HDF5 BoF
State of the Union

November 16, 2016

The HDF Group

BoF Session Leaders

DAVID PEARAH,
CEO @ HDF Group

JEROME SOUMAGNE,
HPC Engineer @ HDF Group

*Note: **Quincey Koziol** @ Lawrence Berkeley National Laboratory + **Elena Pourmal** @ HDF Group couldn't attend but send their regards!*

Agenda

1. BACKGROUND: **HDF GROUP + HDF5**
2. FIRST 6 MONTHS
3. SUPPORT PACKAGES
4. HPC VENDOR PARTNER PROGRAM
5. HDF5 1.10: **MARCH 2016**
6. HDF5 1.10.1: **JANUARY 2017**
7. HDF5 ROADMAP: **2017 – 2018**
8. COMMUNITY OUTREACH

Who is the HDF Group?

HDF Group has developed open source solutions for Big Data challenges for nearly 30 years

Small company (40+ employees) with focus on High Performance Computing and Scientific Data

Offices in Champaign, IL + Boulder, CO

Our flagship platform – HDF5 – is at the heart of our open source ecosystem.

Tens of thousands use HDF5 every day, as well as build their own solutions (700+ projects in Github)

“De-facto standard for scientific computing” and integrated into every major analytics + visualization tool

What does the HDF Group do?

Products

- **HDF Platform**
- Connectors: ODBC, Cloud
- Add-Ons: compression, encryption

Support

- Helpdesk
- Support for h5py + PyTables + pandas (NEW)
- Training

Consulting

- HDF: new functionality + performance tuning for specific platforms
- HPC software engineering with scientific domain expertise
- Metadata science and expert services

Our Industries

Financial Services

Oil and Gas

Aerospace

Automotive

Medical & Biotech

Silicon Manufacturing

Electronics Instrument

Government

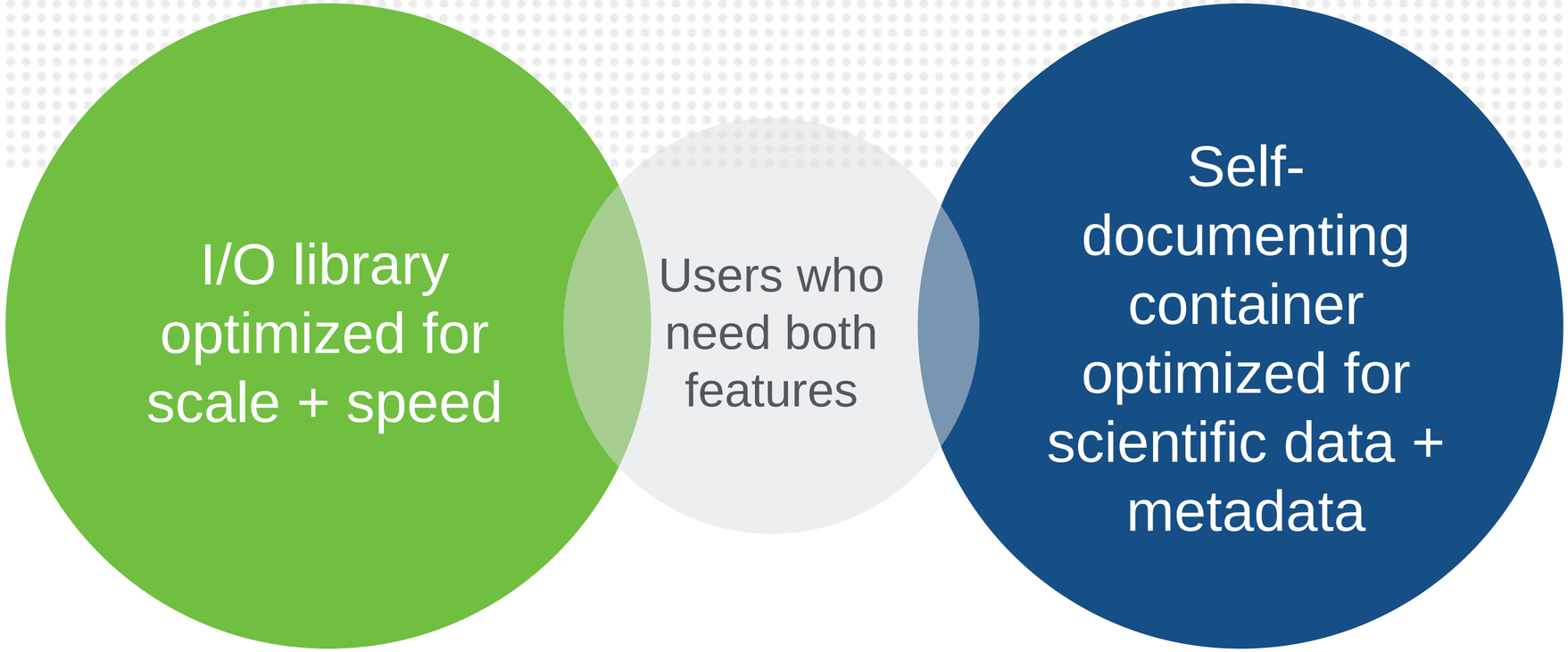
Defense & National Security

Academic Research

A few of our users

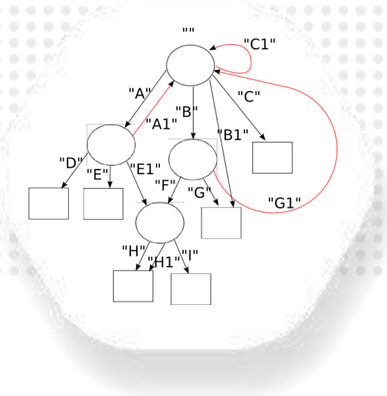
Cargill
Ford
ECP EXASCALE COMPUTING PROJECT
U.S. DEPARTMENT OF ENERGY
NASA
Deutsche Bank
Raytheon
Sandia National Laboratories
CPP INVESTMENT BOARD
SPACEX
SIG SUSQUEHANNA INTERNATIONAL GROUP, LLP
BERKELEY LAB
Lawrence Livermore National Laboratory
jumptrading
Schlumberger
CHOPPER TRADING
MathWorks
bp
akuna capital
CAT
Allotrope Foundation
Bristol-Myers Squibb
McLaren AUTOMOTIVE
CERN
Oxford NANOPORE Technologies
gsk GlaxoSmithKline
RESQML
NOAA
CGNS
AIRBUS
GUGGENHEIM

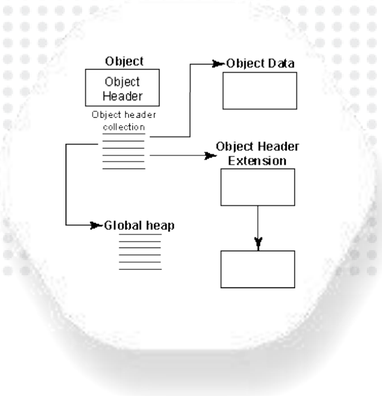
Why Use HDF5?


