A

PERFORMANCE OF VARIOUS COMPUTERS USING STANDARD LINEAR EQUATIONS SOFTWARE

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A.1 Introduction and Objectives

The timing information presented here should in no way be used to judge the overall performance of a computer system. The results reflect only one problem area: solving dense systems of equations.

This report provides performance information on a wide assortment of computers ranging from the home-used PC up to the most powerful supercomputers. The information has been collected over a period of time and will undergo change as new machines are added and as hardware and software systems improve. The programs used to generate this data can easily be obtained over the internet. While we make every attempt to verify the results obtained from users and vendors, errors are bound to exist and should be brought to our attention. We encourage users to obtain the programs and run the routines on their machines, reporting any discrepancies with the numbers listed here.

Table A.1 reports three numbers for each machine listed (in some cases the numbers are missing because of lack of data). All performance numbers reflect arithmetic performed in full precision (usually 64 bit), unless noted. On some machines full precision may be single precision, such as the CRAY, or double precision, such as the IBM. The first number is for the LINPACK [1] benchmark program for a matrix of order 100 in a FORTRAN environment. The second number is for solving a system of equations of order 1000, with no restriction on the method or its implementation. The third number is the theoretical peak performance of the machine.

LINPACK programs can be characterized as having a high percentage of floating-point arithmetic operations. The routines involved in this timing study, SGEFA and SGESL, use column-oriented algorithms. That is, the programs usually reference array elements sequentially down a column, not across a row. Column orientation is important in increasing efficiency because of the way FORTRAN stores arrays. Most floating-point operations in LINPACK take place in a set of subprograms, the Basic Linear Algebra Subprograms (BLAS) [3], which are called repeatedly throughout the calculation. These BLAS, referred to now as Level 1 BLAS, reference one-dimensional arrays, rather than two-dimensional arrays.

In the first case, the problem size is relatively small (order 100), and no changes were made to the LINPACK software. Moreover, no attempt was made to use special hardware features or to exploit vector capabilities or multiple processors. (The compilers on some machines may, of course, generate optimized code that itself accesses special features.) Thus, many high-performance machines may not have reached their asymptotic execution rates.

In the second case, the problem size is larger (matrix of order 1000), and modifying or replacing the algorithm and software was permitted to achieve as high an execution rate as possible. Thus, the hardware had more opportunity for reaching near-asymptotic rates. An important constraint, however, was that all optimizated programs maintain the same relative accuracy as standard techniques, such as Gaussian elimination used in LINPACK.

Furthermore, the driver program (supplied with the LINPACK benchmark) had to be run to ensure that the same problem is solved. The driver program sets up the matrix, calls the routines to solve the problem, verifies that the answers are correct, and computes the total number of operations to solve the problem (independent of the method) as $2n^3/3 + 2n^2$, where $n = 1000$.

The last column is based not on an actual program run, but on a paper computation to determine the theoretical peak MFLOPS rate for the machine. This is the number manufacturers often cite; it represents an upper bound on performance. That is, the manufacturer guarantees that programs will not exceed this rate—sort of a "speed of light" for a given computer.

The theoretical peak performance is determined by counting the number of floating-point additions and multiplications (in full precision) that can be completed during a period of time, usually the cycle time of the machine. As an example, the CRAY Y-MP/8 has a cycle time of 6 ns. During a cycle the results of both an addition and a multiplication can be completed $\frac{2 \text{ operations}}{1 \text{ cycle}} * \frac{1 \text{ cycle}}{6 \text{ ns}} = 333$ MFLOPS on a single processor. On the CRAY Y-MP/8 there are eight processors; thus, the peak performance is 2667 MFLOPS.

The information in this report is presented to users to provide a range of performance for the various computers and to show the effects of typical FORTRAN programming and the results that can be obtained through careful programming. The maximum rate of execution is given for comparison.

The column labeled "Computer" gives the name of the computer hardware on which the program was run on. In some cases we have indicated the number of processors in the configuration and, in some cases, the cycle time of the processor in nanoseconds.

The column labeled "LINPACK Benchmark" gives the operating system and compiler used. The run was based on two routines from LINPACK: SGEFA and SGESL were used for single precision, and DGEFA and DGESL were used for double precision. These routines perform standard LU decomposition with partial pivoting and back-substitution. The timing was done on a matrix of order 100, where no changes are allowed to the Fortran programs.

The column labeled "TPP" (Toward Peak Performance) gives the results of hand optimization; the problem size was of order 1000.

The final column labeled "Theoretical Peak" gives the maximum rate of execution based on the cycle time of the hardware.

The same matrix was used to solve the system of equations. The results were checked for accuracy by calculating a residual for the problem $||Ax - b||/(||A||||x||)$.

The term MFLOPS, used as a rate of execution, stands for millions of floating-point operations completed per second. For solving a system of n equations, $2/3n^3 + 2n^2$ operations are performed (we count both additions and multiplications).

The information in the tables was compiled over a period of time. Subsequent systems software and hardware changes may alter the timings to some extent.

One further note: The following tables should not be taken too seriously. In multiprogramming environments it is often difficult to reliably measure the execution time of a single program. We trust that anyone actually evaluating machines and operating systems will gather more reliable and more representative data.

A.2 A Look at Parallel Processing

While collecting the data presented in Table A.1, we were able to experiment with parallel processing on a number of computer systems. For these experiments, we used either the standard LINPACK algorithm or an algorithm based on matrix-matrix [2] techniques. In the case of the LINPACK algorithm, the loop around the SAXPY can be performed in parallel. In the matrix-matrix implementation the matrix product can be split into submatrices and performed in parallel. In either case, the parallelism follows a simple fork-and-join model where each processor gets some number of operations to perform.

For a problem of size 1000, we expect a high degree of parallelism. Thus, it is not surprising that we get such high efficiency (see Table A.2). The actual percentage of parallelism, of course, depends on the algorithm and on the speed of the uniprocessor on the parallel part relative to the speed of the uniprocessor on the non-parallel part.

A.3 Massively Parallel Computing

With the arrival of masssively parallel computers there is a need to benchmark such machines on problems that make sense. The problem size and rule for the runs reflected in the Tables A.1 and A.2 do not permit massively parallel computers to demonstrate their potential performance. The basic flaw is the problem size is too small. To provide a forum for comparing such machines the following benchmark was run on a number of massively parallel machines. The benchmark involves solving a system of linear equations (as was done in Tables A.1 and A.2). However in this case, the problem size is allowed to increase and the performance numbers reflect the largest problem run on the machine.

The ground rules are as follows: Solve systems of linear equations by some method, allow the size of the problem to vary, and measure the execution time for each size problem. In computing the floating-point execution rate, use $2n^3/3 + 2n^2$ operations independent of the actual method used. (If you choose to do Gaussian Elimination, partial pivoting must be used.) Compute and report a residual for the accuracy of solution as $\|Ax - b\|/(\|A\|\|x\|)$.

The columns in Table A.3 are defined as follows:

r_{max} the performance in Gflops for the largest problem run on a machine.

n_{max} the size of the largest problem run on a machine.

$n_{1/2}$ the size where half the r_{max} execution rate is achieved.

r_{peak} the theoretical peak performance in Gflops for the machine.

In addition, the number of processors and the cycle time is listed.

A.4 Obtaining the Software and Running the Benchmarks

The software used to generate the data for this report can be obtained by sending electronic mail to *netlib@ornl.gov.*

a. LINPACK Benchmark

The first results listed in Table A.1 involved no hand optimization of the LINPACK benchmark.

To receive the single-precision software for this benchmark, in the mail message to *netlib@ornl.gov* type: *send linpacks from benchmark* .

To receive the double-precision software for the LINPACK Benchmark, type: *send linpackd from benchmark* .

To run the timing programs, one must supply a real function SECOND which returns the time in seconds from some fixed starting time.

There is only one ground rule for running this benchmark:

- No changes are to be made to the FORTRAN source code, not even changes in the comments.

The compiler and operating system must be generally available. Results from a beta version of a compiler are allowed, however the standard compiler results must also be listed.

b. Toward Peak Performance

The second set of results listed in Table A.1 reflected user optimization of the software.

To receive the single-precision software for the column labeled "Toward Peak Performance," in the mail message *netlib@ornl.gov* type: *send 1000s from benchmark*

To receive the double-precision software, type: *send 1000d from benchmark*

The ground rules for running this benchmark are as follows:

- Replacements or modifications are allowed in the routine LU.
- The user is allowed to supply any method for the solution of the system of equations.
- The MFLOPS rate will be computed based on the operation count for LU decomposition.
- In all cases, the main driver routine, with its test matrix generator and residual check, must be used.

This report is updated from time to time. A fax copy of this report can be supplied, for details contact the author. To obtain a Postscript copy of the report send mail to *netlib@ornl.gov* and in the message type: *send performance from benchmark.*

To have results verified, please send the output of the runs to

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References

[1] Dongarra, J. J., J. Bunch, C. Moler, and G. W. Stewart, *LINPACK User's Guide*, SIAM, Philadelphia, PA, 1979.

[2] Dongarra, J. J., I. S. Duff, D. C. Sorensen, and H. A. van der Vorst, *Solving Linear Systems on Vector and Shared Memory Computers*, SIAM Publications, Philadelphia, PA, 1990.

[3] Lawson, C., R. Hanson, D. Kincaid, and F. Krogh, "Basic linear algebra subprograms for Fortran usage," *ACM Trans. Math. Softw.*, **5**, 308–323, 1979.

