The HPC Challenge Benchmark

http://icl.cs.utk.edu/hpcc/

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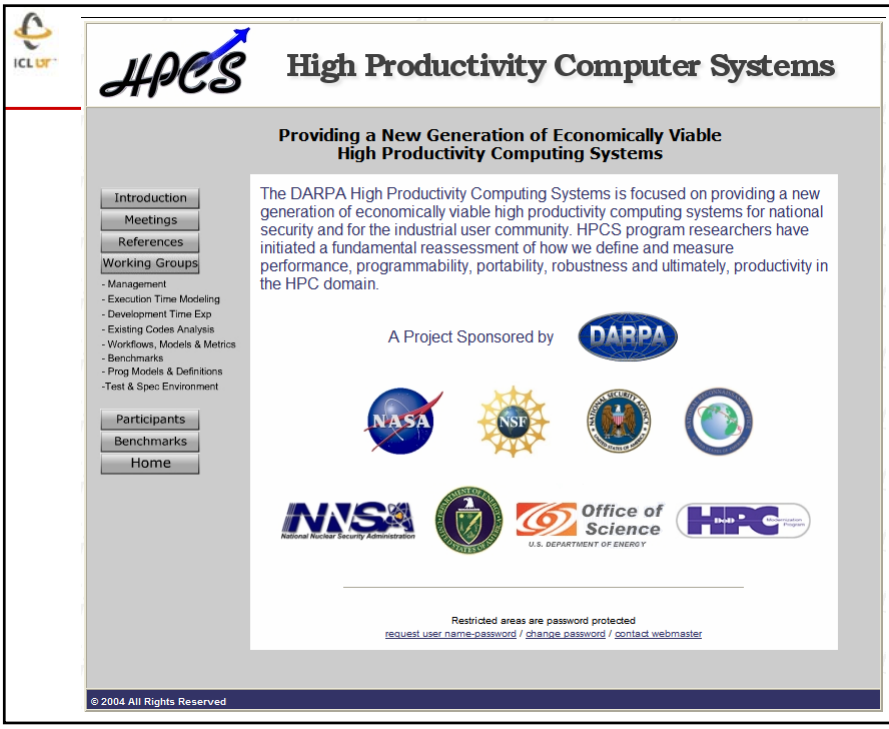
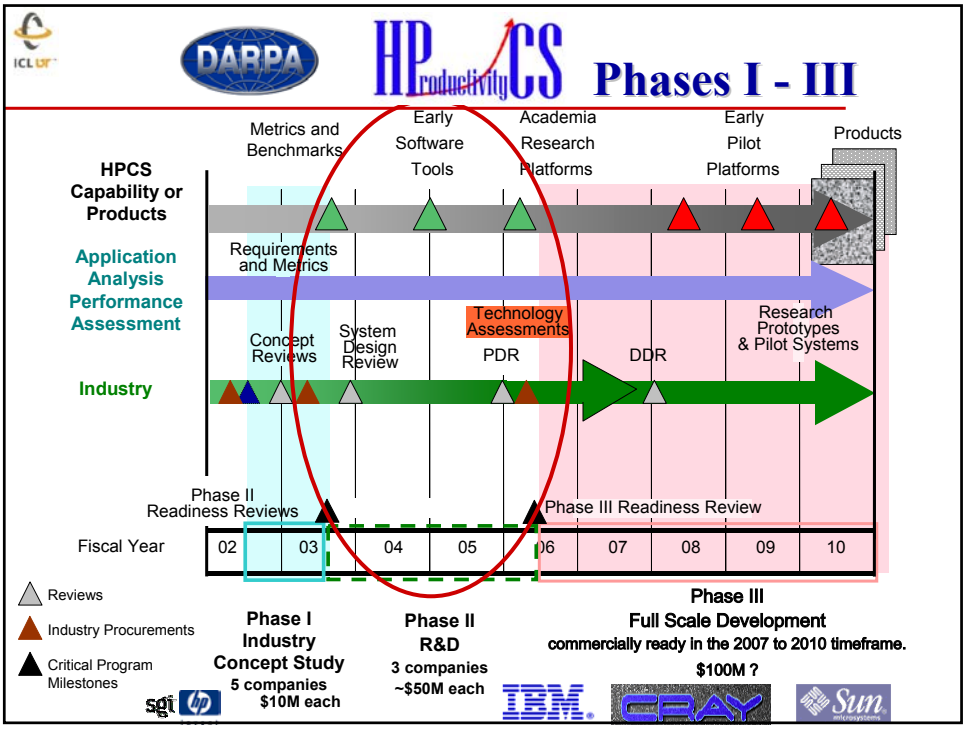