I/O library optimized for scale + speed
Users who need both features
Self-documenting container optimized for scientific data + metadata

The HDF5 Platform

Marriage of data model + I/O software + binary container





HDF5 **abstract data model**

HDF5 **library**

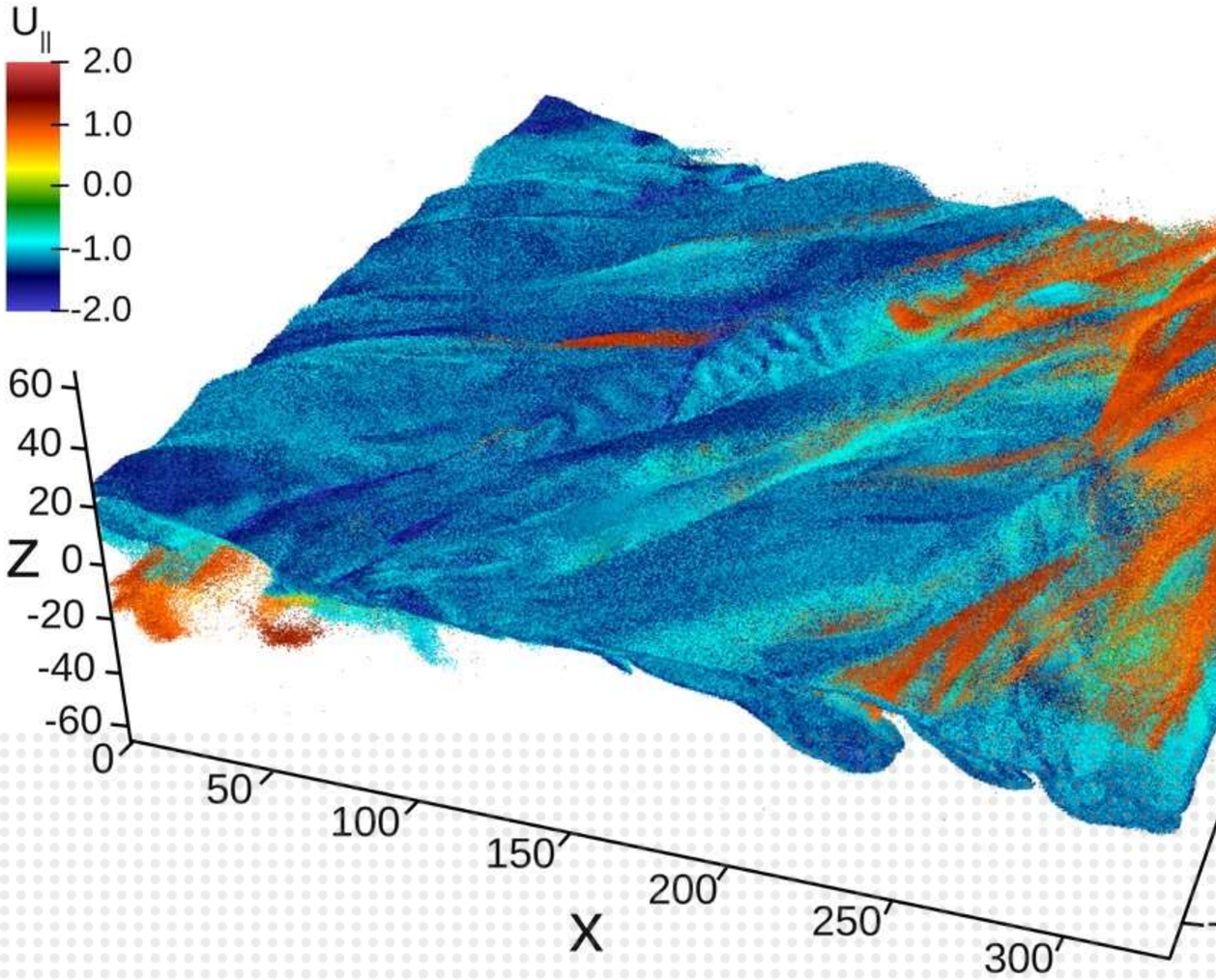
HDF5 **file format**

TRILLION-PARTICLE SIMULATION

Lawrence Berkeley National Laboratory (LBNL)

- Complex collisions of particle that light up the aurora borealis can fracture Earth's magnetic shield and wreak havoc on electronics, power grids, and space satellites

- Visualization of trillion-particle datasets made possible with HDF5 are helping scientists decipher how.

