How to get, setup and run SPEC benchmarks

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https://www.spec.org/hpg/publications

http://pages.iu.edu/~lijunj/sc19/

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- How to run SPEC benchmarks?
  - Benchmark components & workloads
  - Runspec & run rules
  - Configuration files
  - From base to peak runs
  - Switch of compiler
- How to publish SPEC benchmark results?
  - Output files
  - Reportable runs
  - Process of publishing

Cluster login

- Read section “Login” in handout
- Follow instructions in section “Setup” in handout
- Then, stop.
- Follow along interactive demo

- **Interactive demo time!**
- **We present SPEC Accel config files**
- **Opportunity to follow instructions interactively (also see handouts)**
- **Later: run benchmarks**
  Accel OpenACC on CPU and GPU
  (Note: OpenMP and MPI runs take long – not covered here)
- **Interpret results**

If you have any problems, let us know immediately! We are happy to help you!

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System Requirements

OpenMP: http://spec.org/omp2012/Docs/system-requirements.html
MPI: http://spec.org/mpi2007/Docs/system-requirements.html
ACCEL: https://www.spec.org/accel/Docs/system-requirements.html

links

- Different benchmarks suites
  → different requirements
  - SPEC OMP2012, SPEC MPI2007, SPEC ACCEL
- Supported operating systems: AIX, Linux, MacOS, Solaris, Windows (except very old Windows)
  - Please do not use Windows/Unix compatibility products
- Compatible processors
  - CPU
  - GPU
  - APU
  - Xeon Phi

System Requirements

OpenMP: http://spec.org/omp2012/Docs/system-requirements.html
MPI: http://spec.org/mpi2007/Docs/system-requirements.html
ACCEL: https://www.spec.org/accel/Docs/system-requirements.html

links

- Memory requirements
  - OpenMP: 28GB for the whole system
  - MPI: 1GB/rank (medium size) and 2GB/rank (large size)
  - ACCEL: 4GB of host mem + 2GB of device mem
  - Otherwise, you are measuring your paging file, not your system
- Disk space requirements
  - OpenMP: 8GB
  - MPI: 10GB (medium), 17GB (large, big endian), 24GB (large, little endian)
  - ACCEL: 9GB
- Support of compilers
  - C99, C++98 and Fortran-95 compilers + MPI library for SPEC MPI 2007

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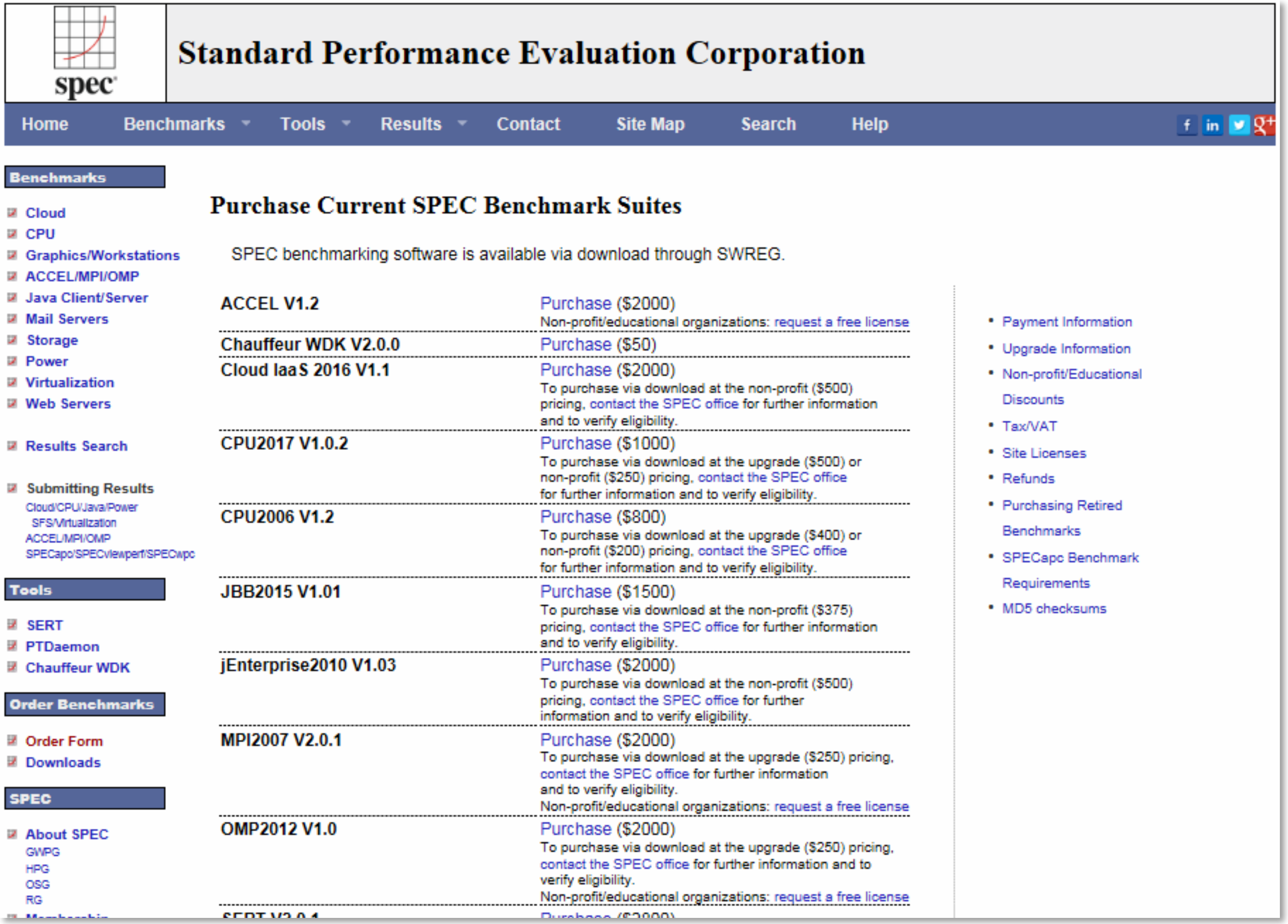
Acquisition of SPEC Benchmarks



Standard Performance Evaluation Corporation

Benchmarks

- Cloud
- CPU
- Graphics/Workstations
- ACCEL/MPI/OMP
- Java Client/Server
- Mail Servers
- Storage
- Power
- Virtualization
- Web Servers

- Results Search

- Submitting Results
  - Cloud/CPU/Java/Power
  - SFS/Virtualization
  - ACCEL/MPI/OMP
  - SPECapc/SPECviewperf/SPECwpc

Tools

- SERT
- PTDaemon
- Chauffeur WDK

Order Benchmarks

- Order Form
- Downloads

SPEC

- About SPEC
  - GWPG
  - HPG
  - OSG
  - RG
- Membership

Purchase Current SPEC Benchmark Suites

SPEC benchmarking software is available via download through SWREG.

ACCEL V1.2	Purchase ($2000) Non-profit/educational organizations: request a free license
Chauffeur WDK V2.0.0	Purchase ($50)
Cloud IaaS 2016 V1.1	Purchase ($2000) To purchase via download at the non-profit ($500) pricing, contact the SPEC office for further information and to verify eligibility.
CPU2017 V1.0.2	Purchase ($1000) To purchase via download at the upgrade ($500) or non-profit ($250) pricing, contact the SPEC office for further information and to verify eligibility.
CPU2006 V1.2	Purchase ($800) To purchase via download at the upgrade ($400) or non-profit ($200) pricing, contact the SPEC office for further information and to verify eligibility.
JBB2015 V1.01	Purchase ($1500) To purchase via download at the non-profit ($375) pricing, contact the SPEC office for further information and to verify eligibility.
jEnterprise2010 V1.03	Purchase ($2000) To purchase via download at the non-profit ($500) pricing, contact the SPEC office for further information and to verify eligibility.
MPI2007 V2.0.1	Purchase ($2000) To purchase via download at the upgrade ($250) pricing, contact the SPEC office for further information and to verify eligibility. Non-profit/educational organizations: request a free license
OMP2012 V1.0	Purchase ($2000) To purchase via download at the upgrade ($250) pricing, contact the SPEC office for further information and to verify eligibility. Non-profit/educational organizations: request a free license
SERT V2.0.1	Purchase ($2000)

- Payment Information
- Upgrade Information
- Non-profit/Educational Discounts
- Tax/VAT
- Site Licenses
- Refunds
- Purchasing Retired Benchmarks
- SPECapc Benchmark Requirements
- MD5 checksums

http://spec.org/order.html
https://www.spec.org/hpg/joining.html

links

- Single SPEC suites
  - Commercial license
  - Non-profit license
- SPEC membership
  - Receive benchmarks for free

