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Los Alamos Scientific Laboratory

Computer Benchmark Performance 1979

University of California

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COMPUTER BENCHMARK PERFORMANCE 1979

by

Ann H. Hayes and Ingrid Y. Bucher

ABSTRACT

Benchmarking of computers for performance evaluation and procurement purposes is an ongoing activity of the Research and Applications Group (Group C-3) at the Los Alamos Scientific Laboratory (LASL). Compile times, execution speeds, and comparison histograms are presented for a representative set of benchmark programs and the following computers: Cray Research, Inc. (CRI) Cray-1; Control Data Corporation (CDC) 7600, 6600, Cyber 73, Cyber 760, Cyber 750, Cyber 730, and Cyber 720; and IBM 370/195 and 3033.

I. INTRODUCTION AND PURPOSE

This is the second annual report summarizing the benchmarking activities undertaken by the Research and Applications Group (Group C-3) at the Los Alamos Scientific Laboratory (LASL). Performance evaluation of both internal and external (non-LASL) computers of interest to the Laboratory is an ongoing project at LASL [1].

The purpose of the study is twofold. By benchmarking all the major computers in the LASL Central Computing Facility (CCF), performance evaluation of current operating systems and computers can be obtained. As a guide for future trends and procurement of computers for the Laboratory, benchmarking of new machines at external sites is performed wherever possible.

Table I describes the operating systems and compilers used in the benchmarking, Table II lists the computers used and their characteristics, Table III gives the compilation times, and Table IV gives the execution times. The benchmark programs are described in Appendix A, and histograms comparing the performance of the various computers on the codes are given in Appendix B.

II. SELECTION OF THE BENCHMARK PROGRAMS

In selecting benchmark programs, the intent is to include problems that typify the workload at the Laboratory. The programs are all coded in ANSI-standard FORTRAN to facilitate portability. All programs are self-contained and self-checking. Most of the codes are compute-bound. Two of them (Programs 2 and 21) have extensive I/O activity, constituting up to half the total execution time on some of the computers tested. Programs 16 and 23 are linear system solvers requiring over 600000 words of storage. These can be executed only on computers allowing a field length of this size; they measure performance of a fully-utilized memory. Programs 1-18 comprise the original benchmark set. During the past year, three additional programs (21, 22, and 23) were added to the existing set. Although some programs have been phased out, the original program numbers have been retained; 15 codes are currently being used.

In a representative set of benchmark programs, some will be highly affected by optimization and vectorizing techniques, others little or not at all. On computers with vector capability, the codes were run in both vectorized and nonvectorized mode to determine the degree to which vectorization affected execution speed.

III. COMPUTERS USED IN THE STUDY

The results in this report were obtained by executing the codes on the following LASL computers: a Cray Research, Inc. (CRI) Cray-1, a Control Data Corporation (CDC) 7600, a CDC 6600, and a CDC Cyber 73. Other computers in the study are: Cray-1s at various installations with different operating systems, a CDC 7600 outside LASL, an IBM 370/195, an IBM 3033, and several members of the CDC 700 series computers.

IV. NOTES ABOUT THE RESULTS

Because the programs are written in ANSI-standard FORTRAN, few modifications were needed to execute them on various computers. An exception to this is the handling of I/O. Program 2 required such extensive changes that it could not be modified within the time constraints imposed and therefore was not run in some cases.

Another serious consideration involves the timing measurement used on various systems. It is important to understand precisely what an installation's timing routine measures. Almost all timing routines that were used in this benchmark study accurately measured CPU times; exceptions to this have been noted in Table III.

In a minority of cases, programs executed more slowly on computers with a known faster cycle time. This can be attributed to the optimizing capability of the compiler used on the faster runs. An example of this is Program 6, a linear system solver that achieves its fastest execution time on the CDC 7600. This program contains long-used but outdated algorithms for solving linear systems. It should be noted that this program does not vectorize and is included primarily for comparison purposes.

To determine the extent to which execution was affected by compiler modifications and operating systems, runs were made on the same model computer at various installations whenever possible. All the execution time results are presented as raw data in Table IV and as histograms of execution times in Appendix B.

V. CONCLUSIONS

No significant changes were observed from last year's results for CDC 7600 computers at LASL or LLL [1]; however, there were some differences for the Cray-1. The CFT compiler showed some speed-up, most significantly a reduction of the run time of the particle-in-cell code (Program 11). Most of the nonvectorizing codes, however, still run 10 to 30% slower than when compiled with the XFC cross-compiler (which now is no longer available).

Both the IBM 370/195 and the IBM 3033 show little difference in execution speeds for single- and double-precision floating point arithmetic. The new optimizing H compiler is a great improvement over the older version G, speeding up execution of some programs by factors of up to 7. Although the results of Program MFLOPS indicate similar megaflop rates for the IBM 370/195 and the CDC 7600, many programs of the LASL benchmark set run considerably slower on the IBM machine, indicating that simple comparisons can be misleading.

Run times for the new Cyber 760 are from 30 to 40% longer than those for the CDC 7600; those for the Cyber 750 are longer by 70 to 100%.

We wish to reiterate two of the conclusions drawn in last year's report:

1. With the arrival of vector, parallel, and multiple processor architectures, it is no longer sufficient to define workloads in terms of number of operations and their frequency.

2. The design of algorithms that exploit particular features of an architecture has profound effects on execution speeds.

As in the 1978 benchmarking, we used a set of representative programs that implement both new and old algorithms for our study. It is evident from the tabulated results that speed depends not only on algorithm design and architecture but on the quality of compiler optimization.

ACKNOWLEDGMENTS

The authors appreciate the assistance of the many persons who gave of their time at Argonne National Laboratory, Argonne, Illinois; Control Data Corporation Benchmark Facility, Minneapolis, Minnesota; and Lawrence Livermore Laboratory, Livermore, California. Thanks are also due to Larry Creel and Brian Dye of LASL, who generated the data and prepared the histograms in this report. Many hours of computer time and analysis have been spent in obtaining the results; it is hoped they are of value in portraying the state of the art in computing.

REFERENCES

1. A. L. McKnight, "LASL Benchmark Performance 1978," Los Alamos Scientific Laboratory report LA-7957-MS (August 1979).

TABLE I

OPERATING SYSTEMS AND COMPILERS USED IN THE BENCHMARKING PROGRAM

Installation	Operating Systems	Compilers
Argonne National Laboratory (ANL)	OSMVT (Operating System Multiple Variable Task). A batch operating system used with IBM computers.	ANL G, H. The FORTRAN language in-house compilers used on IBM computers at ANL. The G compiler is non-optimizing; the H compiler has three levels of optimization.
Control Data Corporation (CDC)	NOS (Network Operating System). A time-sharing system developed by CDC for their 6600 computers.	FTN. A CDC compiler designed to comply with American National Standards Institute as described in the X3.9-1966 document.
Lawrence Livermore Laboratory (LLL)	CTSS (Network Operating System). The time-sharing system developed for the Cray-1 computers at LLL. LTSS (Livermore Time-Sharing System). The time-sharing system developed for the CDC 7600 computers at LLL.	CFT (CrayFortran). The FORTRAN language compiler developed by CRI for the CRI Cray-1 computer. FTN (FORTRAN Extended). A CDC-supplied compiler designed to comply with the American National Standards Institute as described in the X3.9-1966 document.
Los Alamos Scientific Laboratory (LASL)	ALAMOS (A Los Alamos Modular Operating System). The LASL-designed operating system developed for the CRI Cray-1 computer in the Central Computing Facility (being replaced by CTSS). CTSS (CRAY Time-Sharing System). The time-sharing system developed for the Cray-1 computers at LLL and adapted for the Cray-1 computers at LASL. LTSS (Livermore Time-Sharing System). The time-sharing system used on the CDC 7600s in the Central Computing Facility. NOS (Network Operating System). The CDC time-sharing system used on the CDC 6600 and CDC Cyber 73 computers in the Central Computing Facility.	FTN (FORTRAN Extended). A CDC-supplied compiler (see above) with local modifications as documented in LASL Programmer's Information Manual, Volume 3, LA-5525-M. XFC (FORTRAN cross-compiler). A compiler developed at LASL to produce code on the CDC 7600 that can be assembled by CAL (the Cray-1 assembly language) and executed.

TABLE II

CHARACTERISTICS OF COMPUTERS USED IN THE BENCHMARKING PROGRAM

Computer	Installation	Word Size (bits)	Operating System(s)	Compiler	Available Memory (Words)	Cycle Time (ns)	Disks Used
CDC Cyber 73	LASL	60	NOS	FTN	100 000	100	CDC 844
CDC 6600	LASL	60	NOS	FTN	100 000	100	CDC 844
CDC 7600	LASL	60	LTSS	FTN; SLOPE2	54 000 SCM[a] 430 000 LCM[b]	27.5	CDC 819 dual-density
Cray-1	LASL	64	ALAMOS; CTSS	XFC;CFT	800 000 900 000	12.5	Cray DD-19
Cray-1	LLL	64	CTSS	CFT	900 000	12.5	Cray DD-19
IBM 370/195	ANL	32	OSMVT	ANL G,H	500 000		IBM 3330
IBM 3033	ANL	32	OSMVT	ANL G,H	750 000	57	IBM 3350; IBM 3350, Mod 11
CDC 720	CDC	60	NOS	FTN	270 000	50	CDC 844
CDC 730	CDC	60	NOS	FTN	270 000	50	CDC 844
CDC 750	CDC	60	NOS	FTN	270 000	25	CDC 844
CDC 760	CDC	60	NOS	FTN	270 000	25	CDC 844

[a]Small Core Memory
[b]Large Core Memory

TABLE III

COMPILE TIME - IN SECONDS

Program	CRI CRAY-1 LASL ALAMOS XFC/Non-Vect	CRI CRAY-1 LASL ALAMOS CFT 1.05 Vectorized	CRI CRAY-1 LASL ALAMOS CFT 1.05 Non-Vect	CRI CRAY-1 LASL CTSS CFT 1.06 Vectorized	CRI CRAY-1 LASL CTSS CFT 1.06 Non-Vect	CRI CRAY-1 LLL CTSS CFT 1.06 Vectorized	CRI CRAY-1 LLL CTSS CFT 1.06 Non-Vect	CDC 7600 LASL LTSS FTN/OPT1	CDC 7600 LASL LTSS FTN/OPT2	CDC 7600 LASL LTSS SLOPE2 FTN/OPT1	CDC 7600 LASL LTSS SLOPE2 FTN/OPT2	CDC 7600 LLL LTSS FTN/OPT1	CDC 7600 LLL LTSS FTN/OPT2
1	0.612	NOT	AVAILABLE	0.215	0.205	0.217	0.216	0.461	0.656	0.521	0.715	0.486	0.644
2	11.507			4.003	3.793	4.055	4.045	9.327	12.975	10.176	12.917	10.393	14.020
4	0.432			0.176	0.165	0.179	0.173	0.392	0.537	0.488	0.638	0.388	0.510
5	1.336			0.429	0.416	0.434	0.432	0.901	1.267	1.053	1.318	1.005	1.361
6	0.492			0.198	0.191	0.199	0.199	0.389	0.518	0.367	0.464	0.420	0.531
8	0.268			0.129	0.122	0.131	0.127	0.276	0.349	0.229	0.279	0.270	0.327
11	1.324			0.596	0.533	0.601	0.575	1.259	1.359	1.307	1.345	1.399	1.467
14	0.397			0.200	0.193	0.203	0.200	0.356	0.490	0.331	0.420	0.330	0.476
15	0.456			0.205	0.198	0.207	0.205	0.404	0.542	0.392	0.487	0.437	0.549
16	0.460			0.203	0.195	0.205	0.204	-	-	-	-	-	-
18	0.193			0.103	0.097	0.103	0.101	0.233	0.296	0.181	0.218	0.212	0.267
21	0.506			0.186	0.177	-	-	0.428	0.568	0.414	0.502	-	-
22	0.441			0.207	0.199	0.209	0.207	0.466	0.618	0.436	0.586	0.441	0.559
23	0.412			0.195	0.187	0.197	0.195	-	-	-	-	-	-
MFLOPS	0.834			0.377	0.354	0.381	0.372	0.823	1.028	0.778	0.938	0.823	1.052

Program	CDC 6600 LASL NOS FTN/OPT1	CDC 6600 LASL NOS FTN/OPT2	CDC CYBER 73 LASL NOS FTN/OPT1	CDC CYBER 73 LASL NOS FTN/OPT2	CDC 720 CDC Benchmark Facility NOS FTN/OPT1	CDC 730 CDC Benchmark Facility NOS FTN/OPT2	CDC 750 CDC Benchmark Facility NOS FTN/OPT1	CDC 760 CDC Benchmark Facility NOS FTN/OPT2	IBM 3033 Argonne Nat'l. Laboratory OSMVT H/OPT3[a]	IBM 3033 Argonne Nat'l. Laboratory OSMVT H/OPT3[b]	IBM 3033 Argonne Nat'l. Laboratory OSMVT G
1	2.040	3.025	2.548	5.415	5.140	3.230	1.051	0.691	1.55	1.66	0.92
2	48.907	67.709	85.210	122.700	124.544	80.101	24.120	16.260	-	-	-
4	1.632	2.233	2.804	3.878	3.873	2.410	0.770	0.517	1.38	1.35	0.84
5	4.523	6.488	7.842	11.470	11.493	7.070	2.307	1.528	2.97	3.23	2.19
6	1.561	2.074	2.670	3.602	3.574	2.230	0.721	0.473	1.58	1.63	0.86
8	0.921	1.187	1.567	2.022	1.920	1.190	0.387	0.252	1.21	1.13	0.75
11	6.776	7.498	11.939	13.235	13.366	8.080	2.746	1.782	3.49	3.67	2.81
14	1.354	1.924	2.289	3.309	3.320	2.070	0.670	0.447	1.35	1.38	0.74
15	1.598	2.200	2.751	3.819	3.792	2.380	0.769	0.502	1.46	1.47	0.86
16	-	-	-	-	-	-	-	-	1.46	1.52	0.96
18	0.701	0.904	1.172	1.523	1.430	0.925	0.298	0.194	1.05	1.00	0.67
21	1.825	2.408	3.153	4.197	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-