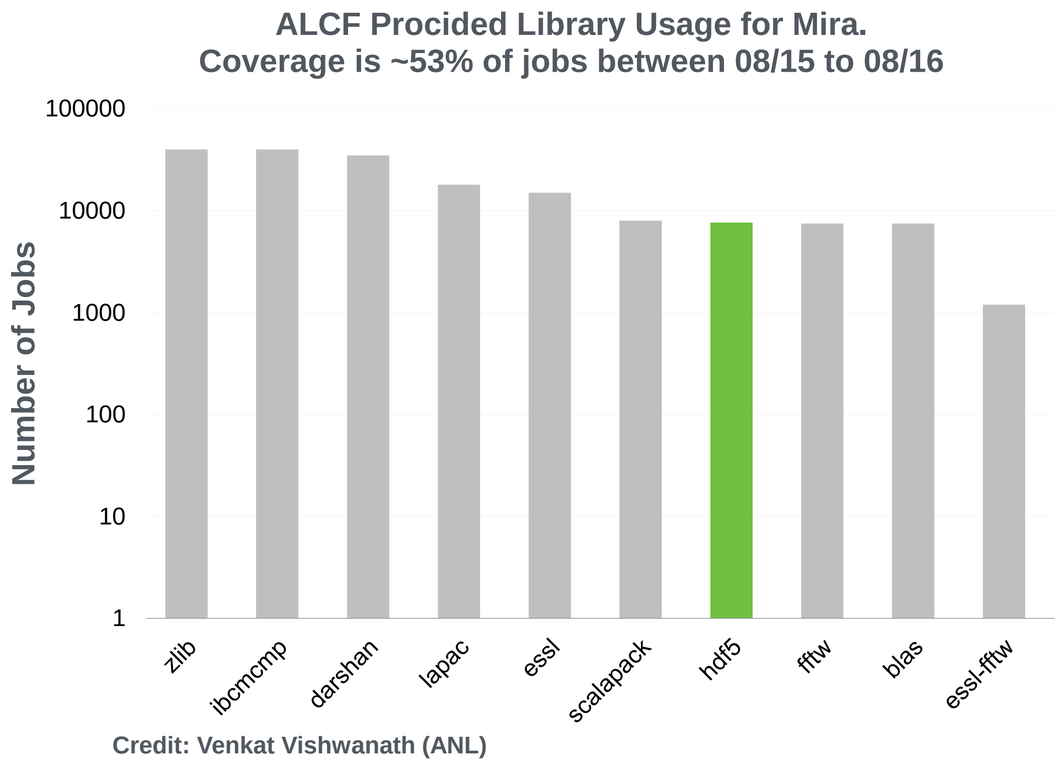


EARTH OBSERVING SYSTEM

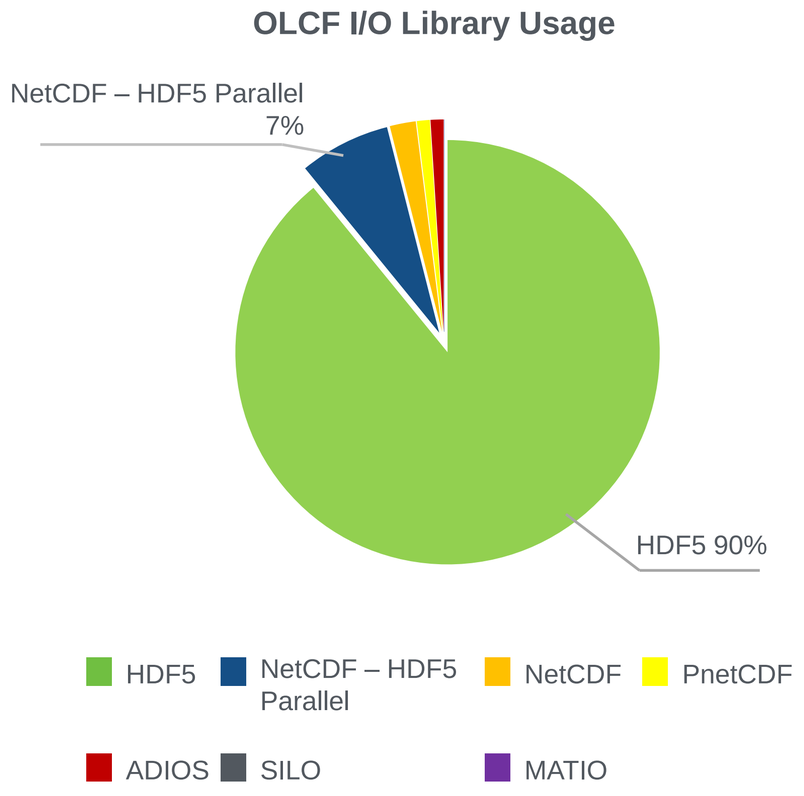
NASA

- Deliver 6,700 Different Data Products to 12 Data Archive Centers
- Nearly 16 terabytes per day are redistributed to more than 1.7 million end users worldwide

I/O library usage on leadership systems



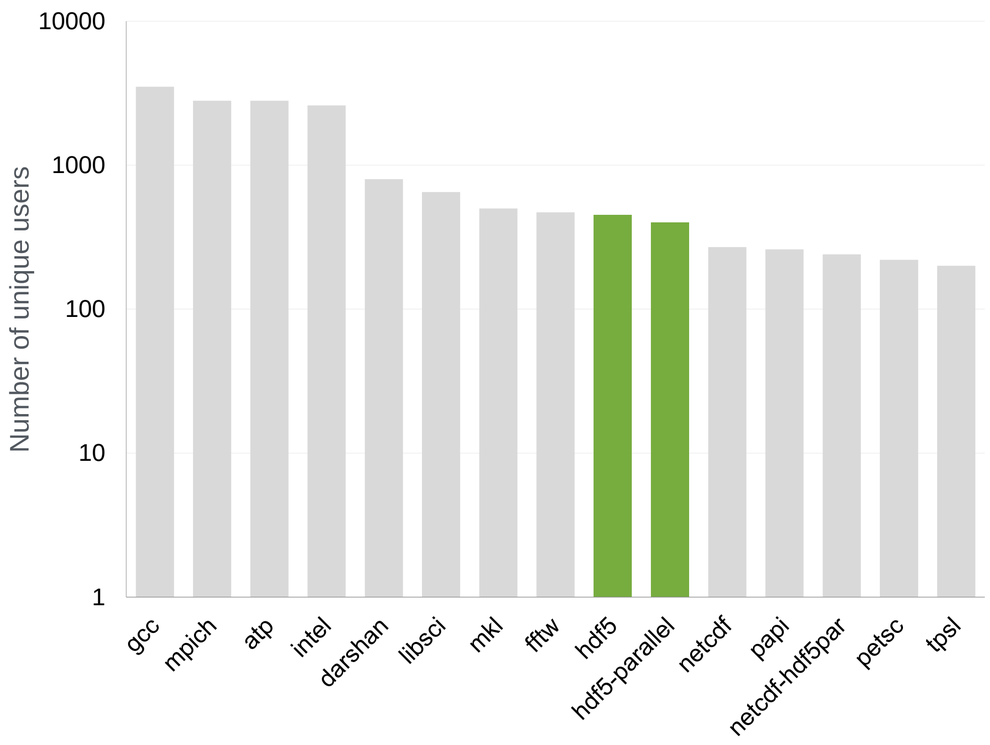
Credit: Venkat Vishwanath (ANL)

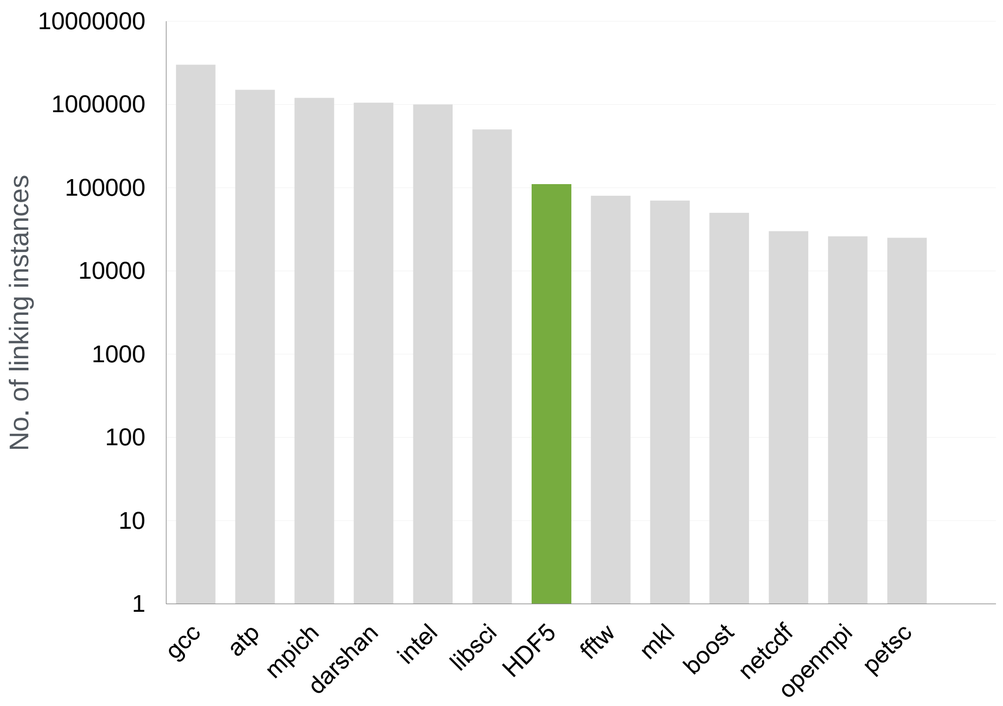


Credit: Scott Atchley (ORNL)

I/O library usage on leadership systems

Library usage on Edition by number of unique users 1/13/2015 to 1/12/2016





Credit: Zhengji Zhao (NERSC)

First 6 Months: What's New

WHAT'S ALREADY WORKING

- Users committed to success of HDF, e.g. community-driven growth from 600 to 700 projects on Github in just 6 months
- HDF5 core platform equals very high quality software
- Reputation + track record of HDF Group: speaks for itself

WHAT'S CHANGING

- **Launched Support Packages**
- **Launched HPC Vendor Partner Program** (to support vendors and end users and also develop optimized + advanced versions of HDF5)
- Increased focus on commercial clients, particularly Fintech
- Added expertise for Big Data (Spark) + Cloud (AWS) products and services
- Expanded engineering team to tackle general HPC + Scientific Data projects… not "just" HDF5

Support Packages (NEW)

- https://www.hdfgroup.org/support/
- **Bigger differentiation between free vs paid support**
  - Retain free HDF Help Desk but more limited in scope and increased reliance on HDF community itself
  - Emphasis on comprehensive support packages
  - Paid support directly funds team that maintains and extends the core platform
- **NEW: Adding official HDF Group support**
  - Python, including Pandas + PyTables + h5py
  - R
  - .NET

