Programming Models with the ROCm™ Compiler

Speaker: JP Lehr

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AMD Compilers

AMD INSTINCT

- **ROCm™ Compiler Collection**
- **Supports offloading to AMD GPUs**

- C, C++ and Fortran compilers based on LLVM with additional open-source features and optimizations

AMD EPYC

- **AMD Optimizing C/C++ Compiler (AOCC)**
- **Targets x86 AMD CPUs (no offloading)**

- C, C++ and Fortran compilers based on LLVM with extensive optimizations for AMD EPYC™ processors

AMD ROCm Open Software Platform

AMD INSTINCT GPU

Benchmarks & App Support	HPC Applications and Optimized Training / Inference Models HPL/HPCG · Life Science · Geo Science · Physics · MLPERF
Operating Systems Support	Ubuntu · RHEL · SLES · CentOS
Cluster Deployment	Docker® · Singularity · Kubernetes® · SLURM
Framework Support	Kokkos/RAJA · PyTorch · TensorFlow
Libraries	BLAS · RAND · FFT · MIGraphX · MIVisionX · PRIM SOLVER · ALUTION · SPARSE · THRUST · MIOpen · RCCL
Programming Models	HIP API · OpenMP® API · OpenCL™
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AMD ROCm
Open Software Platform

AMD INSTINCT
GPU

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ROCm™ Programming Models

HIP	Grid Language	Maximum Control
OpenMP®	Fork-Join Model	Standardized
OpenCL™	Grid Language	Standardized

ROCm™ Programming Models

HIP

OpenMP®

OpenCL™

ROCm™ Programming Models

HIP		C++		StdPar
OpenMP®	×	C	×	ROCm™ Libs
OpenCL™		Fortran		hipFORT

[Public]

ROCm™ Programming Models

HIP
OpenMP®
OpenCL™

×

C++
C
Fortran

×

StdPar
ROCm™ Libs
hipFORT

ROCm™ Programming Models

HIP
OpenMP®
OpenCL™

×

C++
C
Fortran

×

StdPar
ROCm™ Libs
hipFORT

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Common LLVM Compiler Backend

