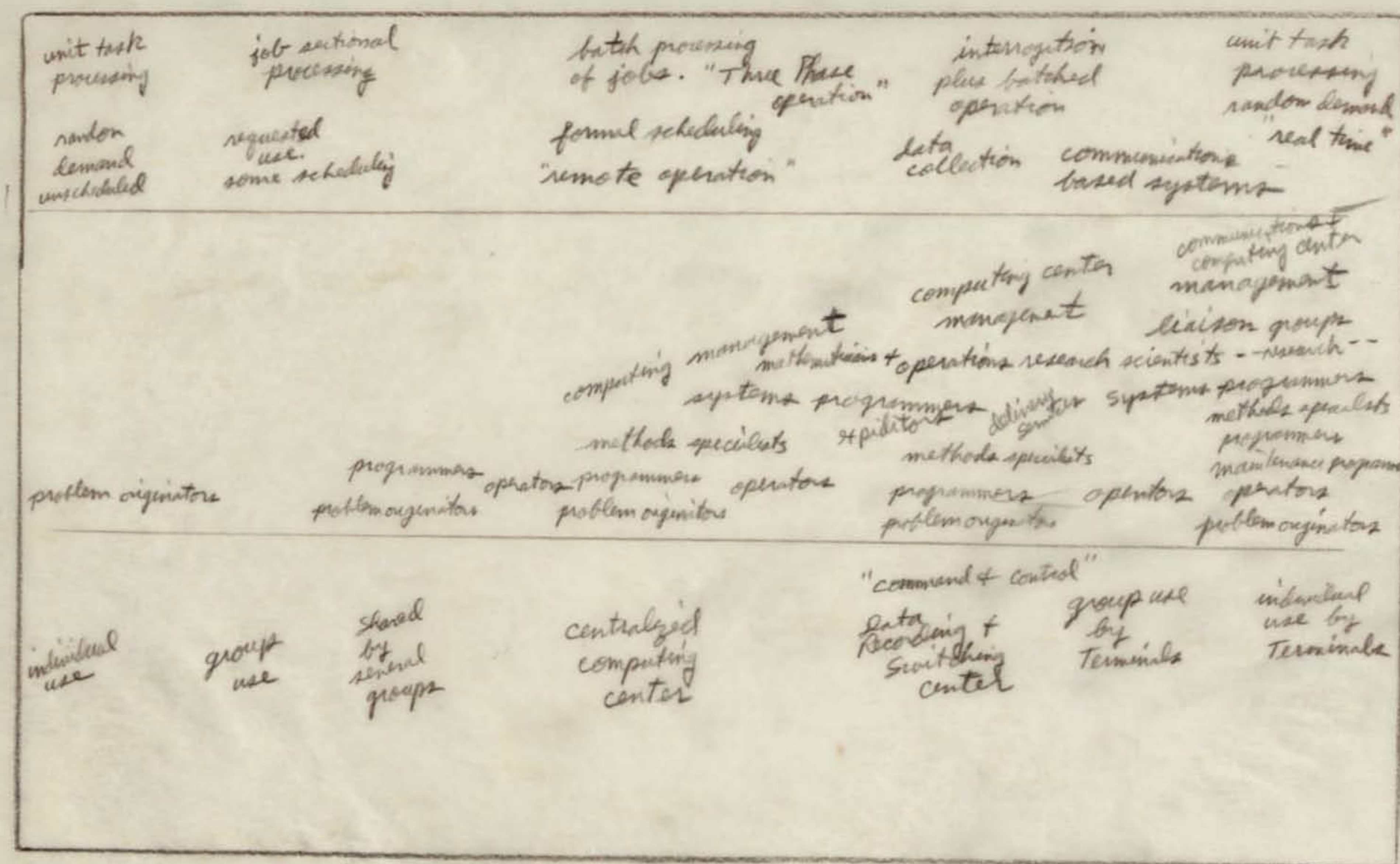


Size of System ⟶

Figure ——, Variation of some characteristics of use and organization vs the size of a Data Processing System.

1963

HGK

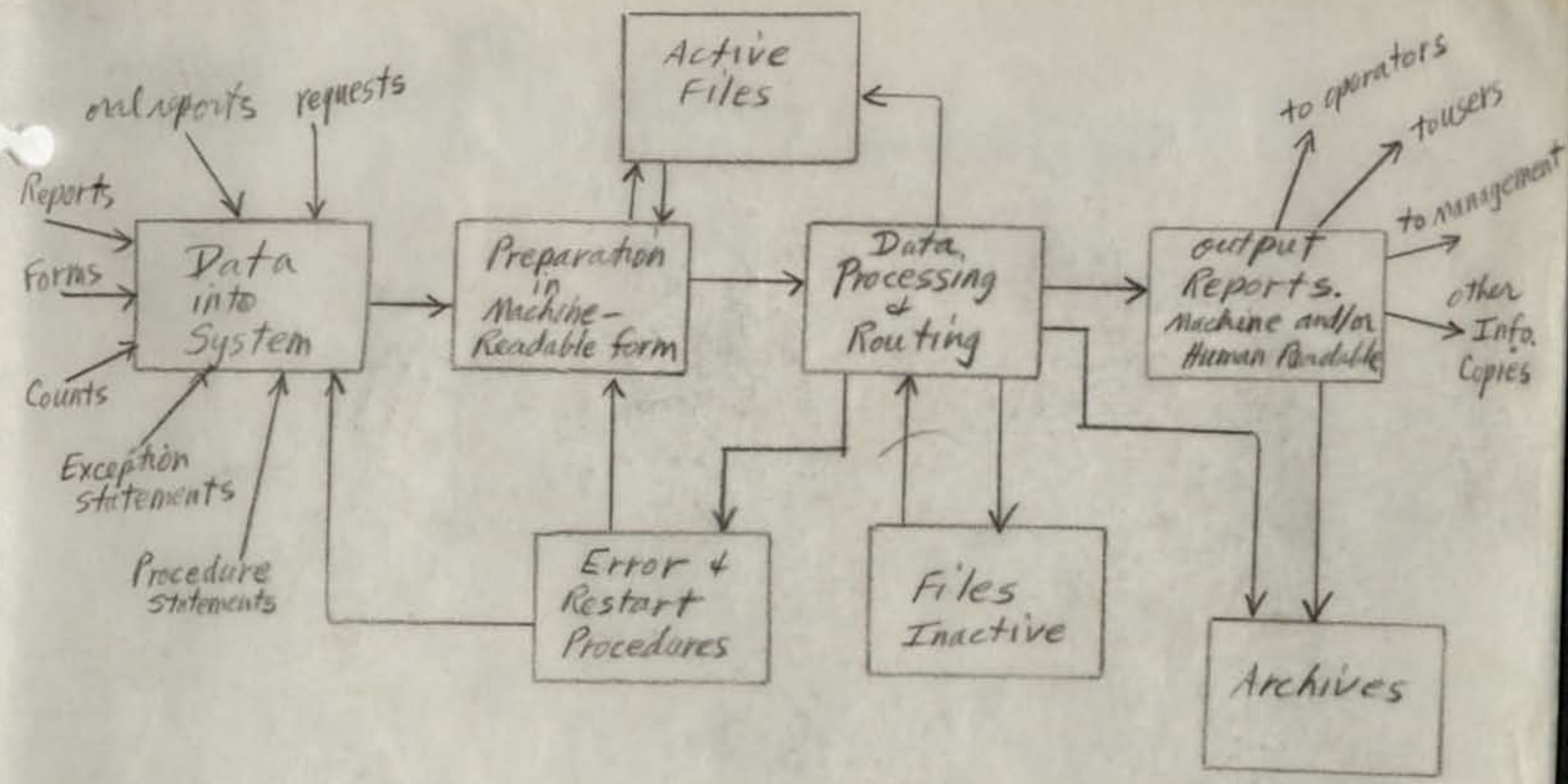


Figure 1. Data Flow in a Typical Data Processing System

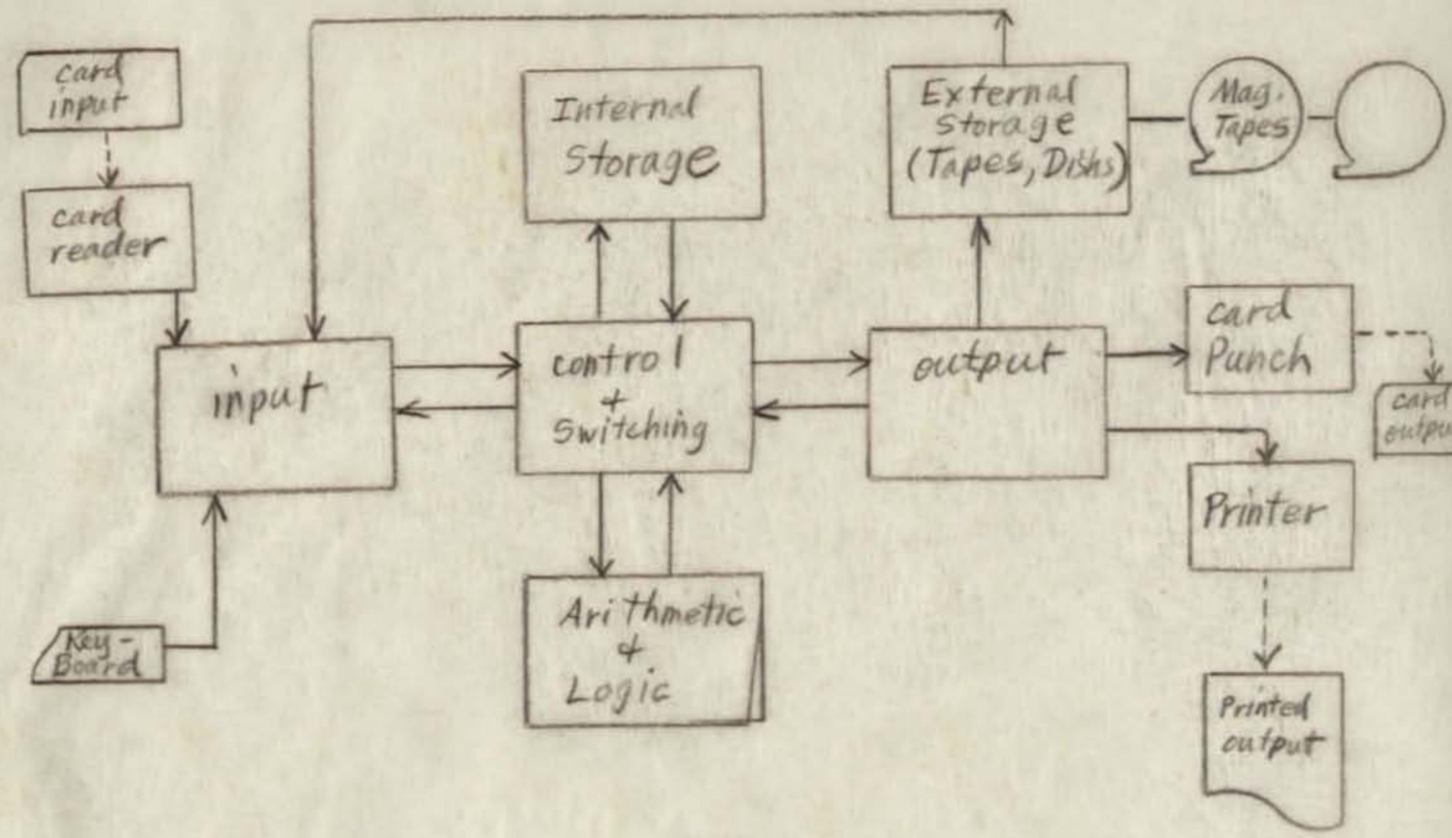


Figure 2. Schematic of a typical Computer

HGN

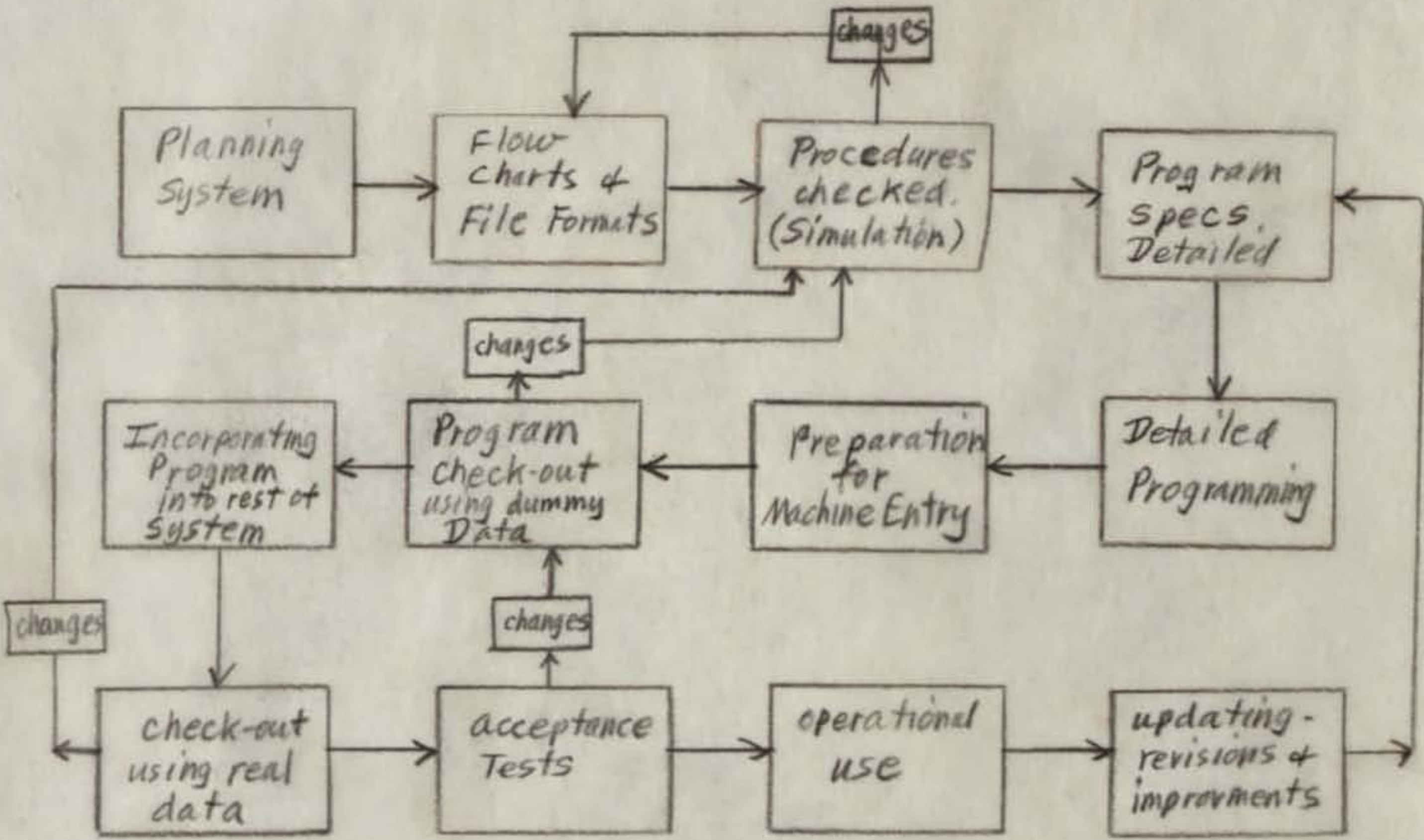


Figure ____. Preparation of a Program for entry into a Data Processing System.

HGK

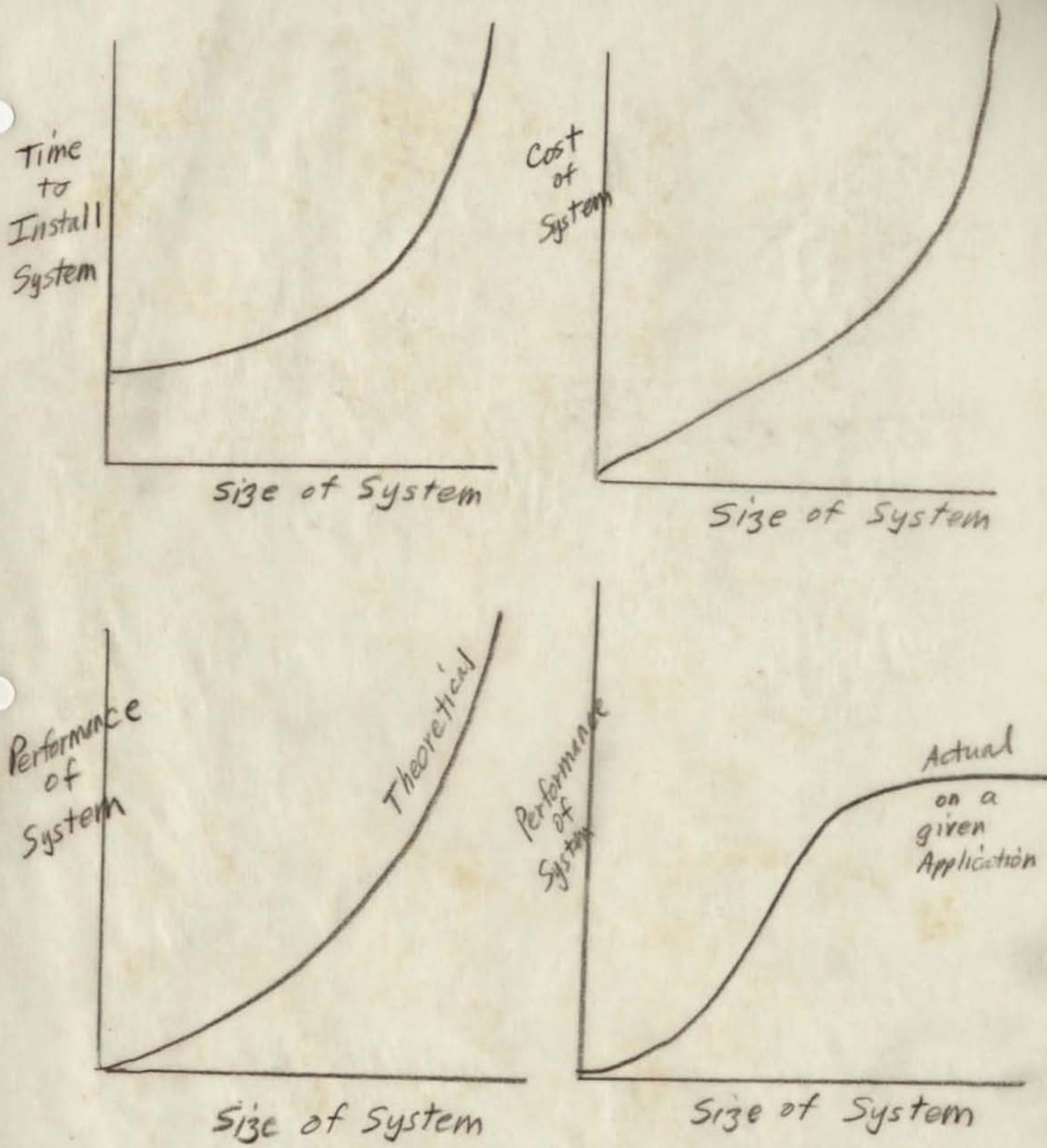


Figure ___, Qualitative Variation of Some Data Processing System Parameters vs. System Size

HGK

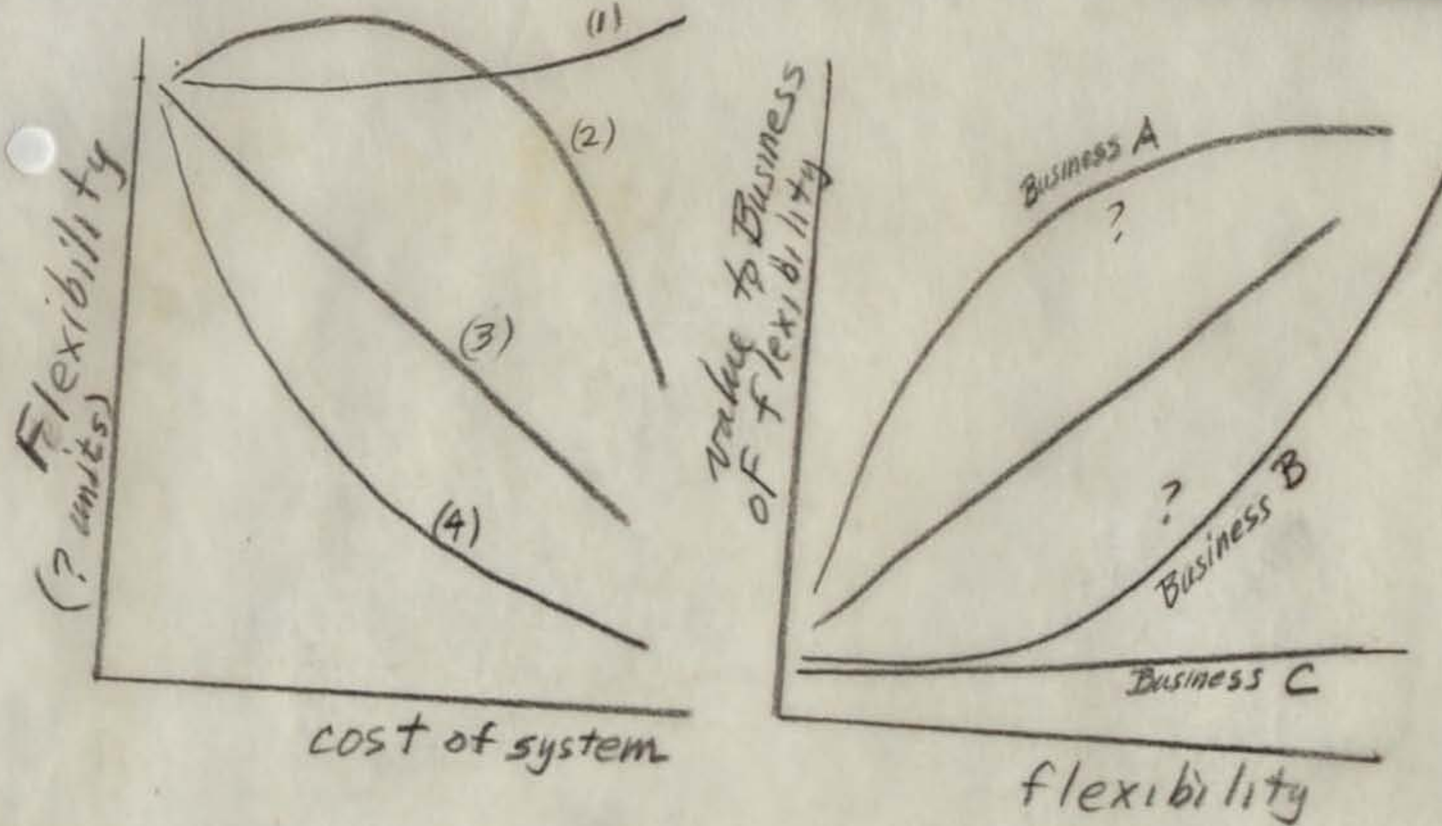
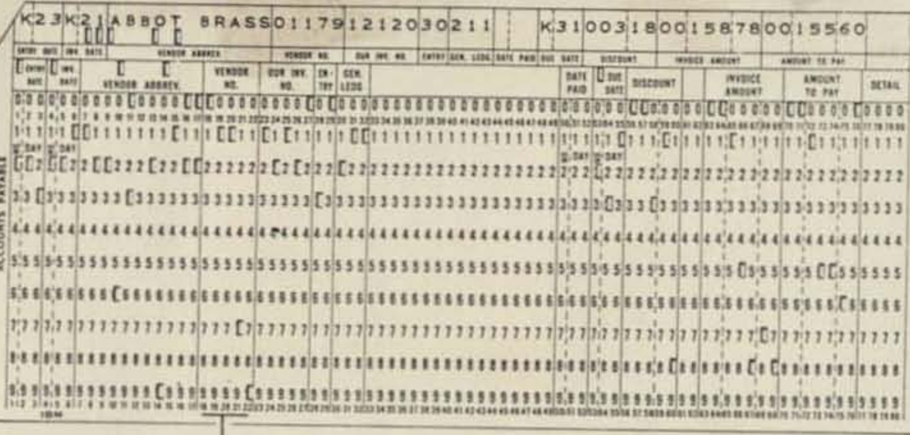


Figure ____. Some Intangible Factors and costs in a Data Processing System,

H6K



CASH REQUIREMENTS STATEMENT

VENDOR ABBREVIATION	VENDOR NUMBER	DUE DATE MO.	DUE DATE DAY	DISCOUNT	INVOICE AMOUNT	AMOUNT TO PAY	TOTAL BY DATE
ABBOT BRASS	1179	12	31	318	15878	15560	
ABBOT BRASS	1179	12	31	196	9813	9617	
ABRAMS COAL	1180	12	31	831	27735	26904	
ABRAMS COAL	1180	12	31	1050	30000	28950	
BARR MACH	3076	12	31	15077	301527	286450	
EL TRUST CO	C9521	12	31		5125	5125	
KARTAGE INC	44860	12	31		21875	21875	
LEHIGH COAL	48678	12	31	1384	69178	67794	
MAIZE REF	58091	12	31		11823	11823	
N MILT SUPP	60035	12	31		21415	21415	
N Y CAS EL	61221	12	31		67595	67595	
STATE N Y	74213	12	31		179286	179286	
W COR TEL	81469	12	31		23729	23729	
WICKWIRE BR	86341	12	31		36043	36043	
WISELO INC	88213	12	31		19518	19518	

Figure — . Example of a punched card record and a corresponding report listed from such records.