Let’s go shopping!
Non-profit organizations get 100% off

spec

Press Release 2018: https://www.spec.org/news/hpgnonprofitpricing.html

Non-commercial download + definition:
http://spec.org/hpgdownload.html

links

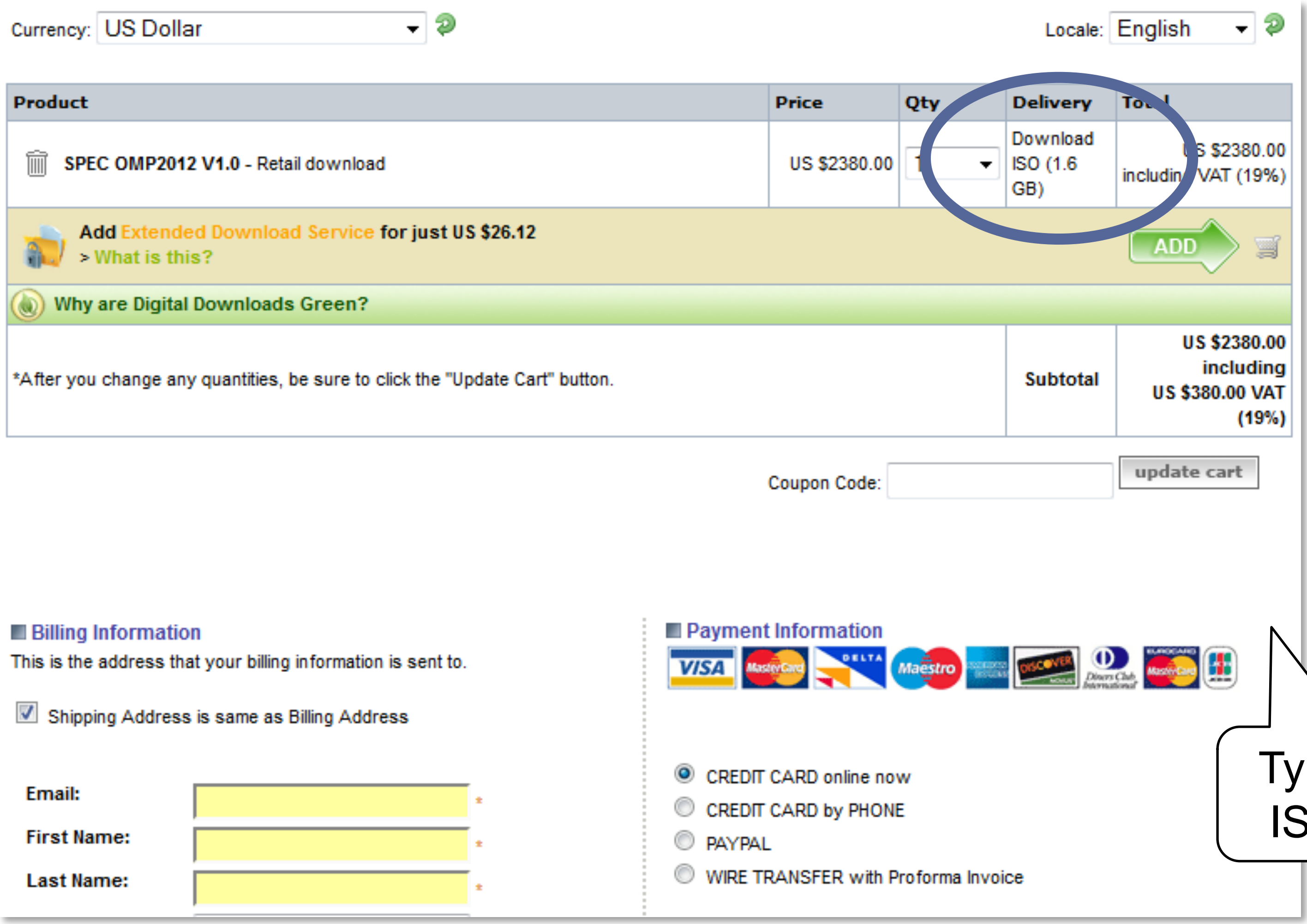
- Commercial license
  - Must be purchased via order form
  - Commercial enterprises (not being SPEC/HPG member) engaging in marketing, developing, testing, consulting for and/or selling computers, computer services, accelerator devices, drivers, software or other high performance computing systems or components in the computer marketplace
- Non-commercial license
  - Free of charge
  - Organizations that do not require a commercial license
  - Valid for the organization (not individual)
  - Institutional e-mail address required

Benchmark Suite	Non-Profit	Commercial
CPU2017 V1.0.2	$250	$1,000
ACCEL V1.3	free	$2,000
OMP2012 V1.0	free	$2,000
MPI2007 V2.0.1	free	$2,000
SPECpower_ssj2008 V1.12	$400	$1,600

SALE
100%
OFF

Download

Order Form



Currency: US Dollar

Locale: English

Product	Price	Qty	Delivery	Total
SPEC OMP2012 V1.0 - Retail download	US $2380.00	1	Download ISO (1.6 GB)	US $2380.00 including VAT (19%)

Add Extended Download Service for just US $26.12
> What is this?

ADD

Why are Digital Downloads Green?

*After you change any quantities, be sure to click the "Update Cart" button.

Subtotal: US $2380.00 including US $380.00 VAT (19%)

Coupon Code:

update cart

Billing Information

This is the address that your billing information is sent to.

☑ Shipping Address is same as Billing Address

Email: *

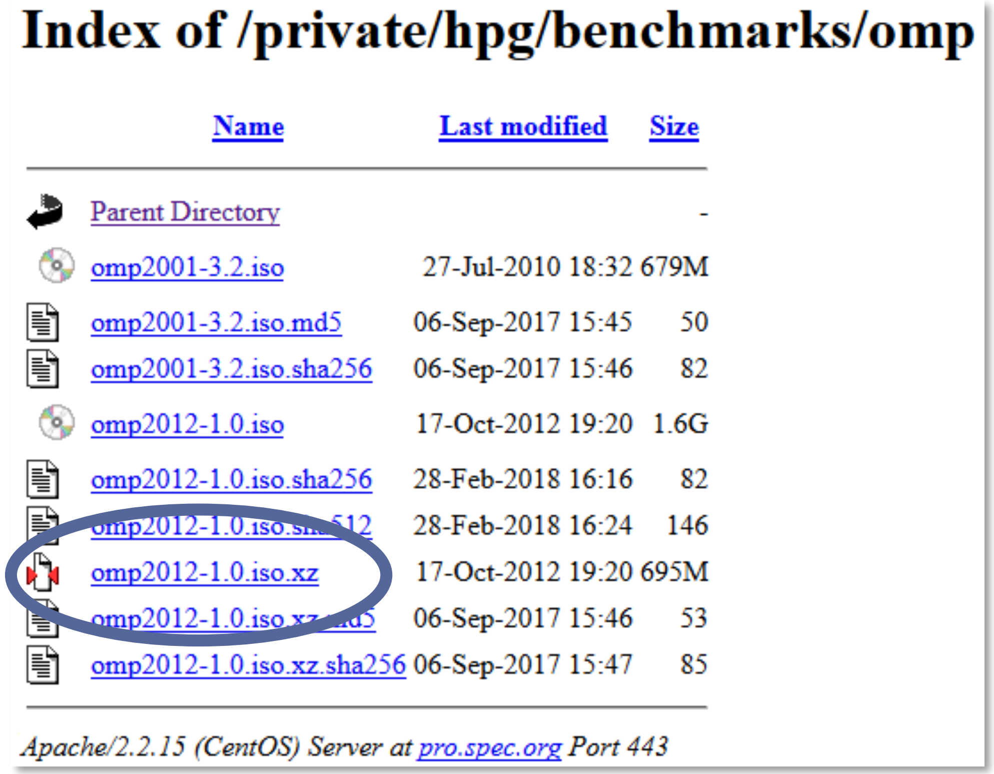
First Name: *

Last Name: *

Payment Information

● CREDIT CARD online now
○ CREDIT CARD by PHONE
○ PAYPAL
○ WIRE TRANSFER with Proforma Invoice

Download as member



Index of /private/hpg/benchmarks/omp

Name	Last modified	Size
Parent Directory		-
omp2001-3.2.iso	27-Jul-2010 18:32	679M
omp2001-3.2.iso.md5	06-Sep-2017 15:45	50
omp2001-3.2.iso.sha256	06-Sep-2017 15:46	82
omp2012-1.0.iso	17-Oct-2012 19:20	1.6G
omp2012-1.0.iso.sha256	28-Feb-2018 16:16	82
omp2012-1.0.iso.sha512	28-Feb-2018 16:24	146
omp2012-1.0.iso.xz	17-Oct-2012 19:20	695M
omp2012-1.0.iso.xz.md5	06-Sep-2017 15:46	53
omp2012-1.0.iso.xz.sha256	06-Sep-2017 15:47	85

Apache/2.2.15 (CentOS) Server at pro.spec.org Port 443

Typically an ISO image

Unpacking (when you can mount ISO images)

```
$> md5sum -c accel-1.2.iso.xz.md5

$> xz -d accel-1.2.iso.xz

$> mkdir spec-iso

$> mount -t iso9660 -o loop,ro accel-1.2.iso spec-iso
```

Check for correct download

Unpack archive

Mount ISO image in subdirectory

Useful hint:
Generate a subdirectory for every benchmark suite! Move the downloads there!