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretical Peak" Mflop/s
CRAY Y-MP C90 (16 proc. 4.2 ns)	CF77 5.0 -Zp -Wd-e68	479	9715	15238
CRAY Y-MP C90 (8 proc. 4.2 ns)	CF77 5.0 -Zp -Wd-e68	468	5994	7619
CRAY Y-MP C90 (4 proc. 4.2 ns)	CF77 5.0 -Zp -Wd-e68	388	3272	3810
CRAY Y-MP C90 (2 proc. 4.2 ns)	CF77 5.0 -Zp -Wd-e68	387	1709	1905
CRAY Y-MP C90 (1 proc. 4.2 ns)	CF77 5.0 -Zp -Wd-e68	387	874	952
NEC SX-3/44R (4 proc. 2.5 ns)			15120	25600
NEC SX-3/42R (4 proc. 2.5 ns)			8950	12800
NEC SX-3/41R (4 proc. 2.5 ns)			4815	6400
NEC SX-3/24R (2 proc. 2.5 ns)			9454	12800
NEC SX-3/22R (2 proc. 2.5 ns)			5116	6400
NEC SX-3/21R (2 proc. 2.5 ns)			2627	3200
NEC SX-3/14R (1 proc. 2.5 ns)	f77sx 040 R2.2 -pi*:*	368	5199	6400
NEC SX-3/12R (1 proc. 2.5 ns)	f77sx 040 R2.2 -pi*:*	368	2757	3200
NEC SX-3/44 (4 proc. 2.9 ns)			13420	22000
NEC SX-3/24 (2 proc. 2.9 ns)			8149	11000
NEC SX-3/42 (4 proc. 2.9 ns)			7752	11000
NEC SX-3/22 (2 proc. 2.9 ns)			4404	5500
NEC SX-3/14 (1 proc. 2.9 ns)	f77sx 020 R1.13 -pi*:*	314	4511	5500
NEC SX-3/12 (1 proc. 2.9 ns)	f77sx 020 R1.13 -pi*:*	313	2283	2750
CRAY Y-MP/832 (8 proc. 6 ns)	CF77 4.0 -Zp -Wd-e68	275	2144	2667
Fujitsu VP2600/10 (3.2 ns)	FORTRAN77 EX/VP V11L10	249	4009	5000
CRAY Y-MP/832 (4 proc. 6 ns)	CF77 4.0 -Zp -Wd-e68	226	1159	1333
Cray Y-MP M98 (8 proc. 6 ns)	CF77 5.0 -Zp -Wd-e68	204	1733	2666
Fujitsu VP2200/10 (3.2 ns)	FORTRAN77 EX/VP V12L10	203	1048	1250
NEC SX-3/11R (1 proc. 2.5 ns)	f77sx 040 R2.2 -pi*:*	202	1418	1600
NEC SX-3/1LR (1 proc. 2.5 ns)	f77sx 040 R2.2 -pi*:*	201	767	800
CRAY Y-MP/832 (2 proc. 6 ns)	CF77 5.0 -Zp -Wd-e68	181	604	667
CRAY X-MP/416 (4 proc. 8.5 ns)	CF77 4.0 -Zp -Wd-e68	178	822	940
Cray Y-MP M98 (4 proc. 6 ns)	CF77 5.0 -Zp -Wd-e68	177	1114	1333
NEC SX-3/11 (1 proc. 2.9 ns)	f77sx 020 R1.13 -pi*:*	173	1223	1370
NEC SX-3/1L (1 proc. 2.9 ns)	f77sx 020 R1.13 -pi*:*	171	661	680
Fujitsu VP2400/10 (4 ns)	FORTRAN77 EX/VP V11L10	170	1688	2000
CRAY Y-MP/832 (1 proc. 6 ns)	CF77 5.0 -Zp -Wd-e68	161	324	333
Cray Y-MP M98 (2 proc. 6 ns)	CF77 5.0 -Zp -Wd-e68	154	596	666
Cray Y-MP M98 (1 proc. 6 ns)	CF77 5.0 -Zp -Wd-e68	150	307	333
CRAY Y-MP M92 (2 proc. 6 ns)	CF77 5.0 -Zp -Wd-e68	145	550	666
CRAY Y-MP M92 (1 proc. 6 ns)	CF77 5.0 -Zp -Wd-e68	145	332	333
CRAY X-MP/416 (2 proc. 8.5 ns)	CF77 5.0 -Zp -Wd-e68	143	426	470
CRAY 2S/4-128 (4 proc. 4.1 ns)	CF77 5.0 -Zp -Wd-e68	129	1406	1951
Fujitsu VP2200/10 (4 ns)	FORTRAN77 EX/VP V11L10	127	842	1000
CRAY X-MP/416 (1 proc. 8.5 ns)	CF77 5.0 -Zp -Wd-e68	121	218	235
CRAY 2S/4-128 (2 proc. 4.1 ns)	CF77 5.0 -Zp -Wd-e68	113	741	976
Fujitsu VP2100/10 (4 ns)	FORTRAN77 EX/VP V11L10	112	445	500
Hitachi S-820/80 (4 ns)	FORT77/HAP V23-0C	107		3000

Table A.1 Performance in solving a system of linear equations.

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretic Peak" Mflo
CRAY 2S/4-128 (1 proc. 4.1 ns)	CF77 5.0 -Zp -Wd-e68	107	384	488
CRAY 2S/8-128 (8 proc. 4.1 ns)	CF77 4.0 -Zp -Wd-e68	102	2171	3902
ETA 10-G (1 proc. 7 ns)	ETAV/FTN200	93	496	571
CONVEX C-3880 (8 proc.) (16.7 ns)	fc7.0 -tm c38 -O3 -ep 8 -ds -is .	86	795	960
IBM ES/9000-982 VF(8 proc 7.1ns)	VAST-2/VS Fortran V2R5		2278	4507
IBM ES/9000-972 VF(7 proc 7.1ns)	VAST-2/VS Fortran V2R5		2072	3944
IBM ES/9000-962 VF(6 proc 7.1ns)	VAST-2/VS Fortran V2R5		1923	3380
IBM ES/9000-952 VF(5 proc 7.1ns)	VAST-2/VS Fortran V2R5		1681	2817
IBM ES/9000-942 VF(4 proc 7.1ns)	VAST-2/VS Fortran V2R5		1377	2254
IBM ES/9000-831 VF(3 proc 7.1ns)	VAST-2/VS Fortran V2R5		1082	1690
IBM ES/9000-821 VF(2 proc 7.1ns)	VAST-2/VS Fortran V2R5		767	1127
IBM ES/9000-711 VF(1 proc 7.1ns)	VAST-2/VS Fortran V2R5	86	422	563
CONVEX C-3840 (4 proc.) (16.7 ns)	fc7.0 -tm c38 -O3 -ep 4 -ds -is .	75	425	480
CONVEX C-3830 (3 proc.) (16.7 ns)	fc7.0 -tm c38 -O3 -ep 3 -ds -is .	71	327	360
CONVEX C-3820 (2 proc.) (16.7 ns)	fc7.0 -tm c38 -O3 -ep 2 -ds -is .	62	222	240
CRAY-2/4-256 (4 proc. 4.1 ns)	cf77 3.0	62	1406	1951
ETA 10-E (1 proc. 10.5 ns)	ETAV/FTN200	62	334	381
IBM ES/9000-900 VF(6 proc. 9 ns)	VAST-2/VS Fortran V2R4		1457	2664
IBM ES/9000-860 VF(5 proc. 9 ns)	VAST-2/VS Fortran V2R4		1210	2220
IBM ES/9000-820 VF(4 proc. 9 ns)	VAST-2/VS Fortran V2R4		1003	1776
IBM ES/9000-740 VF(3 proc. 9 ns)	VAST-2/VS Fortran V2R4		775	1332
IBM ES/9000-640 VF(2 proc. 9 ns)	VAST-2/VS Fortran V2R4		539	888
IBM ES/9000-660 VF(2 proc. 9 ns)	VAST-2/VS Fortran V2R4		535	888
IBM ES/9000-520 VF(1 proc. 9 ns)	VAST-2/VS Fortran V2R4	60	338	444
CRAY X-MP/14se (10 ns)	cf77 3.0	53	184	210
CRAY-2/4-256 (2 proc. 4.1 ns)	cf77 3.0	48	709	976
IBM ES/9000-711 (1 proc 7.1ns)	VAST-2/VS Fortran V2R5	48		
CONVEX C-3810 (1 proc.) (16.7 ns)	fc7.0 -tm c38 -O2 -is .	44	113	120
DEC 10000-660 Alpha AXP(6 proc)			751	1200
DEC 10000-650 Alpha AXP(5 proc)			639	1000
DEC 10000-640 Alpha AXP(4 proc)			523	800
DEC 10000-630 Alpha AXP(3 proc)			403	600
DEC 10000-620 Alpha AXP(2 proc)			273	400
DEC 10000-610 Alpha AXP 200 MHz	3.2 inl=daxpy,ur=4,ur2=240	43	155	200
NEC SX-2 (6 ns)	FORTRAN 77/SX	43	885	1300
HP 9000/735 (99 MHz)	+OP3 -Wl,-aarchive -WP,-nv -w,MLIB	41	107	198
CRAY Y-MP EL98 (8 proc. 30 ns)	CF77 5.0 -Zp -Wd-e68	40	567	1068
CRAY Y-MP EL98 (4 proc. 30 ns)	CF77 5.0 -Zp -Wd-e68	40	357	534
CRAY S-MP/11v2 (1 proc. 30 ns)	uf77 5.1.2 vec=collapse pi+	39	206	267
CRAY Y-MP EL (4 proc. 30 ns)	CF77 5.0 -Zp -Wd-e68	39	345	532
DEC 7000-660 Alpha AXP (6 proc)			683	1092
DEC 7000-650 Alpha AXP (5 proc)			586	910
DEC 7000-640 Alpha AXP (4 proc)			484	728
DEC 7000-630 Alpha AXP (3 proc)			369	546
DEC 7000-620 Alpha AXP (2 proc)			250	364
DEC 7000-610 Alpha AXP(182 MHz)	3.2 inl=daxpy,ur=4,ur2=240	39	141	182

Table A.1 Performance in solving a system of linear equations (continued).

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretical Peak" Mflop/s
CRAY-2/4-256 (1 proc. 4.1 ns)	cf77 3.0	38	360	488
IBM RISC Sys/6000-580 (62.5MHz)	v2.3 xlf -O -P -Wp,-ea478	38	104	125
IBM RISC Sys/6000-980 (62.5MHz)	v2.3 xlf -O -P -Wp,-ea478	38	104	125
IBM ES/9000-520 (1 proc. 9 ns)	VAST-2/VS Fortran V2R4	38		
IBM ES/9000-820 (1 proc. 9 ns)	VAST-2/VS Fortran V2R4	38		
DEC 4000-620 Alpha AXP (2 proc)			187	320
DEC 4000-610 Alpha AXP(160 MHz)	3.2 inl=daxpy,ur=4,ur2=240	36	114	160
NEC SX-1	FORTRAN 77/SX	36	422	650
CRAY Y-MP EL98 (2 proc. 30 ns)	CF77 5.0 -Zp -Wd-e68	35	192	267
CONVEX C-3440 (4 proc.)	fc7.0 fc -O3 -ep 4 -ds -is .	34	172	200
CRAY Y-MP EL98 (1 proc. 30 ns)	CF77 5.0 -Zp -Wd-e68	34	107	133
ETA 10-Q (1 proc. 19 ns)	ETAV/FTN200	34	185	210
CRAY Y-MP EL (2 proc. 30 ns)	CF77 5.0 -Zp -Wd-e68	33	191	266
CRAY S-MP/MCP784(84 proc. 25 ns)			742	3360
CRAY S-MP/MCP756(56 proc. 25 ns)			678	2240
CRAY S-MP/MCP728(28 proc. 25 ns)			508	1120
CRAY S-MP/MCP707 (7 proc. 25 ns)	MCP Release 2.2	33	194	280
FPS 510S MCP784 (84 proc. 25 ns)			548	3360
FPS 510S MCP756 (56 proc. 25 ns)			513	2240
FPS 510S MCP728 (28 proc. 25 ns)			414	1120
FPS 510S MCP707 (7 proc. 25 ns)	pgf77 -O4 -Minline	33	184	280
CDC Cyber 2000V	Fortran V2	32		
CONVEX C-3430 (3 proc.)	fc7.0 fc -O3 -ep 3 -ds -is .	32	132	150
CRAY Y-MP EL (1 proc. 30 ns)	CF77 5.0 -Zp -Wd-e68	32	107	133
NEC SX-1E	FORTRAN 77/SX	32	221	325
Alliant FX/2800-200 (14 proc)	fortran 1.1.27 -O -inline	31	325	560
IBM RISC Sys/6000-970 (50 MHz)	v2.2.1 xlf -O -P -Wp,-ea478	31	84	100
IBM RS/6000 Cluster(8 proc 62.5 MHz)			269	1000
IBM RS/6000 Cluster(4 proc 62.5 MHz)			206	500
IBM RS/6000 Cluster(2 proc 62.5 MHz)			144	250
IBM RS/6000 Cluster(8 proc 50 MHz)			194	800
IBM RS/6000 Cluster(6 proc 50 MHz)			174	600
IBM RS/6000 Cluster(4 proc 50 MHz)			152	400
IBM RS/6000 Cluster(2 proc 50 MHz)			111	200
IBM RISC Sys/6000-560 (50 MHz)	v2.2.1 xlf -O -P -Wp,-ea478	31	84	100
IBM ES/9000-742 VF(4 proc 11ns)	VAST-2/VS Fortran V2R5		441	752
IBM ES/9000-732 VF(3 proc 11ns)	VAST-2/VS Fortran V2R5		352	545
IBM ES/9000-622 VF(2 proc 11ns)	VAST-2/VS Fortran V2R5		244	364
IBM ES/9000-621 VF(2 proc 11ns)	VAST-2/VS Fortran V2R5		244	364
IBM ES/9000-521 VF(2 proc 11ns)	VAST-2/VS Fortran V2R5		185	364
IBM ES/9000-511 VF(1 proc 11ns)	VAST-2/VS Fortran V2R5	30	130	182
DEC 3000-500 Alpha AXP(150 MHz)	3.2 inl=daxpy,ur=4,ur2=240	30	107	150
Alliant FX/2800-200 (12 proc)	fortran 1.1.27 -O -inline	29	290	480
Alliant FX/2800 210 (1 proc)	fortran 1.3.02 -Ovg -inline	25	34	50
Alliant FX/2800-200 (10 proc)	fortran 1.1.27 -O -inline	27	250	400
ETA 10-P (1 proc. 24 ns)	ETAV/FTN200	27	146	167