[a] Single Precision
[b] Double Precision

TABLE IV

EXECUTION TIME - IN SECONDS

	CRI CRAY-1							CDC 7600					
	LASL					LLL		LASL				LLL	
Program	ALAMOS XFC/Non-Vect	ALAMOS CFT 1.05 Vectorized[f]	ALAMOS CFT 1.05 Non-Vec[f]	CTSS CFT 1.06 Vectorized	CTSS CFT 1.06 Non-Vect	CTSS CFT 1.06 Vectorized	CTSS CFT 1.06 Non-Vect	LTSS FTN/OPT1	LTSS FTN/OPT2	LTSS SLOPE2 FTN/OPT1	LTSS SLOPE2 FTN/OPT2	LTSS FTN/OPT1	LTSS FTN/OPT2
1	30.8	58.9	59.2	58.2	75.1	59.0	72.5	48.2	28.9	48.7	29.3	49.9	29.7
2	17.8	30.4	44.6	22.6	24.1	22.7	23.7	37.5	35.2	40.0	39.6	36.4	35.2
4	45.3	22.6	30.3	21.8	30.5	22.4	30.6	53.3	51.5	55.6	52.9	57.5	50.2
5	26.0	27.3	27.3	29.2	28.2	28.7	28.5	49.6	48.9	51.9	51.3	50.9	49.8
6	153.3	212.5	212.5	208.7	209.9	210.3	210.2	102.1	86.5	96.9	87.1	104.7	89.8
8	37.0	19.1	36.9	19.0	36.9	19.3	37.2	61.3	41.3	63.2	43.0	62.7	44.3
11	162.2	142.8	178.2	104.2	177.3	104.1	167.0	397.2	361.7	400.0	368.4	398.2	366.8
14	33.7	2.9	15.9	3.0	16.1	2.9	16.3	23.9	20.6	22.7	20.6	24.3	20.9
15	132.4	16.7	65.3	16.3	65.2	16.8	65.4	100.7	84.9	94.0	85.2	103.2	87.5
16	657.0	37.7	298.5	36.3	298.7	36.7	298.3	-	-	-	-	-	-
18	20.3	2.4	20.3	2.4	21.2	2.8	20.7	31.9	23.3	33.1	24.5	33.6	24.6
21	4.8	4.8	4.8	4.8	4.8	-	-	7.9	6.1	8.1	6.2	-	-
22	120.7	-	-	16.9	64.5	17.0	64.7	84.2	80.6	83.6	80.5	101.0	80.5
23	619.6	-	-	32.3	240.4	32.2	240.7	-	-	-	-	-	-
MFLOPS[a]	6.0	20.5	6.6	23.2	6.6	22.9	7.2	3.3	4.2	3.3	3.9	3.3	4.2
Date Run	4/80	4/80	4/80	2/80	4/80	2/80	2/80	1/80	1/80	1/80	1/80	2/80	2/80

TABLE IV (cont.)

	CDC 6600 LASL		CDC CYBER 73 LASL		CDC 720 CDC Benchmark Facility	CDC 730	CDC 750	CDC 760	IBM 370/195 ANL			IBM 3033 ANL		
Program	FTN/OPT1	FTN/OPT2	FTN/OPT1	FTN/OPT2	FTN/OPT2	FTN/OPT2	FTN/OPT2	FTN/OPT2	H/OPT3[c]	H/OPT3[d]	G	H/OPT3[c]	H/OPT3[d]	G
1	287.3	201.8	744.7	457.0	456.6	297.3	54.9	41.1	96.6	95.2	199.8	60.6	60.7	131.9
2	210.5	209.0	584.7	579.6	486.9	333.1	71.8	50.9	-	-	-	-	-	-
4	264.1	230.3	867.7	752.2	633.3	445.3	73.5	52.0	38.8	37.0	147.9	55.3	59.5	123.1
5	248.6	247.5	740.9	731.4	567.1	412.8	97.6	67.1	115.0	108.2	168.0	98.1	134.4	137.2
6	583.2	495.9	2326.2	1656.6	1305.6	969.0	155.7	114.3	79.3	82.4	T.O.[e]	146.6	162.2	T.O.[e]
8	341.0	238.0	1353.2	1205.4	853.9	652.0	77.0	58.0	51.4	59.8	163.3	104.1	124.4	154.1
11	2156.0	1940.0	6640.0	6156.0	4684.0	3376.0	733.5	490.6	429.0	T.O.[e]	T.O.[e]	T.O.[e]	T.O.[e]	T.O.[e]
14	134.0	119.5	460.0	414.0	326.0	241.4	34.6	26.5	20.8	21.0	142.0	35.9	40.1	113.0
15	547.2	481.5	1854.6	1633.5	1278.6	948.0	148.5	109.6	83.3	82.2	T.O.[e]	140.0	154.1	T.O.[e]
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	188.9	134.8	777.1	714.8	513.5	397.7	40.8	30.1	25.0	28.6	87.6	58.3	69.1	86.2
21	42.7	37.6	111.9	95.0	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MFLOPS[a]	0.6	0.8	0.2	0.2	0.2	0.3	2.7	3.3	4.5	4.2	1.7	-	-	-
Date Run	12/79	12/79	12/79	12/79	12/79	12/79	12/79	12/79	7/79	7/79	7/79	7/79	7/79	7/79

[a]Results are in megaflops/second.

[b]Double CPU.

[c]Single Precision

[d]Double Precision

[e]Job did not complete within a 10-minute submittal period and was not rerun.

[f]Includes I/O time.

APPENDIX A

PROGRAM DESCRIPTIONS

Program No. 1 - Monte Carlo
- -347 source lines.
- -No I/O.
- -Code is compute bound and uses integer arithmetic. Computers using 24-bit integer arithmetic will produce incorrect answers.
- -Output consists of the self-contained "input" values and several statistical computed values, plus execute time.
- -Field length required to execute: 104000B.

Program No. 2 - Two-dimensional Lagrangian hydrodynamics program.
- -7000 source lines.
- -Not vectorizable.
- -Much I/O activity (approximately one-half of running time). In addition to output file, five additional files are used.
- -Code has a built-in test for error checking of computed variables based on data obtained in a previous run.
- -Execute time for longer or shorter runs is near linear and is a function of an internal variable.
- -Output consists of setup data, relative errors of selected output variables, and total execution time.
- -Field length required to execute: 200000B.

Program No. 4 - Fast Fourier Transform code.
- -230 source lines.
- -Not vectorizable.
- -No I/O.
- -Output consists of the solution array for a subset of the steps computed, plus execution time.
- -Field length required to execute: 215000B.

Program No. 5 - Equation of state kernel.
- -720 source lines.
- -Not significantly vectorizable.
- -No I/O.
- -Code has built-in test for error checking and accuracy similar to tests in Program 2. Execute time is a linear function of an internal variable.
- -Output consists of setup data, relative errors of selected output variables, and total execution time.
- -Field length required to execute: 50000B.

Program No. 6 - Linear system solver - solves systems of the order of 100.
- -320 source lines.
- -Not vectorizable.
- -No I/O.
- -Output consists of the first three elements of the solution vector, the Central Processor Unit (CPU) time in each subroutine for one case, and the total time for execution.
- -Field length required to execute: 34000B.

Program No. 8 - Vector calculations.
- -189 source lines.

-Code calls five separate routines to perform a variety of vector operations. Vector lengths range from 20 to 5000.
-Three of the routines are vectorizable, two are not.
-No I/O.
-Output consists of total CPU time in each subroutine for each vector length, the average time/element for each routine, and the total time to execute the code.
-Field length required to execute: 105000B.

Program No. 11 - Particle pusher kernel widely used in particle-in-cell calculations.
-740 source lines.
-Depending on compiler used, code is vectorizable. XFC, both vectorized and nonvectorized, performed significantly better than CFT on this code.
-No I/O.
-Output consists of time/particle in each subroutine called.
-Field length required to execute: 70000B.

Program No. 14 - Matrix calculations including multiplication and transpose.
-343 source lines.
-Code goes through eight cases of 100 x 100 matrix, with variations of multiplication.
-Code uses LINPACK routines and is highly vectorizable.
-No I/O.
-Output consists of the matrix diagonal and the total execution time for all eight cases.
-Field length required to execute: 111000B.

Program No. 15 - Linear system solver for systems of the order 100.
-399 source lines.
-Vectorizable on all compilers.
-No I/O.
-Output consists of the first three elements of the solution vector, the CPU time in each subroutine, and total execution time.
-Field length required to execute: 34000B.

Program No. 16 - Linear system solver for matrices of the order of 100 x 100 to 800 x 800.
-400 source lines.
-Vectorizable on all compilers.
-No I/O.
-Output consists of the first three elements of the solution vector, the CPU time in each subroutine for one case, and the total time for all cases.
-Field length required to execute: 2500000B.

Program No. 18 - Vector calculations (a variation of Program 8).
-147 source lines.
-Vectorizable--consists of the three routines found in Program 8, which vectorize well while eliminating the remaining two, which do not vectorize. Separate cases use vector lengths ranging from 20 to 5000.
-No I/O.
-Output consists of the total CPU time in each subroutine for each vector length, the average time/element for each routine, and the total time to execute the code.
-Field length required to execute: 105000B.

Program No. 21 - Integer Monte Carlo.
-370 source lines.
-Not vectorizable.

-Moderate I/O activity.
-Output consists of selected table values, total execution time, and times for individual phases of the program.
-Field length required to execute: 30000B.

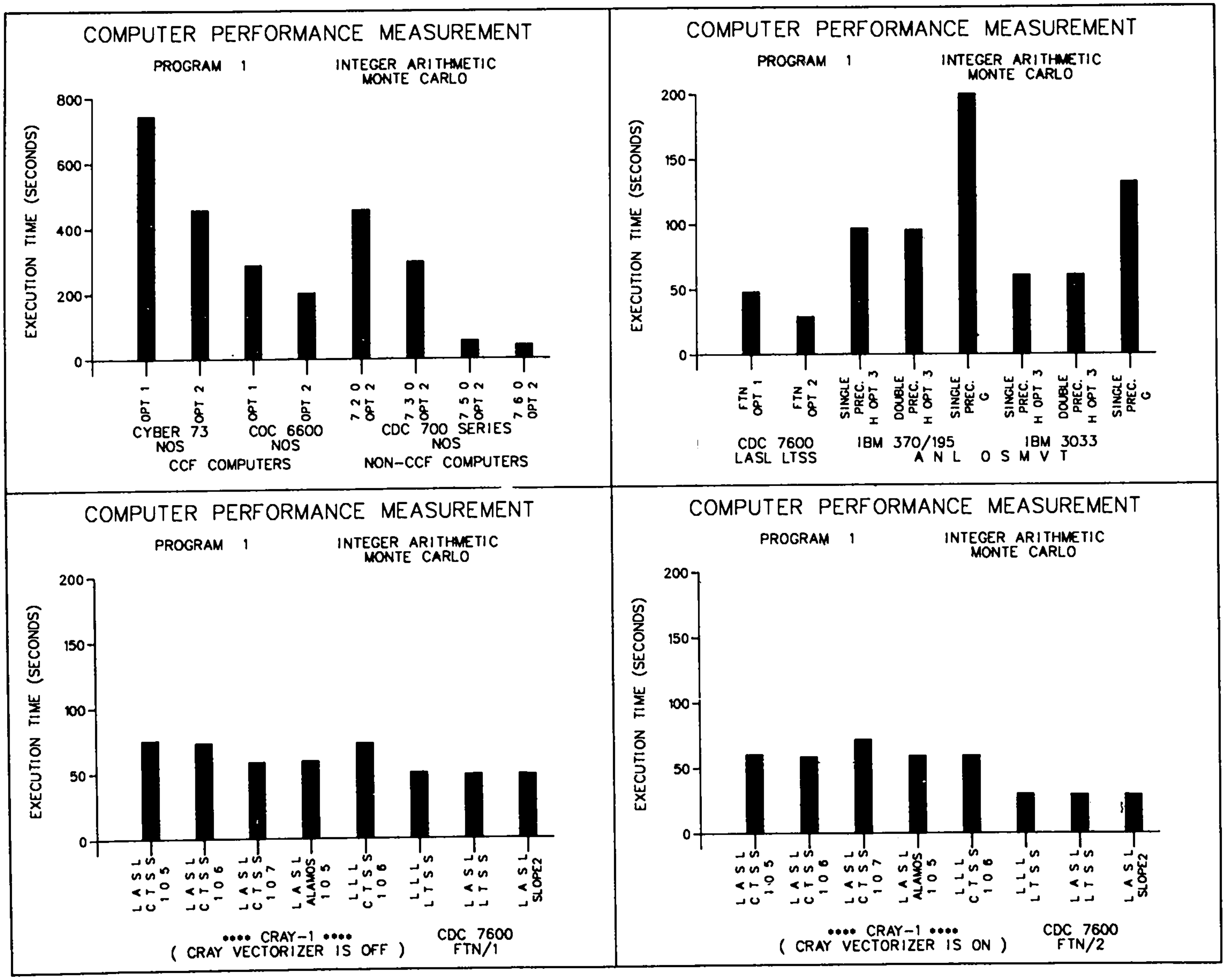
Program No. 22 - Linear system solver for systems of the order 100 (a variation of Program 15).
-423 source lines.
-Vectorizable on all compilers.
-No I/O.
-Code has newer algorithms for matrix-solving than Program 15, otherwise is identical to Program 15.
-Output consists of the first three elements of the solution vector, the CPU time in each subroutine and total execution time.
-Field length required to execute: 34000B.