Unpacking (when you cannot mount ISO images)

- Use the tar.xz file (available to members and upon requests)

```
$> md5sum -c accel-1.2.tar.xz.md5

$> tar xvJf accel-1.2.tar.xz
```

Check for correct download

Unpack archive

- *OR*: Copy tar archive from the ISO
  - Use tools such as `isoinfo` or `mc`

List files in iso image

Extract md5 and tar ball from iso image
`-i`: iso image
`-x`: extracts to stdout, redirect needed

```
$> isoinfo -J -l -i accel-1.2.iso
S> isoinfo -J -i accel-1.2.iso -x /install_archives/accel.tar.xz.md5 >
   accel.tar.xz.md5
$> isoinfo -J -i accel-1.2.iso -x /install_archives/accel-1.2.tar.xz > accel-
   1.2.tar.xz
```

Then: unpack tar ball (see above)

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Installation

```
$> ./install.sh
```

Install SPEC suite `[-d <dest dir>]`

hands-on

```
SPEC ACCEL Installation

Top of the ACCEL tree is '/home/spec/accel-1.2'

Installing FROM /home/spec/accel-1.2
Installing TO /home/spec/accel-1.2

Is this correct? (Please enter 'yes' or 'no’)
yes
```

Type `yes` and hit enter

http://spec.org/omp2012/Docs/install-guide-unix.html

links

Installation

```
The following toolsets are expected to work on your platform.  If the
automatically installed one does not work, please re-run install.sh and
exclude that toolset using the '-e' switch.

The toolset selected will not affect your benchmark scores.

linux-suse10-amd64            For 64-bit AMD64/EM64T Linux systems running
                              SuSE Linux 10 or later, and other
                              compatible Linux distributions, including
                              some versions of RedHat Enterprise Linux
                              and Oracle Linux Server.

                              Built on SuSE Linux 10 with
                              GCC v4.1.0 (SUSE Linux)

linux-redhat72-ia32           For x86, IA-64, EM64T, and AMD64-based Linux
                              systems with GLIBC 2.2.4+.
                              Built on RedHat 7.2 (x86) with gcc 3.1.1

=================================================================
Attempting to install the linux-suse10-amd64 toolset...
```

Attempt to automatically determine platform

http://spec.org/omp2012/Docs/install-guide-unix.html

links

Installation

```
=================================================================
Attempting to install the linux-suse10-amd64 toolset...

Checking the integrity of your source tree...


Checksums are all okay.

Removing previous tools installation

Unpacking binary tools for linux-suse10-amd64...

Checking the integrity of your binary tools...

Checksums are all okay.

Testing the tools installation (this may take a minute)

........................................................................o.....................
..............................................................................................
..............................
```

Automatic unpacking of files

Automatic testing of installation

http://spec.org/omp2012/Docs/install-guide-unix.html

links

Loading SPEC tools

```
[..]
Installation successful.  Source the shrc or cshrc in
/home/spec/accel-1.2
to set up your environment for the benchmark.
```

Hint how to proceed

```
>$ source ./shrc.sh
```

hands-on

Source `shrc` or `cshrc`!
Without this nothing will work!!

Setup of environment variables and paths for SPEC, e.g., `$SPEC` to root path

http://spec.org/omp2012/Docs/install-guide-unix.html

links

Setup SPEC Accel on Summit

- Change the directory:

  ```
  cd $MEMBERWORK/trn001
  ```

- Create a new directory to install the benchmark suite:

  ```
  mkdir accel && cd accel
  ```

- Install the spec suite into your scratch space:

  ```
  /ccs/proj/trn001/accel-1.2/install.sh -d $PWD
  ```

- Follow the prompt instructions

Setup SPEC Accel on Summit

- Config files provided in :

  /ccs/proj/trn001/sc19tut/config/*.cfg

  Copy into your install directories config directory

- Flag descriptions files:

  /ccs/proj/trn001/sc19tut/config/*.xml

  Copy into your install dir

- Job scripts:

  /ccs/proj/trn001/sc19tut/scripts/* .

  Copy into your install dir

We will run SPEC Accel while I introduce the config file

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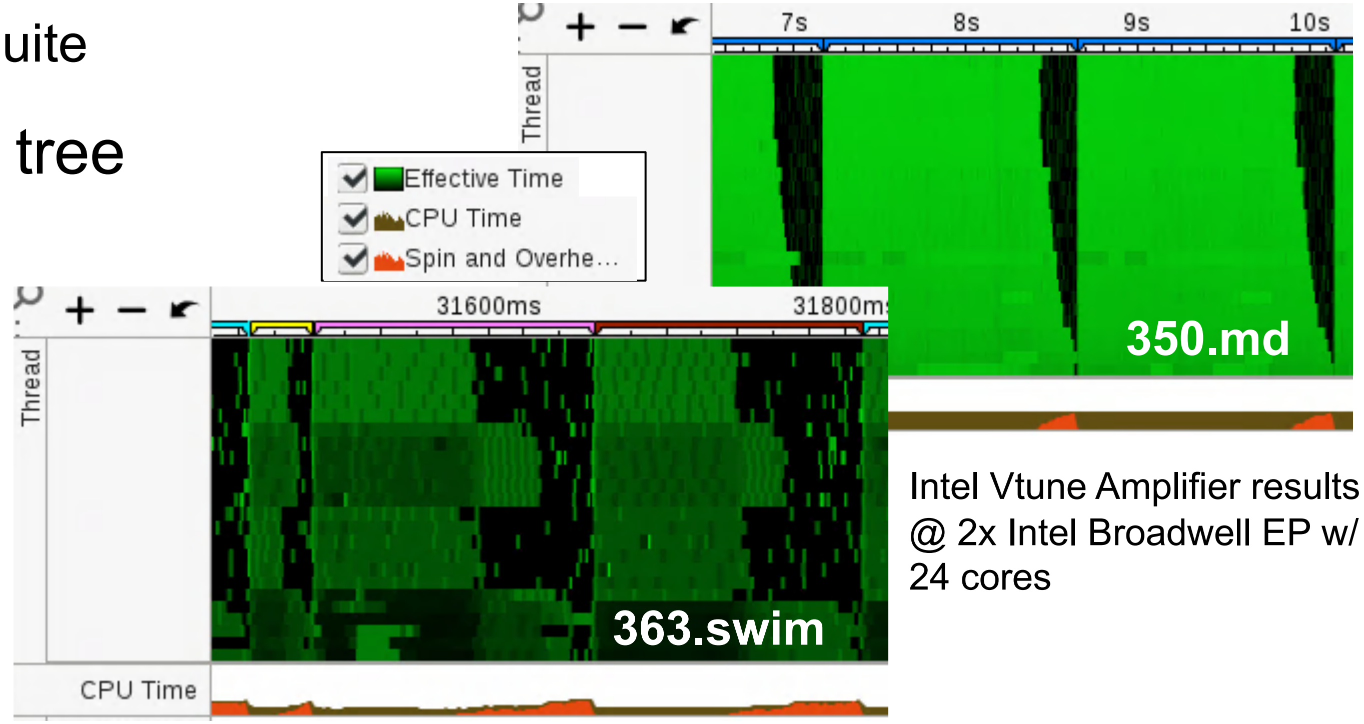
Benchmark components

- Coming from real-world applications
- May have completely different characteristics
- Identification: number and name
  - First number: affiliation to specific SPEC suite
- Documentation: website/ benchmark tree
  - Language, application domain,…

Intel Vtune Amp.	350.md	363.swim
CPI rate	0.698	1.634
CPU utilization	69 %	23.6 %
Memory bound	11.8 %	48.5 %
% of packed FP instr	9.7 %	100 %



Intel Vtune Amplifier results @ 2x Intel Broadwell EP w/ 24 cores

Description of benchmarks: https://www.spec.org/omp2012/Docs/index.html

links

Workloads

Data set sizes

- **`test`**: data for a simple test that an executable is functional
- **`train`**: data for feedback-directed optimization
- **`ref`**: the real data set, required for all result reporting

→ Runtime increases from a few seconds to tens of minutes per benchmark (depending on your configuration)

SPEC Tools

Tools provided to ensure consistent operation of benchmarks across variety of platforms

- **`specmake, specperl, specsha512sum,etc`**
  - make, perl, sha512sum, etc.
- **`runspec`**
  - Primary tool in the suite
  - Used to build the benchmarks, run them, and report their results
  - Config file needed for usage (with detailed instructions on building/running the benchmarks)
- **`rawformat`**
  - Results formatter needed for publishing SPEC results
- And more

Tool overview: http://spec.org/omp2012/Docs/tools-build.html

links

runspec - Run SPEC benchmarks

```
$> . ./shrc
$>

$> runspec --config=openacc-pgi              --tune=base,peak  350
```

Reminder! Must be sourced before usage

Use specific config file

option: base & peak runs

Run selected (single) benchmark: `350`
Or: whole suite, i.e., `all`

- Select benchmarks (suite or single ones)
- Specify config file
- Specify options
  - E.g., data set size, iteration number, device number (for Accel), thread number (for OMP2012)
- Specify actions
  - E.g., compile single benchmarks, run them and validate them

Can overwrite parameters in config file

Runspec: https://www.spec.org/accel/Docs/runspec.html

links

Run rules

OpenMP: https://www.spec.org/omp2012/docs/runrules.html
MPI: https://www.spec.org/mpi/docs/runrules.html
ACCEL: https://www.spec.org/accel/docs/runrules.html

links

- Part of SPEC's philosophy
  (see Part A "Overview of SPEC and SPEC HPG")
- Aim: fair and objective benchmarking

  → Published results are meaningful, comparable to other results, reproducible
- Public SPEC results must be compliant to these rules (license agreement)
  - or must be clearly described as *estimate*
- Estimates
  - May fail to provide one or more of the characteristics of public results
    - E.g., new chip design, prototype/ research compilers
  - Still encouraged to obey as many of the run rules as practical
  - Deviations from the rules must be clearly disclosed

You can use SPEC results as "estimates" in your research environment (also for publications)!

