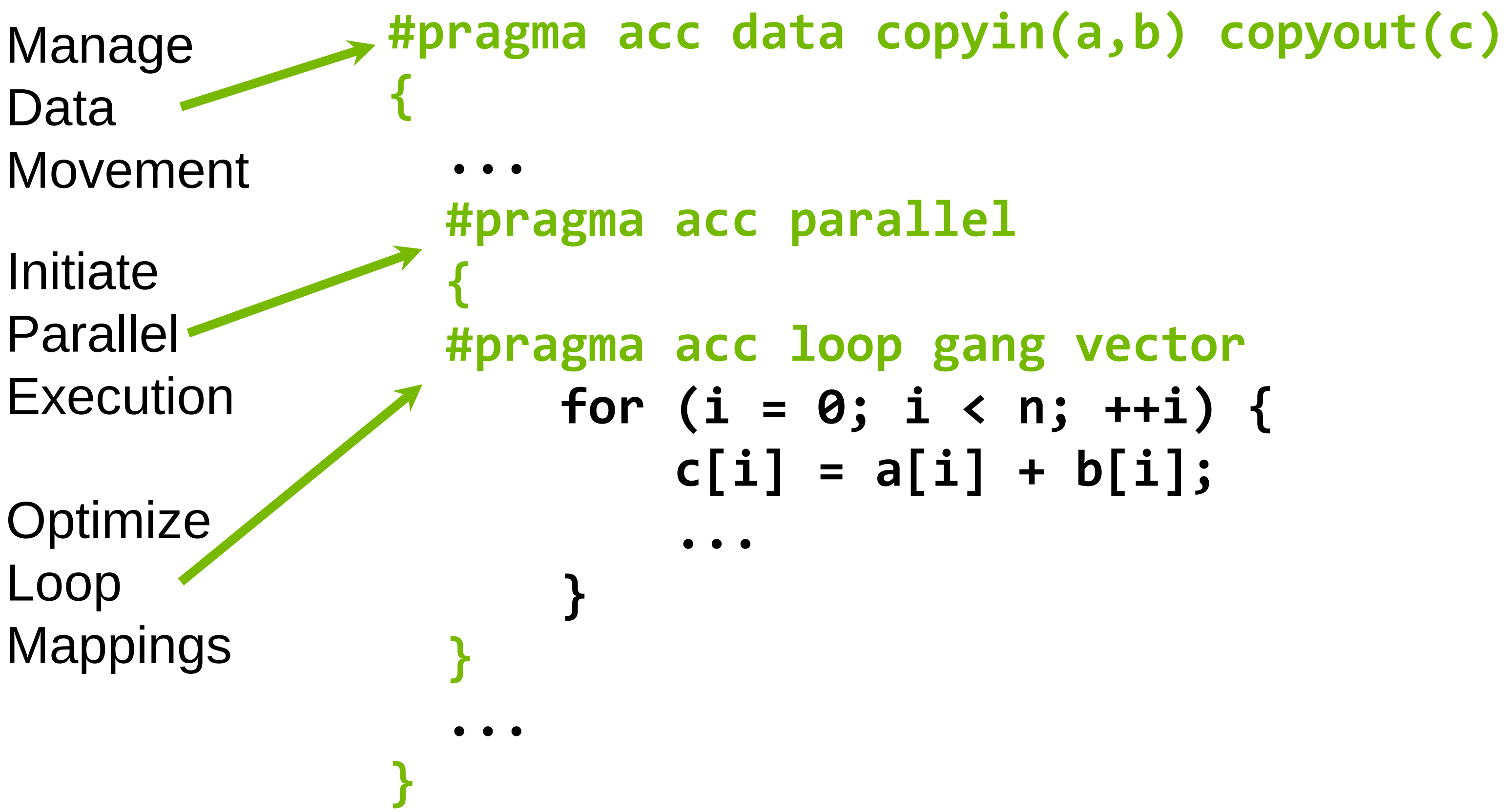
# OPENACC AND UNIFIED MEMORY

Doug Miles, Cray User Group Meeting, 10 May 2017

# OPENACC DIRECTIVES

## Data directives are designed to be optional



Manage Data Movement

Initiate Parallel Execution

Optimize Loop Mappings

```
#pragma acc data copyin(a,b) copyout(c)
{
  ...
  #pragma acc parallel
  {
  #pragma acc loop gang vector
      for (i = 0; i < n; ++i) {
          c[i] = a[i] + b[i];
          ...
      }
  }
  ...
}
```