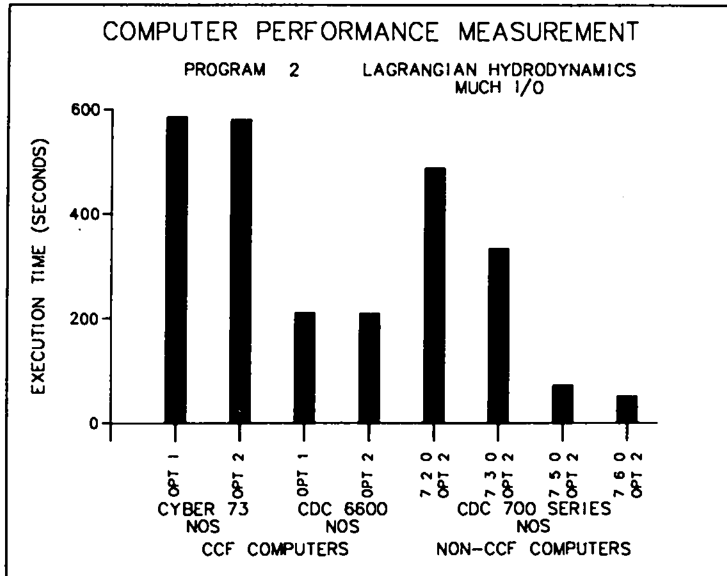
Program No. 23 - Linear system solver for matrices of the order 100 x 100 to 800 x 800 (a variation of Program 16).
-447 source lines.
-Vectorizable on all compilers.
-No I/O.
-Code has newer algorithms for matrix-solving than Program No. 16, but is otherwise the same.
-Output consists of the first three elements of the solution vector, the CPU time in each subroutine, and total execution time.
-Field length required to execute: 2500000B.

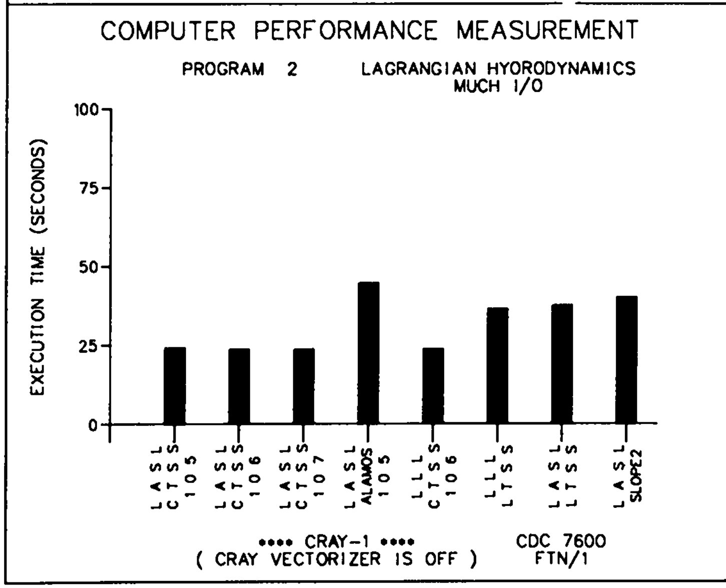
Program MFLOPS - set of benchmark kernels to measure number of floating point operations/second.
570 source lines.
-Vectorizable on all compilers.
-Little I/O.
-Output consists of the megaflop rate for each kernel, plus average megaflop rate overall.
-Field length required to execute: 21000B.

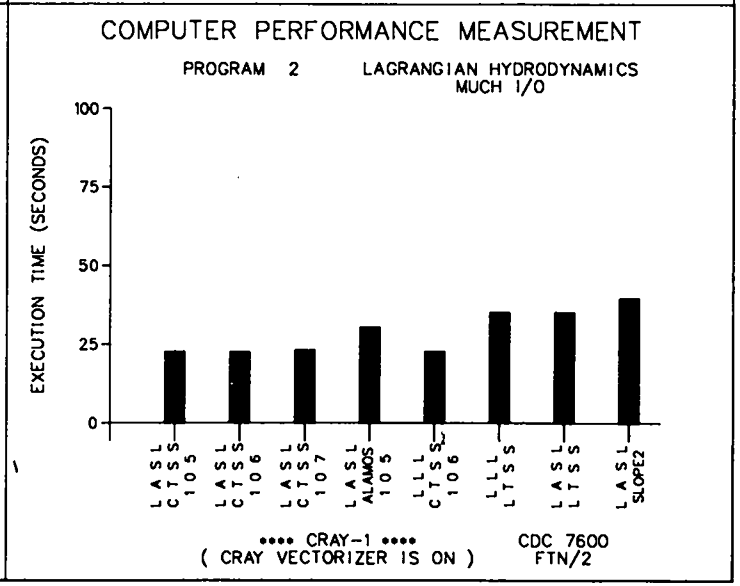
APPENDIX B

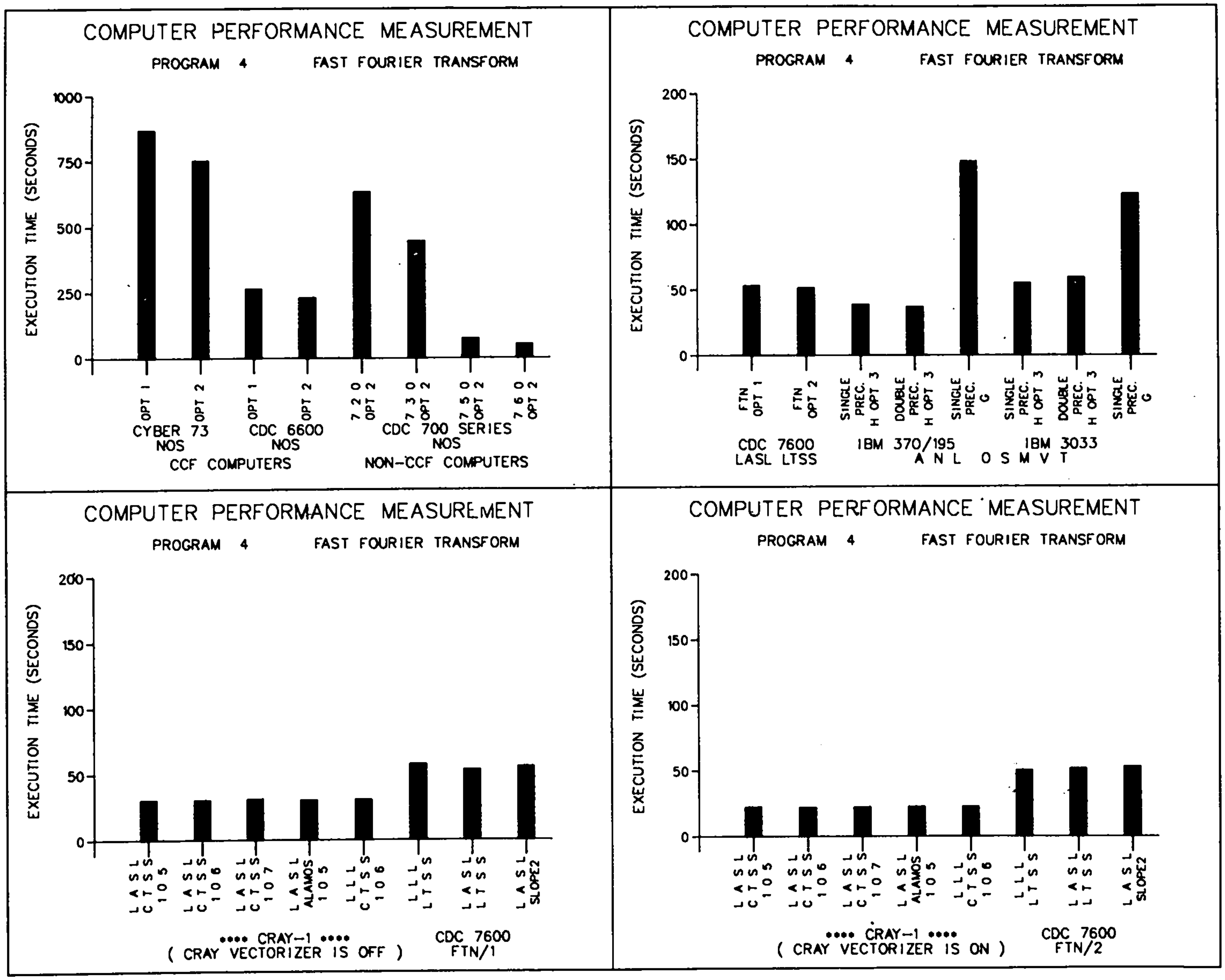
COMPUTER PERFORMANCE COMPARISONS

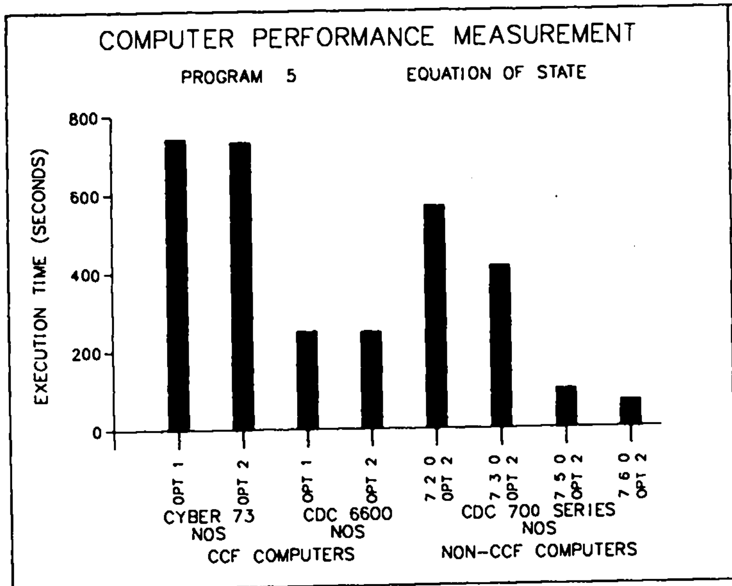


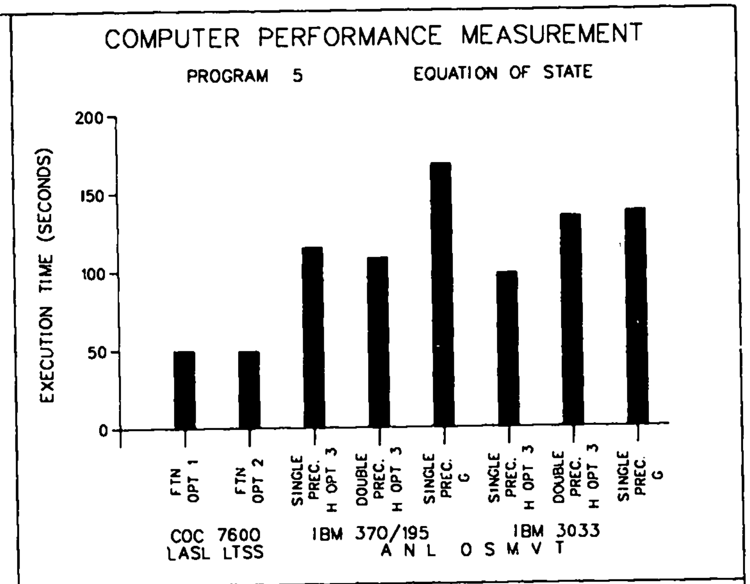

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 2 LAGRANGIAN HYDRODYNAMICS
MUCH I/O
EXECUTION TIME (SECONDS)
600
400
200
0
OPT 1
OPT 2
OPT 1
OPT 2
7 2 0 OPT 2
7 3 0 OPT 2
7 5 0 OPT 2
7 6 0 OPT 2
CYBER 73
NOS
CDC 6600
NOS
CDC 700 SERIES
NOS
CCF COMPUTERS
NON-CCF COMPUTERS

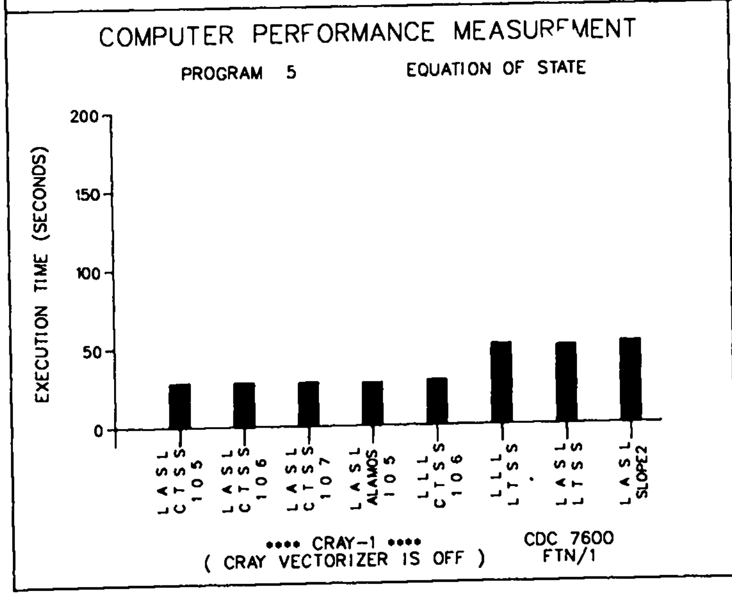

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 2 LAGRANGIAN HYORODYNAMICS
MUCH I/O
EXECUTION TIME (SECONDS)
100
75
50
25
0
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS OFF)
CDC 7600
FTN/1