Run rules

OpenMP: https://www.spec.org/omp2012/docs/runrules.html
MPI: https://www.spec.org/mpi/docs/runrules.html
ACCEL: https://www.spec.org/accel/docs/runrules.html
[1] For MPI2007: medium and large data sets

links

Run rules basics:

- Same compiler flags for all in base run
- Individually tuned flags in peak run
- Three iterations needed for reportable run, medium is reported.
- Document all performance related software and hardware

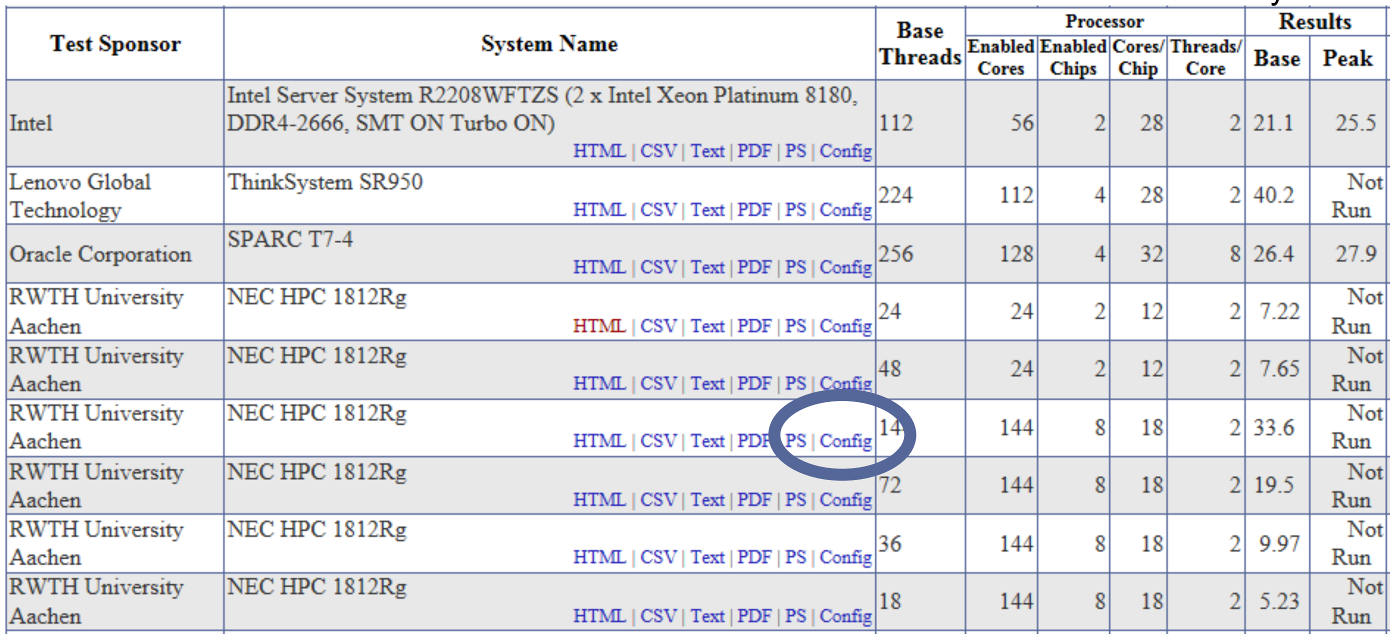
Details see later

Config Files

- Contain instructions for
  - Building benchmarks
  - Running them
  - Description of system under test

Key for reproducibility!

Source: as of May 2018[2]



Test Sponsor	System Name	Base Threads	Processor				Results	
			Enabled Cores	Enabled Chips	Cores/ Chip	Threads/ Core	Base	Peak
Intel	Intel Server System R2208WFTZS (2 x Intel Xeon Platinum 8180, DDR4-2666, SMT ON Turbo ON) HTML | CSV | Text | PDF | PS | Config	112	56	2	28	2	21.1	25.5
Lenovo Global Technology	ThinkSystem SR950 HTML | CSV | Text | PDF | PS | Config	224	112	4	28	2	40.2	Not Run
Oracle Corporation	SPARC T7-4 HTML | CSV | Text | PDF | PS | Config	256	128	4	32	8	26.4	27.9
RWTH University Aachen	NEC HPC 1812Rg HTML | CSV | Text | PDF | PS | Config	24	24	2	12	2	7.22	Not Run
RWTH University Aachen	NEC HPC 1812Rg HTML | CSV | Text | PDF | PS | Config	48	24	2	12	2	7.65	Not Run
RWTH University Aachen	NEC HPC 1812Rg HTML | CSV | Text | PDF | PS | Config	14	144	8	18	2	33.6	Not Run
RWTH University Aachen	NEC HPC 1812Rg HTML | CSV | Text | PDF | PS | Config	72	144	8	18	2	19.5	Not Run
RWTH University Aachen	NEC HPC 1812Rg HTML | CSV | Text | PDF | PS | Config	36	144	8	18	2	9.97	Not Run
RWTH University Aachen	NEC HPC 1812Rg HTML | CSV | Text | PDF | PS | Config	18	144	8	18	2	5.23	Not Run

- How to write a config file?
  - Often start off using a config file that someone else has previously written[1]
    - E.g. directory `$SPEC/config/`
    - E.g., SPEC result submissions similar to your system[2]
  - Write your own[3]

---

[1] https://www.spec.org/accel/docs/runspec.html#about_config

[2] https://www.spec.org/omp2012/results/omp2012.html

[3] https://www.spec.org/accel/docs/config.html

links

Config Files

Use Case:
How to investigate single-GPU performance with SPEC ACCEL?

What we will investigate (as an outlook)…

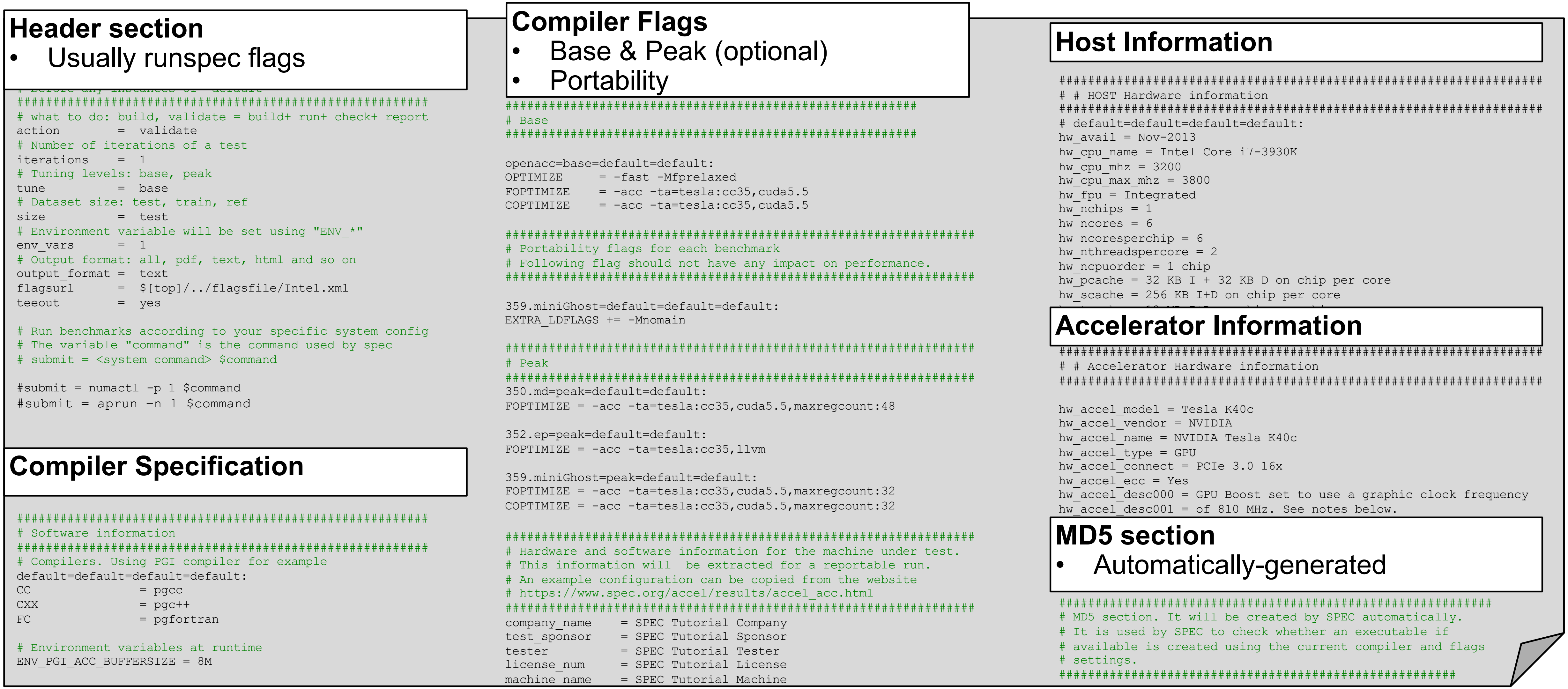
- Basics on writing config files
- SPEC OpenACC with PGI compiler

