2024 HDF5 USER GROUP (HUG) MEETING

U.S. DEPARTMENT OF ENERGY
Office of Science

BERKELEY LAB

Scientific Data Division

Drishti VOL

THE PERFORMANCE PROFILING AND TRACING HDF5 VOL CONNECTOR

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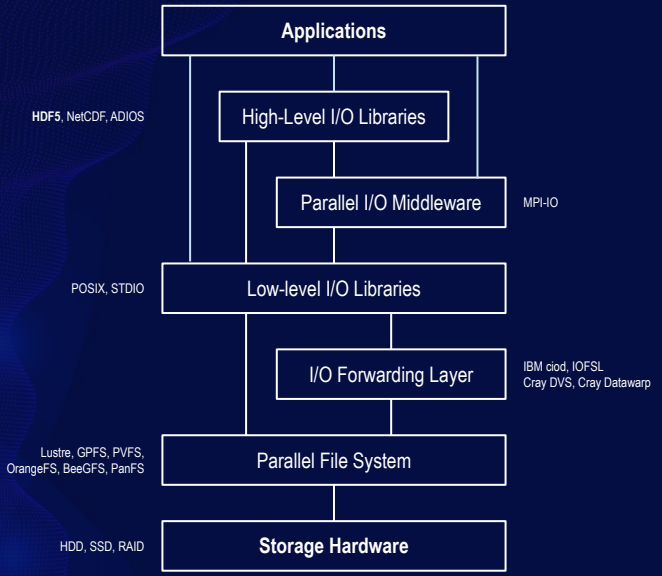
COMPLEX I/O STACK!

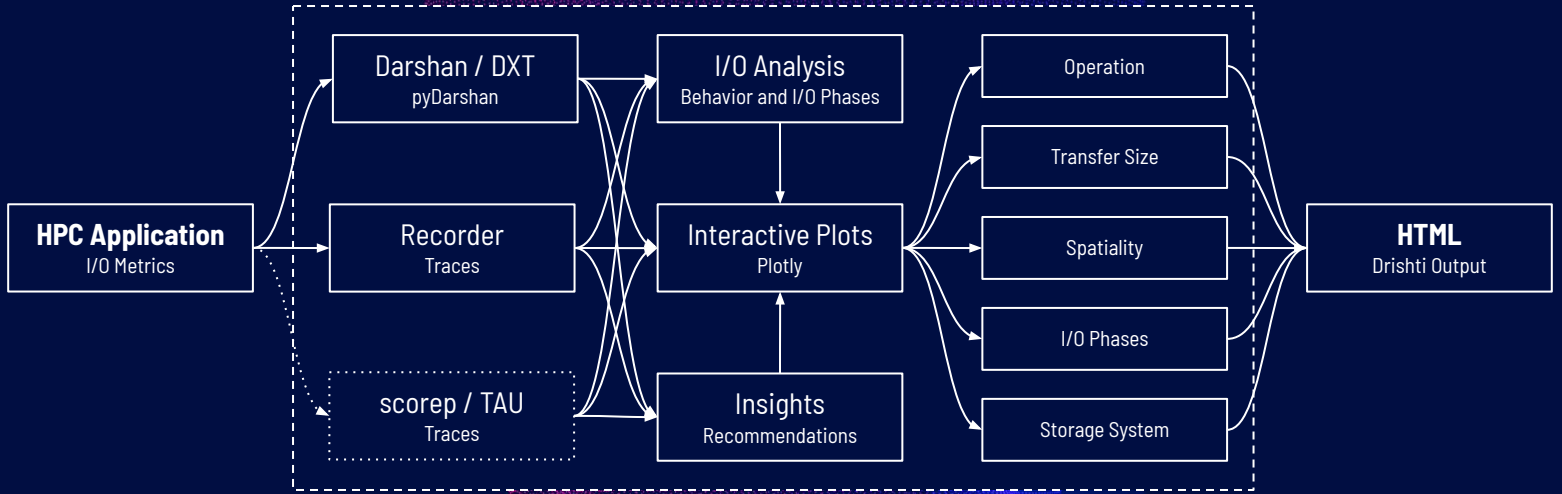
- Using the HPC I/O stack efficiently is a **tricky problem**
- **Interplay of factors** can affect I/O performance
- Various **optimizations** techniques available
- Plethora of tunable **parameters**
- Each layer brings a new set of parameters



WHAT IS THE PROBLEM?