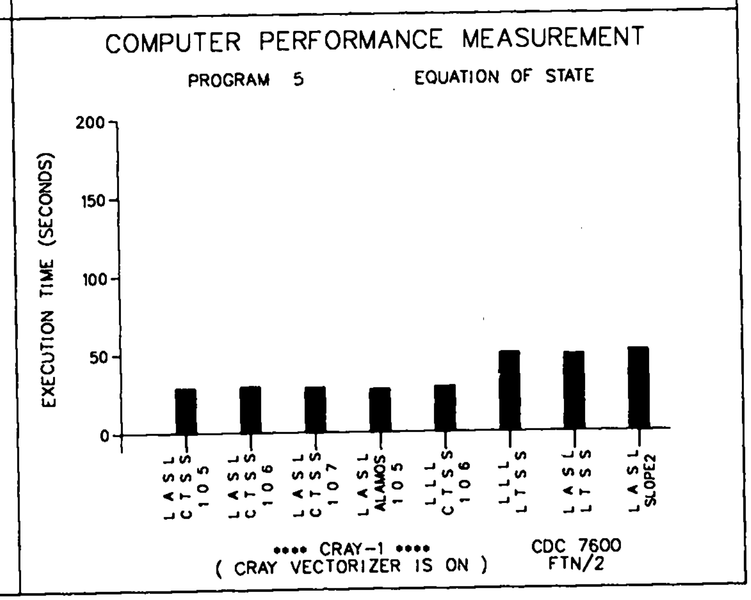

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 2 LAGRANGIAN HYDRODYNAMICS
MUCH I/O
EXECUTION TIME (SECONDS)
100
75
50
25
0
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS ON)
CDC 7600
FTN/2

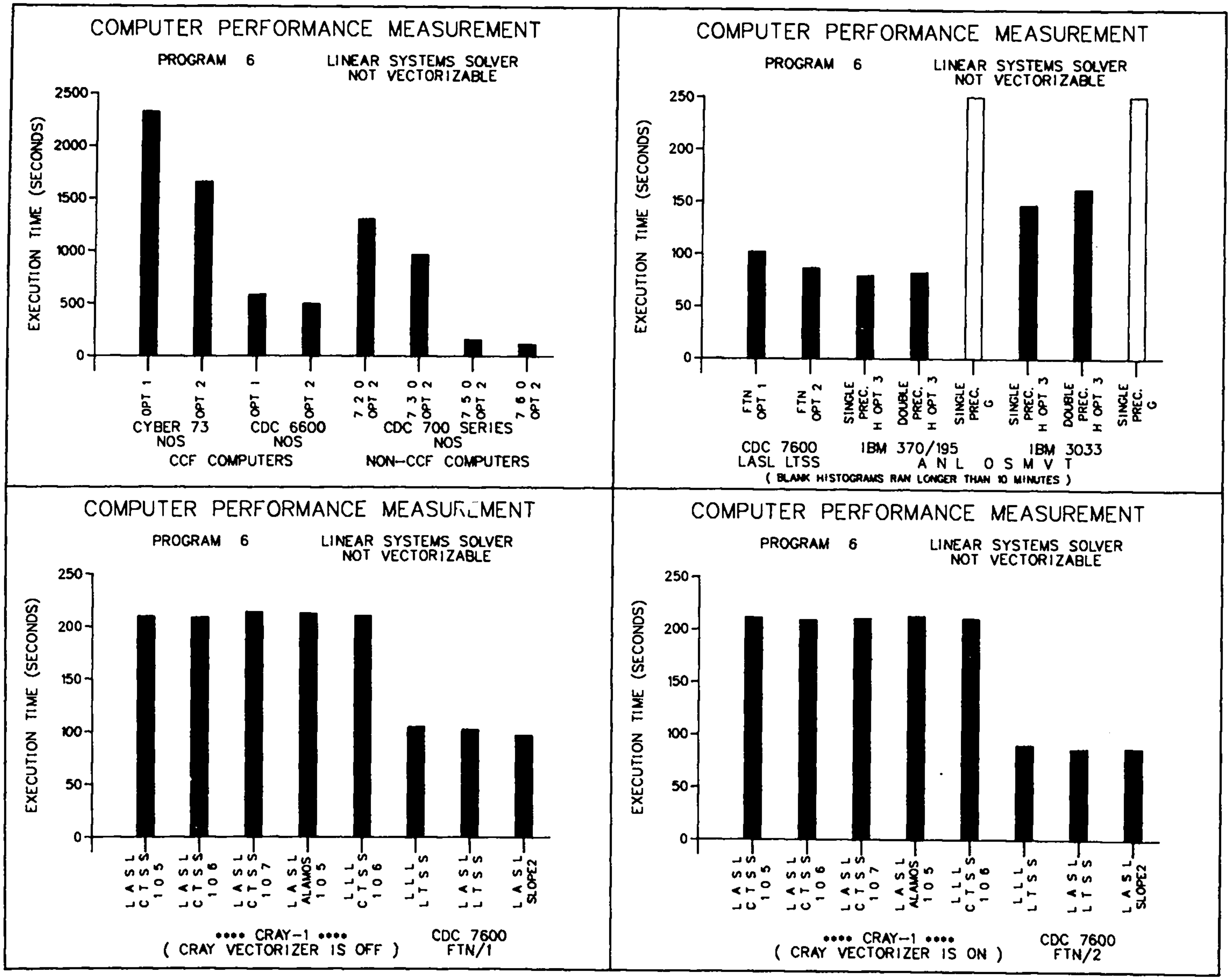

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 4 FAST FOURIER TRANSFORM
EXECUTION TIME (SECONDS)
1000
750
500
250
0
OPT 1
OPT 2
OPT 1
OPT 2
7 2 0 OPT 2
7 3 0 OPT 2
7 5 0 OPT 2
7 6 0 OPT 2
CYBER 73 NOS
CDC 6600 NOS
CDC 700 SERIES NOS
CCF COMPUTERS
NON-CCF COMPUTERS
COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 4 FAST FOURIER TRANSFORM
EXECUTION TIME (SECONDS)
200
150
100
50
0
FTN OPT 1
FTN OPT 2
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
CDC 7600 LASL LTSS
IBM 370/195
IBM 3033
A N L O S M V T
COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 4 FAST FOURIER TRANSFORM
EXECUTION TIME (SECONDS)
200
150
100
50
0
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS OFF)
CDC 7600 FTN/1
COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 4 FAST FOURIER TRANSFORM
EXECUTION TIME (SECONDS)
200
150
100
50
0
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS ON)
CDC 7600 FTN/2

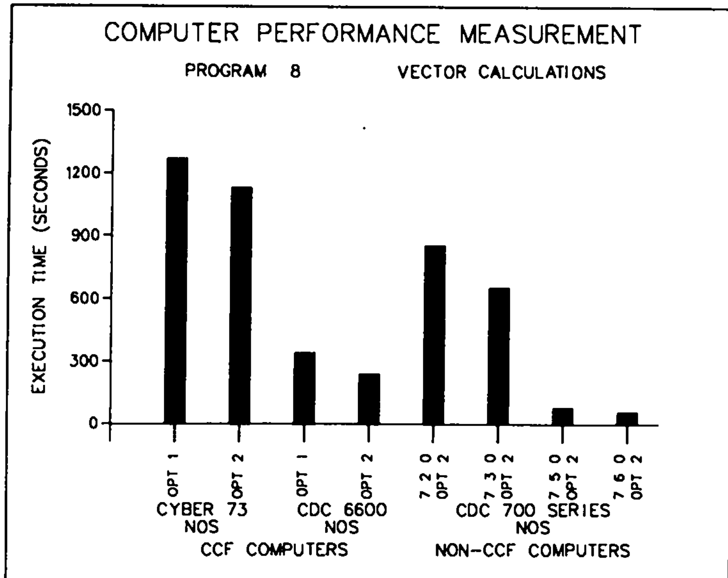

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 5
EQUATION OF STATE
EXECUTION TIME (SECONDS)
800
600
400
200
0
OPT 1
OPT 2
OPT 1
OPT 2
7 2 0 OPT 2
7 3 0 OPT 2
7 5 0 OPT 2
7 6 0 OPT 2
CYBER 73 NOS
CDC 6600 NOS
CDC 700 SERIES NOS
CCF COMPUTERS
NON-CCF COMPUTERS

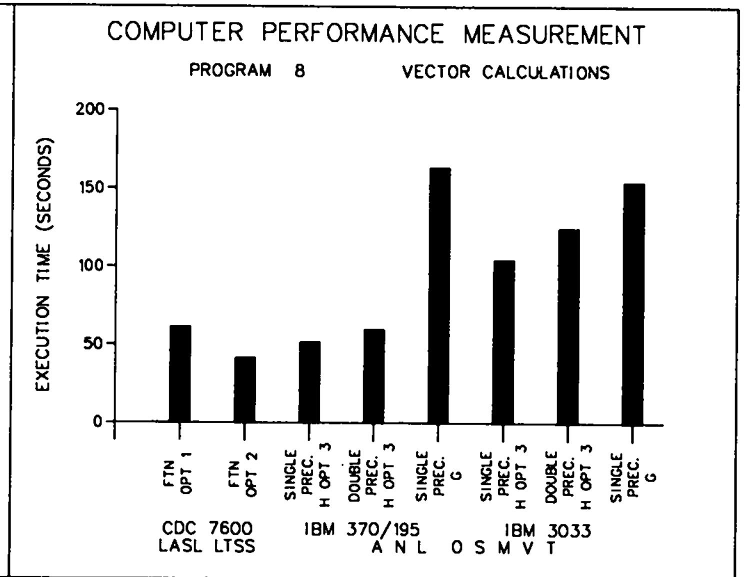

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 5
EQUATION OF STATE
EXECUTION TIME (SECONDS)
200
150
100
50
0
FTN OPT 1
FTN OPT 2
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
CDC 7600 LASL LTSS
IBM 370/195
IBM 3033
A N L O S M V T

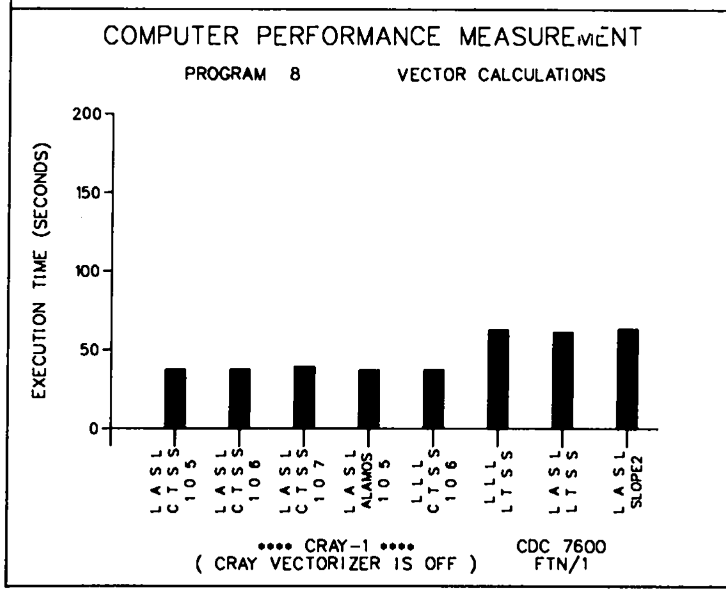

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 5
EQUATION OF STATE
EXECUTION TIME (SECONDS)
200
150
100
50
0
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS OFF)
CDC 7600 FTN/1

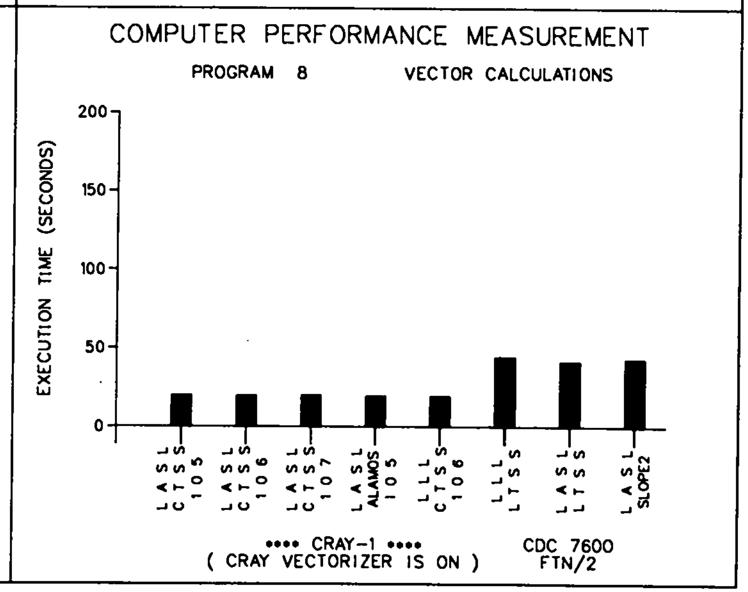

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 5
EQUATION OF STATE
EXECUTION TIME (SECONDS)
200
150
100
50
0
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS ON)
CDC 7600 FTN/2