Not covered here

- SPEC OpenCL
- SPEC OpenMP with target offloading

Later: Have some (hands-on) time to run SPEC benchmarks
Run Accel OpenACC on GPU & CPU on Summit

Structure of Config Files



Header section
- Usually runspec flags

```
##########################################################
# what to do: build, validate = build+ run+ check+ report
action        =  validate
# Number of iterations of a test
iterations    =  1
# Tuning levels: base, peak
tune          =  base
# Dataset size: test, train, ref
size          =  test
# Environment variable will be set using "ENV_*"
env_vars      =  1
# Output format: all, pdf, text, html and so on
output_format =  text
flagsurl      =  $[top]/../flagsfile/Intel.xml
teeout        =  yes

# Run benchmarks according to your specific system config
# The variable "command" is the command used by spec
# submit = <system command> $command

#submit = numactl -p 1 $command
#submit = aprun -n 1 $command
```

Compiler Specification

```
##########################################################
# Software information
##########################################################
# Compilers. Using PGI compiler for example
default=default=default=default:
CC                = pgcc
CXX               = pgc++
FC                = pgfortran

# Environment variables at runtime
ENV_PGI_ACC_BUFFERSIZE = 8M
```

Compiler Flags
- Base & Peak (optional)
- Portability

```
##########################################################
# Base
##########################################################

openacc=base=default=default:
OPTIMIZE      = -fast -Mfprelaxed
FOPTIMIZE     = -acc -ta=tesla:cc35,cuda5.5
COPTIMIZE     = -acc -ta=tesla:cc35,cuda5.5

##################################################################
# Portability flags for each benchmark
# Following flag should not have any impact on performance.
##################################################################

359.miniGhost=default=default=default:
EXTRA_LDFLAGS += -Mnomain

##################################################################
# Peak
##################################################################
350.md=peak=default=default:
FOPTIMIZE = -acc -ta=tesla:cc35,cuda5.5,maxregcount:48

352.ep=peak=default=default:
FOPTIMIZE = -acc -ta=tesla:cc35,llvm

359.miniGhost=peak=default=default:
FOPTIMIZE = -acc -ta=tesla:cc35,cuda5.5,maxregcount:32
COPTIMIZE = -acc -ta=tesla:cc35,cuda5.5,maxregcount:32

##################################################################
# Hardware and software information for the machine under test.
# This information will  be extracted for a reportable run.
# An example configuration can be copied from the website
# https://www.spec.org/accel/results/accel_acc.html
##################################################################
company_name     = SPEC Tutorial Company
test_sponsor     = SPEC Tutorial Sponsor
tester           = SPEC Tutorial Tester
license_num      = SPEC Tutorial License
machine_name     = SPEC Tutorial Machine
```

Host Information

```
####################################################################
# # HOST Hardware information
####################################################################
# default=default=default=default:
hw_avail = Nov-2013
hw_cpu_name = Intel Core i7-3930K
hw_cpu_mhz = 3200
hw_cpu_max_mhz = 3800
hw_fpu = Integrated
hw_nchips = 1
hw_ncores = 6
hw_ncoresperchip = 6
hw_nthreadspercore = 2
hw_ncpuorder = 1 chip
hw_pcache = 32 KB I + 32 KB D on chip per core
hw_scache = 256 KB I+D on chip per core
```

Accelerator Information

```
####################################################################
# # Accelerator Hardware information
####################################################################

hw_accel_model = Tesla K40c
hw_accel_vendor = NVIDIA
hw_accel_name = NVIDIA Tesla K40c
hw_accel_type = GPU
hw_accel_connect = PCIe 3.0 16x
hw_accel_ecc = Yes
hw_accel_desc000 = GPU Boost set to use a graphic clock frequency
hw_accel_desc001 = of 810 MHz. See notes below.
```

MD5 section
- Automatically-generated

```
##############################################################
# MD5 section. It will be created by SPEC automatically.
# It is used by SPEC to check whether an executable if
# available is created using the current compiler and flags
# settings.
#########################################################
```

SPEC Accel Config File (1/8)

config file: $SPEC/config/openacc-pgi.cfg

hands-on

```
######################################################################
# The header section of the config file.  Must appear
# before any instances of "default="
######################################################################


# what to do: build, validate = build + run + check + report
action        =  validate


# Number of iterations of a test
iterations    =  1


# Tuning levels: base, peak
tune          =  base


# Dataset size: test, train, ref
size          =  test
```

- **`build`**: compile benchmarks
- **`validate`**: benchmarks are built if necessary, run and reports are generated

- How many times to run each benchmarks
- e.g. for reportable run = 3

- **`base`**: flags for all benchmarks the same
- **`peak`**: set of optimizations individually selected for that benchmark

- Data set sizes (from small to big): `test`, `train`, `ref`
- e.g. test for debugging new set of compilation options

SPEC Accel Config File (2/8)

config file: $SPEC/config/openacc-pgi.cfg

hands-on

```
######################################################################
# The header section of the config file.  Must appear
# before any instances of "default="
######################################################################

# which accelerator to use
device         =    0


# Environment variable will be set using "ENV_*", see the next section
env_vars        =   1


# Output format: all, pdf, text, html and so on
output_format =   text
flagsurl        =   $[top]/../flagsfile/Intel.xml
teeout          =   yes
```

- Use the 1st accelerator device (optional)

- Environment settings
- `ENV_VAR = …`
- Apply to build phase → rebuild if any changes

- Different output formats possible
- In `$SPEC/results`

- Description of portability & tuning options (“Flags File”)
- Information on syntax of flags and their meanings
- Needed for valid reports
- Flags file: http://spec.org/accel/Docs/flag-description.html)

Displays the build commands to screen

SPEC Accel Config File (3/8)

config file: $SPEC/config/openacc-pgi.cfg

```
# How to run the benchmarks according to your specific system configuration
# The variable "command" is the command used by spec
# submit = <system command> $command
# e.g., submit = aprun -n 1 $command
# e.g., submit = taskset -c 0-23 $command
# e.g., submit = numactl -n 1 $command
```

- **How to execute the benchmarks**
- Use `$command` for SPEC command
- Preferred to assign work to processors
  - May place benchmarks on desired processors or benchmark memory on a desired memory unit
  - Especially needed for MPI runs
  - Example 1: run job on one node
  - Example 2: assign job to cores
- Can be used to change the run time environment
  `submit = export ENV_VAR=…; …`
  → no rebuild if any changes occur

SPEC Accel Config File (4/8)

config file: $SPEC/config/openacc-pgi.cfg

hands-on

```
####################################################################
#  Software information
####################################################################

#  Compilers. Using Intel compiler for example
default=default=default=default:
CC              =  pgcc
CXX             =  pgc++
FC              =  pgfortran

############################################################################
#  Base
####################################################

openacc=base=default=default:
OPTIMIZE        = -fast -Mfprelaxed
FOPTIMIZE       = -acc -ta=tesla:cc70,cuda10.1
COPTIMIZE       = -acc -ta=tesla:cc70,cuda10.1
```

Named section

`benchmark[,…]=tuning[,…]`
`=extension[,…]=machine[,…]:`

- Settings for base runs
- Compiler flags or environment variables

SPEC Accel Config File (5/8)

config file: $SPEC/config/openacc-pgi.cfg

hands-on

```
# Environment variables at runtime
ENV_PGI_ACC_BUFFERSIZE = 8M


############################################################################
# Portability flags for each benchmark
# Following flag should not have any impact on performance.
############################################################################
```

Environment variables

- Active if `env_vars` is set to `1` (see prior slides)
- Need to start with `ENV_`

Set portability flags if benchmark cannot be built/ execute correctly w/o these flags.

Other typical portability flags: language standards (-std=c99), Fortarn format (-free), memory models (-mcmodel=medium)

SPEC Accel OpenACC current doesn’t need portability flag with PGI.

SPEC Config File: portability flags

You will likely need different portability flags when you experiment with a different compiler.