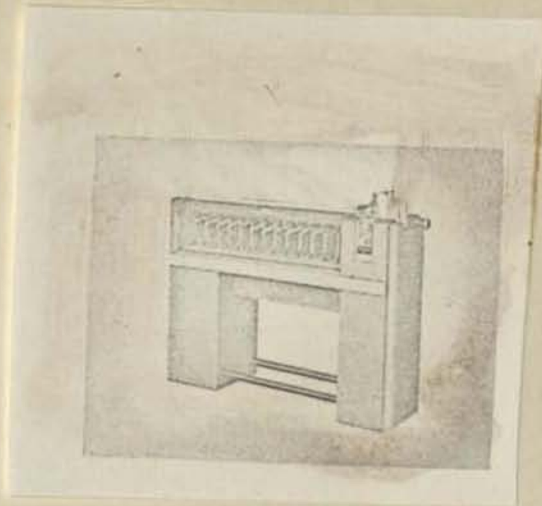


Figure ___. a punched card sorting machine. Each card is placed in an output pocket based on the value of the number punched in the card. (IBM 082)

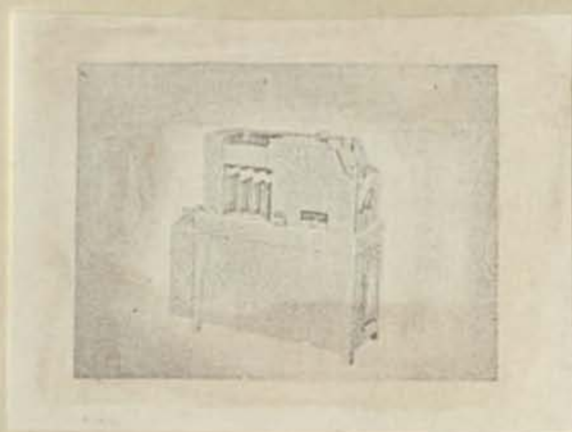


Figure ___, a punched card collating machine. Cards from each of two feeds are merged together under control of a wired plug board. (IBM 077)

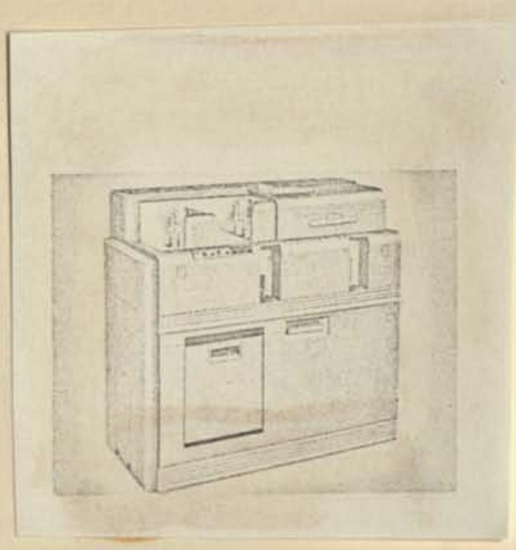


Figure ___. A punched card reproducing machine. It also permits rearrangement of columns and fields on the cards under plug board control. (IBM 510).

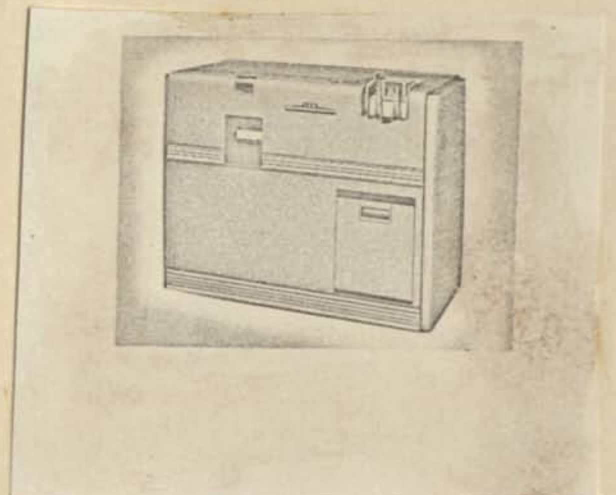


Figure ___. A punched card calculating machine. For logical elements and storage elements it uses electrical relays. Program control is by wired plugboard. (IBM 602A)

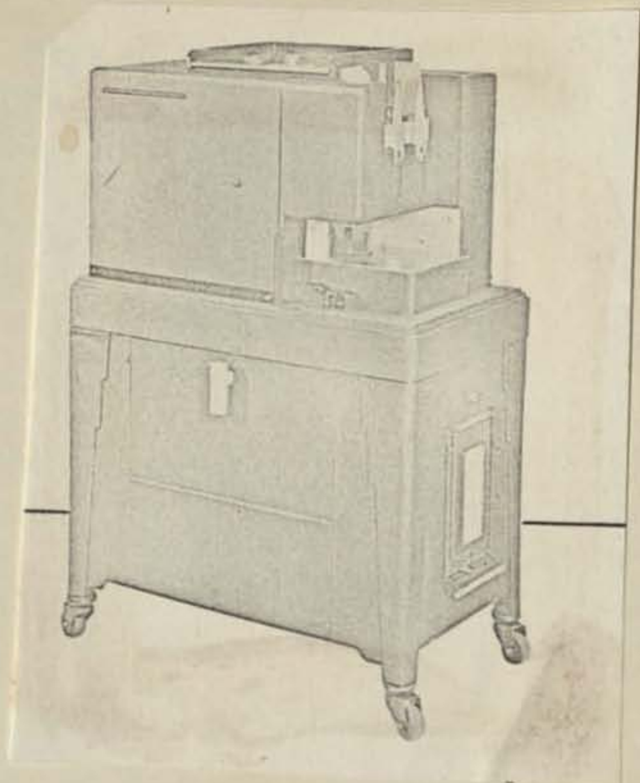


Figure ___. A punched card interpreter. Prints the information punched on the card across the top of the card. (IBM 552)

Figure ___. Key Punch. Prepares punched cards for entry into other machines. A similar machine verifies that cards already punched are correct (IBM 026)

Program Suppress	Program Step	Operation	Storage Unit 1L	Storage Unit 1R (Divr.–Mult.)	Counter 1 (Dividend)	Counter 2 (Dividend)	Counter 3	Counter 4	Counter 5	Counter 6	Storage Units 2L	2R	3L	3R	4L	4R	Punch units
		READ CYCLE		READ IN 7R X00	ADD A XX	ADD B XX					READ IN C XX	READ IN D XX	READ IN E XX				
	1	ADD C to A ADD D to B			ADD C XX	ADD D XX					READ OUT	READ OUT					
	2	ADD E to (B+D)				ADD E XX							READ OUT				
	3	ADD (B+D+E) to (A+C)			ADD (B+D+E) XX	READ OUT & RESET											
	4	MULTIPLY			READ OUT XX					ADD PRODUCT XXXX00							

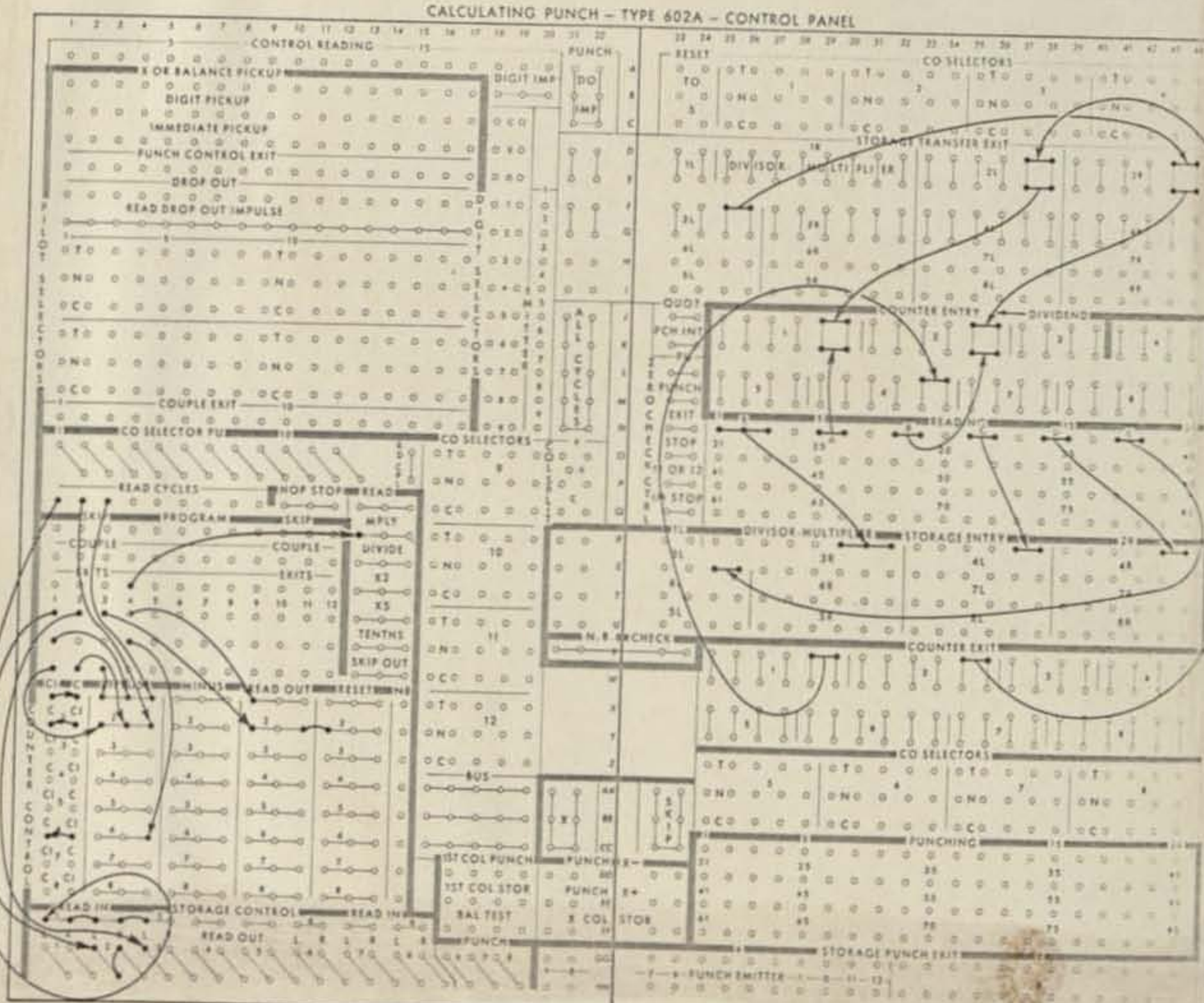


Figure ___. Example of Programming Sheet and plugboard wiring diagram for a old style punched card calculator (IBM 602A).

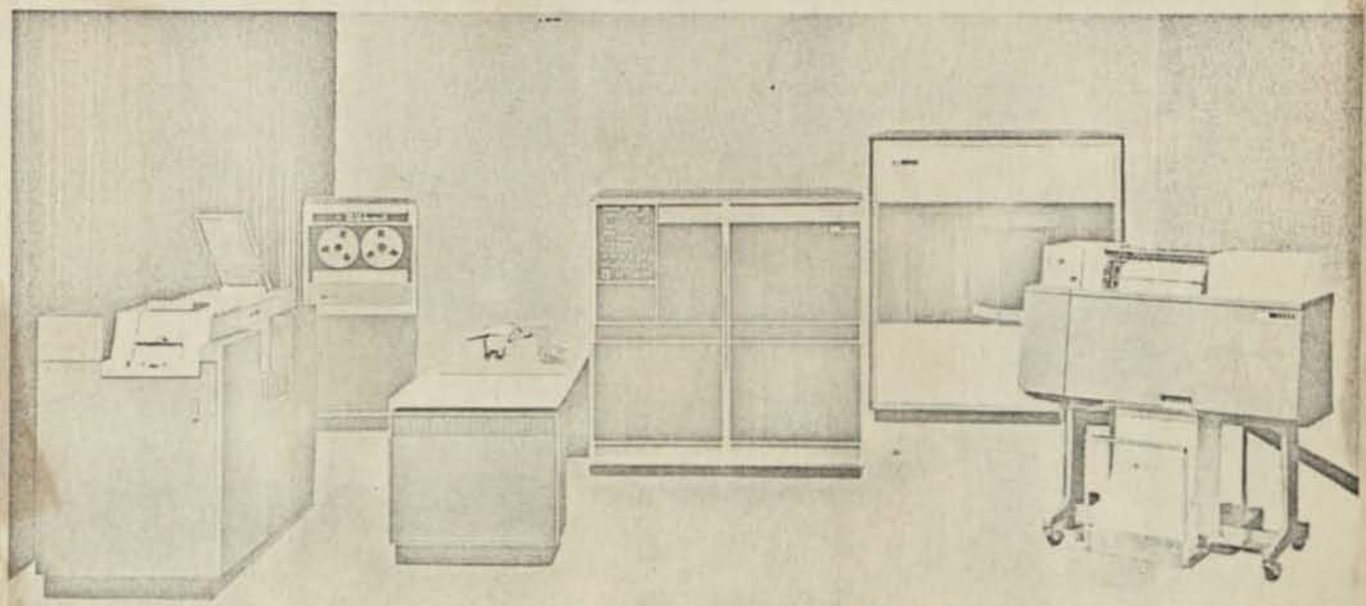


Figure ___. A typical Computing System used for Commercial Data Processing. (IBM 1401 Data Processing System). Left to Right are: Card reader-card punch combined, Magnetic Tape unit, Operating console, Central processing unit, Magnetic disk file storage, Printer

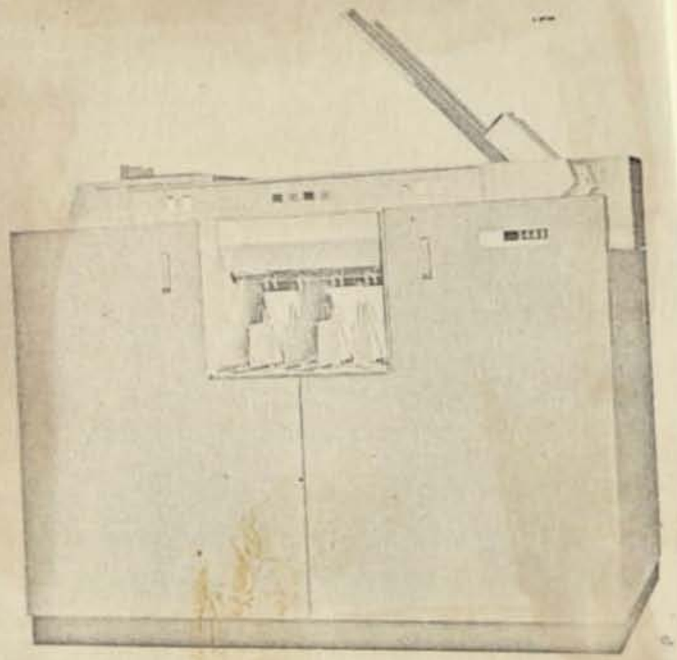


Figure [redacted], IBM 1402 Card Read-Punch

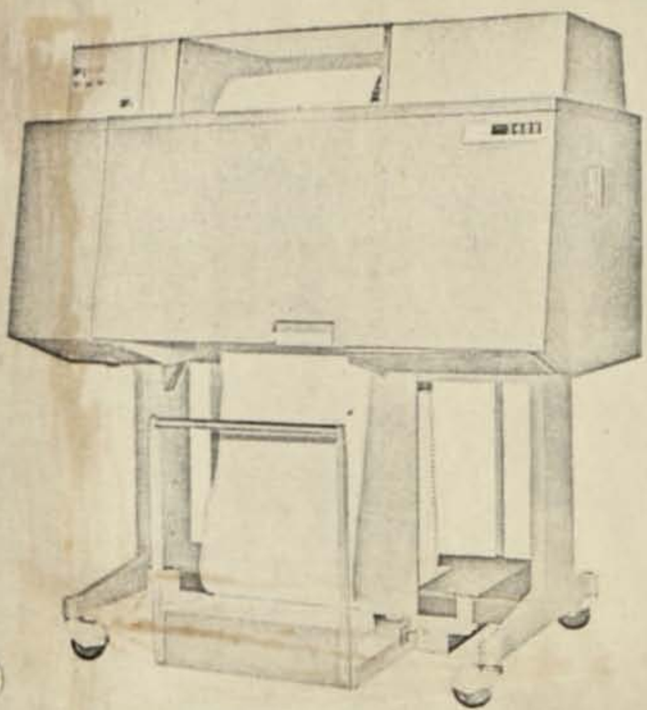
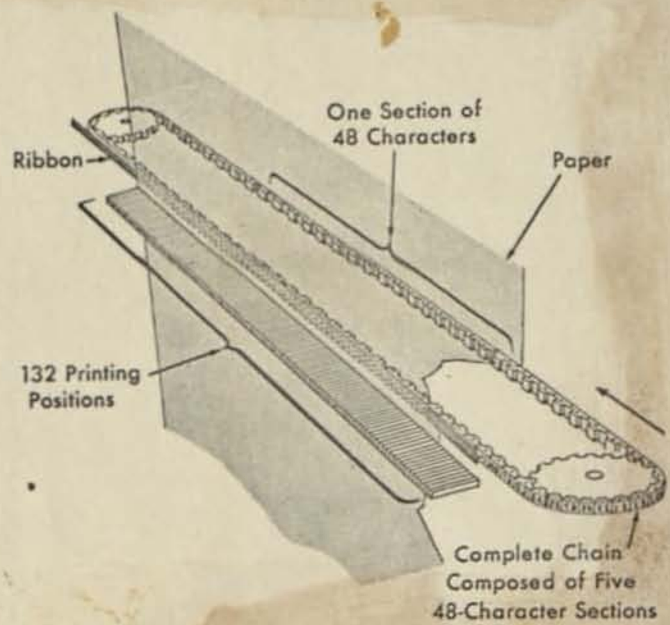


Figure [redacted] IBM 1403 Printer



[redacted]. Printing Mechanism Schematic

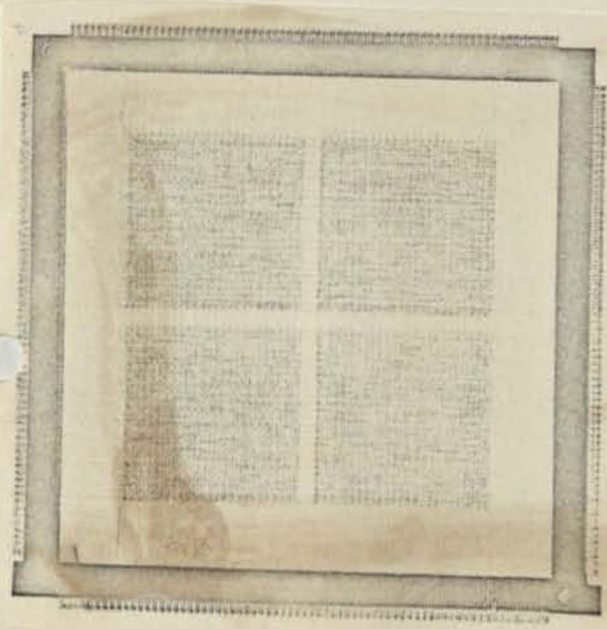
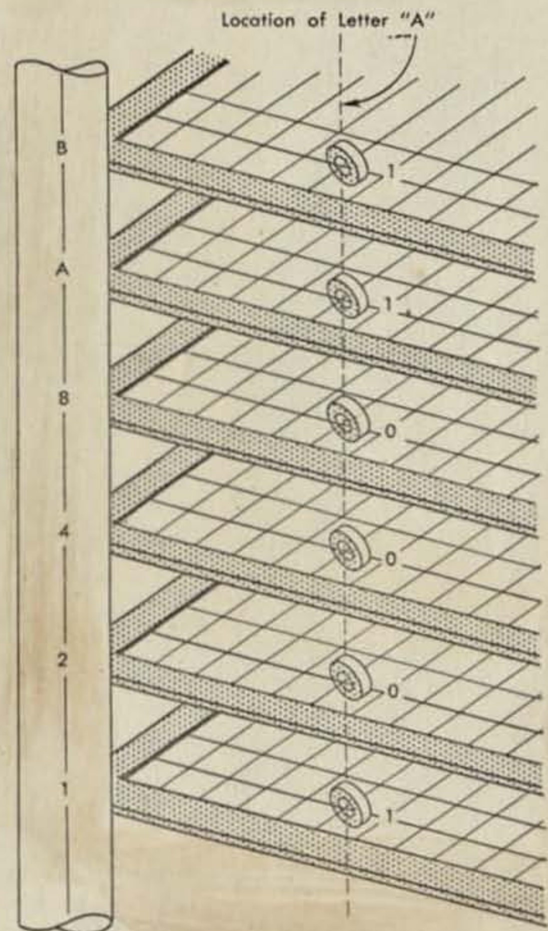


Figure ______. One plane from a Magnetic Core Storage device.



The Letter A Represented in Magnetic Core Storage

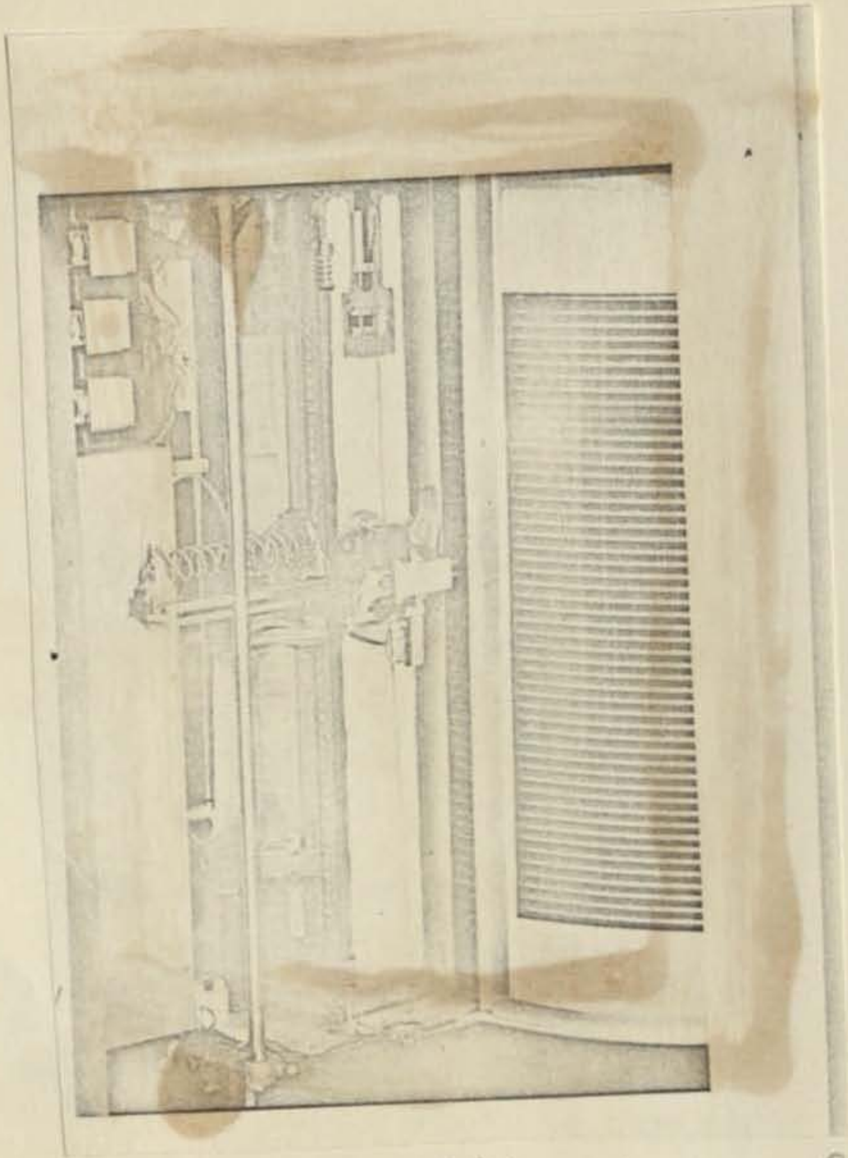


Figure ___. Magnetic Disk Storage Device showing access arm for read-write heads. (IBM 1405 RAMAC)