ROCm™ Programming Models

HIP

C++

StdPar

OpenMP®

C

ROCm™ Libs

OpenCL™

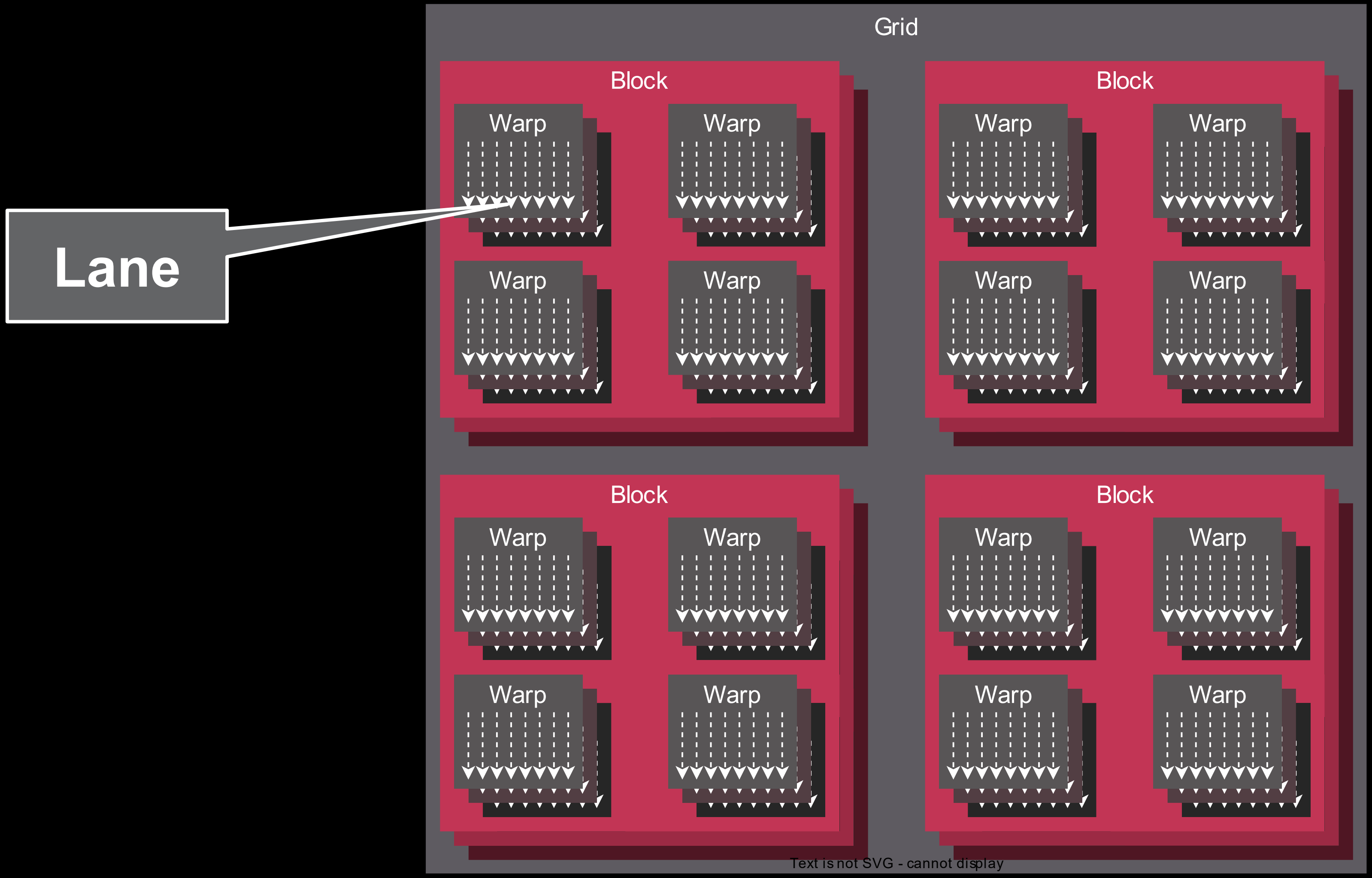
Fortran

hipFORT

ROCm™ Programming Models

HIP	C++	StdPar
OpenMP®	C	ROCm™ Libs
OpenCL™	Fortran	hipFORT

HIP Grid Fundamentals



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HIP Kernel Example

```
__global__
void saxpy(float a, const float* d_x, float* d_y, unsigned int size) {

  const unsigned int global_idx = blockIdx.x * blockDim.x + threadIdx.x;

  if (global_idx < size)
    d_y[global_idx] = a * d_x[global_idx] + d_y[global_idx];
}
```

HIP Kernel Example

```
__global__
void saxpy(float a, const float* d_x, float* d_y, unsigned int size) {

  const unsigned int global_idx = blockIdx.x * blockDim.x + threadIdx.x;

  if (global_idx < size)
    d_y[global_idx] = a * d_x[global_idx] + d_y[global_idx];
}
```

HIP Kernel Launch Example

```
float* d_x{}; float* d_y{};

hipMalloc(&d_x, size_bytes);
hipMalloc(&d_y, size_bytes);
hipMemcpy(d_x, x.data(), size_bytes, hipMemcpyHostToDevice);
hipMemcpy(d_y, y.data(), size_bytes, hipMemcpyHostToDevice);

saxpy <<<dim3(grid_size),
         dim3(block_size),
         0,
         hipStreamDefault>>> (a, d_x, d_y, size);
```