Table A.1 Performance in solving a system of linear equations (continued).

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretical Peak" Mflop/s
CONVEX C-3420 (2 proc.)	fc7.0 fc -O3 -ep 2 -ds -is .	27	90	100
CRAY-1S (12.5 ns)	cf77 2.1	27	110	160
CONVEX C-3240 (4 proc.)	fc -O3 -ep 2 -uo -pp=fcpp1 -is .	26	171	200
CONVEX C-240 (4 proc.)	6.1 -O3 -ep2 -uo -pp=fcpp1 -is .	26	166	200
CONVEX C-3230 (3 proc.)	fc -O3 -ep 2 -uo -pp=fcpp1 -is .	26	132	150
CONVEX C-230 (3 proc.)	6.1 -O3 -ep2 -uo -pp=fcpp1 -is .	26	128	150
DEC 3000-400 Alpha AXP(133 MHz)	3.2 inl=daxpy,ur=4,ur2=240	26	90	133
IBM RISC Sys/6000-950 (42 MHz)	v2.2.1 xlf -O -P -Wp,-ea478	26	70	84
IBM RISC Sys/6000-550 (42 MHz)	v2.2.1 xlf -O -P -Wp,-ea478	26	70	84
IBM RISC Sys/6000-375(62.5 MHz)	v2.3.0 xlf -O -P -Wp,-ea478	26	90	125
IBM RISC Sys/6000-370(62.5 MHz)	v2.3.0 xlf -O -P -Wp,-ea478	26	90	125
Alliant FX/2800-200 (8 proc)	fortran 1.1.27 -O -inline	25	207	320
NAS AS/EX 100 VPF (4 proc)			320	484
NAS AS/EX 90 VPF (3 proc)			251	363
NAS AS/EX 80 VPF (2 proc)			173	242
NAS AS/EX 60 VPF	VAST-2/VS 2.3.0 opt=3	25	94	121
HP 9000/750 (66 MHz)	+OP3 -Wl,-aarchive -WP,-nv -w	24	47	66
HP 9000/730 (66 MHz)	+OP3 -Wl,-aarchive -WP,-nv -w	24	49	66
IBM ES/9000 Model 480 VF	VAST-2/VS Fortran V2R4		180	266
IBM ES/9000-340 VF (14.5 ns)	VAST-2/VS Fortran V2R4	23		138
IBM ES/9000-411 VF(1 proc 11ns)	VAST-2/VS Fortran V2R5	23	99	182
DEC VAX 9000 420VP(2 proc 16 ns)	HPO V1.3-163V, DXML		155	250
DEC VAX 9000 410VP(1 proc 16 ns)	HPO V1.3-163V, DXML	22	89	125
IBM ES/9000-610 VF (4 proc 15 ns)	VAST-2/VS Fortran V2R4		335	532
IBM ES/9000-570 VF (3 proc 15 ns)	VAST-2/VS Fortran V2R4		252	399
IBM ES/9000-490 VF (2 proc 15 ns)	VAST-2/VS Fortran V2R4		171	266
IBM ES/9000-320 VF (1 proc 15 ns)	VAST-2/VS Fortran V2R4	22	91	133
IBM RISC Sys/6000-570 (50 MHz)	v2.3.0 xlf -O -P -Wp,-ea478	22	73	100
IBM RISC Sys/6000-365 (50 MHz)	v2.3.0 xlf -O -P -Wp,-ea478	22	73	100
IBM RISC Sys/6000-360 (50 MHz)	v2.3.0 xlf -O -P -Wp,-ea478	22	73	100
Multiflow TRACE 28/300	Fortran 2.2.1	22	69	123
CONVEX C-3220 (2 proc.)	fc -O3 -ep 2 -uo -pp=fcpp1 -is .	22	89	100
CONVEX C-220 (2 proc.)	6.1 -O3 -ep2 -uo -pp=fcpp1 -is .	22	87	100
Alliant FX/2800-200 (6 proc)	fortran 1.1.27 -O -inline	21	148	240
Siemens VP400-EX (7 ns)	Fortran 77/VP V10L30	21	794	1714
FPS Model 522	F77 4.2	20	105	133
Fujitsu VP-400	Fortran 77 V10L30	20		1142
IBM RISC Sys/6000-530H(33 MHz)	v2.2.1 xlf -O -P -Wp,-ea478	20	55	66
Siemens VP200-EX (7 ns)	Fortran 77 V10L30	20	472	857
Amdahl 1400	77/VP V10L20	19	521	1142
Amdahl 1200	77/VP V10L20	19	424	571
CONVEX C-3410 (1 proc.)	fc7.0 fc -O2 -is .	19	47	50
IBM ES/9000 Model 260 VF (15 ns)	VAST-2/VS Fortran V2R4	19	78	133
IBM RISC Sys/6000-550L(42 MHz)	v2.3.0 xlf -O -P -Wp,-ea478	19	61	82
IBM RISC Sys/6000-540 (30 MHz)	v2.2.1 xlf -O -P -Wp,-ea478	19	50	60
IBM RISC Sys/6000-355 (42 MHz)	v2.3.0 xlf -O -P -Wp,-ea478	19	61	84

Table A.1 Performance in solving a system of linear equations (continued).

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretical Peak" Mflop/s
IBM RISC Sys/6000-350 (42 MHz)	v2.2.1 xlf -O -P -Wp,-ea478	19	61	84
IBM ES/9000-311 VF(1 proc 11ns)	VAST-2/VS Fortran V2R5	19	82	182
CRAY S-MP/11 (1 proc. 30 ns)	uf77 5.1.2 -Oc a2	18	60	67
Fujitsu VP-200	Fortran 77	18	422	533
HP 9000/720 (50 MHz)	HP-UX 8.05 f77 +OP4 +O3	18	36	50
NAS AS/EX 50 VPF	VAST-2/VS 2.3.0	18	82	121
Siemens VP100-EX (7 ns)	Fortran 77/VP V10L30	18	254	428
SGI 4D/480(8 proc) 40MHz	f77 -O2 -mp	18	71	128
Alliant FX/2800-200 (4 proc)	fortran 1.1.27 -O -inline	17	94	160
Amdahl 1100	77/VP V10L20	17	248	285
CDC CYBER 205 (4-pipe)	FTN	17	195	400
CDC CYBER 205 (2-pipe)	FTN	17	113	200
CONVEX C-3210 (1 proc.)	fc -O2 -uo -pp=fcpp1 -is .	17	44	50
CONVEX C-210 (1 proc.)	6.1 -O2 -uo -pp=fcpp1 -is .	17	44	50
Cray XMS (55 ns)	cf77 5.0 -Zp -Wd-e68	17	34	36
Hitachi S-810/20	FORT77/HAP	17		840
IBM ES/9000 Model 210 VF (15 ns)	VAST-2/VS Fortran V2R4	17	72	133
Siemens VP50-EX (7 ns)	Fortran 77/VP V10L30	17	238	285
Multiflow TRACE 14/300	Fortran 2.2.1	17	42	63
Hitachi S-810/10	HAP V21.00	16		315
IBM 3090/600J VF (6 proc, 14.5 ns)			540	828
IBM 3090/500J VF (5 proc, 14.5 ns)			458	690
IBM 3090/400J VF (4 proc, 14.5 ns)			370	552
IBM 3090/380J VF (3 proc, 14.5 ns)			282	414
IBM 3090/300J VF (3 proc, 14.5 ns)			284	414
IBM 3090/280J VF (2 proc, 14.5 ns)			191	276
IBM 3090/200J VF (2 proc, 14.5 ns)			192	276
IBM 3090/180J VF (1 proc, 14.5 ns)	VS Fortran V2R3	16	97	138
IBM 3090/180S VF (1 proc, 15 ns)	VS Fortran 2.3.0	16	92	133
Fujitsu VP-100	Fortran 77	16		267
Amdahl 500	77/VP V10L20	16	133	142
Hitachi M680H/vector	Fort 77 E2 V04-0I	16		
SGI Crimson(1 proc 50 MHz R4000)	-O2 -mips2 -G 8192	16	32	50
SGI 4D/380(8 proc) 33MHz	f77 -O2 -mp	16	60	106
SGI Indigo2 Extreme(R4000/100MHz)	-O2 -mips2 -G 8192	15		
FPS Model 511	F77 4.2	15	56	67
Hitachi M680H	Fort 77 E2 V04-0I	15		
IBM RISC Sys/6000-930 (25 MHz)	v2.2.1 xlf -O -P -Wp,-ea478	15	42	50
IBM RISC Sys/6000-530 (25 MHz)	v2.2.1 xlf -O -P -Wp,-ea478	15	42	50
IBM RISC Sys/6000-340 (33 MHz)	v2.2.1 xlf -O -P -Wp,-ea478	15	49	66
IBM ES/9000-511 (1 proc 11ns)	VAST-2/VS Fortran V2R5	15		
Kendall Square (32 proc)			513	1280
Kendall Square (16 proc)			307	640
Kendall Square (8 proc)			146	320
Kendall Square (4 proc)			47	160
Kendall Square (1 proc)	ksrf77 -O2 -r8 -inline_auto	15	31	40

Table A.1 Performance in solving a system of linear equations (continued).

