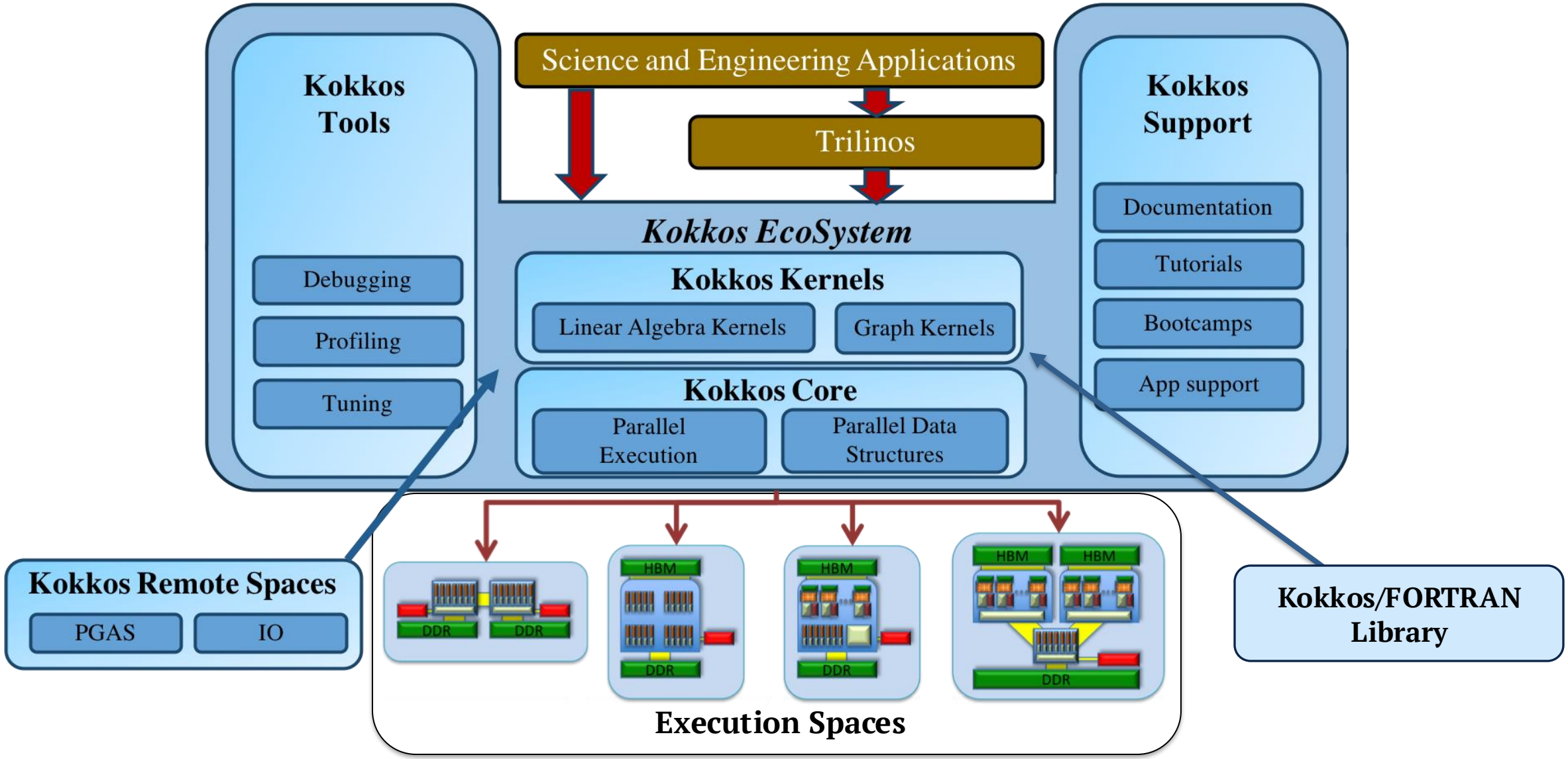
Kokkos

What is Kokkos?