HIP Porting From CUDA

HIP supports AMDGPU and CUDA

Allows incremental porting

HIP Porting From CUDA

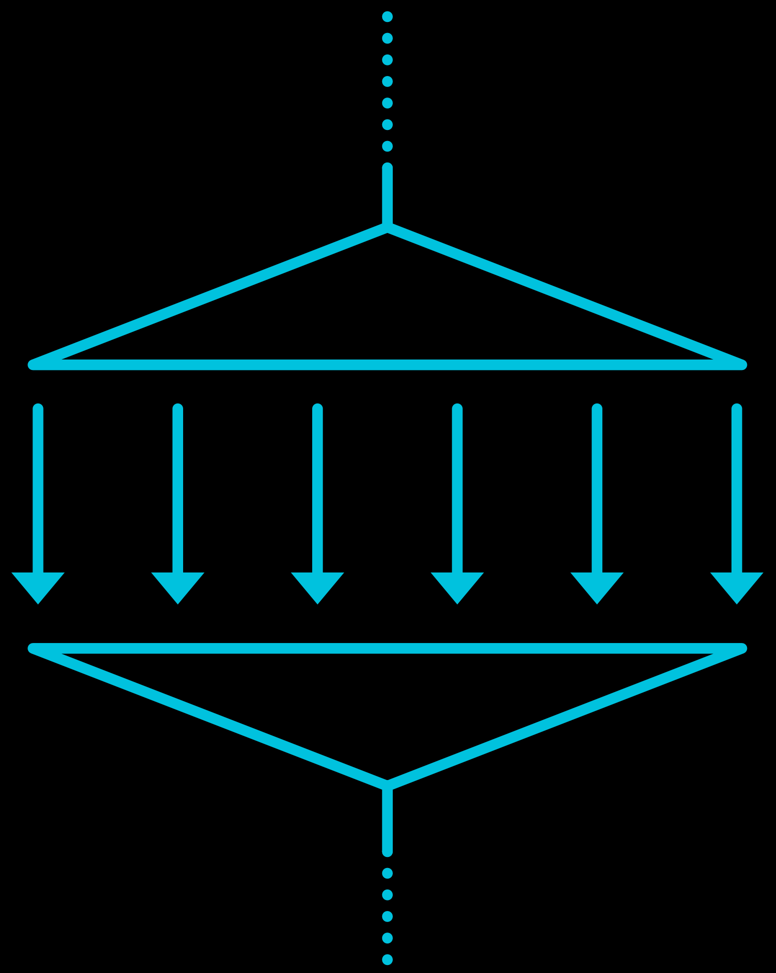
Text-based **HIP** translation

Compiler-based **HIP** translation

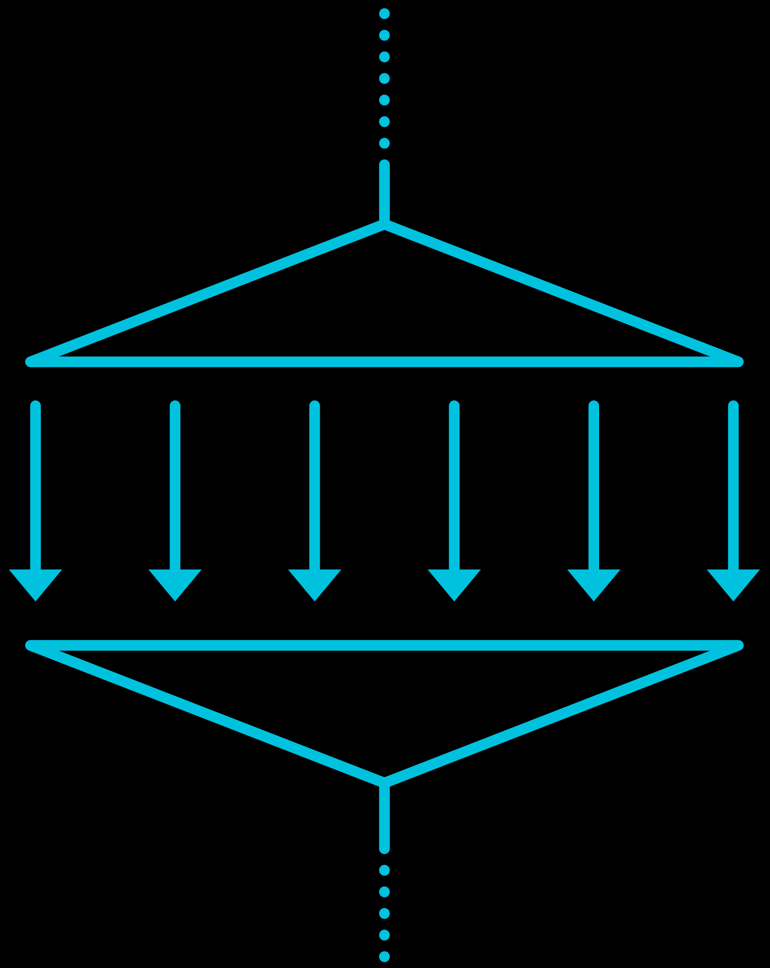
ROCm™ Programming Models

HIP	C++	StdPar
OpenMP®	C	ROCm™ Libs
OpenCL™	Fortran	hipFORT

OpenMP® Fundamentals



OpenMP® Fundamentals



Compiler

OpenMP® and C++

```
void saxpy(float a, const float* x, float* y, unsigned int size) {

  #pragma omp target teams distribute parallel for \
              map(to: x[0:size]) map(tofrom: y[0:size])
  for (int i = 0; i < size; ++i)
    y[i] = a * x[i] + y[i];

}
```

OpenMP® and C++

```
int main() {
  float a = .8f;
  float *x = new float[size];
  float *y = new float[size];

  #pragma omp target teams distribute parallel for \
              map(to: x[0:size]) map(tofrom: y[0:size])
  for (int i = 0; i < size; ++i)
    y[i] = a * x[i] + y[i];

  return 0;
}
```

Initialization omitted for brevity

Printing y and deletion omitted for brevity

OpenMP® and Fortran

```
subroutine saxpy(x,y,size,a)
