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FOREWORD

A study of three APT processors on the IBM System 360 is summarized in this document. Systems analyzed included APT/70 (J40), proprietary to Symbolic Control, Inc.; NC/360 4M2 distributed by IBM; and APT IV 4X3, provided by the APT Long-Range Program (ALRP). These systems are analyzed with respect to absolute and comparative reliability, processing efficiency (speed), cost (speed and hardware resources) and compatibility. The analysis was performed on an IBM System 360/67 at NASA/Ames Research Center under OS/360 (MFT). One hundred and fifty test and production parts, with a wide range of size and complexity, were processed against each of the APT systems. Statistical data gathered includes success rate (APT system failure), processing times, and costs. Significant differences in both processing efficiency, cost and reliability are identified and documented.

This study was funded by NASA/Ames Research Center under Contract No. NAS2-6313, Task I, APT Comparative Study. The cognizant technical monitor is Mr. J. A. Jeske, Ames Mathematician. Messrs. Aranda, Brandin, Collins and Liveright of the Symbolic Control Staff contributed to this study and report. The support of the Ames Staff was invaluable and is gratefully acknowledged.

Respectfully submitted,

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Vice President

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APT COMPARATIVE STUDY

This Document is submitted as a final report for Task I, APT Comparative Study, contract No. NAS2-6313, IBM 360 Numerical Control Software Support.

1. INTRODUCTION

This report contains a summary of the results obtained from a comparative analysis of several APT processors on the IBM System 360. The pertinent computer output listings are attached to, and made part of, this report. Also attached is a 150-page document entitled "Itemized Part Program Results" which delineates the testing results for each part program processed in the study.

1.1 Purpose of Study

The primary purpose of the study was to determine the most cost-effective APT processor for NASA/Ames Research Center. In addition to being cost-effective, the APT System was also required to meet the following criteria:

- 5-Axis Capability
- Process Large APT Surfaces (e.g. RLDSRFs)
- Extendable to Sculptured Surfaces
- Extendable to TSS/360
- Extendable to Accepting External Datasets as Part Program Source Data
- Require Minimal Maintenance

The study included the analysis of many parameters including efficiency, reliability, and use of computing resources. Of course, heavy testing was necessary to obtain meaningful results. 150 part programs were used in the study.

1.2 Current 360 APT Implementations

At present there exist four APT systems for processing 5-axis APT part programs on the IBM System 360. Those selected for testing were:

. APT/70 - Supplied by Symbolic Control
. NC/360 - Supplied by IBM
. APT IV - Supplied by APT Long-Range Program (ALRP).

The fourth alternative -- APT III V9 Emulator -- was rejected due to nonstandard IBM 360 hardware requirements.

Each of the tested processors have different implementation characteristics, computer dependence and independence, processing efficiency, vendor support, documentation, core requirements, etc. They are analyzed in considerable detail below.

1.3 Organization of Report

This report is organized in five key sections. Section 1 contains the necessary introductory material. Section 2 discusses the System specifications and ground rules surrounding the study. Section 3 presents the results in tabulated form. Section 4 contains an analysis of performance, reliability and other important parameters. Section 5 is brief and contains some final comments.

2. GENERAL CONDITIONS

This section of the report is concerned with the various systems analyzed, their general characteristics and specifications and the various ground rules surrounding the study.

2.1 Systems Studied

Three systems were selected for analysis by the Ames monitor. These are:

1. APT/70 (J40.T5) - Released by Symbolic Control, January 25, 1971.
2. APT IV (4X3) - Released by ALRP, January, 1971.
3. NC/360 (4M2) - Released by IBM, October, 1970.

Each system was implemented on the Ames computer exactly as released by the distributor. Updates to the systems, made available after the study began, were not implemented. This restriction was placed on the study to maintain as objective a test as possible.*

2.1.1 APT/70

APT/70 is a new APT Processor developed by Symbolic Control, Inc. It is based upon an extended re-design of both APT III and APT IV. The entire processor was rewritten with the exception of ARELEM. The ARELEM included in APT/70 is derived from APT III V9 -- the most reliable APT system ever released by ALRP.

APT/70 was designed in early 1969 and implementation work began in earnest in the Fall of 1969. The first version of APT/70 was released to field test in September, 1970. APT/70 was released for production use in January, 1971. This release was used in the study.

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*It should be noted that IBM has since released 43 updates for NC/360 (4M2) while the present version of APT/70 distributed by Symbolic Control processes over 20 of the 32 part programs which failed to process correctly in this study.

APT/70 is a full 5-axis APT Processor capable of processing standard APT part programs, APT/70 also has superset language features which make it compatible with APT IV, UCC APT III, UNIVAC APT III, ADAPT, etc.

2.1.2 NC/360

NC/360 is supplied by IBM. Based upon APT III, Version 7, it has been reconstituted to process on the IBM System 360. While NC/360 has several APT superset features not defined in a standard APT system, it is basically compatible with existing APT III systems. (It is currently used by approximately 50% of the ALRP membership). Version 4 Modification 2 of NC/360 is the most recent release available from IBM, and was used in the study. It should be noted that NC/360 is a production system and has been in the field approximately five years.

2.1.3 APT IV

APT IV is a new 5-axis APT system released by the APT Long Range Program. It was designed in 1964. The first version of APT IV was implemented on the IBM 7094 in 1967. The first 360 version was released on an experimental basis in 1968. The 4X3 system, released January, 1971 was used in the study.

Because APT IV is an experimental system, certain production tailoring usually performed by user organizations has not been completed. Also, the number of production parts processed by the system is small, resulting in severe limitations in testing since many production parts use features not yet installed in APT IV.