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretical Peak" Mflop/s
NAS AS/EX 60	Fortran	15		40
SGI 4D/440(4 proc) 40MHz	f77 -O2 -mp	15	42	64
Siemens H120F	Fortran 77	15		
Cydrome CYDRA 5	Fortran 77 Rel 2.4.1	14		25
Fujitsu VP-50	Fortran 77	14		133
IBM ES/9000 Model 190 VF(15 ns)	VAST-2/VS Fortran V2R4	14	60	133
IBM 3090/180E VF	VS 2.1.1 opt=3	13	71	116
SGI 4D/340(4 proc) 33MHz	f77 -O2 -mp	13	36	53
CDC CYBER 990E	FTN V2 VL=HIGH	12		
CRAY-1S (12.5 ns, 1983 run)	CFT 1.12	12	110	160
IBM 3090/180 VF	VS Fortran V2	12	65	108
IBM RISC Sys/6000-520H(25 MHz)	v2.2.1 xlf -O -P -Wp,-ea478	12	37	50
IBM RISC Sys/6000-320H(25 MHz)	v2.2.1 xlf -O -P -Wp,-ea478	12	37	50
Stardent 3040	3.0 -inline -nmax=300	12	77	128
Stardent 3030	3.0 -inline -nmax=300	12	63	96
Stardent 2040 (Stellar GS2000)	f77 -O3 -is R2.1	12		40
Stardent 1040 (Stellar GS1000)	f77 -O3 -is -re R2.0	12		40
CDC 4680InfoServer (60 MHz)	f77 2.20 -O3 -mips2 -Wb,-r6000	11		
CRAY S-MP/MCP101 (1 proc. 25 ns)	MCP Release 2.2	11	31	40
FPS 510S MCP101 (1 proc. 25 ns)	pgf77 -O4	11	30	40
IBM ES/9000 Model 340	VAST-2/VS Fortran V2R4	11		
IBM ES/9000-411 (1 proc 11ns)	VAST-2/VS Fortran V2R5	11		
Meiko Comp. Surface (32 proc)			210	1280
Meiko Comp. Surface (16 proc)			187	640
Meiko Comp. Surface (8 proc)			147	320
Meiko Comp. Surface (4 proc)			98	160
Meiko Comp. Surface (2 proc)	-O4 -Mvect=smallvect		58	80
Meiko Comp. Surface (1 proc)	-Minline=daxpy	11	31	40
Stardent 3020	3.0 -inline -nmax=300	11	46	64
Sperry 1100/90 ext w/ISP	UCS level 2	11		
Multiflow TRACE 7/300	Fortran 2.2.1	11	22	31
Alliant FX/2800-200 (2 proc)	fortran 1.1.27 -O -inline	10	53	80
Alliant FX/80 (8 proc.)	-O -DAS -inline	10	69	188
IBM 3090/180J	VS Fortran V2R3	10		
MIPS RC6280 (60.0MHz)	f77 2.20 -O	10	16	24
MIPS RC6260 (60.0MHz)	f77 2.20 -O	10	16	24
Multiflow TRACE 14/200	Fortran 1.7	10		31
Stardent 3010	3.0 -inline -nmax=300	10	25	32
Stardent 1540 (Ardent Titan-4)			47	64
Stardent 1530 (Ardent Titan-3)			37	48
Stardent 1520 (Ardent Titan-2)	f77 1.0 -O3 -inline	10	25	32
SGI 4D/240(4 proc) 25MHz	f77 -O2 -mp	9.8	28	40
Intel iPSC/Delta (512 proc)			446	20480
Intel iPSC/Delta (256 proc)			418	10240
Intel iPSC/Delta (128 proc)			393	5120
Intel iPSC/Delta (64 proc)			352	2560

Table A.1 Performance in solving a system of linear equations (continued).

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoret Peak" M
Intel iPSC/Delta (32 proc)			304	1280
Intel iPSC/Delta (16 proc)			231	640
Intel iPSC/Delta (8 proc)			163	320
Intel iPSC/Delta (4 proc)			100	160
Intel iPSC/Delta (2 proc)	if77 -O3 -Mvect=smallvect		58	80
Intel iPSC/Delta (1 proc)	-Minline=daxpy -Knoieee	9.7	34	40
Intel iPSC/860 d7 (128 proc)			219	5120
Intel iPSC/860 d6 (64 proc)			208	2560
Intel iPSC/860 d5 (32 proc)			167	1280
Intel iPSC/860 d4 (16 proc)			131	640
Intel iPSC/860 d3 (8 proc)			103	320
Intel iPSC/860 d2 (4 proc)			75	160
Intel iPSC/860 d1 (2 proc)	if77 -O3 -Mvect=smallvect		52	80
Intel iPSC/860 d0 (1 proc)	-Minline=daxpy -Knoieee	9.7	34	40
IBM 3090/180S	VS Fortran 2.3.0	9.6	92	133
Alliant FX/80 (7 proc.)	-O -DAS -inline	9.5	63	165
CDC CYBER 4680	f77 2.11.2 o2	9.4		
IBM Power Vis. Sys. (32 proc.)			310	1280
IBM Power Vis. Sys. (1 proc.)	-O4 -Mvect=smallvect:201 -Minline=daxpy	9.3		
NAS AS/EX 50	Fortran	9.3		28
Sun SPARCsystem 10/30 36MHz	f77 -O4 -cg89 -libmil -native	9.3		
SGI 4D/420(2 proc) 40MHz	f77 -O2 -mp	9.3	23	32
IBM RISC Sys/6000-520 (20 MHz)	v2.2.1 xlf -O -P -Wp,-ea478	9	29	40
IBM RISC Sys/6000-320 (20 MHz)	v2.2.1 xlf -O -P -Wp,-ea478	9	29	40
IBM ES/9000-180 VF(15 ns)	VAST-2/VS Fortran V2R4	8.9	48	133
Solbourne 6/904 (Viking sparc)	f77 -O3 -cg89 -dalign	8.9		
IBM RISC Sys/6000-230 (45 MHz)	v2.3.0 xlf -O -P -Wp,-ea478	8.8	19	90
DEC VAXvector 6000/520 (2 proc)	Fortran HPO V1.2	8.8	51	90
Comparex 8/92 (Fujitsu M382)	VS/FORTRAN 2.4.0	8.7		
DEC VAXstation 4000-90	V 5.2	8.7		
IBM ES/9000-311 (1 proc 11ns)	VAST-2/VS Fortran V2R5	8.6		
IBM ES/9000 Model 320	VAST-2/VS Fortran V2R4	8.5		
NAS AS/9160	VAST/VS 1.4.1 opt=3	8.3		
Alliant FX/80 (5 proc.)	-O -DAS -inline	8.1	49	118
IBM ES/9000 Model 260	VAST-2/VS Fortran V2R4	8.0		
SCS-40	CFT 1.13	8.0	17	45
SGI 4D/320(2 proc) 33MHz	f77 -O2 -mp	8.0	20	26
IBM ES/9000 Model 210	VAST-2/VS Fortran V2R4	7.7		
IBM ES/9000 Model 320	VS/FORTRAN V2R4	7.6		
IBM 3090/120E VF	VS 2.1.1 opt=3	7.5	54	108
IBM 3090/180E	VS 2.1.1 opt=3	7.4	71	116
Siemens 7890F	Fortran 77 V10.3	7.2		
CONVEX C-130	Fortran 4.0	7.2	31	36
Alliant FX/80 (4 proc.)	-O -DAS -inline	7.2	33	94
DEC VAXvector 6000/510 (1 proc)	Fortran HPO V1.2	7.0	28	45
Stardent 1510 (Ardent Titan-1)	f77 1.0 -O2 -inline	6.9	13	16

Table A.1 Performance in solving a system of linear equations (continued).

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretical Peak" Mflop/s
IBM RISC Sys/6000-M20 (33 MHz)	v2.3.0 xlf -O -P -Wp,-ea478	6.6	14	66
IBM RISC Sys/6000-M2A (33 MHz)	v2.3.0 xlf -O -P -Wp,-ea478	6.6	14	66
IBM ES/9000 Model 190	VAST-2/VS Fortran V2R4	6.6		133
IBM 3090/180	VS opt=3	6.8	65	108
Alliant FX/40 (4 proc.)	-O -DAS -inline	6.7	33	94
CONVEX C-120	fc 5.1	6.5	17	20
IBM RISC Sys/6000-220 (33 MHz)	v2.2.1 xlf -O -P -Wp,ea478	6.5	14	66
Alliant FX/4 (4 proc.)	-O -DAS -inline	6.4	21	47
Fujitsu M-380	Fortran 77, opt=3	6.3		
DEC VAX 6620	V5.5	6.2		
Alliant FX/2800-200 (1 proc)	fortran 1.1.27 -O -inline	6.4	28	40
Multiflow TRACE 7/200	Fortran 1.4	6.0		15
SGI 4D/420(1 proc) 40MHz	f77 -O2	6.0	12	16
Siemens 7890G	Fortran 77 V10.3 opt=4	5.9		
IBM 3090/150E	VS 2.1.1 opt=3	5.9	64	112
FPS-264 (M64/60)	F02 APFTN64 OPT=4	5.9	34	38
Alliant FX/80 (3 proc.)	-O -DAS -inline	5.9	32	71
SGI 4D/220(2 proc) 25MHz	f77 -O2 -mp	5.9	15	20
Apollo DN10000	f77,10.7	5.8		
Alliant FX/40 (3 proc.)	-O -DAS -inline	5.6	27	71
DEC 5900 RISC	Ultrix 4.1	5.3		
DEC 5000/240	Ultrix	5.3		
Alliant FX/4 (3 proc.)	-O -DAS -inline	5.1	17	35
CDC 4330-300 (33 MHz)	f77 2.20 -O3	5.1		
VAXstation 4000-90	DEC FORTRAN V5.2	5.1		
DEC VAX 6000/610 (1 proc)	VMS V5.2	5.0		
Intel iPSC/2 d4/VX (16 proc)			39	
Intel iPSC/2 d5/VX (32 proc)			52	
SGI 4D/310(1 proc) 33MHz	f77 -O2	5.0	10	13
Honeywell DPS90	ES F77V 1.0	5.0		
Siemens 7890D	Fortran 77 V10.3	5.0		
IBM ES/9000 Model 180 (15 ns)	VAST-2/VS Fortran V2R4	4.9		
CDC CYBER 875	FTN 5 opt=3	4.8		
Number Smasher i860 40MHz	-on -OLM -fdiv -inline	4.7		40
CDC CYBER 176	FTN 5.1 opt=2	4.6		
MIPS RC3360 (33.3MHz)	f77 2.20 -O	4.5	11	13
Alliant FX/80 (2 proc.)	-O -DAS -inline	4.4	22	47
Alliant FX/40 (2 proc.)	-O -DAS -inline	4.3	19	47
NAS AS/EX 30	VS 1.4.1 opt=3	4.3		
SGI 4D/35	f77 -O3	4.3		
SUN 4/600 MP	f77 1.4 -O3 -cg89 -dalign	4.3		
SUN SPARCstation IPX	f77 1.4 -O3 -cg89 -dalign	4.1		
SUN 4/50 IPX	f77 1.4 -O3 -cg89 -dalign	4.1		
CDC CYBER 4360	f77 2.11.2 o2	4.0		
SUN SPARCstation 2	f77 1.4 -O3 -cg89 -dalign	4.0		
Amdahl 5860 HSFPF	H enhanced opt=3	3.9		

Table A.1 Performance in solving a system of linear equations (continued).

