STATUS REPORT
ARRAY PROCESSOR
JAN. 1976

* BACKGROUND
* HARDWARE
* "SOFTWARE"
* APPLICATION STUDIES
* CURRENT ACTIVITIES

ARRAY PROCESSOR
BACKGROUND

* Developed by FSD for Navy
* Part of Proteus Sonar System
* Integer Machine for FFT
* Interest by DP for 2938 Follow-On
* PASC Application Studies
* Elser Task Force

ARRAY PROCESSOR
HARDWARE

* 1 Megabyte Bulk Store (24K points, 1M-purchase)

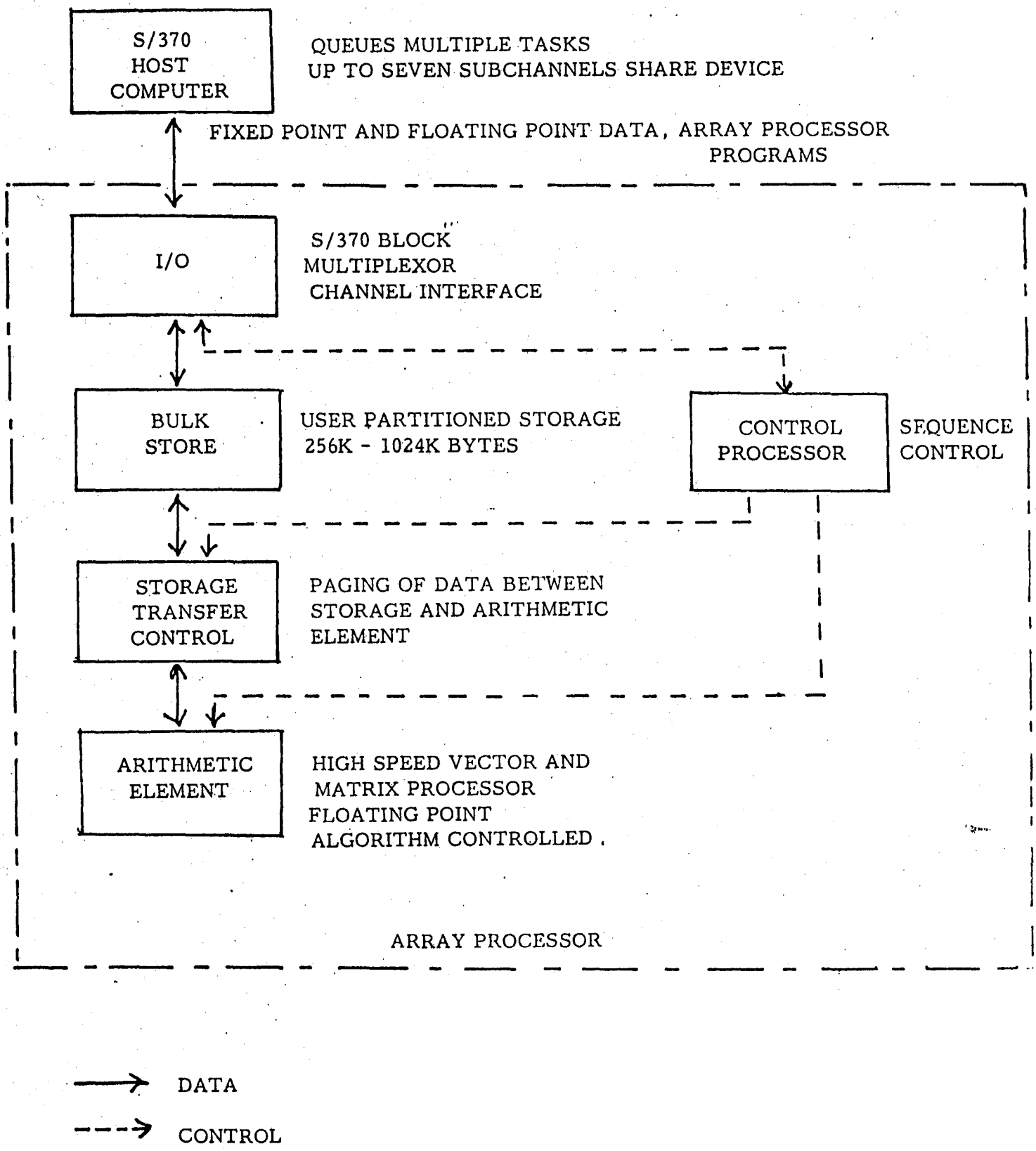
* 24/48 bit Fraction

* Arithmatic Element
  - 2 Adders
  - 1 Multiplier
  - Highly Pipelined
  - 100 ns Cycle
  - 2-1000 Word Working Stores
  - Microprogrammed
  - Short/Long Precision
  - No Error Checking

* Control Processor
  - 2 Micro Second Cycle
  - Controls Data Transfers
    - Host to Bulk Store (3M B/S)
    - Bulk Store to Working Store (40M B/S)
  - Provides Overlap