It should be noted that APT IV has been in development for seven years.

2.1.4 Variations

Each of the three systems studied used a different core/overlay configuration. It was the intent of the study to use the same core resources.. However, attempts to process APT IV in its published 248K byte region failed on NASA's MFT Operating System. Therefore, APT IV was allocated a larger partition. Table 1. lists the configurations studied.

TABLE 1.
Core/Overlay Configurations

System	Partition Size	Core Used	Overlays
APT/70	300K	235K	3
NC/360	300K	256K	5
APT IV	500K	350K (est.)	5

Some comments about Table 1. are pertinent at this point:

1. APT/70 and NC/360 were processed under MFT with a 300K partition which is the most appropriate standard partition size at Ames. Actual core used would be a significant parameter under MVT and would have an effect on cost in most accounting algorithms.

2. Both APT/70 and NC/360 could process in a smaller region size (see below). However, the study attempted to use programs of the same size in studying performance.

3. Actual core used by APT IV is necessarily estimated since the Ames operating system does not print the actual core used.

4. In order to show the effect of smaller core and other parameters which are ignored in the Ames Accounting System, several other runs were performed on another computer -- Optimum Systems, Inc. IBM 360/65, Palo Alto. These variations are listed in Table 2.

TABLE 2.

OSI Core/Overlay Configurations

System	Core Used	Overlays
APT/70 (J71.F3)	160K	4
APT/70 (J71.T5)	208K	3
NC/360 (4M2)	224K	5

2.1.5 Programming Languages

Computer dependence (and independence) is frequently measured by determining the percentage of Fortran and Assembly Language code in a program. Table 3. compares the three systems from this point of view. The data was generated by a clerical review of the source listings and is necessarily approximate. It should be noted that this type of reasoning is suspect and should not be viewed as conclusive evidence of computer dependence or independence.

TABLE 3.

Fortran/Assembly Language

System	Approx. No. of Statements	% Fortran	% Assembly	No. Fortran Routines	No. Assembly Routines
APT/70	48K	76	24	126	44
NC/360	114K	87	13	240	63
APT IV	84K	90	10	331	29

Note that the last entry in Table 3., Number of Assembly Language Routines, is a gross figure and does not accurately reflect consolidation and the effects of multiple entry points.

2.2 Parameters of Interest

A variety of parameters were studied in determing cost effectiveness. The two principle parameters, efficiency and reliability are discussed below.

2.2.1 Efficiency

Efficiency can be measured in several ways. Obvious considerations are:

- CPU Time
- I/O Time
- Turnaround Time
- Cost

Within the Ames accounting scheme, the only efficiency measurement provided is CPU time. Hence, the study is primarily based upon that measurement.

I/O time is another important parameter and the OSI timing runs were made to get some data on this cost element. Although this cost varies with core usage, some interesting results are presented in Section 3.

Unfortunately, the Ames MFT operating system, with fixed partition sizes, made it impossible to obtain meaningful turnaround time data. In general, however, turnaround time varies directly with core used since most scheduling algorithms penalize the larger programs.

Cost, at Ames is directly related to CPU time. The OSI runs present rather startling cost results when I/O times and core utilization are included in the cost of the run.

2.2.2 Reliability

Reliability, in an APT system, is usually a relative measurement. The complexity of APT processors is greater than that found in most Fortran compilers, and, as such, all APT processors have a certain amount of inconsistencies. Historically, APT programs have been tested by processing a given input stream of part programs and comparing both absolute and relative performance with other APT systems. This has also been done in this study with the following guidelines:

- Most part programs, although written for NC/360, were not modified to process under any of the systems. They were run "as is".
- Each failure was carefully analyzed to determine if it was a:
    - Part programming error
    - Minor anomaly (see below)
    - Major error in system
- The more serious cause of failure was arbitrarily selected as the specific cause of a failure in runs which had more than one problem.
- Consistency with documentation was carefully checked in determining whether an error could actually be specified as a part programming error. Thus, each system actually determined different numbers of part programming errors, due to their slightly different part programming specifications.

Part program results were distributed into several major and minor categories. These were:

1. Successful Runs
    - Runs which processed correctly
    - Runs which diagnosed part program errors correctly

2. Minor Anomalies

   . Copy/Edit malfunctions (considered minor errors which occur only in output and are easily repaired, and do not affect critical APT processing.
   . Missing postprocessor words (this category would be non-existent if the APT processors had been tuned to Ames' requirements).
   . Missing language features (similar in complexity to missing postprocessor words).
   . Missing geometric definitions (again, this category would be eliminated when tailoring an APT system to Ames production needs).
   . Synonym statement overflow (the APT IV processors have a small limit on the number of arguments in a SYN statement and it seemed technically unfair to categorize part program failures in this area as system bugs.

3. Major Errors

   . Actual Translator (Section 1.) errors
   . Actual ARELEM (execution) failures
   . Actual Geometric Calculation errors
   . System failures (e.g., LOOPS, ABENDS, Addressing Errors, etc.)

Study results are presented in these categories in Section 3.

2.3 Types and Sources of Data

Symbolic Control collected 150 part programs for use in the study.* These parts were drawn from many sources and cover a wide spectrum of applications.

2.3.1 Sources

Data was collected from seventeen (17) sources and is summarized in Table 4.

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*31 parts were selected for analysis by NASA/Ames. These parts required a considerable number of part program changes to be processed on all 3 systems. The analysis was performed by Mr. E. Pucine of the NASA staff and is reported separately.

TABLE 4.