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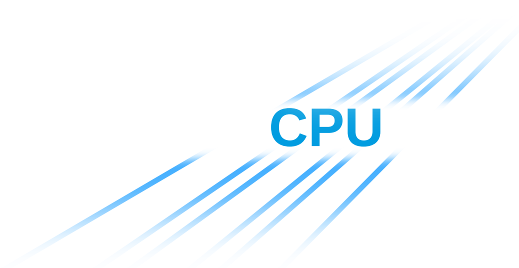
        c[i] = a[i] + b[i];
        ...
    }
}
...
```

# OPENACC FOR MULTICORE CPUS & GPUS

```
 98 !$ACC KERNELS
 99 !$ACC LOOP INDEPENDENT
100      DO k=y_min-depth,y_max+depth
101 !$ACC LOOP INDEPENDENT
102        DO j=1,depth
103          density0(x_min-j,k)=left_density0(left_xmax+1-j,k)
104        ENDDO
105      ENDDO
106 !$ACC END KERNELS
```

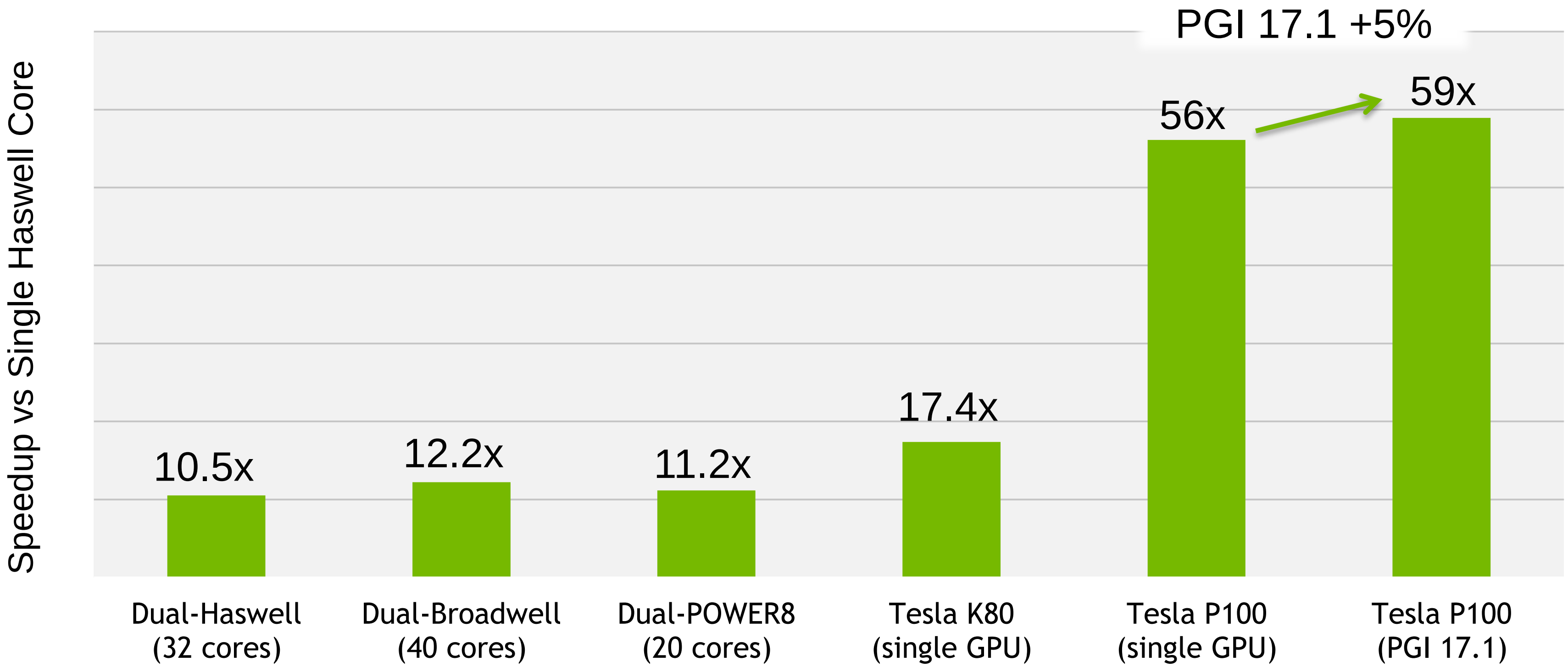


```
% pgfortran -ta=multicore -fast -Minfo=acc -c \
  update_tile_halo_kernel.f90
  . . .
  100, Loop is parallelizable
       Generating Multicore code
       100, !$acc loop gang
  102, Loop is parallelizable
```