DARPA
HPCS
Phases I - III
Metrics and Benchmarks
Early Software Tools
Academia Research Platforms
Early Pilot Platforms
Products
HPCS Capability or Products
Application Analysis Performance Assessment
Industry
Requirements and Metrics
Concept Reviews
System Design Review
Technology Assessments
PDR
DDR
Research Prototypes & Pilot Systems
Phase II Readiness Reviews
Phase III Readiness Review
Fiscal Year
02
03
04
05
06
07
08
09
10
Reviews
Industry Procurements
Critical Program Milestones
Phase I
Industry
Concept Study
5 companies
$10M each
Phase II
R&D
3 companies
~$50M each
Phase III
Full Scale Development
commercially ready in the 2007 to 2010 timeframe.
$100M ?
IBM
CRAY
Sun


Productivity Team
DARPA
Industry:
IBM
Sun
CRAY
Mission partners:
Office of Science
U.S. Department of Energy
NASA
NNSA
Productivity team (Lincoln Lab lead)
MIT Lincoln Lab
ISI
UCSD
PI: Kepner
PI: Lucas
PI: Basili
PIs: Benson, Snavely
PI: Dongarra
MITRE
ARGONNE NATIONAL LABORATORY
UCSB
OAK RIDGE NATIONAL LABORATORY
Los Alamos
BERKELEY LAB
LCS
Ohio State
CODESOURCERY
PI: Koester
PIs: Vetter, Lusk, Post, Bailey
PIs: Gilbert, Edelman, Ahalt, Mitchell

Motivation for Additional Benchmarks

- From Linpack Benchmark and Top500: "no single number can reflect overall performance"
- Without HPL Linpack only peak will be reported
- Clearly need something more than Linpack
- HPC Challenge Benchmark

Goals HPC Challenge Benchmark

- Stress CPU, memory system, interconnect
- Allow for optimizations
  - Record effort needed for tuning
- Provide verification of results
- Archive results
- Requires: MPI and BLAS

HPC Challenge Benchmark
Initial Release 11/03

Consists of basically 5 benchmarks;

- Think of it as a framework or harness for adding benchmarks of interest.

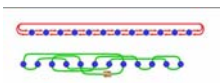
1. HPL (LINPACK) — MPI on whole system (Ax = b)
2. STREAM — single CPU
   *STREAM — embarrassingly parallel whole system

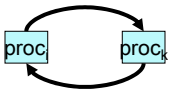
Name	Kernel	Bytes/iter	FLOPS/iter
COPY:	a(i) = b(i)	16	0
SCALE:	a(i) = q*b(i)	16	1
SUM:	a(i) = b(i) + c(i)	24	1
TRIAD:	a(i) = b(i) + q*c(i)	24	2

3. PTRANS ($A \leftarrow A + B^T$) — MPI on whole system
4. RandomAccess — single CPU
   *RandomAccess — embarrassingly parallel
   RandomAccess — MPI on whole system