Support Packages (NEW)

	Support package:			
	Community	Basic	Pro	Premier
Online knowledgebase + Community Forum	★	★	★	★
Training Videos		★	★	★
Flexible Assistance on HDF Group's Technologies: annual hour for development, testing, support, documentation or training.		10	40	80
Onsite Customized Training			★	★
Email Support: initial response SLA	No SLA	< 2 days	< 1 day	< 4 hours
Phone Support: initial response SLA			< 1 day	< 4 hours
Rapid Issue Response: best efforts for a fix or workaround for your confirmed bugs within 5 days				★
C, C++, Fortran, Java	★	★	★	★
.NET: C#, Visual Basic			★	★
Python: h5py, PyTables, pandas				★
R: rhdf5				★

HPC Vendor Partner Program (NEW)

- **HDF5 works best when**
  - **HPC Vendors** work with HDF Group to develop versions of HDF5 to showcase and take advantage of unique customizations
  - **HPC Users** (e.g. programmers, scientists) have access to HDF5 expertise, particularly when starting out or delving into the more advanced features
- **Examples:**
  - Intel: support for DAOS-M… allowing existing apps built on HDF5 to support their next-generation object store
  - NCSA Blue Waters… working directly with scientists to build and improve their apps
  - European Light Sources centers (DESY + ESRF + DLS)… delivering advanced functionality (compression plugins + VDS + SWMR)

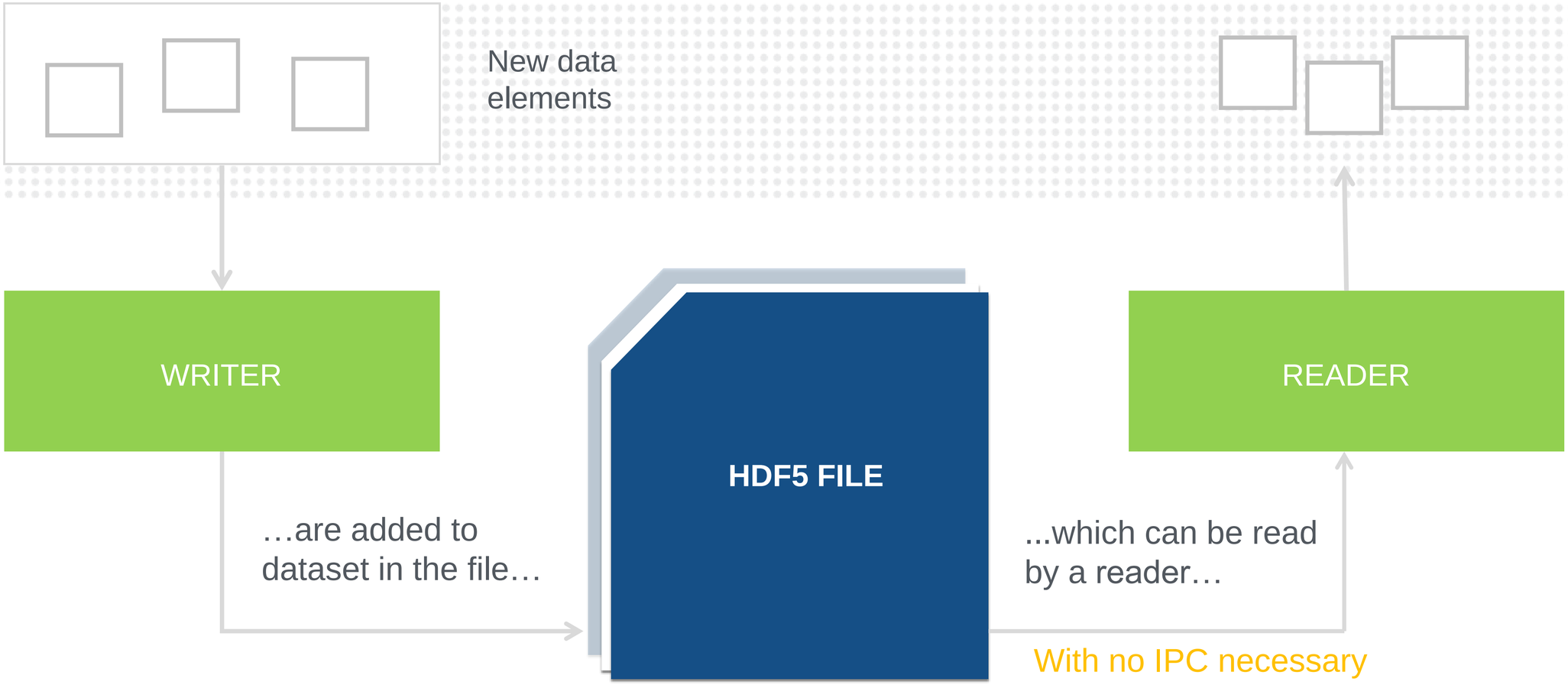
HPC Vendor Partner Program (NEW)

- **We're interested in working with vendors to**
  - Create optimized and custom versions of HDF5: create a competitive advantage through unique configurations
  - Build scientific applications, including working with HPC prospects evaluating your platform as part of the sales process
  - Support platform vendors and their end users (generating additional revenue for platform vendors)
- **As part of this proactive stance, the HDF Group will no longer provide platform-specific support unless we have a partner agreement in place**
  - It takes a lot of work to build and maintain HDF5 to target platforms, and that work needs to be supported.
  - HDF Group will not longer be certifying, testing, or providing releases for platforms outside our Partner Network
  - Questions around 1. building for specific platforms or 2. vendor-created binaries (i.e. not certified by HDF Group) should be directed to the vendor

HDF5 1.10: Released in March 2016

- **Concurrent Read Access (SWMR)**
- **VDS**
- **Parallel I/O performance improvements**
  Collective metadata read and write
- **New internal structures to support SWMR**
- **1.10.0 is compatible by default with 1.8 and only incompatible when new features (like SWMR or VDS) are used**
  h5format_convert (rewrite just metadata in place) to have 1.8 file

Concurrent Read Access (SWMR)

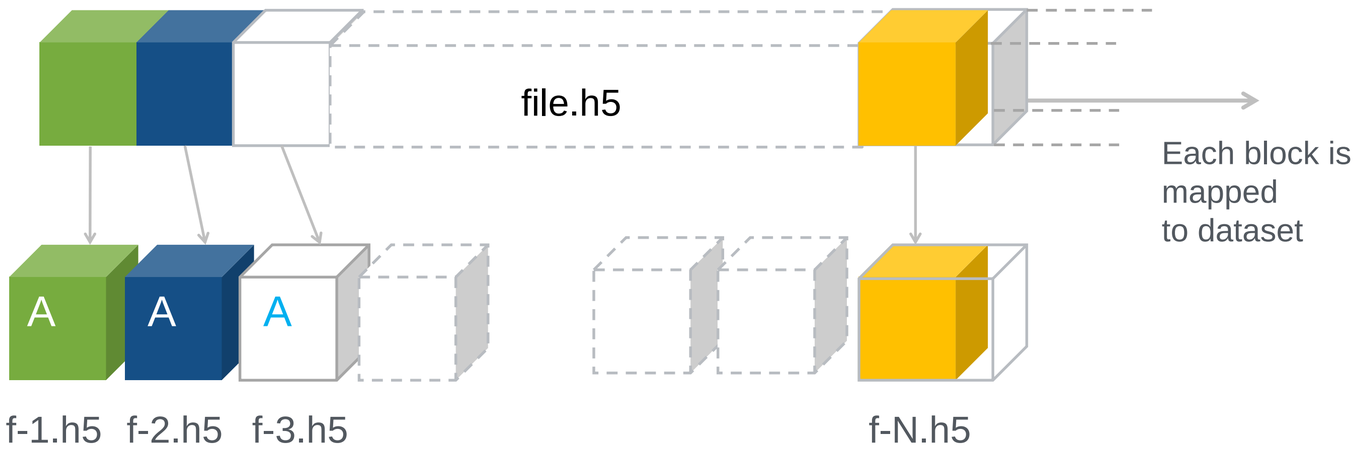


Virtual Datasets (VDS)