Sources of Part Programs

	Organization	Number of Programs
1.	APT Long-Range Program (Standard Tests)	1
2.	Boeing Computing Services Company	11
3.	Bunker Ramo Company	6
4.	Eastman Kodak Company	11
5.	Fairchild Hiller (Republic Aircraft)	4
6.	General Electric Company (Mr. Ken Kreh)	2
7.	General Motors (Detroit Diesel)	1
8.	Lockheed Missile & Space Company	8
9.	McDonnell Automation Company	3
10.	McDonnell-Douglas Corporation (Long Beach)	15
11.	NASA/Ames Research	1
12.	North American Rockwell (Rocketdyne Division)	7
13.	North American Rockwell (Space Division)	2
14.	Northrop Aviation	18
15.	Rohr Corporation	17
16.	Ryan Aeronautical Company (Teledyne)	8
17.	Western Electric Company	10
	TOTAL	150

All 150 part programs were used in the study at Ames. Tests run at OSI included the Western Electric set and the General Motors part program.

2.3.2 Type of Data

Part programs ranged in size from 10 statements to 1800 statements and exercised virtually every standard APT language feature with the exception of system macros. However, regular macro features were tested extensively. Execution times ranged from .04 to 5 minutes.

Figure 1. (in two parts) displays the distribution of part programs by size. The types of features analyzed and tested are summarized below in Table 5. and in Figure 2.

TABLE 5.
Part Program Features Tested

Feature	Number of Part Programs
2-Axis Parts	28
Limited 3-Axis Parts	27
3-Axis Parts	33
Multi-Axis Parts	37
Section I Processing Only	11
Point-Point Processing	37
Contouring	101
TABCYL	17
RLDSRF	9
PATERN	7
QADRIC	4
LCONIC	9
GCONIC	7
POCKET	6
LOOPS	28
MACROS	65
REFSYS	35
TLAXIS	23
Multiple Check Surfaces	4
COPY	32
THICK	13
TRACUT	34
MAXDP	1