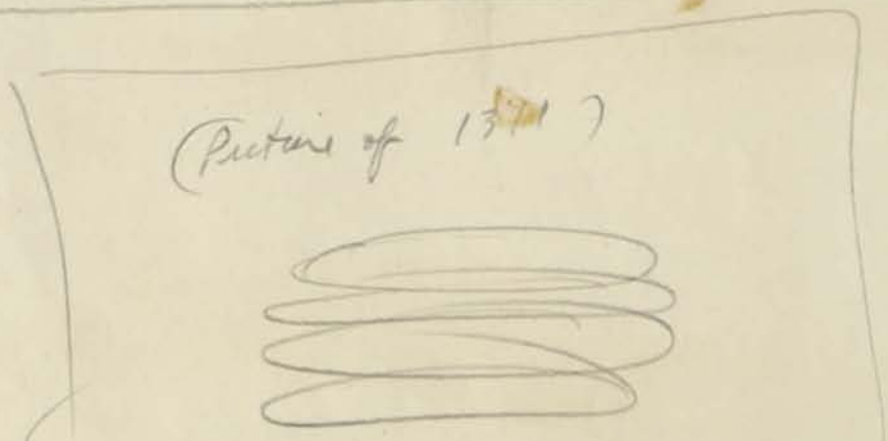
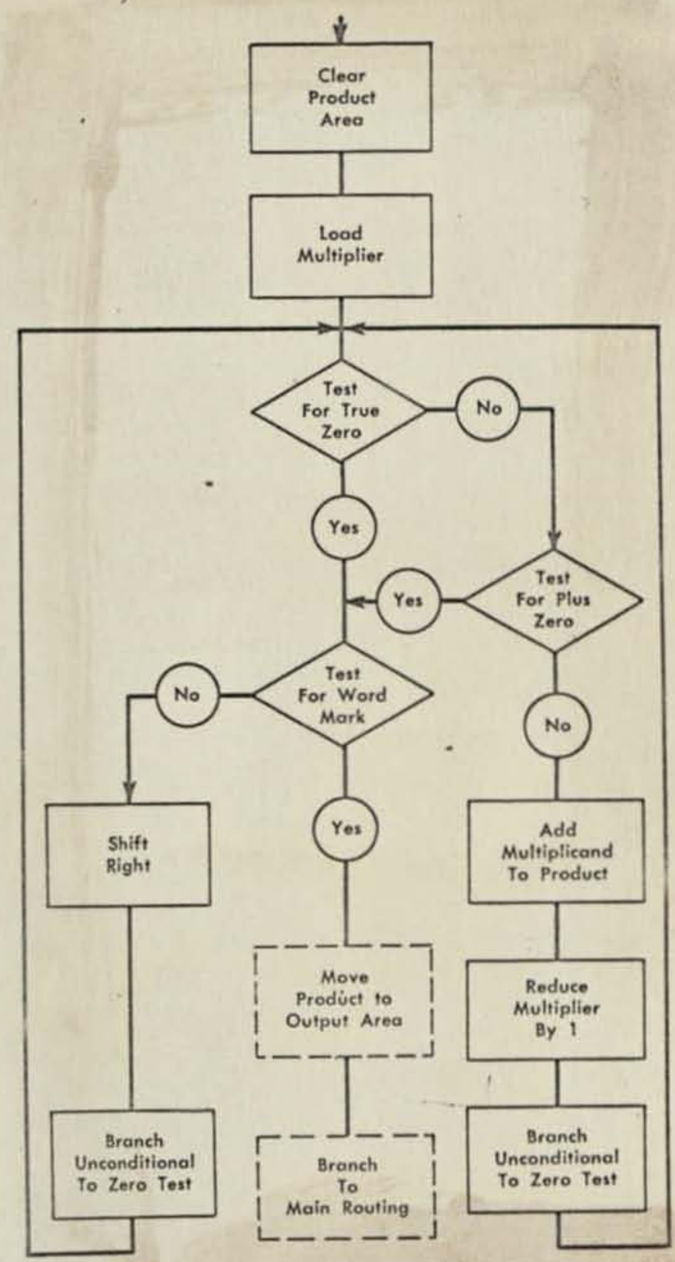


Figure ___ A removable Disk device which combines the many of features of disks & tapes (IBM 1311 RAMPAC)



Multiply Flow Chart

Figure ____ : Example of flow chart used in computer programming

IBM 1401 Symbolic Programming System

Coding Sheet

Program *Multiply Subroutine*

Page No. __ of __

Programmed by ______ Date ______ Identification ______

Line	Count	Label	Operation	(A) Operand Address	±	Char. Adj.	(B) Operand Address	±	Char. Adj.	d	Comments
010			LCA	BLANKS			AREA				CLEAR PROD AREA
020			LCA	MPLIER			AREA	-	020		LOAD MPLIER
030		ZROTST	B	TESTWM			AREA	-	020	0	BRANCH TRUE ZERO
040			B	TESTWM			AREA	-	020	?	BRANCH PLUS ZERO
050			A	MCAND			AREA	-	008		ADD MCAND
060			S	ONE			AREA	-	020		SUBT FROM MPLIER
070			B	ZROTST							BRANCH TO ZROTST
080		TESTWM	BWZ	LAST			AREA		020	1	TEST FOR WM
090			LCA	AREA	-	001	AREA				SHIFT AREA RT 1
100			B	ZROTST							BRANCH TO ZROTST
110		LAST	B	0000							MULT COMPLETE
120											
130											
140											
150											
160	30	BLANKS	DCW	*							
170	30	AREA	DCW	*							
180	9	MPLIER	DCW	*							
190	11	MCAND	DCW	*							
200	1	ONE	DCW	*		1					

Multiply Subroutine (Symbolic)

IBM 1401 PROGRAM CHART

Program: Multiply Subroutine

Programmer: ______ Date ______

Step No.	Inst. Address	Op	Instruction A/I	B	d	Remarks	Effective No. of Characters Inst.	Data	Total
1	930	/	929			Clear Product Area	4		
2	934	L	XXX	909		Load Multiplier	7		
3	941	B	975	909	0	Test 909 for true zero	[illegible]		
4	949	B	975	909	?	No true zero - test for plus zero	8		
5	957	A	YYY	921		No zero - add Multiplicand to Product	[illegible]		
6	964	S	994	909		Reduce Multiplier by 1	[illegible]		
7	971	B	941			Branch to zero test	4		
8	975	V	995	909	1	Test 909 for Word Mark	8		
9	983	L	928	929		No Word Mark - Shift Right	[illegible]		
10	990	B	941			Branch to zero test	4		
11	994	1				Constant "1"	1		
12	995	B	ZZZ			Multiplication complete - Branch back to Program			
			XXX			Location of Multiplier			
			YYY			Location of Multiplicand			
			ZZZ			Address of next Program Step			
						9 digit Multiplier			
						11 digit Multiplicand			
						20 digit Product			

Multiply Subroutine (Actual)

Figure _____. Examples of Symbolic and Machine Language Programs.

Figure 249. IBM 1401 Operation Codes

Sample of operation codes

INPUT-OUTPUT CODES

OPERATION CODE	FUNCTION	MNEMONIC	BCD CODE	CARD CODE
1	Read a Card	R	1	1
2	Write a Line	W	2	2
2□	Write Word Marks		□ is modifier	
3	Write-Read	WR	C21	3
4	Punch a Card	P	4	4
4R	Read-Punch Feed*		R is modifier	
4(I)R	Read-Punch Feed and Branch*		R is modifier	
5	Read-Punch	RP	C41	5
6	Write-Punch	WP	C42	6
6R	Write-Read Punch Feed*		R is modifier	
6(I)R	Write-Read Punch Feed and Branch*		R is modifier	
7	Write-Read-Punch	WRP	421	7
8	Start Read Feed*	SRF	8	8
9	Start Punch Feed*	SPF	C81	9

ARITHMETIC CODES

OPERATION CODE	FUNCTION	MNEMONIC	BCD CODE	CARD CODE
A	Add	A	BA1	12-1
S	Subtract	S	CA2	0-2
?	Zero and Add	ZA	CBA82	12-0
!	Zero and Subtract	ZS	B82	11-0
@	Multiply*	M	C84	4-8
%	Divide*	D	A84	0-4-8

LOGIC OPERATION CODES

OPERATION CODE	FUNCTION	MNEMONIC	BCD CODE	CARD CODE
B(I)	Branch	B	BA2	12-2
B(I)d	Branch if Indicator ON		d is modifier	
B(I)(B)d	Branch if Character is Equal	Contents of B compared to d		
V(I)(B)d	Branch if WM and/or Zone	BWZ	A41	0-5

MOVE AND LOAD CODES

OPERATION CODE	FUNCTION	MNEMONIC	BCD CODE	CARD CODE
D	Move Numerical	MN	BA[illegible]	[illegible]
L	Load Character to A Word Mark	LCA	B21	[illegible]
M	Move Characters to A or B Word Mark	MCW	CB[illegible]	[illegible]
Y	Move Zone	MZ	CA[illegible]	[illegible]
Z	Move Characters and Suppress Zeros	MCS	AB1	0-9
,	Set Word Mark	SW	CA821	0-3-8
□	Clear Word Mark	CW	CBA84	12-4-8

* Special Feature

MISCELLANEOUS OPERATION CODES

OPERATION CODE	FUNCTION	MNEMONIC	BCD CODE	CARD CODE
C	Compare	C	CBA21	12-3
E	Move Characters and Edit	MCE	CBA41	12-5
F	Control Carriage	CC	CBA42	12-6
H	Store B-Address Register*	SBR	BA8	12-8
K	Select Stacker	SS	CB2	11-2
N	No Operation	NOP	B41	11-5
Q	Store A-Address Register*	SAR	CB8	11-8
/	Clear Storage	CS	CA1	0-1
.	Halt	H	BA821	12-3-8
#	Modify Address*	MA	821	3-8

CHARACTER AT d FOR BRANCH

d	BRANCH ON	d	BRANCH ON
␢	Unconditional	R	Carriage Busy*
9	Carr. Chan. #9	T	Low Compare B < A*
A	"Last Card" Switch	U	High Compare B > A*
B	Sense Switch B*	Z	Overflow
C	Sense Switch C*	?	Reader Error if I/O Check Stop Switch OFF
D	Sense Switch D*		
E	Sense Switch E*	!	Punch Error if I/O Check Stop Switch OFF
F	Sense Switch F*		
G	Sense Switch G*	⌑	Printer Error if I/O Check Stop Switch OFF
K	End of Reel*	@	Carr. Chan. #12
L	Tape Error*	%	Processing Check with Process Check Switch OFF
S	Equal Compare B = A*		
P	Printer Busy*	/	Unequal Compare B ≠ A

CHARACTER AT d FOR MAGNETIC TAPE / DISK STORAGE

d	OPERATION	d	BRANCH ON
B	Backspace Tape Record	N	Access Inoperable
E	Skip and Blank Tape	V	Read/Write Parity Check or Read Back Check Error
M	Write Tape Mark	W	Wrong-Length Record
R	Rewind Tape	X	Unequal Address Compare
U	Rewind Tape and Unload	Y	Any Disk Storage Error Condition

CHARACTER AT d FOR 1407 CONSOLE INQUIRY STATION

d		d	
Q	Inquiry Request (1407)	.	Inquiry Clear (1407)

MAGNETIC TAPE %UX TAPE UNIT ADDRESS

INSTRUCTION	FUNCTION	MNEMONIC	BCD CODE	CARD CODE
L(%UX)(B)d	Read/Write Tape with Word Marks	d-modifier, R-Read Tape W-Write Tape		
M(%UX)(B)d	Read/Write Tape			
M(%CX)(B)R	Read Compressed Tape*	(%CX) is address of tape unit		
P(A)(B)	Move Characters to Record or Group Mark*	MCM	CB421	11-7
U(%UX)d	Control Unit	CU	CA4	0-4
X(A)(B)	Move and Insert Zeros*	MIZ	CA421	0-7

COLUMN BINARY

INSTRUCTION	FUNCTION	REMARKS
1C	Read Column Binary	C is Modifier
4C	Punch Column Binary	C is Modifier
M(A)(B)A	Move and Binary Decode	A is Modifier
M(A)(B)B	Move Binary Code	B is Modifier
M(%BX)(A)R	Read Binary Tape	%BX is Address of tape unit
M(%BX)(A)W	Write Binary Tape	
W(I)(B)d	Branch if Bit Equal	BBE is mnemonic

DISK STORAGE %FX DISK OPERATION

INSTRUCTION	FUNCTION	REMARKS
M(%F0)(B)R	Seek Disk	B is Disk Address
M(%FX)(B)R	Read Disk	X can be 1, 2, or 3
M(%FX)(B)W	Write Disk	1 Specifies Single Record
L(%FX)(B)R	Read Disk with Word Marks	2 Specifies Full Track
L(%FX)(B)W	Write Disk with Word Marks	3 Specifies a Write Disk Check operation M(%F3)(B)W

1407 INQUIRY %T0 ADDRESS

INSTRUCTION	FUNCTION	REMARKS
M(%T0)(B)R	Read Console Printer	Data from 1407 transferred to B-address
M(%T0)(B)W	Write Console Printer	Data at B-address transferred to 1407
L(%T0)(B)R	Read Console Printer with Word Marks	Data from 1407 transferred to B-address with Word Marks
L(%T0)(B)W	Write Console Printer with Word Marks	Data at B-address transferred to 1407 with Word Marks
M(%T0)(B)W	Line Space	B is address of a Group Mark with a Word Mark

IS INFORMATION PROCESSED EFFICIENTLY ?

THIS INFORMATION . . . IS PROCESSED BY THIS METHOD (%)

	MANUALLY	CONTROL BOARDS	EDGE-NOTCHED CARDS	PUNCHED CARD TAB. EQUIPMENT	COMPUTER	NO METHOD
CUSTOMER DELIVERY SCHEDULES AND ORDER BACKLOG	58	7	2	27	10	4
PRODUCTION ORDER:						
QUANTITY AND TIMING	66	8	1	15	11	1
PREPARATION	67	3	2	15	8	2
DETAIL SCHEDULES FOR PRODUCTION DEPARTMENT	69	11	1	11	5	7
FOLLOW-UP REPORTING OF PROGRESS ON SCHEDULES	68	7	1	14	5	4
INVENTORY RECORDS:						
FINISHED GOODS	56	1	1	34	15	1
WORK IN PROCESS	59	3	3	24	9	5
RAW MATERIALS	67	1	1	23	10	1

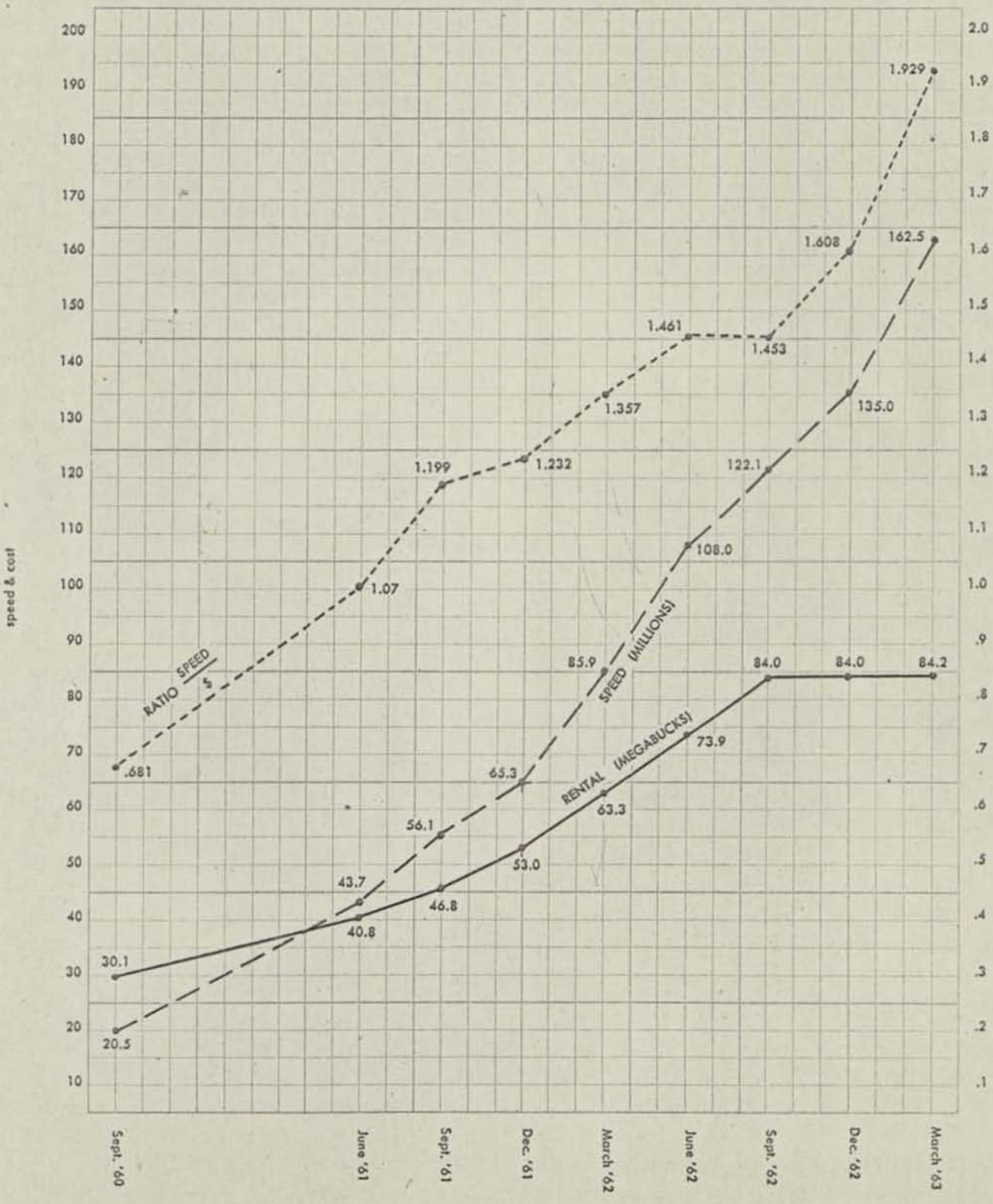
DATAMATION'S QUARTERLY INDEX OF COMPUTING

With compute speed increasing and rental costs remaining constant, the computer-per-buck ratio has risen sharply during the first quarter of 1963. Two factors contribute to this rising computing index: sales of small to medium range hardware at a faster rate than the replacement of vacuum tube devices, and the addition of large computers to the constantly-revised basis of the statistics.

The number of ops/sec rose 20.3 per cent over the previous quarter, from 135.0-162.5, attributable to both the readjusted statistical base and continuing installations of 7070s and 90s, a combined total now exceeding 500.

Concurrently, however, the cost index rose a negligible 0.2 of a point, remaining level at 84.2 megabucks for the second consecutive quarter—during which the speed index increased by 24.8 per cent.

The resultant ratio of computing power per dollar, which represents the quotient of the speed and operations per dollar indices, is established at 1.929. The 20 per cent increase is the largest during the history of this study.



PROCESS CONTROL COMPUTERS

computer list

<table>
<tr><th></th><th>First Delivery Month and Year</th><th>Processor Speed Complete Add Time in Microseconds</th><th>Storage Cycle Time in Microseconds</th><th>Internal Storage Capacity in Words / Type</th><th>Logic Word Size / Instr. Addresses</th><th>Magnetic Tape Thousands of Characters per Second / Buffering</th><th>Maximum Units Attachable</th><th>Random Access File Capacity / Access Time in Milliseconds</th><th>Peripheral Devices Cards per Minute In—Out</th><th>Paper Tape Characters per Second In—Out</th><th>Printer Lines per Minute</th><th>Input-Output Channels Number and Type</th><th>Direction</th><th>Transfer Rate</th><th>Other Features: Program Interrupt</th><th>Index Registers</th><th>Indirect Addressing</th><th>Floating-point Arith.</th><th>Console Typewriter</th></tr>
<tr><td>DAYSTROM 46</td><td>/58</td><td>220</td><td>10</td><td>4-16K core
16-100K drum</td><td>21b[E]
1</td><td>83
RC, WC</td><td>4</td><td>—
—</td><td>12
12</td><td>300
110</td><td>300</td><td>1p[Q]</td><td>I & O</td><td>100K</td><td>√</td><td>1</td><td>—</td><td>—</td><td>I/O</td></tr>
<tr><td></td><td colspan="19">E. Double-precision arithmetic available. Q. Channel with direct access to memory.</td></tr>
<tr><td>DAYSTROM 136</td><td>8/61</td><td>28</td><td>4</td><td>4-16K core
16-172K drum</td><td>25b[E]
1</td><td>83
RC, WC</td><td>4</td><td>—
—</td><td>12
12</td><td>300
110</td><td>300</td><td>1p</td><td>I or O</td><td>890K</td><td>√</td><td>64</td><td>√</td><td>—</td><td>I/O</td></tr>
<tr><td></td><td colspan="19">E. Double-precision arithmetic available. Note. UNICOMP (Universal Compiler for Process Control) available 4/63. System designed to work in vans and under extreme temperatures.</td></tr>
<tr><td>DAYSTROM 636</td><td>8/63</td><td>17</td><td>4</td><td>4-32K core
16-262K drum</td><td>15b[E]
1</td><td>83
RC, WC</td><td>4</td><td>—
—</td><td>60
12</td><td>300[N]
110</td><td>300[P]</td><td>1p[Q]</td><td>I or O</td><td>890K</td><td>√</td><td>2</td><td>√</td><td>—</td><td>I/O</td></tr>
<tr><td></td><td colspan="19">E. Double-precision arithmetic instructions included along with variable-field selection and partial operand instructions. N. Lower speed paper-tape equipment available. Eleven column lines. Input-output channel has direct access to the core memory UNICOMP (Universal Compiler for Process Control) available 4/63. System designed to operate in vans and at extreme temperatures.</td></tr>
<tr><td>COLLINS ★ DATA CENTRAL</td><td>?</td><td>10
6</td><td>5</td><td>4-65K core[D]</td><td>1
1</td><td>?
MRWC</td><td>4</td><td>40M[K]</td><td>?
?</td><td>350
110</td><td>600</td><td>1sp
1sp</td><td>I & O
I & O</td><td>1.6K
2.4K</td><td>√[T]</td><td>?</td><td>?</td><td>?</td><td>?</td></tr>
<tr><td></td><td colspan="19">D. System features programmed logic through a separate "programmed logic unit storage" of 512 to 1,024 words of one-microsecond cycle time, non-destructive. K. Disc storage of 20 million bits per disc and 12 discs per unit. T. Priority processing.</td></tr>
<tr><td>GENERAL ☆ ELECTRIC 312</td><td>?</td><td>196</td><td>?</td><td>8-56K drum[D]</td><td>20b
1</td><td>—
—</td><td>—</td><td>—
—</td><td>—
—</td><td>60
60</td><td>—</td><td>1</td><td>I & O</td><td>3K</td><td>?</td><td>?</td><td>?</td><td>?</td><td>?</td></tr>
<tr><td></td><td colspan="19">D. 640-word fast track.</td></tr>
<tr><td>GENERAL ☆ ELECTRIC 412</td><td>?</td><td>40</td><td>?</td><td>4-8K core</td><td>20b
1</td><td>—
—</td><td>—</td><td>—
—</td><td>40
—</td><td>100
100</td><td>—</td><td>1</td><td>I & O</td><td>3K</td><td>?</td><td>?</td><td>?</td><td>?</td><td>?</td></tr>
<tr><td>GENERAL ★ PRECISION LIBRATROL 1000</td><td>/60</td><td>1000</td><td>17000</td><td>8-16K drum[D]</td><td>32b
2</td><td>—
—</td><td>—</td><td>—
—</td><td>—
—</td><td>500
60</td><td>300</td><td>1s[Q]
1p</td><td>I
O</td><td>2K
2K</td><td>—</td><td>1</td><td>—</td><td>—</td><td>I/O</td></tr>
<tr><td></td><td colspan="19">D. Drum offers 128 words in dual access tracks of four- to six-microsecond access time and eight words with a two-microsecond maximum access time. Q. Input system features a 200-microsecond analog to digital converter yielding 11-bit words. Control outputs are 10-bit words. Note. This is the industrial control version of the RPC 4000.</td></tr>
<tr><td>HONEYWELL ☆ 290</td><td>/60</td><td>140</td><td>20</td><td>1-4K core
8-256K drum</td><td>186
1</td><td>15
RC, WC</td><td>2</td><td>—
—</td><td>—
—</td><td>110
60</td><td>—</td><td>?</td><td>?</td><td>?</td><td>√</td><td>√[U]</td><td>—</td><td>√</td><td>I/O</td></tr>
<tr><td></td><td colspan="19">U. Any core location may be used as an index register.</td></tr>
<tr><td>IBM 1710 ☆</td><td>2/62</td><td>560[B]</td><td>20</td><td>20-60K core</td><td>1d
2</td><td>—
—</td><td>—</td><td>15M[K]
250</td><td>250
150</td><td>150
15</td><td>—</td><td>?</td><td>?</td><td>?</td><td>√</td><td>—</td><td>√</td><td>√</td><td>I/O</td></tr>
<tr><td></td><td colspan="19">B. Add time assumes a five-character field. K. Up to five 1311 disc drives with interchangeable packs of three million characters each. Note. This is the industrial control version of the IBM 1620 computer.</td></tr>
<tr><td>ITT 025 ☆</td><td>/59</td><td>16</td><td>8</td><td>16-65K core[D]</td><td>32b
1</td><td>15
RW</td><td>16</td><td>1.3M[K]
9.6</td><td>250
100</td><td>—
—</td><td>900</td><td>86p
32p
1p
1p</td><td>I & O
I & O
I & O
I & O</td><td>2.4K
4.8K
.6M
.6M</td><td>√</td><td>256</td><td>√</td><td>—</td><td>—</td></tr>
<tr><td></td><td colspan="19">D. 256-word index and 256-word program storage included with six-microsecond access time. Up to sixteen drums of 16,000 words each.</td></tr>
<tr><td>ITT 525-VADE ☆</td><td>•3/63</td><td>6</td><td>2</td><td>4-32K core[D]</td><td>32b
1</td><td>15
RW</td><td>8</td><td>—
—</td><td>—
—</td><td>300
10</td><td>8</td><td>16s
128s</td><td>I & O
I & O</td><td>8M
?</td><td>√</td><td>1</td><td>—</td><td>—</td><td>I/O</td></tr>
<tr><td></td><td colspan="19">D. Six-microsecond commands use micro-logic mode and require three memory cycles.</td></tr>
<tr><td>RAMO- ★ WOOLDRIDGE TRW 300</td><td>?</td><td>780</td><td>?</td><td>8-15K drum</td><td>18b[E]
2</td><td>7.5
—</td><td>8</td><td>—
—</td><td>—
—</td><td>60
60</td><td>—</td><td>1024p
128p</td><td>I
O</td><td>25K
600</td><td>?</td><td>?</td><td>?</td><td>?</td><td>?</td></tr>
<tr><td></td><td colspan="19">E. Two words per instruction.</td></tr>
<tr><td>RAMO- ★ WOOLDRIDGE TRW 330</td><td>?</td><td>2600</td><td>?</td><td>7-130K drum</td><td>28b
1</td><td>—
—</td><td>—</td><td>—
—</td><td>?
?</td><td>?
?</td><td>?</td><td>1
1</td><td>I
O</td><td>1680
100K</td><td>√</td><td>3</td><td>?</td><td>?</td><td>?</td></tr>
<tr><td>RAMO- ★ WOOLDRIDGE TRW 340</td><td>?</td><td>16</td><td>8</td><td>4-16K core
8-131K drum</td><td>28b
1</td><td>—
—</td><td>—</td><td>—
—</td><td>?
?</td><td>?
?</td><td>?</td><td>1
1</td><td>I
O</td><td>1680</td><td>?</td><td>?</td><td>?</td><td>?</td><td>?</td></tr>
</table>

☆ Information supplied or confirmed by manufacturer but not reviewed in detail by publisher.
★ Incomplete information compiled from various sources but not confirmed by manufacturer.