- There is still a gap between profiling and tuning
- How to convert I/O metrics to **meaningful information**?
  - **Visualize** characteristics, behavior, and bottlenecks
  - **Detect** root causes of I/O bottlenecks
  - **Map** I/O bottlenecks into actionable items
  - **Guide** end-user to tune I/O performance
- Towards a **cross-layer** I/O profiling exploration

Drishti


HPC Application
I/O Metrics
Darshan / DXT
pyDarshan
Recorder
Traces
scorep / TAU
Traces
I/O Analysis
Behavior and I/O Phases
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Storage System
HTML
Drishti Output

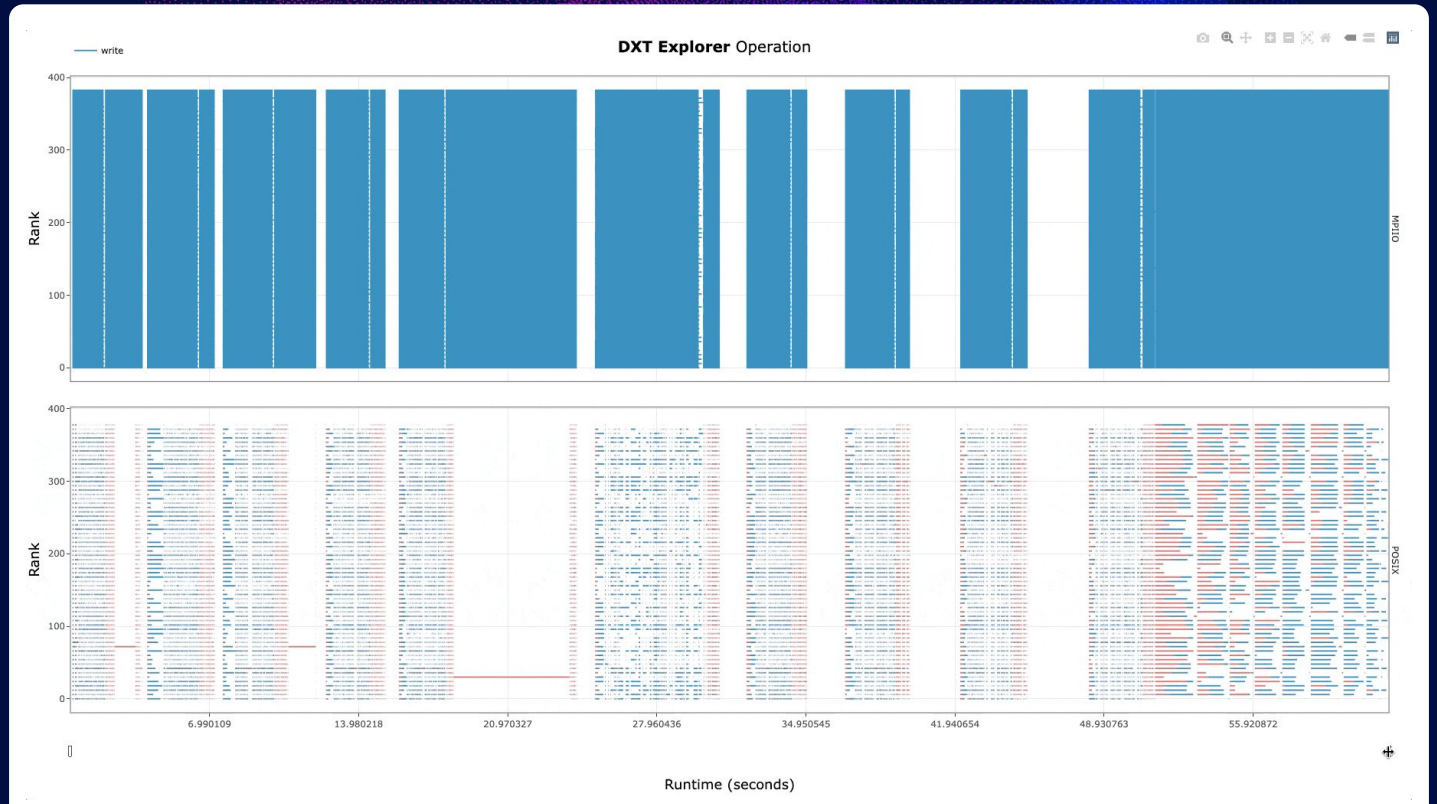
DARSHAN DXT

- Darshan collects **I/O profiling**
- It **aggregates** information
- **Extended tracing** mode (**DXT**)
  - Fine grain view of I/O behavior
  - POSIX or MPI-IO, read/write
  - Rank, segment, offset, size
  - Start and end timestamp

