURS		

BREAKDOWN OF CONTRACT CHARGES — N/C CONVERSION COST SAVINGS (HRS) ____________ N/C MACHINE ____________

JUSTIFICATION: ____

**N/C Programer and Machine Operator.
*Inspection time is a function of production run time based on the complexity of part, duplicate hole sizes and patterns.

Approved By ____________ Date ____________
Standards By ____________ Date ____________

The sample shown had only 1 part of 42 that could have benefitted from a multiaxis machine because the airplanes being serviced at the facility were large cargo types, in which the basic contour lines are mostly straight.

Column 18--material

The answers to this column would assist in determining the speed selection and range of the spindle motor and the horsepower required. Such factors as adaptive control features might also be considered if hard materials, such as titanium, were used.

Column 19--recommend type of machine

This column, which notes the general type of machine felt to be best suited for each part in the sample, offers a guide to the most suitable mix of machines. Further analysis would be required to arrive at a more positive determination.

At this activity, 14 of the 42 parts appeared to be best suited for machining centers, but not necessarily with automatic tool changers. Twenty-eight of the parts would be best suited for relatively small, inexpensive profile mills. Yet only one-third of the activity's NC machines were profile mills, and these were relatively large.

GAO QUESTIONNAIRE SENT TO ACTIVITIES

WITH GOVERNMENT-OWNED NC EQUIPMENT

Name of Organization ______________________________

Name of person(s) to contact about the questionnaire _______

____

Phone ______________________________________

Address ____________________________________

1. List your Government-owned NC equipment by manufacturer, model, type, and control unit. (Example: Sundstrand OM3 5-axis machining center, General Electric Mark Century)

Manufacturer	Model	Type machine	Manufacturer and model of control unit

2. Do you plan to buy additional NC machines in the next 3 years? ____________________

If so please list the quantity by type of machine you plan to buy (Example: 4 horizontal boring mills) and the approximate cost of the machine.

Quantity	Type	Cost per machine

3. Approximately how many man-hours each month are spent in part programing for NC?

____

a. What percentage of your programing is point-to-point?

____

NUMERICAL CONTROL MANUFACTURING ANALYSIS

PART NUMBER ____________ REVISION ____________ E.O. ____________

PART NAME ____________ TAPE NUMBER ____________

MATERIAL ____________ HEAT TREAT ____________ FINISH RQMTS ____________

FIXTURE DESCRIPTION ____________

____

	HOURS PER FUNCTION	TOTAL HOURS	CURRENT RATE/HR	COST PER FUNCTION	TOTAL COST
PROGRAMMING.................					
DATA PREPARATION............					
(Key Punch, Verity & List) .					
COMPUTING					
TAPE PREPARATION					
MACHINE SET UP..............					
MACHINING..................					
TOOL DESIGN					
TOOL FABRICATION					
GRAND TOTALS					

COST PER PART WHEN TOTAL QUANTITY IS ____________

1 PART ____________ *

20 PARTS ____________ *

60 PARTS ____________ *

100 PARTS ____________ *

250 PARTS ____________ *

*Figures are based on one setup.

REMARKS ____________

____

____

SPECIAL TOOLS	CUTTER SIZE	TEETH OR FLUTES	SPINDLE SPEED	FEED RATE
______	______	______	______	______
______	______	______	______	______

PREPARED BY ____________ NUMERICAL CONTROL - MANUFACTURING ENGINEERING

APPENDIX II

8. Please describe the system at your activity for reporting the utilization of the NC machines. Include in your description the basis for your statistics (i.e., man-hours, power meters, etc.), the way the data is entered into your system and compiled, the types of reports generated, the categories used in reports, what data is used to make up the categories, and the number of shifts on which the data is based.

9. Using the data from the reporting system described above, list the 1973 production utilization for each NC machine.

10. Is getting spare parts quickly for NC machines a problem?

____

Summarize the procedures and describe the time it takes to get a part after a request is made from the shop.