Can aggregate multiple source datasets into a single virtual dataset

Supports unlimited dimensions in both source and virtual datasets

Virtual Datasets (VDS)



- Extension to the existing selection API
- Multiple files can be used to write in parallel
- Virtual view of single dataset

```
start[0] = 0; start[1] = 0; start[2] = 0;
stride[0] = DIM0; stride[1] = 1; stride[2] = 1;
count[0] = H5S_UNLIMITED; count[1] = 1; count[2] = 1;
block[0] = DIM0;
block[1] = DIM1;
block[2] = DIM2;


status = H5Sselect_hyperslab (vspace, H5S_SELECT_SET,
                              start, stride, count, block);
status = H5Pset_virtual (dcpl, vspace, "f-%b.h5", "/A",
                         src_space);
```

HDF5 1.10.1: Jan 2017 Release

Performance Optimization

Cache image
Saves cache entries in the file for restart

Page aggregation and buffering
- I/O performance improvement
- Avoids small I/O operations
- Uses fixed-size blocks/pages when writing HDF5 file

Avoid truncate
Avoids expensive file truncate operation on file close

Memory Usage

Evict on close feature
Keeps metadata cache small by evicting MD items when HDF5 object is closed

HDF5 Roadmap: 2017 – 2018 (already in motion)

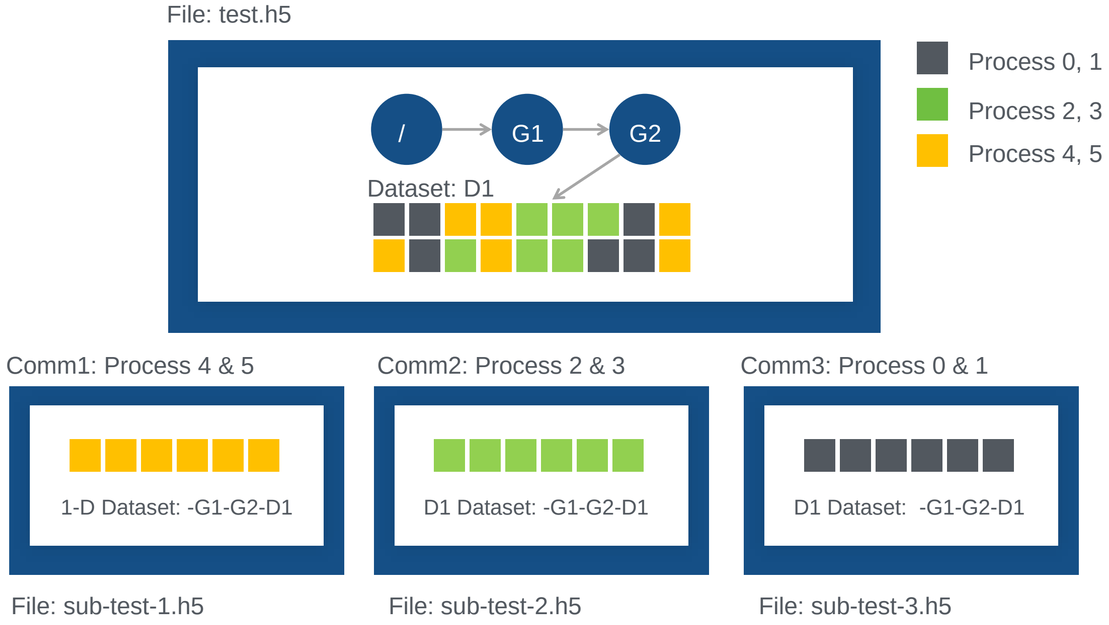
- **Sub-Filing**
- **Parallel compression**
- **Additional features**
  Driven by research projects
- **Productized and added to maintenance releases through Exascale Computing Project (ECP)**