Example here is portability flag of SPEC OMP2012.

hands-on

```
# Environment variables at runtime
ENV_OMP_PROC_BIND = close
ENV_OMP_PLACES    = cores
ENV_OMP_NESTED    = FALSE
ENV_OMP_DYNAMIC   = FALSE

########################################################################
####
# Portability flags for each benchmark
# Following flag should not have any impact on performance.
########################################################################
####
350.md=default=default=default:
FPORTABILITY = -free

357.bt331=default=default=default:
PORTABILITY  = -mcmodel=medium

363.swim=default=default=default:
PORTABILITY  = -mcmodel=medium

367.imagick=default=default=default:
CPORTABILITY = -std=c99
```

Set portability flags if benchmark cannot be built/ execute correctly w/o these flags

SPEC Accel Config File (6/8)

config file: $SPEC/config/openacc-pgi.cfg

```
############################################################################
# Hardware and software information for the machine under test.
# This information will  be extracted for a reportable run.
# An example configuration can be copied from the website
# https://www.spec.org/accel/results/accel_acc.html
#############################################################

company_name     = SPEC Tutorial Company
test_sponsor     = SPEC Tutorial Sponsor
tester           = SPEC Tutorial Tester
license_num      = SPEC Tutorial License
machine_name     = SPEC Tutorial Machine

hw_vendor        = NEC
hw_avail         = NOV-2016
hw_cpu           = Intel Xeon E5-2650 v4
hw_cpu_mhz       = 2200
hw_cpu_max_mhz   = 2900
```

HW & SW description

- Needed only for reportable runs
- `runspec` tools captures information in submission file
- Very detailed information

Information on host configuration, e.g. CPU

hands-on

SPEC Accel Config File (7/8)

config file: $SPEC/config/openacc-pgi.cfg

```
########################################################################
# HOST Hardware information
######################################################################## default=default=default=default:
hw_avail = Nov-2013
hw_cpu_name = Intel Core i7-3930K
hw_cpu_mhz = 3200
hw_cpu_max_mhz = 3800
hw_fpu = Integrated
hw_nchips = 1
hw_ncores = 6
hw_ncoresperchip = 6
hw_nthreadspercore = 2
hw_ncpuorder = 1 chip
hw_pcache = 32 KB I + 32 KB D on chip per core
hw_scache = 256 KB I+D on chip per core
hw_tcache = 12 MB I+D on chip per chip


########################################################################
# Accelerator Hardware information
#######################################################################

hw_accel_model = Tesla K40c
hw_accel_vendor = NVIDIA
hw_accel_name = NVIDIA Tesla K40c
hw_accel_type = GPU
hw_accel_connect = PCIe 3.0 16x
hw_accel_ecc = Yes
```

Performance critical aspects of Host and Accelerator are documented

SPEC Accel Config File (8/8)

config file: $SPEC/config/openacc-pgi.cfg

```
####################################################################
#  Software information
####################################################################
default=default=default=default:
sw_avail = Feb-2014
sw_compiler = PGI Accelerator Server Complete, Release 14.2
sw_accel_driver = NVIDIA UNIX x86_64 Kernel Module 319.60




############################################################################
# MD5 section. It will be created by SPEC automatic
# It is used by SPEC to check whether an ex
# the current compiler and flags settings.
##################################################
```

Information on software configuration, e.g. compilers

MD5 section

- Automatically generated by SPEC tools
- Used to check whether an executable is created using the current settings

Run Accel OpenACC: on GPU

batch script: accel-pgi.bsub

```
$> runspec --config=sc19tut-openacc-pgi --tune=base --size=ref 353 370
```

Name of the config file

hands-on

- Run in **base** mode
- Use ref data set
- Execute benchmarks 353.clvrleaf (Hydrodynamics) and 370.bt (PDE solver)

```
$> bsub  accel-pgi.bsub
```

Submit to batch system.
Note: Machine is only available on day of tutorial

hands-on

Timing on Ref

	353.clvrleaf	370.bt
V100 GPU	37s	10s

Run Accel OpenACC: on CPU

batch script: accel-pgi-multicore.bsub

```
$> runspec --config=sc19tut-openacc-pgi-multicore --tune=base --size=ref 353 370
```

Name of the config file

hands-on

- Run in **base** mode
- Use ref data set
- Execute benchmarks 343.clvrleaf (Hydrodynamics) and 370.bt (PDE solver)

```
$> bsub accel-pgi-multicore.bsub
```

Submit to batch system.
Note: Machine is only available on day of tutorial

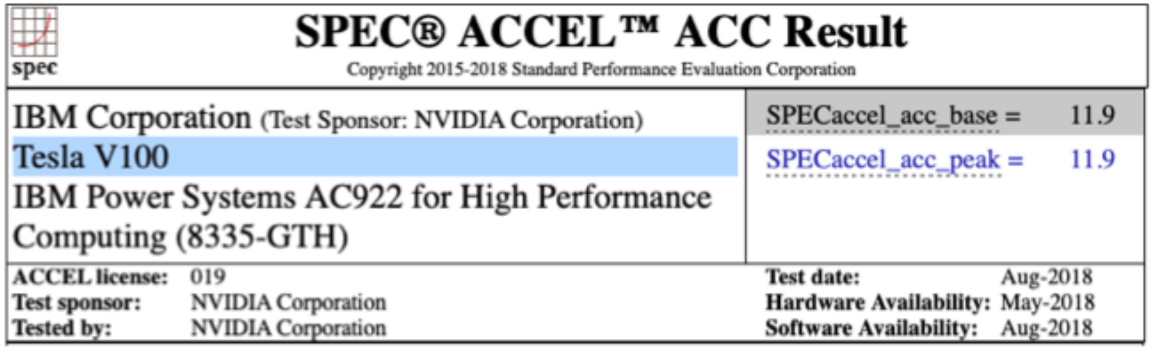
hands-on

Timing on Ref

	353.clvrleaf	370.bt
V100 GPU	37s	10s
Power 9 CPU	132s	110s

Run Accel OpenACC: published results

https://www.spec.org/accel/results/res2018q3/accel-20180814-00114.html



SPEC® ACCEL™ ACC Result

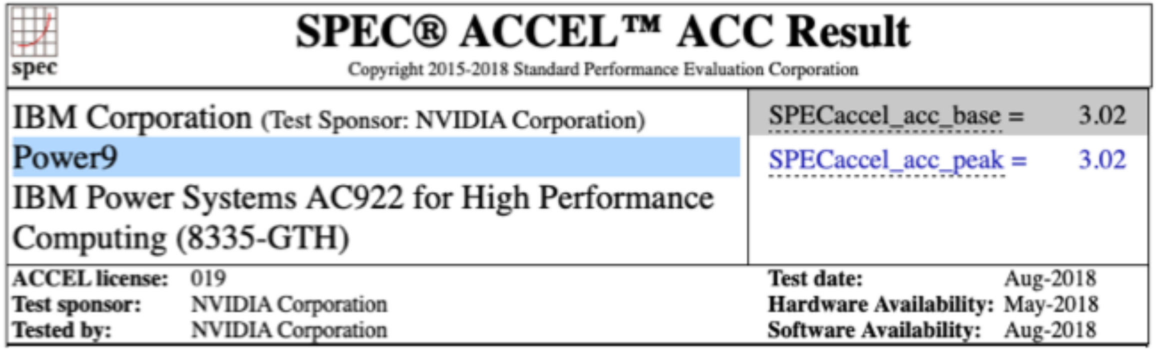
Copyright 2015-2018 Standard Performance Evaluation Corporation

IBM Corporation (Test Sponsor: NVIDIA Corporation)
Tesla V100
IBM Power Systems AC922 for High Performance Computing (8335-GTH)

SPECaccel_acc_base = 11.9
SPECaccel_acc_peak = 11.9

ACCEL license: 019
Test sponsor: NVIDIA Corporation
Tested by: NVIDIA Corporation
Test date: Aug-2018
Hardware Availability: May-2018
Software Availability: Aug-2018

https://www.spec.org/accel/results/res2018q3/accel-20180814-00113.html



SPEC® ACCEL™ ACC Result

Copyright 2015-2018 Standard Performance Evaluation Corporation

IBM Corporation (Test Sponsor: NVIDIA Corporation)
Power9
IBM Power Systems AC922 for High Performance Computing (8335-GTH)

SPECaccel_acc_base = 3.02
SPECaccel_acc_peak = 3.02

ACCEL license: 019
Test sponsor: NVIDIA Corporation
Tested by: NVIDIA Corporation
Test date: Aug-2018
Hardware Availability: May-2018
Software Availability: Aug-2018

Results available on www.spec.org

Run Accel OpenACC: your full run on GPU

batch script: accel-pgi.bsub

```
$> runspec --config=sc19tut-openacc-pgi --tune=base --size=ref openacc
```

Run the whole OpenACC suite

hands-on

- Run in base mode
- Run ref data set
- Execute entire OpenACC suite (replace benchmark “353 370” by “openacc”)

```
$> bsub  accel-pgi.bsub
```