11. Describe how you decide which jobs will be done on NC. (Include criteria, personnel responsible, and procedures to insure that jobs are put on NC when they should be.)

12. Describe your system for determining when you need to buy NC.

13. Are there NC machines which you need but cannot buy because you do not have enough workload? _______________

If so, name the machines and describe briefly the situation, including approximate number of hours per shift you could use each machine.

14. Describe your system, if any, for exchanging NC tapes or NC packages with other activities and/or contractors. Include in your discussion any available statistics on number of tapes or packages exchanged, with whom, and resulting savings.

15. Do you usually purchase the manufacturer's spare parts kit for the machine tool and control unit for your NC machines?_____________

b. What percentage of the point-to-point programing is done manually?

____

c. What percentage of the contour programing is done manually?

____

4. Describe your arrangements for NC computer assistance, such as a minicomputer in your production department, remote computer terminal in your production or programing department, computer in ADP department to which data is hand-carried, or commercial computer to which data is hand-carried or mailed. Include manufacturer names and models for computers. If several types of arrangements are used, indicate the relative use of each arrangement.

5. For each arrangement noted above, what is the average time it takes to get your program back after submitting it for computer processing?

6. List the languages you use to program your NC, indicating the percentage each is used.

Language	Percentage used

7. How many postprocessors do you have? ______________

For each postprocessor, give the following information.

a. the machine tool manufacturer and model number

b. manufacturer and model of control unit for the machine tool

c. computer make and model

d. language in which postprocessor is written

e. cost of the postprocessor

f. where you obtained the postprocessor

APPENDIX III

For each spare parts kit you have, provide the following data.

Spare kit no.	Cost	NC machine it is for

16. If you do not usually buy spare parts kits, please describe below the reasons for not doing so and the system you use to decide which spare parts to buy.

17. List the approximate total value of spare parts you have on hand for all your NC machines, including control units.

18. If you have a Kearney and Trecker Milwaukee Matic II, Sundstrand OM3, Pratt and Whitney 4-axis horizontal machining center, model 3050, list by machine the spare parts you stock for the machine tools and control units.

Machine	Name of part	Part no.	Number of parts	Cost per part

19. Describe your system for determining whether your NC equipment is providing the savings you predicted on your justification.