  real :: a, x(:), y(:)
  integer :: size, i
  !$omp target teams distribute parallel do map(to: x) map(tofrom: y)
  do i = 1, size
    y(i) = a*x(i)+y(i)
  enddo
end subroutine saxpy
```

ROCm™ Programming Models

HIP	C++	StdPar
OpenMP®	C	ROCm™ Libs
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C++ and StdPar

```
void saxpy(float a, std::vector<float> &x, std::vector<float> &y) {

  std::transform(x.begin(), x.end(), y.begin(), y.begin(),
                   [a](float xi, float yi) { return a * xi + yi; });

}
```

C++ and StdPar

```
void saxpy(float a, std::vector<float> &x, std::vector<float> &y) {

  std::transform(std::execution::par_unseq,
                 x.begin(), x.end(), y.begin(), y.begin(),
                 [a](float xi, float yi) { return a * xi + yi; });

}
```

ROCm™ Libraries

```
rocblas_create_handle(&handle);

// -- Allocate and initialize/copy device d_x and d_y; h_alpha on host

rocblas_set_pointer_mode(handle, rocblas_pointer_mode_host);

rocblas_saxpy(handle, n, &h_alpha, d_x, incx, d_y, incy);

// -- Copy result back to host

rocblas_destroy_handle(handle);
```