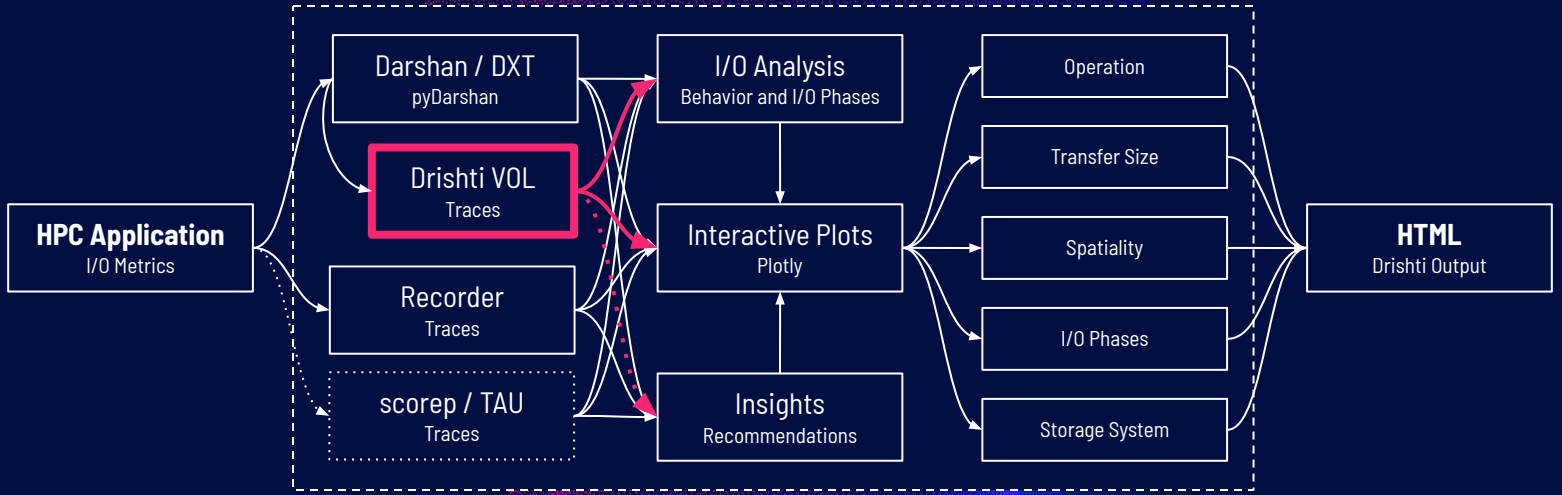
```
# ***************************************************
# DXT_POSIX module data
# ***************************************************

# DXT, file_id: 13771918696892050919, file_name:
/gpfs/alpine/csc300/scratch/houjun/Flash-X-apr8.gcc/FLASH_IO_hdf5_1.10.6/2366525/flash.par
# DXT, rank: 0, hostname: d11n01
# DXT, write_count: 0, read_count: 3
# DXT, mnt_pt: /gpfs/alpine, fs_type: gpfs
# Module    Rank  Wt/Rd  Segment          Offset       Length    Start(s)      End(s)
 X_POSIX       0   read        0               0            783      0.0110      0.0110
 X_POSIX       0   read        1             783              0      0.0111      0.0111
 X_POSIX       0   read        2             783              0      0.0111      0.0111

# DXT, file_id: 17855743881390289785, file_name:
/gpfs/alpine/csc300/scratch/houjun/Flash-X-apr8.gcc/FLASH_IO_hdf5_1.10.6/2366525/flash.log
# DXT, rank: 0, hostname: d11n01
# DXT, write_count: 62, read_count: 0
# DXT, mnt_pt: /gpfs/alpine, fs_type: gpfs
# Module    Rank  Wt/Rd  Segment          Offset       Length    Start(s)      End(s)
 X_POSIX       0  write        0               0            4105      0.0518      0.0527
 X_POSIX       0  write        1            4105            4141      0.0530      0.0530
 X_POSIX       0  write        2            8246            4127      0.0532      0.0532
 X_POSIX       0  write        3           12373            4097      0.0534      0.0547
...
```


write
DXT Explorer Operation
Rank
400
300
200
100
0
MPIIO
POSIX
6.990109
13.980218
20.970327
27.960436
34.950545
41.940654
48.930763
55.920872
Runtime (seconds)

Drishti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WHAT ABOUT HDF5?