APPENDIX IV

COMPUTATIONS USED FOR NC COST-SAVINGS MODEL
BY JAMES J. CHILDS

COSTS	One-half shift (1,000 hours)				One shift (2,000 hours)				Two shifts (4,000 hours)				Three shifts (6,000 hours)			
	1 Machine	3 Machines	6 Machines	12 Machines	1 Machine	3 Machines	6 Machines	12 Machines	1 Machine	3 Machines	6 Machines	12 Machines	1 Machine	3 Machines	6 Machines	12 Machines
Machine $204,000 (Assume 10-year life) Shipping and Installation (15%) 30,600 $234,600 $234,600 x No. of machines / 10	$23,460	$70,380	$140,760	$281,520	$23,460	$70,380	$140,760	$281,520	$23,460	$70,380	$140,760	$281,520	$23,460	$70,380	$140,760	$281,520
Tooling: Assume automatic tool changer = $20,000 per machine (10-yr. life) $20,000 x No. of automatic tool changers / 10 Assume: Automatic tool changers 1 machine has 1 3 machines have 2 6 machines have 4 12 machines have 6	2,000	4,000	8,000	12,000	2,000	4,000	8,000	12,000	2,000	4,000	8,000	12,000	2,000	4,000	8,000	12,000
Tool Storage and setup equipment: $10,000 / 10-yr. life (1,3,6 machines) $15,000 / 10-yr. life (12 machines)	1,000	1,000	1,000	1,500	1,000	1,000	1,000	1,500	1,000	1,000	1,000	1,500	1,000	1,000	1,000	1,500
Part-programing off-site training and travel (5-yr. turnover): $2,000 per course x No. of men / 5	400 (1 man)	400 (1 man)	800 (2 men)	1,200 (3 men)	400 (1 man)	400 (1 man)	800 (2 men)	1,600 (4 men)	400 (1 man)	800 (2 men)	1,600 (4 men)	3,200 (8 men)	800 (2 men)	1,200 (3 men)	2,400 (6 men)	4,800 (12 men)
Part-programing services: $8 an hr. + 32.8% fringe benefits = $10.62 $10.62 x No. of machines x hrs. x No. of men (Consider 2,000 man-hours/yr./man.)	7,965 (3/8 man)	15,930 (3/4 man)	31,860 (1-1/2 men)	63,720 (3 men)	10,620 (1/2 man)	21,240 (1 man)	42,480 (2 men)	84,960 (4 men)	21,240 (1 man)	42,480 (2 men)	84,960 (4 men)	169,920 (8 men)	31,860 (1-1/2 men)	63,720 (3 men)	127,440 (6 men)	254,880 (12 men)
Data Processing: Consider dedicated minicomputer with UNIAPT $65,000 Postprocessor 3,500 (7 yr. life) Updates 5,000 $73,500 $73,500 / 7 (1 and 3 machines) $65,000 4 postprocessors 14,000 (6 machines) Updates 10,000 $85,500 / 7 $65,000 6 postprocessors 21,000 (12 machines) Updates 12,000 $98,000 / 7 [a]Variation due to postprocessors	10,500	10,500	12,210[a]	14,000[a]	10,500	10,500	12,210	14,000	10,500	10,500	12,210	12,210	10,500	10,500	12,210	14,000
Maintenance: $10.62/hr. (assumed same as programers) $10.62 x 2,000 x No. of men	7,965 (3/8 man)	15,930 (3/4 man)	31,860 (1-1/2 men)	42,480 (2 men)	10,620 (1/2 man)	21,240 (1 man)	42,480 (2 men)	63,720 (3 men)	21,240 (1 man)	31,860 (1-1/2 men)	63,720 (3 men)	127,440 (6 men)	42,480 (2 men)	63,720 (3 men)	95,580 (4-1/2 men)	191,160 (9 men)
Maintenance training (offsite expenses and travel): $2,000 x No. of men / 5 (5 yr. turnover)	400 (1 man)	400 (1 man)	800 (2 men)	800 (2 men)	400 (1 man)	400 (1 man)	800 (2 men)	1,200 (3 men)	400 (1 man)	800 (2 men)	1,200 (3 men)	2,400 (6 men)	800 (2 men)	1,200 (3 men)	2,000 (5 men)	3,600 (9 men)
Total	$53,690	$118,540	$227,290	$417,220	$59,000	$129,160	$248,530	$460,500	$80,240	$161,820	$313,450	$610,190	$112,900	$215,720	$389,390	$763,460
GROSS SAVINGS																
Machinists' salaries: Assume 3:1 productivity ratio Operators' cost $7.40 an hour, including fringe benefits Save 2 operators per year per shift ($7.40 x 2 x No. hours x machines)	$14,800	$44,400	$88,800	$177,600	$29,600	$88,800	$177,600	$355,200	$59,200	$177,600	$355,200	$710,400	$88,800	$266,400	$532,800	$1,065,600
Tooling: $5,000 x No. of machines x No. of shifts over or under 1	2,500	7,500	15,000	30,000	5,000	15,000	30,000	60,000	10,000	30,000	60,000	120,000	15,000	45,000	90,000	180,000
Scrap: Same as for tooling	2,500	7,500	15,000	30,000	5,000	15,000	30,000	60,000	10,000	30,000	60,000	120,000	15,000	45,000	90,000	180,000
Total	$19,800	$59,400	$118,800	$237,600	$39,600	$118,800	$237,600	$475,200	$79,200	$237,600	$475,200	$950,400	$118,800	$356,400	$712,800	$1,425,600

c. Utilization;

d. Preventive maintenance and spare parts acquisition;

e. Inventory reporting; and

f. Planning for standardization of NC hardware/software.

The Tri-Service NC Committee will continue in its efforts to improve DoD's management of NC. The results of your questionnaire have been most helpful in identifying areas in need of emphasis.