ROCm™ Libraries

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ROCm™ Programming Models

HIP

C++

StdPar

OpenMP®

C

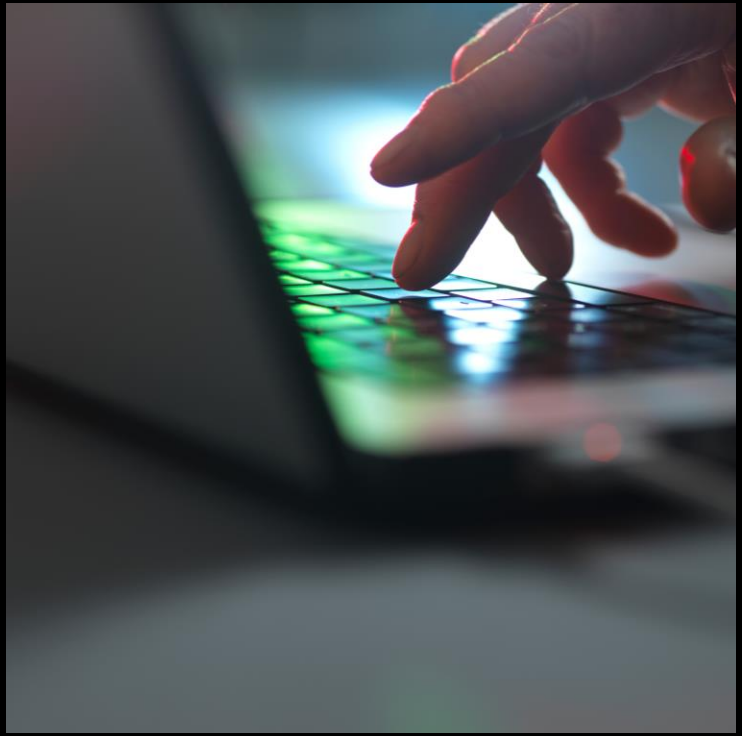
ROCm™ Libs

OpenCL™

Fortran

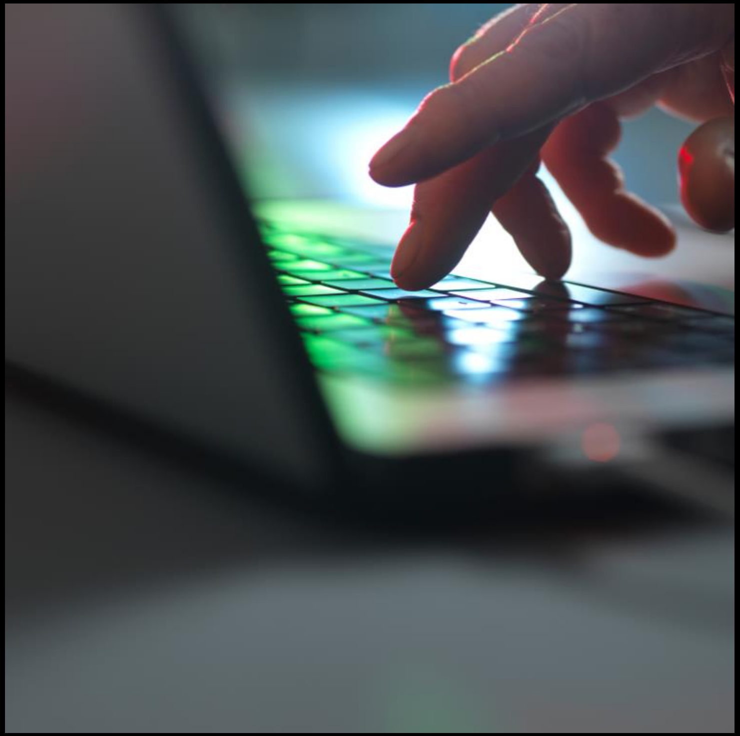
hipFORT

Next Generation Fortran Compiler Journey

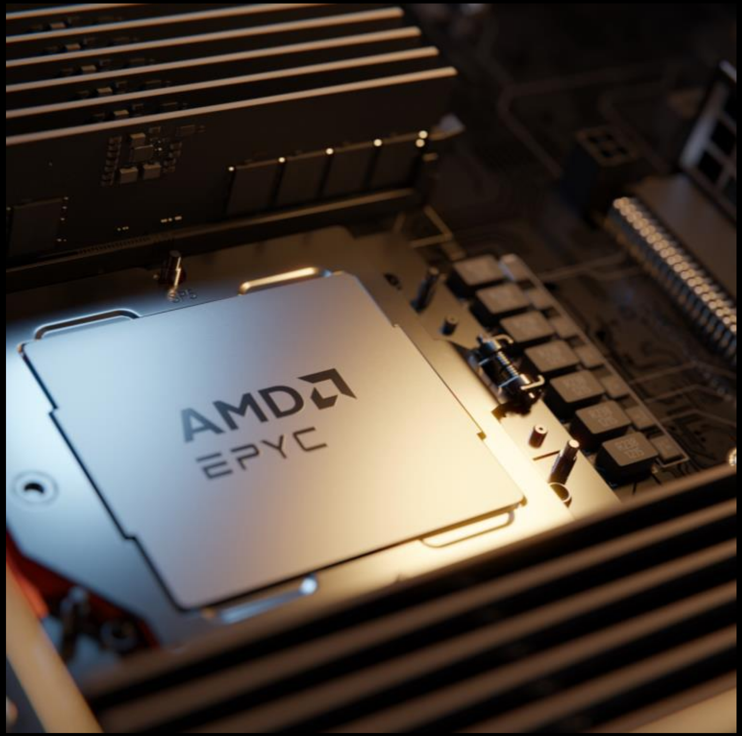


Fortran Language

Next Generation Fortran Compiler Journey

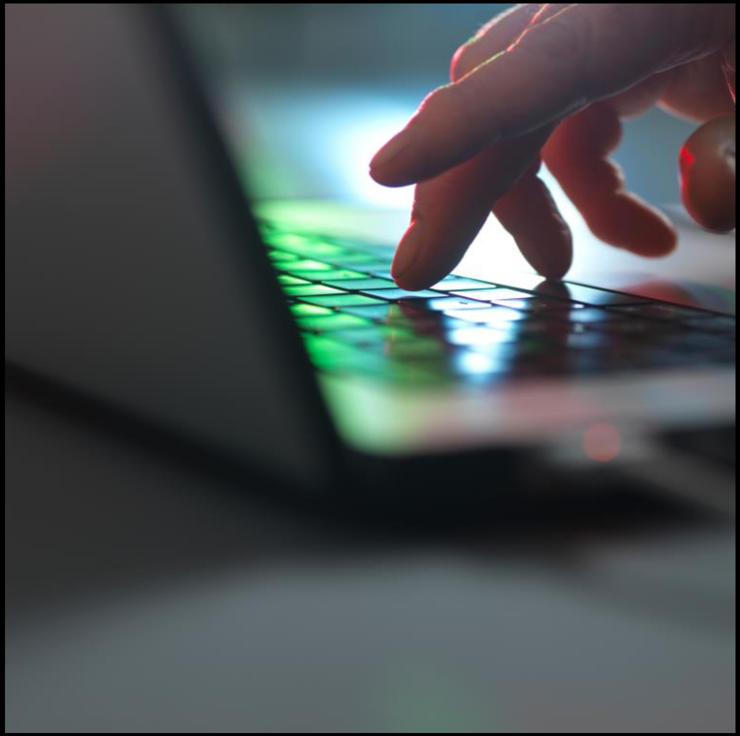


Fortran Language