- Focus on:
  - The aspects upon which the user might have control
  - Dynamic user metadata defined by the attributes API
  - Operations that go through the VOL
- Ensured **timestamps** (microseconds) from Darshan DXT and VOL will match
- Implemented as a **passthrough** VOL connector
- Designed for use in combination with **Darshan DXT**
- VOL traces stored in **memory** and persisted in a **file-per-process** at the end

github.com/hpc-io/vol-drishti

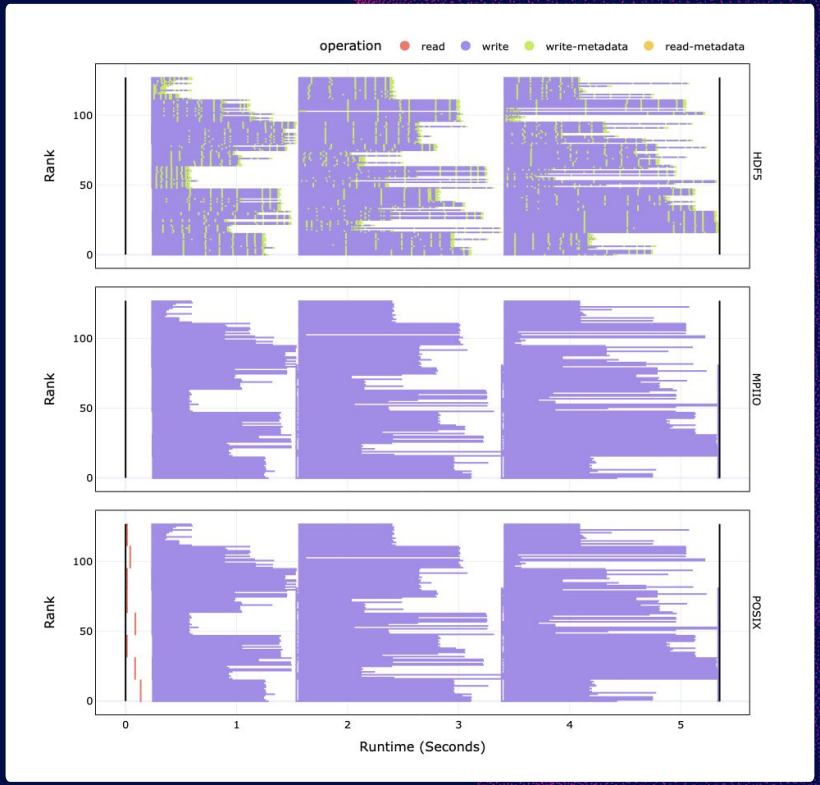
DRISHTI VOL

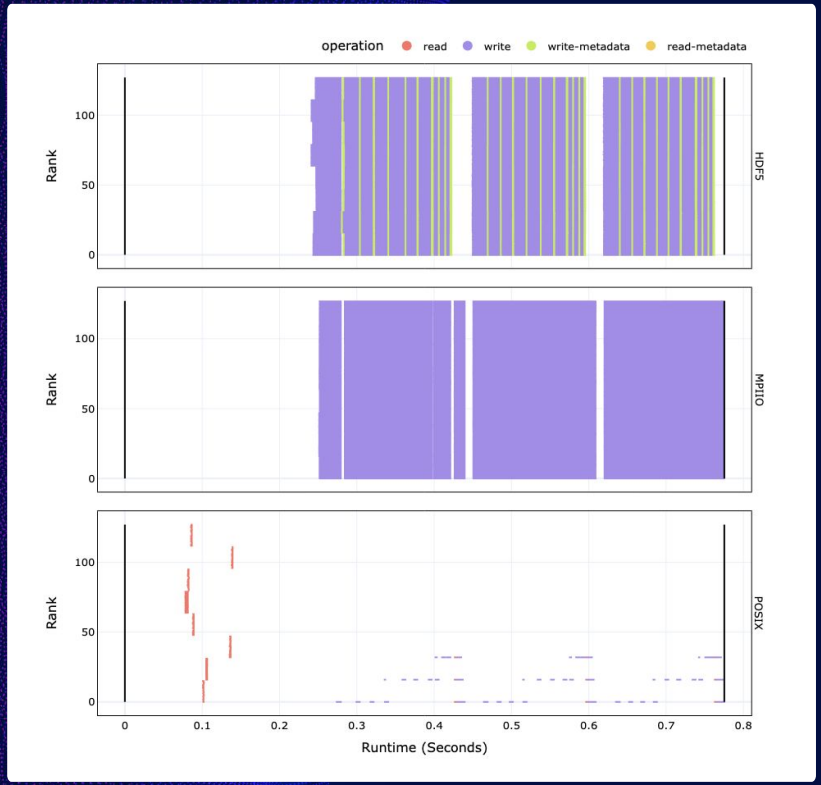
	Operation	File Operations	Drishti-VOL
Datasets	H5Dcreate	✅*	⛔
	H5Dopen	⛔	⛔
	H5Dwrite	✅	✅
	H5Dread	✅	✅
	H5Dclose	⛔	⛔
Attributes	H5Acreate	⛔	⛔
	H5Aopen	⛔	⛔
	H5Awrite	✅	✅
	H5Aread	✅	✅
	H5Aclose	⛔	⛔