With regard to your recommendation on the need for additional guidance on sizing of industrial facilities for mobilization in the event of an emergency, we believe that the current guidance is adequate. Our current Industrial Preparedness Production Planning Directives, Instructions and Manual and the implementing regulations of the Services are very comprehensive. Mobilization planning is based upon specific production requirements/rates for various end items as dictated by the various scenarios of potential conflicts. These rates are used to determine the production equipment needed to support mobilization, keeping in mind the make-or-buy situation for the items. When the requirements for all the items assigned to a specific activity are totaled, they provide definitive guidance for the mobilization capacity needed by that activity.

With reference to your recommendation concerning our procedures for soliciting bids for machined parts from private machine shops, we believe that the existing procedures are adequate. The Armed Services Procurement Regulations (ASPR) are very comprehensive on all aspects of procurement of goods and services from private industry. We recognize that it is possible to identify isolated examples where it appears, on the surface, that individual items have been made in-house at a higher cost than if they had been procured from industry. However, the question of make-or-buy of an individual item cannot be viewed as an isolated case. The decision on make-or-buy of any item at a specific point in time must be made from the perspective of the total environment at that particular moment. We believe our current guidance is adequate and that further action is not warranted at this time.

Your recommendation concerning arrangements for using other activities' unused capacities before requesting additional in-house machining capacities has merit and we have made every attempt to achieve that goal. We have established policies and procedures for interservice, interdepartmental and interagency support and they are being used in the broad context of the total manufacturing capacity within DoD.

It is our understanding that your questionnaire requested data only on work exchange between NC activities. It must be recognized that transfer of work between NC activities may be inhibited by the amount of effort required

ASSISTANT SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

INSTALLATIONS AND LOGISTICS

14 FEB 1975

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

Dear Mr. Shafer:

Reference is made to an 18 December 1974 conversation between you and Mr. Clifford Falkenau, Deputy Comptroller for Audit Reports, wherein it was agreed that a final response to your draft report on "Opportunities for Increasing Productivity Through Numerically Controlled Equipment" (OSD Case #3954) would be provided subsequent to review of all agency comments. Our comments are as follows:

The recommendations of your draft report fall into four areas; (a) management of numerically controlled machine tool resources, (b) instructions on sizing manufacturing capacity for emergency mobilization, (c) procedures for soliciting bids for machined parts from industry, and (d) arrangements for work exchange between installations before adding additional in-house capacity. Our reply will address each area separately.

In our earlier response to your previous report, "Progress and Problems with Numerically Controlled Machine Tools", we agreed that DoD could do more to improve the management of its NC resources. As a result, we established the Tri-Service NC Management Committee which is looking at resolving the problems you identified in your first report and those additional areas outlined in the current report.

The group has prepared a Draft DoD Instruction 4215.xx, "Management of Numerically Controlled Industrial Plant Equipment", which, when implemented, will be a major step toward improving the management of our NC resources. The document is currently being edited and will soon be processed through our normal DoDI implementation channels. In its current form it addresses the following major areas:

a. Planning (including personnel and computer support for peacetime and mobilization workloads, and also work mix studies to improve identification of types of NC machines required);

b. Economic justification and follow-up;

UNITED STATES OF AMERICA
GENERAL SERVICES ADMINISTRATION
WASHINGTON, DC 20405

B-140389

FEB 11 1975

Honorable Elmer B. Staats
Comptroller General of
the United States
General Accounting Office
Washington, DC 20548

Dear Mr. Staats:

Thank you for the opportunity to review and comment on your draft report, "Opportunities for Increasing Productivity Through Numerically Controlled Equipment," November 26, 1974.

Starting with page 9, the narrative discusses the availability of parts from original manufacturers at lower costs. From the examples cited, it appears that the major criticism relates to the fact that the comparative costs of leaving parts made in-house versus out-house were not usually considered. We agree with this observation in recognition of the importance of economical practices. We would suggest, however, that while costs should be given adequate emphasis, the other factors noted in OMB Circular A-76 (pages 7 and 8 of the report) which cites the circumstances permitting in-house operations, should also receive appropriate attention.