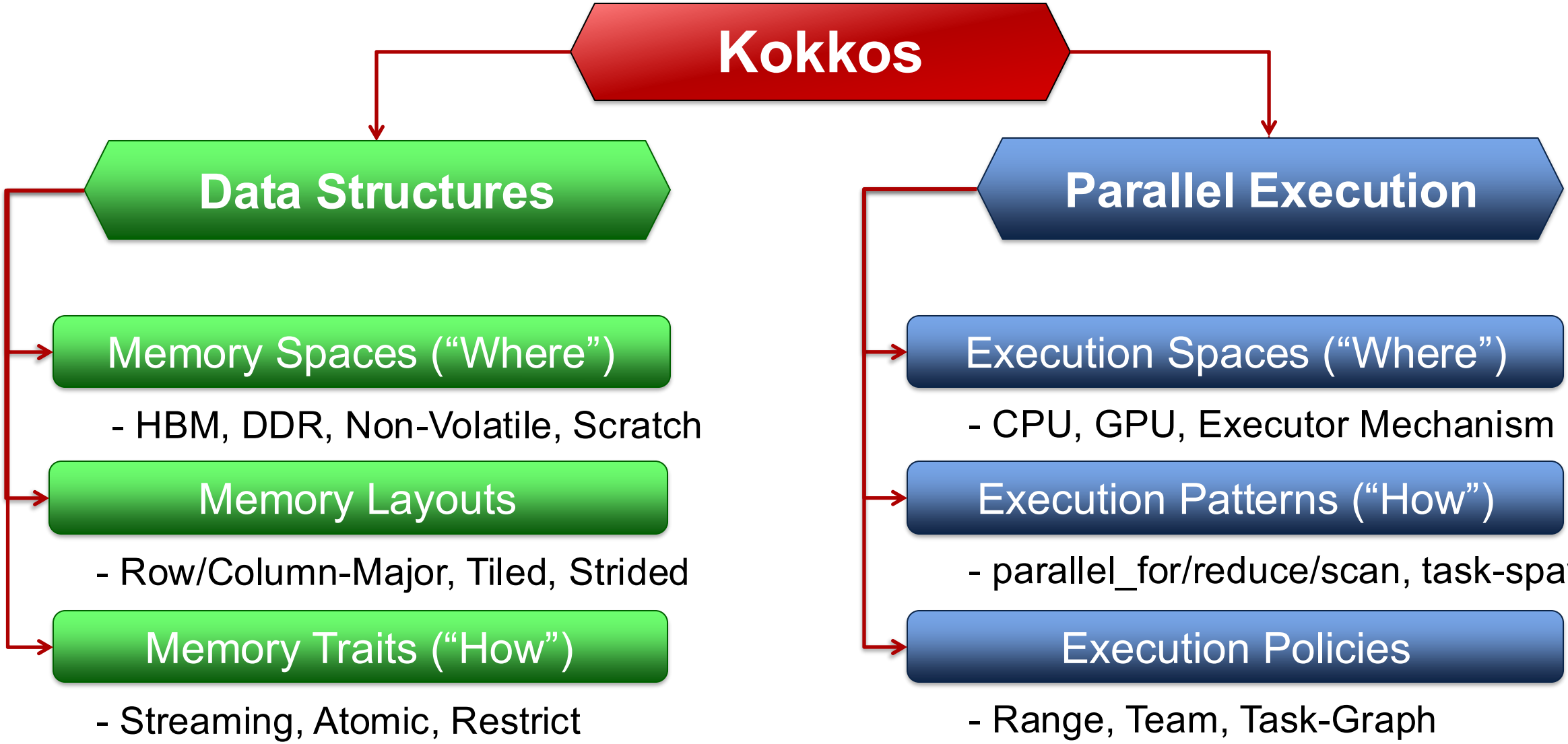
Sandia National Laboratories

- A C++ Programming Model for Performance Portability
  - Implemented as a template library on top of CUDA, OpenMP, SYCL, …
  - Aims to be descriptive not prescriptive
  - Aligns with developments in the C++ standard
- Expanding solution for common needs of modern science/engineering codes
  - Math libraries based on Kokkos
  - Tools which allow inside into Kokkos
- It is Open Source
  - Maintained and developed at https://github.com/kokkos
- It has many users at wide range of institutions.