* H5Dcreate could result in I/O operations if file space allocation is set

CROSS LAYER EXPLORATION

HDF5 VOL CONNECTOR





OVERHEAD? YES, BUT...

- Our target is exploratory/debug **small-scale** runs to replicate the issue
  - Tracing is **expensive**!
- **Non-negligible** overhead of collecting data from multiple layers of the I/O stack

	Runtime (seconds)			Overhead (Min. %)	Combined Log/Trace
	Min.	Median	Max.		
Baseline	5.99	7.52	8.62	-	-
+ Darshan	6.59	8.03	8.57	+9.62	35.88 KB
+ DXT	6.76	7.53	8.51	+3.03	38.88 MB
+ VOL	7.09	8.73	11.19	+4.88	41.69 MB

CROSS LAYER EXPLORATION

SOURCE CODE

AMREX

DARSHAN | 3 critical issues | 2 warnings | 8 recommendations

- 57 files (2 use STDIO, 1 use POSIX, 10 use MPI-IO)
- Application is write operation intensive (99.98% writes vs. 0.02% reads)
- Application is write size intensive (100.00% write vs. 0.00% read)

- High number (491640) of small write requests (< 1MB)
  - 99.99% of all write requests
  - Observed in 10 files:
    - plt00007.h5 with 49164 (10%) small write requests
      - 1 rank made small write requests to "plt00007.h5"
        - /home/abuild/rpmbuild/BUILD/glibc-2.31/csu/../sysdeps/x86_64/start.S:122
        - /h5bench/amrex/Src/Extern/HDF5/AMReX_PlotFileUtilHDF5.cpp:380
        - /h5bench/amrex/Tests/HDF5Benchmark/main.cpp: 134
        - /h5bench/amrex/Tests/HDF5Benchmark/main.cpp: 24
    - plt00004.h5 with 49164 (10%) small write requests:
      - 1 rank made small write requests to "plt00004.h5"
        - /home/abuild/rpmbuild/BUILD/glibc-2.31/csu/../sysdeps/x86_64/start.S:122
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```
SOLUTION EXAMPLE SNIPPET
MPI_File_open(MPI_COMM_WORLD, "out.txt", MPI_MODE_CREATE|MPI_MODE_WRONLY, MPI_INFO_NULL, &fh);
MPI_File_write_all(fh, &buffer, size, MPI_CHAR, &s);
```

- Detected data transfer imbalance caused by stragglers
  - Observed in 10 shared file:
    - plt00007.h5 with a load imbalance of 100.00%
      - /home/abuild/rpmbuild/BUILD/glibc-2.31/csu/../sysdeps/x86_64/start.S: 122
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      - /h5bench/amrex/Src/Extern/HDF5/AMReX_PlotFileUtilHDF5.cpp: 516
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  - Recommended action:

E3SM

- High number (10878) of small read requests (< 1MB)
  - 100% of all read requests
  - Observed in 1 files:
    - map_f_case_16p.h5 with 49164 (10%) small read requests
      - 1 rank made small write requests to "map_f_case_16p.h5"
        - /h5bench/e3sm/src/drivers/e3sm_io_driver.cpp: 120
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  - Recommended action:
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- High number (4122) of random read operations (< 1MB)
  - 37.89% of all read requests
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    - Below is the backtrace for these calls
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KEY TAKEAWAYS

- Drishti:
  - **Detects** root causes based on metrics
  - **Maps** them to I/O bottlenecks, and
  - **Recommends** actionable items to tune I/O performance
- Drishti uses > 30 triggers to check how an application is accessing data
- Drishti can ingest **multiple sources** of I/O metrics (e.g., Darshan, DXT, Recorder, scorep)
- Drishti VOL connector enhances the reports with **HDF5**-related metrics

github.com/hpc-io/vol-drishti

Drishti

github.com/hpc-io/drishti

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