We would agree that it may be desirable for the Secretary of Defense to direct "that work-mix studies be made to achieve a better match of machines and work and to identify opportunities for cost-effective investments," (page 29). Your previous study (B-140389) indicates that most Department of Defense agencies do not have properly trained staff to conduct work-mix studies and perform conventional versus numerically controlled equipment trade-off studies. This is an important point and worth reiteration in Chapter 3 of your final report.

Chapter 4 of your report addresses, in part, the need for standardizing numerically controlled languages, equipment, data packages, reporting systems, etc. While we agree with the need for standardizing numerically controlled elements as much as possible, we wish to point out that the high degree of fragmentation of the industry standardization practices relative to such elements, inhibits the Government's ability to standardize.

GAO note: Page number references in this appendix may not correspond to the pages of this report.

to reprogram the receiving activity's NC equipment. The routine exchange of NC programming data is not yet a technical reality. A lack of standardization of hardware and software has precluded private industry and/or government from achieving this goal. Our Tri-Service NC Committee is looking at this problem and with the implementation of their new DoDI we hope to make some inroads toward the eventual realization of this concept.

Sincerely,

John J. Bennett
Principal Deputy Assistant Secretary of Defense
(Installations and Logistics)

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

JAN 28 1975

Mr. Henry Eschwege, Director
Resources and Economic Development Division
U. S. General Accounting Office
Washington, D. C. 20548

Dear Mr. Eschwege:

This is in response to your November 26, 1974, letter requesting any suggestions on the draft report entitled "Opportunities for Increasing Productivity Through Numerically Controlled Equipment." Enclosed are comments prepared by the Director, Division of Procurement, who has responsibility in the area covered by the report.

If we may be of further help, please contact us.

Sincerely,

R. J. Griffin, Jr.
Acting Deputy Director
Office of Audit and Inspection

Enclosure:
As stated

Finally, we disagree with two points discussed in paragraph 2, page 24. First, tapping and boring capabilities of machining centers are standard and not "significant" or "overly elaborate" features as indicated in your report. Secondly, the parts examined by GAO had no requirements for automatic tool changers or rotating table; however, this does not mean that past or future workloads do not have these requirements. Furthermore, rotary tables and automatic tool changers are extremely rapid payback investments.

In summary, we commend GAO for making such a timely, in-depth review of ways to increase productivity through numerically controlled equipment.

Sincerely,

Dwight Ink

Dwight A. Ink
Deputy Administrator

Also, it should be pointed out that segments of Government, private enterprise, learning institutions and publishing houses have contributed in the development of these systems. Unfortunately, the work has not gone far enough, nor has the endeavor had adequate administrative support or funding.

Finally, we interpret the GAO report to suggest that now is the time to integrate industrial plant equipment management within Government and to strive for standardization of procedures and industry cooperation. We are in accord with such an endeavor. Basic in this respect are improved communications, refinement of productivity measurement techniques and a systematic approach to advancing related technologies. Progress in these areas will promote cross-servicing, reinforce make-or-buy decisions and provide the best management information obtainable on:

1. Defense preparedness and mobilization planning;
2. Budgeting and financial control;
3. Replacement and modernization guidance;
4. Inventory and production control; and
5. Equipment procurement, utilization, maintenance and disposal.

Comments in Re:

GAO DRAFT REPORT TO THE CONGRESS ENTITLED, "OPPORTUNITIES FOR INCREASING PRODUCTIVITY THROUGH NUMERICALLY CONTROLLED EQUIPMENT, DEPARTMENT OF DEFENSE"

Generally, we conclude that the timing and substance of the GAO survey was fitting and appropriate and that the conclusions and recommendations in the report are constructive.