* 370 Channel Interface

BLOCK DIAGRAM



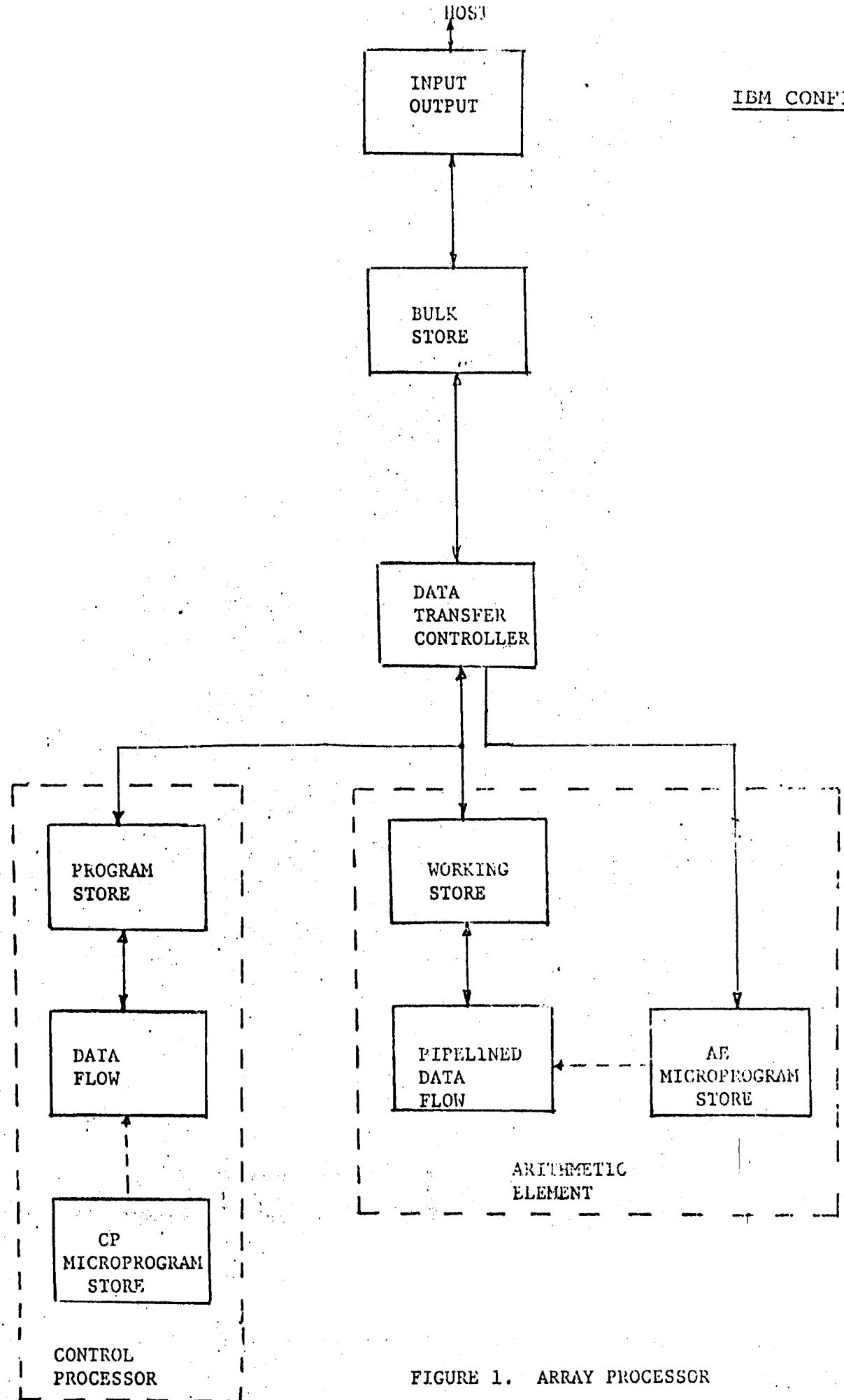


FIGURE 1. ARRAY PROCESSOR

ARRAY PROCESSOR

"SOFTWARE"

* AE - Microcode

* CP - SPL (370 BAL-Like)
  - Controls Data Transfer
  - AE Scheduling
  - Multiprogramming

* Host - VPAM
  - VPAM is 2938, APAM Follow-On
  - User Program

* Overhead Estimates
  - 1.8 ms - Initialization
  - 1 ms - Branching
  - 300 ms - Initialization per Algorithm
  - Binding may Eliminate
  - Overlapped with AE and IO

ARRAY PROCESSOR

APPLICATION STUDIES

* Nuclear Reactor Diffusion Equation
  - Golub-Varga-Tridiagonal System
  - 50-75% of Running Time
  - Special Microcode
  - AP is 2-3 X 168
  - Bulk Store Limitation

* Atmospheric Radiation
  - Matrix Multiply - AP ix 5-10 X 168
  - Matrix Inversion (LU) - AP is 7 X 168
  - 80% or more in AP

* Plasma Computation
  - Vlasov-Poisson Equations
  - ASD Method (FFT)
    - 56% of Computation is FFT
    - 24% Vector OPS
  - 80% can be done in AP