Random integer read; update; & write

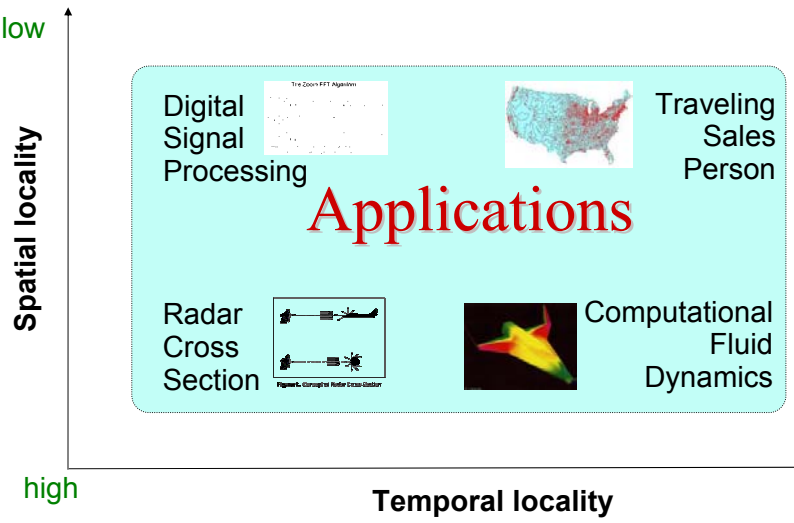
5. BW and Latency – MPI



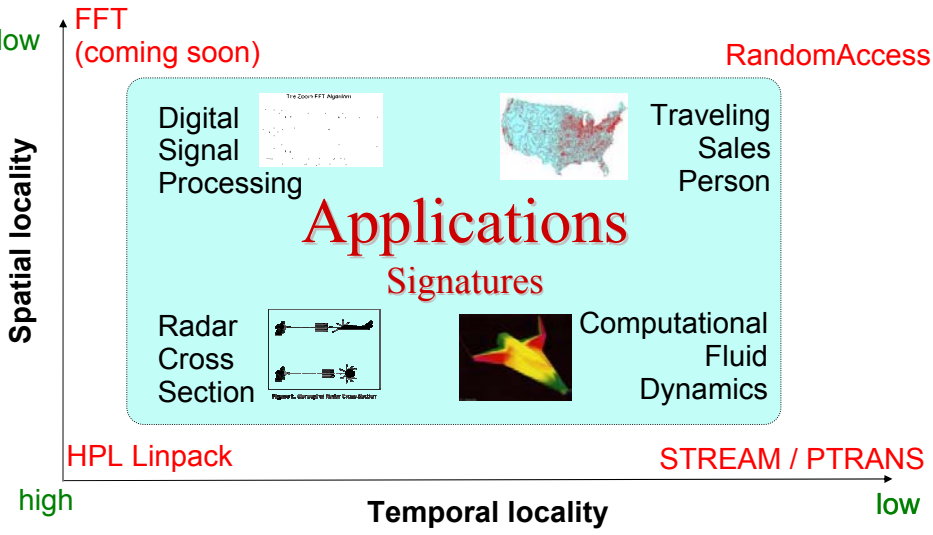


Coming soon: FFT and Matrix Multiply

Memory Access Patterns



Memory Access Patterns



How Will The Benchmarking Work?

- Single program to download and run
  - Simple input file similar to HPL input
- Base Run and Optimization Run
  - Base run must be made
    - User supplies MPI and the BLAS
  - Optimized run allowed to replace certain routines
    - User specifies what was done
- Results upload via website
- html table and Excel spreadsheet generated with performance results
  - Intentionally we are not providing a single figure of merit (no over all ranking)
- Goal: no more than 2 X the time to execute HPL.