It seems, however, that too little consideration was given to mission and workload differences of Government installations when compared to industrial installations, especially from the ERDA viewpoint. For example, a sizeable portion of the ERDA-owned, numerically controlled (N/C) equipment is necessarily of unique design or put to use in a way that does not permit make-or-buy options, prohibits work-mix or restricts cross-servicing, even within plant. Nevertheless, the problems encountered and the opportunities for increasing productivity as discussed in the report are applicable to the ERDA. We recognize a number of potentials for improved efficiency and management effectiveness; the GAO data does add insight in developing those potentials. We, too, have technical task groups functioning in specific areas of industrial plant equipment management, including an N/C group. In this connection, broad distribution of the GAO report and the establishment of information exchange between the DoD central group and its counterparts elsewhere in Government seems advisable.

Substantial gains in management effectiveness can be realized through greater standardization, improved maintenance management and especially the advancement of productivity measurement techniques.

In summary, most problem areas, as well as the opportunities for increasing productivity as presented in the report, are directly related to the need for a meaningful, quantitative method of determining productivity for any given piece of industrial plant equipment. Appendixes I, II and IV are steps in that direction, but they do not produce the level of confidence needed in the true sense, nor is there an established system that does fully meet the need. However, some work in this direction has been done which is worthy of mention. Since the introduction of N/C equipment, various performance capability and productivity rating systems have evolved. Examples are as follows:

1. Productive Criteria Quotients (PCQ) system.
2. Form DD 1106, Machine Tool Replacement Analysis, which incorporates the Productivity Increase Ratio (PIR).
3. Machinery and Allied Products Institute (MAPI) formula.
4. Productivity Index factored ratings.

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

	Tenure of office From	To
DEPARTMENT OF DEFENSE		
SECRETARY OF DEFENSE:		
James R. Schlesinger	July 1973	Present
William P. Clements, Jr., (acting)	Apr. 1973	July 1973
Elliot L. Richardson	Jan. 1973	Apr. 1973
Melvin R. Laird	Jan. 1969	Jan. 1973
DEPUTY SECRETARY OF DEFENSE:		
William P. Clements, Jr.	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 Callaway	May 1973	Present
Robert F. Froehlke	July 1971	May 1973
Stanley R. Resor	July 1965	June 1971

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

JAN 9 1975

REPLY TO
ATTN OF: D

Mr. Richard W. Gutmann, Director
Procurement and Systems Acquisition Division
United States General Accounting Office
Washington, D. C. 20548

Dear Mr. Gutmann:

The draft report on the opportunities for increasing productivity through numerically controlled equipment, forwarded by your letter of November 26, 1974, has been reviewed pursuant to your request.

Although our inventory of numerically controlled equipment is small and essentially committed to low density, complex work, the findings of the report for increasing productivity through the use of this equipment identified areas in which better planning and machine utilization would be beneficial. Please be assured that the National Aeronautics and Space Administration will participate fully with the Secretary of Defense in the pursuit of an effective program for advancing the field of numerically controlled equipment.

Sincerely yours,

Bernard Moritz
Associate Administrator for
Organization and Management

DEPARTMENT OF THE AIR FORCE

	Tenure of office From		Tenure of office To	
SECRETARY OF THE AIR FORCE:				
Dr. John L. McLucas	July	1973	Present	
Dr. Robert C. Seamans, Jr.	Jan.	1969	July	1973
ASSISTANT SECRETARY OF THE AIR FORCE (INSTALLATIONS AND LOGISTICS):				
Frank A. Shrontz	Oct.	1973	Present	
Richard J. Keegan (acting)	Aug.	1973	Sept.	1973
Lewis E. Turner (acting)	Jan.	1973	Aug.	1973
Philip N. Whittaker	May	1969	Jan.	1973

	Tenure of office From		To	
DEPARTMENT OF THE ARMY (continued)				
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Kenneth F. Belieu	Aug.	1971	June	1973
Thaddeus R. Beal	Mar.	1969	July	1971
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Edwin Griener (acting)	May	1974	Aug.	1974
Vincent P. Huggard (acting)	Apr.	1973	Apr.	1974
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
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Vacant	June	1974	Aug.	1974
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