Kokkos EcoSystem



Kokkos Core Abstractions



Example: Conjugent Gradient Solver

- Simple Iterative Linear Solver
- For example used in MiniFE
- Uses only three math operations:
  - Vector addition (AXPBY)
  - Dot product (DOT)
  - Sparse Matrix Vector multiply (SPMV)
- Data management with Kokkos Views:

```
View<double*,HostSpace,MemoryTraits<Unmanaged> >  h_x(x_in, nrows);
View<double*> x("x",nrows);
deep_copy(x,h_x);
```

CG Solve: The AXPBY

- Simple data parallel loop: Kokkos::parallel_for
- Easy to express in most programming models
- Bandwidth bound
- Serial Implementation:

```
void axpby(int n, double* z, double alpha, const double* x,
                  double beta,  const double* y) {
  for(int i=0; i<n; i++)
    z[i] = alpha*x[i] + beta*y[i];
}
```

- Kokkos Implementation:

```
void axpby(int n, View<double*> z, double alpha, View<const double*> x,
                  double beta,  View<const double*> y) {
  parallel_for("AXpBY", n, KOKKOS_LAMBDA ( const int i) {
    z(i) = alpha*x(i) + beta*y(i);
  });
}
```

Parallel Pattern: for loop

String Label: Profiling/Debugging

Execution Policy: do n iterations

Loop Body

Iteration handle: integer index

Kokkos Parallelism

- **Simple** usage is similar to OpenMP, advanced features are also straightforward
- Three common **data-parallel patterns** are parallel for, parallel reduce, and parallel scan.
- A parallel computation is characterized by its **pattern, policy, and body**.
- User **provides computational bodies** as functors or lambdas which handle a single work item.

```
double * x = new double[N]; // also y and z
parallel_for(”AXpBY", N, [=] (const int64_t i) {
   z[i] = alpha * x[i] + beta * y[i];
 });
```

Lambda

```
struct Functor {
double *_x, *_y, *_z, _a, _b;
void operator ()( const int64_t i) const {
   _z[i] = _a * _x[i] + _b * _y[i]; }
};
```

Functor

Kokkos Memory Management

- Data is stored in Views that are “pointers” to **multi-dimensional arrays** residing in **memory spaces**.
- Views **abstract away** platform-dependent allocation, (automatic) deallocation, and access.
- **Heterogeneous nodes** have one or more memory spaces.
- **Mirroring** is used for performant access to views in host and device memory.

```
// Create view array in device memory space.
using view_type = Kokkos::View<double*, Space>;
view_type view (…);

// Mirror view in host memory space.
view_type::HostMirror hostView = Kokkos::create_mirror view(view);

// Fill host view from input.
populateView(hostView);

// Copy host view to view on device.
Kokkos::deep copy(view, hostView);

// Use the view on the device.
Kokkos::parallel_for(…
```

Quickstart

kokkos_user@aurora:> git clone https://github.com/kokkos/kokkos-tutorials.git

kokkos_user@aurora:> module load kokkos cmake

kokkos_user@aurora:> env | grep KOKKOS
KOKKOS_ROOT=/opt/aurora/24.347.0/spack/unified/0.9.2/install/linux-sles15-x86_64/oneapi-2025.0.5/kokkos-4.5.01-kcmoh6f

kokkos_user@aurora:> cd kokkos-tutorials/Exercises/04
kokkos_user@aurora:> ls
Begin Solution

kokkos_user@aurora:> cd Solution
kokkos_user@aurora:> cmake -B build_sycl -DKokkos_ENABLE_SYCL=ON

kokkos_user@aurora:> cmake –build build_sycl

Resources

- **Getting Started**
  - Kokkos Tutorials: https://github.com/kokkos/kokkos-tutorials
  - Kokkos Lectures: https://kokkos.org/kokkos-core-wiki/tutorials-and-examples/video-lectures.html
- **Documentation**
  - Kokkos Documentation: https://kokkos.org/kokkos-core-wiki/
  - Kokkos git: https://github.com/kokkos/kokkos
- **Running on Aurora**
  - Kokkos on Aurora: https://docs.alcf.anl.gov/aurora/programming-models/kokkos-aurora/
  - Running jobs on Aurora: https://docs.alcf.anl.gov/aurora/running-jobs-aurora/
- **Getting Help**
  - ALCF Help: https://docs.alcf.anl.gov/support/
  - Kokkos Slack: https://kokkosteam.slack.com