```
% pgfortran -ta=tesla -fast -Minfo=acc -c \
  update_tile_halo_kernel.f90
  . . .
  100, Loop is parallelizable
  102, Loop is parallelizable
       Accelerator kernel generated
       Generating Tesla code
       100, !$acc loop gang, vector(4) ! blockidx%y threadidx%y
       102, !$acc loop gang, vector(32) ! blockidx%x threadidx%x
```

# OpenACC SPEC ACCEL 1.1 Benchmarks

## Geometric mean across all 15 benchmarks



Performance measured February and March, 2017 and are considered estimates per SPEC run and reporting rules. SPEC® and SPEC ACCEL® are registered trademarks of the Standard Performance Evaluation Corporation (www.spec.org).

# CUDA UNIFIED MEMORY FOR TESLA

## Servicing CPU *and* GPU Page Faults

GPU Code

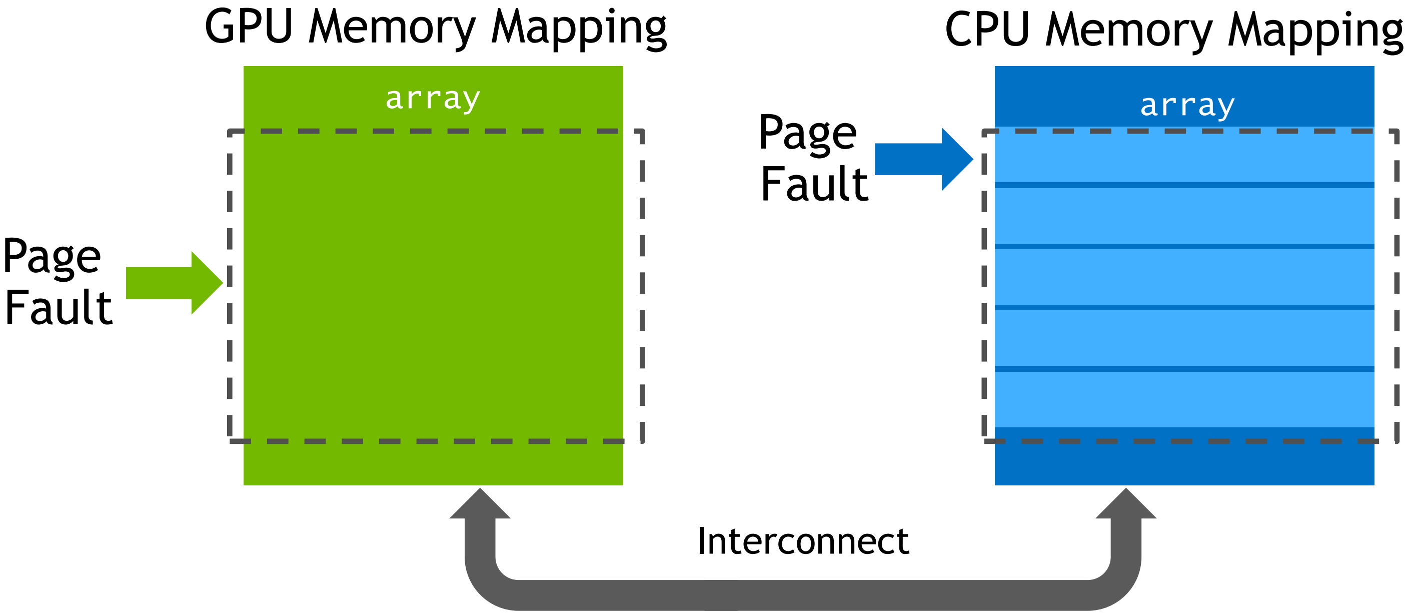
```
__global__
Void setValue(char *ptr, int index, char val)
{
  ptr[index] = val;
}
```

CPU Code

```
cudaMallocManaged(&array, size);