  - AP 5 X 168

* NOAA Weather Model

  Already Vectorized
  80% or more in AP
  AP 1-2 X 168 using APAM

* European Weather Center

  J. Hague - UK
  Microcode Approach
  50 Algorithms
  100 Man Month Estimate
  20 MIPS (6 X 168)

* Earth Resource

  Digital Filtering
  FFT
  ERTS Data

* Seismic

Vector OPS	10-20 X 2938
Vector OPS	2-10 X 168
FFT	24 X 168
Overall	4 X 168

Timing Comparisons

	2938	Gusher	2938/ Gusher
Case A	8.38	3.17	2.65
B	12.53	4.62	2.71
C	41.44	6.34	6.54
D1	615.57	27.73	22.2
D2	825.84	32.54	25.4
E	59.07	9.51	6.21
F1	25.06	9.51	2.64
F2	82.85	10.96	7.56
F3	48.96	6.34	7.72
F4	97.89	10.96	8.93
G	82.88	6.34	13.07

Case A Autocorrelation 640 point window, 64 output points

B Deconvolution (short filter) 1500 pt trace, 32 pt filter

C Band pass filter (long filter) 1500 pt trace, 125 pt filter

D1 Vibroseis (Step 1) Cross Correlation, 4000 pt Window, 201 output pts.

D2 Vibroseis (Step 2) Cross Correlation, 7000 pt Window, 3000 output pts.