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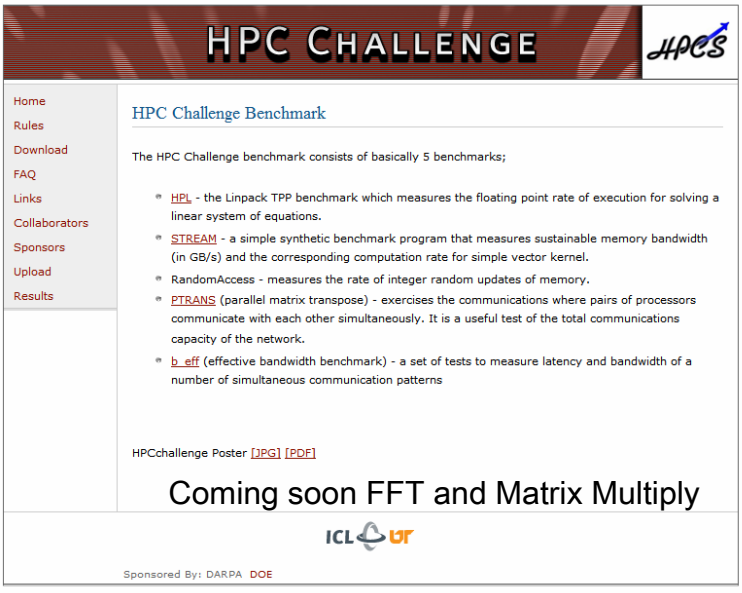
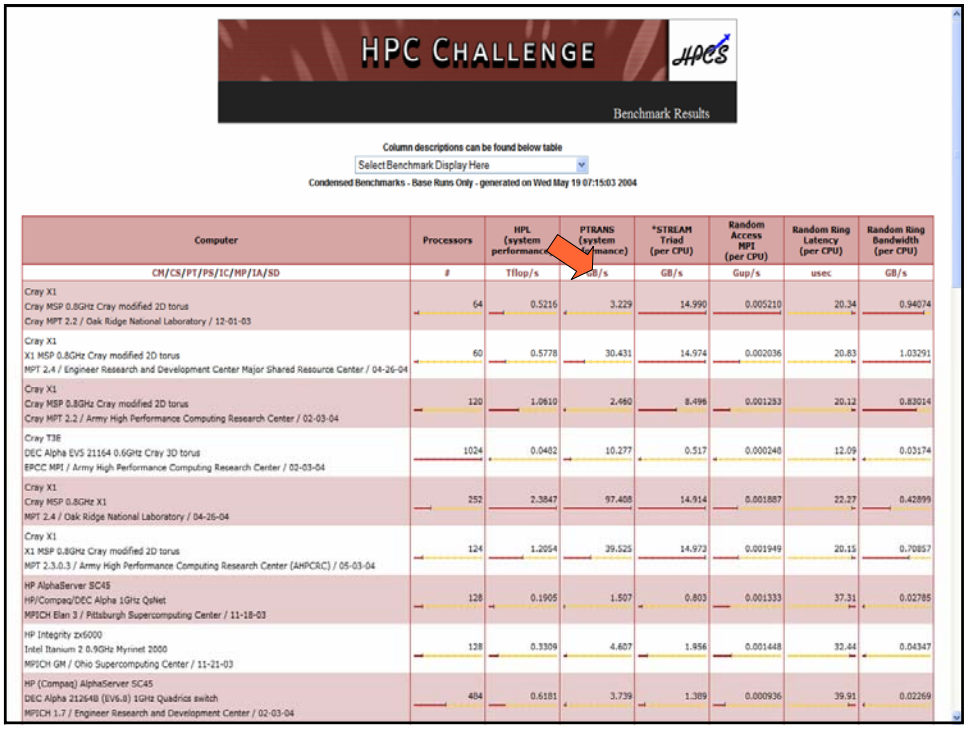