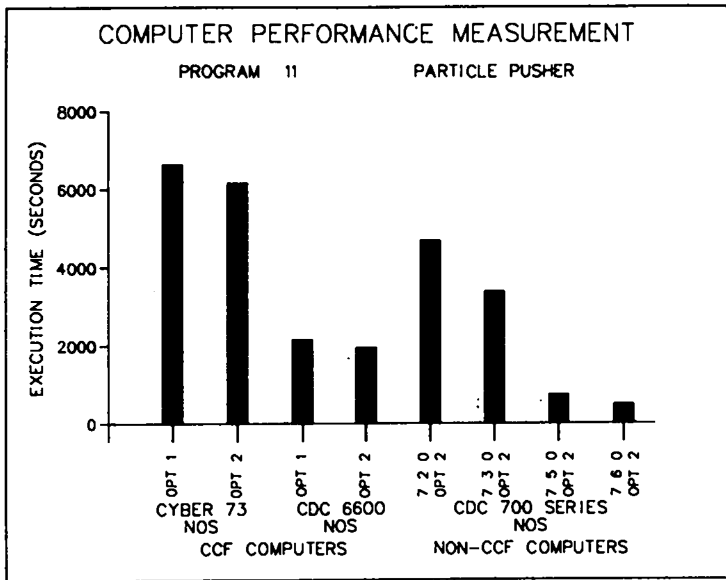

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 6
LINEAR SYSTEMS SOLVER
NOT VECTORIZABLE
EXECUTION TIME (SECONDS)
OPT 1
OPT 2
CYBER 73
NOS
CDC 6600
NOS
7 2 0 OPT 2
7 3 0 OPT 2
7 5 0 OPT 2
7 6 0 OPT 2
CDC 700 SERIES
NOS
CCF COMPUTERS
NON-CCF COMPUTERS
COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 6
LINEAR SYSTEMS SOLVER
NOT VECTORIZABLE
EXECUTION TIME (SECONDS)
FTN OPT 1
FTN OPT 2
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
CDC 7600
LASL LTSS
IBM 370/195
IBM 3033
A N L O S M V T
(BLANK HISTOGRAMS RAN LONGER THAN 10 MINUTES)
COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 6
LINEAR SYSTEMS SOLVER
NOT VECTORIZABLE
EXECUTION TIME (SECONDS)
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS OFF)
CDC 7600
FTN/1
COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 6
LINEAR SYSTEMS SOLVER
NOT VECTORIZABLE
EXECUTION TIME (SECONDS)
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 8
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS ON)
CDC 7600
FTN/2

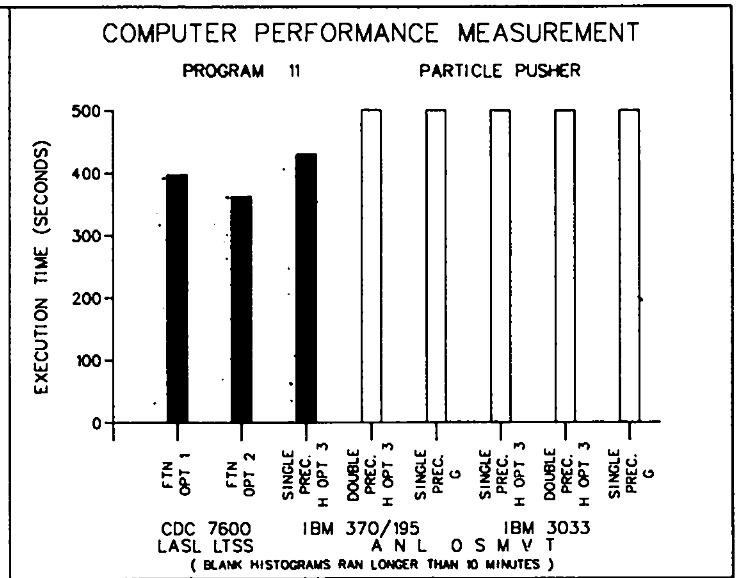

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 8 VECTOR CALCULATIONS
EXECUTION TIME (SECONDS)
0
300
600
900
1200
1500
OPT 1
OPT 2
OPT 1
OPT 2
7 2 0 OPT 2
7 3 0 OPT 2
7 5 0 OPT 2
7 6 0 OPT 2
CYBER 73 NOS
CDC 6600 NOS
CDC 700 SERIES NOS
CCF COMPUTERS
NON-CCF COMPUTERS

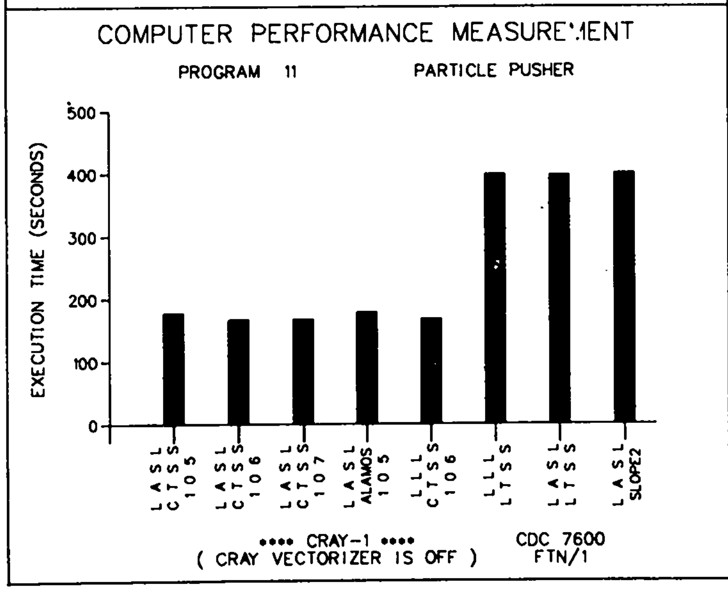

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 8 VECTOR CALCULATIONS
EXECUTION TIME (SECONDS)
0
50
100
150
200
FTN OPT 1
FTN OPT 2
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
CDC 7600 LASL LTSS
IBM 370/195
IBM 3033
A N L O S M V T

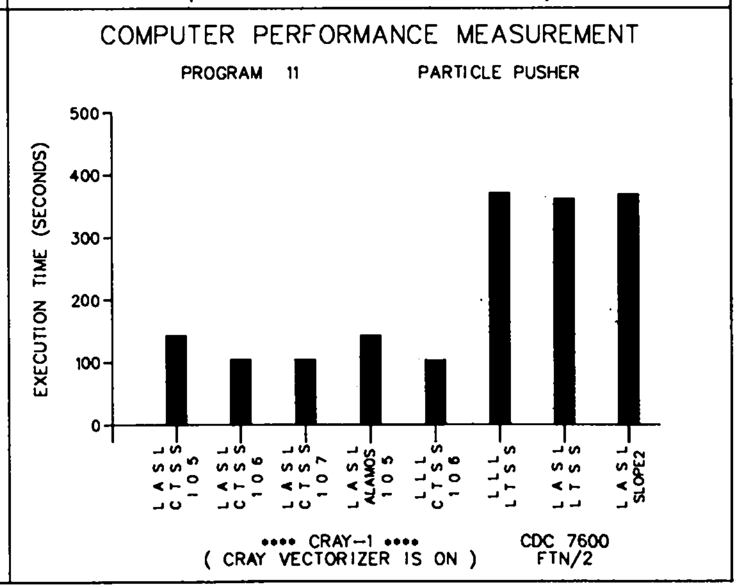

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 8 VECTOR CALCULATIONS
EXECUTION TIME (SECONDS)
0
50
100
150
200
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS OFF)
CDC 7600 FTN/1

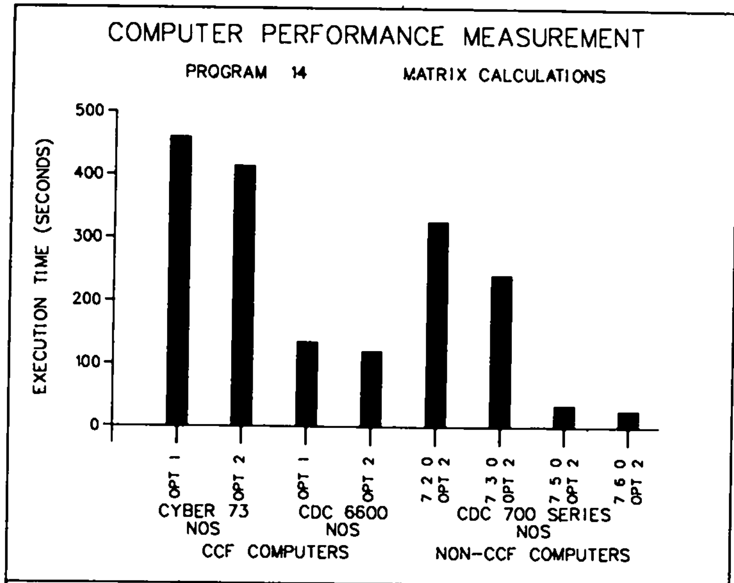

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 8 VECTOR CALCULATIONS
EXECUTION TIME (SECONDS)
0
50
100
150
200
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS ON)
CDC 7600 FTN/2

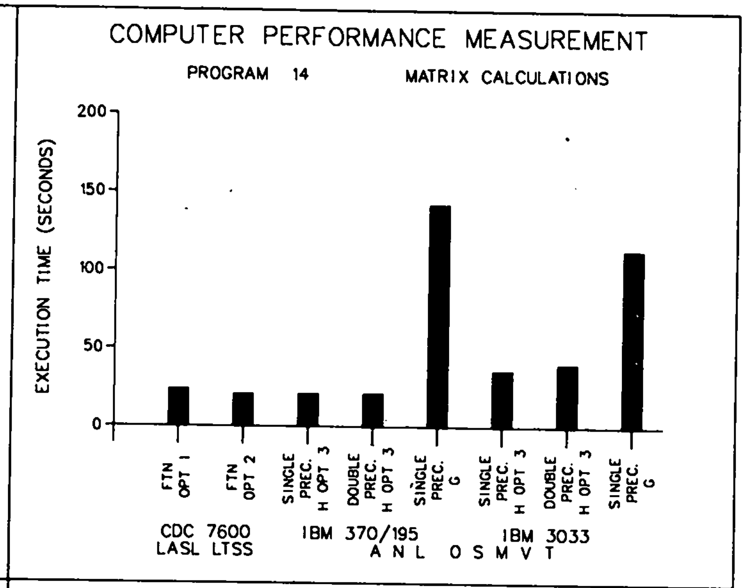

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 11 PARTICLE PUSHER
EXECUTION TIME (SECONDS)
8000
6000
4000
2000
0
OPT 1
OPT 2
OPT 1
OPT 2
7 2 0 OPT 2
7 3 0 OPT 2
7 5 0 OPT 2
7 6 0 OPT 2
CYBER 73 NOS
CDC 6600 NOS
CDC 700 SERIES NOS
CCF COMPUTERS
NON-CCF COMPUTERS

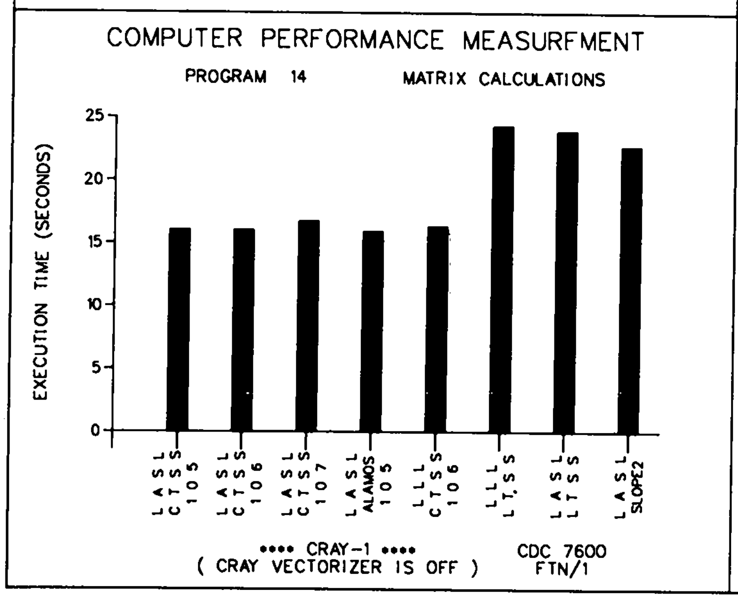

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 11 PARTICLE PUSHER
EXECUTION TIME (SECONDS)
500
400
300
200
100
0
FTN OPT 1
FTN OPT 2
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
CDC 7600 LASL LTSS
IBM 370/195
IBM 3033
A N L O S M V T
(BLANK HISTOGRAMS RAN LONGER THAN 10 MINUTES)

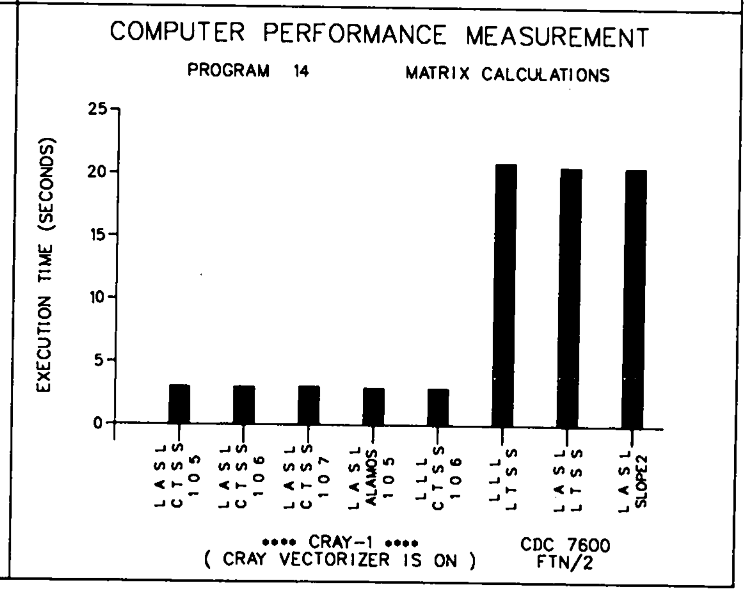

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 11 PARTICLE PUSHER
EXECUTION TIME (SECONDS)
500
400
300
200
100
0
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS OFF)
CDC 7600 FTN/1

