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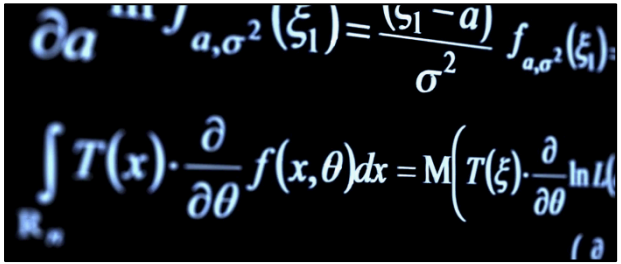

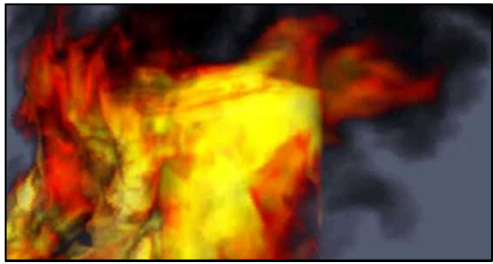

Profiling Kokkos Applications

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Center for Computing Research, Sandia National Laboratories/NM

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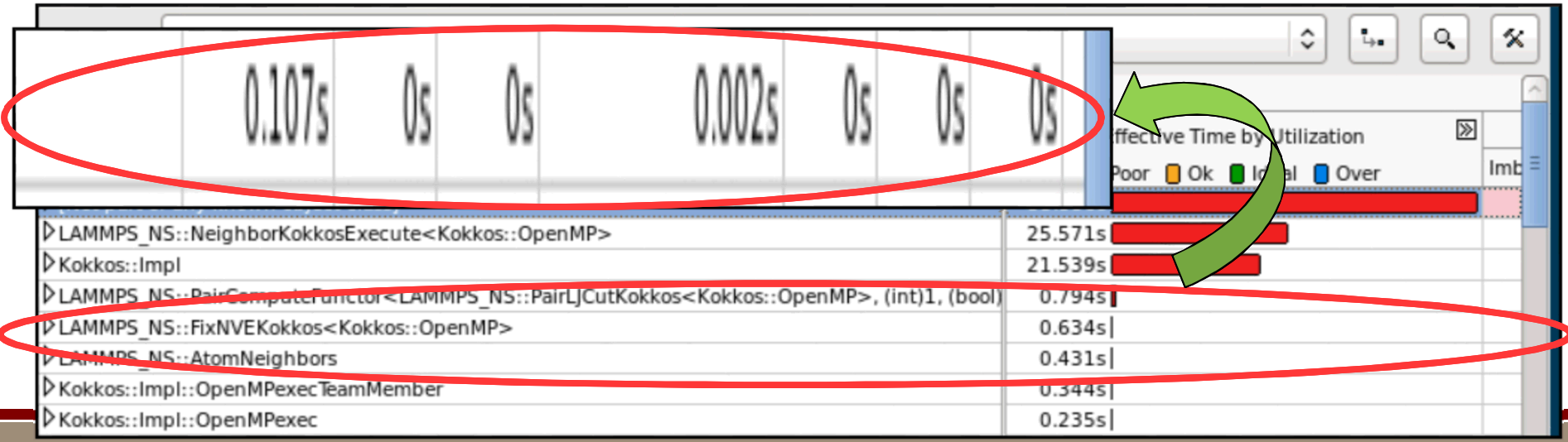
Background