Go to…

- **http://icl.cs.utk.edu/hpcc/**



HPC Challenge

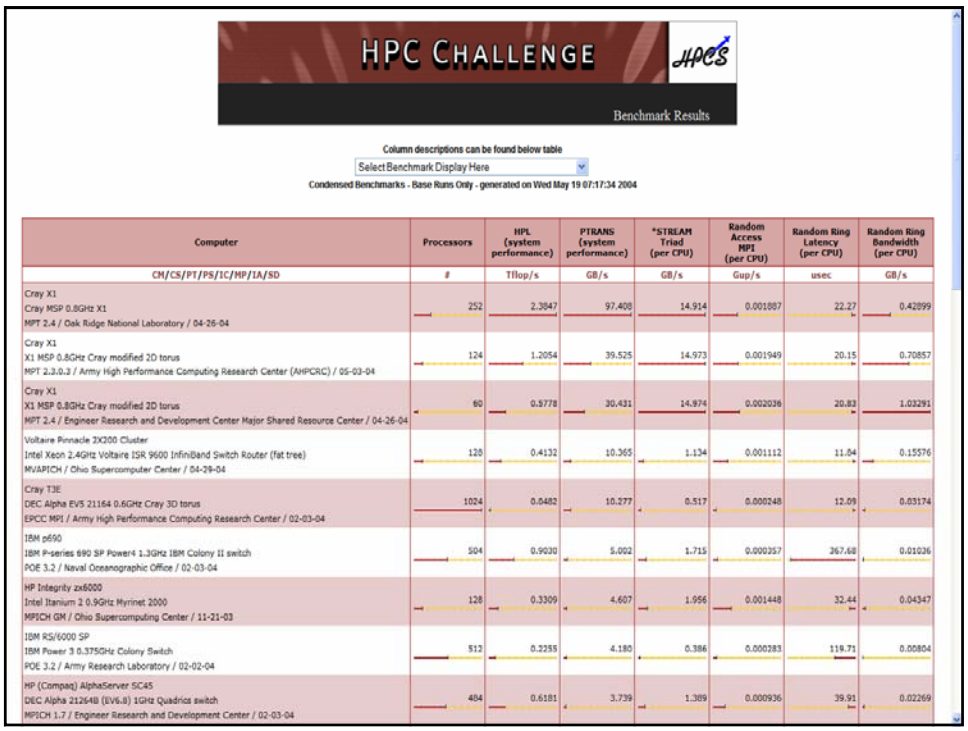
Benchmark Results

Column descriptions can be found below table

Select Benchmark Display Here

Condensed Benchmarks - Base Runs Only - generated on Wed May 19 07:15:03 2004

Computer	Processors	HPL (system performance)	PTRANS (system performance)	*STREAM Triad (per CPU)	Random Access MPI (per CPU)	Random Ring Latency (per CPU)	Random Ring Bandwidth (per CPU)
CM/CS/PT/PS/IC/MP/IA/SD	#	Tflop/s	GB/s	GB/s	Gup/s	usec	GB/s
Cray X1 Cray MSP 0.8GHz Cray modified 2D torus Cray MPT 2.2 / Oak Ridge National Laboratory / 12-01-03	64	0.5216	3.229	14.990	0.005210	20.34	0.94074
Cray X1 X1 MSP 0.8GHz Cray modified 2D torus MPT 2.4 / Engineer Research and Development Center Major Shared Resource Center / 04-26-04	60	0.5778	30.431	14.974	0.002036	20.83	1.03291
Cray X1 Cray MSP 0.8GHz Cray modified 2D torus Cray MPT 2.2 / Army High Performance Computing Research Center / 02-03-04	120	1.0610	2.460	8.496	0.001253	20.12	0.83014
Cray T3E DEC Alpha EV5 21164 0.6GHz Cray 3D torus EPCC MPI / Army High Performance Computing Research Center / 02-03-04	1024	0.0482	10.277	0.517	0.000248	12.09	0.03174
Cray X1 Cray MSP 0.8GHz X1 MPT 2.4 / Oak Ridge National Laboratory / 04-26-04	252	2.3847	97.408	14.914	0.001887	22.27	0.42899
Cray X1 X1 MSP 0.8GHz Cray modified 2D torus MPT 2.3.0.3 / Army High Performance Computing Research Center (AHPCRC) / 05-03-04	124	1.2054	39.525	14.973	0.001949	20.15	0.70857
HP AlphaServer SC45 HP/Compaq/DEC Alpha 1GHz QsNet MPICH Elan 3 / Pittsburgh Supercomputing Center / 11-18-03	128	0.1906	1.507	0.803	0.001333	37.31	0.02785
HP Integrity zx6000 Intel Itanium 2 0.9GHz Myrinet 2000 MPICH GM / Ohio Supercomputing Center / 11-21-03	128	0.3309	4.607	1.956	0.001448	32.44	0.04347
HP (Compaq) AlphaServer SC45 DEC Alpha 21264B (EV6.8) 1GHz Quadrics switch MPICH 1.7 / Engineer Research and Development Center / 02-03-04	484	0.6181	3.739	1.389	0.000936	39.91	0.02269