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretical Peak" Mflop/s
MIPS M/2000 (25.0MHz)	f77 2.20 -O	3.9	7.9	10
MIPS RC3260 (25.0MHz)	f77 2.20 -O	3.9	7.9	10
Alliant FX/4 (2 proc.)	-O -DAS -inline	3.8	12	24
SGI 4D/210(1 proc) 25MHz	f77 -O2	3.9	7.8	10
Amdahl 5860 HSFPF	VS opt=3	3.8		
CDC 4320	f77 2.20 opt=02	3.7		
DEC station 5000/200 (25 Mhz)	MIPS f77 2.0	3.7		
MIPS RS3230 (25.0MHz)	f77 2.20 -O	3.7	7.8	10
DEC VAXvector 6000/420 (2 proc)	Fortran HPO V1.0		43	90
DEC VAXvector 6000/410 (1 proc)	Fortran HPO V1.0	3.6	24	45
SUN 4/490	4.1.1 f77 -O3	3.6		
CDC 4330	f77 2.20 opt=02	3.5		
NAS 8093 w/HSA	VS 1.4.0 opt=3	3.5		
CDC 7600	FTN	3.3		
CDC CYBER 960-31	NOS/VE 1.3.1 FTN 1.6	3.1		
Gould NP1	Fortran	3.1		
IBM 3090/120E	VS 2.1.1 opt=3	3.1	54	108
MIPS RC3240 (25.0MHz)	f77 2.20 -O	3.1	7.1	10
CDC CYBER 4340	f77 2.11.2 o2	3.0		
CONVEX C-1/XP	Fortran 2.0	3.0		20
DEC VAX 6540	VMS 5.4-2	3.0		
FPS-264/20 (M64/50)	F02 APFTN64 OPT=4	3.0	17	
Harris Nighthawk 4802 (88100)	f77	3.0		
CONVEX C-1/XL	Fortran 1.6	2.9		20
IBM ES/9000 Model 150	VS Fortran V2R4	2.9		
NAS AS/EX 25	VS 1.4.1 opt=3	2.9		
Solbourne 5/602	f77 (Sun) 1.2 -O3 -dalign	2.9		
SUN 4/330	f77 1.4 -O3 -dalign	2.7		
SUN 4/370	f77 1.3.1 -O3 -cg89 -dalign	2.7		
CDC CYBER 760	FTN 5, opt=3	2.6		
CyberPlus	CPFTN 1.1-07	2.6		
IBM 370/195	H enhanced opt=3	2.5		
SUN 4/330 SparcServer	f77 1.2, -O3 -dalign	2.5		
Alliant FX/80 (1 proc.)	-O -DAS -inline	2.4	12	24
Alliant FX/40 (1 proc.)	-O -DAS -inline	2.4	10	24
Gateway 2000 66 MHz 80486-DX2	F77L-EM32 5.01 /4 /Z1	2.4		
HP-APOLLO 9000/425e (68040)	f77 -O4 rev 10.3.5	2.3		
NAS AS/EX 20	VS 1.4.1 opt=3	2.2		
Fujitsu AP1000 (512 proc.)			610	2844
Fujitsu AP1000 (256 proc.)			333	1422
Fujitsu AP1000 (128 proc.)			193	711
Fujitsu AP1000 (64 proc.)			100	356
Fujitsu AP1000 (1 proc.)	SUN f77 1.3.1 -O3 -dalign	2.2	1.7	5.6
HP-APOLLO 9000/425t (68040)	f77 -O4 rev 10.3.4	2.2		
Alliant FX/4 (1 proc.)	-O -DAS -inline	2.1	6.3	12
CDC CYBER 175	FTN 5 opt=2	2.1		

Table A.1 Performance in solving a system of linear equations (continued).

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretical Peak" Mflop/s
CDC CYBER 180-860	NOS/VE OPT=HIGH	2.1		
FPS-M64/30	APFTN464 OPT=4	2.1	10	
IBM ES/9000 Model 130	VS Fortran V2R4	2.1		
IBM 3081 K (1 proc.)	H enhanced opt=3	2.1		
MIPS M120-5	UMIPS v.3 3.0 f771.31 -O	2.1	3.6	8.3
MIPS M/120 (16.7MHz)	f77 2.20 -O	2.1	4.8	6.7
Prism" 486-50 (50 MHz)	Salford v2.69 /optimise	2.1		
Tadpole SPARCbook (25 MHz)	f77 -O	2.1		
Apple Macintosh QUADRA 950	Absoft -w -v -O -f -s -N40	2.0		
CDC 7600	Local	2.0		
IBM 3081 K (1 proc.)	VS opt=3	2.0		
Culler PSC	CSD Fortran 3.21	2.0		5
FPS M64/35	APFTN464	2.0		
HP 425T (68040)		1.9		
CDC CYBER 175	FTN 5 opt=1	1.8		
HP 9000 Series 835	2.1 fc -O	1.8		
Sperry 1100/90	FTN opt=ZEO	1.8		
SUN SPARCstation 1+	f77 1.4 -O3 -cg89 -dalign	1.8		
ELXSI 6420 (5 proc.)			6.4	
ELXSI 6420 (3 proc.)			4.0	
ELXSI 6420 (2 proc.)			2.7	
ELXSI 6420 (1 proc.)	EMBOS 6.3 +opt+inline+vector	1.7	1.4	
FPS-164/364 (M64/40)	F02 APFTN64 OPT=4	1.7	9	
Honeywell DPS 8/88	FR7X	1.7		
IBM 3033	H enhanced opt=3	1.7		
IBM 3033	VS opt=3	1.7		
IBM 3081 D	VS opt=3	1.7		
MIPS RS2030 (16.7MHz)	f77 2.20 -O	1.7	4.7	6.7
Sperry 1100/90 ext	UFTN	1.7		
HP 9000 Series 850 w/fp	2.0 fc -O	1.6		
Amdahl 470 V/8	H enhanced opt=3	1.6		
CDC CYBER 170-750	FTN 5.1, opt=3	1.6		
CDC CYBER 180-850	NOS/VE OPT=HIGH	1.6		
DECstation 3100	V3.0/V1.31 -O	1.6		
DEC 5400	f77 -O3	1.6		
Amdahl 470 V/8	VS opt=3	1.5		
DEC VAXstation 4000-60	V 5.2	1.5		
MIPS M/1000 (15.0MHz)	f77 2.20 -O	1.5	3.7	6
NAS 8093	VS 1.4.0 opt=3	1.5		
Siemens 7570-P	For1 1.6A	1.5		
AIR 486/33 m-board, 256K cache	Lahey F77L3, v5.0 /Z1	1.4		
Apple Mac Quadra 700	Absoft -w -v -O -f -s -N40	1.4		
Compaq Deskpro 486/33l-120 w/487	Microway NDPF487 -O -OL -on	1.4		
NeXTCube	2.0 gcc 1.36 -O	1.4		
SUN SPARCstation 1	f77 1.3.1 -O3 -cg89 -dalign	1.4		
IBM 4381-23	VS Fortran 2.1.1 opt=3	1.3		

Table A.1 Performance in solving a system of linear equations (continued).

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretical Peak" Mflop/s
Compaq Deskpro 486/33l-120 w/487	Salford FTN77/ optimized	1.3		
Compaq Deskpro 486/33l-120 w/487	Watcom WFC386P /OL /OT	1.3		
AIR 486/33 m-board, 256K cache	Lahey F77L3, v5.0 /nZ1	1.2		
CDC 7600	CHAT, No opt	1.2		
DEC VAX 6000/460 (6 proc)			8.4	15
DEC VAX 6000/450 (5 proc)			7.1	13
DEC VAX 6000/440 (4 proc)			5.8	10
DEC VAX 6000/430 (3 proc)			4.4	7.6
DEC VAX 6000/420 (2 proc)			3.0	5.1
DEC VAX 6000/410 (1 proc)	VMS V5.2	1.2	1.5	2.6
IBM ES/9000 Model 120	VS Fortran V2R4	1.2		
MIPS M/800 (12.5MHz)	f77 1.31 -O	1.2		5
Prime P6350	f77 rev 20.2.b2 -opt	1.2		
IBM 4381 90E	VS Fortran 2.1.1 opt=3	1.2		
CSPI MAP-6430	Fortran 1.5.35	1.2		
IBM 4381-13	VS 1.4.0 opt=3	1.2		
IBM 370/168 Fast Mult	H Ext	1.2		
ELXSI 6420	Fortran 5.14 opt=10	1.2	1.4	
Amdahl 470 V/6	H opt=2	1.1		
Compaq Deskpro 486/33l-120 w/487	Lahey F77L3 /Z1	1.1		
SUN 4/260	f77 -O sys4-beta2	1.1	1.1	3.3
CDC CYBER 180-840	NOS/VE OPT=HIGH	.99		
DEC VAX 8800 (4 proc)			4.9	
DEC VAX 8800 (3 proc)			3.7	
DEC VAX 8800 (2 proc)			2.5	
DEC VAX 8550/8700/8800	VMS v4.5	.99	1.3	
Solbourne	f77 -O	.98		
IBM 4381-22	VS Fortran 2.1.1 opt=3	.97		
IBM 4381 MG2	VS Fortran opt=3	.96		
IBM 4381-12	VS Fortran 1.4.0 opt=3	.95		
ICL 3980 w/FPU	FORTRAN77 PLUS V10.02	.93		
IBM-486 33MHz	Microsoft 5.1	.94		
Siemens 7860E	Fortran 77 V10.3	.92		
Concurrent 3280XP	Fortran VII,Z 8.1	.87		
MIPS M800 w/R2010 FP	f77 1.10	.87		
Gould PN 9005	VTX/32 2.0 Fortran 77	.87		
VAXstation 3100-76	DEC FORTRAN V5.2	.85		
IBM 9370-90	VS Fortran 1.3.0 opt=3	.78		
nCUBE 2, 1024 proc			258	2409
nCUBE 2, 512 proc			204	1205
nCUBE 2, 256 proc			165	602
nCUBE 2, 128 proc			116	301
nCUBE 2, 64 proc			76.9	151
nCUBE 2, 32 proc			46.0	75
nCUBE 2, 16 proc			26.1	38
nCUBE 2, 8 proc			14.2	19

Table A.1 Performance in solving a system of linear equations (continued).