Submit to batch system.
Note: Machine is only available on day of tutorial

hands-on

Flags - From base to peak runs

https://www.spec.org/omp2012/docs/runrules.html#section2.2.4

links

Portability flags

- Allowed if benchmark cannot be built and execute correctly w/o these flags
- Must be performance neutral
- Requirements
  - Provided over `PORTABILITY` flag
  - Must be approved by SPEC HPG committee

Flags - From base to peak runs

Base optimization rules: https://www.spec.org/omp2012/Docs/runrules.html#section2.3

links

Base runs (recap from Part A)

- Common set of optimizations & environment settings for all benchmarks
- “baseline”
  - single set of switches
  - single-pass make process
  - high degree of portability, safety, performance
- Must adhere to strict rules
  - e.g. same compiler for all modules of a given language
  - All flags, options must be the same, e.g., also the level of parallelism
  - Only portability switches allowed
  - More rules (base & peak) on names, library substitutions, data type sizes, source code changes

Flags - From base to peak runs

Peak optimization rules: https://www.spec.org/omp2012/Docs/runrules.html#section2.4
Published results OMP2012: https://www.spec.org/omp2012/results/omp2012.html

links

Peak runs

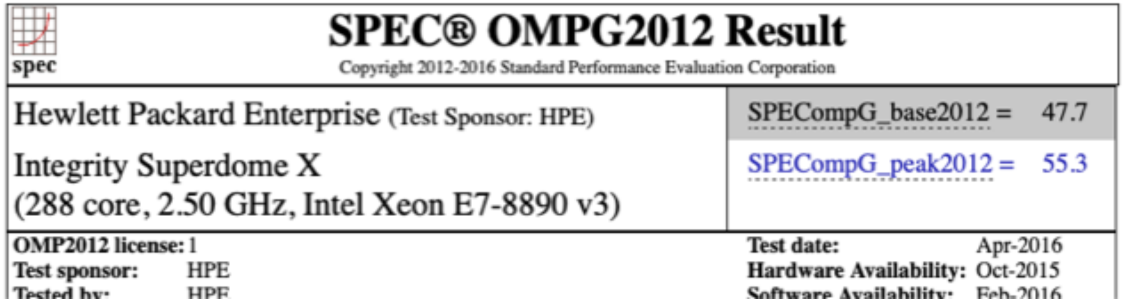
- Set of optimizations individually selected for each benchmark
  - e.g. different compilers, flags
- Called “aggressive compilation”

Summary

- Many published results do not contain peak results (often coming from academic institutions)
- Results submitted by vendors often contain peak results

Flags - From base to peak runs

- Modifying the config file
  - Once you have a config file that runs on your system, it is easy to modify it
  - E.g. `peak` optimizations for better performance
  - SPEC Accel is relatively new, lack of peak run results (maybe you can produce one?)
  - Showing OMP2012 as example.
- Example:

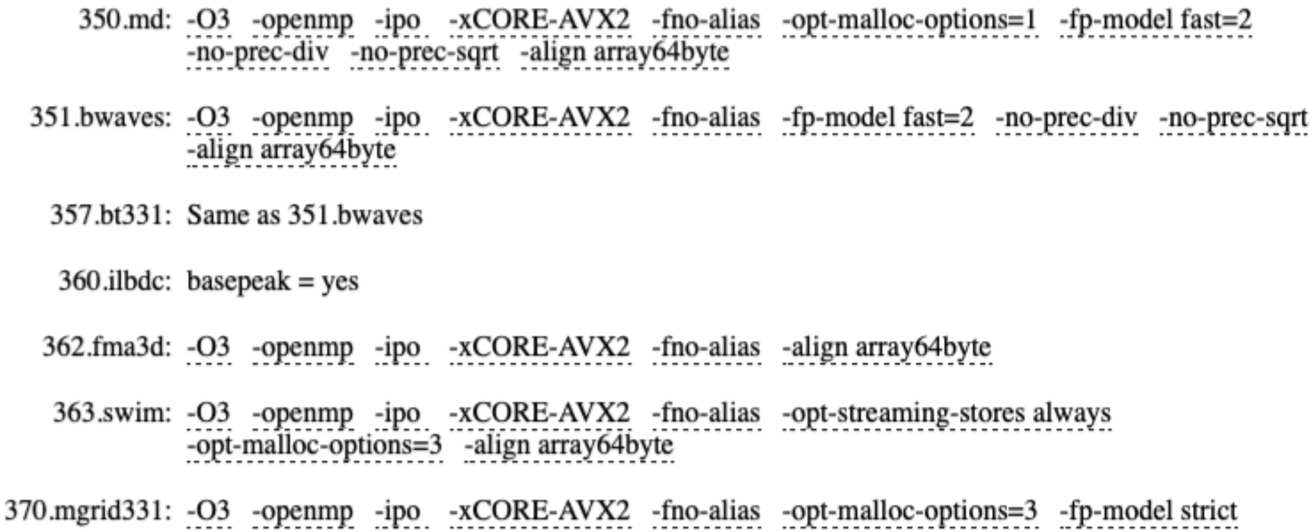


SPEC® OMPG2012 Result

Copyright 2012-2016 Standard Performance Evaluation Corporation

Hewlett Packard Enterprise (Test Sponsor: HPE)	SPECompG_base2012 = 47.7
Integrity Superdome X (288 core, 2.50 GHz, Intel Xeon E7-8890 v3)	SPECompG_peak2012 = 55.3

OMP2012 license:	1	**Test date:**	Apr-2016
Test sponsor:	HPE	**Hardware Availability:**	Oct-2015
Tested by:	HPE	**Software Availability:**	Feb-2016



350.md: -O3 -openmp -ipo -xCORE-AVX2 -fno-alias -opt-malloc-options=1 -fp-model fast=2 -no-prec-div -no-prec-sqrt -align array64byte

351.bwaves: -O3 -openmp -ipo -xCORE-AVX2 -fno-alias -fp-model fast=2 -no-prec-div -no-prec-sqrt -align array64byte

357.bt331: Same as 351.bwaves

360.ilbdc: basepeak = yes

362.fma3d: -O3 -openmp -ipo -xCORE-AVX2 -fno-alias -align array64byte

363.swim: -O3 -openmp -ipo -xCORE-AVX2 -fno-alias -opt-streaming-stores always -opt-malloc-options=3 -align array64byte

370.mgrid331: -O3 -openmp -ipo -xCORE-AVX2 -fno-alias -opt-malloc-options=3 -fp-model strict

SPEC Peak run example: OMP Config File

Just show you how a peak run will look like:

```
#########################################################
#  Peak
#########################################################
default=peak=default=default:
OPTIMIZE    = -O3 -qopenmp -ipo -xCORE-AVX2 -no-prec-div
COPTIMIZE   = -ansi-alias
CXXOPTIMIZE = -ansi-alias
FOPTIMIZE   = -align

# [..] Environment variables

350.md=peak=default=default:
OPTIMIZE=-O3 -qopenmp -ipo -xCORE-AVX2 -ansi-alias -qopt-malloc-options=1
FOPTIMIZE=-fp-model fast=2 -no-prec-div -no-prec-sqrt -align array64byte

363.swim=peak=default=default:
OPTIMIZE=-O3 -qopenmp -ipo -xCORE-AVX2 -ansi-alias -qopt-streaming-stores always
         -qopt-malloc-options=4
threads=24
```

- `-qopt-malloc-options`: alternate algorithm for malloc
- `-fp-model fast=2`: aggressive optimization on FP computations
- `-no-prec-sqrt`: less precise square root computations/ more performance
- `-align array64byte`: align arrays to 64 Byte
- `-qopt-streaming-stores always`: use non-temporal stores (write through)

FP optimizations

memory optimizations

Summary

- SPEC ACCEL for accelerators
  - Including benchmarks implemented using OpenACC, OpenCL and OpenMP target
  - --device to choose device number
  - works with a wide range of acclerators (NVIDIA GPU, AMD GPU, Xeon Phi), also CPU.

Contents

- Cluster login
- Overview of system requirements
- How to get SPEC benchmarks?
  - Benchmark acquisition & licensing
  - Download & unpacking
- How to setup SPEC benchmarks?
  - Installation
- How to run SPEC benchmarks?
  - Benchmark components & workloads
  - Runspec & run rules
  - Configuration files
  - From base to peak runs
  - Switch of compiler
- How to publish SPEC benchmark results?
  - Output files
  - Reportable runs
  - Process of publishing

Output files

- SPEC runs create results in `result` subdirectory
- Text files, ".txt",
  - Preview of the result as it would look on the SPEC website
- Log files, ".log", ".log.debug"
  - Verbose output of the benchmark run
- Raw files, ".rsf",
  - Above the "line" are editable fields about the run such as system or software configuration
  - Below the "line" are the encoded results. Tampering with the results will corrupt the file.