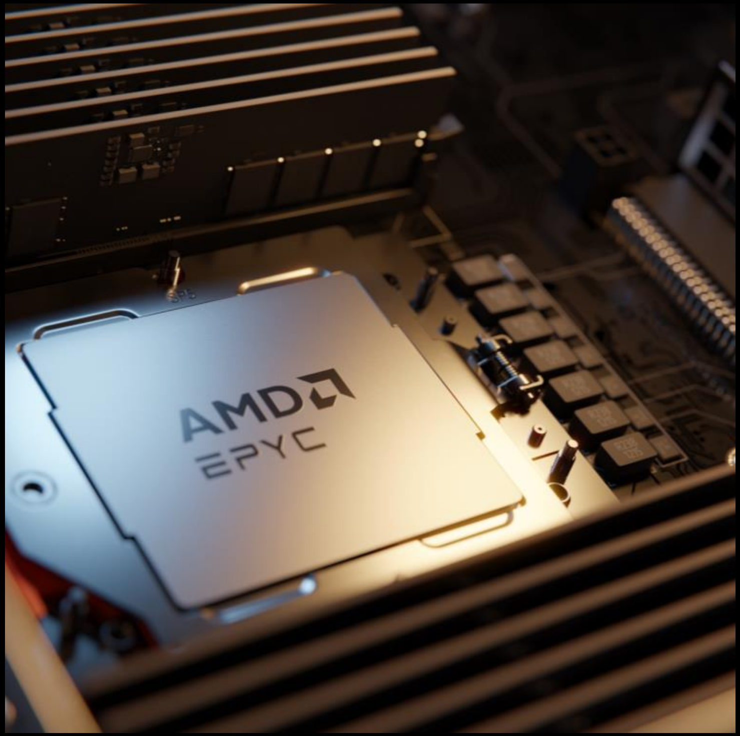


OpenMP® Host Support

Next Generation Fortran Compiler Journey



Fortran Language



OpenMP® Host Support

OpenMP® GPU Support

Fortran Journey Blog Post

Jacobi Solver

```
module jacobi_mod
  use kind_mod, only: RK
  implicit none

  type :: jacobi_t
    real(kind=RK), allocatable :: u(:,:), rhs(:,:), au(:,:), res(:,:)
  end type jacobi_t

  contains
    < Next Slides >

end module jaboci_mod
```