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretical Peak" Mflop/s
nCUBE 2, 4 proc			7.50	9.4
nCUBE 2, 2 proc			3.91	4.7
nCUBE 2, 1 proc	Fort77/ncc -O3	.78	2.02	2.35
IBM 370/165 Fast Mult	H Ext	.77		
Prime P9955II	f77 rev 20.2.b2 -opt	.72		
DEC VAX 8530	VMS v4.6	.73		
HP 9000 Series 850	2.0 fc -O	.71		
DEC VAX 8650	VMS v4.5	.70		
DEC VAX 8500	VMS v4.5	.65		
HP/Apollo DN4500 (68030 + FPA)		.60		
Mentor Graphics Computer	fortran	.60		
MIPS M/500 (8.3HHz)	f77 1.21 -O	.60		3.3
Data General MV/20000	f77	.59		
IBM 9377-80	VS Fortran 2.1.1 opt=3	.58		
Sperry 1100/80 w/SAM	FTN opt=ZEO	.58		
CDC CYBER 930-31	NOS/VE 1.2.2	.58		
Russian PS-2100	FORTRAN-PS	.57	1.6	
Harris H1200	VOS 4.1 opt g	.56		
HP/Apollo DN4500 (68030)		.55		
HP 9000 Series 825	2.0 fc -O	.53		
HP-APOLLO 9000/400t (68030)	f77 -O4 rev 10.8(190)	.51		
Harris HCX-9	hf77 -O3	.50		
Pyramid 9810	OSx 4.0	.50		
HP 9000 Series 840	2.0 fc -O	.49		
DEC VAX 8600	VMS v4.5	.48		
Harris HCX-7 w/fpp	f77 1.0	.48		
CDC 6600	FTN 4.6 opt=2	.48		
CDC CYBER 170-835	FTN 5 opt=2	.47		
CCI Power 6/32 w/fpa	UNIX 4.2 bsd f77	.47		
IBM 4381-21	VS Fortran 2.1.1 opt=3	.47		
Sperry 7000	4.2	.47		
Gould PN9000	UNIX	.47		
SUN-3/260 + FPA	3.2 f77 -O -ffpa	.46		
IBM 4381 MG1	VS Fortran opt=3	.46		
DEC VAX 6210 (1 proc.)	VMS v5.0	.46		
CDC CYBER 170-835	FTN 5 opt=1	.44		
HP 9000 Series 840	HP-UX 14.3	.43		
IBM RT 135	AIX-2.2	.42		
Harris H1000	VOS 3.3 opt g	.41		
microVAX 3200/3500/3600	VMS v4.6	.41		
Apple Macintosh IIfx	A/UX 2.0 f77	.41		
Apollo DN5xxT FPX	DOMAIN/IX SR9.7 opt 4	.40		
microVAX 3200/3500/3600	ULTRIX 2.2/VFU	.40		
IBM 9370-60	VS Fortran 1.4.0 opt=3	.40		
Sun-3/160 + FPA	3.2 f77 -O -ffpa	.40		
Prime P9755	f77 rev 20.2.b2 -opt	.40		

Table A.1 Performance in solving a system of linear equations (continued).

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretical Peak" Mflop/s
Ridge 3200 Model 90	ROS/rf	.39		
IBM 4381-11	VS Fortran 1.4.0 opt=3	.39		
Gould 32/9705 mult acc	fort77+ 4.3	.39		
NORSK DATA ND-570/2	Fortran-500-E	.38		
Sperry 1100/80	FTN opt=ZEO	.38		
Apple Mac IIfx	Absoft -w -v -O -f -s	.37		
CDC CYBER 930-11	NOS/VE OPT=High	.37		
CSA w/T800C-20	Fortran 3L	.37		
Inmos T800 (20 MHz)	Fortran 3L -:o0	.37		
Sequent Symmetry (386 w/fpa)	Fortran -fpa -O3	.37		
CONCEPT 32/8750	UTX/32	.36		
Celerity C1230	UNIX 4.2 bsd f77	.36		
IBM RT PC 6150/115 fpa2	f77	.36		
IBM 9373-30	VS Fortran 2.1.1 opt=3	.36		
CDC 6600	RUN	.36		
Gould PN9080	UTX/32	.35		
Prime 9950	F77 19.4.2	.34		
Opus Series 300pm 30 MHz	UNIX Greenhills	.33		
Masscomp MC5600 w/fpa	f77 v1.2 -O3 rtv v3.1	.33		
Data General MV/10000	f77 opt level 2	.30		
IBM 4361 MG5	VS Fortran opt=3	.30		
DATEK 80386-33 /w 64KB Cache	MS Fortran 5.0 -Ox -AH -G2	.27		
Inmos T800 (20 MHz)	Fortran 3L -:o1	.26		
Apollo DN3500	FTN -CPU 3000 -opt 4	.25		
IRIS 2400 Turbo/FPA	f77	.24		
CDC CYBER 180-830	NOS/VE OPT=HIGH	.24		
Apple Macintosh PowerBook 170	Absoft -w -v -O -f -s	.23		
Gould PN 6005	VTX/32 2.0 Fortran 77	.23		
Harris 800	Fortran 77	.23		
IBM 370/158	H opt=3	.23		
IBM 370/158	VS Fortran opt=3	.22		
NORSK DATA ND-560	Fortran-500	.22		
Celerity C1200	UNIX 4.2 bsd f77	.21		
Honeywell DPS 8/70	FR7X	21		
Denelcor HEP	f77 UPX	.21		
VAX 11/785 FPA	VMS v4.5	.20		
CDC CYBER 170-720	FTN 5, opt=2	.20		
Apple Macintosh IIsi	Absoft -w -v -O -f -s	.19		
Itel AS/5 mod 3	H	.19		
NORSK DATA ND-500	Fortran-500-E	.19		
KONTRON KSM/386	UNIX SVS F77 2.8	19		
Sun 386i/250 25 MHz	SunOS 4.0; Sun 1.1 -O	.19		
CDC CYBER 170-825	FTN 5, opt=2	.19		
IBM 4341 MG10	VS Fortran opt=3	.19		
Apollo DN2500		.18		
Pyramid 98xe	OSx 4.0	.18		

Table A.1 Performance in solving a system of linear equations (continued).

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretical Peak" Mflop/s
IBM 9370-40	VS Fortran 1.4.0 opt=3	.18		
VAX 11/785 FPA	UNIX 4.2 bsd f77	.18		
DEC VAX 8250/8350 (UP)	VMS v4.6	.18		
CDC CYBER 170-825	FTN 5, opt=1	.18		
Ridge Server/RT EFP	ROS/rf	.18		
CDC CYBER 170-720	FTN 5, opt=1	.17		
Ridge 32/130	OS 3.3/RISC	.17		
PC Craft 2400/25MHz w/80387	PLI Fortran 2.09	.17		
Concurrent 3252	OS 6.2.4 fortran z	.17		
Tandy 5000 MC 20 MHz	LPI Fortran 3.0	.17		
Tektronix 4315 w/68882	UTEK f77	.17		
CDC CYBER 180-810	NOS/VE OPT=HIGH	.17		
Prime P2755	f77 rev 20.2.b2 -opt	.17		
Apple Macintosh IIx	A/UX 2.0 f77	.16		
Concurrent 3242	OS 32 v7.2 f77	.16		
Compaq 386/20 w/387	Microsoft Forrtan 4.1	.16		
Apple Macintosh IIcx	Absoft -w -v -O -f -s	.15		
Apple Macintosh IIx	Absoft -w -v -O -f -s	.15		
DEC VAX 8200/8300	VMS v4.5	.15		
IBM PS/2-70 (20 MHz)	AIX 1.2	.15		
Apple Macintosh SE 30	Absoft -w -v -O -f -s	.14		
Apollo DN4000	DOMAIN/IX SR9.7 opt 4	.14		
ICL 2988	f77 OPT=2	.14		
IBM 9370-20	VS Fortran 1.4.0 opt=3	.14		
HP Vectra RS/20C 20 MHz	LPI Fortran 3.0	.14		
VAX 11/780 FPA	VMS v4.5	.14		
Compaq 386/20 w/387	RM/Forrtan 2.43	.13		
microVAX II	VMS v4.5	.13		
Prime P2450	f77 rev 20.2.b2 -opt	.13		
Apple Macintosh IIsi	Fortran	.12		
Apple Mac II/16 Mhz/25 Mhz 68882	Absoft 2.4 -w -v -O -f -s	.12		
CDC 6500	FUN	.12		
CONCEPT 32/6750	UTX/32	.12		
IBM PS/2-70 (16 MHz)	AIX 1.2	.12		
IBM RT w/68881	f77	.12		
VAX 11/750 FPA	VMS v4.1	.12		
micro VAX II	ULTRIX 2.2/VFU	.12		
Prime 750	Primos f77 v19.1	.11		
Sun 3/260, 20 MHz 68881	3.2 f77 -O -f68881	.11		
ENCORE Multimax NS32332	f77	.11		
Tektronix 4315 w/68881	UTEK f77	.11		
HP 9000 Series 350	HP-UX, f77 5.2	.11		
Definicon DSI-780	SVS Fortran (MSDOS)	.11		
Concurrent 3230	OS 6.2.2 fortran 5.2	.11		
VAX 11/780 FPA	UNIX 4.3 BSD f77 -O	.11		
Sun 3/160, 16.7 MHz 68881	3.2 f77 -O -f68881	.10		

Table A.1 Performance in solving a system of linear equations (continued).

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretical Peak" Mflop/s
NCUBE (1 proc. 8 MHz)	Fortran	.10		
Apple Mac SE/30	ABSOFT 2.4	.10		
Apollo DN590	DOMAIN/IX SR9.7 opt 4	.099		
Masscomp MC5600 68881	f77 v1.2 -O3 rtv v3.1	.099		
VAX 11/750 FPA	UNIX 4.2 bsd f77	.096		
Prime 850	Primos	.095		
Sperry 1100/60	FTN opt=ZEO	.093		
Pyramid 90X FPA	UNIX 4.2 bsd f77	.088		
Apple Mac II/16 Mhz/25 Mhz 68882	Absoft 2.4	.087		
SUN-3/50, 16.7 MHz 68881	3.2 f77 -O -f68881	.087		
HP 9000 Series 330	HP-UX, f77 5.2	.087		
Apple Macintosh II	Absoft -w -v -O -f -s	.083		
microVAX II	f77 Ultrix 1.1	.082		
Apple Mac SE + 20 MHz 68881	ABSOFT 2.4	.082		
Ridge 32/110	ROS 3.3/RISC	.081		
Data General MV/8000	f77 opt level 2	.078		
Apple MAC II w/882		.078		
Prime P2350	f77 rev 20.2.b2 -opt	.077		
Apple Mac/Levco Prodigy 4	ABSOFT MacFort 020	.076		
Apple Mac II w/68020	FORTRAN	.074		
HP 9000 Series 320	HP-UX, f77 5.2	.073		
Apollo DN3000	DOMAIN/IX SR9.7 opt 4	.071		
Apollo DN460/660	AEGIS 8.0 FTN	.069		
Masscomp MC500 w/FPP	3.1 Fortran	.061		
Harris HS-20 w/FPP	Fortran 77 3.1	.061		
Sequent Balance 8000	DYNIX Fortran 2.4.4	.059		
Definicon DSI-32/10	Greenhills f77 (MSDOS)	.057		
VAX 11/750	VMS v4.1	.057		
Encore Multimax	f77	.055		
HP 9000 Series 500	Fortran 1.7	.043		
Opus 32.32	UNIX, f77 4.2 bsd	.043		
ATT 3B20 FP	UNIX V 2.0/4	.040		
Acorn Cambridge	fortran	.039		
IBM 4331 MG2	H opt=3	.038		
Burroughs B6800	Fortran 77 ver 34	.037		
VAX 11/725 FPA	VMS v4.1	.037		
Masscomp MCS-541 w/FPB	Fortran 3.1	.037		
IBM RT PC Model 20	f77	.036		
VAX 11/730 FPA	VMS	.036		
Prime 2250	Fortran 77	.034		
IBM PC-AT/370	VS Fortran opt=3	.033		
IBM PC-XT/370	H opt=3	.031		
VAX 11/750	UNIX 4.2 bsd f77	.029		
Apollo DN320	AEGIS 8.0 FTN	.028		
Sun 2/50 + SKY FFP	f77 -O -fsky 3.0	.027		
Ametek S14/32 (1 node)	RM Fortran 2.11	.026		

Table A.1 Performance in solving a system of linear equations (continued).