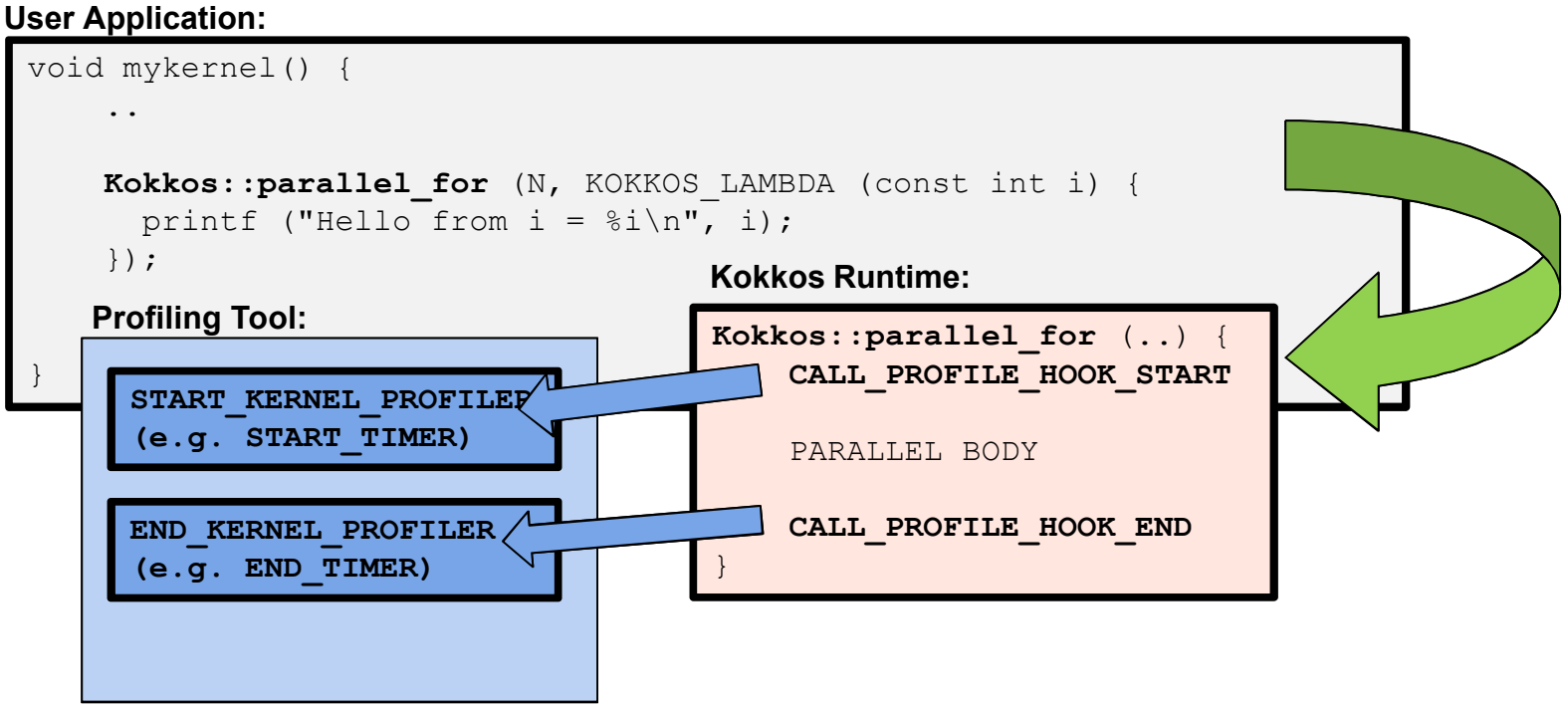
- Greater adoption of Kokkos within Sandia and ECP has driven stronger focus on performance analysis capabilities
- C++ abstractions of Kokkos, particularly with OpenMP challenge existing tools
- Desire for continuous monitoring of overnight testing/builds