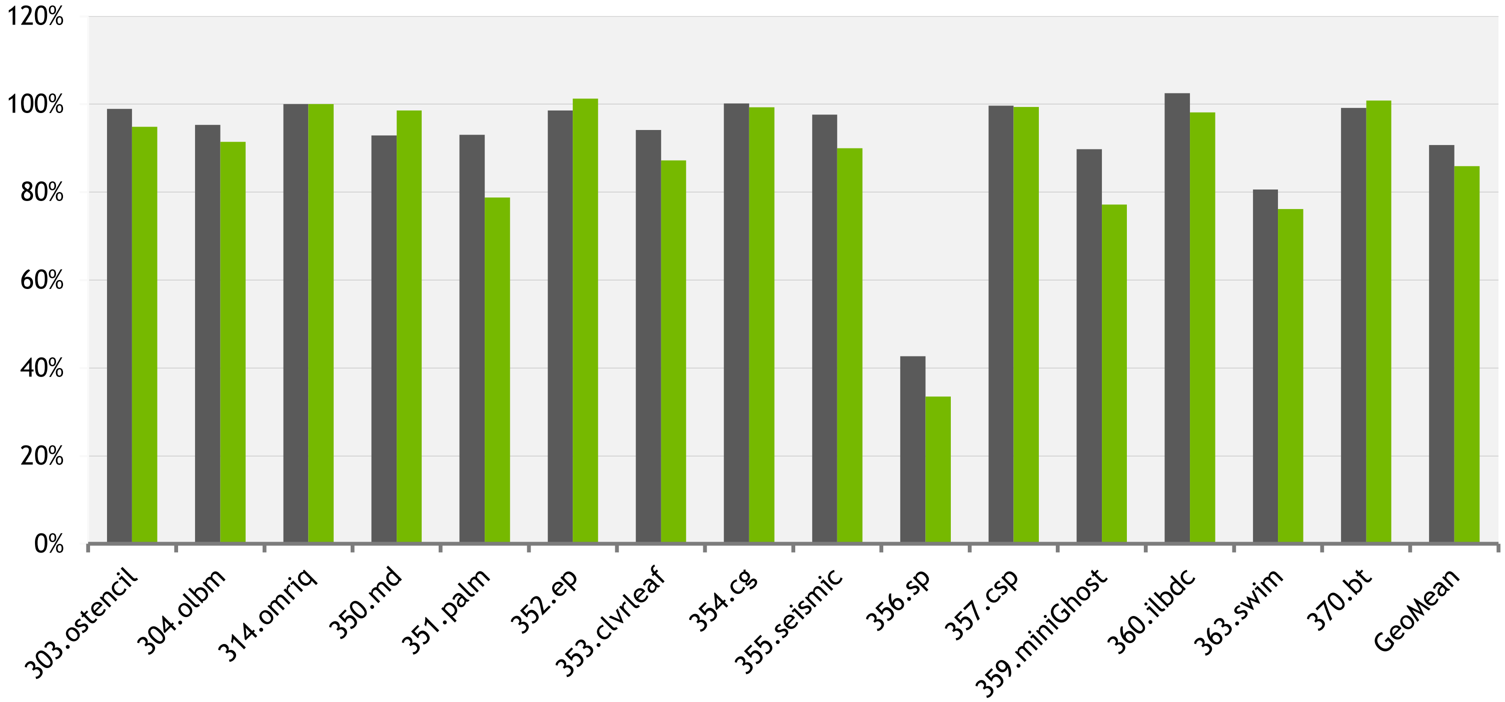
memset(array, size);

setValue<<<...>>>(array, size/2, 5);
```



# OPENACC WITH CUDA UNIFIED MEMORY

## P100 Paging Engine Moves All Dynamically Allocated Data



100% = Pure Directive-based Data Movement

▨ P8+P100 NVLink w/UVM
🟩 HSW+P100 PCIe w/UVM

**Fortran** allocate/deallocate, **C** malloc/calloc/free calls, **C++** new/delete are all intercepted & mapped to CUDA Unified Memory

PGI 17.1 Compilers OpenACC SPEC ACCEL™ 1.1 performance measured March, 2017 SPEC® and the benchmark name SPEC ACCEL™ are registered trademarks of the Standard Performance Evaluation Corporation.

# TESLA GPU PROGRAMMING IN 3 STEPS

## PARALLELIZE

Parallelize with OpenACC for multicore CPUs

% pgc++ –ta=multicore …

```
while ( error > tol && ...
    error = 0.0;
#pragma acc parallel loop ...
    for( int j = 1; ...
#pragma acc loop
        for( int i = 1; ...
        ...
        }
...
```

## OFFLOAD

Port to Tesla using OpenACC with CUDA Unified Memory

## OPTIMIZE

Optimize and overlap data movement using OpenACC data directives

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        }
...
```

## OFFLOAD

Port to Tesla using OpenACC with CUDA Unified Memory

% pgc++ –ta=tesla:managed …

```
while ( error > tol && ...
    error = 0.0;
#pragma acc parallel loop ...
    for( int j = 1; ...
#pragma acc loop
        for( int i = 1; ...
        ...
        }
...
```

## OPTIMIZE

Optimize and overlap data movement using OpenACC data directives

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% pgc++ –ta=multicore …

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while ( error > tol && ...
    error = 0.0;
#pragma acc parallel loop ...
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#pragma acc loop
        for( int i = 1; ...
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        }
...
```

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% pgc++ –ta=tesla:managed …

```
while ( error > tol && ...
    error = 0.0;
#pragma acc parallel loop ...
    for( int j = 1; ...
#pragma acc loop
        for( int i = 1; ...
        ...
        }
...
```

## OPTIMIZE

Optimize and overlap data movement using OpenACC data directives

```
#pragma acc data create ...
while ( error > tol && ...
    error = 0.0;
#pragma acc parallel loop ...
    for( int j = 1; ...
#pragma acc loop
        for( int i = 1; ...
        ...
        }
...
```

# PGI® COMPILERS & TOOLS

NVIDIA®