HPC Challenge

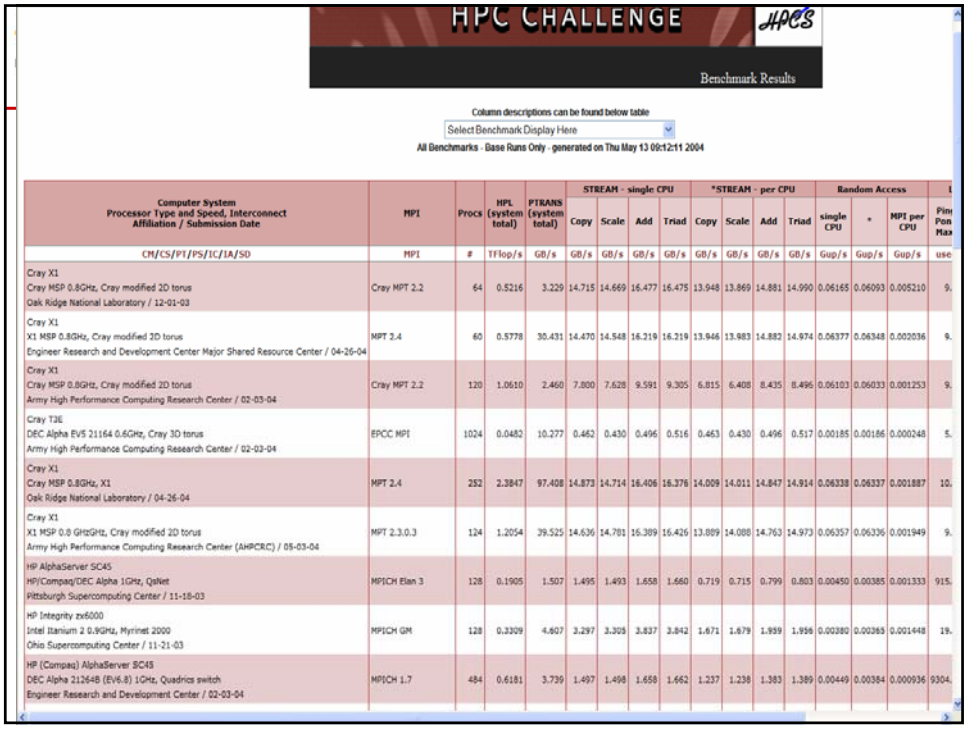
Benchmark Results

Column descriptions can be found below table

Select Benchmark Display Here

Condensed Benchmarks - Base Runs Only - generated on Wed May 19 07:17:34 2004

Computer	Processors	HPL (system performance)	PTRANS (system performance)	*STREAM Triad (per CPU)	Random Access MPI (per CPU)	Random Ring Latency (per CPU)	Random Ring Bandwidth (per CPU)
CM/CS/PT/PS/IC/MP/IA/SD	#	Tflop/s	GB/s	GB/s	Gup/s	usec	GB/s
Cray X1 Cray MSP 0.8GHz X1 MPT 2.4 / Oak Ridge National Laboratory / 04-26-04	252	2.3847	97.408	14.914	0.001887	22.27	0.42899
Cray X1 X1 MSP 0.8GHz Cray modified 2D torus MPT 2.3.0.3 / Army High Performance Computing Research Center (AHPCRC) / 05-03-04	124	1.2054	39.525	14.973	0.001949	20.15	0.70857
Cray X1 X1 MSP 0.8GHz Cray modified 2D torus MPT 2.4 / Engineer Research and Development Center Major Shared Resource Center / 04-26-04	60	0.5778	30.431	14.974	0.002036	20.83	1.03291
Voltaire Pinnacle 2X200 Cluster Intel Xeon 2.4GHz Voltaire ISR 9600 InfiniBand Switch Router (fat tree) MVAPICH / Ohio Supercomputer Center / 04-29-04	128	0.4132	10.365	1.134	0.001112	11.84	0.15576
Cray T3E DEC Alpha EV5 21164 0.6GHz Cray 3D torus EPCC MPI / Army High Performance Computing Research Center / 02-03-04	1024	0.0482	10.277	0.517	0.000248	12.09	0.03174
IBM p690 IBM P-series 690 SP Power4 1.3GHz IBM Colony II switch POE 3.2 / Naval Oceanographic Office / 02-03-04	504	0.9030	5.002	1.715	0.000257	367.68	0.01026
HP Integrity zx6000 Intel Itanium 2 0.9GHz Myrinet 2000 MPICH GM / Ohio Supercomputing Center / 11-21-03	128	0.3309	4.607	1.956	0.001448	32.44	0.04347
IBM RS/6000 SP IBM Power 3 0.375GHz Colony Switch POE 3.2 / Army Research Laboratory / 02-02-04	512	0.2255	4.180	0.386	0.000283	119.71	0.00804
HP (Compaq) AlphaServer SC45 DEC Alpha 21264B (EV6.8) 1GHz Quadrics switch MPICH 1.7 / Engineer Research and Development Center / 02-03-04	484	0.6181	3.739	1.389	0.000936	39.91	0.02269