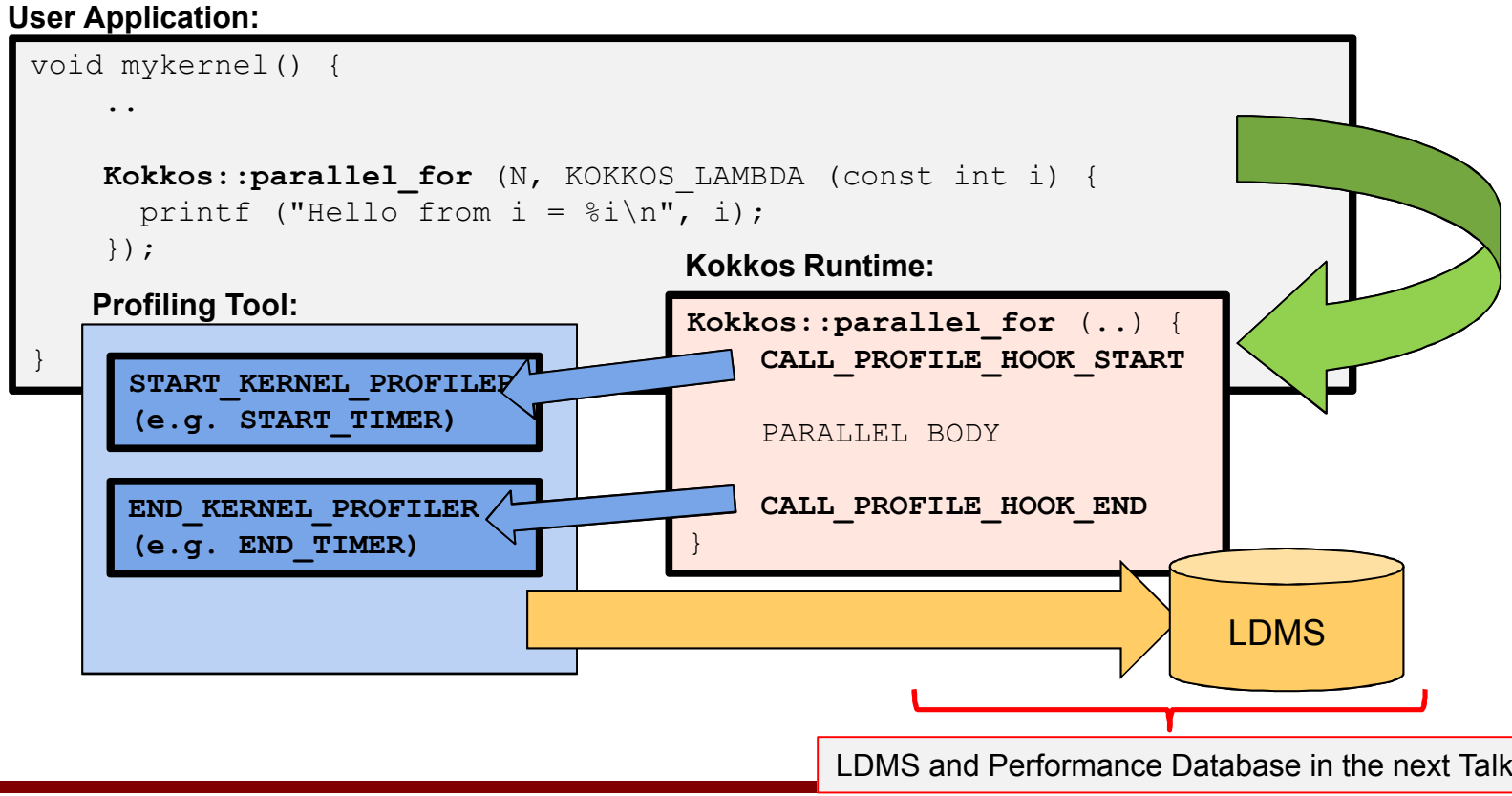
History

- Lightweight performance instrumentation using dynamic tool loading was explored in a Sandia LDRD during 2012
  - Mechanism to instrument loops in preparation for vectorization analysis during Knights Landing exploration
- Initial exploration for Kokkos parallel patterns in 2014
- Profiling of parallel region and data allocations/copying requires **no code instrumentation** based on feedback from users
  - Want a single binary to be able to be profiled without recompilation