FIGURE 1. PART PROGRAM SIZE DISTRIBUTION

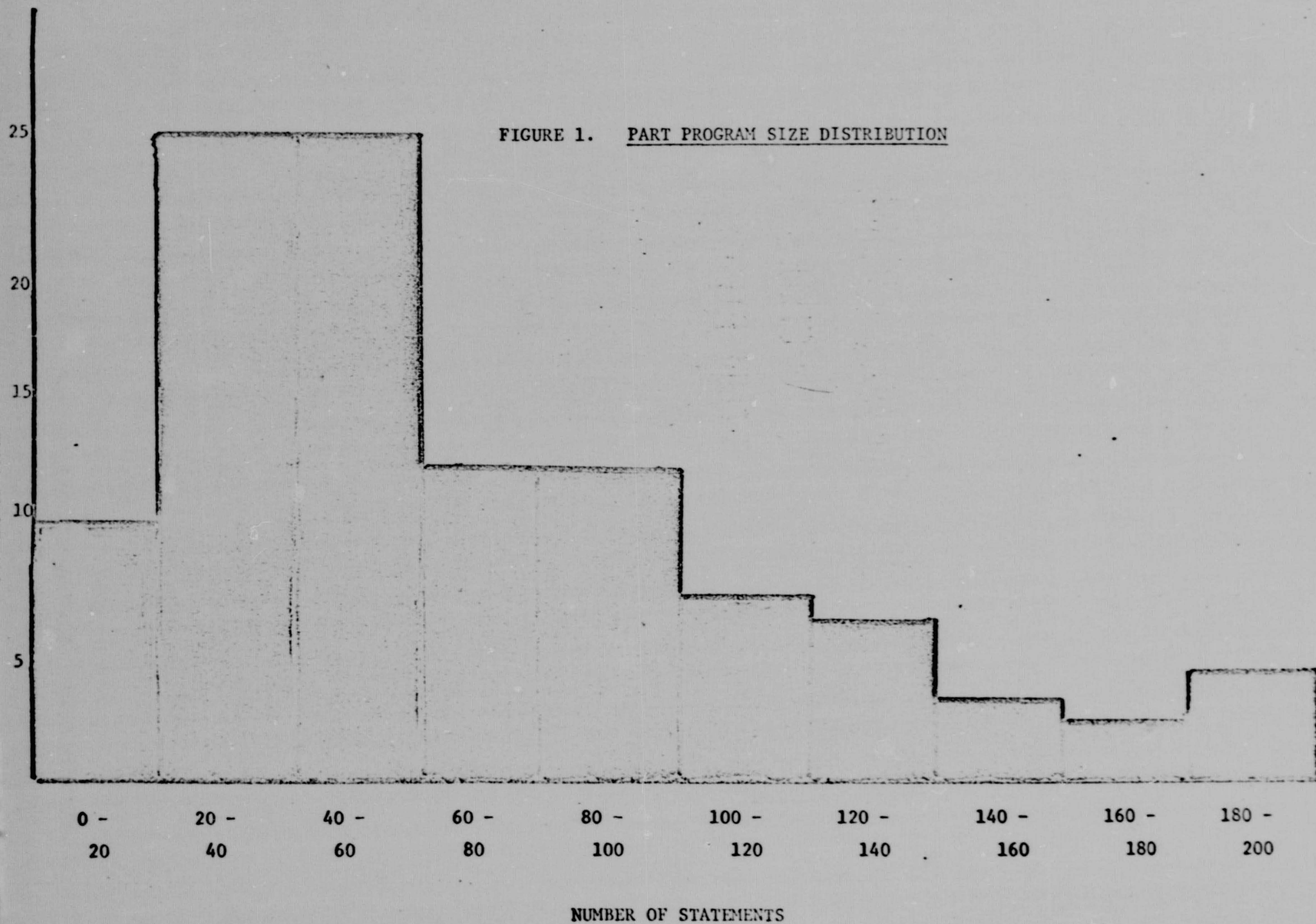
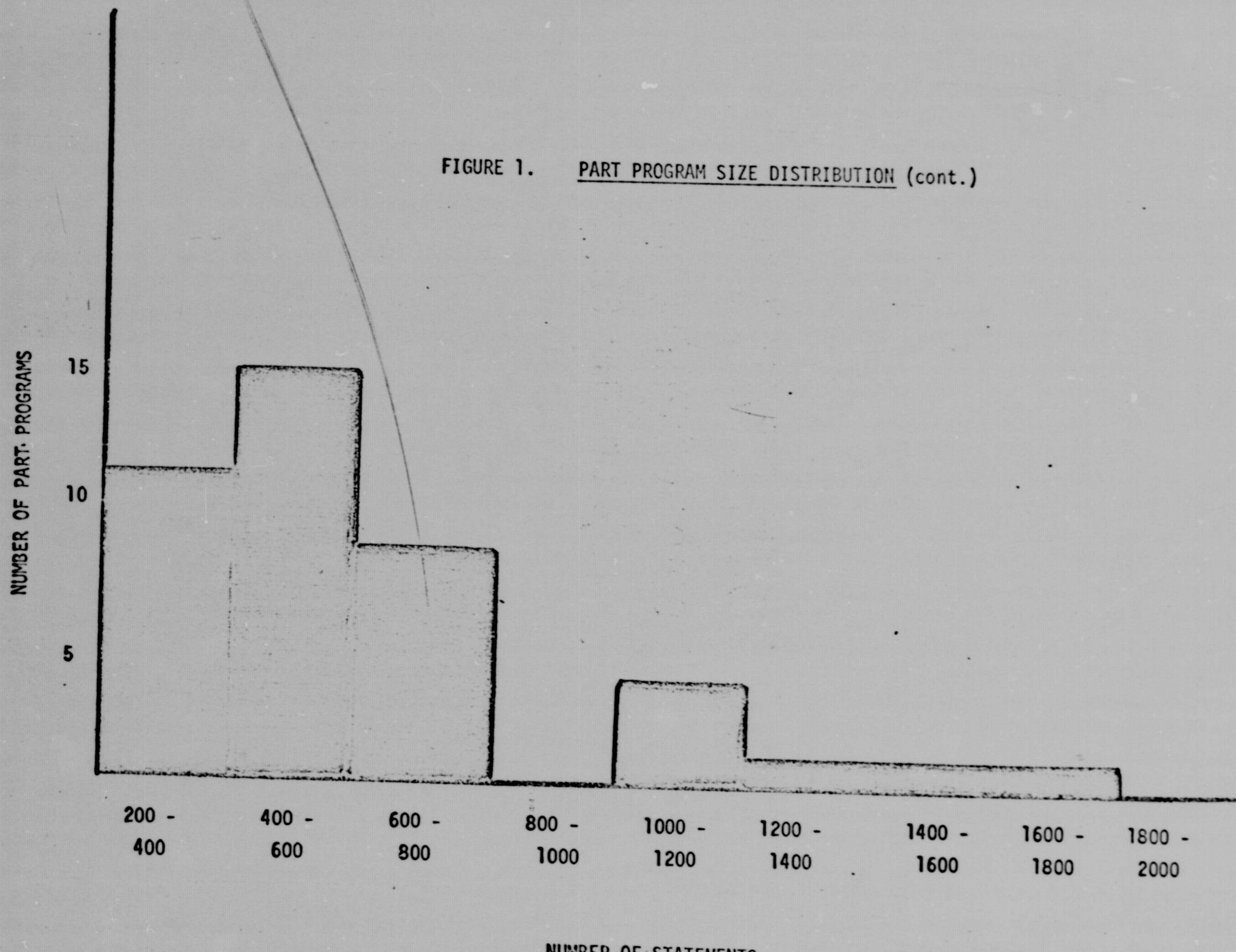


FIGURE 1. PART PROGRAM SIZE DISTRIBUTION (cont.)