E Time Variant Filter - three 500 pt Windows, 150 pt overlap, 125 pt filter

F1 Filtering 3000 pt trace, 32 pt filter

F2 Filtering 3000 pt trace, 125 pt filter

F3 Filtering 1500 pt trace, 150 pt filter

F4 Filtering 3000 pt trace, 150 pt filter

G Filtering 1500 pt trace, 250 pt filter

ALGORITHM EXECUTION TIME

(μs unless noted)

N = no. of elements

ALGORITHM	2938 370/168	3838 min/max range
Vector Element Multiplication	3.75N	0.3N - 0.6N
Vector Element Sum	3.75N	0.3N - 0.6N
Scalar Multiply	2.475N	0.3N - 0.5N
Signed Square Array	2.475N	0.3N - 0.5N
Sum of Squares	2.4N	0.1N - 0.2N
Sum of Vector Elements	2.4N	0.1N - 0.2N
Vector Inner Product	2.55N	0.2N - 0.4N
Convolving Multiplication	0.2N	0.1N - 0.2N
Complex Multiply	3.75N	0.6N - 1.2N
Difference Equation	4.6N	1.1N - 1.2N
Interpolate	12N	3.4N - 3.5N
Partial Matrix Multiplication	3.75N	0.11N
FFT (1024 Points, Complex)	26.6ms	2.66ms
FFT (1024 Points, Real)	NDA	1.43ms
Vector Move Convert	2.475N	0.2N - 0.4N
Vector Floating to Fixed	2.7N	0.2N - 0.4N
Divide	NA	.85N - 1.15N
Square Root	NA	3.0N - 3.2N

Note: NA - not available on 2938
NDA - not directly available

ARRAY PROCESSOR
CURRENT ACTIVITY

* ELSER TASK FORCE MEETING - 1/27/76
* PHASE II REVIEW - 3/76
* IDENTIFY SCIENTIFIC APPLICATIONS
* IDENTIFY CUSTOMERS
* SPECIFY SCIENTIFIC ALGORITHMS
* DESCRIBE SUPPORT
  * SUPPORT GROUP
  * RPQ PROGRAMMING SERVICES
  * CUSTOMER EDUCATION
  * SOFTWARE PRODUCTS
  * DEMONSTRATIONS
* INVESTIGATE
  * SPARSE MATRICIES
  * LINEAR PROGRAMMING
  * PARABOLIC PDE
  * PIC

PDQ7V2

* PDQ7V2 FDP ANN 6/75

* VERSION 1 MODIFICATION 1 - 1/76
  * OS/HPAM DISK ERROR RECOVERY
  * 30% PERFORMANCE IMPROVEMENT (INPUT)
  * CORRECTION OF MINOR PROBLEMS
  * TIMING COMPARISON WITH PDQ7/17 - PDOM

* TIMING COMPARISON
  * 24 TYPICAL PROBLEMS
  * 10-25% FASTER CPU TIME - 2D
  * 2-5 TIMES FASTER CPU TIME - 3D

* FIRST CUSTOMER EXPERIENCE
  * 30% PERFORMANCE IMPROVEMENT OVER PDQ7/17
  * RUNNING 7 HOUR 3D ON 165
  * USING NEW FEATURES
  * ACCURACY BETTER THAN 1/4%
  * PROJECTING 370/168

IBM vs COMPETITION

STATUS IN U.S.

NATIONAL LABS HIGH ENERGY PHYSICS PLASMA PHYSICS	370/168, 195, CDC/7600
WEAPON DEVELOPMENT	CDC/7600
WEATHER BUREAU	370/195
REACTOR MANUFACTURERS	CDC/7600 + GE/635
MANUFACTURING	1108, 360, 370, CDC

PERFORMANCE

RELATIVE RUN TIME

MACHINE	CPU	ELAPSED TIME	PDQ7V2
7600	1	1	1
195	1	0.8 - 1.0	1
168MP	1.1-1.2	1.3-1.5	1-2.2
168UP	2	1.8-2.2	1-2.2
158MP	5-6	5-7	--
158UP	10	9+12	10
145	25	20-30	30

SERVICE BUREAUS

CYBERNET	CDC
INFONET	CSC (1108)
OTHERS	IBM

HARDWARE INSTALLED IN U.S.