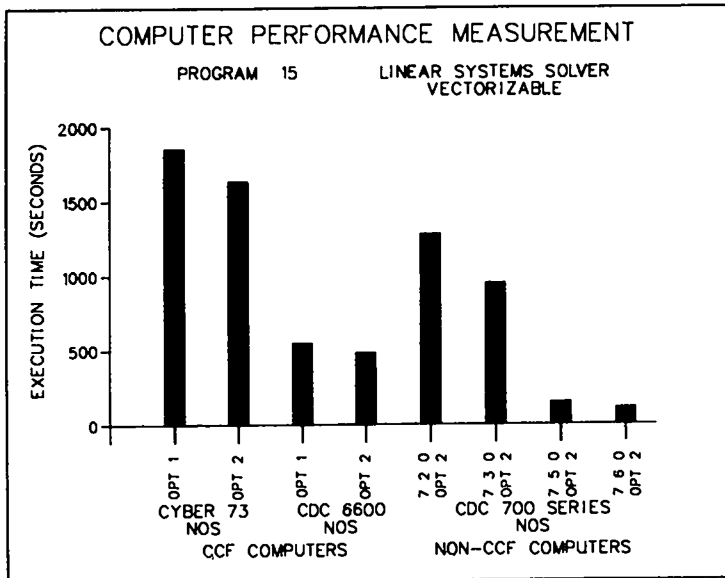

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 11 PARTICLE PUSHER
EXECUTION TIME (SECONDS)
500
400
300
200
100
0
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS ON)
CDC 7600 FTN/2

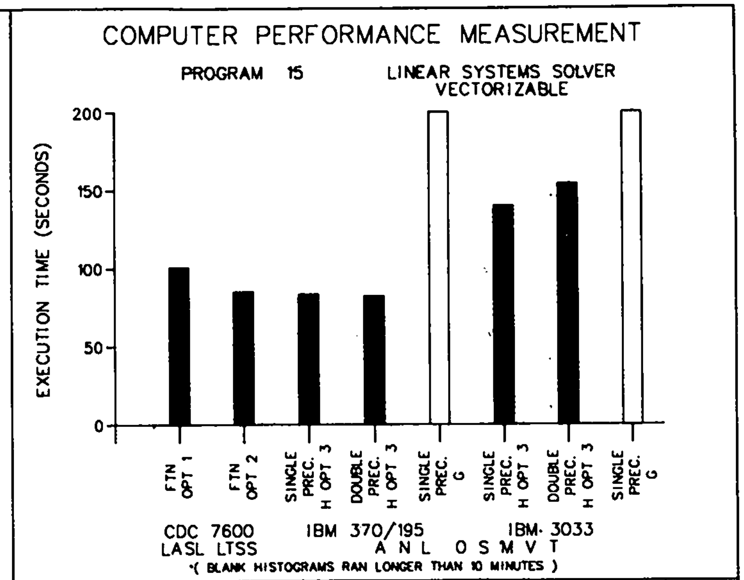

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 14 MATRIX CALCULATIONS
EXECUTION TIME (SECONDS)
0
100
200
300
400
500
OPT 1
OPT 2
OPT 1
OPT 2
7 2 0 OPT 2
7 3 0 OPT 2
7 5 0 OPT 2
7 6 0 OPT 2
CYBER 73 NOS
CDC 6600 NOS
CDC 700 SERIES NOS
CCF COMPUTERS
NON-CCF COMPUTERS

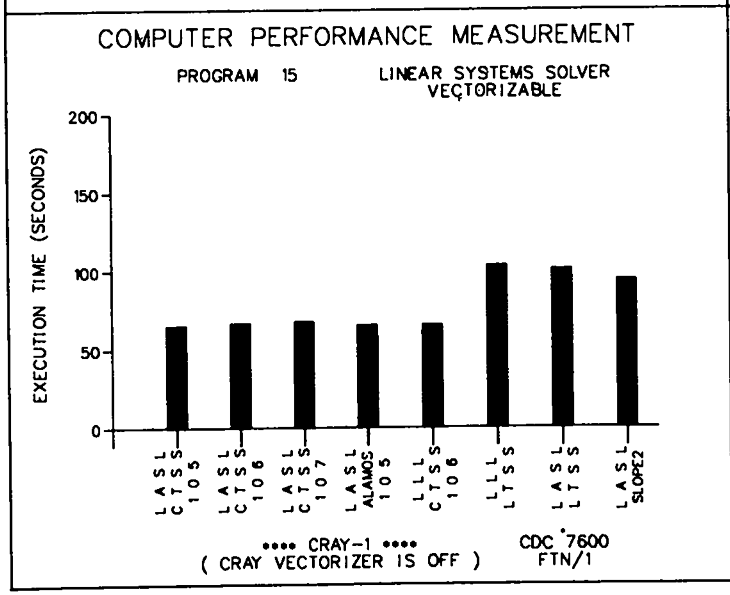

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 14 MATRIX CALCULATIONS
EXECUTION TIME (SECONDS)
0
50
100
150
200
FTN OPT 1
FTN OPT 2
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
CDC 7600 LASL LTSS
IBM 370/195
IBM 3033
A N L O S M V T

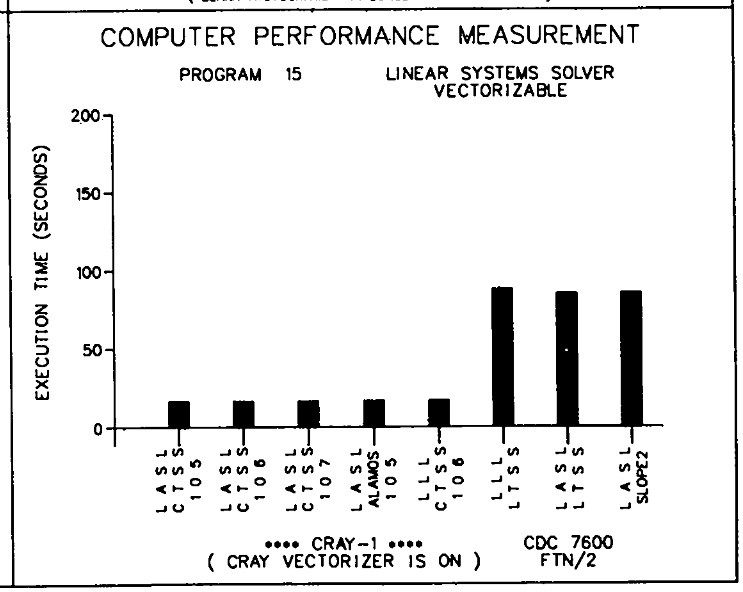

COMPUTER PERFORMANCE MEASURFMENT
PROGRAM 14 MATRIX CALCULATIONS
EXECUTION TIME (SECONDS)
0
5
10
15
20
25
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS OFF)
CDC 7600 FTN/1

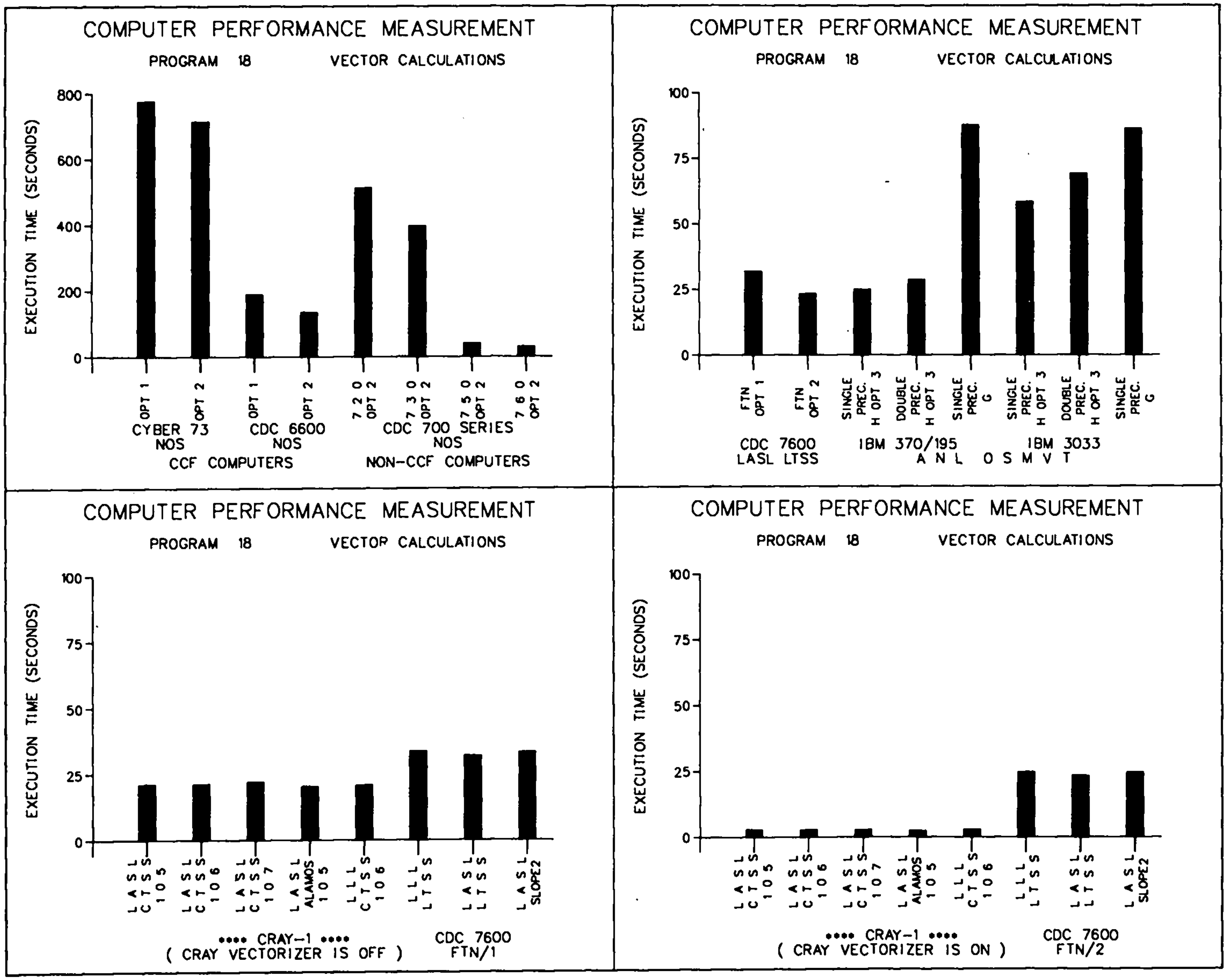

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 14 MATRIX CALCULATIONS
EXECUTION TIME (SECONDS)
0
5
10
15
20
25
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS ON)
CDC 7600 FTN/2

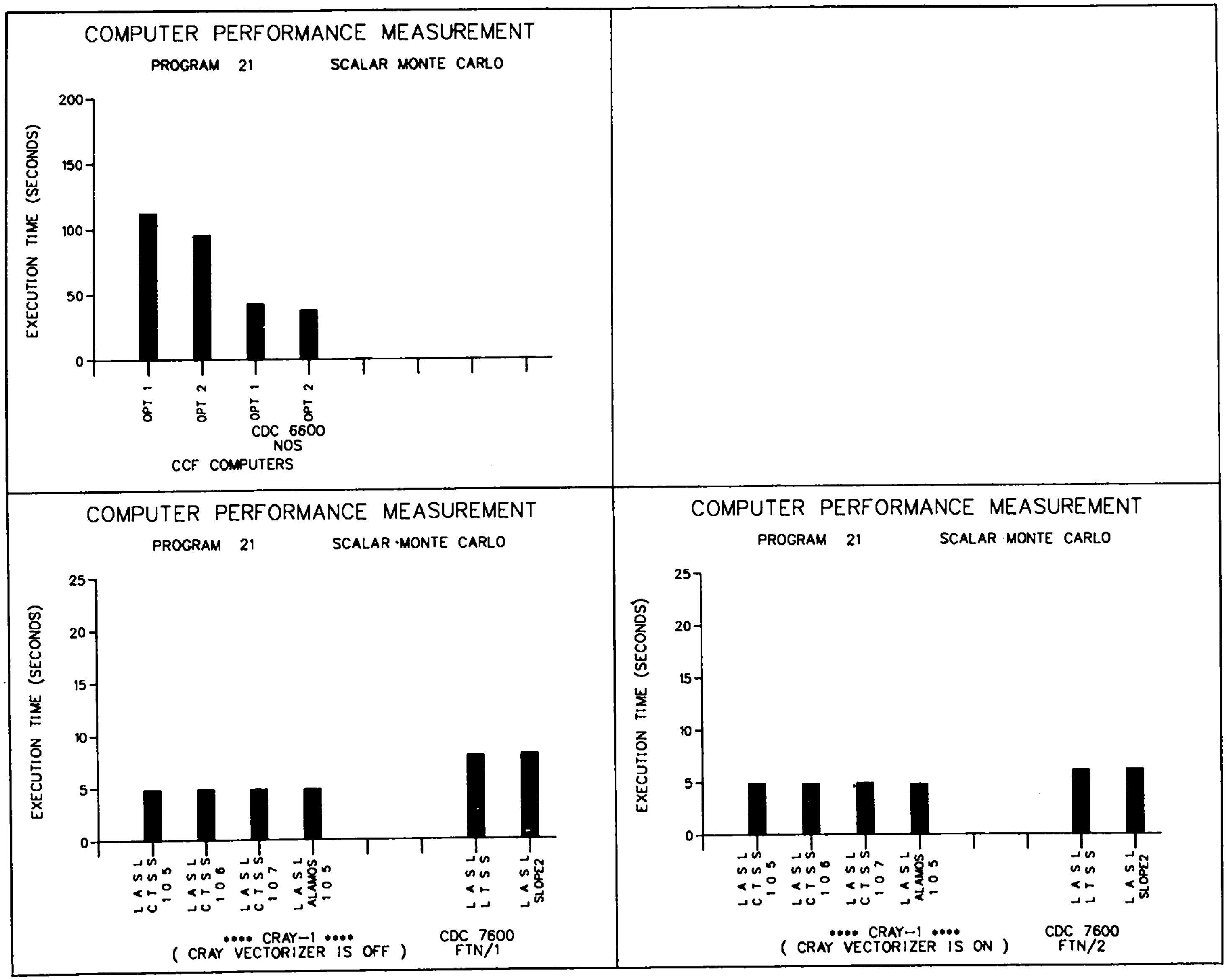

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 15
LINEAR SYSTEMS SOLVER VECTORIZABLE
EXECUTION TIME (SECONDS)
2000
1500
1000
500
0
OPT 1
OPT 2
OPT 1
OPT 2
7 2 0 OPT 2
7 3 0 OPT 2
7 5 0 OPT 2
7 6 0 OPT 2
CYBER 73 NOS
CDC 6600 NOS
CDC 700 SERIES NOS
CCF COMPUTERS
NON-CCF COMPUTERS