SECTION III

DOD & OTHER U. S. GOVERNMENT SYSTEMS

System	First Delivery Month and Year	Processor Speed Complete Add Time in Microseconds	Storage Cycle Time in Microseconds	Internal Storage Capacity in Words	Type	Logic Word Size / Instr. Addresses	Magnetic Tape Thousands of Characters per Second / Buffering	Maximum Units Attachable	Random Access File Capacity / Access Time in Milliseconds	Peripheral Devices Cards per Minute In—Out	Paper Tape Characters per Second In—Out	Printer Lines per Minute	Input-Output Channels Number and Type	Direction	Transfer Rate	Other Features Program Interrupt	Index Registers	Indirect Addressing	Floating-point Arith.	Console Typewriter
GENERAL PRECISION LIBRASCOPE L-2010 ★	?	78	10000	4K	disc	30b 1[F]	— —	—	— —	— —	300 100	—	1p	I or O	?	—	—	—	—	I/O
HONEYWELL PICO ☆	?	12	2	3-8K	core[D]	24b[E] 1	— —	—	— —	— —	— —	— —	32sp 48sp	I O	3M 3M	√	—	—	—	—
IBM AN/FSQ-7 (SAGE) ★	11/57	12	6	69K 153K	core drum	32b[E] 1	18.6 MRWC	8	— —	150 100	— —	500	—[Q]	—	—	—	4	—	—	—
IBM AN/FSQ-32 ★	10/60	2.5[B]	2.5	81-163K	core	48b[E] 1	62.5 MRWC	24	4.4M 11	200 100	— —	600	32s[Q] 40s 32sp 25s 8s 25sp	I I I O O O	1.3K 1.6K 500 1.3K 1.3K 500	—	13	√	√	I/O
PHILCO AN/TYK-4V (COMPAC) ★	?	24	12	4-16K	core	36b 1	45 RC, WC	8	— —	— —	300 30	—	1sp	I & O	45K	?	11	—	—	I/O
PHILCO BASICPAC ★	11/59	24	12	4-28K	core	38b 1	45 MRWC	35[J]	— —	— —	30 20	—	7sp[Q] 6sp 1sp	O I I	75-1.2K 75-1.2K 75-1.2K	√	4	—	—	O
RAMO WOOLDRIDGE TRW 130 ☆	?	12	6	8-32K	core	15b 0-1[F]	15-41 RWC	16	— —	200 —	300 60	150	2p 1p 1p	I or O I or O I or O	1M 500K 25M	√	—[U]	√[V]	—	I/O
SYLVANIA 9400 ☆	10/60	8	4	16-32K	core	36b 1	90 MRWC	252[J]	6300M[K] 53	2000 250	1000 100	900	4p 1p	I or O I & O	740K 9M	√	7	—	√	O
SYLVANIA AN/MYK-1(U) (MOBIDIC) ☆	/59	16	8	4-8K	core	36b 1	38 MRWC	252	315M[K] 53	800 250	1000 100	900	4p 1p	I or O I & O	237K 4.6M	?	?	?	?	?
SYLVANIA M-64 ☆	?	10	4	28K	core	24b 1	45 MRWC	4	— —	200 100	1000 100	300	4sp 1sp	I O	43K 42K	√	2	—	—	O
UNIVAC 1206 ☆	/58	9.6[B] 11.2	8	16-32K	core	30b 1	25 MRWC	168[J]	377M[K] 17	600 150	1500[N] 110	600 700	12p 2p	I or O I or O	.9M .9M	√	7	—	—	I/O
UNIVAC TARGET INTERCEPT ★	10/60	10	2.2[C]	12K	core[D]	24b 1	30 ?	5	— —	— —	— —	— —	?	?	?	√	15	—	—	I/O

GENERAL PRECISION LIBRASCOPE L-2010: F. Instruction contains address of next instruction to be executed. Note. System designed for mobile operation. Size. Computer area 2 cu. ft., weight 60 lbs., power consumption 500w.

HONEYWELL PICO: D. 3,000 words of biax memory permit non-destructive readout for program storage. E. Three instructions stored in every two memory words. Note. System designed for operation in missiles and airplanes under extreme temperatures. Size. Height 5", width 13", depth 10.5", weight 20 lbs., power consumption 46w.

IBM AN/FSQ-7 (SAGE): E. Accumulator split into two 15-bit plus sign registers. Arithmetic commands operate on either half or full (but not coupled) accumulator. Q. All input-output is buffered through the drum system. Size. Computer floor area 1,508 sq. ft., weight 113 tons, power consumption 1,500 kw.

IBM AN/FSQ-32: B. Instruction look-ahead allows increased internal speed. E. Data can be handled in the arithmetic section as two independent half words of 24 bits each, or as six-bit "bytes". Q. Output data must be buffered through "dator" drum system, which has 139,000 words. Input-output data channel has maximum rate of 1.5 million bits per second. Size. Computer floor area 1,161 sq. ft., weight 90 tons, power consumption 203 kw.

PHILCO AN/TYK-4V (COMPAC): Note. Major component of the U. S. Army automatic data processing system. Designed for mobile operation under extreme temperatures. Size. Computer area 9 cu. ft., weight 200 lbs., power consumption 4 kva.

PHILCO BASICPAC: J. One I/O converter handles five I/O devices. System can have up to seven I/O converters. Q. One communications converter handles up to seven two-way real-time channels. Note. System designed to operate in vans and under extreme temperatures. Size. Height 21", width 24", depth 60", weight 900 lbs., power consumption 2.5 kw.

RAMO WOOLDRIDGE TRW 130: F. Two instructions per word in no-address mode. U, V. Indirect addressing, indexing, and multiple-word-length operations facilitated by micro-programming technique. Note. Designed to operate in vans, ships or airplanes under extreme temperatures. Size. Height 59", width 20", depth 16", weight 530 lbs., power consumption 600w.

SYLVANIA 9400: J. Magnetic tapes read in forward and reverse directions. K. Each disc unit has a capacity of 100 million characters. Size. Computer floor area 360 sq. ft., weight 21,825 lbs., power consumption 20 kva.

SYLVANIA AN/MYK-1(U) (MOBIDIC): K. Each disc file unit stores up to 400 million characters. Note. System designed to work in vans and under extreme temperatures. Height 68", width 62", depth 25", weight 1,350 lbs.

SYLVANIA M-64: Note. System designed for operation in vans or ships and under extreme temperatures. Size. Height 38", width 7", depth 22", weight 230 lbs., power consumption 1,281 w.

UNIVAC 1206: B. 9.6 microseconds is add time for repeat mode only. J. Magnetic types read in forward and reverse directions. K. Each flying head drum unit has a capacity of 3,932,160 BCD characters. N. 300 ch/sec reader available.

UNIVAC TARGET INTERCEPT: C, D. Storage consists of 10,000 words of "permanent" storage with a cycle time of 2.8 microseconds; 2,000 words of "variable" storage with a cycle time of 2.2 microseconds; 15 14-bit words of "reference" memory with a cycle time of 0.9 microseconds; and 48 words of "read-time" memory with a cycle time of 2.8 microseconds. Also, an overlapping instruction repertoire and simultaneous execution of arithmetic and non-arithmetic sequences permit concurrent operations.

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FOREIGN COMPUTERS

England

Computer		Monthly Rental: Typical / Range	First Delivery: Month and Year	Processor Speed: Complete Add Time in Microseconds	Storage Cycle Time in Microseconds	Internal Storage: Capacity in Words, Type	Logic: Word Size / Instr. Addresses	Magnetic Tape: Thousands of Characters per Second	Buffering	Maximum Units Attachable	Random Access File: Capacity / Access Time in Milliseconds	Peripheral Devices: Cards per Minute In — Out	Paper Tape Characters per Second In — Out	Printer Lines per Minute	Off-line Equipment	Other Features: Program Interrupt	Index Registers	Indirect Addressing	Floating-point Arith.	Console Typewriter	Software: Algebraic Compiler	Business Compiler	Notes
AEI-1010	☆	$9,800 (6.7-42)	/60	18	8.5	4K core	44b[F] 1	10-120	MRWC	31	5.3M[L] 1000	400 100	1000 300	1000 3000	—	√	7	√	√	I/O	—	—	F. Two instructions per word. L. Carousel file unit with 5.3 million characters. Additional random access of 100,000-character drum storage with 10-millisecond access time. Also, 50,000 characters of additional core with 14-microsecond access time.
COMPUTER ENGINEERING 102	★	?	/61	?	10	20 core[E] 4-28K drum	32b ?	—	—	—	√[K] ?	? ?	200 200	?	?	?	?	?	?	?	?	?	E. Twenty-word core working storage. Optional 4,000 words of core storage instead of drum available. K. Up to seven drums of 4,000 words each.
ELLIOTT 503		$8,300[A] (5.5-26)	4/63	?	3.5	8K core	39b 1	40[K]	RWC	16	131K[L] 15	400 300	1000 100	1000	—	√	√[T]	—	√	I/O	6/62[X]	—	A. Prices include 12.5% import duty. This computer is commercially available in the United States. K. Tapes are IBM compatible. L. Slow-speed core storage (50-microsecond cycle time) in blocks of 16,000 words up to a maximum of eight blocks. T. Any storage location may be used as an index register. X. ALGOL '60, FORTRAN /63.
ELLIOTT 803		$3,750[A] (2.4-8.7)	3/61	576	24	4-8K core	39b 1	4.3	None[J]	4	— —	340 100	500 100	300	—	—	√[T]	—	√	O	6/62[X]	—	A. Prices include 12.5% import duty. This computer is commercially available in the United States. J. Search-compute only. T. Any storage location may be used as an index register. X. ALGOL '60.
EMI EMIDEC 1100	★	?	/60	?	?	1K core[E]	35b ?	?	?	16	320K[L]	400 ?	350 ?	600 3000	?	?	?	?	?	?	?	?	E. Sixty-four-word fast diode storage. L. Four drums of 16,000 words each available.
EMI EMIDEC 2400	★	?	/61	?	?	16K core[E]	34b ?	?	MRWC	25	?	400 ?	350 ?	600 3000	?	?	?	?	?	?	?	?	E. Sixty-four-word fast diode storage.
ENGLISH ELECTRIC KDF 9	★	?	?	?	?	4-32K core[E]	48b ?	?	?	?	?	400 150	?	900	?	?	?	?	?	?	?	?	E. Fifteen-word fast storage.
ENGLISH ELECTRIC KDN 2	★	?	/61	?	?	.5-4K core	18b ?	—	—	—	— —	? ?	20 20	?	?	?	?	?	?	O	?	?	
ENGLISH ELECTRIC KDP 10	★	?	/62	?	?	16-262K core	1a ?	33	?	62	? ?	400 150	? ?	900	?	?	?	?	?	?	?	?	
FERRANTI ATLAS	★	?	/62	1.1[C]	.3 2 12000	8-262K rod[E] 16-262K core 25-100K drum	48b 1	90	MRWC	32	? ?	600 100	1000 300	3000[Q]	?	√	91	√	√	?	√	√	C. Overlapped core memory banks allow increased internal speed. E. Ferrite rod memory is non-destructive and designed for subroutine storage. Q. 600 lpm printer also available. 3000 lpm device is Xeronic printer.
FERRANTI ORION	★	?	?	64	?	1-16K core	48b 2-3	90	MRWC	64	—[L] 12	600 100	1000 300	1000	?	√[S]	64	√	√	I/O	?	?	L. Random access of 16,000-word drums available. S. Priority processing and automatic time-sharing of several simultaneous independent transfers between drums and core are possible.
FERRANTI SIRIUS	★	?	/60	250	4000	1-10K delay	10d ?	?	?	?	? ?	? ?	300 60	?	?	?	?	?	?	?	?	?	
ICT 1301	☆	$3,500[A]	/61	21	?	2K core	12d ?	?[H]	RW	8	96K[L] ?	600 100	? ?	600	?	?	?	?	?	?	?	?	A. Excludes cost of magnetic tape units. H. Ampex FR300 or 400 tape units available. L. One to eight drums, each with a capacity of 12,000 words, may be attached.
ICT 1500	☆	$5,200 (3.3-)	/61	189	7	10-40K core	1a 2	33-66	RC, WC, RW	12	176M[L] 100	600 110	1000 100	1000	?	?	?	?	?	I/O	?	√[Y]	L. Up to two disc file units, each with a capacity of 22, 44, 66, or 88 million alphanumeric characters, are available. Up to six record files, with a capacity of 4.6 million alphanumeric characters, are also available. Y. COBOL. Note. This appears to be a version of the RCA 301.
LEO III	☆	$11,200 (8.4-19.6)	/62	34[C]	13.5	4-32K core	40b[F] 1[G]	22-90	MRWC	32	— —	600 100	1000 110	1000	—	√	12	√	√	O	√[X]	√[Y]	C. Built-in mixed-radix arithmetic and data-handling operations. F. Multi-programming of up to 13 programs, each fully protected by tag reservation. G. Instructions stored two per word. X, Y. CLEO.

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★Incomplete information compiled from various sources but not confirmed by manufacturer.

System		Monthly Rental Typical Range	First Delivery Month and Year	Processor Speed Complete Add Time in Microseconds	Storage Cycle Time in Microseconds	Internal Storage Capacity in Words	Type	Logic Word Size Instr. Addresses	Magnetic Tape Thousands of Characters per Second Buffering	Maximum Units Attachable	Random Access File Capacity Access Time in Milliseconds	Peripheral Devices Cards per Minute In—Out	Paper Tape Characters per Second In—Out	Printer Lines per Minute	Off-line Equipment	Other Features Program Interrupt	Index Registers	Indirect Addressing	Floating-point Arith.	Console Typewriter	Software Algebraic Compiler	Business Compiler
LEO III/F	☆	$14,000 (11.2-33.6)	/64	4[C] 12	2[D] 6	4-32K	core	40b[F] 1[G]	22-90 MRWC	32	— —	600 100	1000 110	1000	—	√	12	√	√	O	√[X]	√[Y]
		C. Built-in mixed-radix arithmetic and data-handling operations. D. Two-microsecond core memory available as option. F. Multi-programming of up to 13 programs, each fully protected by tag reservation. G. Instructions stored two per word. X, Y. CLEO.																				
STC STANTEC ZEBRA	★	$2,100	/58	?	?	8K 12	drum fast	33b ?	? ?	32	? ?	? ?	200 10	?	?	?	?	?	?	?	?	?

France

System		Monthly Rental Typical Range	First Delivery Month and Year	Processor Speed Complete Add Time in Microseconds	Storage Cycle Time in Microseconds	Internal Storage Capacity in Words	Type	Logic Word Size Instr. Addresses	Magnetic Tape Thousands of Characters per Second Buffering	Maximum Units Attachable	Random Access File Capacity Access Time in Milliseconds	Peripheral Devices Cards per Minute In—Out	Paper Tape Characters per Second In—Out	Printer Lines per Minute	Off-line Equipment	Other Features Program Interrupt	Index Registers	Indirect Addressing	Floating-point Arith.	Console Typewriter	Software Algebraic Compiler	Business Compiler
BULL GAMMA 10	☆	$2,000 (1.6-24)	/63	200	7	1-4K	core	1a 2	— —	—	— —	300 300	— —	300 600	—	√	—	√	—	—	—	—
BULL GAMMA 30		$7,000 (4-16)	2/62	217	7	10-40K	core	1a 2	10-66 RC, WC, RW	14	176M[L] 100	600 300	1000 100	1000	—	—	—	√	—	I/O	—	/63[Y]
		L. Each disc unit has a capacity of 4.6 million characters. Up to six disc units, with an average access time of 4.25 seconds, may be attached. Additionally, up to two Bryant disc file units, each of four modules of 22, 44, 66, or 88 million alphanumeric characters, are available. Y. COBOL. Note. Central processor is a version of the RCA 301.																				
BULL GAMMA 30S		$8,800 (6.3-18)	/63	70	7	20-40K	core	1a 2	10-66 RWC	14	177M[L] 100	600 300	1000 100	1000	—	—	3	√	√	I/O	/63[X]	/63[Y]
		L. Up to two Bryant disc file units, each of four modules of 22, 44, 66, or 88 million alphanumeric characters, are available; or up to six record files of 4.6 million characters each are also available. X. ALGOL. Y. COBOL. Note. Central processor is a version of the RCA 301 Model 354, 355.																				
BULL GAMMA 60	☆	$32,000 (28-68)	/60	200	10	8-32K	core	24b 1-3	21 MRWC	48	512K[L] 10	300 300	800	300[Q]	—	√	—	√	√	I/O	/63[X]	/63[Y]
		L. Random access of up to four drum units each with 153,600 characters. Q. Double-feed type line printer. X. ALGOL. Y. COBOL.																				
BULL GAMMA MDE (300)	☆	$4,200 (3.7-4.6)	10/59	865	173	64	delay[E]	12d 1	21 RWC	8	196K[L] 11	300 300	— —	300	—	√	—	—	√	—	/57	—
		E. Additional delay line storage available. L. Drum storage.																				
CIT CITAC 210B	☆	$2,000 (1.6)	/61	150	20	4-32K	core	21b[F] 1	— —	—	72M[L] 100	— —	500[P] 40	—	—	√	7	—	—	—	—[X]	—
		F. Two words per instruction. L. Disc units in increments of three million alphanumeric characters. P. Analog input and output systems available. X. CITAC AUTOCODE.																				
SEREL 1001	☆	$3,000 (2-6)	/60	20	6	4-32K	core	20b 1	√ MRWC	√	700M[L] 10	√[N] √	√[P] √	√[Q]	—	√	2	√	—	I/O	—	—
		L. Random access drums with capacity chosen according to specific requirements. N, P, Q. Any manufactured equipment adaptable.																				

Germany (West)

System		Monthly Rental Typical Range	First Delivery Month and Year	Processor Speed Complete Add Time in Microseconds	Storage Cycle Time in Microseconds	Internal Storage Capacity in Words	Type	Logic Word Size Instr. Addresses	Magnetic Tape Thousands of Characters per Second Buffering	Maximum Units Attachable	Random Access File Capacity Access Time in Milliseconds	Peripheral Devices Cards per Minute In—Out	Paper Tape Characters per Second In—Out	Printer Lines per Minute	Off-line Equipment	Other Features Program Interrupt	Index Registers	Indirect Addressing	Floating-point Arith.	Console Typewriter	Software Algebraic Compiler	Business Compiler
TELEFUNKEN TR4	★	?	?	11	6	4-32K	core	48b ?	37.5 MRWC	64	? ?	800[M] 250	1000[N] 300	?	?	?	?	?	?	?	?	?
		M. 700 cpm reader and 100 cpm punch available. N. 500 cps reader and 150 cps punch available.																				
TELEFUNKEN TR5	★	?	?	?	?	64K	core	1d ?	35 ?	8	? ?	800 250	1000 300	?	?	—	252	—	—	—	?	?
ZUSE Z23	☆	$3,700 (2-5.5)	/60	300	18 5000	.2-8K 8K	core drum	40b 2	15 RC, WC	4	— —	120 120	300 150	300	—	√	240	√	—	I/O	—	—
ZUSE Z25	☆	$1,300 (.7-5.6)	—	125	10	1-18K	core[E]	18b 1	15-100 None	8[K]	√[L] 10	200 100	300 150	300	—	√	√	√	—	I/O	—	—
		E. Fixed-core storage of 1,000 to 2,000 words is included. K. Additional tape units available as option. L. Random access drum files available.																				
ZUSE Z31	☆	$5,500 (2.1-15.8)	/62	420	420	1-10K	core[E]	11d 1	18[H] None	12[K]	2.6M[L] 20	800 300	300 150	1000	—	—	10	√	—	I/O	—	—
		E. Fixed-core storage of 2,600 words is included. H. Transfer rate is for four-bit decimal characters. K. Additional tape units are available as option. L. Additional drums of 66,000 BCD characters each are available.																				

Japan

System		Monthly Rental Typical Range	First Delivery Month and Year	Processor Speed Complete Add Time in Microseconds	Storage Cycle Time in Microseconds	Internal Storage Capacity in Words	Type	Logic Word Size Instr. Addresses	Magnetic Tape Thousands of Characters per Second Buffering	Maximum Units Attachable	Random Access File Capacity Access Time in Milliseconds	Peripheral Devices Cards per Minute In—Out	Paper Tape Characters per Second In—Out	Printer Lines per Minute	Off-line Equipment	Other Features Program Interrupt	Index Registers	Indirect Addressing	Floating-point Arith.	Console Typewriter	Software Algebraic Compiler	Business Compiler
FUJI FACOM 222	★	?	10/60	160	?	2-10K	core	7d 1	15 ?	10	700K[L] ?	500 200	400 170	300 500	?	?	99	?	—	—	?	?
		L. Random access is drum.																				
FUJI FACOM 241	★	?	6/61	250	?	1-4K	core	7d 1	15 ?	10	? ?	500 200	400 170	300 500	?	?	4	?	—	—	?	?

☆Information supplied or confirmed by manufacturer but not reviewed in detail by publisher.
★Incomplete information compiled from various sources but not confirmed by manufacturer.

Computer	Monthly Rental Typical Range	First Delivery Month and Year	Processor Speed Complete Add Time in Microseconds	Storage Cycle Time in Microseconds	Internal Storage Capacity in Words / Type	Logic Word Size Instr. Addresses	Magnetic Tape Thousands of Characters per Second Buffering	Maximum Units Attachable	Random Access File Capacity Access Time in Milliseconds	Peripheral Devices Cards per Minute In — Out	Paper Tape Characters per Second In — Out	Printer Lines per Minute	Off-line Equipment	Other Features Program Interrupt	Index Registers	Indirect Addressing	Floating-point Arith.	Console Typewriter	Software Algebraic Compiler	Business Compiler
HITACHI HITAC 103 ★	?	/60	400	10	1K core 8K drum	48b 1	2 ?	8	? ?	—	200 8	300	?	?	0	?	√	I/O	?	?
HITACHI HITAC 201 ★	?	6/61	4000	3300	9K core 4K drum	12d 1	.2 ?	4	48K[L] ?	—	200 6	120	?	?	8	?	—	I/O	?	?
	L. Random access is drum.																			
HITACHI HITAC 301 ★	?	5/59	3000	3000	.2K core 2K drum	12d 1	2 ?	10	108K[L] ?	200 100	200 8	300	?	?	0	?	√	O	?	?
	L. Random access is drum.																			
HITACHI HITAC 3010 ★	?	?	300	70	40K core 4K disc	? 2	1.3 ?	?	? ?	?* ?	1000 100	1000	?	?	?	?	?	?	?	?
MATSUSHITA MADIC IIA ☆	$1,000 (1.2-1.7)	/61	1000	11	4K drum	33b 1[G]	.4 None	2	— —	— —	200[P] 70	—	—	—	2	—	√	I/O	/63[X]	—
	G. The last address indicates the address of the next instruction. P. 1,000-conversion-per-second analog to digital converter available. X. ALGOL.																			
MATSUSHITA MADIC IIIB ☆	$5,000 (2-7.5)	/63	540	10	4K core	36b 1	15 RWC	8[K]	— —	400 100	400[P] 100	500	—	√	64	√	√	I/O	/63[X]	—
	K. Tapes are IBM compatible. P. 1,000-conversion-per-second analog to digital converter available. X. ALGOL.																			
MITSUBISHI MELCOM 1101F ★	?	3/60	160	7800	4K drum	32b 2	.025 ?	?	? ?	? ?	600 20	—	?	?	7	?	√	I/O	?	?
NIPPON ELECTRIC NEAC 2203 ★	?	5/59	3300	700 8300 20000	.2K core 2K drum 100K drum	12d 1	8 ?	10	? ?	200 100	200 50	200 350	—	?	3	?	√	—	?	?
NIPPON ELECTRIC NEAC 2204 ★	?	12/61	1500	13000	.1K core 3K drum	12d 3	? ?	6	? ?	200 100	200 50	200	—	?	14	?	—	—	?	?
NIPPON ELECTRIC NEAC 2205 ★	?	3/61	2900	12000	3-6K drum	10d 1	.4 ?	4	— —	200 100	100 50	200	?	?	3	?	—	—	?	?
NIPPON ELECTRIC NEAC 2206 ★	?	3/62	100	50	4-10K core 120K drum	12d 1	90 —	20	? ?	600 250	600 50	900	?	?	54	?	√	—	?	?
OKI ELECTRIC 5090D ☆	?	10/61	400	10	4K core	12d 1	10 ?	6	— —	500 150	200 65	500	—	—	1	—	√	I/O	√[X]	—
	X. OKI PAL, OKI ART.																			
TOSHIBA TOSBAC 3100 ★	?	9/61	420	7000	5-10K drum	12d ?	6 RW	10	—	400 100	400 70	200	?	?	3	?	√	?	?	?
TOSHIBA TOSBAC 3200 ★	?	?	240	?	1-5K drum	6d ?	—	—	—	—	400 10	?	?	?	?	?	?	?	?	?
TOSHIBA TOSBAC 4200 ★	?	12/61	420	200	2-40K core	1d 2	6 ?	10	— —	400 100	400 70	200	?	?	6	?	—	I/O	?	?