Kokkos Profiling Overview

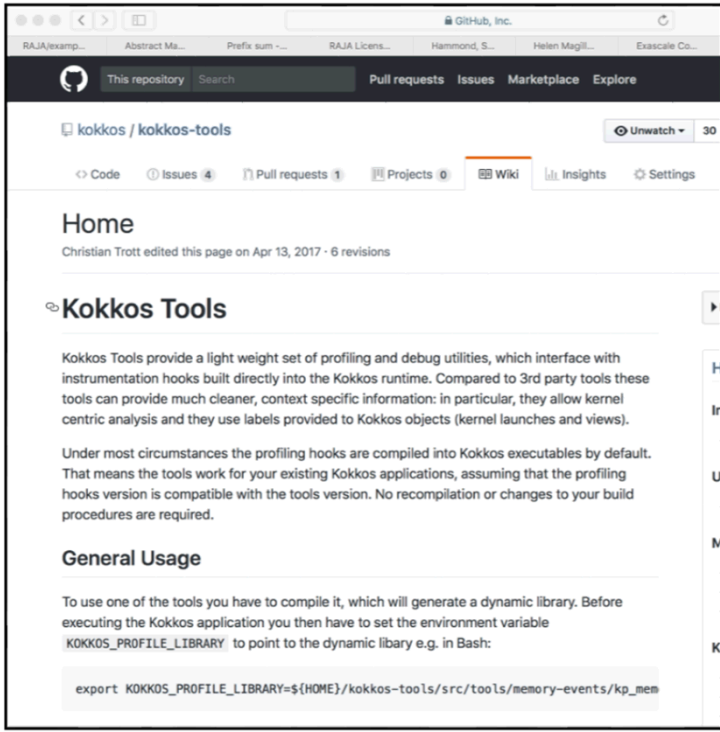


Kokkos Profiling Overview



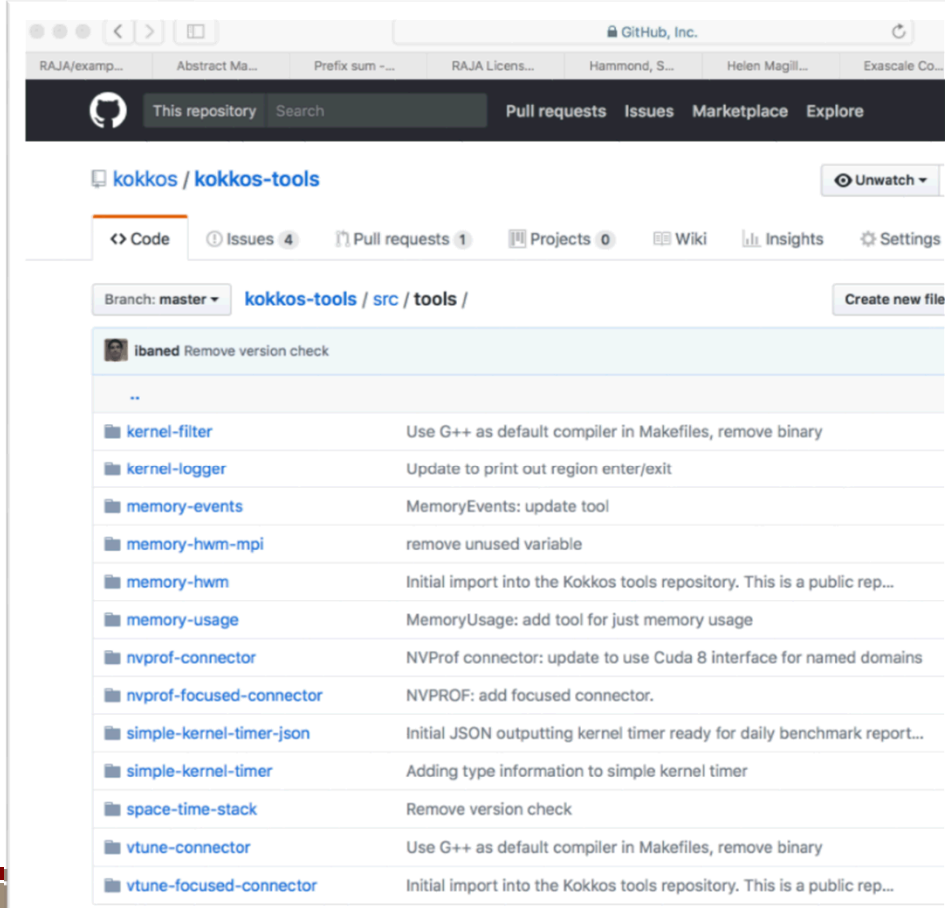
Updates in the Profiling Interface

- Added hooks to track allocations performed in Kokkos
  - Typically the largest consumers of memory in an application/HWM
  - Want to track NVLINK operations
- Unstructured profiling sections/regions
  - Used in Trilinos to provide better insights into solver performance
- Documentation



Lightweight Tools in House

- Memory events tracking
  - Allocations, copying etc
  - Memory high water mark
- Connectors for NVIDIA Profiler and Intel VTune
  - Prototypes for CrayPAT and Allinea MAP
- TAU and HPCToolkit added interfaces for ECP



Example Use Cases (Memory)