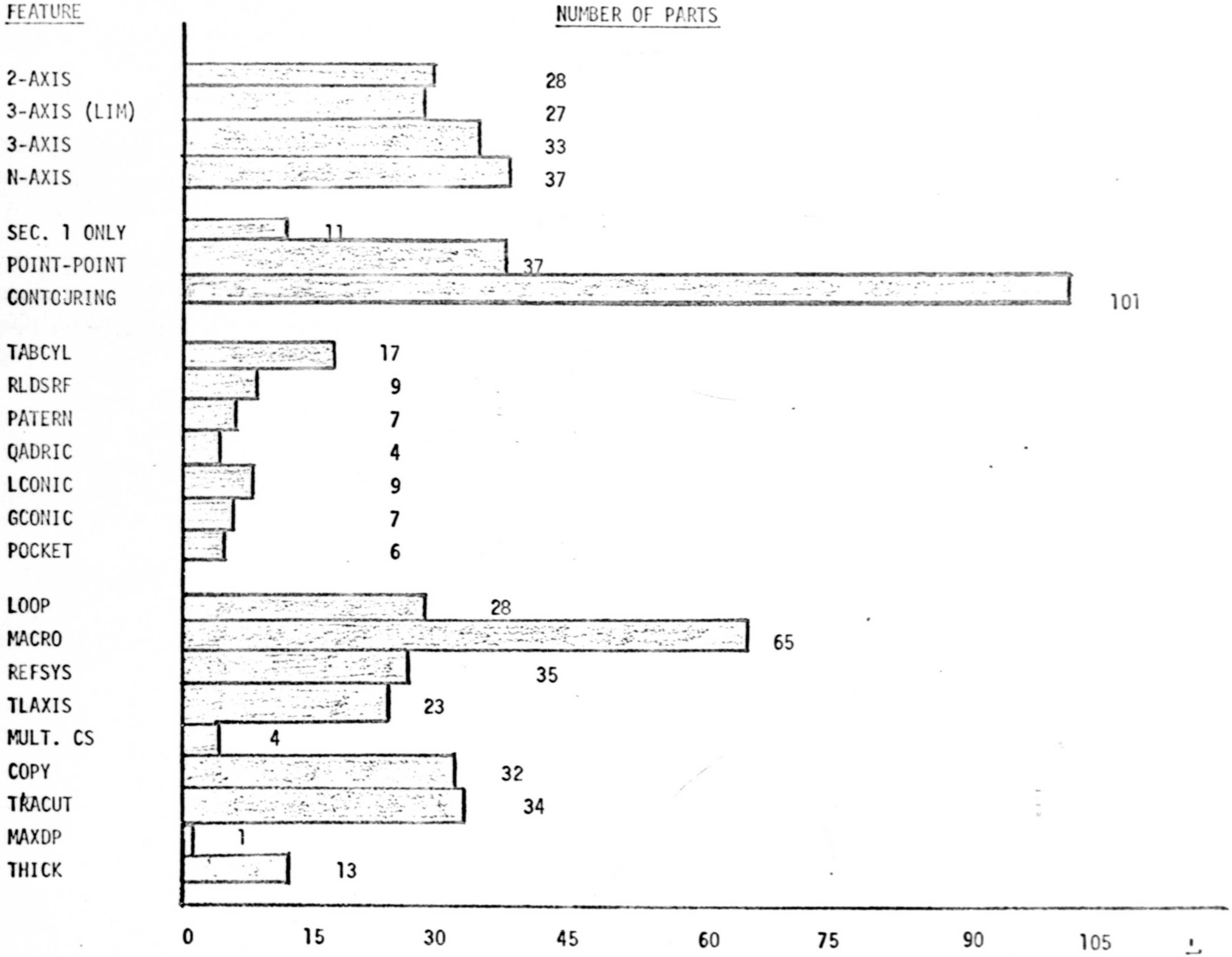


FIGURE 2 DISTRIBUTION OF PART PROGRAM FEATURES TESTED

2.4 Computing Environment

2.4.1 Hardware & Operating System

This study was performed on an IBM System 360/67 at NASA/Ames. The Ames 360/67 is a dual processor with 1M bytes of core memory. The pertinent operating system was OS/360 (MFT). In this mode the computer is functionally equivalent to a stand-alone 360/65.

2.4.2 Timing Data

To minimize any internal clock differences in each of the three systems, NASA/Ames accounting printout was used as the measure of CPU time. (These figures do not include I/O as a separate item, but the amount of I/O effects total CPU time.) Part programs were not batched so that each run time includes both execution and loading times.

Data extracted for runs performed at OSI was drawn from the OSI Accounting Printouts. This data includes the effects of core used and I/O time along with CPU time.

2.4.3 Calendar

Data used in this report was collected in February and March, 1971.

2.4.4 Cost Calculations

Cost calculations presented in the results are based upon an assumed cost of $400./CPU hour and is independent of core used. Actually, the reader need only compare CPU times to determine performance differences at Ames.

In most organizations, the OSI Cost Data (which includes core) is more significant. Interestingly, these results were considerably more dramatic.

3. RESULTS

Testing results are presented in this section. First, we display general reliability results and then move into specific causes of failure. Performance results are then summarized in a series of tables.

3.1 Reliability Results

Table 6. summarizes the reliability results by major categories.

TABLE 6.
Reliability by Major Category

Category	APT/70	NC/360	APT IV
Successful	118	119	93
Minor Anomalies	22	7	34
Major Errors	10	24	23

Table 7. itemizes the successful category.

TABLE 7.
Itemized Successful Category

Category	APT/70	NC/360	APT IV
Correct Processing	103	106	81
Proper Detection of Part Programming Errors	15	13	12
TOTALS	118	119	93

Table 8. itemizes the minor anomaly category.

TABLE 8.

Itemized Minor Anomaly Category

Minor Category	APT/70	NC/360	APT IV
		System	
Copy/Edit Malfunction	16	0	3
Missing Postprocessor Words	1	5	3
Missing Language Feature	1	2	14
Missing Geometric Definition	4	0	0
SYN Statement Overflow	0	0	14
TOTALS	22	7	34

It is interesting to note that Table 8. reflects the fact that NC/360 has been a production system for five years.

Table 9. itemizes the causes of major failures.

TABLE 9.

Itemized Major Error Category

Category	APT/70	NC/360	APT IV
		System	
Translator Errors	0	11	9
ARELEM Errors	5	10	6
Geometric Calculation Errors	2	0	3
System Errors	3	3	5
TOTALS	10	24	23

Table 10.(A-C) lists the specific causes of various deficiencies in each of the three systems.

TABLE 10.A.