Jacobi Solver

```
subroutine init_jacobi(this, mesh)
  type(jacobi_t), intent(inout) :: this
  type(mesh_t), intent(inout) :: mesh

  allocate( < All components > )
  ! ... Initialization code removed for brevity ...

  !$omp target enter data map(to:this%u,this%rhs,this%au,this%res)

  ! ... some code removed for brevity ...
end subroutine init_jacobi
```

Jacobi Solver

```
subroutine run_jacobi(this, mesh)
  do while (this%iters < max_iters .and. resid > tolerance)

    call laplacian(mesh,this%u,this%au)
    call boundary_conditions(mesh,this%u,this%au)
    call update(mesh,this%rhs,this%au,this%u,this%res)

    resid = norm(mesh,this%res)

    this%iters = this%iters + 1
  end do
end subroutine run_jacobi
```

Jacobi Solver

```
subroutine run_jacobi(this, mesh)
  do while (this%iters < max_iters .and. resid > tolerance)

    call laplacian(mesh,this%u,this%au)
    call boundary_conditions(mesh,this%u,this%au)
    call update(mesh,this%rhs,this%au,this%u,this%res)

    resid = norm(mesh,this%res)

    this%iters = this%iters + 1
  end do
end subroutine run_jacobi
```

Jacobi Solver

```
subroutine update(mesh,rhs,au,u,res)
  real(kind=RK) :: temp

  !$omp target teams distribute parallel do collapse(2) private(temp)
  do j = 1,mesh%n_y
    do i = 1,mesh%n_x
      temp = rhs(i,j) - au(i,j)
      res(i,j) = temp
      u(i,j) = u(i,j) + temp*factor
    end do
  end do
end subroutine
```

Jacobi Solver

```
function norm(mesh, res) result(norm_val)

  !$omp target teams distribute parallel do collapse(2)
  !$omp& reduction(+:norm_val)
  do j = 1,mesh%n_y
    do i = 1,mesh%n_x
      norm_val = norm_val + res(i,j)**2*dx*dy
    end do
  end do

  norm_val = sqrt(norm_val)/(mesh%n_x*mesh%n_y)
end function norm
```