Sweden

Computer	Monthly Rental Typical Range	First Delivery Month and Year	Processor Speed Complete Add Time in Microseconds	Storage Cycle Time in Microseconds	Internal Storage Capacity in Words / Type	Logic Word Size Instr. Addresses	Magnetic Tape Thousands of Characters per Second Buffering	Maximum Units Attachable	Random Access File Capacity Access Time in Milliseconds	Peripheral Devices Cards per Minute In — Out	Paper Tape Characters per Second In — Out	Printer Lines per Minute	Off-line Equipment	Other Features Program Interrupt	Index Registers	Indirect Addressing	Floating-point Arith.	Console Typewriter	Software Algebraic Compiler	Business Compiler
SAAB D21	$10,000 (4-20)	/62	9.6	4.8	65K core	24b 1	48 MRWC	256	—[L] —	1200 120	1000[P] 150	1000	—	√	√	—	√	I/O	—[X]	—[Y]
	L. Various random access stores can be connected. P. Analog conversion equipment available. X. DAC 11/62, ALGOL 9/63, GENIOUS 12/63. Y. DAC 11/62, COBOL 9/64, GENIOUS 12/63, SORT GENERATOR 6/63.																			

The Netherlands

Computer	Monthly Rental Typical Range	First Delivery Month and Year	Processor Speed Complete Add Time in Microseconds	Storage Cycle Time in Microseconds	Internal Storage Capacity in Words / Type	Logic Word Size Instr. Addresses	Magnetic Tape Thousands of Characters per Second Buffering	Maximum Units Attachable	Random Access File Capacity Access Time in Milliseconds	Peripheral Devices Cards per Minute In — Out	Paper Tape Characters per Second In — Out	Printer Lines per Minute	Off-line Equipment	Other Features Program Interrupt	Index Registers	Indirect Addressing	Floating-point Arith.	Console Typewriter	Software Algebraic Compiler	Business Compiler
ELECTROLOGICA X1	$8,300 (2.7-26)	/58	64	16	.5-32K core	27b 1	30 MRWC	16	31M[L] 15	700 120	1000 300	600	same	√	1	√	√	I/O	6/60[X]	—
	L. Up to eight drums, each with a capacity of 524,288 words. X. ZEBRA, ALGOL '60.																			

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★Incomplete information compiled from various sources but not confirmed by manufacturer.

1963

A SURVEY AND STUDY OF THE COMPUTER FIELD

good survey article

Industrial Securities Committee
Investment Bankers Association of America
Washington 4, D.C.

The editors are pleased to be the first to publish this informative and interesting report on the technology, economics, and application of computers, and of the history, status, and future of the computer industry.

PART 1

THE computer industry is relatively young in age when compared to most other industries. Measured from the date of the first computer installation in 1951, the industry is a little more than a decade old. The more significant date when discussing the industry's development would be the 1953-1954 period, when mass production techniques were applied to computer manufacture, and commercial electronic computers started to be produced on a large scale.

FROM practically no installations or sales in 1951, the industry has grown to a point where there are now 10-12,000 computers in use, with yearly shipments on the order of $1.5 billion. Within the short period of ten years, this industry now finds ranking among the billion dollar industries. There are no official industry statistics available, but it has been estimated that the computer market has been growing twice as fast as the market for office business machines, and on the basis of a 25% annual growth rate since 1957, is growing twice as fast as the electronic industry as a whole.

(Based on a Report of the Committee at the 51st Annual Convention, Hollywood, Fla., November 25-30, 1962.)

AN estimated cumulative total of 16,187 computers have been installed to date. Based on an average selling price when new, the value of these installations is estimated to be in excess of $4.5 billion. Industry experts are predicting shipments of $5.5 billion in 1970, so that this cumulative value could approach $15-20 billion by that date, or an increase of 350% from present levels.

THE rate of technological improvement has been one of the industry's outstanding characteristics. Despite its short history, two generations of computers, vacuum tube and solid state systems, have already been introduced, and a third generation should be introduced by late 1964 or early 1965. These machines will incorporate such advanced components as magnetic thin films, tunnel diodes, and micro-miniaturized circuits, and will operate at speeds measured in billionths of a second. These operating speeds compare with thousandths of a second in vacuum tube machines, and millionths of a second in solid state computers. Future computers will perform up to 2 million operations a second.

THESE technological advances are leading to lower costs per calculating operation. Third generation computers will cost 2.5-times more than current equipment, but will operate 10-times faster. The greatest technological advances will come in peripheral equipment. The development of optical scanners, data transmission equipment and video display systems will open up new multi-million dollar industries.

ECONOMIC justification for the utilization of computers is based on the savings effected in such areas as clerical personnel and inventory. Computer usage has led to savings of 10-25% in clerical costs in many cases, and savings of 10-20% in inventory costs. The greatest payoff, however, will be in sophisticated total management information systems, employing such advanced management science techniques as operations research and linear programming. Costly decisions of the past, such as Ford's Edsel model, and General Dynamics' Convair 990, might be avoided with these techniques. There are over 500 areas in which computers are finding an application today, and these are growing every day. Future applications will include income tax processing, weather forecasting, medical analysis and diagnosis, traffic control and automatic classroom instruction, amongst many others.

Competitive Conditions

The computer industry has developed some very definite patterns and characteristics during its ten year life period. Of the nine major companies manufacturing computers, only two are showing any profits. One of these companies is IBM, which accounts for approximately 80% of the computer market. Large capital investments and research and development expenditures are required to remain competitive, and the breakeven point for most companies still appears to be 2 to 3 years away. This profit picture becomes critical in view of the capital requirements necessary for effective competition. Another industry characteristic is that 80% of the computer installations are leased. The huge investment required to carry rented equipment is straining the budgets of even the largest companies in the industry. Stiff competition, the absence of profits, and huge financial requirements could lead to some attrition in this industry within the next decade. The long-term reward for the successful companies, however, will be considerable.

Public Acceptance

As the communications problem between man and machine improves with the utilization of packaged language programs offered by computer manufacturers, the computer could one day become as easy to use as a desk calculator. This will open vast, untapped markets. Computers appear to be today where the automobile was when it generally gained public acceptance. Electronic data processing will lead to a dramatic increase in technological progress as it extends man's capabilities and intellect. Computers will help to channel man's efforts into areas and directions promising the greatest profits and rate of return on investment. These machines will not only aid in the restoration of former profit levels for business as a whole, but will be an invaluable tool in meeting the serious challenge our country faces in international trade competition.

Technological Advances

Tremendous strides have been made in hardware and software technology since the introduction of the first computer in 1944. The term "hardware" includes the computer itself and its tape transports, printers, card punchers, automatic typewriters, and other accessories. "Software" includes all the programming systems required for the effective utilization of the hardware of a computer. A brief look at these areas will show the tremendous progress being made in the field.

The first general-purpose automatic digital computer was the Automatic Sequence-Controlled Calculator, a machine introduced in 1944 under the joint development of Harvard University and IBM. This machine handled numbers of 23 decimal digits, stored them in 72 storage registers, and performed additions in approximately 1/3 of a second and multiplication in about 6 seconds. This machine was followed by the Eniac (Electronic Numerical Integrator and Calculator) which was completed in 1946 at the Moore School of Engineering at the University of Pennsylvania. The Eniac contained 20 registers, where numbers of 10 decimal digits could be stored. It could add numbers at the rate of 5,000 additions per second, and could carry out from 360-500 multiplications per second. The prodigious development since these early machines is indicated in the operating characteristics of today's machines. Addition speeds have gone to more than 100,000 additions per second and multiplication speeds have risen to more than 10,000 per second. The amount of storage capacity accessible to the computing unit has gone from 72 storage registers to literally millions of registers. Some of these registers are accessible to the calculating unit in less than a millionth of a second. Today the most powerful machine can take in information, remember it without forgetting it, at the rate of about 100,000 characters per second. As a common or convenient length of word is twelve characters, a speed of 96,000 characters per second is the same as a speed of 8,000 words per second. Although the ability of machine and man is different, it might be noted that human beings could not take in even one twelve-digit number in one second. In this light, it might be fair to say that computers have an input advantage over the human being by a factor of 1,000:1. In terms of output, a computer can record on magnetic tape at the rate of 100,000 characters a second. It can control a paper tape punch which punches tape at the rate of 100,000 characters per second, or a card punch which punches standard punched cards at the rate of 30 per second. High speed printers print 17 lines of 80-120 characters a second, or over 1,000 lines a minute. A fairly representative ratio of computer output speed would be about 8,000 words a second, while the top output of human beings is approximately four words a second. This gives the computer an advantage factor over a man of 2,000:1. These statistics provide ample evidence why computers are displacing human beings in handling repetitive types of data.

Reliability

Not only speed and capacity, but reliability of automatic computers has also been multiplied by a factor of tens of thousands. Reliability has increased to a point where a billion to ten billion operations take place without errors. It is not uncommon for computers to be operating at uptimes in excess of 95%. In addition, automatic checking has been built into computers, so that the release of wrong results is virtually an impossibility.

Software

The importance of software development to computer users is illustrated by the fact that investments in program development amount to over one-half of the total rental expenditures for machines, and at the current rate of program development, these costs could equal the total machine rental cost by 1965. Computer users, consultants, and manufacturers have invested hundreds of man-years of work and millions of dollars in packaged programs and systems in order to simplify the task of using electronic computers. One of the facts contributing to this cost is the lack of compatibility between different types of digital computers. Programming dollars are spent on duplicate development due to differences in equipment and methods of documentation. A great turmoil is currently going on in the software area in search for standardized computer programs and languages. Improved software packages, or ready-made programs that come with almost every computer now made, have reduced programming costs, but it has been estimated that U. S. business and government computer users have invested over $2 billion in privately developed programs since 1950. These programs are both general and specialized. The general programs are written to represent general management problems common to all industry, such as linear programming, sales forecasting, scheduling complex projects and balancing production lines. More specialized types of programs cover such areas as demand deposit accounting in banks, hospital accounting, and automobile rating for insurance companies. Some of the more common general automatic programming systems include ALGOL, COBOL, FORTRAN, FACT, GECOM, and JOVIAL. Each of these programs is inadequate as a standard language, because it lacks a complete range of expression. More computer programs are written in FORTRAN, a scientific language, than in any other programming language due to the fact that IBM has such a considerable investment in its processors and programs. FORTRAN processors have been implemented for 26 machine types. For business purposes, however, FORTRAN involves great technical detail, and is difficult to learn. For scientific purposes, it lacks the power and flexibility of ALGOL or JOVIAL. COBOL, COmmon Business Oriented Language, developed by the Department of Defense, is being implemented for 35 machine types by 15 manufacturers. ALGOL has been described as a more powerful and general language than FORTRAN, since it allows the user to write more comprehensive problems in source language. However, ALGOL compilers are in existence for only three machines. The greatest advantage of these programs will come with one truly high level programming language, saving users many years of systems and programming efforts. This could conceivably be a combination of ALGOL, COBOL, and a third language suitable for systems programming. The day may come when all we have to do is to present the data and general problem to the computer, and it will figure out how to find a solution and write a program.

Software is available from both computer manufacturers and computer user groups. IBM has the largest library of computer programs in the industry, containing close to 6,500 programs, some of them with up to 120,000 instructions. It has been estimated that over 725 man-years of programming efforts would be required to duplicate the programs in this collection. No value has been placed on the collection in this library, but original programming can cost from $2.00 to $20.00 per instruction. In addition to computer manufacturer programs, computer user groups collect and distribute programs developed by its members. Any member gets access to a great deal of programming done by other members, thus saving much duplication. The largest program collection of any computer user group is that of SHARE, for the IBM 704, 709, and 7090 computers, with over 1,800 programs. Other computer user groups include EXCHANGE (Bendix), CUBE (Burroughs), CO-OP (Control Data), GET (General Electric), and USE (Univac). Not only do users groups correct defects in specific programs, but they are helpful in organizing and stimulating ideas for new programs. Computer users have found ways of using the machines that the manufacturer never imagined.

Computer Economics

The computer, the industrial revolution and the automation of factory processes have been described as the three most important events in the development of Western business. Computer development has emerged from two main trends in the growth of our country. One is the explosion of scientific and engineering knowledge, and the realization that long laborious calculations could not be handled in ordinary, symbolic mathematical ways. The other trend is from the business world, with enormous quantities of records and calculations required for businesses to function. Our civilization has not only grown complex engineering-wise and technologically, but also business-wise and industrially, so that it has produced an enormous growth in the information to be handled. This has provided the impetus behind the great development of automatic handling of information, expressed in computing and data processing systems.

Economic Justification

Three primary factors are leading to structural changes in businesses today: (1) the availability of computers to any size of business; (2) the fantastic quantities of internal and external data generated by government and business reports; and (3) a structural change in the economy itself.

Formerly, wrong decisions were not fatal to a company's existence, as illustrated by Chrysler's square automobile design, Lever Brothers' decision to stay out of the detergent field, General Dynamics' decision to build the 990, and Ford's marketing of the Edsel. Today, businesses vitally need data to prevent making a wrong decision or being locked in a situation. The focal point of many of these decisions revolves around a computer.

Computer utilization is justified in situations where greater speed in processing data is required, or where the complexities of data processing cannot be simplified without electronic assistance, or when the investment in computer equipment is substantially offset by both quantitative and qualitative benefits. With the exception of scientific and military applications, computers are usually purchased for the direct savings which they effect. The urgent need to displace human beings performing clerical and accounting tasks is illustrated by the fact that during the last ten years, the number of clerical personnel has grown 29%, and salaries have been increasing at an average rate of 3% a year. On an annual basis, wages for clerical personnel alone are in the area of $392 billion.

Clerical Savings

Company after company can cite huge clerical savings through the use of data processing machines. McDonnell Aircraft, in completely automating its purchasing cycle, estimates it will save $100-200,000 annually, mostly accounted for by clerical savings, with a machine renting for $6,400 a month. Sylvania Electric estimates that it will save approximately $400-500,000 annually in such areas as clerical and inventory reductions through the use of machines renting for an estimated $325,000 a year. Nationwide Insurance has produced savings of about $200,000 a year in the area of Renewal Billings, with a machine which rents for an average of $9,000 a month. Most of this is the result of clerical reductions. Nationwide has projected saving in excess of $1.0 million over the next seven years. Reductions in both the level and carrying costs of inventories have also justified the utilization of computers. Many cases could be cited for savings of 5-30% annually in this area. American Cyanamid expects its computer-controlled finished-goods inventory system to yield savings of at least 10-15% of its annual cost. Annual savings are estimated in the area of $200-340,000 a year. Martin-Marietta expects inventory levels to be slashed by more than 60% when its IBM 7070 data processing system goes into full operation. In addition to clerical and inventory savings, a faster flow of vital information and the elimination of paper work delays and duplication will save companies like Lockheed $2.0 million annually, with the annual rental cost of the system involved about a third of these annual savings.

In addition to cost savings, a number of other important contributions are being effected by computers. Some of these include: increased speed and accuracy in preparing management reports, better customer service, lower costs to the consumer, and improved control over the operations of the business. The full potential of the computer has not been realized yet, and the greatest potential payoff appears to be in sophisticated areas which have been out of man's reach to date; such as totally integrated management information systems.

Urgent Business Problems

Two very urgent problems are facing businesses today: (1) the need for increased profitability; and (2) the ability to compete in international markets.

The cost-price squeeze which has characterized our economy during the past decade has steadily decreased after-tax profit margins from 9.1% in 1950 to 5.8% in 1961. One of the major cost items for business has been wages. Manufacturing weekly earnings have increased from $63.34 in 1951 to $95.75 in 1962, or a 50% increase during this period. In comparison to other countries, the United States has lagged substantially behind many countries in terms of growth in Gross National Product, Industrial Production and Manufacturing Productivity per person over the past decade (see Table 1). In addition, our arch rival, the Soviet Union, plans to increase industrial output by 150% within ten years, thus exceeding the level of U. S. industrial output. It plans to increase industrial output 500% in twenty years, and raise the productivity of labor 300-350% during this time. This is to be accomplished by a mass scale of comprehensive automation, with primary emphasis on fully automated shops and factories. Cybernetics, computers, and control systems will be widely used to meet these goals. The Soviet spent $180 million for developing computers in 1958, and plans to spend between $800-850 million by 1965.

Selecting a Computer

A recently completed independent survey of computer users[1] indicated the following factors as influencing the choice of a computer: 1) the computer which offers the greatest anticipated pay-off in clerical savings, 2) reputation of the manufacturer, 3) maintenance factor, 4) comparison of costs, 5) purchase prestige, 6) product support, 7) compatibility with existing systems, and 8) error-checking characteristics. The same report stated that 90% of the users reported they had realized the savings estimated in the original computer study. It is not uncommon for computer feasibility studies to run up to 12 months, since such a large investment is involved. The factor of prestige has not always been beneficial to users, however, for when prestige superseded efficient systems engineering, ineffective computer utilization has been the result. Systems application or engineering has not only been the key to successful computer utilization, but has also been the reason for success or mediocrity on the part of computer manufacturers.

Determining the type, size, capacity and competency of a computer is not an easy task. Compromises must be made in most instances, with systems application the dominant factor. If a computer fits the requirements of a particular application, then the aforementioned benefits usually follow automatically. Prospective computer users must analyze many computer characteristics in relation to the job to be done and the cost involved.

Computer feasibility studies must also consider the question of lease versus purchase. The industry is currently favoring the lease method, with approximately 80% of machine installations on a rental basis, with an option to buy. Typical rental costs are misleading if taken at face

Table 1

A. Average Annual Rates of Economic Growth in Eight Countries, 1951-60 (in Percent)

Country	Real GNP (Gross National Product)	Industrial Production
U. S.	2.9	3.2
Canada	3.6	4.3
France	4.2	6.6
Germany (F. R.)	7.2	8.8
Great Britain	2.7	3.2
Italy	5.8	8.5
Japan	8.7	14.5
Sweden	3.7	3.7

B. Percent Increase in Output and Manufacturing Productivity in Eight Countries, 1951-60

Country	Real GNP per Capita	Mfg. Productivity per Person Employed in Mfg.
U. S.	12	22
Canada	9	28
France	33	62
Germany (F. R.)	70	50
Great Britain	22	24
Italy	58	85
Japan	92	151
Sweden	31	33

Source: Bureau of Labor Statistics, Monthly Labor Review value. For example, rental costs usually account for approximately one-fourth to one-third of total annual operating costs, so that a computer which rents for $200,000 a year could cost $600-800,000 annually in direct operating costs. In addition, start-up costs usually range between one and two years' operating costs. Taking all of these costs into account, therefore, a computer which rents for $200,000 a year could conceivably have resulted in operating expenditures of $1.2-2.4 million by the end of the first year. The government has approached the problem of lease versus purchase by setting up a cost advantage point. This is a point in time when one-time expenditures for purchase and accrued maintenance will equal cumulative rental payments for a particular machine. In situations where the cost advantage point is reached in six years or less, and the computer still fits the requirements of the job without major modification, a set of conditions exist which warrant purchasing the equipment. These policy guidelines should lead to a substantial proportion of purchased computer equipment by the government in the future. This approach, plus the slowing down of technological obsolescence and the ability of computers to vary in speeds and capabilities through the building-block modularity of central processing hardware, could lead to a higher ratio of sales than at present.

Unit Cost Per Calculating Operation

One of the most important factors in the cost of a computer is the unit cost per calculating operation. As the price of a computer goes up, the cost per calculating operation goes down. For the most expensive computers, the cost is least. For example, an IBM STRETCH, which rents for $300,000 a month, and performs an estimated 500,000 calculating operations per second, will during the period of a month perform calculations at the rate of 100,000 operations for 2½¢. It would cost $10,000 to perform a certain computation on a desk calculator, $10 to perform the same computation on an IBM 650 and about 50¢ to perform the computation on a STRETCH system. Using the same machines on a time basis, it would take approximately 1,000 hours to perform the sample calculation with a desk calculator, 6 minutes with the IBM 650 and only 12 microseconds with the STRETCH machine.

Tremendous increases in the ratio of computing power per dollar have been made in the last two years. The total rental of current machine installations is in the area of $73.9 million a month; and these machines in total can perform 108 million operations per second. When the operating ability of the installed machines is divided by total rental costs, a measure of computer power is available which can be used as a basis for comparing the advances made in computing power per dollar. On the basis of statistics, today's theoretical computing power per dollar ratio is 1.46, which is a 155% increase over the ratio of .57 in 1960. Expressed in another way, through-put speeds have increased at the rate of over 40% a year. As computing power per dollar continues to increase, more and more companies will find it economically feasible to invest in million dollar computers. A typical example is Sylvania Electric, which has found that its current machines operate at three to four times the speed of previous machines, while rental costs have been reduced by approximately 25%.

Areas of Computer Applications

The degree to which computer technology has become more specific and complex is illustrated in the fact that today there are over 500 areas in which computers are finding an application. Computer manufacturers have had to gear their marketing efforts to specific user problems, but in the process have opened up even more areas for the utilization of computers. A long list of some of the functions computers are performing in different areas has been published.[2] A number of these areas will be reported in more detail, in order to determine the significance of computer application to this area or industry, and to discuss the importance of these markets in light of computer usage trends.

Commercial Banking

Data processing firms have a business potential of some 5,400 commercial banks out of the 14,000 in this country. These are banks with over $75 billion in total deposits. The banks which have installed computers have found that they not only have better reports and tighter audit and control procedures, but are now able to offer new customer services and improve their competitive position. The major breakthrough in the banking industry with EDP did not come until 1959, when the final specifications for printing of checks coated with Magnetic Ink Character Recognition (MICR) numerals were approved by the American Banking Association. An estimated 68.3% of all checks cleared through Federal Reserve Banks now contain magnetic ink symbols, compared to 36.1% a year ago. The volume of checks processed in 1951 was 2.1 billion, but is expected to reach 22 billion in 1970, and 29 billion in 1975. By this time, most of these checks will be coated with magnetic symbols, and will be processed by computers.

EDP will have its greatest impact on the demand deposit sector of bank employment. About 20% of all bank workers doing work related to demand deposit bookkeeping will be seriously affected by the advent of automation. One major bank indicated that computers have led to an 80% decline in the number of bookkeepers in demand deposit activity over a four-year period, despite a 10% rise in demand deposit accounts.

One of the newest developments in the banking industry is the use of on-line computers. On-line, or real-time systems process transactions individually as they arrive at processor inputs, and usually return a result to the point of origin immediately following processing. In other words, this will make every bank office a main office for every customer, regardless of its location. Three banks in the East—Howard Savings, Union Dime, and Society for Saving (Hartford)—have installed on-line systems. The benefits from these systems have been a 90% reduction in back office teller work, and a 30% reduction in transaction processing time. The Howard Savings Institution expects to save over $100,000 with its system over the next five years.

The smaller banks which cannot afford computers are joining together in a cooperative movement. For example, six upstate New York banks are cooperating in three new computer centers equipped with $3.8 million worth of computing equipment. This movement could assume major proportions among smaller banks in the near future.

The value of total computer installations in banks through 1962 is estimated at $176 million. It is estimated that shipments to this industry will total $80-90 million a year between 1963-1965, so that a total cumulative market in the area of $450 million is possible by 1965. Computer companies which will share this field include IBM, GE, NCR and Burroughs.

Communications

As the applications for computers increase, and as the requirement for up-to-date information grows, there will be a greater demand for data transmission equipment. Data transmission systems perform such functions as tying together a production line and a data processing center, sending the latest marketing and production facts from the field to a data processing center, and providing management with up-to-date information for more accurate forecasting, inventory control, and money savings. The most common medium used for data transmission is telephone lines. The method of transmitting over this medium is either punch card to punch card, paper tape to paper tape, magnetic tape to magnetic tape, or computer to computer. IBM and RCA are two major computer companies who have made contributions in the communications area. The importance of data transmission is indicated by the fact that AT&T expects that as much digital data will be carried by its wires as voice communication by 1970. RCA has estimated that the annual market for data transmission equipment will be over $300 million by 1965, and that the growth rate for this equipment will be roughly 30% a year. By the mid-60's, one-third of all electronic data processing sales will include communications equipment. Within 20 or 30 years, we could have an international information network operating via Telstar, with communications service on the order and scope of world-wide telephone networks today. IBM has experimented with low-power microwave transmission, and this could extend the capabilities of its Tele-Processing system for long-distance computer-to-computer communications to areas where common carrier facilities are not available, or where customers wish their own facilities. The linking of advanced communication devices with advanced data-processing systems will provide the big breakthrough in real-time total management information systems.