Deficient APT/70 Runs

1. Copy/Edit Malfunction - Bug in Cleditor in Output Transformations only.
2. Missing Postprocessor Word - POSMAP
3. Missing Language Feature - TLAXIS/ATANGL, A, B
4. Missing Geometric Definition - LINE TANTO TABCYL
   CIRCLE TANTO TABCYL
5. ARELEM Errors - Small Move to CS Failed
   - Negative Thick, Move to CS Failed
   - Valid Move to Psuedo CS Ignored
   - PSIS Pocket Bottom Definition Failed
6. Geometric Calculation Failures - Poor Cylinder Definition
   - Patern Generates Extra Point
7. System Errors - Termination in Print/3
   - Addressing Error
   - Execution Loop

TABLE 10.B.

Deficient NC/360 Runs

1.	Missing Postprocessor Words	- POSMAP
		- TOOL
2.	Missing Language Features	- UCC Definition
		- Point Definition
3.	Translator Errors	- Accepts a 6 Parameter GODLTA
		- Rejected Valid TLAXIS Statement
		- Rejected Valid SELECT Statement
		- Rejected ZLARGE in Line Definition
		- Rejected Valid MATRIX Definition
4.	ARELEM Errors	- RLDSRF Generates Incorrect Cut Sequence
		- TLAXIS/NORMPS Move In Wrong Direction
		- ARLM3 Iteration Failed to Converge
		- ARELEM Failure in Standard Test Part 19
		- Small Move to CS Failed
		- Incorrect Cutter Positioning
		- GOTO within REFSYS Treated as TRACUT
		- Negative THICK, Move to CS Failed
5.	System Errors	- Execution LOOP
		- ABEND

TABLE 10. C
Deficient APT IV Runs

1. Copy/Edit Malfunction - Cleditor Errors - Minor Output Bug.

2. Missing Postprocessor Words - POSMAP
   - MAGTAP
   - PPTOL

3. Missing Language Features - CANON/ON-OFF
   - MULTAX/ON
   - TLAXIS/ATANGL, A, B
   - PPRINT/"LIST"
   - CLPRNT/OPTION
   - GOUGCK/ON
   - E-Type Format
   - TANF Function
   - Long Lists in PRINT/3 and SYN
   - PRINT/0

4. Translator Errors - PARLEL Not Synonomous with Grid
   - Rejected Valid FROM
   - Rejected ZLARGE in Line Definition
   - Rejected Valid PATERN Definition
   - Rejected Valid POCKET Definition
   - Rejected Valid TABCYL Definition
   - Rejected Valid GOTO Statement
   - Diagnosed Defined Variable as Undefined

5. ARELEM Errors - Valid GOTO Statement Rejected
   - ARLM3 Iteration Failed to Converge
   - Small Move to CS Failed
   - Cutter Moves in Wrong Direction Under INDIRV
   - STARTUP Failed

6. Geometric Calculation Errors - Generates Diagnostics for Valid Definition
   - Rejected Valid Definition

7. System Errors - ABEND
   - Execution Loop
   - PPRINT Loop
   - Addressing Error

The following part programming errors were detected by all three systems:

- Missing Cards
- Card Shuffle
- Cutter out of tolerance of Ds
- Impossible Geometry
- Invalid Line Definition
- Missing Modifiers
- Invalid TABCYL Definition

The remaining errors detected were, in some cases, unique to the particular APT processor.

Table 11. illustrates the types of part programming errors uniquely detected by the three systems.

TABLE 11.
Part Programming Errors

Error	APT/70	NC/360	APT IV
Spurious Commas	Detected*	Acceptable**	Detected
6 Parameter GODLTA	Detected	Not Detected	Detected
SYN Statement Usage (2 Vocab. Words)	Acceptable	Detected	Detected
MATRIX Algebra	Acceptable	Acceptable	Detected
Tagged Feedrate in Implied CS	Acceptable	Acceptable	Detected
Duplicate Labels	Acceptable	Acceptable	Detected
GODLTA/VECTOR	Acceptable	Acceptable	Detected
Bad MATRIX Definition	Detected	Detected	Not Reached
Ref. to CS, INDIRV	Acceptable	Detected	Acceptable
New Point Definition	Acceptable	Detected	Acceptable
SRFVCT, CS	Acceptable	Detected	Acceptable
REMARK Starts in Col. 7	Acceptable	Detected	Acceptable
Undefined Variables	Detected	Detected	Not Reached
Mixed Surface Types	Acceptable	Detected	Detected

* Detected is defined to mean properly diagnosed part programming error.
** Acceptable is defined to mean the APT System accepts the statement without considering the statement in error.

Table 12. summarizes the General Reliability Results.

TABLE 12.
General Reliability Results Summary

	Category	APT/70	NC/360	APT IV
1.	Successful Runs	118	119	93
2.	Success Rate	79%	79%	62%
3.	Relative Success Rate*	100%	100%	78%
4.	Minor Anomalies	22	7	34
5.	Anomaly Rate	14%	5%	22%
6.	Major Errors	10	24	23
7.	Error Rate	7%	16%	16%
8.	Success & Anomalies	140	126	127
9.	Success & Anomalies Rate	93%	84%	84%
10.	Anomalies & Errors	32	31	57
11.	Anomalies & Errors Rate	21%	21%	38%

* With respect to NC/360
All other percentages are based on 150 part programs

3.2 Performance Results

Comparisons are presented below for each subset of part programs which processed on each of the three systems. Thus, there are four primary categories:

- Parts which processed satisfactorily on all 3 systems
- Parts which processed satisfactorily except on APT IV
- Parts which processed satisfactorily except on NC/360
- Parts which processed satisfactorily except on APT/70

These subsets are referred to as Subset A, Subset B, Subset C, and Subset D respectively. Table 13 indicates the relative sizes of each subset.

TABLE 13.