The ROCm™ Next Generation Fortran Compiler

Latest Preview Available on Infinity Hub

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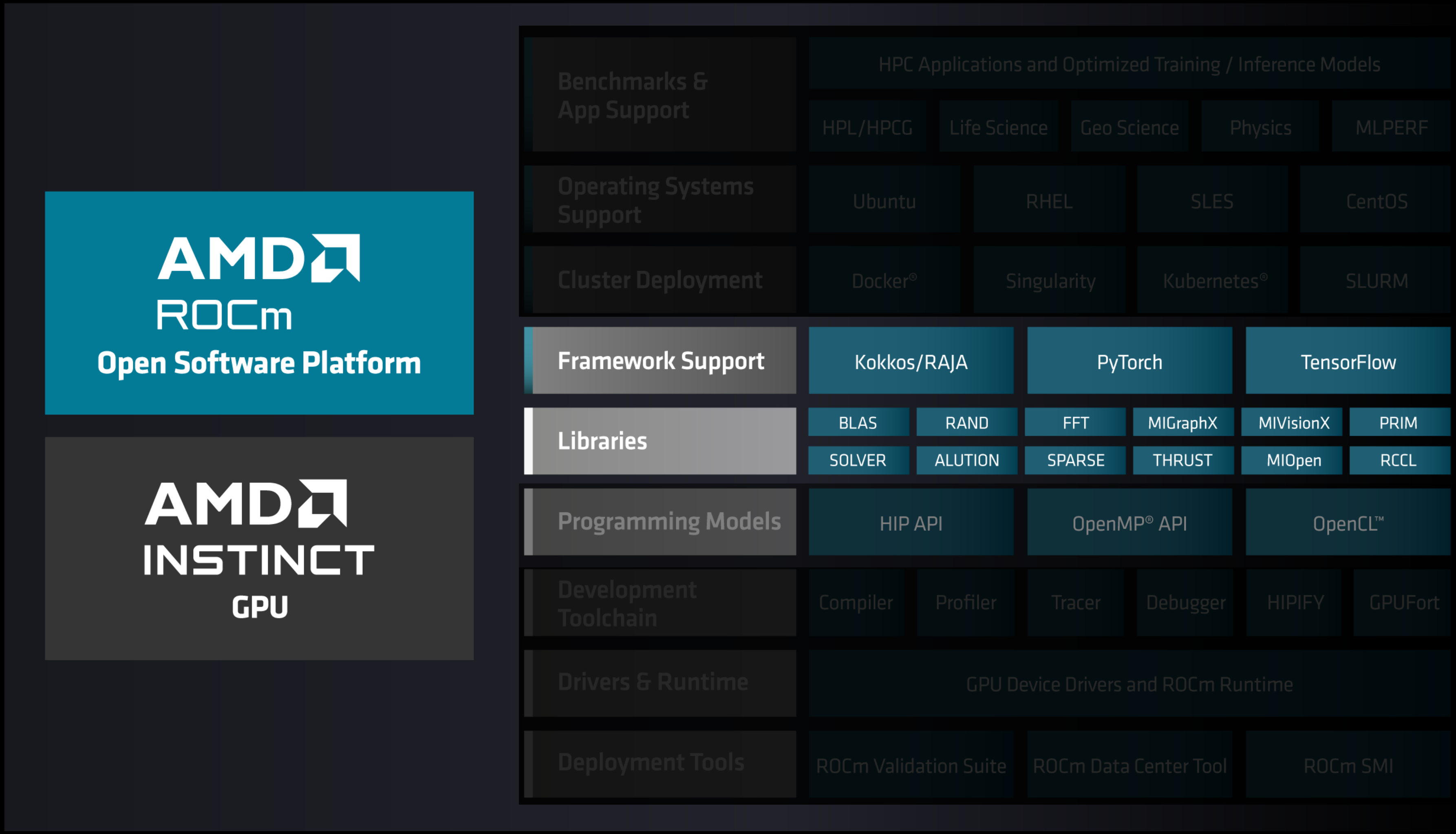
[Public]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SPARSE
THRUST
MIOpen
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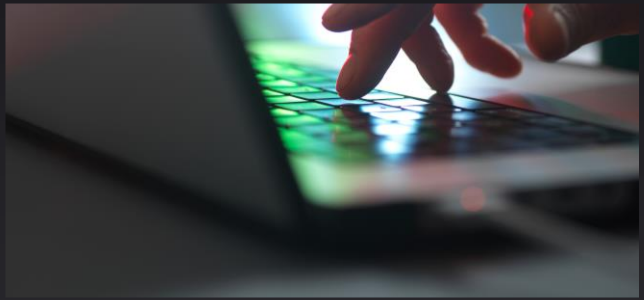
AMD ROCm™

High Performance

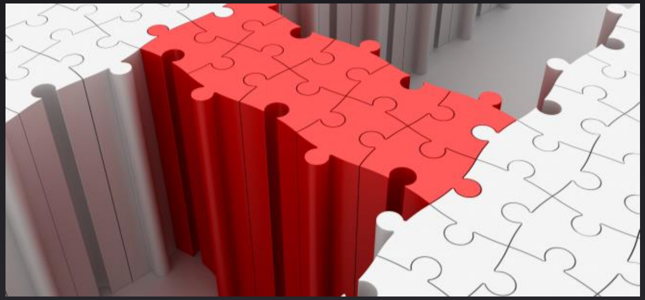
- Powers the top500 list leader
- Solutions for HPC and AI
- Compilers, Libraries, Frameworks

Open Source



- Committed to open ecosystem
- Active community engagement
- Driving development

Portable



- Portable / Standardized languages
- Solutions for evolving accelerators
- Support via third-party libraries

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