Education

New developments in computer technology are leading to increased automation in our public schools and universities. More than 200 school districts and departments of education in 45 states already use electronic accounting machinery to process business, pupil-personnel, and administrative data. On the university level, hardware valued at more than $115 million is currently in use in colleges and universities. Universities are not only good customers for large-scale computation facilities, but also are in a position to apply and teach techniques developed in other areas. Many colleges with computers have introduced computation courses, so that a large fraction of the students are exposed to programming at some stage of their undergraduate career. One of the most rapidly developing applications of computer technology to education is the use of computer-based teaching machines. A number of institutions are exploring the potential of the computer for controlling instruction of individual students on the basis of differences in learning rate, background and aptitude. The University of Illinois uses a computer to control a teaching system consisting of slides, TV displays and a student response panel. Answers to questions are transmitted to the computer through a response panel, and the computer judges the answers, indicates whether the student is right or wrong, and selects simpler material if the student commits an error. If this type of research is applied to school systems in general, then education is in for a major renovation.

Government

The Government is the largest single user of computers, with a total of 1,006 installations as of June 1962, excluding special military computers. Operating costs in 1961 (rental, amortization, personnel, etc.) were approximately $597 million, and probably in excess of $1.5 billion with the inclusion of military operational applications. Today there are over 45,000 employees in positions related to management or operation of computers in the Federal Government. The Bureau of the Budget has estimated that by 1966, 1,500 computers will be installed by the government.

Computers are being used for a number of new applications by the government in the non-military field. The Internal Revenue Service has turned to computers to process its 95 million tax returns. These tax returns have grown from 20 million two decades ago, and could reach 135 million in 1980. The only logical means to handle all this paper work is high-speed electronic equipment. The system will be in full effect in 1965, and should prove a very effective means of catching up with tax evaders. The Social Security Administration is using computers to speed the processing of claims for social security benefits. District offices transmit data via AT&T's Data-Phone system to a computer center in Baltimore. Information is produced on magnetic tape, which can be fed directly to the computing center for further processing. The government is also using computers to cut administrative costs in the federal farm program. The utilization of computers will cut out 241 jobs and save a total of $1.5 million a year when the plan is fully in effect by 1964. The government is keenly aware of the cost savings apparent in computers, and is employing them in very sophisticated applications to increase its efficiency.

The military has been the largest developer and user of computer technology to date. The military value of improved computer characteristics has led to the support of government-sponsored research projects which the computer industry would not have undertaken on its own. Due to the requirements of space, speed, and reliability, military control and command systems are far more sophisticated than commercial systems. However, many of the techniques developed by the military are adaptable to business systems. This could prove particularly applicable in on-line, or real-time systems. Advances made in the peripheral equipment area, especially advanced display techniques, could form the basis of a new multi-million dollar industry in itself. The space program has also opened up a huge market for computers. Four large digital computers form a network during an orbital mission, and provide a running display of important launch, orbital and re-entry information. Computers, with the help of radar, will be used in achieving orbital rendezvous during the first U.S. lunar landing mission late in this decade. The importance of the military market to the computer industry is indicated by the fact that annual shipments to this segment of the market will reach an estimated $2.5 billion by 1970.

Insurance

The first computer was installed in this industry eight years ago, and since then it has been one of the nation's biggest users of electronic data processing equipment. No large life insurance company could operate competitively today without an electronic data processing installation. More than three-fourths of the nation's 120-million policyholders are now on tape. It is estimated that more than 75 large-scale computers, approximately 200 medium-size machines and many hundreds of small units are now operating in life company offices. These numbers are growing every day. In addition to its normal functions, computers will be used increasingly as an analytical tool in providing life companies with marketing analysis and financial forecasts. Operations research techniques will be used to provide life companies with scientific reports. Nationwide Insurance is a good example of what insurance companies are doing with computers. It installed an IBM 650 to calculate Renewal Billings, and in this one application produced annual savings of $200,000 as a result of clerical reduction. An NCR 304 was installed to create an integrated processing system, and to produce better and more accurate management reports at a minimum cost. With the help of these machines, Nationwide has projected savings in excess of $1 million over a seven-year period. In addition to the large companies like Nationwide, medium and small insurance companies will also need computers in the future. The insurance industry has installed machines valued at $400 million through 1962, and expects shipments of $100 million a year during the period 1963-1965. This would lead to a cumulative market of $700 million by 1965.

Investment Banking

In the financial community, computers are used in such applications as payroll, margin and cash accounting, customer statements, trade confirmations, commissions, dividends, and a host of allied management reports. Computers are also used to speed up such routine work as figuring portfolio market values and yields, and making records of company earnings, dividends and profit margins. A number of firms are experimenting with these machines for security analysis work. At this point, computers are supplying the various mathematical formulas and ratios which analysts use in judging the value of a security, and are providing the necessary statistics which determine the relative attractiveness of stocks. There is a limitation in the ability of a computer to recommend the sale or purchase of a stock, but current applications should improve the over-all quality of investment decisions.

Computers are also widely used in the various stock exchanges. The Midwest Stock Exchange is developing an electronic centralized bookkeeping service which will reduce back office expenses by more than 70% per order, and will save member firms an estimated $3 million a year in labor and machines. The NYSE's Stock Clearing Corporation uses computers to verify and clear thousands of transactions each day. A computer system which will automate the Exchange's ticker and quotation service is expected to go into operation early in 1965. This system will run the 3,800 stock tickers in the U.S. and Canada, and will provide a voice recording to announce prices over its telephone quotation service. A computer is used by one Wall Street firm to perform calculations required in bidding on serial bond issues, and to handle the mass of information involved in maintaining up-to-date files on all bonds.

Process Control

The use of computers for process control applications in factory automation appears to be on a level where general-purpose computers were in 1952. With increasing computer speeds and advanced programming methods, the control computer is taking over as a dynamic optimizer, readjusting plant operations to achieve continuous optimization of performance, rather than serving merely in a supervisory capacity. With increasing applications in the power and chemical industries, sales of digital computers for process control are increasing at the rate of about 50% a year. The power generating industry is first in the number of digital process control systems on order, which is estimated at 200. The rest of the market is comprised of the chemical, petro-chemical, petroleum, paper, glass and cement industry. As automatic process control is still in its infancy, the potential size of the market for computers is still a question. Some sources have indicated a $500 million market in this area by 1970. Computer companies which should share in this market include GE, IBM, RCA and Thompson-Ramo.

Production Control

Manufacturing companies are using computers for off-line production control in such applications as shop scheduling, assembly line balancing, scheduling labor utilization, and numerically controlling machine tools. Advanced management sciences, such as operations research, will find increasing use with computers to optimize decision-making on inventory policy, long-range market strategies, plant and warehouse locations, and capital investment programs. Simulation techniques will reveal unprofitable or inadequate courses of action in advance, thus avoiding costly errors in judgment. Competitive pressures are forcing industry to take advantage of these techniques, which should provide a sizeable market for computers. This area could account for a $2-3 billion cumulative market through 1970.

Retailing

The potential for computing equipment in the retailing industry is considered very large, but will not attain fruition until three elements are more fully developed—optical scanners; methods of inexpensive data transmission; and larger, less expensive random-access memory devices. A number of retailing firms have installed computers to handle accounts payable, payroll, sales audit and accounts receivable. Notable savings are being achieved in these areas alone. For example, Stix, Baer and Fuller of St. Louis is projecting a five-year savings of $400,000 primarily in clerical savings, by employing two computers. The extension of computers into merchandise control, inventory control, and market analysis could prove to be even more significant in terms of savings. In this respect, retailing firms could very well follow the pattern set by such apparel companies as Bobbie Brooks, which is speeding up its inventory turnover by 30-40%, and expects to save over $1 million in the process over the next five years. As extensive improvements are being made in optical scanners, communication equipment and memory devices, it is conceivable that computer installations in the retail industry could reach $1.5-2.0 billion by 1970. NCR and Burroughs appear to be in favorable positions in this industry.

These are just a few areas in which computers are finding applications today. In addition, there are a number of areas with large, but relatively untapped potential, which appear to be ready markets for computers. These include: service organizations (hospitals, hotels), the transportation field (airlines, trucking, traffic control), local government, information retrieval, medicine, advertising, and law. The uses for computers appear limited only by man's imagination. Eventually, computers could become as commonplace as the office telephone.

History and Development of the Industry

History Since 1952

The years between the building of the first computer in 1944 and 1952 were years of experiment by universities, government departments and small businesses. At that time, major business machine, electric and electronic manufacturers became convinced that machines which could compute and process data automatically were important, and they entered the field on a big scale. Sperry Rand had a big jump on the field when they acquired Eckert-Mauchly Computer Corporation in 1950 and Engineering Research Associates in 1952. The founders of the former company were the designers of the Eniac, and their Univac I was the first general-purpose electronic computer designed for business data processing. This machine was complemented by a machine for scientific computations built by the Engineering Research Associates group. Sperry Rand embarked upon a vigorous marketing of both machines. The first commercial computer installation was in 1951, when a Univac was installed at the Bureau of Census. The first large-scale electronic computer to process business data, the Univac I, was delivered to General Electric in January, 1954. IBM turned down the Eckert-Mauchly Corporation because it felt that the greatest market potential for computers was in scientific rather than business applications. IBM did have twelve installations of its 701 in 1953, primarily for scientific work. The company's 702, a business version of the 701 meant to compete with Univac, was a failure. A crash program followed at IBM to replace the 701 and 702 with the 704 and 705, respectively, by January, 1956. In the meantime, IBM was making the most of Sperry Rand's mistakes. Sperry Rand failed to see the importance of service, customer education, and the development of high-speed output equipment. IBM sales strategy was not to deliver a machine until the customer had been completely educated and could utilize the equipment fully from the date of installation. This sales strategy paid off spectacularly, and the five-year lead which Sperry Rand once had on the field was erased by the end of 1955, when IBM was ahead of Sperry Rand in orders booked. By mid-1956 it had $100 million worth of its 700 series machines installed, against $70 million for Univac. Burroughs looked like a strong contender in the computer race when it acquired the Electro-Data Corporation in 1956. The company's Datatron computer proved excellent competition for the IBM 650 at the time. RCA made a huge initial investment of over $25 million to get into the computer field and sold its first Bizmac in 1956 for $4 million. This was the industry's biggest single installation to that date. There were four companies making large-scale computers in 1957, and industry sales were $350 million. By 1959, nine firms had made heavy commitments in the field, and industry sales were an estimated $500 million. Machine introductions were made by Bendix in 1955, General Precision in 1956, Minneapolis-Honeywell in 1957, Philco and Monroe in 1958, General Electric in 1959 and Control Data, National Cash and Packard Bell in 1960.

Industry Characteristics

The computer industry, when compared to other industries, is relatively young in age. Measured from the date of the first computer installation in 1951, the industry is a little more than a decade old. In terms of development, the years 1952-53 would be more appropriate in defining age, as this was the period when mass production techniques were applied to computer manufacturing. From virtually no sales or installations in 1950, the industry has grown to an estimated sales of $1.5 billion in 1962, with an estimated 10-12,000 computer installations. Today there are over 20 companies manufacturing electronic digital computers, with more than 200 companies making peripheral and accessory equipment. There are now over 150,000 persons employed in the manufacture, programming, operation and maintenance of computers. Despite a relatively short history, the industry has developed some very definite patterns and characteristics. One is the noticeable absence of profits.

With the exception of IBM and Control Data, no other major factor in the industry is making money on computer operations. This may be attributed to the fact that these two firms derive a great majority of their revenues from computers. In almost every other company, computing is a side line or a division at most. This factor of concentration, together with the excellent sales strategy and sales force of IBM, which accounts for approximately 80% of the computer market, has led industry spokesmen to believe that it will be a minimum of two or three years before most companies will begin to show profits from computers. Large companies like GE, RCA and Minneapolis-Honeywell have adequate finances to sustain these losses until profits are shown. Smaller companies, however, will not be able to absorb these losses from year to year, so that the field may narrow down through mergers or drop-outs in the near future. The computer industry has estimated that the total cumulative loss in its ten-year life history already approaches the sum of the two biggest corporate losses in business history, i.e., Ford Motor's Edsel model and General Dynamics' Convair 990. This profit picture becomes extremely critical in light of the capital needed to finance computer operations.

Heavy Outlays

The production of computers involves very heavy outlays. For example, RCA and Minneapolis-Honeywell have invested over $100 million each in their computer business, and for both companies it might be a minimum of two years before they realize any return on this investment. A good measure for financial requirements is the capital: sales ratio of the two profitable companies in the industry. IBM had a gross income of $1.69 billion in 1961, and total invested capital of $1.61 billion, or a ratio of almost 1:1. Control Data had invested capital of $23.4 million at the end of its 1962 fiscal year, on a sales volume of $41 million. Recently, however, the company issued $15 million in convertible debentures, bringing invested capital up to $38 million, for a ratio of almost 1:1 in terms of capital to sales. These financial requirements are staggering even to the budgets of the largest companies in the country, but are necessitated both by heavy research and development costs and by the methods of financing computer purchases.

The very nature of the computer industry makes heavy outlays on research inevitable. Producers must keep up with competition, and this requires heavy research expenditures, which cut sharply into profits. As it is relatively new, the computer field involves many very costly problems in developing new products. The advantages of long experience which is available in older industries are not present in this field. As an indication of the magnitude of these research expenditures, Control Data spent approximately

$2.6 million, or 6.3% of sales, on research and development last year. The company-sponsored portion of the research and development program was supplemented by $5.9 million, primarily from government research and development contracts, so that total research expenditures amounted to 20.7% of revenues. IBM spent $100 million on research in 1961, and will spend an estimated $115-120 million in 1962. With the exception of Sperry Rand, IBM research and development expenditures alone exceed the revenues of any company in the industry. These outlays have made possible a carefully-planned program of new product introductions. The result has been a forced obsolescence of previous IBM machines. This has not always been to the benefit of computer users, but has shown amazing results for profit-oriented IBM.

Time Lag

Another basic reason for large capital requirements is the time lag between the development of a computer and its sale or lease. In a typical case, it takes three years to develop a computer. The machine is usually announced before it is finished, and at that time, a customer may either decide to purchase or lease. After an order is placed, the delivery time before installation is usually around 12 months. It then takes about 3-5 years to get invested funds back from leasing, so that the total cycle time is around 8-10 years. When a company leases a machine, it usually incurs a net loss for two years subsequent to installation due to heavy research and development, selling, installation and accelerated depreciation charges. Gross profit from leasing a computer approximates gross profit from outright sale in about the fourth year. After that, leasing is far more profitable than selling, assuming a machine stays leased long enough. The problem facing manufacturers is that, with the technical life of most machines increasing to 5-8 years, technological obsolescence is becoming less a factor. The former favors manufacturers under leasing conditions, but the latter encourages more outright purchases by users. The leasing method, however, should still remain the principal method of computer financing in the next decade: This will not help the immediate profit picture of most companies, but will be most remunerative in the long run.

Continual Flux

The rapid growth and the extremely competitive nature of the industry keeps it in a state of continual flux. The magnitude of the industry's potential continually attracts new firms, both large and small, into the field. Small companies like Advanced Scientific Instruments and Scientific Data Systems could survive by concentrating on a small area or special application. Ultimately, many of these companies will become good buy-out candidates. Larger firms, like Hughes and Stelma, which have recently announced their entrance into the field, will find competition very stiff. This proved to be the case wth General Mills, Royal McBee and Underwood, all of whom have dropped out of the industry. It is interesting to note that such firms as Motorola and Westinghouse have not become directly involved in computer manufacturing, even though they have the finances and electronic capabilities. One other area of change in the industry has been management. With such tremendous stakes involved, a wrong management decision could easily obviate many years of development, and postpone projected profits further into the future. Companies have been shifting managements in an attempt to find the road to profits more quickly, and this has been evidenced in such companies as Sperry Rand, RCA and Philco.

Buyers' Market

The growth of the industry has not been without its problems. All manufacturers are aware that computers are offered today to a buyers' market. This has led to a very close working relationship of user and manufacturer. Price has not been the only consideration in a computer purchase. Potential users now demand more detailed programming, want technical assistance after installation, are seeking guaranteed repayments of any losses resulting from system changeovers, and are interested in other services which are very costly to the manufacturer. A problem from the user's point of view is that the computer industry, much like the auto industry, has been engaged in a race for horsepower. One of the results has been that some computers in business are not being used to their fullest capacity. These problems, however, are considered minor in view of the over-all progress being exhibited by the industry, the savings being effected by users and the huge market potential facing manufacturers in the next decade.

There are a number of factors which spell the difference between success and failure in the computer industry, but the key ingredients required to compete successfully in this industry seem to be: (1) a realistic product pricing; (2) thoroughly proven equipment and sof'ware programs; (3) equipment designed to meet specific market requirements; (4) marketing management experienced in the computer field, along with skilled salesmen and systems engineering backup; (5) farsighted and determined top-management support, willing to forego present profits, and accepting risks for long-term gains; and (6) adequate finances.

Present and Potential Computer Market

There are a number of methods of expressing the size of the computer market. Three of these would include: (1) factory sales or shipments per year, (2) factory sales plus rental income, and (3) the total cumulative value of machine installations. Each of these methods has its own merit in presenting a different perspective of the industry. From an industry point of view, this study will concentrate on both factory shipments and cumulative installation value. As annual shipments and particular machine installation information is considered proprietary information by many of the computer companies, the computer market will be the total cumulative value of machine installations when discussing individual computer companies.

Present Market

Computer and data processing equipment have been classified under the industrial products section of the electronic industry by the Electronic Industries Association. Computing, data processing and industrial control and processing equipment account for approximately 50% of the industrial product group sales. Sales of this equipment have been growing at the average annual rate of 25% a year since 1957, compared with an average growth rate of 17.5% annually for the industrial products group as a whole, and 13.5% a year for electronic industry sales. Computers and data processing equipment are one reason why industrial products are the fastest growing portion of this market. The rapid growth of industrial products could serve to achieve a better balance in the electronics industry, since 59% of total industry sales is currently for military and space applications. In terms of shipments, the market for business and scientific general-purpose digital computers and special military computers has been as follows:

Year	*Business & Scientific*	*Special Military*
1960	$ .5 billion	$ .6 billion
1961	1.1 billion	1.0 billion
1962E	1.5 billion	1.3 billion

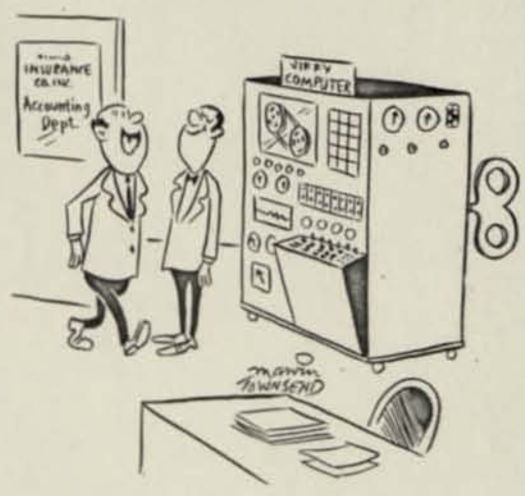
An analysis of 1961 sales shows that 39% of sales was made to industrial and commercial users, 22% went to agencies of the Federal Government, 11% each went to utilities and aviation, 10% was sold for scientific purposes, 2% for educational purposes, and 5% went to miscellaneous users. The total domestic market, including computers, peripheral gear, software and services is expected to reach $2.8 billion in 1962, representing a 20% increase over 1961. The market for peripheral equipment from independent makers is expected to approach $300 million in 1962, with magnetic tape transports ($80 million) and electromechanical printers ($50 million) accounting for almost one-half of these sales. As a measure of magnitude, sales of peripheral equipment will be close to four times 1962 sales of analog computers, which is estimated to be an $80 million market. An examination of the digital computer manufacturers will indicate which companies are leaders in terms of installations, and what future relative positions could be based on present backlog figures.

1 See "Big Five Computer Vendors Face-to-Face" by Patrick J. McGovern, in *Computers and Automation*, August, 1962, p. 38.

2 "Over 500 Areas of Application of Computers" by Neil Macdonald, in *Computers and Automation*, June, 1962, p. 140 ff.

[To be continued in the February issue]

The Key to Computer Economy



"So this is the computer you managed to buy at such an unbelievably low price?"

A SURVEY AND STUDY OF THE COMPUTER FIELD

PART 2

Industrial Securities Committee
Investment Bankers Association of America
Washington 4, D.C.

(Continued from the January issue)

A. *Company Position by Value of Installations*—the computer industry, as mentioned previously, is very close with its so-called proprietary information, so that installation and backlog figures are the result of educated guesses by industry spokesmen, consultants, trade and technical publications, and computer users. A combination of these sources has been used in the compilation of a computer census.[3] This chart shows the total number of computers installed to date by each manufacturer, including vacuum tube and solid state machines, the estimated value of these installations, the number of computers on order and the estimated value of these orders. As it would be impossible to know the sales value of each installation, an average system price was used. Since the introduction of the first Univac until September 1962, it has been deduced that there have been 16,187 computers installed, with an installation value of $4.5 billion when new. The exhibit clearly indicates the dominance of IBM in the computer industry. The company has installed 78.3% of the total number of machines with its 12,743 installations, the cumulative estimated value of which is $3.5 billion (see Table 2). A trend is the rapid decline in use and production of vacuum tube computers. IBM and Sperry Rand, the two major contenders in the industry initially, have had the greatest number of vacuum tube computer installations. Although many of these computers are still in use, production of nearly all has been phased out. If these machines were excluded from consideration when discussing market share, Table 3 indicates that IBM's position would be relatively unchanged. Sperry Rand would only have 5.4% of the market under this assumption, but the newer companies like RCA, Control Data, Minneapolis-Honeywell and General Electric would benefit significantly. As solid-state computers have just about completely replaced vacuum tube machines, Table 3 indicates which companies are improving their relative standings in terms of present market share and machines on order. Viewed in this light, Sperry Rand, National Cash and Burroughs all appear to be in a position to improve their relative standings.

B. *Company Position by Machine Size*—there are many ways of classifying computers by size, but the two most common methods are rental cost per month, and average selling price per system. The latter method will be used

Table 2

Present Market Share *

Company	Percent of Market* based on Number of Machine Installations	Percent of Market based on $ Value of Machine Installations	Percent of $ Value of Machines on Order
IBM	78.3	79.2	77.9
Sperry Rand	4.8	8.5	7.8
RCA	1.2	2.3	3.1
Control Data	1.5	2.0	1.5
Minneapolis-Honeywell	0.5	1.9	1.8
General Electric	0.7	1.2	1.3
National Cash	1.9	1.2	2.3
Burroughs	1.9	1.0	2.6
Philco, Bendix, General Precision, Monroe, Packard Bell, Autonetics, Clary, Advanced Scientific Instruments	9.2 combined	2.7 combined	1.7 combined

* Based on the total number of machine installations (16,187) and on the total dollar value of these machines, using a typical sales price ($4,517,956,000).

in this study, and machine sizes will be classified as follows: extra large, $5 billion and up; large, $1-5 billion; medium, $500,000-$1,000,000; small, $50,000-$500,000; and desk-size, under $50,000. This is an arbitrary classification, and could possibly place a computer or two in a wrong category if the average price is not a representative figure. Using this classification, it is apparent from Exhibit 4 and Table 4 that IBM is particularly strong in the large and medium size fields. IBM has 85.5% of the large-scale market, with 193 installations of the 7090 series and 340 installations of the 7070 series, accounting for installation values of $579 million and $360 million, respectively. Minneapolis-Honeywell has 5.5% of the total value of the large computer market, primarily due to its 800 computer. Control Data has 5.3% of this market, with 41 installations of its 1604.

IBM has dominated the medium-scale field, due to the success of its 1401. The company has installed 94.3% of the computers in this area, with an estimated value of $1.2 billion. No other computer manufacturer has as much as 5% of this market. RCA has 4.5% of the market, based on 78 installations of its 501, valued at $62.4 million. GE occupies third place with a market share of 2.9%, on 50 installations of its 210 machine, valued at $40 million. Burroughs' share of this market is 2.2%, which is the result of 55 installations of its vacuum tube B-220 computer. The ability to retain this position will depend on the marketing success of the solid-state B-5000, which currently has an excellent backlog of orders.

Table 3

Present Market Share *

Company	Percent of Market Based on Number of Machine Installations	Percent of Market Based on $ Value of Machine Installations	Percent of $ Value of Machines on Order	Percent of Number on Order
IBM	79.1	77.8	77.9	72.8
Sperry Rand	4.7	5.4	7.8	13.0
RCA	1.5	3.3	3.1	2.9
Control Data	1.9	3.0	1.5	1.0
Minneapolis-Honeywell	0.5	2.6	1.8	.8
General Electric	0.7	1.8	1.3	1.3
National Cash	2.4	1.5	2.3	4.2
Burroughs	1.6	1.3	2.6	3.0
Philco	0.1	1.2	1.1	.3
Bendix	2.7	1.1	0.3	.1
General Precision, Monroe, Packard Bell, Autonetics, Clary, Advanced Scientific Instruments	4.8 combined	1.0 combined	Less than 1.0% combined	

* Based on the number of computer installations (12,928) and their market value ($2,990,347,000), with the exclusion of vacuum tube computers which are no longer in production.