Part Program Subsets

Subset	Description	Number of Parts
A.	Process OK on all systems	59
B.	Fail on APT IV only	21
C.	Fail on NC/360 only	9
D.	Fail on APT/70 only	6
	TOTAL	95

From Table 13. it is clear that 55 part programs either:

- Had part program errors
- Failed on more than one of the systems

A fifth subset, consisting of the General Motors and Western Electric parts was used for testing at OSI. For convenience, we shall describe these results separately in Section 3.2.2.

3.2.1 AMES Performance Results

Table 14. presents the results for Subset A (Parts which processed on all three systems.) Table 14.A presents the itemized results for each part in the subset.

Table 14.

Subset A Results (59 parts)

	System		
	APT/70	NC/360	APT/IV
Total CPU Time (Minutes)	10.88	14.35	25.98
Ratios (To APT/70)	100%	130%	238%
Cost ($400/hour)	$72.46	$95.57	$173.03

TABLE 14.A

Itemized Results for Subset A

PARTNO	CPU TIMES (Minutes) APT/70 (J40)	NC/360 (4M2)	APT/IV (4X3)
BOEING 6	.11	.22	.36
BOEING 7	.19	.29	2.03
BOEING 8	.10	.14	.23
BOEING 9	.06	.09	.18
BUNKER 3	.16	.21	.47
BUNKER 4	.06	.08	.15
BUNKER 5	.04	.07	.12
DAC 22014	.05	.07	.13
DAC 31501	.05	.08	.14
DAC 33003	.05	.10	.15
DAC 51028	.07	.11	.18
DAC 54030	.06	.10	.15
DAC 55011	.16	.24	.36
DAC 55051	.05	.08	.13
DAC 55052	.41	.53	1.01
DAC 57906	.23	.33	.51
DAC 310151	.05	.08	.14
DAC 310152	.23	.30	.55
IITRI 2	.12	.18	.37
IITRI 3	.17	.22	.28
IITRI 4	.40	.51	.62
IITRI 6	.59	.81	.91
IITRI 7	.06	.07	.16
IITRI 8	.07	.11	.15
IITRI 10	.38	.46	.59
IITRI 12	.07	.10	.16
IITRI 13	.18	.21	.24
IITRI 14	.04	.05	.11
IITRI 15	.08	.12	.19

TABLE 14.A

Itemized Results for Subset A

(Continued)

	CPU Times (Minutes)		
PARTNO	APT/70 (J40)	NC/360 (4M2)	APT/IV (4X3)
IITRI 16	.12	.16	.23
IITRI 17	.05	.08	.15
IITRI 18	.09	.15	.20
IITRI 21	.22	.29	.48
IITRI 24	.06	.09	.16
KODAK C	.09	.14	.25
KODAK E	.11	.13	.22
KODAK K	.26	.34	.42
LOCK 4	.61	.95	2.77
NORTHROP 6	.04	.05	.08
NORTHROP 12	.04	.06	.11
NORTHROP 13	.03	.05	.12
REPUBLIC 4	.35	.50	.99
ROCK 1	.11	.16	.25
ROCK 3	.56	.70	1.48
ROHR 2	1.45	1.42	1.49
ROHR 3	.20	.26	.43
ROHR 4	.16	.18	.32
ROHR 9	.09	.11	.22
ROHR 10	.09	.11	.22
ROHR 17	.45	.40	.54
ROHR 21	.09	.11	.19
ROHR 23	.18	.27	.68
ROHR 24	.19	.26	.44
ROHR 25	.11	.15	.28
ROHR 30	.27	.38	.78
WE2	.06	.08	.15
WE3	.27	.45	.97

TABLE 14.A

Itemized Results for Subset A

(Continued)

	CPU Times (Minutes)		
PARTNO	APT/70 (J40)	NC/360 (4M2)	APT IV (4X3)
WE 8	.14	.21	.37
WE 9	.10	.15	.22
TOTALS	10.88	14.35	25.98

Table 15. presents the results for Subset B (parts which failed on APT IV only). Table 15.A itemizes this data.

TABLE 15.

Subset B Results (21 parts)

	System	
PARTNO	APT/70	NC/360
Total CPU Time (Minutes)	8.66	11.07
Ratios	100%	128%
Cost ($400/hour)	$57.67	$73.73

TABLE 15.A

Itemized Results for Subset B

PARTNO	APT/70	NC/360
	System	
AMES 1	.35	.47
BOEING 11	.98	1.06
DAC 31037	.05	.06
DAC 33017	.29	.38
DAC 41012	.09	.12
DAC 51036	.05	.08
KREH 2	.20	.44
LOCK 5	1.67	2.28
NORTH 2	.05	.06
NORTH 7	.06	.15
NORTH 9	.04	.06
NORTH 10	.03	.05
NORTH 18	.05	.07
ROCK 10	.41	.59
ROCK 15	.62	.99
ROHR 5	.12	.17
ROHR 14	.49	.39
ROHR 15	1.10	1.34
RYAN 13	1.79	1.99
WE 1	.06	.10
WE 4	.16	.22
TOTALS	8.66	11.07

In Table 16. we have consolidated the results for APT/70 and NC/360.

TABLE 16.
Consolidated Comparison Between
APT/70 and NC/360 (80 parts)

	System	
	APT/70	NC/360
Total CPU Time (Minutes)	19.54	25.42
Cost ($400/hour)	$130.14	$169.30
Ratios (To APT/70)	100%	130%

Table 17. presents the results for Subset C (parts which failed on NC/360 only). This list is sufficiently small to present the itemized list in one table.