HPC CHALLENGE

HPCS

Benchmark Results

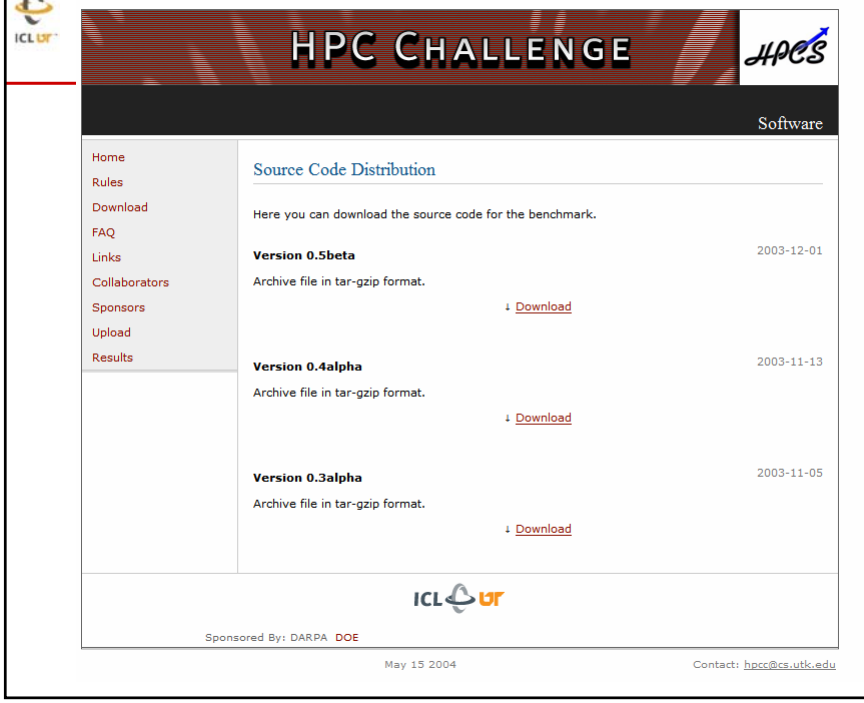
Column descriptions can be found below table

Select Benchmark Display Here

All Benchmarks - Base Runs Only - generated on Thu May 13 09:12:11 2004

Computer System Processor Type and Speed, Interconnect Affiliation / Submission Date	MPI	Procs	HPL (system total)	PTRANS (system total)	STREAM - single CPU				*STREAM - per CPU				Random Access			
					Copy	Scale	Add	Triad	Copy	Scale	Add	Triad	single CPU	*	MPI per CPU	Pin Pon Max
CM/CS/PI/PS/IC/IA/SD	MPI	#	TFlop/s	GB/s	GB/s	GB/s	GB/s	GB/s	GB/s	GB/s	GB/s	GB/s	Gup/s	Gup/s	Gup/s	use
Cray X1 Cray MSP 0.8GHz, Cray modified 2D torus Oak Ridge National Laboratory / 12-01-03	Cray MPT 2.2	64	0.5216	3.229	14.715	14.669	16.477	16.475	13.948	13.869	14.881	14.990	0.06165	0.06093	0.005210	9.
Cray X1 X1 MSP 0.8GHz, Cray modified 2D torus Engineer Research and Development Center Major Shared Resource Center / 04-26-04	MPT 2.4	60	0.5778	30.431	14.470	14.548	16.219	16.219	13.946	13.983	14.882	14.974	0.06377	0.06348	0.002036	9.
Cray X1 Cray MSP 0.8GHz, Cray modified 2D torus Army High Performance Computing Research Center / 02-03-04	Cray MPT 2.2	120	1.0610	2.460	7.800	7.628	9.591	9.305	6.815	6.408	8.435	8.496	0.06103	0.06033	0.001253	9.
Cray T3E DEC Alpha EV5 21164 0.6GHz, Cray 3D torus Army High Performance Computing Research Center / 02-03-04	EPCC MPI	1024	0.0482	10.277	0.462	0.430	0.496	0.516	0.463	0.430	0.496	0.517	0.00185	0.00186	0.000248	5.
Cray X1 Cray MSP 0.8GHz, X1 Oak Ridge National Laboratory / 04-26-04	MPT 2.4	252	2.3847	97.408	14.873	14.714	16.406	16.376	14.009	14.011	14.847	14.914	0.06338	0.06337	0.001887	10.
Cray X1 X1 MSP 0.8 GHzGHz, Cray modified 2D torus Army High Performance Computing Research Center (AHPCRC) / 05-03-04	MPT 2.3.0.3	124	1.2054	39.525	14.636	14.781	16.389	16.426	13.889	14.088	14.763	14.973	0.06357	0.06336	0.001949	9.
HP AlphaServer SC45 HP/Compaq/DEC Alpha 1GHz, QsNet Pittsburgh Supercomputing Center / 11-18-03	MPICH Elan 3	128	0.1905	1.507	1.495	1.493	1.658	1.660	0.719	0.715	0.799	0.803	0.00450	0.00385	0.001333	915.
HP Integrity zx6000 Intel Itanium 2 0.9GHz, Myrinet 2000 Ohio Supercomputing Center / 11-21-03	MPICH GM	128	0.3309	4.607	3.297	3.305	3.837	3.842	1.671	1.679	1.959	1.956	0.00380	0.00365	0.001448	19.
HP (Compaq) AlphaServer SC45 DEC Alpha 21264B (EV6.8) 1GHz, Quadrics switch Engineer Research and Development Center / 02-03-04	MPICH 1.7	484	0.6181	3.739	1.497	1.498	1.658	1.662	1.237	1.238	1.383	1.389	0.00449	0.00384	0.000936	9304.