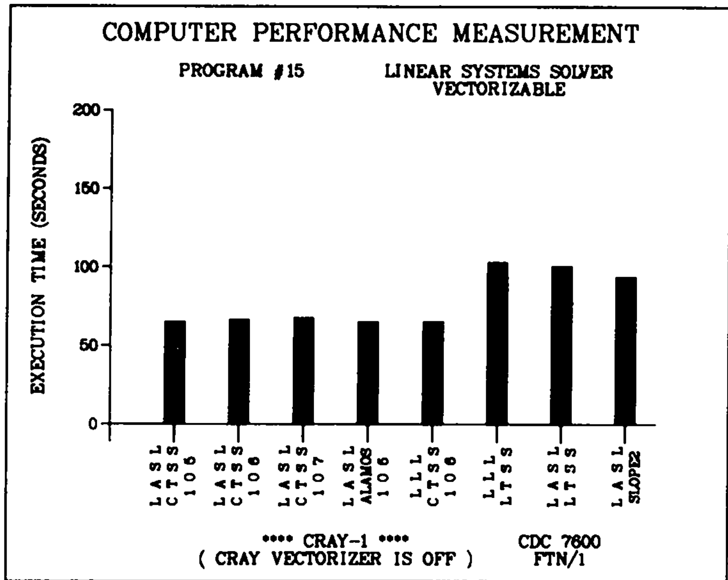

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 15
LINEAR SYSTEMS SOLVER VECTORIZABLE
EXECUTION TIME (SECONDS)
200
150
100
50
0
FTN OPT 1
FTN OPT 2
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
CDC 7600 LASL LTSS
IBM 370/195 A N L
IBM 3033 O S M V T
*(BLANK HISTOGRAMS RAN LONGER THAN 10 MINUTES)

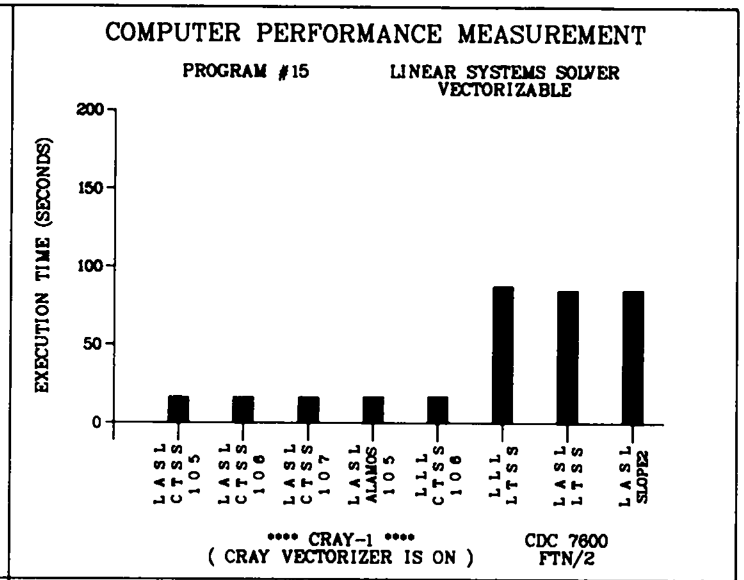

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 15
LINEAR SYSTEMS SOLVER VECTORIZABLE
EXECUTION TIME (SECONDS)
200
150
100
50
0
L A S L CTSS 1 0 5
L A S L CTSS 1 0 6
L A S L CTSS 1 0 7
L A S L ALAMOS 1 0 5
L L L CTSS 1 0 8
L L L LTSS
L A S L LTSS
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS OFF)
CDC 7600 FTN/1

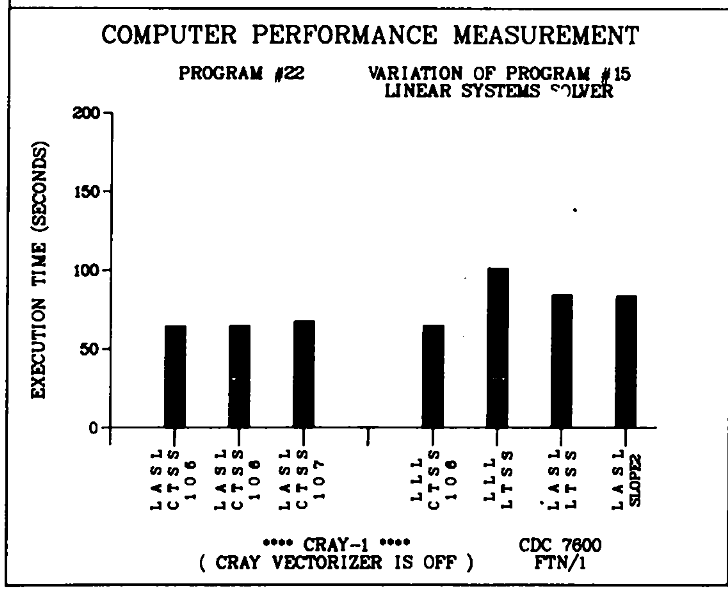

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 15
LINEAR SYSTEMS SOLVER VECTORIZABLE
EXECUTION TIME (SECONDS)
200
150
100
50
0
L A S L CTSS 1 0 5
L A S L CTSS 1 0 6
L A S L CTSS 1 0 7
L A S L ALAMOS 1 0 5
L L L CTSS 1 0 8
L L L LTSS
L A S L LTSS
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS ON)
CDC 7600 FTN/2

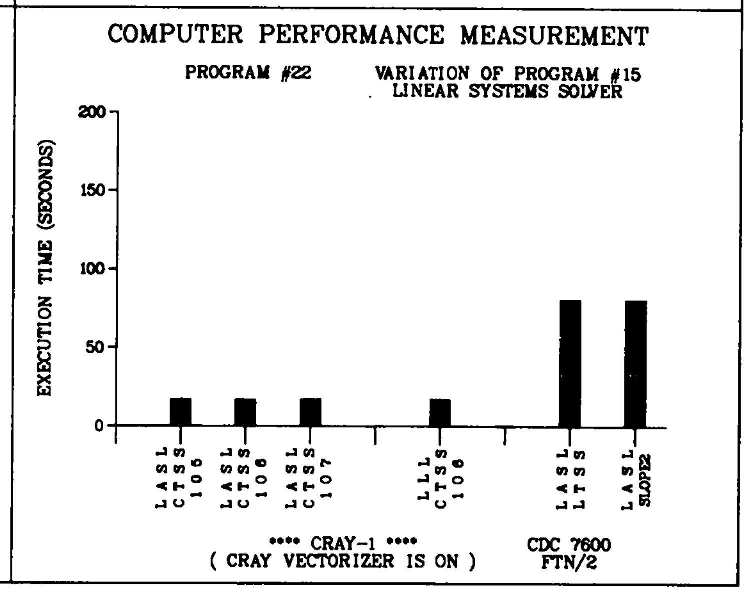

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 18 VECTOR CALCULATIONS
EXECUTION TIME (SECONDS)
OPT 1
OPT 2
720 OPT 2
730 OPT 2
750 OPT 2
760 OPT 2
CYBER 73 NOS
CDC 6600 NOS
CDC 700 SERIES NOS
CCF COMPUTERS
NON-CCF COMPUTERS
COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 18 VECTOR CALCULATIONS
EXECUTION TIME (SECONDS)
FTN OPT 1
FTN OPT 2
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
CDC 7600 LASL LTSS
IBM 370/195
IBM 3033
A N L O S M V T
COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 18 VECTOR CALCULATIONS
EXECUTION TIME (SECONDS)
LASL CTSS 105
LASL CTSS 106
LASL CTSS 107
LASL ALAMOS 105
LLL CTSS 106
LLL LTSS
LASL LTSS
LASL SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS OFF)
CDC 7600 FTN/1
COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 18 VECTOR CALCULATIONS
EXECUTION TIME (SECONDS)
•••• CRAY-1 ••••
(CRAY VECTORIZER IS ON)
CDC 7600 FTN/2

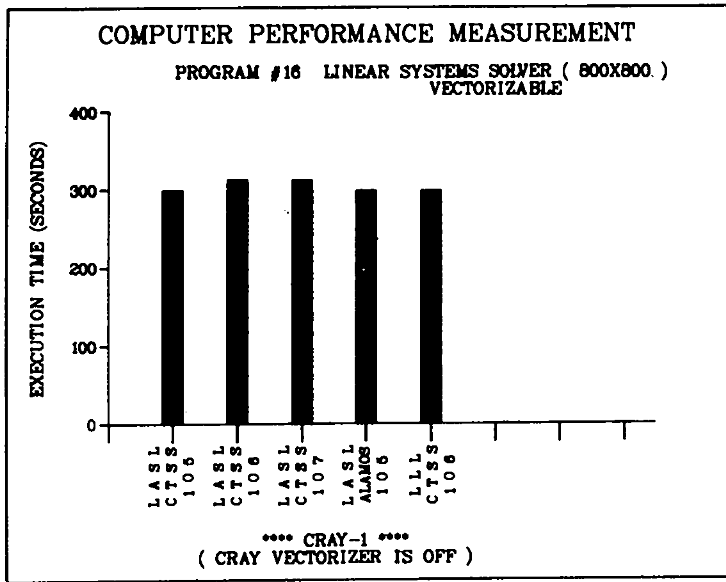

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 21
SCALAR MONTE CARLO
EXECUTION TIME (SECONDS)
0
50
100
150
200
OPT 1
OPT 2
OPT 1
OPT 2
CDC 6600
NOS
CCF COMPUTERS
COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 21
SCALAR MONTE CARLO
EXECUTION TIME (SECONDS)
0
5
10
15
20
25
LASL CTSS 105
LASL CTSS 106
LASL CTSS 107
LASL ALAMOS 105
LASL LTSS
LASL SLOPE2
•••• CRAY—1 ••••
(CRAY VECTORIZER IS OFF)
CDC 7600
FTN/1
COMPUTER PERFORMANCE MEASUREMENT
PROGRAM 21
SCALAR MONTE CARLO
EXECUTION TIME (SECONDS)
0
5
10
15
20
25
LASL CTSS 105
LASL CTSS 106
LASL CTSS 107
LASL ALAMOS 105
LASL LTSS
LASL SLOPE2
•••• CRAY—1 ••••
(CRAY VECTORIZER IS ON)
CDC 7600
FTN/2

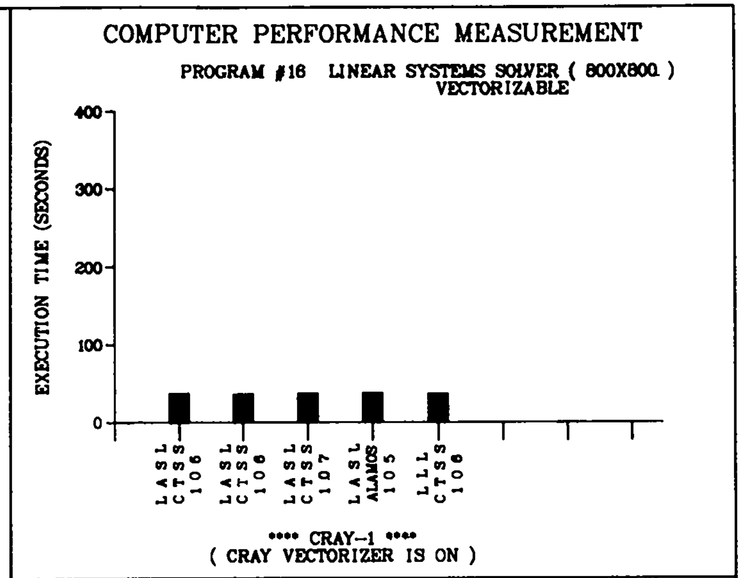

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM #15
LINEAR SYSTEMS SOLVER VECTORIZABLE
EXECUTION TIME (SECONDS)
200
150
100
50
0
LASL CTSS 105
LASL CTSS 106
LASL CTSS 107
LASL ALAMOS 106
LLL CTSS 106
LLL LTSS
LASL LTSS
LASL SLOPE2
**** CRAY-1 ****
(CRAY VECTORIZER IS OFF)
CDC 7600
FTN/1