TABLE 17.
Subset C. Results (9 parts)

	System	
PARTNO	APT/70	APT IV
IITRI 9	.08	.17
IITRI 19	.11	.31
IITRI 20	.44	.45
IITRI 22	.05	.15
IITRI 23	.06	.17
IITRI 25	.08	.15
IITRI 27	.13	.17
LOCK 7	.71	1.64
NORTH 4	.05	.12
Total CPU Time (Minutes)	1.71	3.33
Cost	$11.38	$22.18
Ratios (To APT/70)	100%	196%

Table 18. presents the itemized results for Subset D (parts which fail only on APT/70.

TABLE 18.

Subset D. Results (6 parts)

	System	
PARTNO	NC/360	APT IV
IITRI 11	.18	.22
NORTH 11	.09	.20
NORTH 14	.08	.12
REPUBLIC 1	.61	1.19
ROHR 16	.12	.35
WE 6	.11	.24
Total CPU Time (Minutes)	1.19	2.32
Costs	$7.92	$15.45
Ratios (To NC/360)	100%	196%

The results presented in Tables 14. through Table 18. can be summarized:

APT/70 is 30% faster, on the average, than NC/360!

APT/70 is two to two and one half times faster than APT IV!

NC/360 is twice as fast as APT IV!

The same relationship, of course, applies to cost.

It is interesting to note that these results are similar to those obtained last Fall during a preliminary analysis. However, these results do not include I/O costs or any core considerations. The data presented in the next section was collected for the purpose of examining these other costs.

3.2.2 OSI Performance Results

In order to account for additional cost parameters, several APT systems were tested at OSI. APT IV, because of its general Ames performance, was deleted from the OSI study to reduce costs.

At OSI we were particularly interested in determining the core utilization and I/O effects on cost. Also, we were interested in evaluating the core vs. I/O usage variation in APT/70. Eleven part programs were batched together in this study. The results indicate significant differences in cost and are presented in Table 19.

TABLE 19.
OSI Performance Results

	Parameters	APT/70 4 Overlays	APT/70 3 Overlays	NC/360 5 Overlays
			System	
1.	Core Used	162K	210K	224K
2.	CPU Time (Minutes)	6.94	6.62	13.19
3.	I/O Time (Minutes)	1.21	.87	1.96
4.	Step Time (Minutes)	8.15	7.49	15.15
5.	Machine Units (Inc. Core)	12.46	12.97	28.07
6.	Cost	$62.30	$64.85	$140.35
	Ratios (To APT/70)	100%	104%	225%

These results were generally consistent and can be summarized easily:

Both versions of APT/70 are more than two times cheaper to process the given part programs than NC/360.

4. ANALYSIS

The results presented in Section 3 are quite consistent from a technical point of view. These results are discussed below.

4.1 Efficiency

With respect to efficiency, APT/70 outperforms both APT IV and NC/360. APT/70 consistently ran 30% faster than NC/360 on small non-batched part programs and better than twice as fast on batched or large part programs. The comparison to APT IV was more dramatic with APT/70 performing at least twice as fast as APT IV.. NC/360 also outperformed APT IV by a factor of two (2).

4.2 Reliability

Both APT/70 and NC/360 demonstrated similar levels of reliability with essentially identical success rates. In the other two categories APT/70 had more minor anomalies while NC/360 had more major errors. APT IV, with its lack of production tuning fell considerably below both APT/70 and NC/360 in reliability.

The fact that both APT/70 and NC/360 demonstrated similar reliability levels is rather remarkable considering that NC/360 has been in production five years and APT/70 is two months into production.

4.3 Cost Effectiveness

Cost, of course, is geared directly to computational efficiency. With similar reliability levels (at this time), it is clear that APT/70 will reduce the computing costs by a minimum of 30% on small part programs under an Ames-type accounting system. However, the savings under a more commercial-type accounting scheme, such as OSI, are much more dramatic. These savings, as demonstrated in Table 19. were 125%.

APT IV demonstrated poor cost-effectiveness in the Ames runs averaging 2-3 times the cost of APT/70 or NC/360. Although not tested at OSI, it is clear that the APT IV system would be at least four times more expensive to process under a commercial-type accounting system than either APT/70 or NC/360.

4.4 Diagnostic Aids

APT/70 produced the maximum number of diagnostic aids per run due to its processing structure. We expected similar performance from APT IV, however, the lack of production tuning prohibited APT IV from continuing its error scan in many cases. This was caused by SYN statement limitation and a peculiar tendency of the APT IV translator to terminate execution on missing words.

NC/360, as an APT III-type system, produced fewer diagnostics but in most cases the system diagnosed the significant errors.

4.5 Simplicity of Use

In general, NC/360 and APT/70 were equally simple to use with very little part program tailoring required. APT IV, again with virtually no production tuning, would have been the most difficult system to use. It is estimated that 3 to 6 man-months would be necessary to bring APT IV up to a similar level of production tuning.

4.6 Expandability

Because APT/70 and APT IV are newer systems which were designed for expanded capability, they are much more amenable to introducing:

- New procedures
- New algorithms
- New language features

In this case, both systems are probably identical in terms of complexity in adding new capability. However, APT IV is large and users must consider the fact that very little space is available (in core) for these new features.

NC/360 would be the most difficult system to add new capability. As an example, Table 20. estimates the labor necessary to add the use of external datasets for TABCYL input to the systems.

TABLE 20.

Labor Estimate, External Datasets

System		
APT/70	NC/360	APT IV
2 man-months	6 man-months	3 man-months

5. CONCLUSIONS

We have chosen not to make any recommendations in this report. As a distributor of APT/70, such recommendations might constitute a conflict of interest.

Sufficient data should be contained within this report to serve as a basis for selecting and implementing an APT system under TSS/360.