	A	B	C	D	E	F	G	H
1	Condensed Benchmarks - Base Runs Only - generated on Sat May 15 07:08:44 2004							
2								
3	Computer	Processors	HPL (system performance)	PTRANS (system performance)	*STREAM Triad (per CPU)	Random Access MPI (per CPU)	Random Ring Latency (per CPU)	Random Ring Bandwidth (per CPU)
4								
5								
6	System	#	TFlop/s	GB/s	GB/s	Gup/s	usec	GB/s
7								
8	Cray X1							
9	Cray MSP 0.8GHz Cray modified 2D torus							
10	Cray MPT 2.2 / Oak Ridge National Laboratory / 12-01-03	64	0.52156	3.22883	14.9896	0.00520955	20.3449	0.940743
11	Cray X1							
12	X1 MSP 0.8GHz Cray modified 2D torus							
13	MPT 2.4 / Engineer Research and Development Center Major Shared Resource Center / 04-26-04	60	0.577779	30.4313	14.9741	0.00203643	20.8272	1.03291
14	Cray X1							
15	Cray MSP 0.8GHz Cray modified 2D torus							
16	Cray MPT 2.2 / Army High Performance Computing Research Center / 02-03-04	120	1.06097	2.46034	8.49599	0.00125309	20.1151	0.830137
17	Cray T3E							
18	DEC Alpha EV5 21164 0.6GHz Cray 3D torus							
19	EPCC MPI / Army High Performance Computing Research Center / 02-03-04	1024	0.0481695	10.2765	0.516838	0.000247753	12.0935	0.0317446
20	Cray X1							
21	Cray MSP 0.8GHz X1							
22	MPT 2.4 / Oak Ridge National Laboratory / 04-26-04	252	2.38473	97.4076	14.9143	0.00188656	22.271	0.428985
23	Cray X1							
24	X1 MSP 0.8GHz Cray modified 2D torus							
25	MPT 2.3.0.3 / Army High Performance Computing Research Center (AHPCRC) / 05-03-04	124	1.20542	39.5252	14.9731	0.00194928	20.152	0.708573
26	HP AlphaServer SC45							
27	HP/Compaq/DEC Alpha 1GHz QsNet							
28	MPICH Elan 3 / Pittsburgh Supercomputing Center / 11-18-03	128	0.19046	1.50668	0.802626	0.00133347	37.3113	0.0278468
29	HP Integrity zx6000							
30	Intel Itanium 2 0.9GHz Myrinet 2000							
	MPICH GM / Ohio Supercomputing Center							



Expanded Set of Benchmarks

- Constructing a framework for benchmarks
- Developing machine signatures
- Plans are to expand the benchmark collection
- Currently working on
  - DGEMM and *DGEMM
  - FFT (1d Complex)

HPC CHALLENGE HPCS

Future Directions

- Port to new systems
- Provide more implementations
  - Languages (Fortran, UPC, Co-Array)
  - Environments
  - Paradigms
- Other basic operations
  - Sparse matrix
  - I/O

Collaborators

- Piotr Łuszczek, U of Tennessee
- David Bailey, NERSC/LBL
- Jeremy Kepner, MIT Lincoln Lab
- David Koester, MITRE
- Bob Lucas, ISI/USC
- John McCalpin, IBM, Austin
- Rolf Rabenseifner, HLRS Stuttgart

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