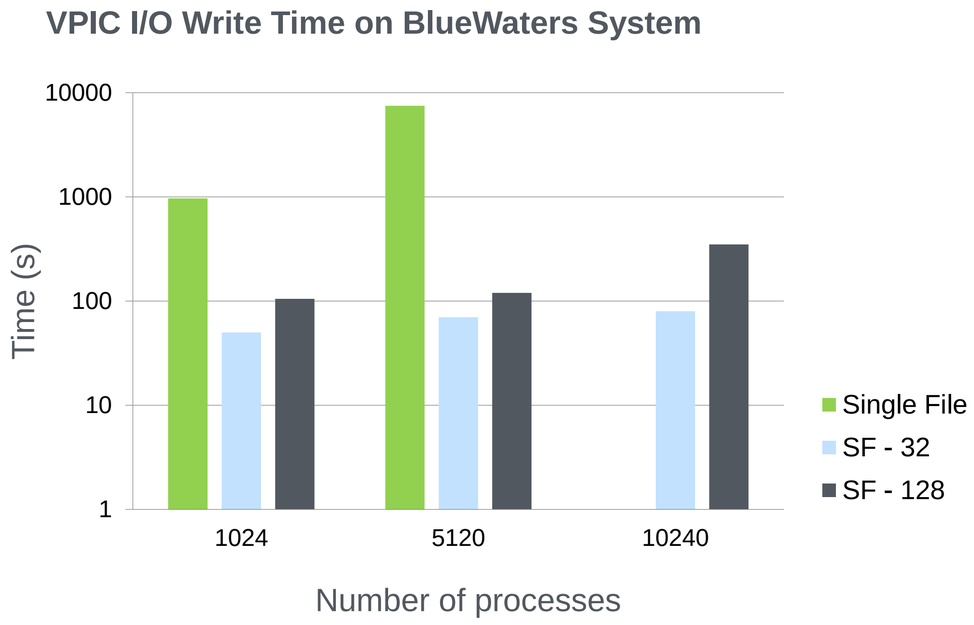
Sub-Filing

Translate single file I/O to multiple files

Reduce file locking and contention

Existing VDS feature internally used

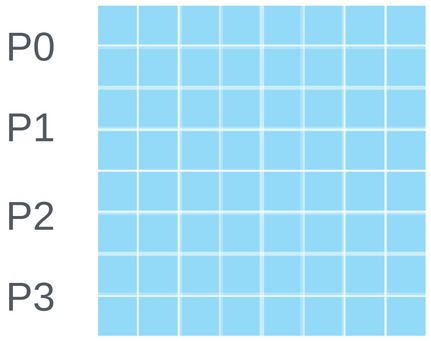


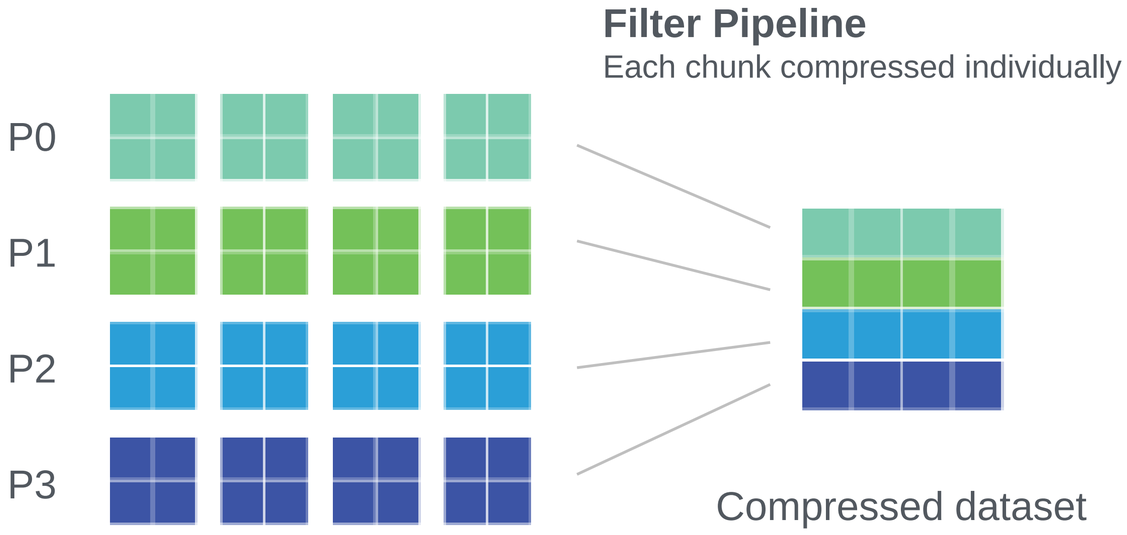


Parallel Compression

Split up filtering overhead between multiple processes / additional communication cost