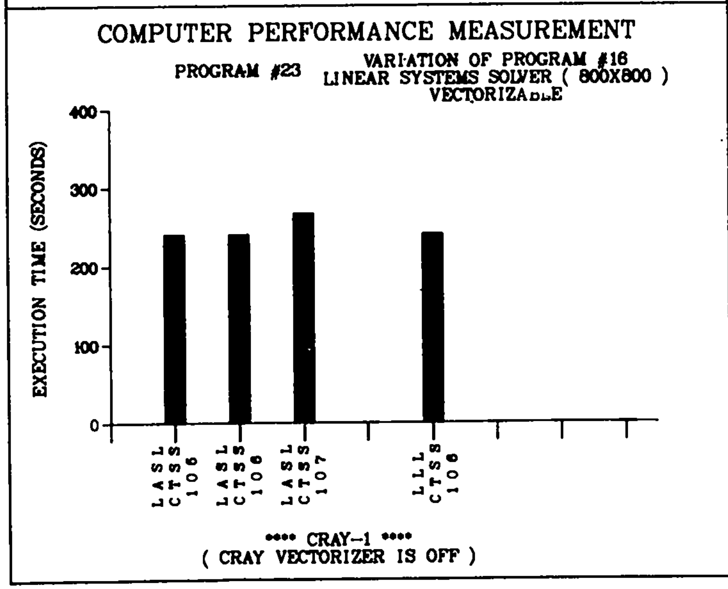

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM #15
LINEAR SYSTEMS SOLVER VECTORIZABLE
EXECUTION TIME (SECONDS)
200
150
100
50
0
LASL CTSS 105
LASL CTSS 106
LASL CTSS 107
LASL ALAMOS 105
LLL CTSS 106
LLL LTSS
LASL LTSS
LASL SLOPE2
**** CRAY-1 ****
(CRAY VECTORIZER IS ON)
CDC 7600
FTN/2

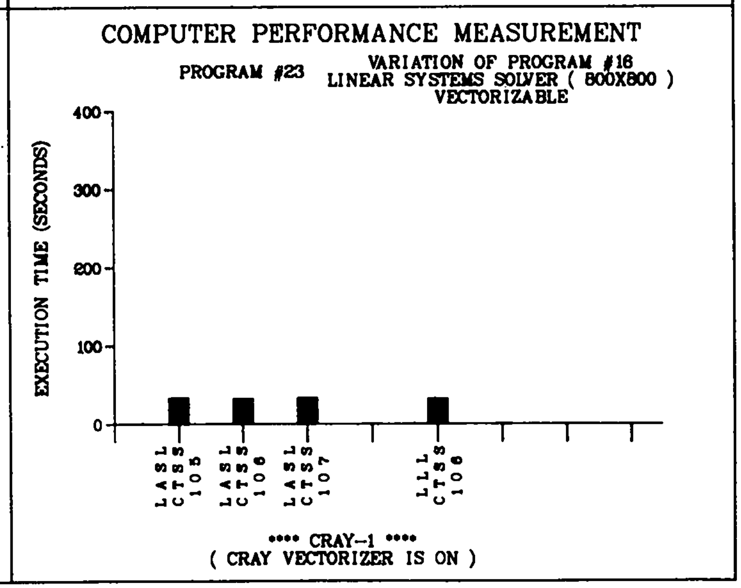

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM #22
VARIATION OF PROGRAM #15
LINEAR SYSTEMS SOLVER
EXECUTION TIME (SECONDS)
200
150
100
50
0
LASL CTSS 105
LASL CTSS 106
LASL CTSS 107
LLL CTSS 106
LLL LTSS
LASL LTSS
LASL SLOPE2
**** CRAY-1 ****
(CRAY VECTORIZER IS OFF)
CDC 7600
FTN/1

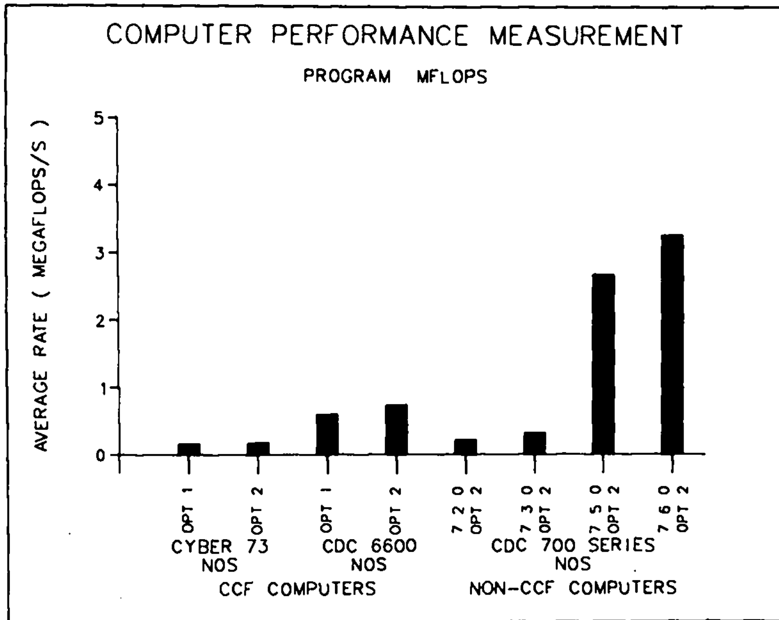

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM #22
VARIATION OF PROGRAM #15
LINEAR SYSTEMS SOLVER
EXECUTION TIME (SECONDS)
200
150
100
50
0
LASL CTSS 105
LASL CTSS 106
LASL CTSS 107
LLL CTSS 106
LASL LTSS
LASL SLOPE2
**** CRAY-1 ****
(CRAY VECTORIZER IS ON)
CDC 7600
FTN/2

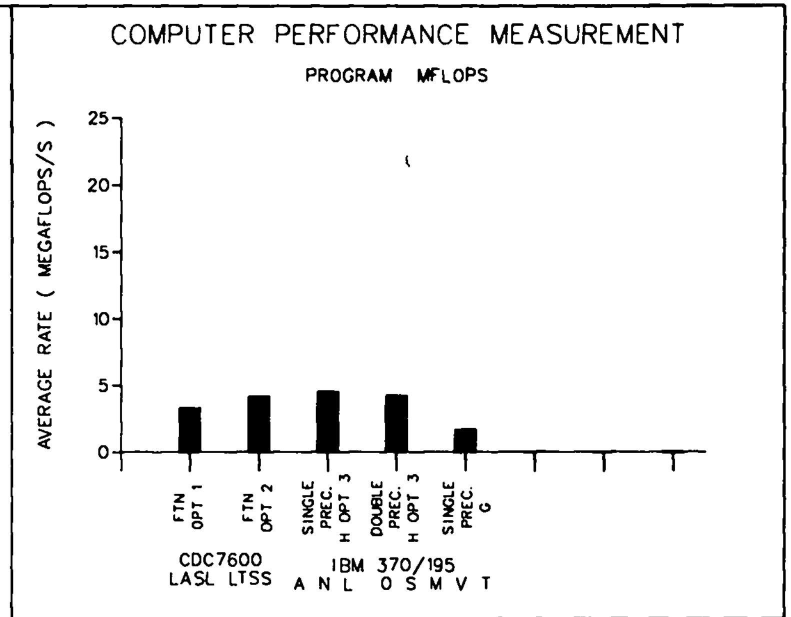

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM #16 LINEAR SYSTEMS SOLVER (800X800)
VECTORIZABLE
EXECUTION TIME (SECONDS)
0
100
200
300
400
LASL CTSS 105
LASL CTSS 106
LASL CTSS 107
LASL ALAMOS 105
LLL CTSS 106
**** CRAY-1 ****
(CRAY VECTORIZER IS OFF)

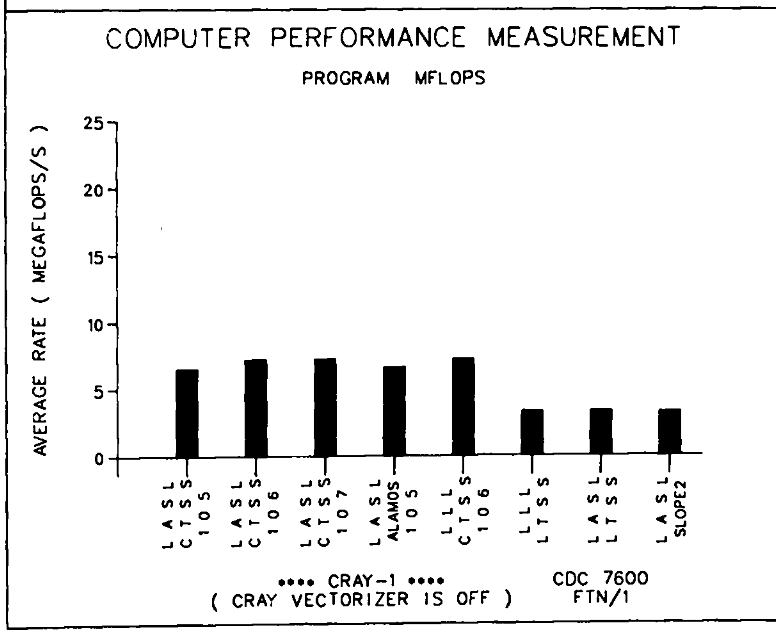

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM #16 LINEAR SYSTEMS SOLVER (800X800)
VECTORIZABLE
EXECUTION TIME (SECONDS)
0
100
200
300
400
LASL CTSS 105
LASL CTSS 106
LASL CTSS 107
LASL ALAMOS 105
LLL CTSS 106
**** CRAY-1 ****
(CRAY VECTORIZER IS ON)

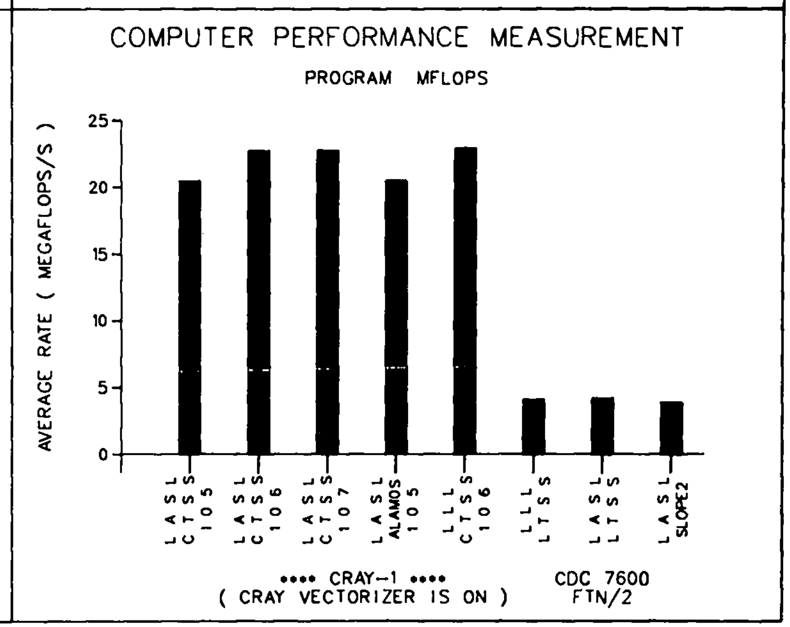

COMPUTER PERFORMANCE MEASUREMENT
PROGRAM #23
VARIATION OF PROGRAM #16
LINEAR SYSTEMS SOLVER (800X800)
VECTORIZABLE
EXECUTION TIME (SECONDS)
0
100
200
300
400
LASL CTSS 105
LASL CTSS 106
LASL CTSS 107
LLL CTSS 106
**** CRAY-1 ****
(CRAY VECTORIZER IS OFF)


COMPUTER PERFORMANCE MEASUREMENT
PROGRAM #23
VARIATION OF PROGRAM #16
LINEAR SYSTEMS SOLVER (800X800)
VECTORIZABLE
EXECUTION TIME (SECONDS)
0
100
200
300
400
LASL CTSS 105
LASL CTSS 106
LASL CTSS 107
LLL CTSS 106
**** CRAY-1 ****
(CRAY VECTORIZER IS ON)


COMPUTER PERFORMANCE MEASUREMENT
PROGRAM MFLOPS
AVERAGE RATE (MEGAFLOPS/S)
0
1
2
3
4
5
OPT 1
OPT 2
OPT 1
OPT 2
7 2 0 OPT 2
7 3 0 OPT 2
7 5 0 OPT 2
7 6 0 OPT 2
CYBER 73 NOS
CDC 6600 NOS
CDC 700 SERIES NOS
CCF COMPUTERS
NON-CCF COMPUTERS


COMPUTER PERFORMANCE MEASUREMENT
PROGRAM MFLOPS
AVERAGE RATE (MEGAFLOPS/S)
0
5
10
15
20
25
FTN OPT 1
FTN OPT 2
SINGLE PREC. H OPT 3
DOUBLE PREC. H OPT 3
SINGLE PREC. G
CDC7600 LASL LTSS
IBM 370/195 A N L O S M V T


COMPUTER PERFORMANCE MEASUREMENT
PROGRAM MFLOPS
AVERAGE RATE (MEGAFLOPS/S)
0
5
10
15
20
25
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS OFF)
CDC 7600 FTN/1


COMPUTER PERFORMANCE MEASUREMENT
PROGRAM MFLOPS
AVERAGE RATE (MEGAFLOPS/S)
0
5
10
15
20
25
L A S L C T S S 1 0 5
L A S L C T S S 1 0 6
L A S L C T S S 1 0 7
L A S L ALAMOS 1 0 5
L L L C T S S 1 0 6
L L L L T S S
L A S L L T S S
L A S L SLOPE2
•••• CRAY-1 ••••
(CRAY VECTORIZER IS ON)
CDC 7600 FTN/2

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