Publish results on SPEC website

- Publishing SPEC HPG results helps to get a rich set of different HW, compilers, configurations, etc.
  - But it’s **not** required
  - Note: non SPEC members pay publication fee
- Recap (Part A): Result Submission Process
  - Obtain and install the benchmark
  - Perform a valid run → Adhere to all **run rules** + create config file + **reportable run**
  - Supply hardware and software description → **Edit documentation** portion of results ((raw) file)
  - **Submit result for review (and publication) to SPEC HPG**
    - 2 week review process
    - (Define embargo period)
  - Use the result as you would like

https://www.spec.org/omp2012/docs/runrules.html#section4.7
https://www.spec.org/hpg/submitting_results.html

links

Run rules

OpenMP: https://www.spec.org/omp2012/docs/runrules.html
MPI: https://www.spec.org/mpi/docs/runrules.html
ACCEL: https://www.spec.org/accel/docs/runrules.html
Defs: https://www.spec.org/omp2012/Docs/runrules.html#section4.2.1

links

A published result means

1. Performance observation → testing
   - Generally no code modifications of provided sources allowed
   - Tester supplies compiler, system, config files
   - Tester provides description of performance-relevant conditions
2. Declaration of expected performance → reproducing
   - Observed level of performance obtainable by others (e.g., used by vendors)
   - Components (e.g., hardware, OS) obtainable by others
3. Claim about maturity of performance methods
   - E.g., correct code generation & improved performance for a class of programs larger then the SPEC suite

Test Sponsor: entity sponsoring the testing (defaults to hardware vendor) → *or can be your university*

Tester: entity actually carrying out the tests (defaults to test sponsor) → *or can be your name*

Reportable runs

Create valid/ compliant result: **`runspec --reportable [..]`**

- `--tune [base|all]`
- Entire SPEC suite (no single benchmarks)
- Workload: `test`, `train`, `ref` will be run → `ref` results are taken
  - Verification for all three data set sizes
- #iterations = 3 → median is taken
- #threads: one fixed number in base (variable per benchmark in peak)

Configuration disclosure (in config file or with `rawformat` – see next slide)

Reportable run: https://www.spec.org/omp2012/Docs/runspec.html#section3.1.1
https://www.spec.org/omp2012/Docs/runspec.html#reportable

links

Preparing a result for submission

- Flags and platform files
  - XML files containing detailed descriptions of the compiler flags and platform settings.
- Edit documentation portion of results: **`rawformat`**
  - Script used to format a raw file into text, html, Postscript, or PDF
  - Also performs a submission check to determine result is valid

Useful hint:
Make a backup copy of the rawfile before editing.

```
$> rawformat outputfile.rsf
$>
$> rawformat -F path/to/flagsfile.xml
```

Runs offline verification of result (similar to submission), produces same output as online

Adds flags-file to the result

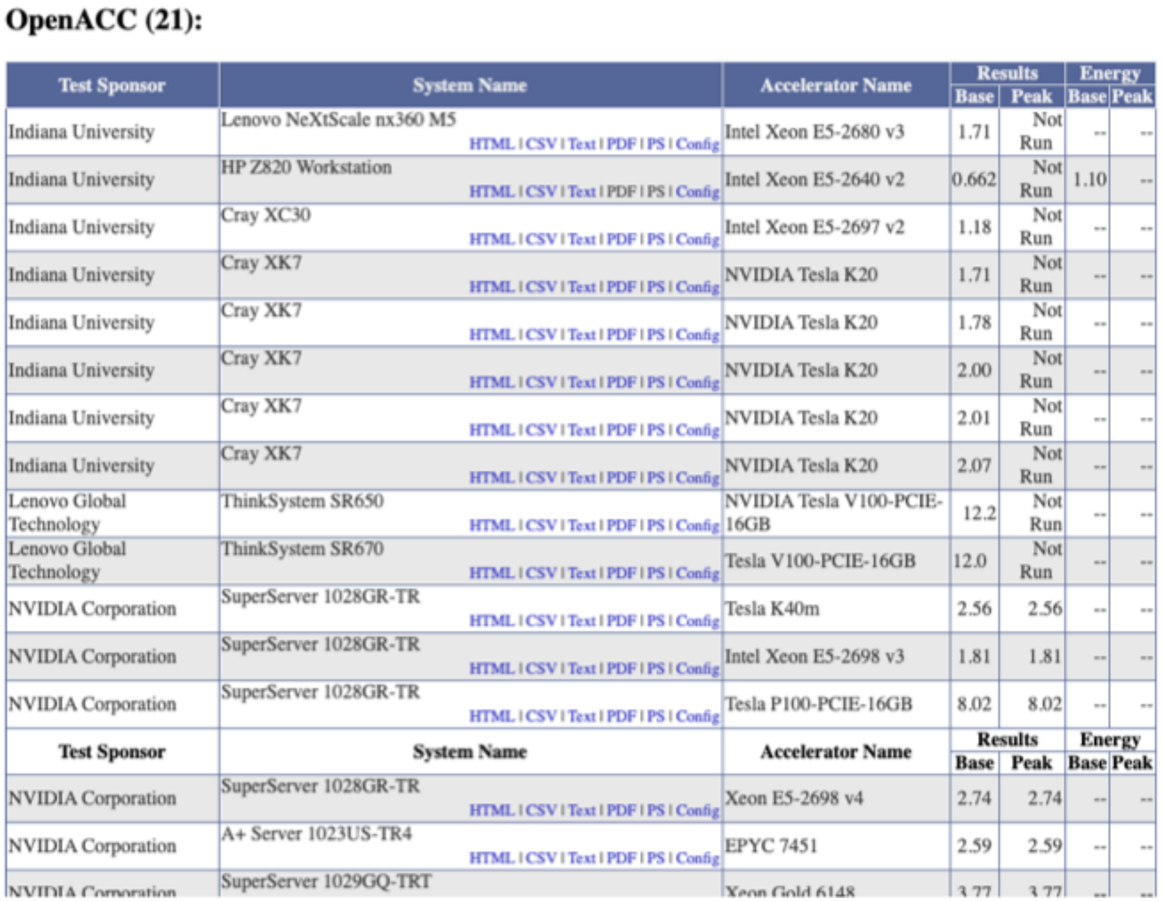
Rawformat: https://www.spec.org/omp2012/docs/utility.html#rawformat

links

Submitting results to SPEC

- Submission of SPEC results
  1. Process your rsf-file through rawformat to check for anything missing/ faulty
  2. Attach your rsf-file to an e-mail to, e.g., subaccel@spec.org
  3. Receive a reply with a sub-file attached
  4. For updates, modify the sub-file and attach to an e-mail to, e.g., resubaccel@spec.org
- Submitted results reviewed before publication by SPEC committee
  - Schedule: 2 weeks until reply (see (3))

Source: https://www.spec.org/accel/results/accel_acc.html



OpenACC (21):

Test Sponsor	System Name	Accelerator Name	Results		Energy	
			Base	Peak	Base	Peak
Indiana University	Lenovo NeXtScale nx360 M5 HTML | CSV | Text | PDF | PS | Config	Intel Xeon E5-2680 v3	1.71	Not Run	--	--
Indiana University	HP Z820 Workstation HTML | CSV | Text | PDF | PS | Config	Intel Xeon E5-2640 v2	0.662	Not Run	1.10	--
Indiana University	Cray XC30 HTML | CSV | Text | PDF | PS | Config	Intel Xeon E5-2697 v2	1.18	Not Run	--	--
Indiana University	Cray XK7 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K20	1.71	Not Run	--	--
Indiana University	Cray XK7 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K20	1.78	Not Run	--	--
Indiana University	Cray XK7 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K20	2.00	Not Run	--	--
Indiana University	Cray XK7 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K20	2.01	Not Run	--	--
Indiana University	Cray XK7 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla K20	2.07	Not Run	--	--
Lenovo Global Technology	ThinkSystem SR650 HTML | CSV | Text | PDF | PS | Config	NVIDIA Tesla V100-PCIE-16GB	12.2	Not Run	--	--
Lenovo Global Technology	ThinkSystem SR670 HTML | CSV | Text | PDF | PS | Config	Tesla V100-PCIE-16GB	12.0	Not Run	--	--
NVIDIA Corporation	SuperServer 1028GR-TR HTML | CSV | Text | PDF | PS | Config	Tesla K40m	2.56	2.56	--	--
NVIDIA Corporation	SuperServer 1028GR-TR HTML | CSV | Text | PDF | PS | Config	Intel Xeon E5-2698 v3	1.81	1.81	--	--
NVIDIA Corporation	SuperServer 1028GR-TR HTML | CSV | Text | PDF | PS | Config	Tesla P100-PCIE-16GB	8.02	8.02	--	--
Test Sponsor	**System Name**	**Accelerator Name**	**Results**		**Energy**	
			Base	**Peak**	**Base**	**Peak**
NVIDIA Corporation	SuperServer 1028GR-TR HTML | CSV | Text | PDF | PS | Config	Xeon E5-2698 v4	2.74	2.74	--	--
NVIDIA Corporation	A+ Server 1023US-TR4 HTML | CSV | Text | PDF | PS | Config	EPYC 7451	2.59	2.59	--	--
NVIDIA Corporation	SuperServer 1029GQ-TRT	Xeon Gold 6148	3.77	3.77	--	--

https://www.spec.org/accel/docs/runrules.html
https://www.spec.org/hpg/submitting_results.html

links

Thank you!

Questions?

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