# Time	Ptr	Size	MemSpace	Op	Name
0.002958	0x7f5c9dd030a0	8998912	Host	Allocate	Vector
0.004280	0x7f5c9d46d0a0	8998912	Host	Allocate	Vector
0.005055	0x7f5c9cbd70a0	8998912	Host	Allocate	Vector
2.008489	0x2c60470	4499464	Host	Allocate	MatrixRowOffsets
2.009254	0x7f5c40b0f0a0	119164000	Host	Allocate	MatrixLocalIndicies
2.017489	0x7f5c327c50a0	238328000	Host	Allocate	MatrixValues
4.638244	0x7f5c7f76a0a0	8998912	Host	Allocate	no-label
4.832563	0x373b0d0	562440	Host	Allocate	MatrixRowOffsets
4.832609	0x7f5c7c72e0a0	14609056	Host	Allocate	MatrixLocalIndicies
4.833970	0x7f5c6a4220a0	29218112	Host	Allocate	MatrixValues
5.154044	0x3a12ed0	1124864	Host	Allocate	Vector
5.154236	0x3b25970	1124864	Host	Allocate	Vector
5.154358	0x3c38410	8998912	Host	Allocate	Vector
5.155568	0x44cd4b0	1124864	Host	Allocate	no-label
5.178790	0x4fa7bf0	70312	Host	Allocate	MatrixRowOffsets
5.178849	0x4fba010	1755904	Host	Allocate	MatrixLocalIndicies
5.179045	0x5166bb0	3511808	Host	Allocate	MatrixValues
5.217818	0x4646f40	140608	Host	Allocate	Vector
5.218140	0x4669520	140608	Host	Allocate	Vector
5.218422	0x468bb00	1124864	Host	Allocate	Vector
5.220563	0x479e5a0	140608	Host	Allocate	no-label
5.223459	0x4903620	8792	Host	Allocate	MatrixRowOffsets
5.223489	0x49069f0	202616	Host	Allocate	MatrixLocalIndicies

HPCG Kokkos Data Allocation Profile

Example Use Cases (Kernel Time)

Reference: ComputeSPMV (Region)	0.83942	205	0.00409	7.219	2.422
Main: Validation Testing Phase (Region)	0.73603	1	0.73603	6.330	2.123
Main: Reference SpMV+MG (Region)	0.31914	1	0.31914	2.744	0.921
Optimized: ComputeDotProduct (Region)	0.09877	474	0.00021	0.849	0.285
Optimized: ComputeWAXPBY (Region)	0.08671	468	0.00019	0.746	0.250
Reference: ComputeDotProduct (Region)	0.04568	151	0.00030	0.393	0.132
Main: Reference CG::OptimizeProblem (Region)	0.03189	1	0.03189	0.274	0.092
Reference: ComputeWAXPBY (Region)	0.03050	150	0.00020	0.262	0.088
Main: Clean up (Region)	0.01020	1	0.01020	0.088	0.029
Main: Report Results (Region)	0.00265	1	0.00265	0.023	0.008
Main: TestNorms (Region)	0.00000	1	0.00000	0.000	0.000

N11KokkosGraph19GraphColoringHandleIKiS1_S1_N6Kokkos6OpenMPENS2_9HostSpaceES4_E16ReduceMaxFunctorE (ParRed)	0.00013	4	0.00003	0.001	0.000
KokkosKernels::Impl::StridedCopy (ParFor)	0.00002	4	0.00000	0.000	0.000

```
---------------------------------------------------------------------
Summary:

Total Execution Time (incl. Kokkos + Non-Kokkos:        34.66302 seconds
Total Time in Kokkos kernels:                           11.62839 seconds
   -> Time outside Kokkos kernels:                      23.03464 seconds
   -> Percentage in Kokkos kernels:                        33.55 %
Total Calls to Kokkos Kernels:                          31732
```

HPCG Kokkos Kernel Timer Profile

Current Work

- Want to expand Kokkos profiling to be useful for continuous integration benchmarking
  - Feedback from ATDM development teams that this is crucial for cross platform perspective
  - Intense focus on parallel kernel performance (natural alignment with Kokkos profiling hooks)

- Add historical analysis/trends capability to inform development teams
- Working with LDMS team for broader performance characterization
  - KokkosP provides strong application connectivity

Information and Tools

Sandia National Laboratories

- Available on the Kokkos Github website
  - http://github.com/kokkos

- Integration into TAU is already complete, HPCToolkit on-going
- Close connection with Score-P and ExaPAPI ECP projects
  - Will soon be able to capture Kokkos events in Score-P tracing operations and view in Vampir

- Tools working on KNL, POWER8/9, ARM, Sky Lake and AMD systems

Kokkos Profiling Overview