Computer	"LINPACK Benchmark" n = 100 OS/Compiler	Mflop/s	"TPP" Best Effort n=1000, Mflop/s	"Theoretical Peak" Mflop/s
Apollo DN550 FPA	AEGIS 8.0 FTN	.025		
AMSTRAC 1512 8086/8087 9.54 MHz	MS-Fortran 4.0 -Ox -AH	.022		
microVAX I	VMS	.023		
Canaan	VS	.021		
Chas. River Data 6835+SKY	SVS Fortran 77	.018		
Apollo DN 420 PEB	AEGIS 7+ FTN	.017		
IBM AT w/80287	PROFORT 1.0	.012		
IBM PC w/8087	PROFORT 1.0	.012		
Cadtrak DS1/8087	Intel Fortran 77	.011		
Apple Mac Classic II/16 MHz68030	Absoft 2.4	.011		
IBM PC/AT w/80287	Microsoft 3.2	.0091		
Chas. River Data 6835	SVS Fortran 77	.0088		
Apollo DN300	AEGIS 8.0 FTN	.0071		
Masscomp MC500	3.1 Fortran	.0070		
IBM PC w/8087	Microsoft 3.2	.0069		
Apple Mac II	ABSOFT 2.4	.0064		
HP 9000 Series 200	HP-UX	.0062		
Sun 2/50	f77 -O -fsoft 3.0	.0055		
Atari ST	ABSOFT AC/Fortran v2.2	.0051		
Apple Macintosh	ABSOFT 2.0b	.0038		

Table A.1 Performance in solving a system of linear equations (continued).

Computer	1000 x 1000 Problem with Parallel Processing				
	Time uniprocessor	no. of processors	Time multiprocessors	Speedup	Efficiency
NEC SX-3/*4R	0.128	4	.0442	2.91	.73
NEC SX-3/*4R	0.128	2	.0707	1.82	.91
NEC SX-3/*4	0.148	4	.0498	2.98	.74
NEC SX-3/*4	0.148	2	.0821	1.81	.90
NEC SX-3/*2R	0.243	4	.0747	3.25	.81
NEC SX-3/*2R	0.243	2	.1307	1.86	.93
NEC SX-3/*2	0.293	4	.0863	3.40	.85
NEC SX-3/*2	0.293	2	.1518	1.93	.96
NEC SX-3/*1R	0.472	4	.139	3.40	.85
NEC SX-3/*1R	0.472	2	.255	1.85	.93
CRAY Y-MP C90	0.765	16	.0688	11.12	.69
CRAY Y-MP C90	0.765	14	.0751	10.19	.73
CRAY Y-MP C90	0.765	12	.0831	9.21	.77
CRAY Y-MP C90	0.765	10	.0951	8.04	.80
CRAY Y-MP C90	0.765	8	.112	6.85	.86
CRAY Y-MP C90	0.765	6	.145	5.28	.88
CRAY Y-MP C90	0.765	4	.204	3.74	.94
CRAY Y-MP C90	0.765	2	.391	1.96	.98
NEC SX-3	0.149	2	.0820	1.82	.91
CRAY Y-MP/8	2.17	8	.312	6.96	.87
CRAY Y-MP/8	2.17	4	.577	3.76	.94
CRAY Y-MP/8	2.17	3	.754	2.88	.96
CRAY Y-MP/8	2.17	2	1.11	1.96	.98
CRAY Y-MP/98	2.17	8	.386	5.65	.71
CRAY Y-MP/98	2.17	4	.600	3.63	.91
CRAY Y-MP/98	2.17	2	1.12	1.94	.97
CRAY 2S	1.76	4	.476	3.66	.91
CRAY 2S	1.76	3	.617	2.82	.94
CRAY 2S	1.76	2	.902	1.93	.96
CRAY X-MP/4	3.10	4	.813	3.78	.94
CRAY X-MP/4	3.10	3	1.07	2.87	.96
CRAY X-MP/4	3.10	2	1.57	1.96	.98
CONVEX C3880	5.90	8	.841	7.02	.88
CONVEX C3840	5.90	4	1.58	3.74	.94
CONVEX C3830	5.90	3	2.05	2.88	.96
CONVEX C3820	5.90	2	3.01	1.96	.98
CRAY S-MP/MCP784	21.4	84	0.902	23.7	.28
CRAY S-MP/MCP756	21.4	56	0.986	21.7	.39
CRAY S-MP/MCP728	21.4	28	1.32	16.2	.58
CRAY S-MP/MCP707	21.4	7	3.46	6.19	.88
Fujitsu AP1000	160	512	1.10	147	.29
Fujitsu AP1000	160	256	1.50	108	.42
Fujitsu AP1000	160	128	2.42	66.5	.52
Fujitsu AP1000	160	64	3.51	46.0	.72

Table A.2 A look at parallel processing.

Computer	1000 x 1000 Problem with Parallel Processing				
	Time uniprocessor	no. of processors	Time multiprocessors	Speedup	Efficiency
Fujitsu AP1000	160	32	6.71	24.0	.75
Fujitsu AP1000	160	16	11.5	13.9	.87
Fujitsu AP1000	160	8	22.6	7.12	.89
Fujitsu AP1000	160	4	41.3	3.90	.97
Fujitsu AP1000	160	2	81.4	1.96	.98
IBM 3090/600S VF	7.27	6	1.29	5.64	.94
IBM 3090/500S VF	7.27	5	1.52	4.78	.96
IBM 3090/400S VF	7.27	4	1.89	3.85	.96
IBM 3090/300S VF	7.27	3	2.46	2.96	.99
IBM 3090/280S VF	7.27	2	3.65	1.99	.99
IBM 3090/200S VF	7.27	2	3.64	1.99	.99
Intel Delta	22	512	1.5	14.7	.03
Intel Delta	22	256	1.6	13.8	.05
Intel Delta	22	128	1.7	12.9	.10
Intel Delta	22	64	1.9	11.5	.18
Intel Delta	22	32	2.2	10.0	.31
Intel Delta	22	16	2.9	7.59	.47
Intel Delta	22	8	4.1	5.37	.67
Intel Delta	22	4	6.7	3.28	.82
Intel Delta	22	2	11.6	1.90	.95
IBM 3090/600E VF	9.36	6	1.73	5.41	.90
IBM 3090/500E VF	9.36	5	2.02	4.63	.93
IBM 3090/400E VF	9.36	4	2.48	3.77	.94
IBM 3090/300E VF	9.36	3	3.21	2.92	.97
IBM 3090/200E VF	9.36	2	4.73	1.98	.99
Alliant FX/2800-200	22.9	14	2.06	11.1	.79
Alliant FX/2800-200	22.9	12	2.30	10.0	.83
Alliant FX/2800-200	22.9	10	2.68	8.54	.85
Alliant FX/2800-200	22.9	8	3.24	7.07	.88
Alliant FX/2800-200	22.9	4	6.07	3.77	.94
Alliant FX/2800-200	22.9	2	11.8	1.94	.97
IBM PVS	20.4	32	2.17	9.35	.29
IBM PVS	20.4	16	2.35	8.64	.54
IBM PVS	20.4	8	3.41	5.95	.74
IBM PVS	20.4	4	5.71	3.56	.89
IBM PVS	20.4	2	10.6	1.92	.96
nCUBE 2	331	1024	2.59	128	.12
nCUBE 2	331	512	3.29	101	.20
nCUBE 2	331	256	4.05	81.7	.32
nCUBE 2	331	128	5.74	57.7	.45
nCUBE 2	331	64	8.70	38.0	.59
nCUBE 2	331	32	14.5	22.8	.71
nCUBE 2	331	16	25.6	12.9	.81
nCUBE 2	331	8	46.9	7.04	.88
nCUBE 2	331	4	89.1	3.71	.93
nCUBE 2	331	2	171.	1.93	.97

Table A.2 A look at parallel processing (continued).

Computer	1000 x 1000 Problem with Parallel Processing Time uniprocessor	no. of processors	Time multiprocessors	Speedup	Efficiency
Intel iPSC/860	22	128	2.8	7.68	.06
Intel iPSC/860	22	64	3.2	6.72	.11
Intel iPSC/860	22	32	4.0	5.38	.17
Intel iPSC/860	22	16	5.1	4.22	.26
Intel iPSC/860	22	8	6.5	3.31	.41
Intel iPSC/860	22	4	8.9	2.42	.60
Intel iPSC/860	22	2	12.8	1.68	.84
Meiko Computing Surface (i860)	21.9	32	3.19	6.85	.21
Meiko Computing Surface (i860)	21.9	24	3.30	6.62	.28
Meiko Computing Surface (i860)	21.9	16	3.57	6.12	.38
Meiko Computing Surface (i860)	21.9	8	4.56	4.79	.60
Meiko Computing Surface (i860)	21.9	4	6.83	3.20	.80
Meiko Computing Surface (i860)	21.9	2	11.6	1.88	.94
CONVEX C3240	14.9	4	3.92	3.81	.95
CONVEX C3230	14.9	3	5.06	2.95	.98
CONVEX C3220	14.9	2	7.50	1.99	.99
CONVEX C-240	15	4	4.03	3.76	.94
CONVEX C-230	15	3	5.20	2.91	.97
CONVEX C-220	15	2	7.65	1.98	.99
Parsytec FT-400	1075	400	4.90	219.	.55
Parsytec FT-400	1075	256	6.59	163.	.64
Parsytec FT-400	1075	100	13.2	81.4	.81
Parsytec FT-400	1075	64	19.1	56.3	.88
Parsytec FT-400	1075	16	69.2	15.5	.97
FPS Model 522	12	2	6.36	1.89	.95
Suprenum S1C1	51	16	6.4	8.0	.50
Suprenum S1C1	51	14	7.1	7.2	.51
Suprenum S1C1	51	12	7.9	6.5	.54
Suprenum S1C1	51	10	8.9	5.8	.58
Suprenum S1C1	51	8	10.4	4.9	.61
Suprenum S1C1	51	6	13.1	3.9	.65
Suprenum S1C1	51	4	18.1	2.8	.70
Suprenum S1C1	51	2	33.4	1.5	.75
Alliant FX/800-200	24.2	4	7.09	3.41	.85
Alliant FX/800-200	24.2	2	12.7	1.91	.95
Alliant FX/80	57.7	8	9.64	5.99	.75
Alliant FX/80	57.7	7	10.6	5.44	.78
Alliant FX/80	57.7	6	11.8	4.89	.82
Alliant FX/80	57.7	5	13.6	4.24	.85
Alliant FX/80	57.7	4	16.2	3.56	.89
Alliant FX/80	57.7	3	20.7	2.79	.93
Alliant FX/80	57.7	2	29.8	1.94	.97
Stardent 1540 (Ardent Titan-4)	51.2	4	14.3	3.57	.89
Stardent 1530 (Ardent Titan-3)	51.2	3	18.3	2.80	.93
Stardent 1520 (Ardent Titan-2)	51.2	2	26.3	1.95	.97
SGI 4D/480 40 MHz	54.0	8	9.48	5.70	.71

Table A.2 A look at parallel processing (continued).