Sperry Rand emerges as the leader in the small-scale market, with 524 installations valued at $133.7 million. This accounts for 39.1% of this market. IBM is second with 16.7% of the market, based on 600 installations valued at $57 million. RCA (10.6%), Bendix (7.3%), and Control Data (8.5%), also have significant shares of this market.

The classification of IBM's 632 computer as a desk-size machine, gives this company 81.8% of the desk-size market. Among the non-major companies, Packard Bell and Monroe have a respectable share of this market with a 7.2% and 5.4% participation, respectively.

In the extra-large category, there are only two companies with installations today, namely IBM and Sperry Rand. Long production time, and specialized engineering and programming requirements have kept many manufacturers out of this area. However, even the top two producers are not going to stay in this field with their present machines. IBM has two installations of its STRETCH, and Sperry Rand has two installations of its LARC. Both companies have indicated that these machines will no longer be produced. This could leave the whole extra-large field open to Control Data, which will deliver its first 6600 super computer in 1964.

C. *Computer Backlog*—at present, the computer industry has a backlog of 8,496 computers with an estimated installation value of $3.0 billion. As indicated in Exhibit 4 and Table 4, IBM has 6,176 orders for machines valued at $2.36 billion. IBM's backlog accounts for 72.8% of the total backlog number and 77.9% of the backlog dollar value. Sperry Rand (13.0%), National Cash (4.2%), and Burroughs (3.0%) have greater potential percentages of the market in terms of the number of machines on backlog, rather than the dollar value of these machines, indicating a trend toward lower-priced computers. RCA, Control Data, Minneapolis-Honeywell and Philco backlog figures indicate a trend to the higher-priced machines. As a measure of growth, the total backlog of machines today is greater than the total number of machines installed between 1951 and 1960.

Table 4

Computer Manufacturers' Market Share by Machine Types *

Company	Number of Machines	Percent of Total Number	Machine Value	Percent of Total Value
I. Extra Large Computers				
IBM	2	50.0%	18,000,000	47.0%
Sperry Rand	2	50.0	20,000,000	53.0
Total	4	100.0	38,000,000	100.0
II. Large				
IBM	559	83.8%	999,720,000	85.5%
Sperry Rand	4	.7	6,500,000	.6
Control Data	41	6.1	61,500,000	5.3
Minneapolis-Honeywell	43	6.4	64,500,000	5.5
Philco	20	3.0	36,800,000	3.1
Total	667	100.0	1,169,020,000	100.0
III. Medium				
IBM	4,185	94.3%	1,190,875,000	86.9%
RCA	78	1.8	62,400,000	4.5
Minneapolis-Honeywell	24	.5	12,000,000	.9
GE	50	1.1	40,000,000	2.9
National Cash	30	.7	25,500,000	1.8
Burroughs	55	1.2	30,800,000	2.2
Bendix	14	.4	8,162,000	.8
Total	4,436	100.0	1,369,737,000	100.0
IV. Small				
IBM	600	25.2%	57,000,000	16.7%
Sperry Rand	524	22.0	133,705,000	39.1
RCA	121	5.1	36,300,000	10.6
Control Data	205	8.6	29,035,000	8.5
GE	555	2.3	13,750,000	4.0
National Cash	285	11.9	18,750,000	5.5
Burroughs	22	.9	6,600,000	1.9
Bendix	358	15.0	25,060,000	7.3
General Precision	80	3.3	8,900,000	2.6
Adv. Scien. Inst.	3	.4	360,000	.2
Autonetics	125	5.3	12,500,000	3.6
Total	2,378	100.0	341,860,000	100.0
V. Desk-Size				
IBM	4,950	89.4%	59,400,000	81.8%
Burroughs	140	2.6	2,800,000	3.9
Monroe	251	4.5	3,950,000	5.4
Packard Bell	130	2.3	5,200,000	7.2
Clary	64	1.2	1,280,000	1.7
Total	5,535	100.0	72,630,000	100.0

* Excluding vacuum tube computers.

Potential Market

The previous section on computer applications shed some light on the future prospects of the industry. The problem of forecasting in the computer industry is that market estimates by experts in the field have always been on the low side. Looking ahead to 1966, it has been estimated that sales of business-scientific computers could be 75% ahead of 1961, with industrial computers 200% ahead, and process control equipment 400% ahead. In terms of dollar value, shipments are expected to reach $2.2 billion for business and scientific computers, and $2.0 billion for special military computers. The usual method of projecting the future market potential of the computer industry has been to analyze the government, business, scientific and military fields, or to estimate industry and area applications.

One other method which might receive a little more attention is the market for computers which results from cost savings in such areas as clerical personnel and inventory. For example, the clerical force in the U.S. could reach 12.25 million by 1970, assuming a 25% increase in ten years. With salaries increasing at an average rate of 3% a year, the average wage could reach $99.35 a week. Under these assumptions, the annual clerical bill could reach $632.8 billion. If it is assumed that companies employing personnel equivalent to 5% of these total clerical costs could take advantage of cost savings through computers, then clerical personnel earning $31.5 billion would be exposed to replacement by computers. As cited previously, it is not uncommon for computers to save 10-25% in clerical costs, so that a potential computer market in this area alone is on the order of $3.1-7.8 billion by 1970.

The situation with inventory presents somewhat the same picture. During the past decade, manufacturers' inventories increased from $44.4 billion to $55.2 billion, or 25%. If a similar increase can be assumed by 1970, then these inventories could reach $69 billion. Assuming firms carrying one-tenth of this inventory are in a position to employ computers, and if savings under this assumption are 10-20% in each case, then savings of $690 million to $1.4 billion are possible. In other words, savings from clerical and inventory costs could channel as much as $3.8-9.2 billion into computers by 1970.

A. *Military Market*—one area which cannot be overlooked is the military market, which is growing faster than the electronic data processing market as a whole. Electronics industry sources indicate that as much as one-sixth of all defense electronics expenditures go for some type of computer. An estimated $8.0 billion will be spent for military electronics in 1962, with $1.3 billion spent on data processing equipment. If expenditures for defense electronics continue at the present rate, they could reach $15.0 billion in 1970, creating a $2.5 billion military computer market.

B. *Foreign Market*—the future potential of the computer industry is further enhanced by foreign market prospects. There are approximately 2,800 computer systems installed and on order in Western Europe, plus 389 installations in Great Britain. By 1970, there will probably be more than 14,000 installations in Western Europe, and 700 installations in Great Britain. West Germany leads in overseas computing installations with 472 systems, Great Britain is second with 389, and France is third with 342. The biggest market for computers in the future will be in these three countries followed by Italy, the Benelux countries, Scandinavia, Austria, and Switzerland. Of the 14,000 estimated installations by 1970, 10,000 or more are estimated to be small systems, 3,000-4,000 medium-size computers, and 150-250 large-scale computers. The total value of this market should be in the neighborhood of $5 billion. Domestic companies are considered to have a decided advantage in this market, since U.S. technology, sales techniques, programming and computer applications for specific jobs are years ahead of the West Europeans. According to a recently published estimate, the foreign computer market is shared as follows: IBM—70%; Sperry Rand—8%; and two foreign companies, BULL (8%), and International Computers & Tabulators (6%), sharing the rest of the market along with other local firms. In France, there is a sales battle between IBM and Compagnie des Machines BULL, which share almost all of the market in France. BULL is an aggressive firm with excellent government connections. The company has signed a marketing agreement to sell RCA's 301, and in return gets full access to all RCA present and future technical developments. In West Germany, IBM is well in the lead with over 400 installations. Univac and BULL run a distant second, while the major German firms (Siemens, Telefunken, and Zuse), although selling some systems, lack the sales organization needed for market dominance. The Benelux countries have mainly installed IBM and BULL equipment, with some sales going to NCR (through its Elliot Automation affiliate), and Univac. In Italy, most of the 250 computer installations belong to IBM, with BULL and Olivetti sharing the rest of the market. In Great Britain, International Computers & Tabulators (53 installations), and Ferranti (50 installations) are proving excellent competition for IBM (56 installations). A tight labor supply and rapidly increasing wages will lead European industries to push toward more automation. Automation means computers, and computers are what U.S. manufacturers have and know how to sell.

C. *Digital Computer Market in 1970*—industry experts are projecting shipments of $3.0 billion in business and scientific computers in 1970, and $2.5 billion in special military computers. The prospects for a $4-7 billion market in 1970 does not appear overly optimistic in view of growth rates exhibited to date. On this basis, it is estimated that the total cumulative market will grow by 350% in the next eight years, or will increase from $4.5 billion to approximately $20 billion. In view of current machine installations, backlogs, areas of concentration, marketing ability, finances, etc., Table 5 is a prognostication of computer company standings in 1970. IBM should still be the acknowledged leader in the industry, but its share of the market will be less than the 78% which it now commands. This will be the result of a number of factors. As the reliability of machines increases, the offering of service, which has been IBM's strongest selling point, becomes less of an asset. In addition, companies like GE, Philco and Minneapolis-Honeywell, which are large computer users, will start supplying their own company with their respective machines. For example, next to the government, GE has been the largest customer for IBM, employing over 100 computers. Future marketing strategies will become more sophisticated on the part of manufacturers, and since machines will have approximately the same capabilities, the company which can offer the best package and working relationship to a customer should have an advantage over competition. This is one reason why National Cash and Burroughs should do well in their total systems approach. It is a tossup for the number two spot by 1970, but based on present progress and the potential of its electronics capabilities, RCA appears to have a slight edge over GE. RCA's backlog is rapidly approaching that of Sperry Rand, so that the number two position could be decided in a few years. GE faces a more difficult task, but should make its big move late in 1964 or 1965, when it introduces its new line of third generation computers, employing advanced technological concepts.

Table 5

Projected Market Share Through 1970 *

Company	Est. Market Share	Cumulative $ Value of Machine Installations ($ million)
IBM	60-70%	$ 9,000-14,000
RCA	8-10	1,200- 2,000
General Electric	7-10	1,050- 2,000
Sperry Rand	7-10	1,050- 2,000
Control Data	4- 6	600- 1,200
National Cash	4- 6	600- 1,200
Burroughs	3- 5	450- 1,000
Minn.-Honeywell	3- 5	450- 1,000
Philco	2- 3	300- 600
Others	1- 2	150- 400
		$15,000-20,000

* Based on a potential cumulative dollar value of machine installations approximating $15-20 billion.

D. *Potential Analog Computer Market*—the total value of general-purpose analog computers, process control computers and hybrid digital-analog computers is estimated to reach, $180 million by 1966, representing a compound growth rate of 15% a year since 1962. This rate is likely to continue through 1970, so that the total value of analog computers could be $300 million by that date. Electronic Associates accounts for approximately two-thirds to three-fourths of the total general-purpose analog computer market, with the remaining sales divided among Beckman Instruments, Systron-Donner and Applied Dynamics.

The Future

As remarkable as the progress has been in computer technology over the past decade, industry experts regard computers at the same stage of development that automobiles were when they began to be generally accepted by the public. Advances in the state of the art will bring third generation computers employing thin films, cryogenics, micro-miniaturization and tunnel diodes. These components will not only lower costs, but permit operating speeds measured in nanoseconds, or billionths of a second. Looking further to the future, operating speeds some day may be measured in terms of the speed of light. Today's computers perform 200,000 operations a second. MIT has developed a working model for a new generation of machines which will perform over 2,000,000 computations per second. Future computers will be reduced in size to extend their use to smaller organizations, and reduced in prices and rental charges to increase their markets. Advances made in the peripheral equipment area, such as optical scanners, data communication equipment, and data display systems, will open up new multi-million dollar industries.

Extension of computer applications will come with increased emphasis on real-time systems. In the next decade, direct communications with computers from a point of sale will not only result in order filling, data recording, and inventory control, but could also extend further down the line into bank credits and debits. Credit cards could become inputs to computers through data communications equipment. Commercial banks will have inter-connecting systems which will lead to up-to-the-minute information on bank and customer balances, eliminating a great deal of the float in the banking system. Total management information systems will be possible by communications links between industrial control computers and data processing computers, transforming the industrial complex into one continuous loop of synchronized data flow.

Electronic computers will be a great impetus to technological development, as it broadens man's capabilities and intellect. The day of trial-by-error will soon be history, as the analytical approach provided by simulation techniques will channel efforts to decisions providing the greatest payoff and return. Increased automation and productivity will not only lead to increased profits on the part of over-all industry, but will be a vital factor in meeting the serious challenge facing our country in international trade competition.

[3] See Exhibit 4 (which is very voluminous) in the full report of the committee.

Appendix 1

List of Computer Manufacturers

*Advanced Scientific Instruments, 5249 Hanson Court, Minneapolis 22, Minn.

Autonetics, North American Aviation Co., 3584 Wilshire Blvd., Los Angeles 5, Calif.

*Bendix Corporation, 5630 Arbor Vitae St., Los Angeles 45, Calif.

*Burroughs Corporation, 6071 Second Ave., Detroit 32, Mich.

Clary Corporation, 408 Junipero St., San Gabriel, Calif.

*Computer Control Corporation, 2251 Barry Ave., Los Angeles 64, Calif.

*Control Data Corporation, 501 Park Ave., Minneapolis, Minn.

*Digital Equipment Corporation, Main St., Maynard, Mass.

El-Tronics, 13040 S. Cerise Ave., Hawthorne, Calif.

*General Electric Corporation, 13430 N. Black Canyon Highway, Phoenix, Ariz.

*General Precision, Inc., 101 W. Alameda Ave., Burbank, Calif.

*IBM Corporation, 590 Madison Ave., New York, N.Y.

*Minneapolis-Honeywell Regulator Co., 60 Walnut St., Wellesley Hills 81, Mass.

*Monroe Calculating Machine Co., 555 Mitchell St., Orange, N.J.

*National Cash Register Company, Dayton 9, Ohio

Packard Bell Company, 1905 Armacost Ave., Los Angeles 25, Calif.

*Philco Corporation, 3900 Welsh Rd., Willow Grove, Pa.
*Radio Corporation of America, Camden, N. J.
Ramo-Wooldridge Corporation, 8433 Fallbrook Ave., Canoga Park, Calif.
*Remington Rand Corporation, 315 Park Ave. So., New York 10, N.Y.
*Scientific Data Systems, 1542 Fifteenth St., Santa Monica, Calif.

* The authors are indebted to these companies for their cooperation and assistance in the project.

Appendix 2

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Appendix 3

Members of the Industrial Securities Committee

Blancke Noyes, Chairman; Frederick G. Braun, Jr., Gerald F. Brush, John F. Bryan, William E. Fay, Jr., Edward K. Hardy, David W. Hunter, Herbert D. Hunter, James F. Keresey, Thomas A. Larkin, J. Victor Loewi, L. Gordon Miller, Jr., Allen J. Nix, Frank B. Reid, Philip O. Rogers, Jesse A. Sanders, H. Virgil Sherrill, Julian A. Space, Carl Stolle

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Management Applications

H. Morgan Editor

Price/Performance Patterns of U.S. Computer Systems

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Econometric models of the U.S. computer market have been developed to study the relationships between system price and hardware performance. Single measures of price/performance such as "Grosch's Law" are shown to be so oversimplified as to be meaningless. Multiple-regression models predicting system cost as a function of several hardware characteristics do, however, reveal a market dichotomy. On one hand there exists a stable, price predictable market for larger, general purpose computer systems. The other market is the developing one for small business computer systems, a market which is relatively unstable with low price predictability.

Key Words and Phrases: price/performance, Grosch's law, U.S. computer market

CR Categories: 2.0, 2.11, 6.21

Introduction

The relationship between computer price and hardware performance has long been an object of study. Many attempts have been made in the past to define such a relationship, but none has occurred within the last five years. Given the rapid evolution of the industry, particularly in terms of improved hardware technology, a new effort in this area seems well worthwhile.

Many of the past studies focused on a concept known as "Grosch's Law," a rule of thumb in the industry which states that the power of computer systems increases as the square of their costs. In other words, if one pays twice as much for computer B as for computer A, one can expect that computer B will be four times as powerful as A. Dr. Herbert Grosch formulated this principle in the late 1940's. First appearing in print in 1953 [6], "Grosch's Law" has become a generally accepted description of the economies of scale of computer hardware.[1]

This economy of scale concept has been an important factor in the arguments of those who favor highly centralized data processing operations. By centralizing, it is argued, an organization can perform its work on one large machine, rather than on a number of decentralized, smaller machines. Since larger machines are less expensive per unit work performed, the result is an overall cost savings (in terms of hardware).

Several studies in the mid-1960's lent support to Grosch's Law. The most rigorous and widely cited was completed by Kenneth Knight during and after his doctoral studies at the Carnegie Institute of Technology [9]. Knight developed a complex algorithm for measuring computer power which he applied to several hundred computer systems. He then ran regression models, using this power measurement, along with year of introduction (as a proxy for technological advance), as a predictor of system cost. (Actually, Knight's model, like all later ones, used the system *price*, which was an obtainable figure, as a surrogate for system *cost*, which was usually not divulged by the manufacturer.) The results indicated that the cost of computer systems did, in fact, grow as the square root of the power increased. Knight also identified an effect of advancing technology, indicated by the generally improving power/cost ratio over time.

Sharpe compared Knight's work with a number (more limited studies, all of which came to the sam general conclusion concerning economies of scale [11, p 317]. Later literature on the subject (e.g., Golub [5] an Stoneman [11], refer to these studies, the last of whic was completed in 1971, as the basis for their discussio on returns to scale.

Recent advances in electronics technology, manifested by the introduction of a large variety of very low-cost minicomputers and microcomputers, have raised some doubts about the continuing validity of Grosch's Law. Booth [4] suggests that the law should be restated to say that the economy of scale only exists within classes of technology. Hayes [8] and Booth also suggest that discontinuity has developed in the relationship, with very large and very small computer systems offering a superior power/cost ratio as compared to "medium" priced and sized systems. Theis suggests the exact opposite, citing the superior price/performance of a number of "midi" computers [12]. Grosch claims that the relationship described in his law is still valid, but neither he nor those supporting the opposite view have made any rigorous examination of the computer systems of this decade [7].

[1] In its original form, "Grosch's Law" stated that the speed of computer systems increases with the square of their costs. Subsequent tests and publications of the "Law" have usually related system costs to some concept of system power.

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One purpose of this study is to explore the power/cost relationship for the computer systems introduced in the 1970's. The following questions will be addressed:

(1) Does Grosch's Law have any meaning or validity?
(2) Is there any definite relationship between computer power and cost, and if so, what is it?
(3) What are the differences in computer power/cost characteristics which are attributable to the vendor? To technological advance?
(4) If computer systems are divided into classes, such as minis, micros, small business machines, etc., can power/cost relationships be identified within classes? Across classes?

A second, more general goal is to determine what, if any, significant relationships exist between hardware characteristics and computer price. If a simple price vs. power relationship cannot be established (which, we will see, is the case), then what parameters do relate meaningfully to computer price? In this case the goal will be to describe the present computer marketplace in terms of these relationships, and to identify any definite trends. Specific questions to be answered include:

(1) What *measurable* computer characteristics are related to computer price in a statistically significant way?
(2) Do these relationships change for different types of computers? For different vendors?
(3) What changes over time can be identified for these relationships?

1. Data

Much of the data was collected from *DataPro70*, a "consumer guide" to computer systems. *DataPro*, in its hardware volume, groups business computer systems into two classes, general purpose computer systems and small business computers. The general purpose computers comprise the large and intermediate systems manufactured by Burroughs, Control Data, Digital Equipment, Honeywell, IBM, National Cash Register, Sperry-Univac, and (before its demise) Xerox. These are the "old standard" computer companies, most of which have been manufacturing computers for over 20 years.

For these systems, the observations used were the "typical" system configurations given in *DataPro*. These are examples of what are felt to be representative configurations of the various systems, including all necessary peripheral equipment. The memory size, DASD capacity, and purchase price used in the analysis are the ones given for the typical configurations for each machine. The rationale for using this approach was discussed by Knight [9]:

> Although only a few configurations eventually are produced, the modern systems potentially consist of several hundred alternatives. It would be impossible to calculate power for even a few alternatives of each system. We must therefore settle on one configuration for each computer. There appears to be a good method for selecting the configurations, and that is to consider the most typical configurations of the computer.

Exhibit 1 lists the general purpose computer systems included in the study, along with some of their characteristics.

The second class of systems is what *DataPro* [1] refers to as "small business computers." It describes the members of this class as

> ... a business computer scaled down ... Though current small business machines differ widely in their architecture, data formats, peripheral equipment and software, they are generally characterized by purchase prices in the \$5,000 to \$100,000 range, and by a strong orientation, in both equipment and software, toward conventional business data processing applications.

There are several types of vendors in this marketplace, ranging from "Fortune 500" type companies such as IBM and NCR to small independent systems integrators, who fit their software to another vendor's computer and then market the entire package. In general, however, this is a new market, and most of the firms in it are both new and small.

To get typical configurations for the small business computers, vendors of these systems were directly contacted (*DataPro* did not have representative configurations for these). Each vendor listed in the small business computer section of *DataPro* was asked to give characteristics and pricing of what were considered "typical or balanced" configurations of their systems. Exhibit 2 shows the results of this survey. (The response rate was approximately 50 percent.)

Data compiled on each machine included: main storage size; direct access device (DASD) on-line storage capacity; instruction timings; year of introduction; purchase price; peripheral characteristics (printer speed, etc.).

2. Price vs. Power

Ideally, we would like to have some measure, such as horsepower for internal combustion engines, which could be used as a standard of performance. Unfortunately, the concept of computer productivity or performance is confounded by the great flexibility, both in design and in use, of these machines. Computer characteristics or capabilities which are essential measures of performance for one user are often irrelevant or unimportant to another user. Additionally, recent architectural advances which allow software to perform previous hardware functions, and vice versa, further blur the concept of "machine" performance.

Benchmarking several "jobs" on a number of computers can provide a prospective buyer with useful performance information. This has been done in very limited studies such as Solomon's [10, P. 190], in which only a handful of systems were considered. Due to the large effort and expense of programming and acquiring the systems required for benchmarking, this approach is clearly impractical with any large number of systems. Further, the utility of such an approach is limited because

Exhibit 1. General Purpose Computer Systems Used in Analysis.

System	Price ($000)	Memory (K-bytes)	DASD (M-bytes)	Year Introduced
CDC 3170	725.6	195.0	236.0	1970
HONEYWELL 115	166.0	12.0	18.4	1970
NCR CENTURY 300	976.7	512.0	400.0	1970
BURROUGHS B6748	1271.5	768.0	543.0	1971
HONEYWELL 1015	639.0	48.8	36.8	1971
HONEYWELL 2015	916.0	196.5	175.0	1971
HONEYWELL 6030	1209.2	441.0	235.0	1971
HONEYWELL 6050	2032.6	882.0	470.0	1971
HONEYWELL 6070	3319.7	1179.0	707.0	1971
IBM 370/145	1969.7	524.0	1600.0	1971
UNIVAC 70/2	610.7	65.0	14.5	1971
UNIVAC 70/3	927.3	262.0	116.8	1971
UNIVAC 70/6	1282.2	262.0	116.8	1971
UNIVAC 70/7	1821.1	524.0	233.4	1971
XEROX SIGMA 8	770.3	256.0	60.9	1971
XEROX SIGMA 9	1598.2	1024.0	220.1	1971
DEC 1060 (A)	475.1	432.0	25.6	1972
DEC 1060 (B)	826.2	864.0	200.0	1972
HONEYWELL 6040	1279.1	441.0	235.0	1972
HONEYWELL 6060	2113.3	882.0	470.0	1972
HONEYWELL 6080	3434.4	1179.0	707.0	1972
IBM 370/135	583.8	98.0	140.0	1972
IBM 370/135 (B)	860.3	524.0	280.0	1972
BURROUGHS B3741	500.0	100.0	182.4	1973
HONEYWELL 6025	1027.0	360.0	235.0	1973
IBM 370/168	4434.2	2096.0	1216.0	1973
NCR CENTURY 251	490.1	192.0	120.0	1973
UNIVAC 9480	571.0	131.0	116.0	1973
UNIVAC 90/60 (A)	677.2	524.0	600.0	1973
UNIVAC 90/60 (B)	878.5	1048.0	1000.0	1973
UNIVAC 90/70	1678.6	1572.0	1200.0	1973
BURROUGHS B4771	928.9	250.0	543.2	1974
CDC CYBER 172	1452.7	1425.0	472.0	1974
CDC CYBER 173	1976.7	1920.0	472.0	1974
CDC CYBER 174	3077.6	4755.0	1890.0	1974
CDC CYBER 175	4618.8	5242.5	1890.0	1974
HONEYWELL 62/60	187.4	81.0	58.4	1974
HONEYWELL 64/20	362.2	128.0	87.0	1974
HONEYWELL 66/20	1113.9	131.0	400.0	1974
HONEYWELL 66/60	2462.2	1179.0	800.0	1974
HONEYWELL 68/80	3525.5	5850.0	9600.0	1974
IBM SYS/3 MOD 15 (A)	121.2	48.0	4.9	1974
IBM S/3 MOD 15 (B)	252.8	128.0	87.0	1974
NCR CENTURY 151 (A)	133.7	32.0	9.8	1974
NCR CENTURY 151 (B)	275.8	128.0	96.0	1974
NCR CENTURY 201 (A)	300.0	64.0	96.0	1974
NCR CENTURY 201 (B)	634.4	256.0	192.0	1974
UNIVAC 90/30 (A)	162.7	32.0	57.8	1974
UNIVAC 90/30 (B)	231.8	98.0	173.7	1974
UNIVAC 90/30 (C)	417.7	196.0	231.6	1974
XEROX 550	328.7	64.0	14.3	1974
XEROX 560	980.0	160.0	405.8	1974
BURROUGHS B4790	1523.4	400.0	892.8	1975
DEC 1080 (A)	739.6	1152.0	200.0	1975
DEC 1080 (B)	969.5	1152.0	300.0	1975
HONEYWELL 62/40	108.0	65.0	11.6	1975
HONEYWELL 64/40	523.7	160.0	400.0	1975
IBM 370/158-3	2518.2	1048.0	678.0	1975
UNIVAC 1100/20	1173.0	589.5	200.0	1975
UNIVAC 1100/20 (B)	1925.4	1179.0	604.7	1975
BURROUGHS B6807	1030.0	786.0	20.0	1976
BURROUGHS B1776	198.0	81.0	174.4	1976
BURROUGHS B1726	186.8	65.0	87.2	1976
BURROUGHS B1728	416.9	163.0	182.5	1976
DEC 2040 (A)	315.0	576.0	100.0	1976
DEC 2040 (A)	531.4	1152.0	400.0	1976
IBM 370/115-2	268.6	65.0	140.0	1976
IBM 370/115-2	354.3	98.0	140.0	1976
IBM 370/125-2 (B)	525.7	131.0	280.0	1976
IBM 370/148	1225.1	1048.0	420.0	1976
NCR CRITERION 8550	259.0	128.0	200.0	1976
CRITERION 8570	458.3	256.0	300.0	1976
UNIVAC 1100/10	763.6	589.5	116.6	1976
UNIVAC 90/80 (A)	2156.7	1048.0	1200.0	1976
UNIVAC 90/80 (B)	3131.1	2096.0	1600.0	1976
BURROUGHS B1830	108.7	48.0	4.6	1977
BURROUGHS B1860	230.0	128.0	130.4	1977
BURROUGHS B1870	550.0	393.0	361.8	1977
DEC 2050	485.0	1152.0	200.0	1977
IBM 370/138	706.0	512.0	540.0	1977
UNIVAC 1100/80	2430.9	2394.0	2450.0	1977
IBM 370/3033	3800.0	4192.0	1216.0	1978

Exhibit 2. Small Business Computers Used in Analysis. * DEC PDP Based Processor. ** DG Nova or Eclipse Processor. *** INTEL 8080 Processor. # Microdata Processor.