Current architecture enables parallel support for all types of filters



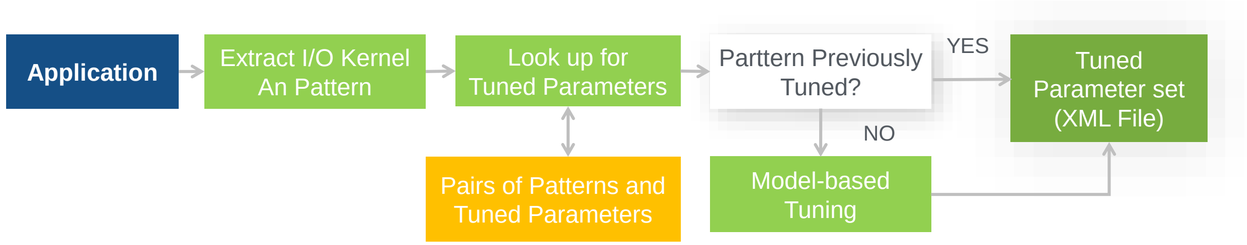


H5Tuner

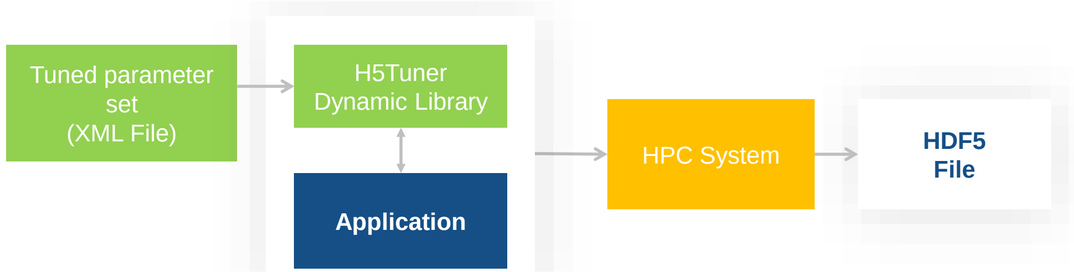
Uses XML description file

Dynamic library redirection through LD_PRELOAD

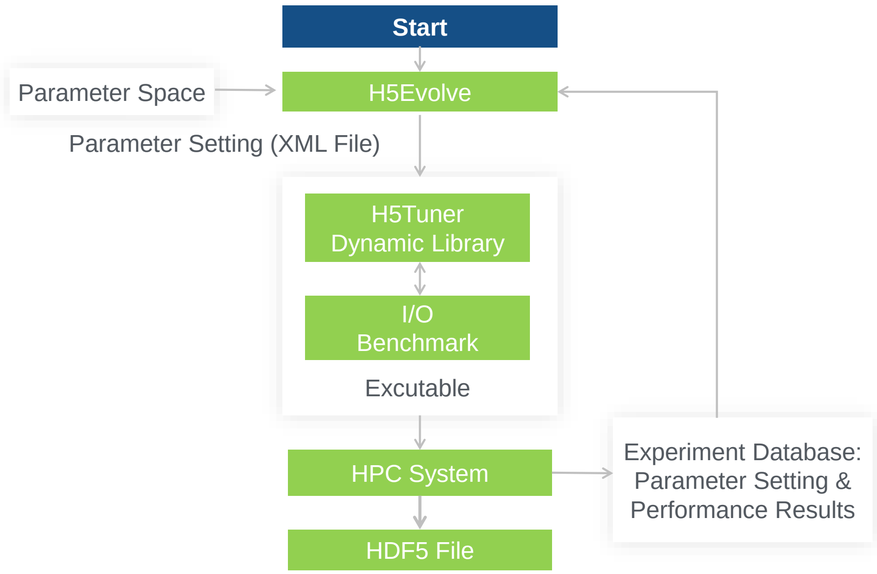
Tuning Phase



Adoption Phase

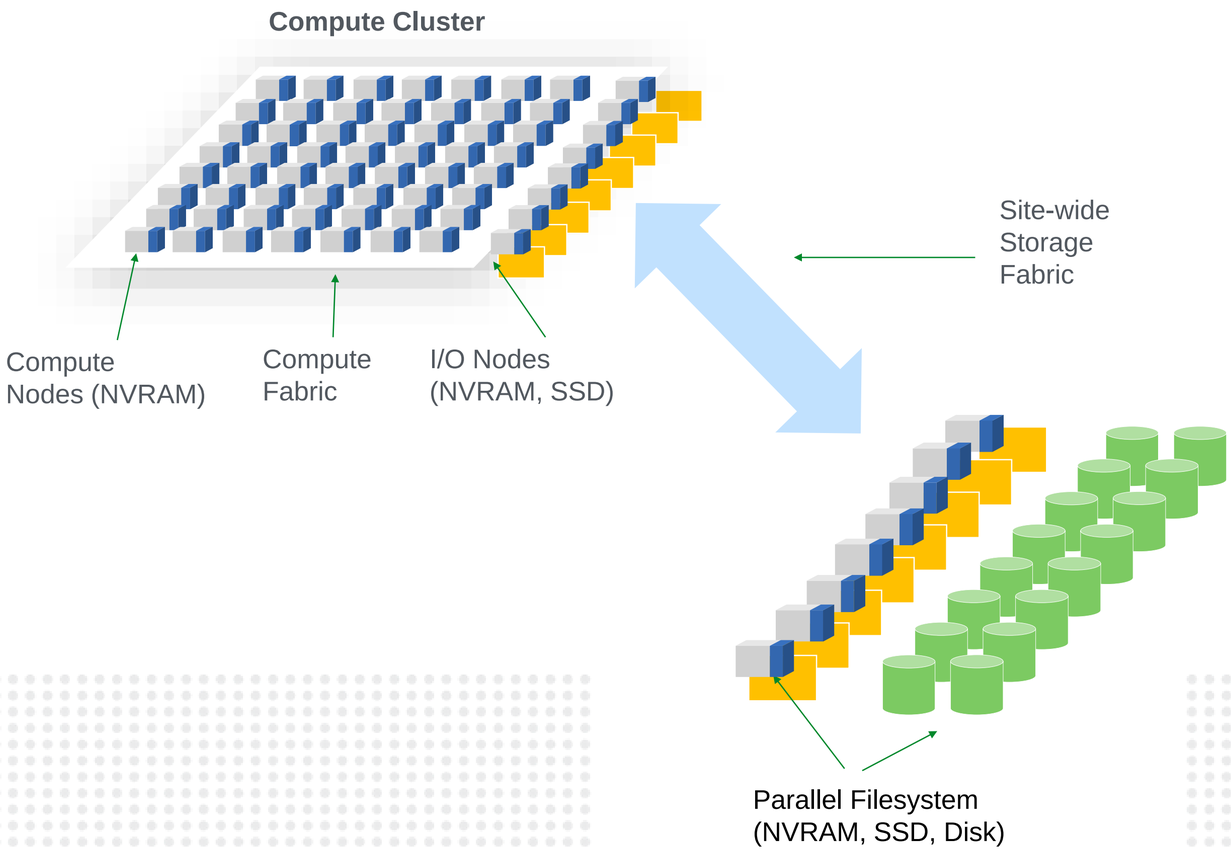


Auto Turning System



Research Projects

- **Extreme Scale Storage and I/O (ESSIO)**
- **Started back in 2012 (FastForward)**
  - Asynchronous I/O (transactional)
  - Query/Indexing
  - Analysis shipping
  - Map object support
  - Data Integrity



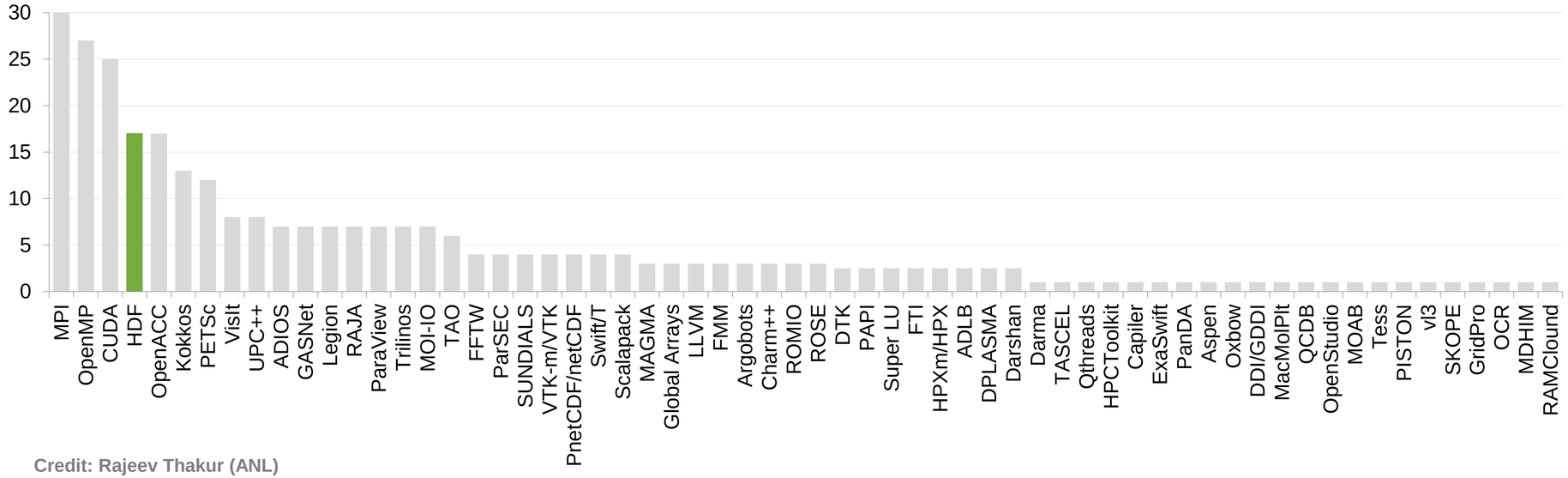
Research Projects

- **Software Defined Service (SDS) = Define HDF5 as a service, definition?**
- **Started in 2016**
- **Develop prototype building blocks (user-space)**
  - Use Mercury (RPC) + Argobots = Margo
  - Enable reusability → rapid development of specialized services
  - BAKE API (Key-value store)
  - Fault detection and group membership
- **HDF5 VOL plugin**
- **Extension to VDS to ”data federation” concept**

Exascale Computing Project (ECP)

- **Collaborative effort of DOE-SC / NNSA-ASC**
- **Accelerate development of a capable exascale computing system**
- **Phase 1: 2016 – 2019 timeframe**

Number of ECP application proposals a software is mentioned in



Credit: Rajeev Thakur (ANL)

LOTS of ECP applications depend on HDF5!