GOVERNMENT

ARGONNE NATIONAL LAB	50,75,195
OAKRIDGE NATIONAL LAB	75,91
BROOKHAVEN NATIONAL LAB	7600
SAVANAH RIVER NATIONAL LAB	195
LOS ALAMOS NATIONAL LAB	4-7600
HANFORD NATIONAL LAB	CYBER 73
NATIONAL REACTOR TEST STATION	75
BETTIS	7600
KAPL	7600
LIVERMORE	4-7600, STAR
SANDIA	7600
SLAC	91, 2-168
PRINCETON (PLASMA)	91
UCLA (PLASMA)	195
WEATHER BUREAU	2-195

REACTOR MANUFACTURERS

GENERAL ELECTRIC	2-GE635
WESTINGHOUSE	2-7600, (IBM)
BABCOCK & WILCOX	7600
COMBUSTION ENGINEERING	7600, (158-168)

ELECTRIC UTILITIES

95% - IBM

RELATIVE HARDWARE PERFORMANCE

SCIENTIFIC COMPUTING

MACHINE	CPU SPEED/168 UP	
	SCALAR MODE	VECTOR MODE
CRAY 1	10	14-?
CDC 7600	2	2-5
IBM 195	2	2-3
CYBER 175	1.5-2.1	2-4
AMDAHL 470/V6	1-2	-
IBM 168 AP	(1.6-1.8)	-
IBM 168 MP	(1.5-1.7)	-
IBM 168 UP	1.0	-
IBM 158 MP	(2/5-1/2)	-
IBM 158 UP	1/5-1/3	-
IBM 145	1/15-1/20	-

APPENDIX D BENCHMARK JOBS - RELATIVE PERFORMANCE

System

1. IBM 360/75 using FORTRAN H with optimization
2. IBM 360/75 using FORTRAN G - no optimization
3. IBM 370/158 using FORTRAN H with optimization
4. IBM 370/168-I using FORTRAN H with optimization, no high speed multiply feature, small cache
5. IBM 370/168-III using FORTRAN H with optimization, with high speed multiply feature, large cache

5a. IBM 370/168-I using FORTRAN H with optimization, with high speed multiply feature and large cache

6. CDC CYBER 173
7. CDC CYBER 175
8. AMDAHL 470V6 - using IBM FORTRAN H with optimization
9. BURROUGHS B7700
10. DEC KL10 using F10 with optimization
11. UNIVAC 1100/40

RELATIVE PERFORMANCE (System 1 = 1.0) TOTAL CPU TIME

	1	2	3	4	5	5a	6	7	8	9	10	11
Job 1	1.00	.84	.86	2.33	4.26	4.15	1.72	8.18	4.81	.54	NR	1.46
Job 2	1.00	.53	.86	2.64	4.59	4.36	.97	11.41	4.60	.82	.53	1.34
Job 3	1.00	1.00	1.11	3.14	3.36	3.36	.41	1.44	6.60	NR	NR	NR
Job 4	1.00	.47	.81	3.25	3.56	3.50	.99	8.50	4.83	.84	1.11	1.99
Job 5	1.00	.80	1.08	3.26	3.77	3.78	NR	NR	5.81	NR	NR	NR

NR - not run

NOTE: The five jobs were run as an informal benchmark. Results are indicative, but not definitive since running conditions - e.g. - standalone vs. multiprogrammed - were not controlled.

Job 1: Author: Dr. Arnett - Astronomy

This is a large compute bound problem, written in FORTRAN. All calculations are done in double precision except on CDC equipment where single 60-bit precision is adequate. (It is estimated that performance would degrade about 10% if CDC used double precision.)

Job 2: Author: EDUCOM Benchmark

This is a small FORTRAN program doing double precision matrix multiply. It tests multiply, add and loop control.

Job 3: Author: Dr. Michalski - Computer Science

This is a large and complex PL/I program using bit manipulation. It is both a test of compiler integrity and computer power.

Job 4: Author: Dr. Wagstaff - Mathematics

This is an intensive test of integer arithmetic on a number theory problem in FORTRAN.

Job 5: Author: Dr. Brown - Mathematics

This is an extended precision arithmetic program testing both integer arithmetic and character manipulation. Code is in both FORTRAN and Assembler.