System	Price ($000)	Memory (K-bytes)	DASD (M-bytes)	Year Introduced
IBM S/3 MOD 10	68.7	12.0	4.9	1970
NCR CENTURY 50	55.8	16.0	8.4	1970
DIG SCI M 4/1130	100.0	64.0	40.0	1970
HONEYWELL 105	77.0	12.0	9.2	1971
BASIC/FOUR M 350	35.0	24.0	20.0	1971
BASIC/FOUR M 400	45.0	32.0	20.0	1971
FOUR PHASE SYS IV/70	110.0	96.0	2.5	1971
DIG SCI M 4/1800	150.0	96.0	100.0	1971
NCR CENTURY 101	80.5	16.0	9.8	1972
COMP INTER COMPRO II	40.0	16.0	26.0	1972
STC ULTIMACC 2000**	44.0	32.0	10.0	1972
XEROX 530	80.1	16.0	0.0	1973
FOUR PHASE SYS IV/40	70.0	72.0	2.5	1973
DISPLAY DATA INSIGHT#	64.0	40.0	40.0	1973
HOTEL	250.0	64.0	5.0	1973
ICL 2903	150.0	336.0	120.0	1973
LOCKHEED SIII/A	20.0	32.0	5.0	1973
MICRODATA REALITY#	66.9	40.0	10.0	1973
MICOS 1003 (MINI-COMP SYST)**	49.9	64.0	10.0	1973
MCS-2000A	150.0	48.0	10.0	1973
MICOS 2003**	74.6	64.0	80.0	1973
MICOS 3003**	84.4	64.0	160.0	1973
MICOS 4006**	104.9	128.0	160.0	1973
CHC DIST SYS*	100.0	128.0	88.0	1974
DATASAAB D15	75.0	32.0	20.0	1974
DIMIS TOTAL 100	135.0	64.0	50.0	1974
LITTON 1300 CASSETTE	19.5	16.0	0.0	1974
LMC ADAM	40.0	32.0	10.6	1974
NORTHROP BDS-2000#	62.8	24.0	20.0	1974
WARREX CENTURION III	35.1	32.0	10.4	1974
WARREX CENTURION IV	42.7	32.0	10.4	1974
IBM S/32 (A)	33.6	16.0	3.6	1975
IBM S/32 (B)	45.1	32.0	9.3	1975
IBM S/32 (C)	67.7	32.0	13.9	1975
IBM S/3 MOD8	63.4	16.0	2.5	1975
BINARY DATA UCOM**	60.0	64.0	10.0	1975
DIG SCI M 4/VM-TSO	140.0	96.0	100.0	1975
GRI SYSTEM 99	33.0	32.0	10.6	1975
GEN ROB TSS/11	59.8	120.0	10.0	1975
LITTON 1300 DISK	21.5	16.0	1.5	1975
NIXDORF 8870 (A)	40.0	48.0	10.0	1975
NIXDORF 8870 (B)	94.2	64.0	20.0	1975
NORFIELD NOVA **	110.0	64.0	25.0	1975
NORTHROP BDS-1000#	49.5	16.0	10.0	1975
QANTEL 900	30.0	32.0	6.0	1975
QANTEL 950	40.0	40.0	12.0	1975
QANTEL 1400	65.0	64.0	25.0	1975
RANDAL LINK 100	20.0	32.0	0.6	1975
RAYTHEON PTS/1200	67.6	48.0	5.0	1975
STC ULTIMACC 3000**	94.0	96.0	30.0	1975
WANG 2200	14.7	16.0	0.0	1975
WANG PCS-II	6.2	16.0	0.5	1975
WINTEX 200 NS	15.0	8.0	0.5	1975
IBM S/3 MOD 12	102.9	32.0	100.0	1976
BASIC/FOUR M600	55.0	32.0	20.0	1976
CADO SYS 40 SBS	20.0	5.0	1.2	1976
FOUR PHASE SYS IV/50	98.0	72.0	2.5	1976
COMPUCORP 450/OPD	18.4	16.0	1.2	1976
SYFA(1) (COMPUTER AUTO)	72.3	64.0	20.0	1976
SYFA(2)	88.0	64.0	20.0	1976
SYFA(3)	117.0	64.0	160.0	1976
COMP COV CPBS-1*	24.0	56.0	0.5	1976
CTL 8030	70.0	96.0	9.6	1976
CTL 8050	147.0	144.0	19.2	1976
ECLIPSE C/330 (DG)**	148.3	256.0	96.0	1976
GIS ABLE/324*	39.0	32.0	7.2	1976
GIS ABLE/322*	24.9	32.0	0.5	1976
GEN ROB GRC 11/03	14.0	24.0	2.4	1976
ICL 2904	260.0	480.0	240.0	1976
IC MIDAS	100.0	96.0	50.0	1976
JACQUARD J100(A)	27.3	64.0	0.0	1976
JACQUARD J100(B)	58.3	128.0	0.0	1976
MICRODATA REALITY 11#	31.5	16.0	10.0	1976
MICRODATA REALITY 11(B)#	45.7	32.0	10.0	1976
MICRODATA EXPRESS III#	70.0	128.0	10.0	1976
MYLEE 3056	40.0	56.0	48.0	1976
MYLEE 3088	80.0	152.0	96.0	1976
QI LITE	21.0	16.0	1.0	1976
RANDAL LINK 200	27.0	32.0	10.0	1976
STC ULTIMACC 3370**	200.0	256.0	400.0	1976
APPLIED DC SER 70 FLOPPY***	12.0	32.0	1.0	1977
APPLIED DC SER 70 CART. DI***	27.0	32.0	10.0	1977
CADO SYS 40 TERM***	15.0	5.0	1.2	1977
NORTHROP BDS-700#	38.9	16.0	10.0	1977
WARREX CENTURION I-A	18.0	32.0	1.0	1977

of the constrained relevance of a general set of benchmark jobs to a particular user. Thus the cost is exorbitant and the benefit slight.

Knight's algorithm for power was a surrogate for benchmark measurements. First he determined, through a set of benchmarks, how a certain "typical" jobstream engaged the basic operating components of the computer. From this, he developed a set of weights for these operating components so that their characteristics could be used to derive a measure of relatively how fast a machine could run the jobstream. This measure, expressed in instructions per second, became Knight's power measurement. In summary form, it is

$$\text{Power} = f\left[\frac{\text{Memory}}{\text{Compute time} + \text{I/O time}}\right]$$

where *Memory* is basically the number of bits in main storage, weighted by a constant. This weighting factor was derived from the opinions of a group of experts as to the effect of memory size on computing power. *Compute time* is the time it takes the processor to perform a certain mix of basic instructions. Five instructions are used, namely fixed-point addition, floating-point addition, multiply, divide, and logical compare, and the timing for each is multiplied by a weighting factor. *Input/output time* is the amount of time the processor would spend waiting for I/O during the execution of the instruction named above, if those instructions were being executed as part of a typical business program. It is calculated through the use of an extremely complicated algorithm.

The advantage of Knight's approach is that it provides a single measure of computer power that can be statistically related to system cost. Unfortunately, his formulation is no longer usable. Computer design has changed so drastically since the early 1960's that his model, formulated for the computers of that time, does not adequately measure the computers of today. The effect of memory size on computer performance is quite different from what it was in 1963, because most large systems today employ some form of virtual memory. Likewise, Knight's input/output time measure is not really applicable to today's systems. It is oriented towards magnetic tape as the primary I/O medium (as it was in 1960) rather than direct access storage (as it is today). Also, Knight's method of measuring I/O time would yield a zero value for most large modern computers, which employ satellite subprocessors to control input/output.

We attempted to build several simplified versions of Knight's model, with single measure surrogates for memory, compute time, and I/O time measures. Unfortunately, we could not develop a convincing rationale for any particular method of combining the measures. Statistically, the formulation

$$\text{Power} = \frac{\text{Memory size} + \text{DASD capacity}}{\text{Add-time}}$$

provided a good correlation with system cost for any given year of introduction. However, other models with equally good correlation values could be obtained with different combinations forming the power measure; they showed markedly different relationships between system price and power.

Rather than continue the attempt to quantitatively define the concept of power, an alternative approach was taken. Using the free market price of systems as the most generally accurate measure of system performance, a model was developed that directly related system costs to measures of significant system component characteristics. The model which provided the most consistent results was

$$\text{Cost} = (B_0 + B_3 \cdot D_1 + \ldots + B_n D_n) \cdot (\text{Memory}^{B_1} + \text{DASD}^{B_2})$$

or, in a form so that it could be run through a least squares regression program,

$$\text{Ln Cost} = B_0 + B_1 \cdot \text{Ln Memory} + B_2 \cdot \text{Ln DASD} + B_3 \cdot D_1 + \ldots + B_n \cdot D_n$$

the value of the variables for each system being developed in the following manner from the manufacturer's data.

Cost

The total system cost including all the peripheral equipment necessary for a balanced system. It is expressed in dollars.

Memory

The amount of main memory in *bytes* which is obtained where appropriate by dividing the word length by 8 and multiplying by memory size. Adjusting to bytes provides a common basis for memory size among computers with different word lengths.

Direct Access Storage Devices (DASD)

This parameter is the number of megabytes of online direct access storage for the system. The same conversion was made from words to bytes where necessary. For the most part this represents disk storage capacity; however, for some systems it includes drum storage, and for some it is diskette (floppy disk) storage.

Year of System Introduction

This system of binary variables representing the year of introduction is defined as follows:

D_1 is 1 if year of introduction is 1972 or 1973; otherwise 0.

D_2 is 1 if year of introduction is 1974 or 1975; otherwise 0.

D_3 is 1 if year of introduction is 1976 or 1977; otherwise 0.

The dummies were set up for two-year intervals because of the uneven distribution of the data over time. With these groupings the distribution of observations was reasonably balanced over the years. Separate variables were used instead of one time variable so that the differing effects over different years could be noted. (Note: The base case, i.e. $D_1 = D_2 = D_3 = 0$, covers computers introduced in 1970 or 1971.)

Identification as Small Business Systems vs. General Purpose

D_4 discriminates between small business computers and general purpose computers. $D_4 = 1$ for small business computers; otherwise 0. The base case of the model then with all variables = 0 is for general purpose computer systems introduced before 1972.

Note that neither add-time nor any other direct measure of processor speed is in the model. The fact is that in all the various formulations which were tried for the model, the coefficient derived for such a measure was not significantly different from zero (i.e. H_0: $B = 0$ could not be rejected at a 95 percent significance level). Thus the final model was run without this variable.

This is explainable by the complexity of modern processors. Add-time, or multiply-time, or the like, is altogether too simplistic a measure of processor power to be useful. Many other aspects of computer architecture (parallel processing, for example) dominate the effect of simple instruction timing. Control Data, for example, specifically points out that because of the concurrent operations of the 12-word instruction stacks in the Cyber 76, 175, and 176, instruction timings are a poor indicator of overall performance [2]. Burroughs even refuses to divulge instruction timings for the B6807, maintaining that because of its unconventional architecture, straightforward instruction time comparisons would be meaningless [2]. Also, memory size and DASD capacity are themselves correlated with and remain a proxy for computer power, thus masking any measurement effect of instruction timings in the model.

Thus we are left with two hardware characteristics as independent variables in our measure of computer performance. This performance characterization assumes that vendors offer and users acquire *balanced* computer systems. The market deems that the critical aspects of modern computers are memory and direct access capacity which are supported by other components that allow them to do proportionately more work than computers with smaller memories and less DASD capacity. This is much the same assumption as used by Chow [3] in his formulation which makes use of only a few characteristics as independent variables. In his words,

> As far as the omitted characteristics of the hardware are concerned, it is assumed that they are highly correlated with the included ones so that our estimate ... would not be too inaccurate.

The high correlation values obtained from the model using only a few characteristics support this hypothesis.

Table I shows the results of a model run on all observations, using dummy variables for time and system type. This model suggests that there are in fact significant differences in the relationship between system price, memory size, and DASD capacity, between different years and system types. To explore this further, the data file was broken into two files, one of which contained the observations on the general purpose systems, and one of which contained the small business computers. A statistical analysis was then run on each set of computers. Table II summarizes the results of these regression models. This analysis identifies a price advantage in the smaller systems. To illustrate this we can look at the predicted cost of a system which falls within the relevant range of either model, and compare how the different models predict.

Table III shows the predicted cost of a system which (1) has 100,000 bytes of main memory; (2) has 100 million bytes of on-line DASD capacity; and (3) was introduced in 1974 or 1975. Such a system is well within the relevant range of any of the models presented. The

Table I. Results of regression model run on all observations using dummy variables for year and type.

Variable	B*	t-Statistic
Constant term	10.3	54
Ln memory size	.5	13.6
Ln DASD capacity	.12	5.7
Effect for 1972–1973	−.3	−2.7
Effect for 1974–1975	−.5	−4.7
Effect for 1976–1977	−.71	−7.2
Effect for small business system	−1.1	−11.2
R^2 = .925 (160 degrees of freedom)		
$t \geq 2.5$ = 99% level of confidence		

* B is the coefficient in the regression equation for each variable. It is the amount the dependent variable changes for each unit change in the independent variable.

Table II. Results of regressions using separate data files for different computer types.

	General Purpose Systems		Small Business Systems	
Variable	B	t-Statistic	B	t-Statistic
Constant term	10.2	51	9.3	35
Ln memory	.42	8.3	.46	6.9
Ln DASD	.24	5.3	.11	4.2
Effect for 1972–1973	−.4	−2.9	−.14	−.7
Effect for 1974–1975	−.54	−4.5	−.43	−2.2
Effect for 1976–1977	−.83	−6.4	−54	−2.8
R^2	.854		.626	
Degrees of freedom	76		79	
$t \geq 2$ = 95% level of confidence				

Table III. Predicted cost of a system introduced in 1974 or 1975 with 100 K-bytes memory and 100 megabytes DASD; predictions according to various models.

Model Used	General Purpose	Small Business Computer
Global	\$313,400	\$104,300
Subdivided by type	\$327,500	\$ 98,200

Table IV. Regression models run on general purpose computer systems only, subdividing the data set by year of introduction.

	Constant		Memory		DASD			
Year	B	t	B	t	B	t	R^2	Degrees of Freedom
1970–71	11	36	.47	4.3	.04	.4	.848	13
1972–73	10	14	.38	2.4	.24	1.6	.669	12
1974–75	10	37	.38	4.8	.3	4.2	.898	26
1976–77	9	21	.49	5.4	.27	3.4	.854	19

Table V. Regression models run on small business computer systems only, subdividing the data set by year of introduction.

	Constant		Memory		DASD			
Year	B	t	B	t	B	t	R^2	Degrees of Freedom
1970–71	Too Few Observations							
1972–73	9.7	14	.45	2	−.6	−.7	.259	12
1974–75	9.1	19	.38	2.5	.18	3.7	.690	27
1976–77	8.5	30	.51	6.9	.14	4.3	.778	29

difference between the predictive models emphasizes the difference in costs—in the individual models the costs diverge by $20,000 greater than with the global model. By way of comparison an integrated SBC system such as the IBM S/3 model 15 used in the database costs $253,000; while a similarly configured nonintegrated SBS, the Computer Horizons Distribution System, comes in at $100,000—some $150,000 less and consistent with our model. The overall appraisal of both analyses indicates that, given hardware characteristics and year of introduction, a system classified as a small business computer is likely to be less costly than its general purpose systems counterpart. The very significant differences in predicted price which result from changing its classification are really reflecting what set of vendors we think that computer might be coming from. If we call it an intermediate system, we are saying that it is coming from IBM, Honeywell, Burroughs, etc. If we call it a small business system, then we are grouping it with those machines which probably do not come from those "old standard" computer companies but from software firms packaging a system around OEM hardware.

The impact of time of introduction on cost vs. capacity was analyzed to better understand the computer system market of the 1970's. Tables IV and V summarize the results of these models. The analysis shows evidence of two quite different markets. The large and intermediate computer systems are sold in a market which has been established for some time. This market has an acknowledged market leader (IBM), and the number of firms competing in it is both small and stable. In fact, competition between vendors in this market is rather limited—customers are usually deterred by the massive conversion costs of switching large installed computer systems from one vendor's equipment to another's. This market has grown because of the continuous development of software unique to the vendor. In short, it is a mature, rationalized market.

For the general purpose data in Exhibit 2, this market indicates that memory size alone is a fairly good predictor of system cost for all systems introduced during the 1970's, and its coefficient is relatively stable over time. The consistently high correlation values over all years suggest that not only is memory a proxy for all the other components of computer performance, but also that there exists a stable price/performance relationship in the industry as well. In this breakdown of observations, DASD is significant only after 1974; however, the small size of the samples may have something to do with this. In general, it can be inferred that the basic pricing policies in this segment of the computer industry are set.

The data on small business computers tell quite a different story. For the period before 1974, no satisfactory model can be built. In fact, this segment of the industry was in th early stages of development in the years before 1974. The distribution of observations across time points to this. Only in the last few years does a definite price/hardware power relationship begin to appear. If we look at the coefficients of the model for small business systems, 1976–77, and compare them with the corresponding coefficients for the general purpose systems of the same time, we will again see the small systems model predicting lower prices for the same hardware. For example, going back to our system with 100K memory and 100 megabytes DASD, we find the small systems model predicting a cost of $98,000, and the general purpose systems model predicting $220,000.

Intuitively, such a price differential is understandable. General purpose computers are usually provided to customers with a wide variety of software, documentation, and other services which are not reflected by hardware characteristics. Small business computers are often of single or limited purpose, and are usually delivered with fewer customer services. Additionally, the lesser complexity of the small business computers reduces the time of design and development cycle, allowing certain technical and cost effective improvements more rapid market availability.

In all formulations of the models, the effect of advancing technology is unmistakable. A system of given hardware characteristics would cost less if introduced later in time. Again using our 100K memory-100 megabyte DASD system, we see that the general purpose system model predicts that it would have cost over $550,000 in 1970, $380,000 in 1972, $330,000 in 1974, and $250,000 in 1976. The other formulations of the model would demonstrate a similar decline in cost. Again, intuitively, this is quite acceptable. One has only to look at the dramatic drop in prices of electronic calculators (which are made with much the same technology) to verify that such a strong technological effect can exist.

In probing for differences in the price/hardware characteristic relationships between various vendors, we

Table VI. Average natural residual by vendor, using as a predictor the model based only on general purpose systems, year dummy variables included.

Vendor	Average Natural Residual
Burroughs Corporation	.03
Control Data Corporation	−.02
Digital Equipment Corporation	−.45
Honeywell Information Systems	.10
IBM	.06
National Cash Register	−.15
Sperry-Univac	.03
Xerox Data Systems	.25
Standard Deviation of Natural Residual	.38

can look at the natural residual values (i.e. actual cost minus predicted cost) sorted by vendor. Table VI summarizes these residual values. It will be noted that only one vendor—Digital Equipment Corporation (DEC)—appears as an "outlier," with an average residual value more than one standard deviation away from zero. Intuitively, this is quite acceptable. The systems offered by DEC are in fact somewhat different from the general purpose computer systems offered by other vendors. DEC's systems are time-sharing oriented machines, many being installed in universities. Those that are used in business organizations typically complement systems manufactured by one of the other large systems vendors, with the DEC system performing some special purpose task, such as driving a time-sharing network for program development. It is quite understandable then that the model might not describe DEC systems as well as other general purpose business systems.

No similar analysis was performed for the small business systems because of the large number of vendors, and the small number of observations (usually 2–4) per vendor. The effect of doing such an analysis would be little different from looking at individual systems' residuals.

3. Conclusions

A. Grosch's Law

It is highly questionable whether a single, simplistic measure of computer power has any meaning. The "power" of a computer is really its ability to perform a given amount of work; therefore any power measurement must be work-specific. There is no independent, generally accepted definition of a unit of work in the computer sciences as there is, for instance, thermodynamics. In other words, it is meaningful to talk about how well different computers execute *a certain jobstream*; it is not meaningful to talk about the computer's power in a general sense. When we say that computer A is more powerful than computer B, we are really saying that we think, for any relevant jobstream that we are interested in, computer A would be a better processor.

Thus, to examine Grosch's Law one would have to restate it slightly: The power of a computer *to process a given jobstream* increases as the square of the computer's price increases. Knight was implicitly addressing this restatement of the law. His power measurement attempted to estimate how well various systems could perform that jobstream with which he developed his algorithm. To perform a study similar to Knight's one would have to develop an algorithm similar to his, (or actually benchmark all the systems) tailored to modern systems. To do so one would have to develop a jobstream which one considered "typical" of business data processing, and then develop a method of measuring how well the various systems executed the jobstream. This measure of "how well" the systems perform could be used as a power measure. And even this approach would be open to question—how exactly does one measure "how well" a system performs a jobstream? Do you judge the system in terms of speed? User convenience? If not these, then what criteria do you apply?

B. Price vs. Hardware Characteristics

The best single measure of computing power is computer price. There no longer exists a single relation between price and power due to the development of a new nonintegrated market in recent times. The market for large and intermediate systems is served by the "old standard" computer manufacturers, and it consists mostly of the established customers of these vendors.

The new market for small business computers, on the other hand, is in a development stage. Most of the vendors in this market are nonintegrated and relatively small with little software dependence. Many of these companies either do not offer support services to their customers, or at least are perceived by customers to not offer such service. Many of these companies' machines are sold for a special purpose, i.e. tailored to a specific application. This fact, along with the relative newness of the small business computer market, hinders the formation of a clear pricing policy.

In both markets technological advance is clearly causing a decrease in the price of any given hardware component. In fact, it is the technological advance itself which has spawned the development of the small computer market. Ten years ago a system such as the Mylee 3088 might have cost nearly one-half million dollars! Just as advancing technology has made calculators available to anyone who can afford one, so too is it offering computers to any business (and many individuals) that can afford them.

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Management Applications

H. Morgan Editor

A Methodology for the Design of Distributed Information Systems

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A macro model of a distributed information system in presented. The model describes the major costs of using an information system from the perspective of the end-user. The model is intended to provide guidance to the system designer by making evident the effect of various design and operating parameters on overall cost per transaction. The technique is illustrated by application to the design of an interactive transaction processing system.

Key Words and Phrases: distributed processing, system design, cost minimization, distributed database, interactive computing, economic modeling, transaction processing

CR Categories: 4.32, 4.33, 6.2, 8.1

1. Introduction

The ultimate objective of a computer system designer is to provide a system configuration which meets the user requirements at the least overall cost. However, as systems and usage become more complex, it becomes increasingly difficult for the designer to relate the effects of his choices and decisions to this ultimate objective.

In this paper we describe a macro model of a computer system "in use," which is intended to provide the designer with a broader perspective in a constructive way. By constructive, we mean that the model provides practical guidance to the designer in making some of his

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