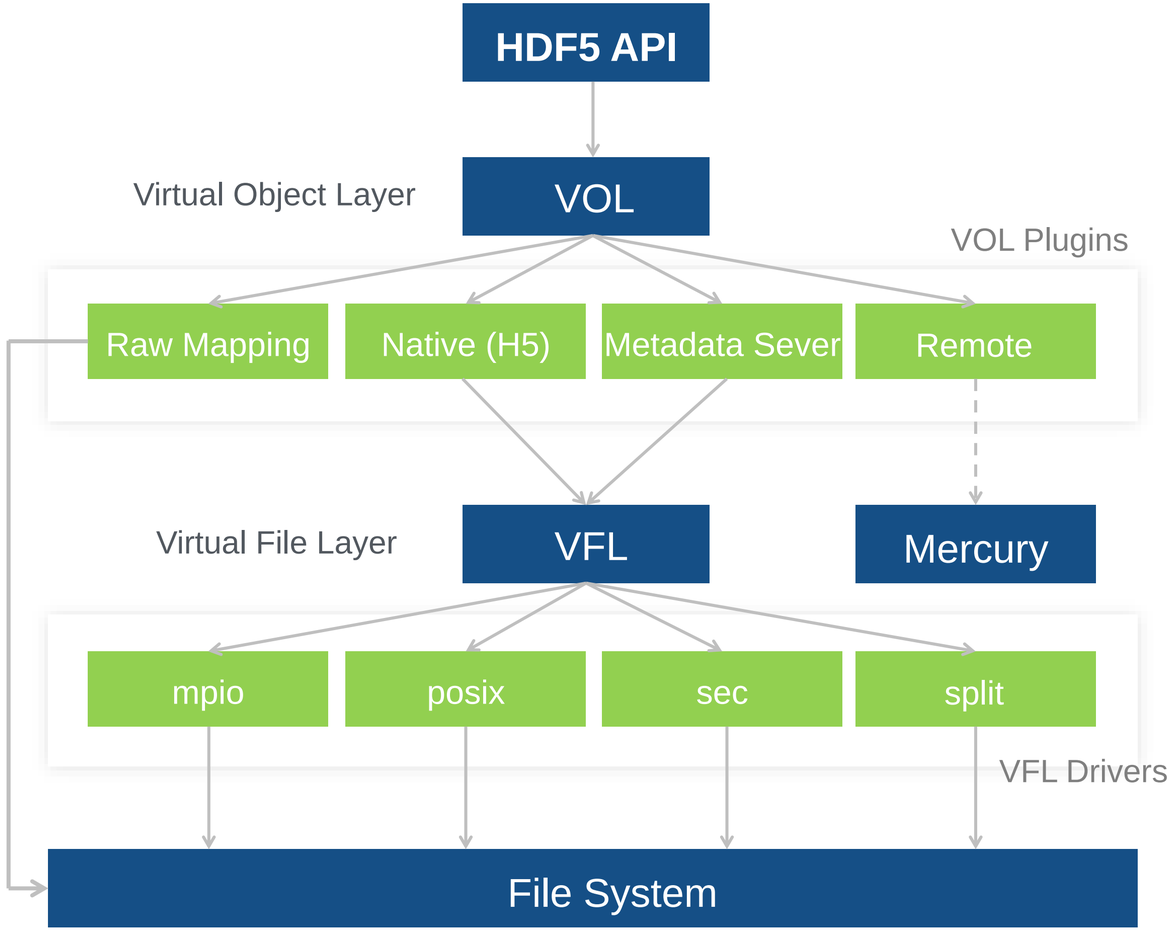
ECP — ExaHDF5 Proposal

- **Collaboration with LBNL and ANL**
- **Virtual Object Layer (VOL)**
  New VOL Plugins: Format adapters for ADIOS and netCDF
- **Query and Indexing**
- **Asynchronous I/O**

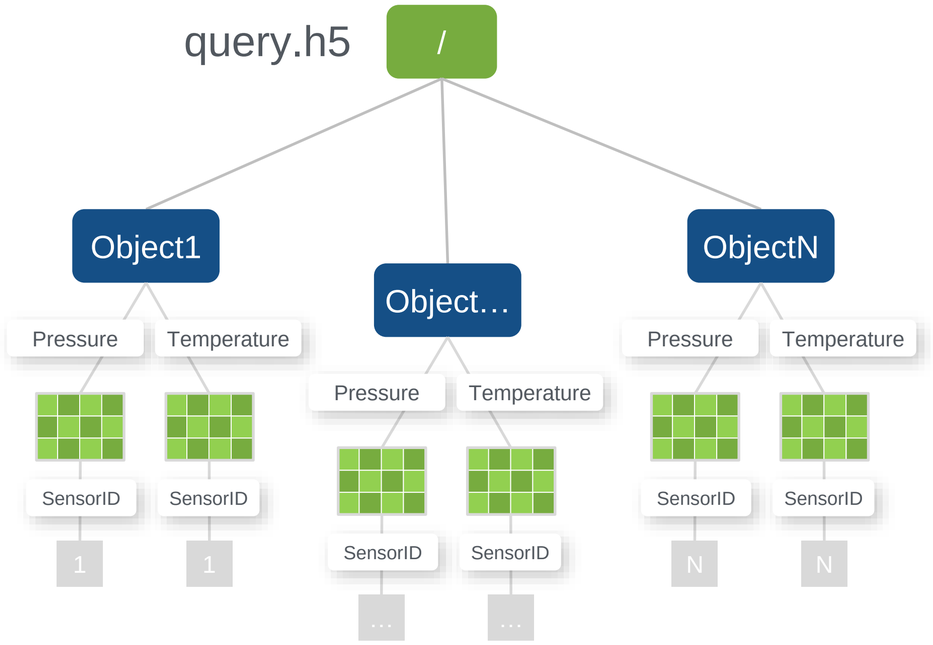
Virtual Object Layer (VOL)

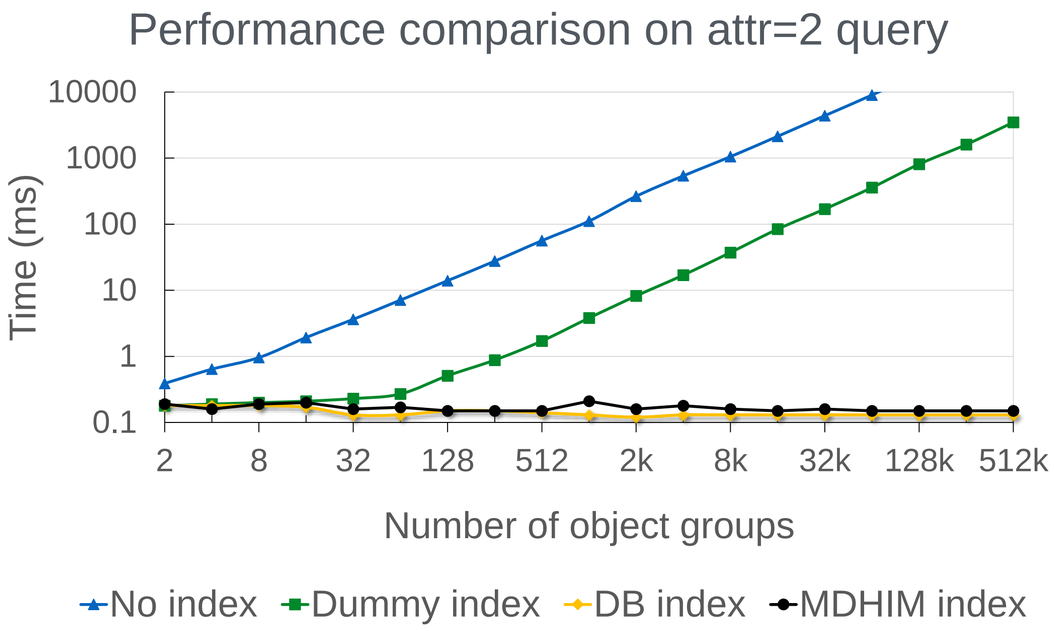
Virtual object layer provides the user with the HDF5 data model and API, but allows different underlying storage mechanisms

- Native HDF5
- Metadata Server
- Remote plugins
- PLFS plugin (Raw)
- IOD/DAOS-M plugin (Raw)



Query / Indexing





View created in memory

Data Index (FastBit)

Metadata Index
(Berkeley DB / MDHIM)

Asynchronous I/O

- **Non-blocking I/O allows asynchronous I/O (i.e., overlapping compute with I/O)**
- **Current HDF5 I/O calls are synchronous or blocking**
- **I/O is initiated within the library after API call**
- **I/O operation completes in the background after API call has returned**
  Beneficial for both raw data and HDF5 metadata I/O
- **Modification of VOL to support non-blocking calls**
- **Support for POSIX AIO, non-blocking MPI I/O, etc**
- **Question of progress**

HDF5 Roadmap: 2017 – 2018 (open for discussion)

- **Enhancements to data model**

  Add key-value object to HDF5: “Map” objects
- **Improve fault tolerance**
  - Metadata journaling
  - Transactions
- **More efficient storage and I/O of variable-length data, including compression**
- **Full C99 type support (long double, complex, boolean types, etc)**
- **Full UTF-8 support**
- **Thread-safety**

Beyond HDF5 Roadmap (open for discussion)

- **Industrial-grade compression libraries**
- **Spark: e.g. H5Spark, RDD VOL, etc.**
- **Cloud**
- **“I/O kernels”**
  - Remove HDF5 bottlenecks discovered
  - Publish repository of I/O kernels with verified results
- **Etc.**

https://goo.gl/4TfpZ3

We are using Git now!

https://git.hdfgroup.org/projects/hdf5

We are accepting patches

- Contact **help@hdfgroup.org**
- Sign Contributor agreement
- Go through our SE process (code review, regression testing, documentation, etc.)

THANK YOU!

Questions & Comments?