Computer	1000 x 1000 Problem with Parallel Processing				
	Time uniprocessor	no. of processors	Time multiprocessors	Speedup	Efficiency
SGI 4D/440 40 MHz	54.0	4	15.91	3.39	.85
SGI 4D/420 40 MHz	54.0	2	28.80	1.88	.94
SGI 4D/380 33 MHz	65.0	8	11.13	5.84	.73
SGI 4D/340 33 MHz	65.0	4	18.62	3.49	.87
SGI 4D/320 33 MHz	65.0	2	34.17	1.90	.95
Alliant FX/40	66.1	4	20.5	3.22	.81
Alliant FX/40	66.1	3	24.9	2.65	.88
Alliant FX/40	66.1	2	34.8	1.90	.95
SGI 4D/240 25 MHz	85.2	4	23.89	3.57	.89
SGI 4D/220 25 MHz	85.2	2	44.89	1.90	.95
Alliant FX/4	106	4	32.3	3.28	.82
Alliant FX/4	106	3	38.7	2.74	.91
Alliant FX/4	106	2	55.8	1.90	.95
DEC VAX 6000-460	439	6	80	5.5	.92
DEC VAX 6000-450	439	5	94	4.7	.94
DEC VAX 6000-440	439	4	114	3.8	.96
DEC VAX 6000-430	439	3	152	2.9	.96
DEC VAX 6000-420	439	2	222	1.9	.99
ELXSI 6420	475	5	104	4.57	.91
ELXSI 6420	475	3	167	2.84	.95
ELXSI 6420	475	2	245	1.94	.97
DEC VAX 6240	1295	4	332	3.90	.98
DEC VAX 6230	1295	3	439	2.95	.98
DEC VAX 6220	1295	2	654	1.98	.99
Sequent Balance 21000	11111	30	445	25.0	.83

Table A.2 A look at parallel processing (continued).

Computer (Full Precision)	Number of Processors	R_{max} Gflop/s	N_{max} order	$N_{1/2}$ order	R_{peak} Gflop/s
Thinking Machines CM-5	1024	59.7	52224	24064	131
Thinking Machines CM-5	512	30.4	36864	16384	66
NEC SX-3/44R (2.5 ns)	4	23.2	6400	830	26
NEC SX-3/44 (2.9 ns)	4	20.0	6144	832	22
Thinking Machines CM-5	256	15.1	26112	12032	33
Intel Delta (40 MHz)	512	13.9	25000	7500	20
CRAY Y-MP C90 (238.1 MHz 4.2 ns)	16	13.7	10000	650	15
NEC SX-3/42R (2.5 ns)	4	11.6	4352	516	13
NEC SX-3/24R (2.5 ns)	2	11.6	4352	492	13
Intel Delta (40 MHz)	384	10.2	20000	6000	15
NEC SX-3/24 (2.9 ns)	2	10.0	4352	500	11
NEC SX-3/42 (2.9 ns)	4	10.0	4608	640	11
Thinking Machines CM-200 (10 MHz)	2048	9.8	29696	11264	20
Thinking Machines CM-5	128	7.7	18432	8192	16
Intel Delta (40 MHz)	256	7.0	18000	5000	10
NEC SX-3/41R (2.5 ns)	4	5.8	3584	414	6.4
NEC SX-3/22R (2.5 ns)	2	5.8	3072	370	6.4
NEC SX-3/14R (2.5 ns)	1	5.8	2816	282	6.4
Intel Delta (40 MHz)	192	5.2	15000	4500	7.7
Thinking Machines CM-2 (7 MHz)	2048	5.2	26624	11000	14
NEC SX-3/22 (2.9 ns)	2	5.0	3072	384	5.5
NEC SX-3/14 (2.9 ns)	1	5.0	3072	384	5.5
Thinking Machines CM-200 (10 MHz)	1024	5.0	21504	8192	10
Alliant CAMPUS/800 (40 MHz)	192	4.8	17024	5768	7.7
Alliant CAMPUS/800 (40 MHz)	168	4.1	16016	5516	6.7
Thinking Machines CM-5	64	3.8	13056	6016	8
Intel Delta (40 MHz)	128	3.5	12500	3500	5
Alliant CAMPUS/800 (40 MHz)	144	3.5	15484	4956	5.8
Alliant CAMPUS/800 (40 MHz)	120	2.9	14000	4620	4.8
NEC SX-3/21R (2.5 ns)	2	2.9	2560	257	3.2
NEC SX-3/12R (2.5 ns)	1	2.9	2048	174	3.2
Intel iPSC/860 (40 MHz)	128	2.6	12000	4500	5.
NEC SX-3/12 (2.9 ns)	1	2.5	2048	256	2.8
Thinking Machines CM-200 (10 MHz)	512	2.4	14848	5632	5
Alliant CAMPUS/800 (40 MHz)	96	2.3	13020	4396	3.8
Intel iPSC/860 (40 MHz)	120	2.3	12000	4500	4.8
Fujitsu AP1000	512	2.3	25600	2500	2.8
Thinking Machines CM-5	32	1.9	9216	4096	4
Intel iPSC/860 (40 MHz)	96	1.9	11000	4000	3.8
nCUBE 2 (20 MHz)	1024	1.9	21376	3193	2.4
Intel Delta (40 MHz)	64	1.7	8000	2500	2.6
Alliant CAMPUS/800 (40 MHz)	72	1.6	12012	3724	2.9
MasPar MP-2216 (80ns)	16384	1.6	11264	1920	2.4
NEC SX-3/11R (2.5 ns)	1	1.5	2048	130	1.6
Intel iPSC/860 (40 MHz)	72	1.4	9000	3500	2.9

Table A.3 Massively parallel computing.

Computer (Full Precision)	Number of Processors	R_{max} Gflop/s	N_{max} order	$N_{1/2}$ order	R_{peak} Gflop/s
Intel iPSC/860 (40 MHz)	64	1.4	9000	3500	2.6
Meiko Computing Surface (40 MHz)	62	1.3	8500	3500	2.5
NEC SX-3/11 (2.9 ns)	1	1.3	2816	192	1.4
Fujitsu AP1000	256	1.2	18000	1600	1.4
Thinking Machines CM-200 (10 MHz)	256	1.2	10752	4096	2.5
Alliant CAMPUS/800 (40 MHz)	48	1.1	10024	3024	1.9
Intel iPSC/860 (40 MHz)	48	.98	7000	3000	1.9
Thinking Machines CM-5	16	.98	6528	3008	2
nCUBE 2 (20 MHz)	512	.958	15200	2240	1.2
IBM PVS (40MHz)	32	.925	6000	1560	1.3
Intel Delta (40 MHz)	32	.9	6000	2000	1.3
Meiko Computing Surface (40 MHz)	32	.825	7000	3000	1.3
NEC SX-3/1LR (2.5 ns)	1	.78	2304	112	0.8
IBM RS/6000 Cluster (PARC) (62.5 MHz)	8	.694	10000	1500	1.0
NEC SX-3/1L (2.9 ns)	1	.67	2048	128	.68
Intel iPSC/860 (40 MHz)	32	.64	6000	2500	1.3
Fujitsu AP1000	128	.566	12800	1100	.71
IBM RS/6000 Cluster (PARC) (50 MHz)	8	.520	7500	1300	.8
Alliant CAMPUS/800 (40 MHz)	24	.504	7000	2492	.96
Intel iPSC/860 (40 MHz)	24	.49	5000	2000	.96
nCUBE 2 (20 MHz)	256	.482	10784	1504	.64
MasPar MP-1216 (80ns)	16384	.473	11264	1280	.55
Intel Delta (40 MHz)	16	.45	4000	1000	.64
Meiko Computing Surface (40 MHz)	16	.445	5000	2000	.64
MasPar MP-1 (80 ns)	16384	.44	5504	1180	.58
IBM RS/6000 Cluster (PARC) (50 MHz)	6	.404	7000	1200	.6
MasPar MP-2204 (80ns)	4096	.374	5632	896	.60
IBM RS/6000 Cluster (PARC) (62.5 MHz)	4	.37	5500	850	.50
Intel iPSC/860 (40 MHz)	16	.36	4500	1500	.64
IBM RS/6000 Cluster (PARC) (50 MHz)	4	.293	5500	1000	.4
Fujitsu AP1000	64	.291	10000	648	.36
nCUBE 2 (20 MHz)	128	.242	7776	1050	.32
Meiko Computing Surface (40 MHz)	8	.235	3500	750	.32
Parsytec FT-400 (20 MHz)	400	.232	7999	814	.6
Intel Delta (40 MHz)	8	.23	3000	1000	.32
IBM RS/6000 Cluster (PARC) (62.5 MHz)	2	.19	4000	350	.25
Intel iPSC/860 (40 MHz)	8	.19	3000	850	.32
Meiko Computing Surface (40 MHz)	4	.121	2500	500	.16
nCUBE 2 (20 MHz)	64	.121	5472	701	.15
Intel Delta (40 MHz)	4	.12	2000	500	.16
MasPar MP-1204 (80ns)	4096	.116	5632	640	.138
Intel iPSC/860 (40 MHz)	4	.10	2250	550	.16
IBM RS/6000 (62.5 MHz)	1	.096	3000		.125
MasPar MP-2201 (80ns)	1024	.092	2816	448	.15
Meiko Computing Surface (40 MHz)	2	.062	1750	250	.08
Thinking Machines CM-5	1	.068	1632	672	.128
nCUBE 2 (20 MHz)	32	.061	3888	486	.075

Table A.3 Massively parallel computing (continued).

Computer (Full Precision)	Number of Processors	R_{max} Gflop/s	N_{max} order	$N_{1/2}$ order	R_{peak} Gflop/s
Intel Delta (40 MHz)	2	.06	1500	500	.08
Intel iPSC/860 (40 MHz)	2	.058	1500	400	.08
nCUBE 2 (20 MHz)	16	.032	5580	342	.038
Meiko Computing Surface (40 MHz)	1	.031	1250		.04
MasPar MP-1201 (80ns)	1024	.029	2816	320	.034
Intel iPSC/860 (40 MHz)	1	.024	750		.040
nCUBE 2 (20 MHz)	8	.0161	3960	241	.019
nCUBE 2 (20 MHz)	4	.0080	2760	143	.0094
nCUBE 2 (20 MHz)	2	.0040	1280	94	.0047
nCUBE 2 (20 MHz)	1	.0020	1280	51	.0024
Thinking Machines CM-200 (half precision)	2048	18.5	39936	14336	40
Thinking Machines CM-2 (half precision)	2048	10.4	33920	14000	28
IBM GF11* (half precision) (51.9 ns)	500	5.6	2500	1060	9.6
Fujitsu AP1000 (half precision)	512	3.53	40000	2368	4.3

* The IBM GF11 is an experimental research computer and not a commercial product.

The columns in Table 3 are defined as follows:

R_{max} the performance in Gflop/s for the largest problem run on a machine.

N_{max} the size of the largest problem run on a machine.

$N_{1/2}$ the size where half the R_{max} execution rate is achieved.

R_{peak} the theoretical peak performance in Gflop/s for the machine.

In addition, the number of processors and the cycle time is listed. Full or half precision reflects the computation was computed using 64 or 32-bit floating point arithmetic respectively.

Table A.3 Massively parallel computing (continued).